Appendix 12-3: Report on Algae Blooms in Eastern Florida Bay and Southern Biscayne Bay

Report on Algae Blooms in Eastern Florida Bay and Southern Biscayne Bay

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SUMMARY

A highly unusual algae bloom has persisted in eastern Florida Bay and southern Biscayne Bay (Manatee Bay, Barnes Sound, and Card Sound) since at least November 2005. Similar algae blooms have been observed in central and western Florida Bay, but never in eastern Florida Bay. Chlorophyll *a* concentrations (an indicator of the amount of algae in the water column) peaked in the fall and early winter in 2005 and after decreasing in the spring, increased again in June and July 2006. These concentrations greatly exceeded values recorded during fifteen years of water quality monitoring in this region (SFWMD/FIU Coastal Water Quality Monitoring Program). A summary timeline of water quality changes in association with other events (US Highway 1 construction, hurricanes, canal discharges) is presented in Table 1.

The algae bloom has been found to be mostly composed of blue-green algae, which are photosynthetic bacteria. The dominant species of blue-green algae in the eastern Florida Bay / southern Biscayne Bay bloom is also the typical dominant species in central Florida Bay blooms. These blue-greens are of marine origin and not toxic; they are not similar to blue-greens that are a focus of concern in many of Florida's fresh water lakes and rivers.

Causes of the bloom are not certain, but may be related to at least two factors: 1) disturbance associated road construction activity along US Highway 1 between the Florida mainland and Key Largo (Eighteen Mile Stretch), and 2) hurricane impacts from August through October 2005 (Katrina, Rita, Wilma). Highway construction has entailed the cutting and mulching of mangrove trees and soil tilling (mixing fresh mulch into the peat soil) and soil stabilization with injection of cement since May 2005. Hurricane disturbances included a large discharge of fresh water and phosphorus from the C-111 canal and the impact of high winds, waves, storm surge and abrupt salinity change on plants, soils, sediments, and ground water. The proximity of the blooms to both sides of US Highway 1 – an area where blooms have not been previously recorded – points to the likelihood that the unique disturbance of road construction is involved as a cause of the bloom. A summary of hypotheses regarding the cause of the blooms is presented in Table 2.

Monitoring results indicate that the bloom was most likely initiated by a large increase in total phosphorus (TP) – a sharp peak in TP concentrations (to record high values) was measured in a small area (Manatee Bay) in late August immediately following Hurricane Katrina and also in the large region of eastern Florida Bay and southern Biscayne Bay in October. The highest P and chlorophyll *a* concentrations were in basins closest to the Eighteen Mile Stretch near Key

Largo. However, some lower, but elevated TP concentrations were also observed at the same time in areas remote from the road. The timing of the TP peak and subsequent bloom appears more associated with hurricane activity, with the TP peak occurring after Hurricanes Rita. Despite major road construction activity during the late spring and through the summer, no blooms or unusually high TP was measured prior to Hurricane Katrina. *Thus, while the spatial pattern of the bloom points toward the importance of road disturbance as a cause of the blooms, the timing of these blooms points toward hurricane disturbance as a cause. An interaction of these two factors (disturbance from road construction plus hurricanes) appears to be the likely cause of the blooms.*

One component of the hurricane effects may have been associated with water management operations. A major runoff event occurred in late August 2005 in association with high rainfall from Hurricane Katrina. This resulted in a large loading of TP into Manatee Bay from the C-111 Canal along with a lower quantity of TP loading into Florida Bay through the southeastern Everglades. After this runoff event, TP concentrations in Manatee Bay sharply increased and then returned to near pre-storm concentrations within one week. TP in Barnes Sound and all Florida Bay waters remained low for more than one month before peaking regionally in October. This one month time lag, along with the absence of a concentration gradient away from Manatee Bay, indicates that the widespread October peak was unlikely to be caused by canal inputs. It is more likely that storm surge transported sediments, seagrasses, organic matter (perhaps including materials from the US 1 worksite) and ground water nutrients. Furthermore, when the TP peak did occur, those areas with low salinity (associated with the most runoff) had lower TP than those areas with higher salinity. Similar discharges of water and TP into Manatee Bay in the 1990s did not result in algae blooms similar to those observed between November 2005 and March 2006.

Table 1. Timeline of Florida Bay & Biscayne Bay algae bloom and potentially associated events.

	WATER QUALITY IN NORTHEAST FL BAY – S. BISC BAY REGION	**U.S. HIGHWAY 1 ACTIVITIES**	**TROPICAL STORM EVENTS**	**C-111 CANAL DISCHARGE**
Apr 2005	No change from historic baseline (low chl *a* with median 0.4 ppb, and TP with median 6 ppb)	Mangrove clearing begins near Jewfish Creek		
May	No change	0.6 miles cleared N of Jewfish Creek		
June	No change	Clearing continues N and S of Lk Surprise		S197 open, 7,000 acre-ft discharge
July	No change	Clearing to Barnes; mixing of soil, mangrove mulch, and cement begins		
Aug	After Katrina, rapid salinity drop, TP increase (84 ppb) in Manatee	Clearing and soil mixing continues N (Barnes Sound area)	Hurricane Katrina (high rainfall, runoff, 47 mph wind, 2 ft. surge)	S197 opens 8/26 (5 d; 27,000 acre-feet; P load 0.8 metric tons)
Sept	TP near baseline in region, chl *a* increase in Manatee and Barnes (7 to 16 ppb)	Clearing and soil mixing continues N (Barnes Sound area)	Hurricane Rita (38 mph wind, 2 ft surge)	S197 open for 3 periods (20 d; 21,000 acre-ft)
Oct	High TP in region (60 to 100 ppb) before Wilma; chl *a* still low except Manatee and Barnes (6 ppb)	Clearing and soil mixing continues N (Barnes Sound area)	Hurr. Wilma (66 mph wind, 2 to 3 ft surge)	S197 opens for 2 periods (10 d; 2,000 acre-ft)
Nov	Regional chl *a* increase (bloom in Blackwater and Barnes to 15 ppb); TP decrease (slightly > baseline)	Clearing to Manatee Bay marina; soil mixing continues N		
Dec	Bloom continues – highest in Barnes (near 10 ppb)	Soil mixing S of Lk Surprise		
Jan 2006	Bloom increases – mapping shows highest chl *a* near US1 and Key Largo (peak 20 ppb), high turbidity	Mangroves cleared near Manatee Bay		
Feb	Bloom continues – chl *a* decrease (< 12 ppb in Blackwater, Barnes, Manatee)	Soil mixing near Barnes Sound		
Mar	Bloom continues – chl *a* decrease (3 to 12 ppb in Blackwater, Barnes, Manatee)	Soil mixing near Barnes Sound		
Apr	Bloom continues - chl *a* less than 10 ppb in Blackwater, Barnes, Manatee	Soil mixing near Manatee Bay		
May Jun July	Bloom decrease in early May (chl *a* < 6 ppb); increase in June–July (> 12 ppb in Blackwater, Barnes, Manatee)	to be determined		

Table 2. Hypotheses that may explain the cause of 2005-2006 algae blooms.

HYPOTHESIS	EVIDENCE SUPPORTING	EVIDENCE REFUTING
US Highway 1 road construction	• No similar algae bloom known to occur in the region prior to road construction • Bloom spatial pattern brackets highway (especially Blackwater-Barnes) • Bloom sustained 9 months after hurricane events, while construction continued • Mangrove mulch decomposition and soil disturbance likely to yield large nutrient release to adjacent waters	• Five months of construction activity before start of bloom • Bloom started immediately after Hurricane Katrina and Rita • Bloom spatial pattern within basins adjacent to road do not show increasing chlorophyll *a* near road
Hurricane Katrina related discharge and P load through S-197 (C-111 Canal)	• High P load event occurred and primary production known to be P limited • Bloom began in Manatee Bay and Barnes Sound immediately after pulse discharge and measured TP increase in Bay	• Elevated TP observed in areas beyond (west of) influence of S-197 discharge • Regional TP peak occurred one month after TP decreased to near baseline in Manatee Bay • TP load associated with particles – bloom does not follow gradient from canal mouth; chlorophyll *a* concentrations higher near Key Largo than mainland • Similar blooms did not occur after similar C-111 releases and TP loads (even after late 1980s – early 1990s drought)
Hurricane wind, waves, surge eroded sediment & plants, stripped leaves, pulsed ground water nutrients	• P increase after Katrina and Rita; regional bloom after Wilma • Spatial pattern of highest chlorophyll *a* appears parallel to Key Largo coastline, as could occur with line of storm deposits or ground water pulse	• Regional TP increase occurred prior to storm with highest surge (Wilma) • No similar blooms after previous storms (e.g. Hurricane Georges)
Hurricane disturbance: salinity drop & seagrass	• Salinity drop near coast with Katrina rapid enough to kill plants	• Salinity drop also occurred in areas with little TP increase and no bloom
Combination of road and hurricane disturbance	• Storm energy could move nutrients from road fill - turbidity barriers next to US1 removed prior to storms • Spatial pattern of bloom follows road for 9 months, while bloom initiation timing follows hurricanes	

TECHNICAL FINDINGS

Phytoplankton Bloom Description

Eastern Florida Bay and southern Biscayne Bay (Barnes Sound, Manatee Bay, and Card Sound) (Figure 1) typically have low phytoplankton (microalgae in the water column) biomass and low productivity, in large part because of low phosphorus availability. The SFWMD/FIU Coastal Water Quality Monitoring program has documented water quality conditions since March 1991 and found that chlorophyll-*a* concentrations, an indicator of phytoplankton biomass, are typically (have a median value) near 0.4 μg/l (equivalent to ppb) and rarely exceed 2 μg/L in eastern Florida Bay and southern Biscayne Bay. Total phosphorus (TP) concentrations are most commonly 0.006 mg/L (6 ppb) and rarely exceed 0.02 mg/L (20 ppb) in this region. In the fall of 2005, however, chlorophyll-*a* and TP concentrations greatly exceeded these values (Figures 2, 3), with the blooms reaching 8 μg/L chlorophyll-*a* and TP reaching near 0.1 mg/L (100 ppb), as measured in the SFWMD/FIU program, and up to 20 μg/L chlorophyll-*a* as measured at different sites and times by SFWMD staff and Miami-Dade DERM staff.

