Florida Bay Watch Report

August 2001 A synthesis document of the Florida Bay and Adjacent Marine Systems Science Program

The Plume and the Bloom

The status of microalgal blooms and why they develop in different regions of Florida Bay has been an issue for a decade. As was discussed in the Florida Bay Watch Report titled *Florida Marine Research Institute Maps Reveal Decreases in Florida Bay Algal Blooms* (1998), two major blooms have been identified in the bay. One, located in the central region of the bay (Figure 1), is dominated by cyanobacteria (a type of microalgae). The other, located in the western bay, is dominated by diatoms and is the subject of this report.

Diatoms are unique among the various types of microalgae found in Florida Bay because they require silicate, a mineral composed of silicon and oxygen, to grow. When the ratio of silicate to nitrogen or silicate to phosphate falls below a threshold value, diatoms are easily out-competed by other types of microalgae, such as cyanobacteria and dinoflagellates (Figures 2 and 3). At that point, diatom growth becomes silicate limited whereas other microalgae continue to grow. Thus, in order for diatoms to fully exploit a newly available supply of nitrogen or phosphorus, a silicate source is also required.

Figure 1. Regions of Florida Bay and important coastal features.

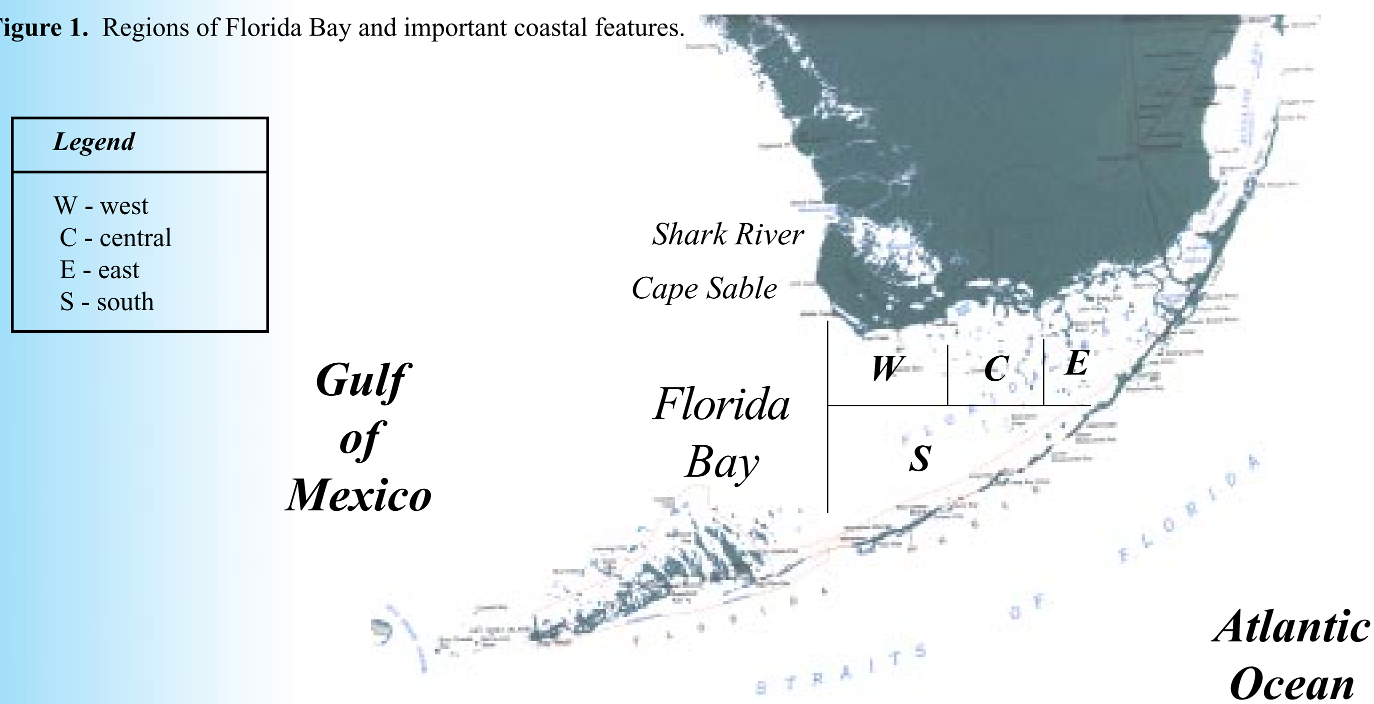


Figure 2. Scanning electron microscopic image of bloom-forming cyanobacteria cells, *Synechococcus elongatus*. Cells measure 1 mm in diameter. Image provided by Florida Marine Research Institute.

