Controlling Hydrilla at Wakulla Springs State Park (1997-2007)

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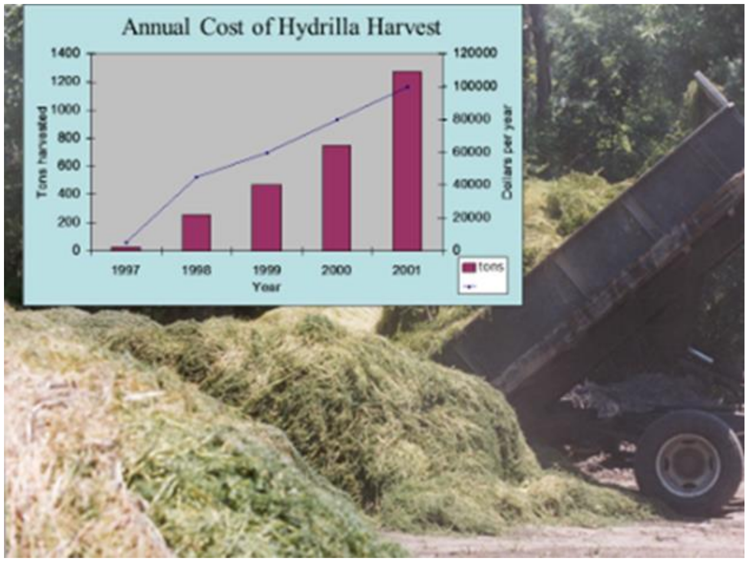
Looking east toward the boat dock, hydrilla mats smother the upper Wakulla River in 2001 (JVD)

HYDRILLA INVASION & EARLY CONTROL EFFORTS (1997-2001)

A mat-forming aquatic plant species were not new to Wakulla Springs State Park in 1997. For years, invasive exotics Brazilian Elodea (*Egeria densa*) and Parrot's feather (*Myriophyllum brasiliense*) had grown to the surface of the upper reaches of the river and periodically impeded the park's tourist vessels. Staff successfully controlled these South American plants with a small, boat-mounted cutting device called a Hockney Cutter. Those days would be remembered fondly shortly after co-worker Kathy Burks noticed a small patch of hydrilla (*Hydrilla verticillata*) near the boat dock in April of that year. When Park Biologist Scott Savory called me about the discovery, I responded, "You're toast." After seeing hydrilla explode in the Wacissa and St. Marks Rivers, I was certain the park's aquatic habitat was perfect for this notoriously invasive species. By the summer of 1998, hydrilla dominated the upper river.

Great effort was made to stem the hydrilla expansion biologically, manually, and via mechanical harvesting. Biological control was attempted through the introduction of 20,000 Hydrilla Leaf Mining Flies (*Hydrellia pakistanae*). Handpicking from the swimming area was also attempted, but the man in charge literally had a breakdown in frustration. Mechanical harvesting opened boat trails in the short term, but harvesting had serious flaws. It was very disruptive to the serenity of the park and the by-catch of juvenile fish and macroinvertebrates was unacceptable. By 2001, nearly 2,000,000 lbs. of hydrilla had been mechanically harvested from the upper river. Scott Savery stated that "each succeeding time we harvest, there are less snails and crawfish." Mechanical harvesting proved to be inefficient due to the rapid regrowth of hydrilla and also quite expensive at $400,000.