Initiation of the bloom occurred in Manatee Bay and Barnes Sound in September 2005 (Figure 4). For about one month following Hurricane Katrina, Miami-Dade DERM frequently sampled these basins to assess S-197 release effects. On September 14, chlorophyll-*a* increased to 16 μg/L in Barnes Sound and 7 μg/L in Manatee Bay. By October 5, chlorophyll-*a* decreased to between 2 and 6 μg/L in these basins (measured by DERM and FIU) and increased to 2 μg/L in Blackwater Sound. By November, the bloom had intensified, with concentrations near 10 μg/L in waters adjacent to the U.S. Highway 1 near Key Largo (Figure 5). Furthermore, the area of the bloom expanded away from its center in Blackwater Sound, Barnes Sound, and Manatee Bay toward eastern Florida Bay and Card Sound (with decreasing chlorophyll-*a* concentrations toward the east, west, and north). The bloom persisted in this region through February 2006, but decreased considerably in March (Figure 5). Recent results show a resurgence of the bloom in June and July 2006 (Figure 4).

In January, April, May and July 2006, SFWMD scientists analyzed the fine-scale spatial pattern of the bloom, using the Dataflow multi-parameter mapping system, which includes a chlorophyll fluorometer. The high resolution map of chlorophyll-*a* distribution (Figures 6-9) derived from Dataflow transects (with a data point collected every 5 seconds from a moving boat) indicates two spatial trends. First, chlorophyll-*a* concentrations were higher in basins immediately east and west of U.S. Highway 1 than farther east (Card Sound) and west (into Florida Bay proper), confirming the general spatial pattern derived from the small set of fixed stations in the water quality monitoring network. After April, the bloom in eastern Florida Bay was largely limited to basins adjacent the Highway (Blackwater Sound, Little Blackwater Sound, Long Sound). Second, chlorophyll-*a* concentrations were higher toward Key Largo than toward the mainland during January, May, and July (April data were insufficient to detect this). Chlorophyll-*a* concentrations were consistently greater than 20 μg/L in Lake Surprise.

Plankton samples were taken in January by SFWMD for analysis of the taxonomic composition of the bloom by scientists at FAU and the Florida Fish and Wildlife Research Institute (FWRI). Dr. Cindy Heil at FWRI found that the samples contained a mixture of taxa, dominated by very small organisms (<2 μm), which were mostly cyanobacteria (blue-green algae). Species were primarily in genus *Synechocystis* and *Synechococcus* (several species, including *elongatus*) and smaller unidentified cyanophyte species. Some smaller diatom species and flagellates were detected, but were rare. The dominance of cyanobacteria was confirmed by Dr. William Louda of FAU by pigment analysis, with 86% of samples containing nearly all cyanobacterial pigments that were similar to *Synechococcous elongatus*.

SFWMD scientists also confirmed that the plankton composing the bloom were photosynthetically active. Changes in dissolved oxygen were measured in March 2006 to estimate productivity in a bloom area in Blackwater Sound (with about 12.5 μg/L) and in northeastern Florida Bay near Duck Key (with about 11.9 μg/L), and in a non-bloom area about one hundred meters beyond the edge of the bloom near Duck Key (with about 0.6 μg/L). Gross primary productivity in the bloom areas was high, with about 0.15 mg O_2 L^{-1} h^{-1} (roughly 0.5 g C m^{-2} d^{-1}) in Blackwater Sound and northeastern Florida Bay, and near zero (about 0.01 mg O_2 L^{-1} h^{-1}) in the adjacent non-bloom area. Previous measurements of net primary production in this region have found rates similar to that measured in the non-bloom area in March.

Hurricane disturbance and the bloom relationship with phosphorus and salinity

Three hurricanes impacted south Florida from August through October 2005 – Katrina, Rita, and Wilma (Figure 10). Katrina was notable in south Florida for its high rainfall and runoff, resulting in a rapid decrease in salinity in south Florida estuaries, particularly close to the coast (Figure 11). Rainfall during Katrina also caused the opening of S-197 to lower stages in the C-111 Canal, yielding the discharge of canal water and associated materials (including TP) from the C-111 Canal into Manatee Bay in late August and early September (Figure 12). Wilma was notable for its strong winds and storm surge, which exceeded those of any 2005 hurricane in the Florida Bay region (Figure 13).

A relationship between TP inputs from Katrina-related canal discharges and the algae bloom appears likely in Manatee Bay. One day after Hurricane Katrina, which passed through south Florida on August 26 with high rainfall, and the discharge of C-111 water through S-197, TP concentrations in Manatee Bay increased to 84 ppb (DERM data). By August 30, TP concentrations had dropped to about 12 ppb. By September 14, chlorophyll-*a* increased to 7 μg /L in Manatee Bay and 16 μg /L in Barnes Sound, far above previously recorded values.

With the exception of the late August peak in TP in Manatee Bay, TP concentrations remained low in the region until early October and chlorophyll-*a* concentrations in the region (other than in Manatee Bay and Barnes Sound) remained low until November (Figure 5).

The spatial pattern of TP concentration in October 2005 (Figure 14) was similar to that of the phytoplankton bloom (Figure 5), with highest concentrations in Barnes Sound and Blackwater Sound and decreasing concentrations toward the east, west, and north. These TP concentrations were far higher than previously measured in this region (Figures 2, 3), with concentrations as high as 60 ppb at Duck Key. Changes in TP spatial pattern through the fall and winter showed a rapid decrease in concentration throughout the region after October and a slight shift in the gradient, with more uniform concentrations in a north-south direction. Concentrations remained above historic values, with these elevated values bracketing U.S. Highway 1. An exception to this pattern occurred in January, when the center of the high TP concentration area was further west in Florida Bay.

The temporal relationship of chlorophyll-*a*, TP, and salinity at three sites within the bloom area is shown if Figure 15. These figures clearly show that the TP peak in October 2005 preceded the sharp increase in chlorophyll-*a* at all stations and that chlorophyll-*a* remained low through the spring and summer months, a period during which considerable road construction occurred along U.S. Highway 1 between Blackwater Sound and Barnes Sound. The magnitude of the phytoplankton bloom at a given site in November 2005 was strongly correlated with TP concentrations at the site in October (Figure 16). This finding is consistent with the expectation that primary producers in this region are strongly limited by P availability. P concentrations dropped after the formation of the strong bloom, but chlorophyll and TP remained tightly correlated (Figure 16).

Figure 15 also shows the drop in salinity associated with Hurricane Katrina in August 2005, which is most evident at the Barnes Sound site, occurred without a concurrent increase in TP. The TP peak occurred about one month after the freshwater pulse. Salinity and peak TP concentrations were not strongly correlated in October 2005 (Figure 17) and the slight positive slope of this relationship shows that TP was not higher in areas with lower salinity, which received more P inputs from the C-111 Canal and the Everglades than areas with higher salinity.

Causes of Phytoplankton Blooms

The results presented here are correlative and do not prove cause and effect relationships. However, these results do point toward the potential importance of U.S. Highway 1 construction and hurricane disturbance as factors stimulating the phytoplankton bloom. Inputs of TP from the C-111 Canal following Hurricane Katrina also may have contributed to the bloom.

Highway construction.

The spatial distribution of the bloom and extremely high TP concentrations corresponded with the vicinity of the highway, with elevated chlorophyll and TP on both sides of the highway (Figures 5-9, 14). Based on these spatial patterns and the chronology of bloom events (Figure 15), it appears that the proximate cause of the bloom was elevated TP. Highway construction potentially released P (along with other nutrients) via two mechanisms: 1) extensive cutting and mulching of mangrove trees along the Highway, and 2) soil disturbance, perhaps including the use of materials added to the soil to stabilize the roadway. The process of mixing fresh organic matter (mangrove mulch) into the peat soil likely resulted in a short-term release of porewater nutrients and a long-term release of decomposition products, including inorganic and organic nutrients. While turbidity barriers were employed during construction, this would not stop the loss of soluble decomposition products (leachates) from mulched organic matter, which commonly constitutes about 30% of organic matter loss from mangrove leaves. Furthermore, these barriers were removed in preparation for hurricane onslaught and an unknown amount of material was lost from the site during Hurricanes Katrina, Rita and Wilma. No major erosion was noted at the site (personal communications with John Palenchar (from FDOT) and Heather Carman (from SFWMD)).

However, the timing of the TP peak and bloom are not consistent with the hypothesis that road construction alone caused the phytoplankton bloom. Mangrove clearing began in April 2005 and proceeded throughout the remainder of the spring and summer months (personal communication J. Palenchar). Soil stabilization, with extensive soil disturbance, began in June 2005. Based on observations of H. Carman, the rate of tree and soil disturbance appeared to be fairly even through these months. The absence of elevated P or chlorophyll from May through September indicates that nutrient inputs from the construction area were not sufficient to stimulate blooms. It should be noted that a study of mangrove leaf decomposition in northeastern Florida Bay (Davis et al. 2003) found initial P loss via leaching during the first three weeks of decomposition, but strong P retention over the next year. If mangrove mulch remained at the construction site, P retention would also be expected.

Hurricane disturbance

The timing of the P peak points toward the possibility that Hurricanes Katrina and Rita played a role in the incidence of elevated P and phytoplankton blooms. Hurricane Katrina impacted the area on August 26 with winds up to about 45 mph (recorded at the SFWMD weather station in Joe Bay) and Hurricane Rita impacted the area on September 20 with winds up to about 37 mph at this station (Figure 10). Hurricane Wilma impacted the area on October 24 with higher winds – 64 mph at Joe Bay. The direct effect of wind may have been secondary to that of fresh water runoff (especially during Katrina) and storm surge (especially during Wilma) (Figure 13).

The October 2005 peak in TP was observed in samples collected on October 6, between Hurricanes Rita and Wilma. The high TP values cannot be attributed to suspended sediments or low dissolved oxygen (DO) at monitoring stations at the time of TP sampling; both turbidity and DO were near typical values at the time of sampling. However, sediments, porewater, ground water under the Florida Bay and Biscayne Bay and the Keys, and seagrass beds that were disturbed during the weeks between sampling times (September 6 to October 6) may have been sources of elevated P. It should be noted that although the highest TP values were found near U.S. Highway 1, lower peaks (that were nevertheless near or above record levels) occurred on October 6 throughout eastern Florida Bay and southern Biscayne Bay, even at sites such as Little Madeira Bay, which is more than 10 miles away from the highway. Rapid salinity changes during and after Hurricane Katrina (Figure 11) in coastal embayments such as Joe Bay and in coastal wetlands, including rapid salinity increases from storm surge and a rapid salinity drops from the subsequent runoff event, may have killed plants and resulted in a time-lagged nutrient release.