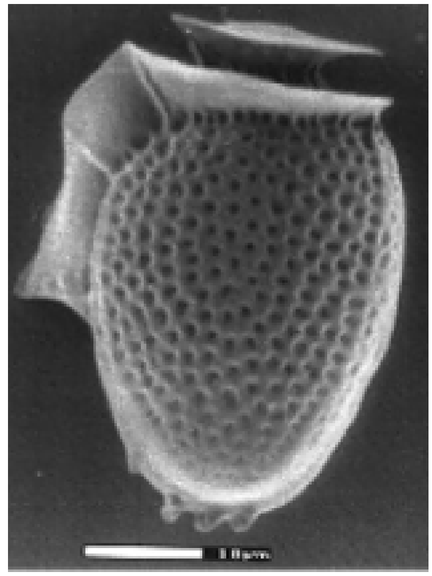


Figure 3. Scanning electron microscopic image of the dinoflagellate, *Dinophysis* sp. Scale bar = 10 mm. Image provided by the Geological Survey of Canada (Atlantic).

Dense diatom blooms were first observed in western Florida Bay in the fall of 1991. The development of these blooms was initially thought to be linked to the vast die-off of seagrass that began in 1987 in central and western Florida Bay (Figure 1). The decomposition of seagrass and increased suspension of bottom sediments were initially thought to be the sources of nutrients that fueled these diatom blooms. However, a four-year delay between the onset of the seagrass die-off and the initiation of diatom blooms suggests that other factors may cause the western Florida Bay blooms.

Other important factors in the initiation of the diatom blooms may instead be the timing and concentration of nutrient inputs from Shark River to western Florida Bay. During much of the year, the freshwater plume of Shark River flows south into western Florida Bay. Similar water flows occur at other river mouths along the southwest Florida coast where freshwater plumes contribute to the development of diatom blooms.

Recent observations indicate that the magnitude of diatom blooms may have declined in western Florida Bay since 1995. This pattern might be explained by trends in water column nutrient concentration. Phosphate levels peaked in 1995 and have since declined to levels lower than those in 1989. Nitrate and ammonium levels peaked somewhat later and have also declined. Declining nutrient concentrations such as these are not necessarily caused by reduced nutrient inputs. Enhanced productivity of microalgae, export of organic material, and dilution can also lower nutrient concentrations.

The Plume

Freshwater flow is a major source of silicate to coastal waters. Therefore, Shark River Slough is a major source of silicate to the southwest Florida Shelf and western Florida Bay. Since 1985, flow through Shark River Slough has been regulated to reflect current rates of evaporation, precipitation, and the previous week's discharge. A regional drought during the late 1980s and early 1990s resulted in the lowest measured water depths (an indicator of river flow) in Shark River Slough since the water management rules for Shark River were established in 1985. A reduction in freshwater flow from Shark River was reflected by high salinity in western Florida Bay from 1989 until 1990. The fall of 1991 marked the end of the drought, and a concomitant increase occurred in outflow from Shark River. The timing of these events coincided with the earliest reports of diatom blooms in western Florida Bay. The increase in freshwater flow in 1991 probably resulted in an enhanced silicate flux to the southwest Florida Shelf. As the freshwater plume from Shark River flowed southeast around Cape Sable and along the western margin of Florida Bay, it provided the silicate necessary to sustain diatom growth.

Presumably, adequate concentrations of nitrate, ammonium, and phosphate were available in western Florida Bay to support diatom blooms prior to 1991. However, it was not until freshwater flows increased that a sufficient concentration of silicate was available to cause the onset of blooms. Diatoms quickly responded to the increased silicate flux, out-competing other microalgal species and producing a diatom bloom. Although several diatom species contribute to development of the bloom, most of them are in the genus *Rhizosolenia* (Figure 4).