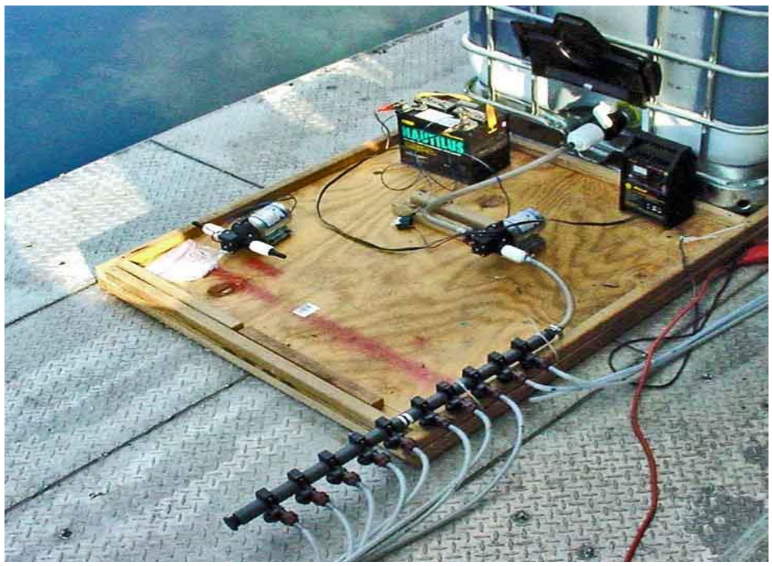
INVESTIGATING THE USE OF HERBICIDES

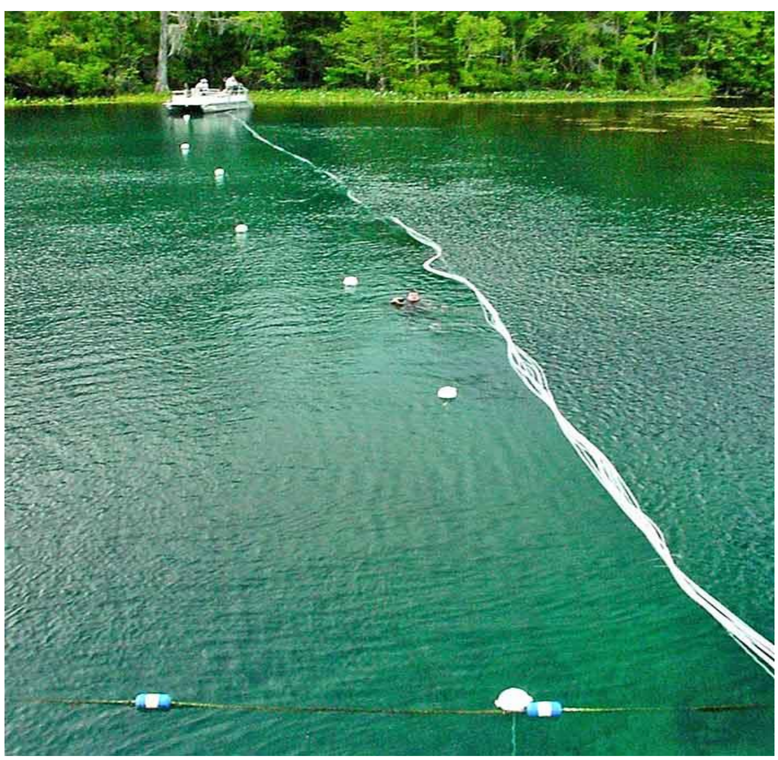
Meanwhile, a confluence of research findings provided the first hope of controlling hydrilla in flowing water. Dr. Mike Netherland's laboratory results at the USACOE on concentrations and exposures times with Aquathol K (40.3% endothall) indicated that concentrations of 2 ppm ae/48hr would reduce hydrilla biomass by 85%. Eurasian Watermilfoil (*Myriophyllum spicatum*), a big problem in the lower Wakulla River at that time, required only 0.5 ppm ae/48 hr. Meanwhile near Marianna, Florida, hydrilla had infested an impounded spring run, called Merritt's Mill Pond (202 acres). After treating the upstream part of the system on two consecutive days, it became clear that a 48-hour contact time provided excellent system-wide results with effective hydrilla control miles downstream. In time, hydrilla was greatly reduced there while its major competitor, *Vallisneria americana*, expanded. I presented the idea of using Aquathol in Wakulla Springs to park manager, Sandy Cook, and park biologist, Scott Savery, by giving them a tour of Merritt's Mill Pond. They were suitably impressed.

In 1999, hydrilla declined while Vallisneria rebounded in Merritt's Mill Pond post treatment (JVD).

HERBICIDE USE IN FLOWING WATER

A key question remained: How would it be possible to maintain the necessary concentration of Aquathol for two days in a larger flowing system like the Wakulla River? Fortunately, the answer had been recently developed for herbicide applications in irrigation canals, called a “drip system.” On a barge next to the park’s diving dock, Terry McNabb of AquaTechnex constructed a simple delivery system for flowing water. Using a 12-volt pump, manifold, regulating orifices, and 10 hoses, Aquathol could be evenly applied at the desired rate over time to the headwaters of the Wakulla River.