An Interactive effect of highway and hurricane disturbance?

Despite the widespread disturbance of the region by hurricane events, perhaps indicated by elevated P throughout the eastern Florida Bay and southern Biscayne Bay, elevated chlorophyll-*a* levels in this region persisted (through July 2006) only in waters adjacent to U.S. Highway 1.

This finding, combined with the timing of P and chlorophyll increases, indicates that the bloom may have been caused by a combination of both Highway and hurricane disturbance. It is possible that soil and mangrove mulch and associated nutrients along the Highway were mobilized by storm surge and local runoff, concentrating nutrients in portions of basins and coves near the Highway.

Fresh water discharge
One major attribute of Hurricane Katrina in south Florida was high rainfall and fresh water runoff. This runoff not only affects salinity conditions in coastal waters, but also can be a mechanism for increased nutrient loading. In August 2005, approximately 0.8 metric tons of P was released into Manatee Bay from the C-111 Canal through structure S197 in association with hurricane runoff (Fig. 11). The calculation of this relatively high P load (the highest monthly value at this site) in August 2005 was mostly attributable to a single TP grab sample (with a concentration of 116 ppb) at S197 on August 27. Much of this P may have been associated with sediment particles; total suspended solids in the C-111 Canal at S197 were extremely high (15 mg/L) in the August 27 grab sample.

The fate of P that entered Manatee Bay through S197 is unknown. While TP concentrations in Manatee Bay were very high for two days following Hurricane Katrina, they were 12 ppb by September 1. It is likely that much of the P input to Manatee Bay during Katrina was associated with particles that settled to the bottom of the Bay and thus was not measured in water samples. It is highly unlikely that the regional peak in TP in October could be explained by the distribution of TP derived from the Katrina discharge. If this were the case, concentrations would most likely have had a gradient from being high at the source (near Manatee Bay) and lower with distance from the source and this clearly was not the case, with higher concentrations toward Key Largo. The greater than one month lag between Katrina and the regional TP peak in October also argues against the C-111 canal being the main source of this TP.

It should be noted that seven pulse water and nutrient releases from C-111, similar to what occurred with Hurricane Katrina, also occurred between 1991 (when the SFWMD/FIU water quality monitoring program began) and 2000 (Figure 11). None of these earlier releases resulted in large phytoplankton blooms similar to those observed from November 2005 – March 2006.

Phosphorus may also have been transported over the banks of the C-111 canal toward Florida Bay through the southeastern Everglades by storm runoff. While TP concentrations in the wetland south of the canal never rose above 18 ppb and almost all values remained below 8 ppb (SFWMD/FIU data), USGS has estimated that about 0.2 MT of TP was loaded into Long Sound from West Highway Creek during September 2005. While inputs were much higher from the C-111 canal, inputs from natural creeks along the northeast Florida Bay and southern Biscayne Bay coast may also have contributed to the bloom. Creek inputs, however, had a low TP concentration (< 6 ppb) and cannot explain much higher concentrations in the bay.

This evidence, combined with the absence of a negative relationship between salinity and TP concentration (Figure 10) indicates that P associated with fresh water discharges during Hurricane Katrina was not a likely source for the P peak that was observed in the entire region (including Florida Bay), especially when the limited hydrodynamic connection of the Biscayne Bay and Florida Bay systems is considered.

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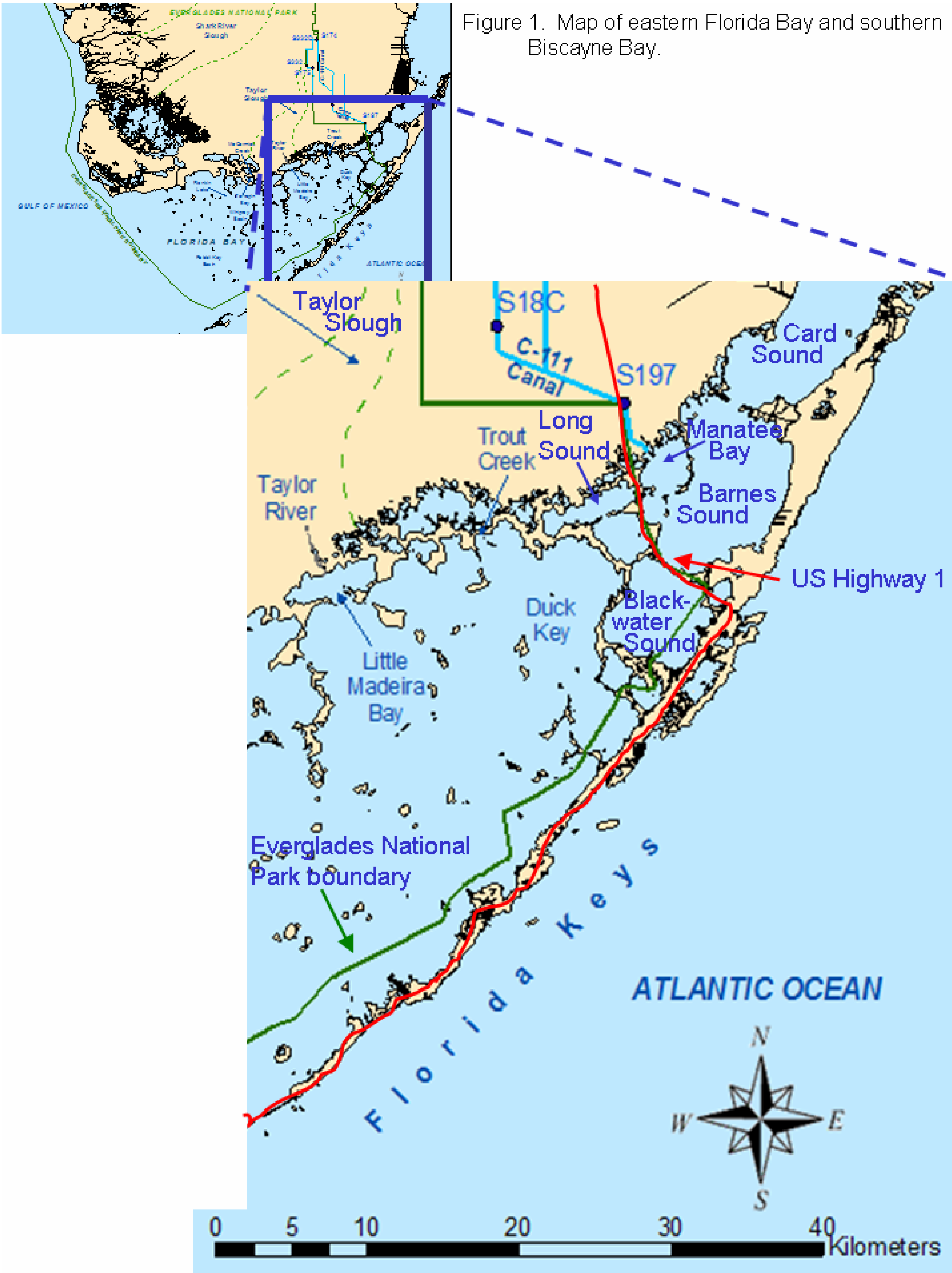


Figure 1. Map of eastern Florida Bay and southern Biscayne Bay.

Figure 2. Long-term record (March 1991 to March 2006) of chlorophyll a and total phosphorus concentrations in Blackwater Sound. Data from FIU/SFWMD coastal water quality monitoring program.

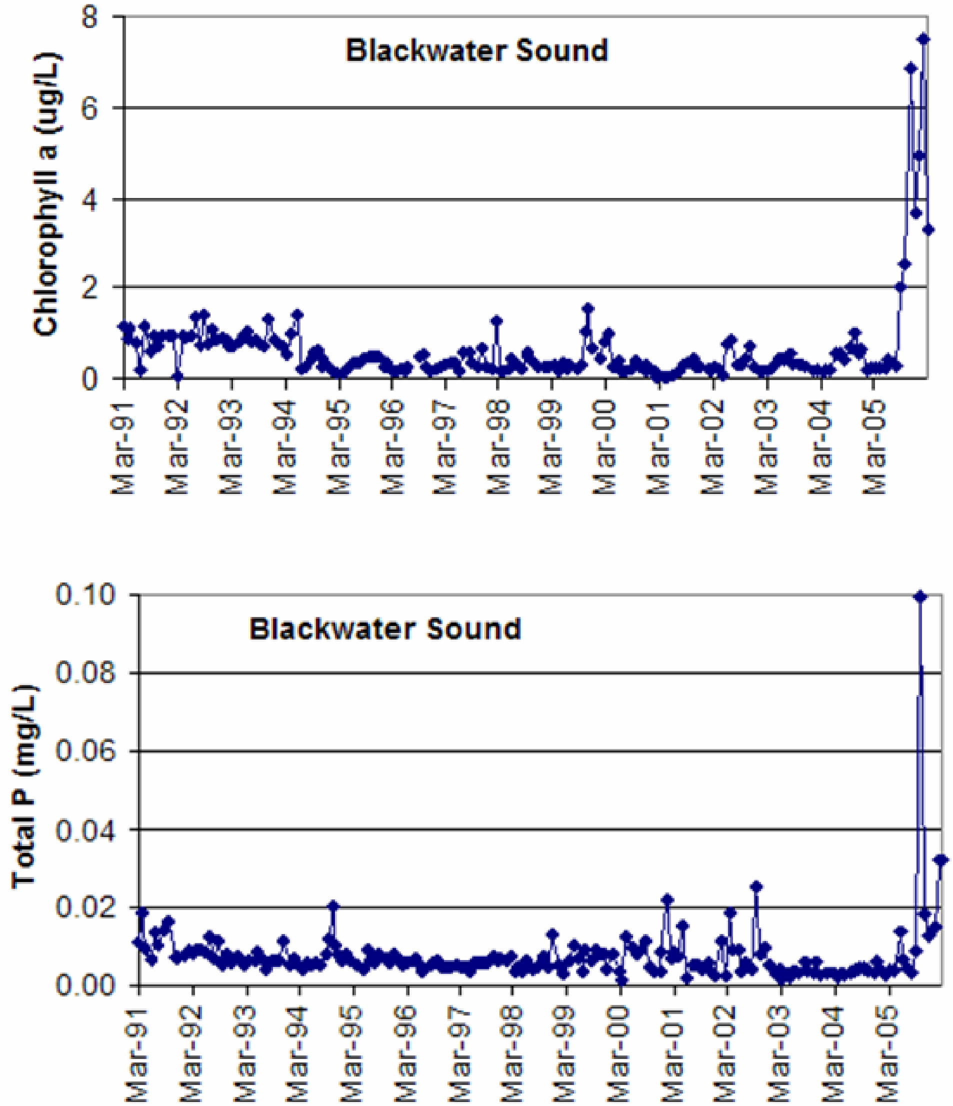
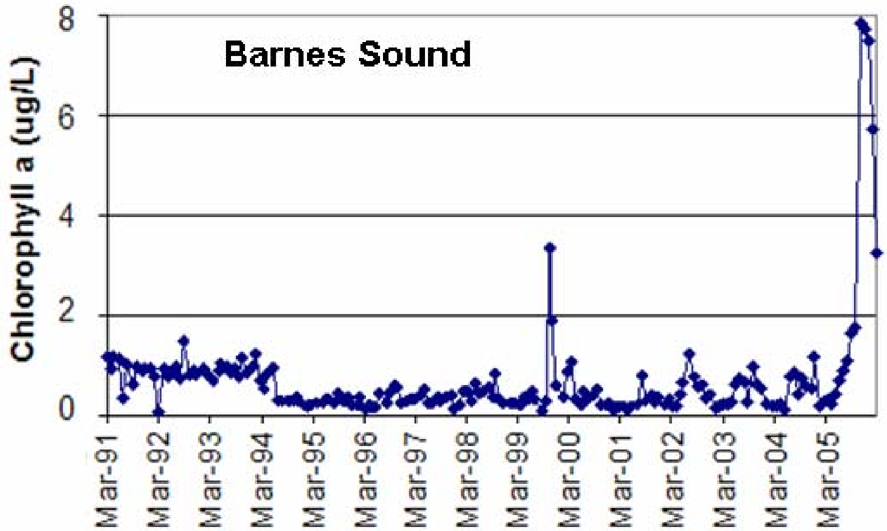


