2015 Florida Bay Seagrass Die-Off

National Park Service
U.S. Department of the Interior

South Florida Natural Resources Center
Everglades National Park

Background

Florida Bay is a large (approximately 2,200 km^2), shallow estuary bounded to the north by the Florida peninsula and to the south and east by the Florida Keys. Though connected to the Gulf of Mexico to the west, the gulf and the bay have limited exchange of water due to the presence of a series of shallow mud banks, typically covered with and stabilized by seagrass communities (Figure 1). These banks separate the bay into basins, each with its own physical characteristics. Much of the bay bottom supports submerged aquatic vegetation; primarily turtle grass (*Thalassia testudinum*), shoal grass (*Halodule wrightii*), and manatee grass (*Syringodium filiforme*). The seagrass beds produce oxygen, vital to the system, and provide critical habitat and food for many invertebrates, fishes, birds, mammals, and reptiles, including threatened or endangered species such as the Florida manatee (*Trichechus manatus latirostris*), sea turtles (primarily *Caretta caretta*), and smalltooth sawfish (*Pristis pectinata*). Approximately 1,625 km^2 of Florida Bay are located within Everglades National Park. The submerged land of Florida Bay within the park is part of the Marjory Stoneman Douglas Wilderness.

The hydrology of Everglades has been severely altered over the last 100 years through the diversion of the southerly flow of surface waters from central Florida and Lake Okeechobee. This has significantly reduced fresh water input to Florida Bay, such that the ecological state of the estuary is now precariously balanced. A localized drought in south Florida, that began in 2014 and continued into 2015, further reduced fresh water flows into Florida Bay to critically low levels. Short-lived, but extreme levels of temperature, salinity, and oxygen followed and produced a substantial collapse of the seagrass ecosystem in the summer and fall of 2015. Specifically, the central region of the bay suffered an extensive turtle grass die-off within an area of approximately 40,000 acres. A die-off this large is an unusual event in the bay, happening only a few times in its recorded history, and may be linked to the 2015 El Niño. Here, we explain the sequence of events that led up to the 2015 seagrass die-off, identify the ecological responses, and discuss ongoing efforts to monitor conditions and minimize additional impacts.

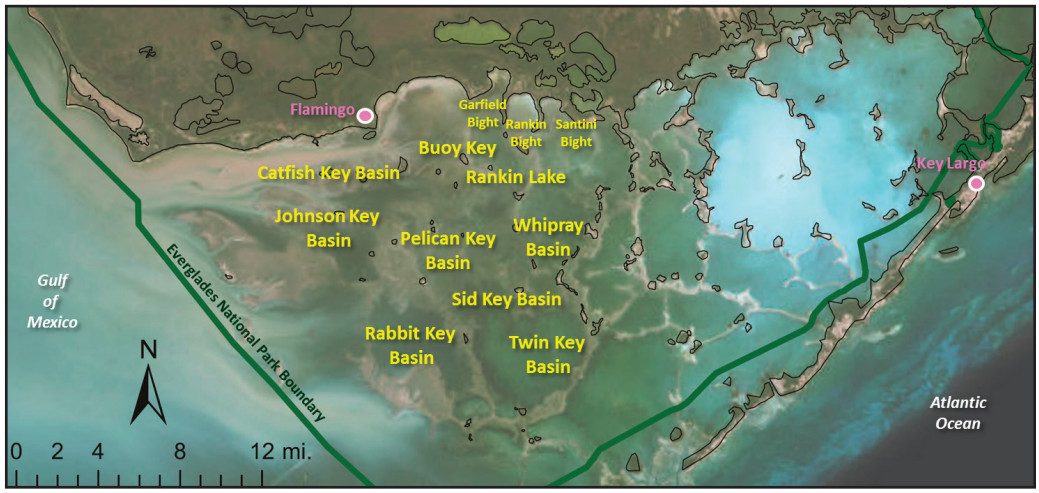

Figure 1. Darker areas in the named basins above indicate seagrass distribution prior to the 2015 die-off.

The 2015 Seagrass Die-Off

In 2015, the dry season, typically November through April, lasted well into the summer, delaying seasonal summer rainfall over the south Florida region and Florida Bay by three months. The period of low rainfall from May through mid-August resulted in record low coastal freshwater discharges into the bay in August (Figure 2).