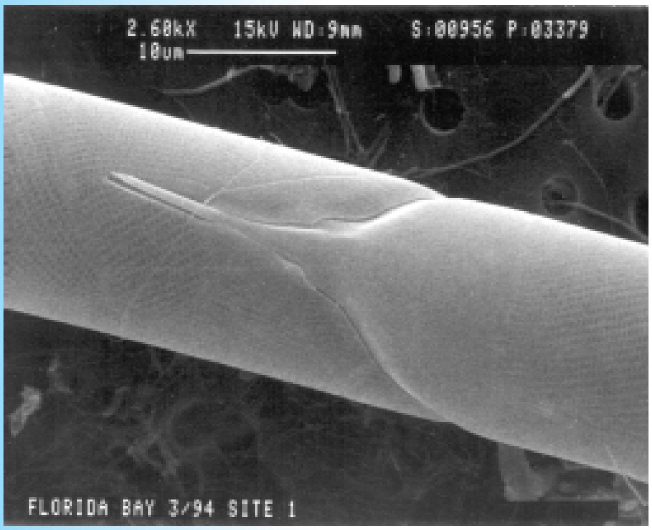


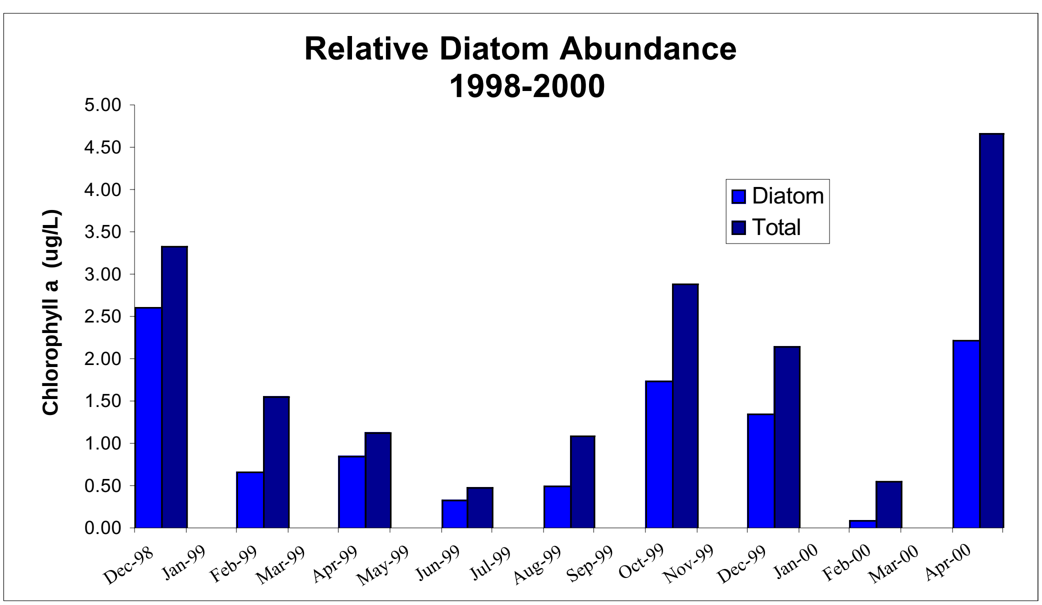
Figure 4. Scanning electron microscopic image of the bloom-forming centric diatom, *Rhizosolenia* sp. Scale bar = 10 mm. Image provided by Florida Marine Research Institute.

The Bloom

The development of diatom blooms in western Florida Bay has been closely monitored since the early 1990s. Throughout the year, biogenic silica concentrations (an index of diatom abundance) are fairly constant near the mouth of Shark River. With the onset of the rainy season in June, flow from Shark River begins to increase and creates a freshwater plume along the adjacent southwest Florida Shelf. Initiation of the bloom occurs during June, off Cape Sable, with a maximum diatom abundance reached in October to December, otherwise known as the "winter bloom" (Figure 5). Diatom abundance increases near Cape Sable as the plume of Shark River flows into western Florida Bay. Diatom abundance continues to increase into late fall, as evidenced by a similar trend in diatom chlorophyll *a* concentrations. Maximum diatom abundance (the "winter bloom") occurs in western Florida Bay in October when the flow from Shark River is at its annual maximum.