Figure 3. Long-term record (March 1991 to March 2006) of chlorophyll a and total phosphorus concentrations in Barnes Sound. Data from FIU/SFWMD coastal water quality monitoring program.



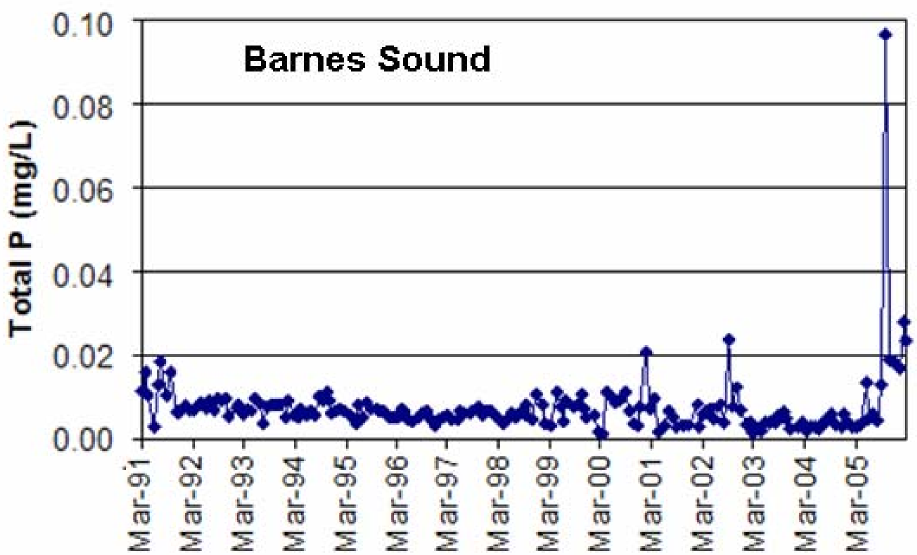


Figure 4. Chlorophyll-a concentrations in Manatee Bay, Barnes Sound, and Card Sound since the initiation of U.S. Highway 1 construction. Data from Miami-Dade DERM (Stations 47, 50, 51).

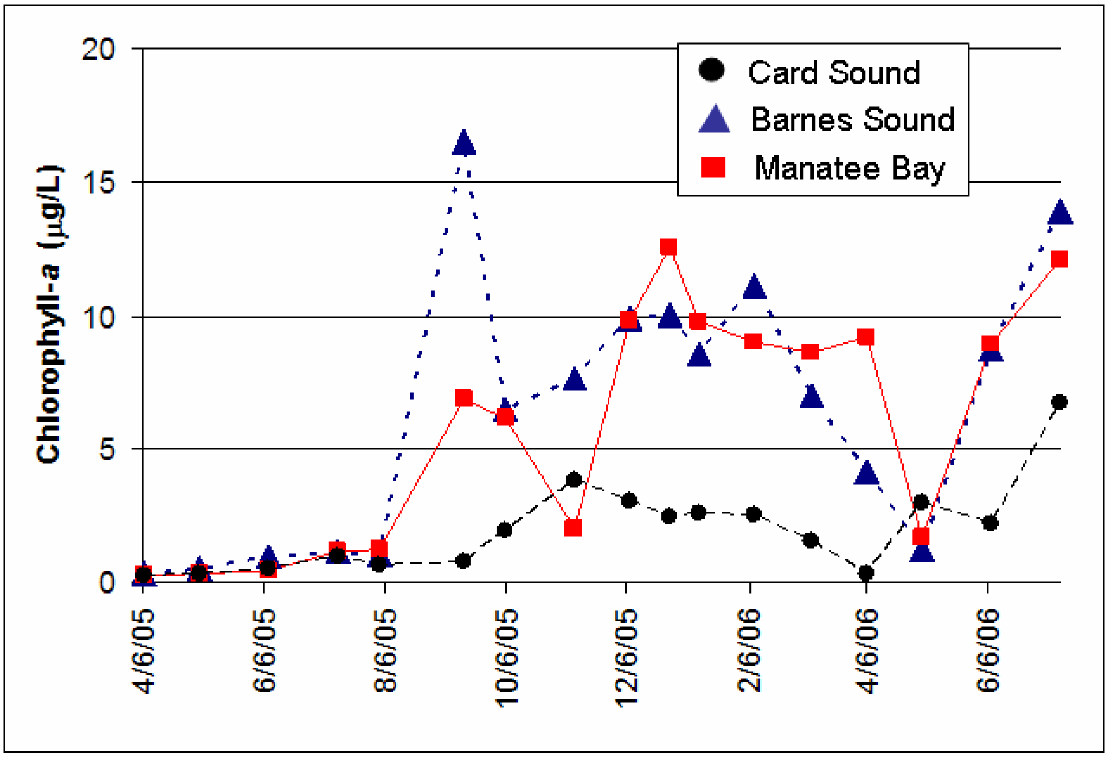


Figure 5. Chlorophyll a concentrations in eastern Florida Bay and southern Biscayne Bay, measured in monthly grab samples as part of the FIU/SFWMD coastal water quality monitoring program. Stations are marked by crosses. Concentration contours calculated by J. Boyer.

