# ANALYSIS OF RESTORATION TRADE-OFFS: A CASE STUDY OF CAUSEWAY REMOVAL IN FLORIDA BAY

Stephen Kelly, Kevin Cunniff, David Rudnick, Amanda McDonald and Christopher Madden (2007)

## Background

Ecosystem restoration entails disturbing the system, yielding ecological effects that the public can perceive as being both positive and negative. Lake Surprise (Key Largo, Florida, USA), is a saline lake located between eastern Florida Bay and southern Biscayne Bay (Figure 1). The lake was bisected in 1906 by a causeway built to support the Flagler Railroad to Key West. The causeway later became the roadbed for the Florida Keys Overseas Highway (U.S. 1). As part of the U.S. 1 widening project, the causeway is scheduled for removal in order to reestablish hydrologic connectivity, improve conditions for the endangered American Crocodile (*Crocodylus acutus*) and other fauna, and increase access for public recreation.

However, causeway excavation could also impact water quality in the lake and adjacent waters by increasing turbidity and nutrient (N and P) loading. This could exacerbate a persistent regional phytoplankton bloom that has peak chlorophyll-*a* concentrations in Lake Surprise (Figure 2). Effects of excavation on the lake's submersed aquatic vegetation (SAV) may determine restoration success in coming years, as SAV can stabilize sediments, minimize pelagic nutrient availability and nutrient export.

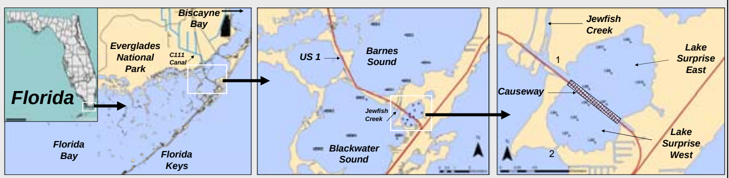



Figure 1. Location of Lake Surprise and surrounding basins. Connections between the Lake and surrounding basins are: 1) a canal between the eastern Lake and Jewfish Creek; and 2) a small cut between the western Lake and Blackwater Sound.

### Field Assessment

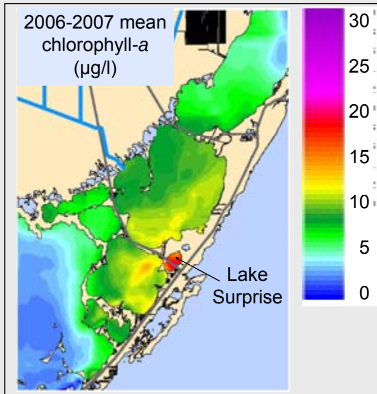
- Water quality surveys for chlorophyll-*a* and nutrients conducted about bimonthly (2006-2007) using the Dataflow system.
- Dissolved oxygen (at one station per basin) measured at 15 minute intervals in September-October 2006, 2007.
- Benthic surveys (stations shown in Figure 1) conducted in 2007 to assess SAV abundance, distribution, and nutrient content, as well as sediment characteristics and nutrient content (Table 1).

Table 1. Site characteristics. Values are mean (standard deviation); ***bold italics*** indicate significant difference (multiple comparisons test) at $p < 0.05$.

| | Lake Surprise | Blackwater Sound | Barnes Sound |
|---|---|---|---|
| Water Depth (m) | ***1.7 (0.2)*** | 2.2 (0.3) | 2.6 (0.7) |
| Light Penetration (%) [1] | ***16 (4)*** | 9 (4) | 8 (7) |
| Chlorophyll-*a* (µg $l^{-1}$) [2] | ***17.5 (6.4)*** | 9.5 (4.2) | 9.3 (3.5) |
| Sediment Bulk Density (gdw $cm^{-3}$) [3] | ***0.2 (0.2)*** | 0.7 (0.3) | 0.4 (0.2) |
| Sediment Organic Matter (%) [3] | ***19 (8)*** | 8 (4) | 14 (3) |
| Sediment Phosphorus (%) [3] | ***0.022 (0.009)*** | 0.007 (0.002) | 0.010 (0.004) |
| Sediment Nitrogen (%) [3] | ***0.8 (0.3)*** | 0.3 (0.1) | 0.5 (0.1) |
| Sediment Carbon (%) [3] | ***15 (2)*** | 12 (1) | 13 (1) |
| Tt Biomass (gdw $m^{-2}$) [4] | ***93 (32)*** | 28 (21) | - |
| Tt Leaf Area ($cm^2$ short $shoot^{-1}$) [4] | ***62 (30)*** | ***20 (11)*** | ***36 (21)*** |
| Tt Phosphorus (% dw) [4] | 0.088 (0.030) | ***0.058 (0.006)*** | 0.088 (0.030) |
| Tt Nitrogen (% dw) [4] | 1.9 (0.1) | 2.0 (0.2) | 2.1 (0.3) |
| Tt Carbon (% dw) [4] | 38 (0.4) | 39 (0.5) | 38 (0.4) |

[1] at top of seagrass canopy; [2] mean concentration from 1/2006 to 9/2007; [3] 0-5 cm section; [4] *Thalassia testudinum*.