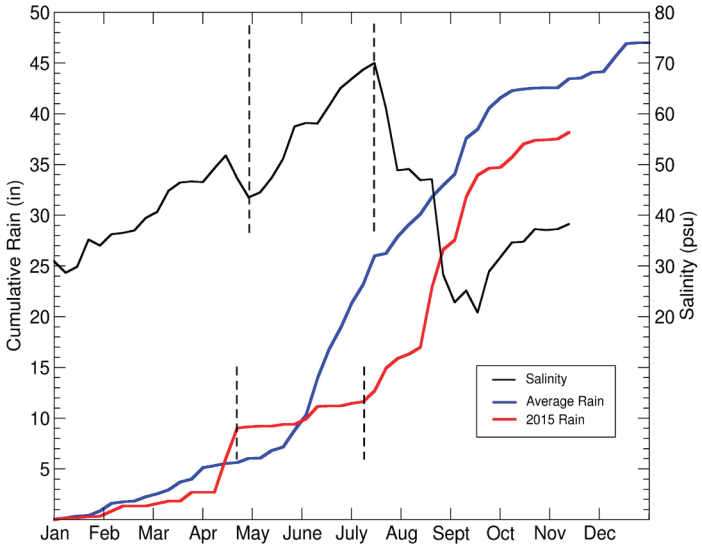

Figure 2. Cumulative rain in inches (red line) and the corresponding salinity in practical salinity units (psu, black line) at Garfield Bight in Florida Bay. Calendar year rainfall by mid-July 2015 was less than 50% of the average cumulative rainfall (blue line).

This period of low precipitation, combined with high temperatures and calm winds that produced rapid evaporation, caused salinity to increase in the semi-enclosed basins in north-central Florida Bay. Within Garfield Bight, water temperatures exceeded 34 C (93.2°F) for more than 77 days and reached a maximum water temperature of 37.9 C (100 °F) at the end of July.

In June 2015, water monitoring stations revealed daily average salinity levels exceeding the maximum values of the last decade in the north-central portion of Florida Bay (Figure 3). By mid-July, salinity values at Garfield Bight peaked at 72 psu (practical salinity units), twice normal ocean salinity, and the highest salinity value ever reported in Florida Bay (the record spanning the last 68 years).

During daylight hours, oxygen is produced via photosynthesis by algae and seagrass. At night, photosynthesis stops, and the amount of oxygen dissolved in water decreases because animals, plants, and microbes use oxygen for their respiration. A daily rise and fall in dissolved oxygen levels in the water results. During the summer of 2015, high temperature and salinity reduced the amount of oxygen that could stay dissolved in the water column which led to night time periods of anoxia (when the water holds no dissolved oxygen). Over the past decade, turtle grass beds in Florida Bay had been thriving and had become dense, and thus, in 2015, had

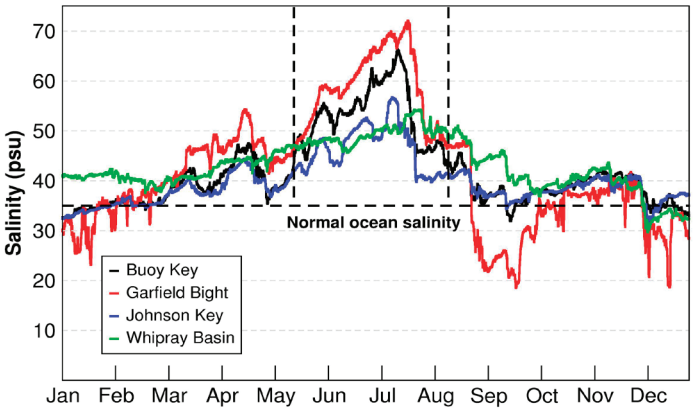

Figure 3. Daily averages of continuous readings of Florida Bay salinity at Garfield Bight (red), Whipray Basin (green), Johnson Key (blue), and Buoy Key (black) monitoring stations during 2015. Ocean water averages 35-37 psu.

a high demand for oxygen at night, increasing susceptibility to stressful physical conditions.

When oxygen is absent, some bacteria in the water column and sediments use sulfur for respiration instead. However, the consequence is hydrogen sulfide production, which is toxic to seagrass. A working hypothesis proposes that prolonged anoxic periods led to sufficient sulfide production to cause extensive areas of turtle grass to die. The anoxia was initiated by low oxygen solubility caused by high salinity and temperature combined with high respiration rates. Bottom waters and sediment pore waters (waters extracted from a wet sediment sample) contained high concentrations of sulfide, 12 milliMolar (mM), levels toxic to turtle grass (Figure 4). The presence of a "rotten egg" odor in the area of the seagrass die-off and observations of a yellow haze in the bottom waters among the seagrass provide further evidence for the role of sulfide in the die-off (Figure 5).