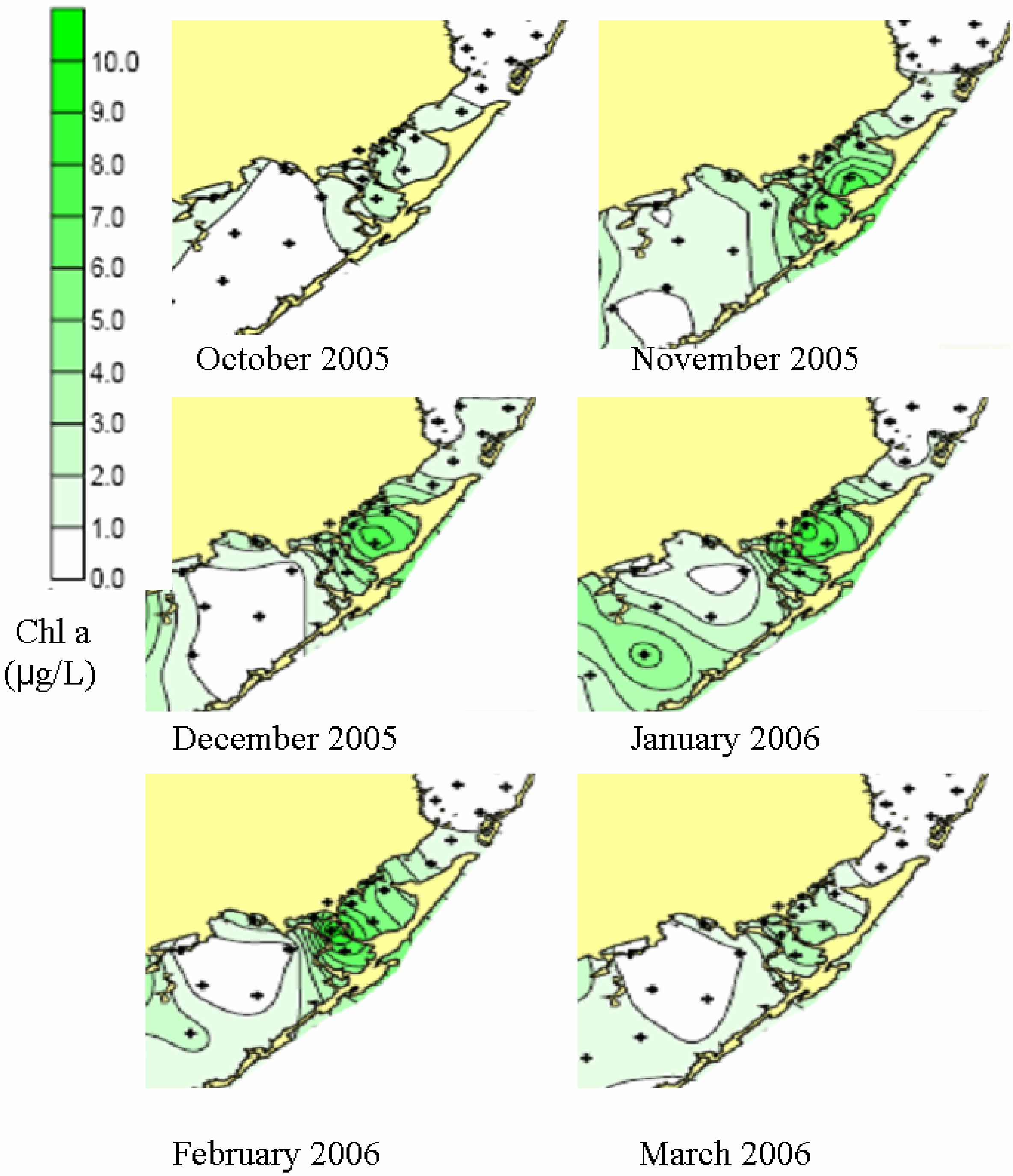
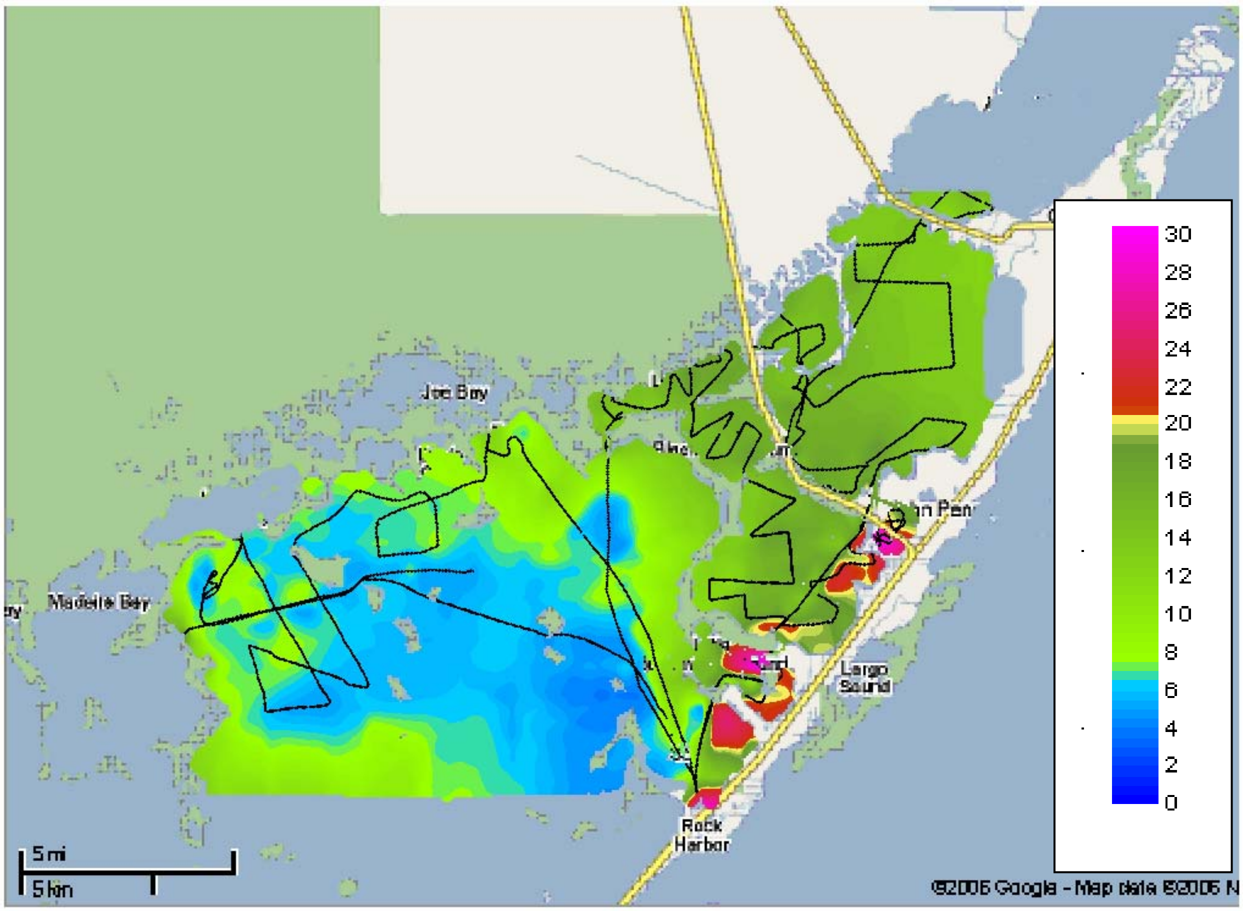


Figure 6. High resolution map of chlorophyll fluorescence (preliminary estimate) in eastern Florida Bay and southern Biscayne Bay, January 24-26, 2006. Map from high density Dataflow boat tracks (black line) throughout the mapped region.

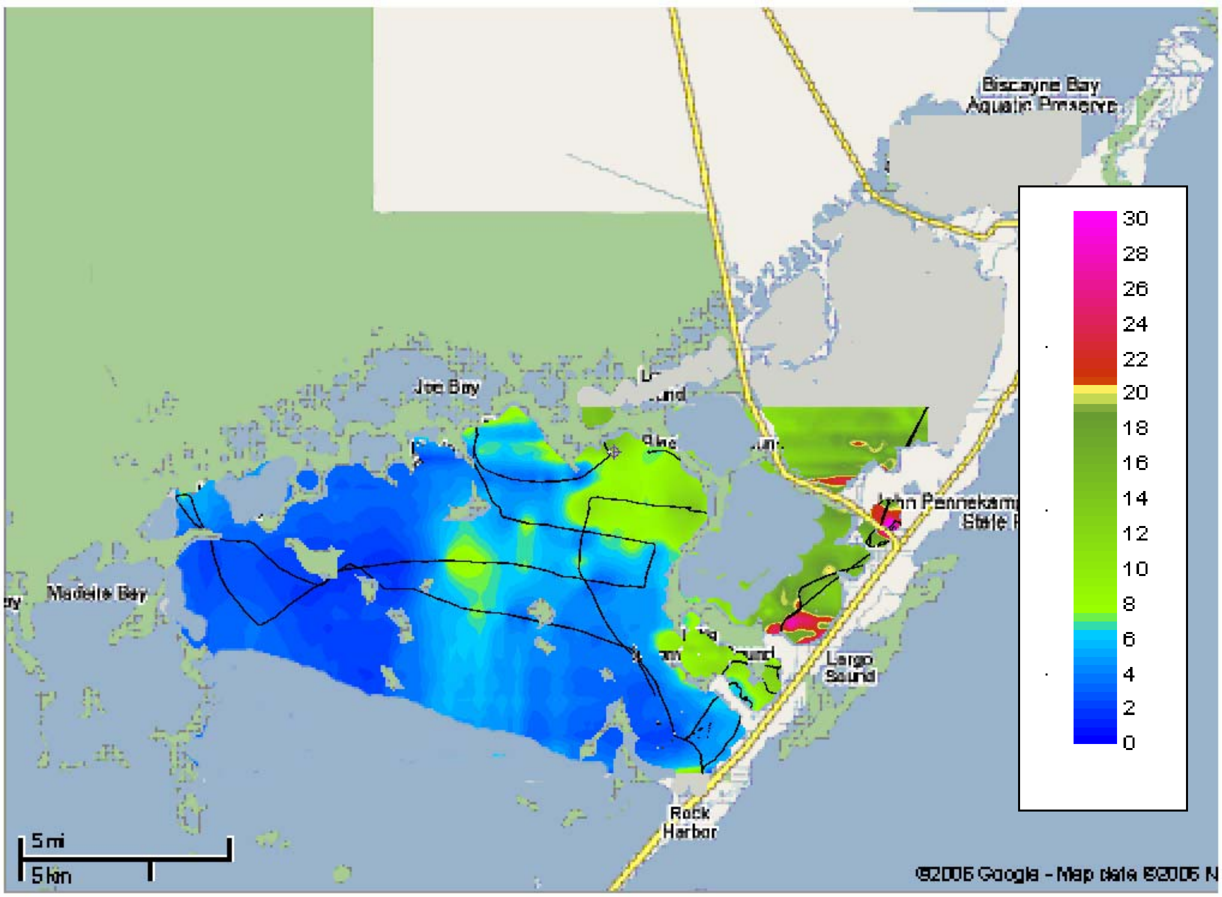
January 2006 – Chlorophyll-*a* (µg /L)



Provisional data (cmadden@sfwmd.gov)

Figure 7. High resolution map of chlorophyll fluorescence (preliminary estimate) in eastern Florida Bay and southern Biscayne Bay, April 11, 2006. Map from high density Dataflow boat tracks (black line) throughout the mapped region, except for north of southern Barnes Sound and Blackwater Sound, where rough conditions prevented analysis. Strong easterly winds existed during this survey.