## Restoration Considerations




A regional phytoplankton bloom (*Synechococcus* spp. dominated) with a geographic center near Lake Surprise (Figure 2) has persisted for two years, yielding concern regarding continuing road excavation. While causes of bloom initiation and sustenance are uncertain, initiation coincided with a set of three hurricanes over three months in 2005 and the bloom spatial distribution bracketed U.S. 1 – both hurricane disturbance and road construction, and the interactions of these factors, were likely contributing causes.

Figure 2. 2006-2007 mean chlorophyll-*a* distribution.

### Current concerns:

- Phytoplankton blooms can spur a cycle of SAV mortality, destabilizing sediments and releasing nutrients for further phytoplankton growth (conceptual model in Figure 3).
- A bloom-SAV mortality cycle appears to have already occurred in Blackwater Sound and Barnes Sound, evidenced by SAV losses since 2005 (Figure 4).
- Causeway excavation could yield additional turbidity, P, and N, and cause a bloom-SAV loss cycle in the shallow lake where SAV biomass is relatively high (Table 1) and a potentially large nutrient source for the bloom.
- Anoxia and sulfide can also cause SAV mortality. Hypoxic periods were observed in Lake Surprise in early fall (Figure 5) – turbidity and organic matter from excavation could increase $O_2$ demand.
- Sediments in Lake Surprise are low density with relatively high organic matter, C, N and P content - potentially high mobility (Table 1).
- If Lake Surprise SAV mortality event occurs with causeway excavation, increased water exchange will increase sediment and nutrient export to adjacent basins.

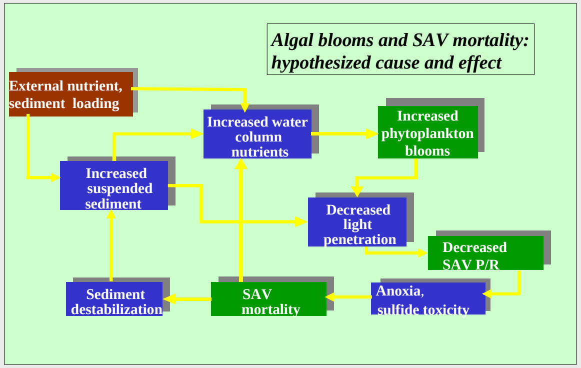



Figure 3. Conceptual model of SAV mortality and phytoplankton bloom feedback loop.

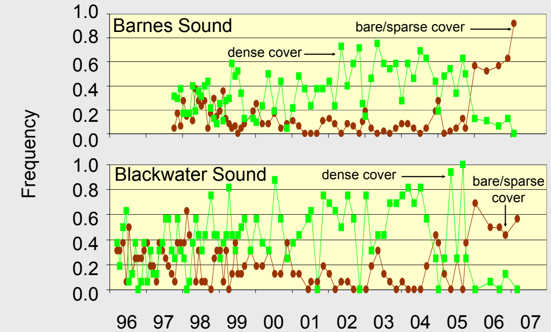



Figure 4. SAV cover time series. Frequency of quadrats with bare/ sparse and dense cover in Barnes and Blackwater Sounds since 1996. 2005-2007 losses mostly *Thalassia testudinum* in Blackwater, mostly macroalgae in Barnes (data from Miami-Dade DERM).

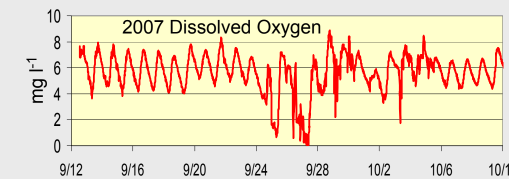



Figure 5. Continuous dissolved oxygen measurements in the Lake Surprise seagrass bed during Sep and Oct 2007. Note the low DO levels (<2 mg $l^{-1}$) on 9/25 (10 hrs) and 9/26-27 (20 hrs).

## Conclusions

- Turbidity and nutrient control: restoration success hinges on the ability to minimize light extinction (by sediment and phytoplankton) and prevent the start of the SAV mortality and phytoplankton feedback loop.
- Timing: causeway removal is scheduled for fall 2008, coincident with seasonally high water temperature and decreasing photoperiod. The potential for hypoxia/anoxia is highest at this time, with dependence on cloud cover, light extinction, organic matter loading from excavation, respiratory oxygen demand and water column stratification after rain events.
- Recognition of tradeoffs: the long-term benefits of causeway removal can best be realized by minimizing effects on SAV. Public awareness of likely short-term negative effects is needed.


Construction of the Lake Surprise causeway circa 1905-1907. Photos from J. Wilkinson, *keyshistory.org*