The hypothesis concerning Shark River as an important silicate source is supported by a gradient that exists in silicate concentrations between the mouth of Shark River and western Florida Bay (Figure 6). During fall and winter, the highest dissolved silicate concentrations on the southwest

Figure 5. Annual trend in total chlorophyll *a* (all microalgae) and netplankton chlorophyll *a* (diatom) concentrations measured bi-monthly in surface waters off Cape Sable. Data correspond to one sample location and are not necessarily maximum values for the region.



Florida Shelf occur near the mouth of Shark River. Dissolved silicate declines to undetectable levels at the easternmost extent of the diatom bloom. The potential contribution of the Shark River silicate source to the development of diatom blooms in western Florida Bay is illustrated by the inverse relationship between dissolved silicate and biogenic silica concentrations (Figure 6). During peak diatom abundance (October to December), biogenic silica concentrations are lowest near the mouth of Shark River, where silicate concentrations are elevated. Conversely, biogenic silica levels are highest in western Florida Bay where silicate concentrations are minimal. The peak diatom abundance in western Florida Bay coincides precisely with the depletion of silicate concentrations to undetectable levels. This relationship probably is caused by the rapid uptake of silicate and conversion to biogenic silica by diatoms. Although silicate may become a limiting nutrient during periods of enhanced diatom

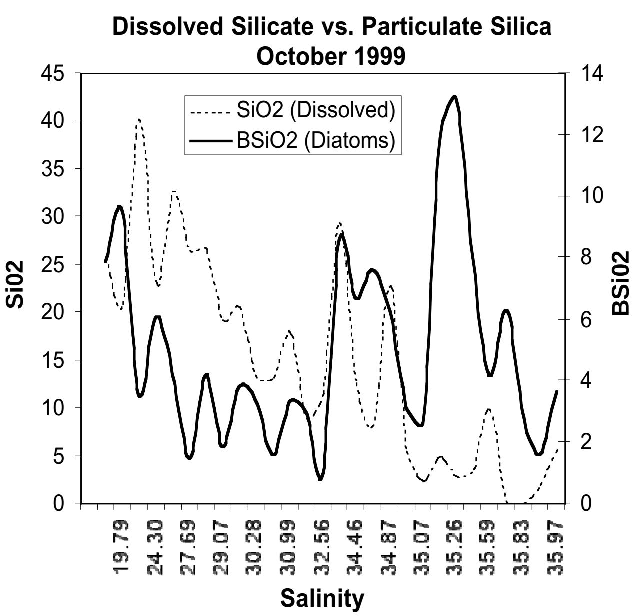


Figure 6. Inverse relationship between biogenic silica ($BSiO_2$) and silicate (SiO_2) concentrations demonstrated with samples collected along the west Florida inner-shelf and western Florida Bay in October 1999. Low salinity values correspond to samples collected near the mouth of Shark River and high salinity values pertain to samples from western Florida Bay.

growth, laboratory experiments have also identified nitrogen as an important nutrient that can also limit diatom growth in western Florida Bay. Enhanced nitrogen concentrations also occur in the freshwater plume of Shark River during October, when both river flow and diatom abundance on the southwest Florida Shelf are at a maximum.

Persistence and Termination of the Bloom

Since diatoms actively remove nutrients from the water as they grow, other nutrient sources must exist to sustain diatom populations when freshwater flows into western Florida Bay decline. When silicate flux to western Florida Bay is reduced or when silicate concentrations become depleted due to rapid uptake by diatoms, a process known as "silicate regeneration" may provide an important means to maintain diatom growth after the silicate inflow is reduced. Silicate regeneration is the dissolution of biogenic silica from diatom skeletal remains (frustules). This is a temperature-dependent process. Since the dissolution rate of silica from diatom frustules increases with increasing water temperature, the rate of regeneration of silicate in the water column is highest during August and September when temperatures are warm and biogenic silica concentrations are high. The resuspension of bottom sediments provides a mechanism by which recently deposited diatom frustules can be re-introduced to the water column, where dissolution rates are enhanced. The importance of biogenic silica dissolution in providing silicate has been demonstrated in recent field experiments where biogenic silica dissolution satisfied up to 70% of the daily silicate demand of diatoms in western Florida Bay (Jurado and Hitchcock, unpublished data).