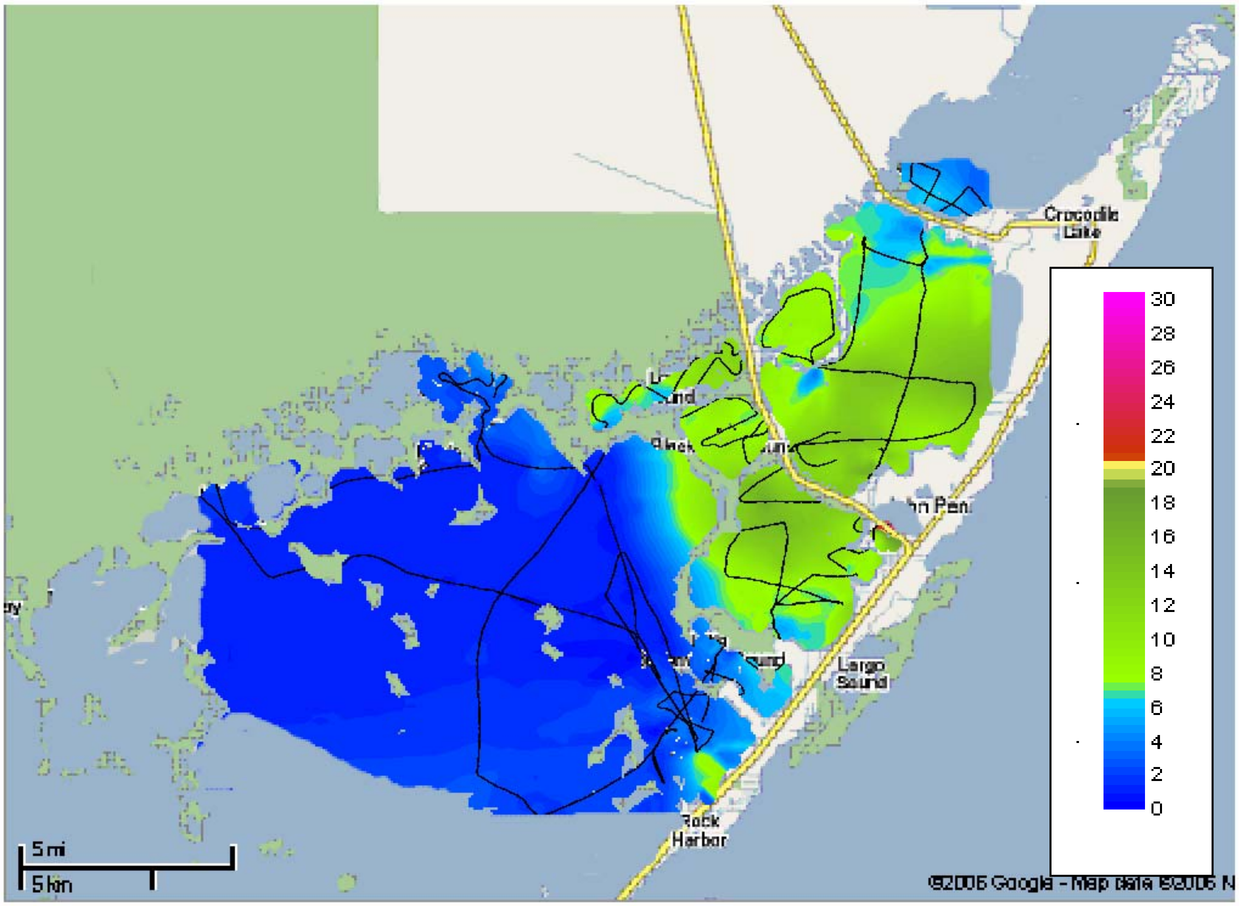
April 2006 – Chlorophyll-*a* (µg /L)



Provisional data (cmadden@sfwmd.gov)

Figure 8. High resolution map of chlorophyll fluorescence (preliminary estimate) in eastern Florida Bay and southern Biscayne Bay, May 25-26, 2006. Map from high density Dataflow boat tracks (black line) throughout the mapped region.

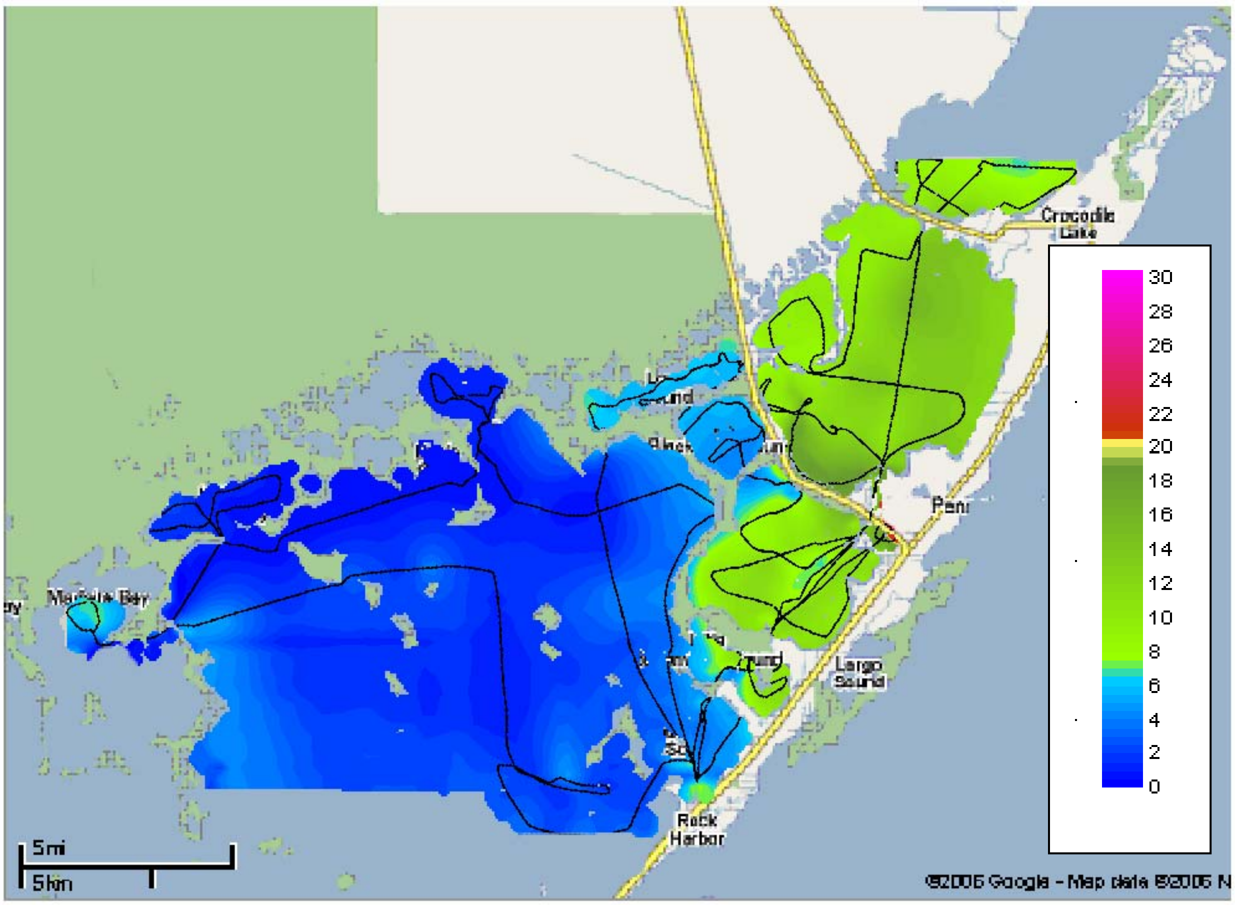
May 2006 – Chlorophyll-*a* (µg /L)



Provisional data (cmadden@sfwmd.gov)

Figure 9. High resolution map of chlorophyll fluorescence (preliminary estimate) in eastern Florida Bay and southern Biscayne Bay, July 19-20, 2006. Map from high density Dataflow boat tracks (black line) throughout the mapped region.

July 2006 – Chlorophyll-*a* (µg /L)



Provisional data (cmadden@sfwmd.gov)

Figure 10. Time series of wind speed measured above Joe Bay during the 2005 hurricane season.

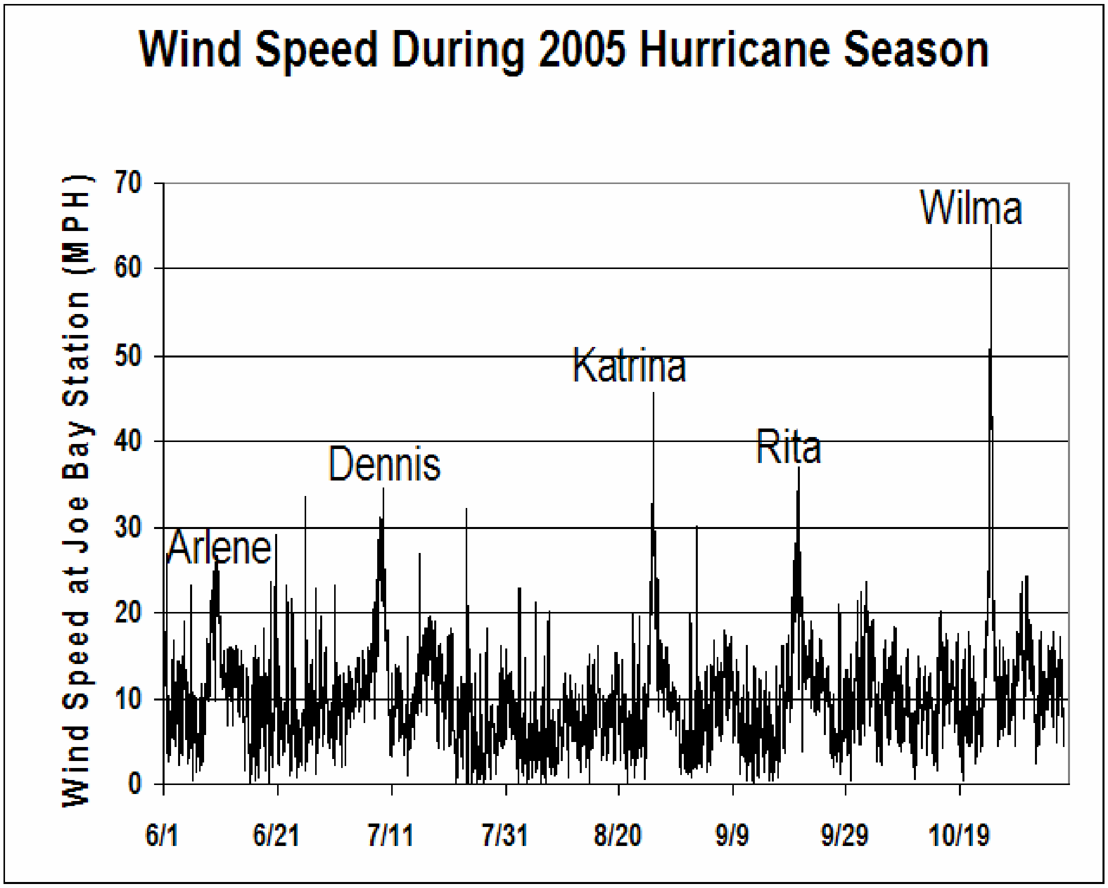


Figure 11. High resolution maps of salinity immediately before and after Hurricane Katrina, which passed through the region on August 26, 2005. High rainfall and runoff resulted in a rapid decrease in salinity, particularly near the coastline. The black line shows the ship track along which data were collected. Maps courtesy of C. Kelble and P. Ortner (NOAA-AOML).