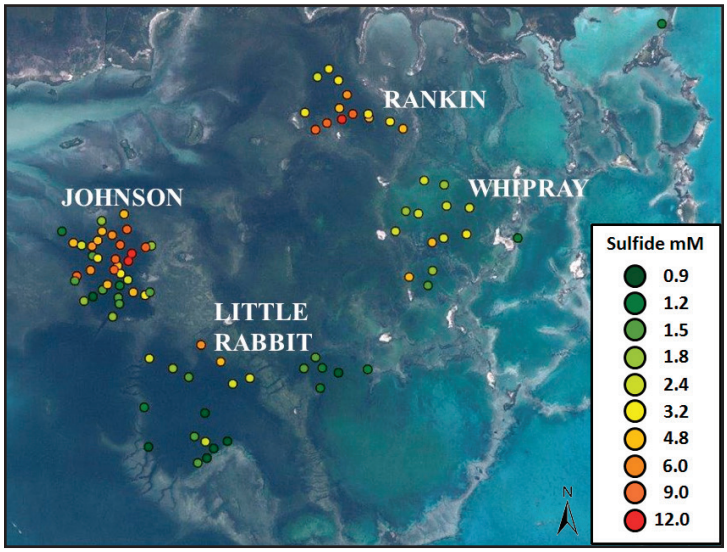

Figure 4. Sulfide concentrations measured in sediment pore water in Rankin Lake, Johnson Key Basin, Little Rabbit Key Basin and Whipray Basin. Yellow, orange, and red dots mark sampling locations where concentrations threaten the viability of turtle grass. Source: Paul Carlson, Florida Wildlife Research Institute, FWC.

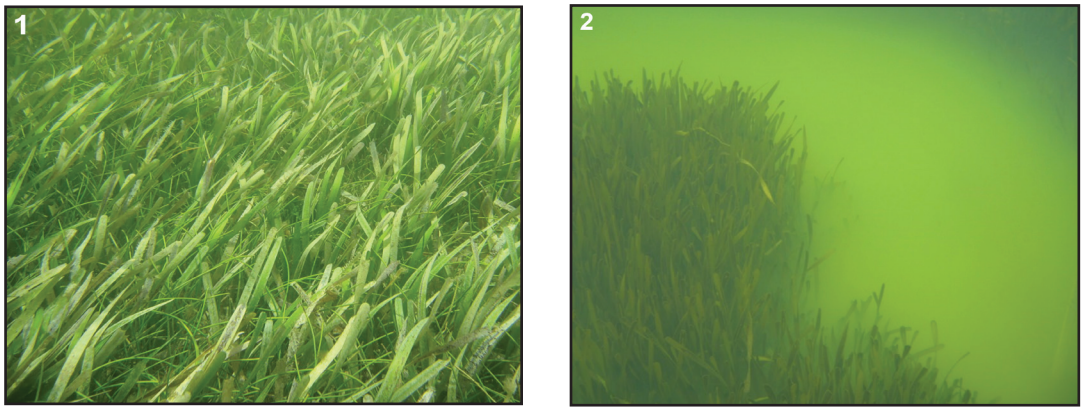

Figure 5. Associated with high sulfide concentrations measured in sediment pore water, a yellow haze was observed on the bottom of die-off areas of Florida Bay in Rankin Lake, near Buoy Key, and in parts of Johnson Key and Whipray Basins. (1) Healthy Seagrass. (2) Yellow haze in waters with high salinity, low oxygen, and high sulfide.

Ecological Consequences

The extreme conditions occurring in the summer of 2015 resulted in an acute, catastrophic loss of seagrass in the north-central and western basins of the bay. Visual bottom surveys, conducted both from boats and by observers in the water, indicate that seagrass was impacted in an area of more than 40,000 acres; with more than half of that area being dead turtle grass. The die-off area consisted of patches of live seagrass of varying size in the midst of large stands of dead turtle grass. Turtle grass mortality in Rankin Lake and Rankin Bight was high, approaching 90% of what had existed. Turtle grass mortality in Johnson Key Basin was between 60%-85%. Pelican Key Basin was greatly affected, with nearly all of the northern portion dead, and the southern portion containing small patches of surviving grass. Initial assessments indicate the die-off zone includes the following areas: Snake Bight, Garfield Bight, Rankin Bight, Santini Bight, Rankin Lake, western Whipray Basin, Pelican Key Basin, Catfish Key Basin, Johnson Key Basin, and small parts of northern Rabbit Key and Sid Key Basins (Figure 6).