The annual termination of the "winter bloom" in western Florida Bay is likely related to seasonal changes in Florida Bay and the southwest Florida shelf. The onset of winter is accompanied by a reversal in the direction of prevailing winds. Light winds from the east characterize summer months in Florida Bay, while in the winter a series of cold fronts occurs, with intermediate-to-strong winds from the west. The passage of these fronts enhances mixing in the shallow waters of western Florida Bay. While the resuspension of bottom sediments during these mixing events makes benthic biogenic silica available for dissolution, it also creates a highly turbid water column. The turbidity reduces light penetration, and may limit diatom growth. As temperature falls in the winter, biogenic silica dissolution rates are reduced, and diatom populations are increasingly dependent upon new silicate delivered from Shark River. However, reduced freshwater outflow from Shark River during the dry winter months reduces the supply of new silicate to western Florida Bay.

Conclusion

The development of diatom blooms in western Florida Bay has previously been attributed to nutrient enrichment following the 1987 seagrass die-off. However, although elevated water column nitrogen concentrations were observed immediately following the die-off, diatom blooms did not develop until four years later. Hence, the hypothesis now is that the delayed response of the pelagic diatom community was caused by reduced freshwater flow into western Florida Bay during the drought of the late 1980s and the early 1990s. The Shark River plume provides a silicate and nitrogen source that initiates the growth of diatoms in western Florida Bay. Freshwater input increases during late summer causing the onset of the diatom bloom. Sediment resuspension also influences nutrient concentrations in western Florida Bay by enhancing the flux of nutrients from bottom sediments into the water column. Biogenic silica dissolution provides a mechanism by which silicate can be recycled in the water column and may be another important means to sustain diatom blooms in western Florida Bay. The annual termination of the "winter bloom" may be linked to several factors, including a reduced inflow of fresh water (and nutrients) from Shark River, reduced rates of silica dissolution, and light-limiting conditions for photosynthesis.

Additional Readings And Resources

http://wwwalker.net/flabay

Boyer, J.N., and R.D. Jones. In press. Long-term trends in the water quality of Florida Bay (June 1989-June 1999). Everglades National Park Publication.

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Phlips, E.J., and S. Badylak. 1996. Spatial variability in phytoplankton standing crop and composition in a shallow inner-shelf lagoon, Florida Bay, Florida. *Bull. Mar. Sci*. **58**: 203-216.

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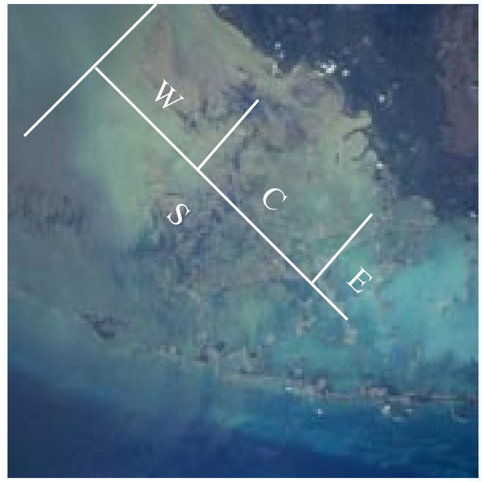
Zieman, J.C., J.W. Fourqurean, and T.A. Frankovich. 1999. Seagrass die-off in Florida Bay: Long-term trends in abundance and growth of turtle grass, *Thalassia testudinum*. *Estuaries* **22** (2B): 460-470.

Acknowledgments

This report was authored by Jennifer Jurado and Gary Hitchcock (University of Miami) and edited by Brian D. Keller (NOAA, Florida Keys National Marine Sanctuary), John Hunt (Florida Fish and Wildlife Conservation Commission, Florida Marine Research Institute, and Florida Bay and Adjacent Marine Systems Program Management Committee), Cluny McCaffrey (The Nature Conservancy), and Laura Engleby (Florida Sea Grant College Program).



NASA satellite imagery with Florida Bay regions superimposed to approximate those indicated in Figure 1.

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