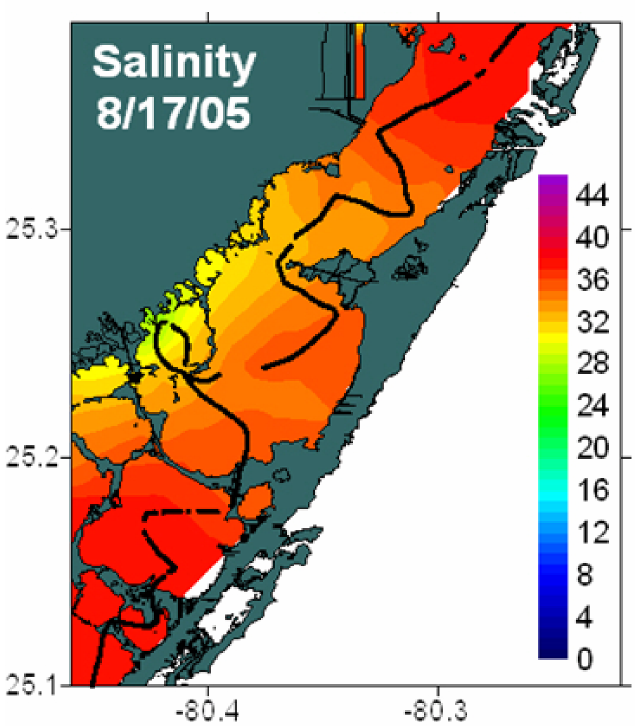


Figure 12. Time series of monthly water discharge and total phosphorus load through the C-111 canal since the initiation of coastal water quality monitoring in 1991. P load is calculated here from grab samples at structures.

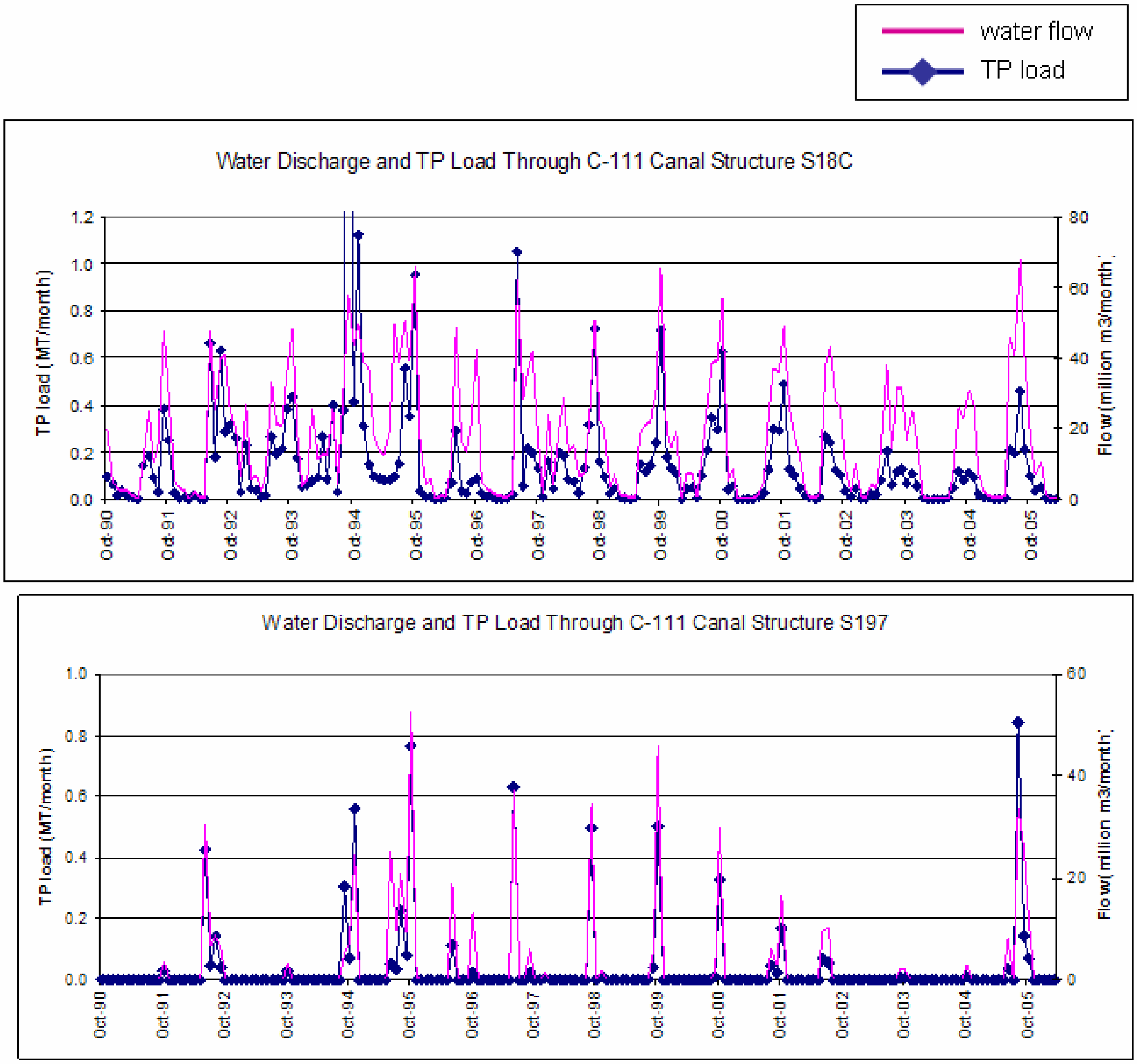


Figure 13. Time series of water levels at three sites in northeastern Florida Bay and southern Biscayne Bay, showing storm the influence of three hurricanes in 2005. The West Highway Creek gage is at the creek mouth in eastern Long Sound, the Manatee Creek gage is at the creek mouth in eastern Manatee Bay, and the Jewfish Creek gage is at its western end in eastern Blackwater Sound. Data and graphic courtesy of Mark Zucker, USGS.

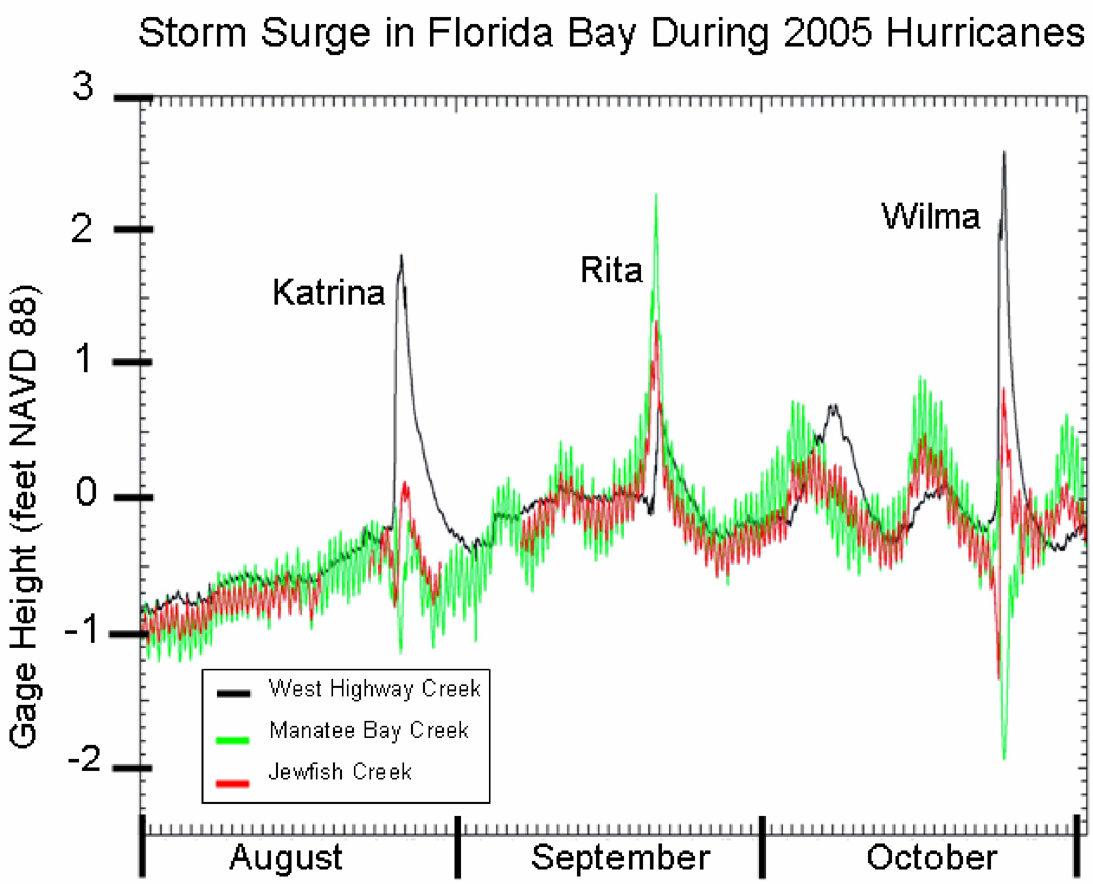


Figure 14. Total phosphorus concentrations in eastern Florida Bay and southern Biscayne Bay, measured in monthly grab samples as part of the FIU/SFWMD coastal water quality monitoring program. Stations are marked by crosses. Concentration contours calculated by J. Boyer.