At the beginning of the event, in July 2015, thick mats of floating dead seagrass were found along the shores and extending offshore in the bights (Snake, Garfield, Rankin, and Santini), and along the mangrove islands and shallow banks (Figure 7). As of January 2016, some parts of the affected areas had dead leaf blades standing in place; while in other areas only leaf sheaths remained, with seagrass roots and rhizomes ("runners") dead beneath the sediment (Figure 8). Previously floating dead plant material covered large areas of the bottom in the die-off zone. Once a die-off is underway, the decay of seagrass on the bay bottom and accumulated in mats along the shoreline consumes even more dissolved oxygen and further contributes to sulfide production. The result can be a continuation of anoxic conditions, fueling even more seagrass die-off.

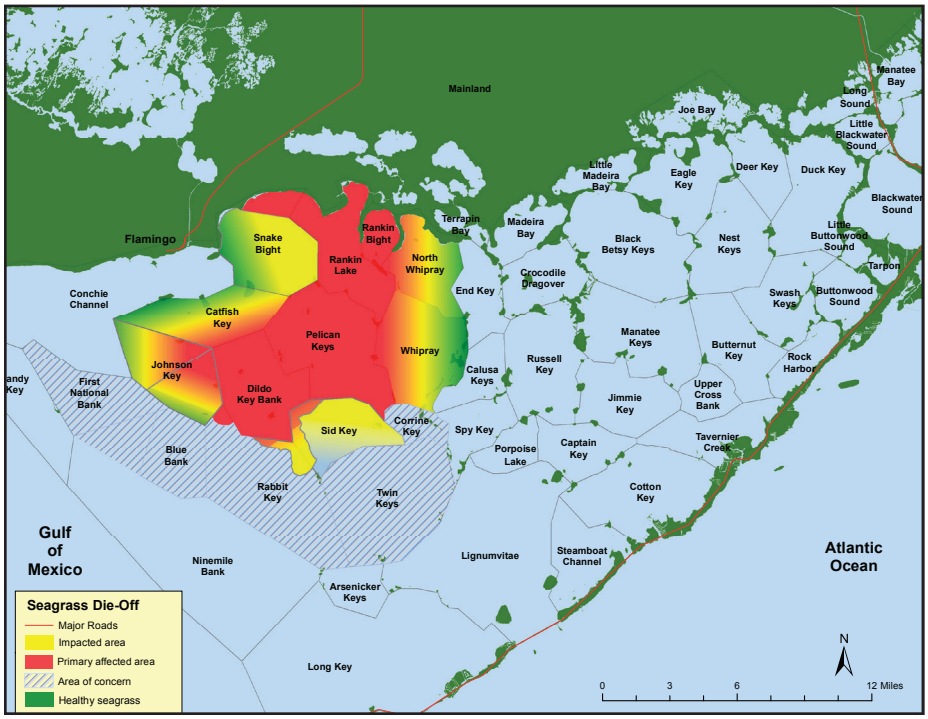

Figure 6. Area of Florida Bay turtle grass die-off event in July 2015 through February 2016. Red = area containing dead turtle grass in patches of varying size; not 100% dead. Yellow = mixed live/dead impacted areas. Green = healthy turtle grass. Striped area = dense seagrass most at risk of die-off expansion.

The consequences of a seagrass die-off with low oxygen and high sulfide are not limited to the seagrasses. Localized fish kills occurred sporadically in the same areas as the 2015 die-off, affecting pinfish, mojarra, mullet, and toad fish. Following the loss of seagrass habitat, animals that normally shelter in seagrass were left exposed in the water column, increasing their risk of predation.

After a seagrass die-off event of this magnitude, the large quantity of dead seagrass and an extensive decaying root system will release nutrients into the water column. The added nutrients may initiate an algal bloom at some time in the future. Once algal blooms are initiated, they can reduce light

Figure 7. The die-off produced mats of floating seagrass on the surface of the water and plant litter decaying on the bay bottom. Bacterial decomposition of large amounts of organic matter can lead to anoxia and algal blooms.