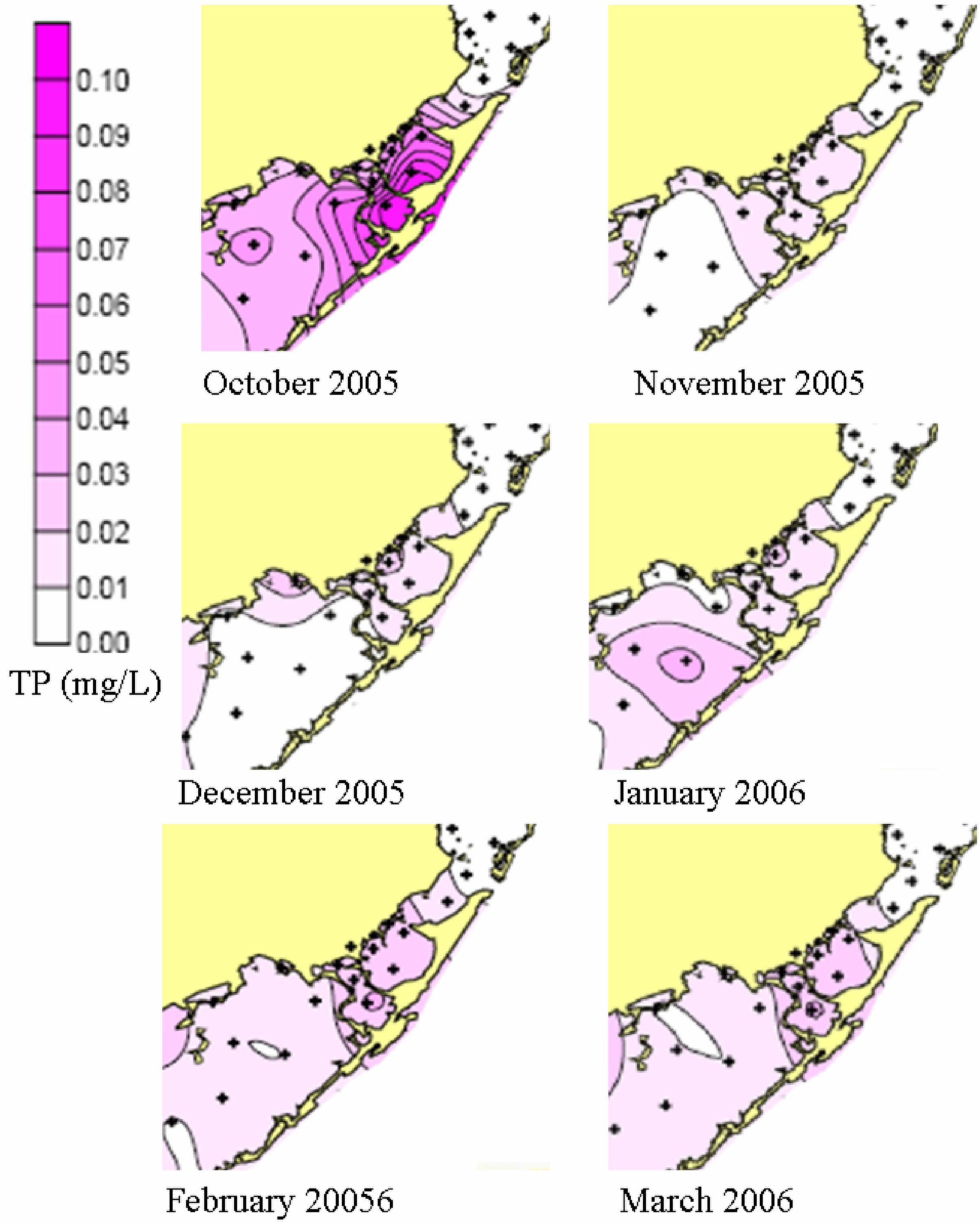


Figure 15. Total phosphorus, chlorophyll a, and salinity at three sites in eastern Florida Bay and southern Biscayne Bay from March 2005 through March 2006, measured in monthly grab samples as part of the FIU/SFWMD coastal water quality monitoring program.

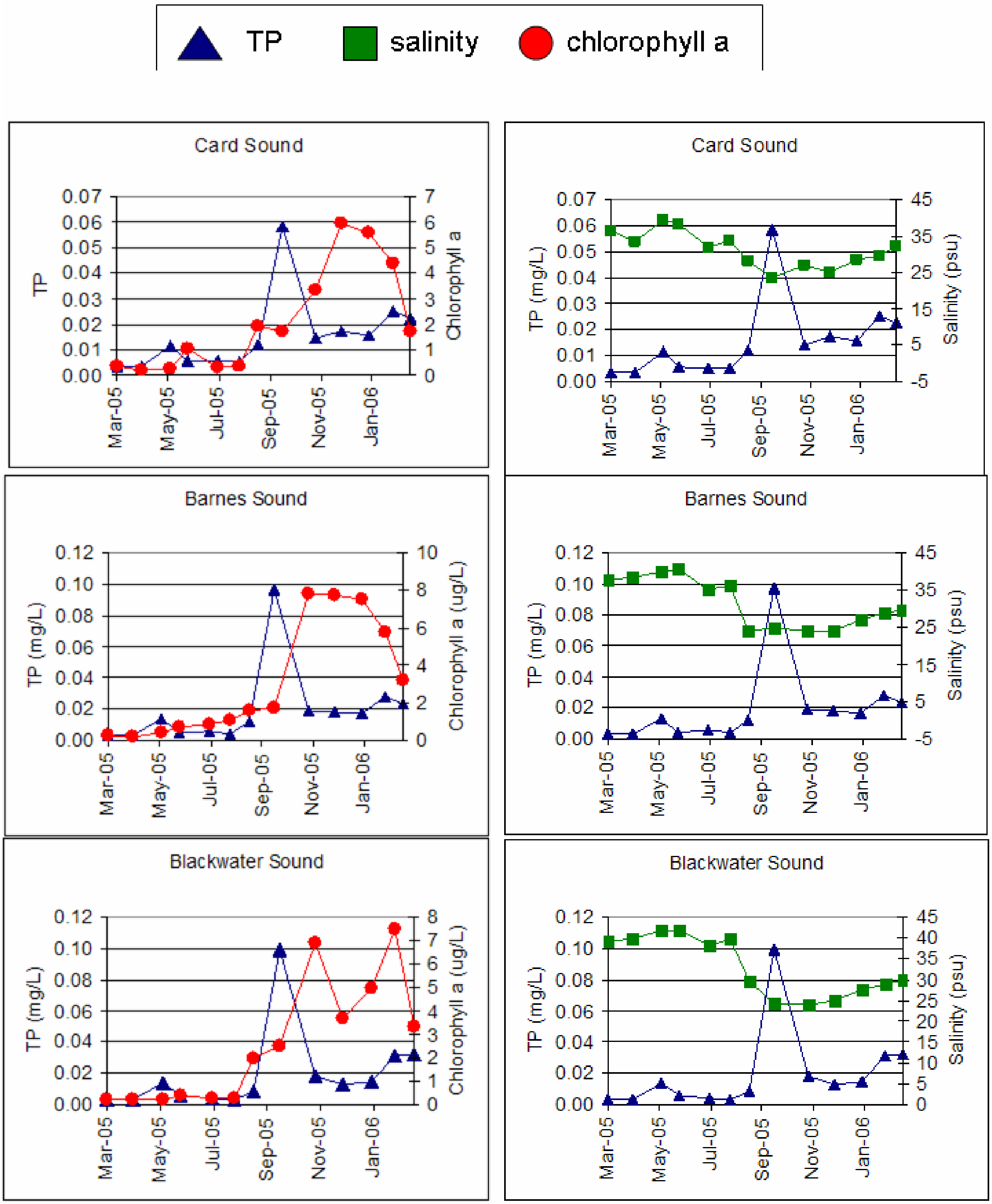
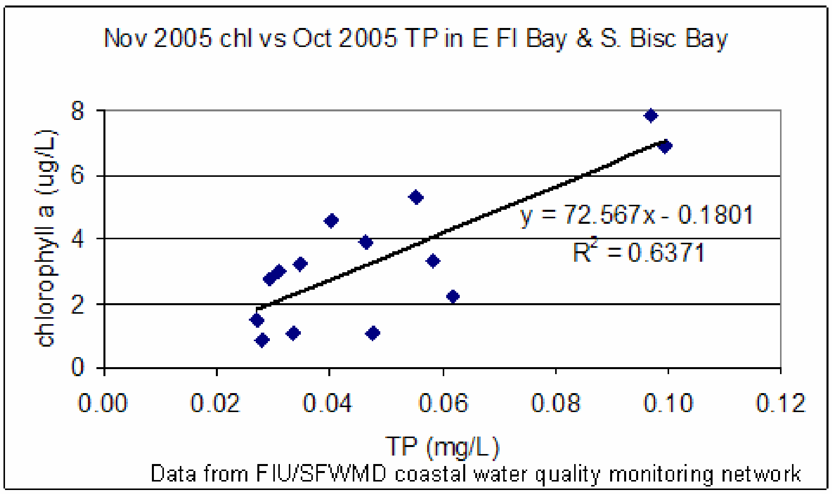


Figure 16. Linear regressions of chlorophyll a concentrations as a function of total phosphorus (TP) concentrations. The top panel shows November chlorophyll with TP from the previous month at all eastern Florida Bay and southern Biscayne Bay sites in the SFWMD / FIU water equality monitoring program. The bottom panel shows concurrent chlorophyll and TP from December 2005 through April 2006 at five sites in southern Biscayne Bay (from S. Blair, Miami-Dade DERM).



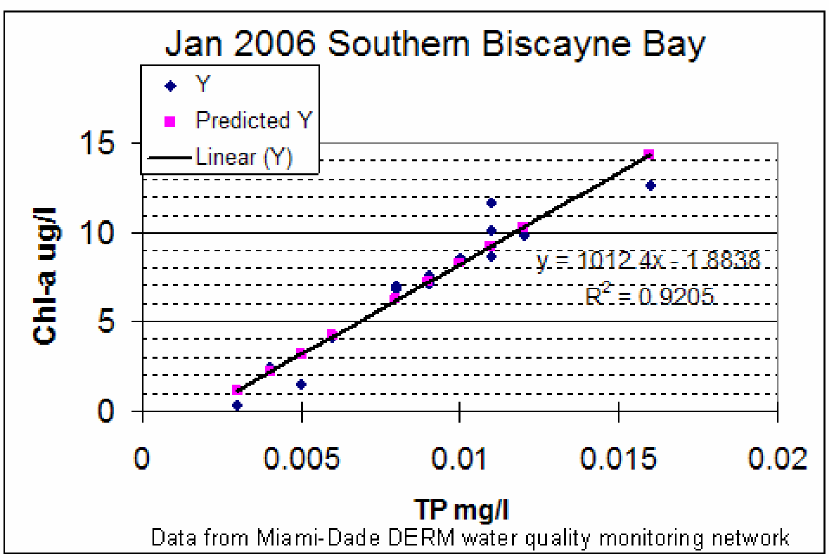


Figure 17. Linear regressions of total phosphorus (TP) concentrations as a function of salinity in October 2006 at all eastern Florida Bay and southern Biscayne Bay sites in the SFWMD / FIU water equality monitoring program.