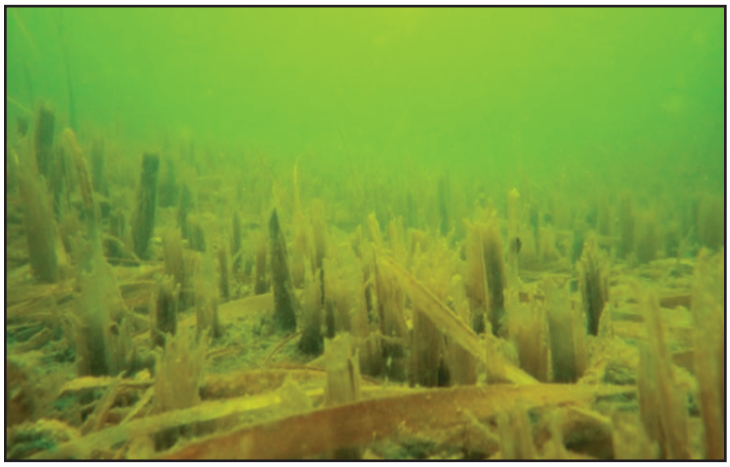

Figure 8. Many areas of former beds of seagrass have been denuded. Only stubble of the turtle grass remains.

penetration to seagrass beds, decreasing seagrass productivity and expanding the area of seagrass die-off. A cycle is triggered as the increase in nutrients fuels additional algal blooms. During past algal blooms in the bay, the production of blue-green algae (which are photosynthetic bacteria) was so high that it killed sponges, one of the bay's best mechanisms to keep the water filtered, clear, and healthy. While an algal bloom may be a relatively short-term event (year), the loss of sponges, reduction of sediment stability, higher turbidity, and changes in benthic flora and fauna resulting from the seagrass die-off can alter the ecology of the bay for many years into the future.

Similar physical conditions in 1987 triggered a seagrass die-off event that killed approximately 10,000 acres of seagrass in central and western Florida Bay. Algal blooms developed in the years following the 1987 die-off, causing further injury. Eventually, almost 60,000 acres of habitat were impacted, and effects of the die-off lasted for over 20 years, including reduced water clarity, elevated nutrients, algal blooms, and damage to fish, lobster, and sponge populations. With such an impacted system, the effects are both biological and economic. Florida Bay provides the nursery area for a multi-billion dollar fishery and tourism-centered economy. When Florida Bay is unhealthy, the impacts are felt across south Florida.

Current Status

Beginning in August 2015 and continuing through the winter, rain events increased fresh water input and reduced salinity to normal levels in the affected areas of the bay. However, episodes of low dissolved oxygen occurred at Buoy Key and Garfield Bight into the early winter, and elevated sulfide continues to be observed as of April 2016, suggesting that the seagrass die-off may continue to expand (Whipray Basin and Rabbit Key Basin). Repeat visits to Whipray Basin indicate that additional areas of turtle grass died between August and November 2015. Fish kills continue to be reported sporadically. Despite some reports from the public, neither widespread nor persistent algal blooms have yet been documented, although elevated levels of chlorophyll-*a* have been recorded in some locations.

Ongoing Efforts

- Monitoring will continue to quantify the extent, pattern, and ecological consequences of this event. Aerial photography has been obtained and is being analyzed to evaluate the quantity and distribution of the seagrass in the die-off zone.
- Interagency efforts to sample and analyze water quality, including sulfide concentrations, will continue. Salinity and water quality are continuously monitored at sentinel stations in some of the affected areas, and at monthly or bimonthly intervals elsewhere. Increased water quality analysis for nitrogen and phosphorus concentrations is needed as an indicator of algal bloom potential.
- Monitoring and assessment, along with surveys of park visitor experience, will inform park management. Possible actions to reduce impacts include closures to protect damaged areas and reductions in fish harvest to protect gamefish populations.
- Implementation of Everglades Restoration projects to restore regional hydrologic conditions will help reduce the likelihood of die-offs in the future. In the short-term, the National Park Service is working with State and Federal water managers to improve flows to Taylor Slough that may help decrease additional negative impacts in Florida Bay.

For further information please contact the Everglades Marine Team at Ever_Marine_Team@nps.gov