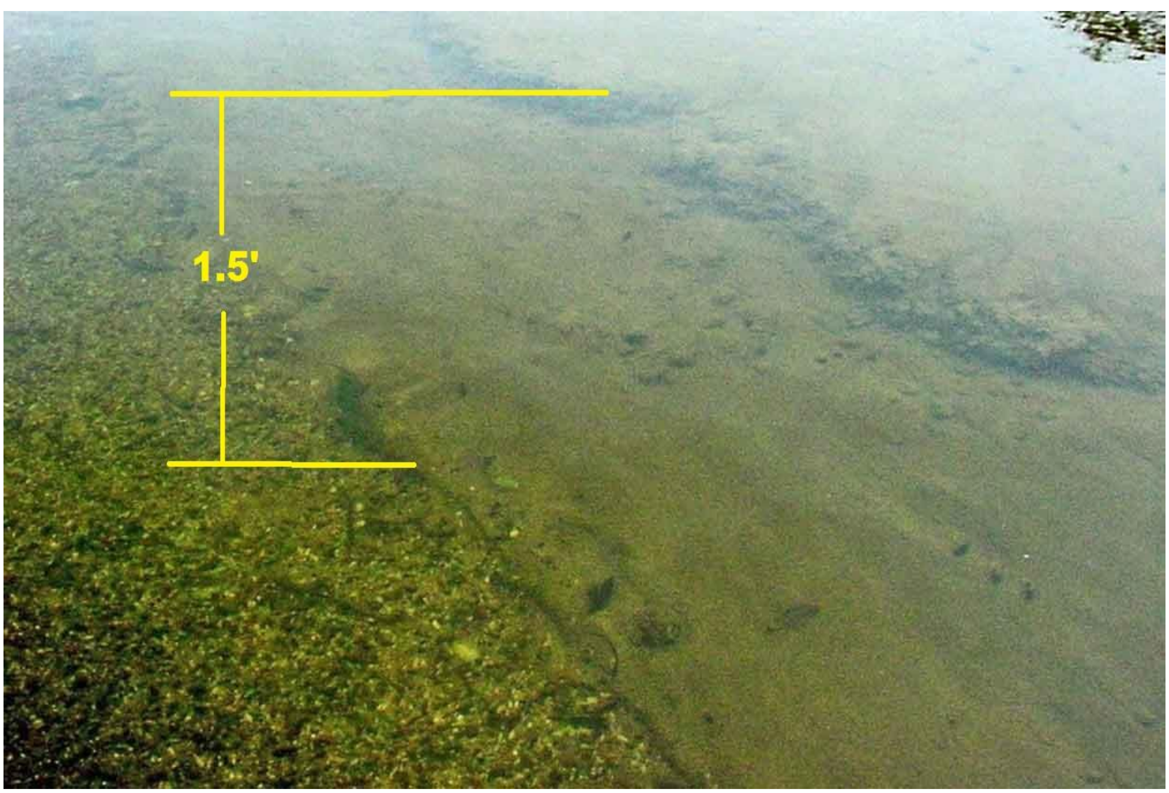


FIRST HYDRILLA TREATMENT

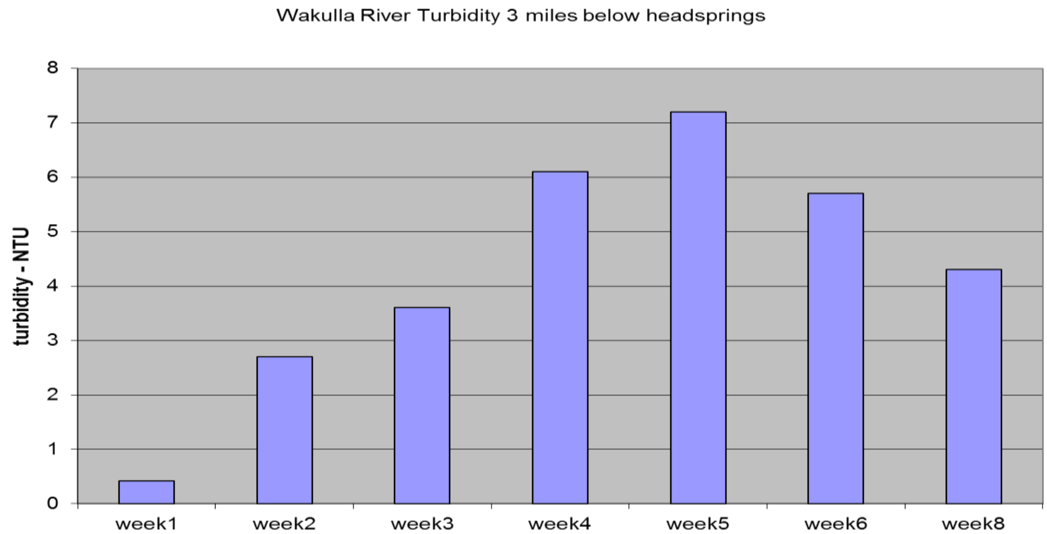
In response to a request from the Park Manager, DEP's Bureau of Invasive Plant Management conducted the first hydrilla treatment in Wakulla Springs on April 15-17, 2002. Over a 52-hour period, 1750 gallons of Aquathol K was applied via ten hoses with outlets evenly-spaced across the entire basin. The flow rate at the time was measured at 145 cfs, so the maximum calculated concentration was 4.24 ppm ae. Water sampling during the treatment revealed that the actual concentrations were 1.75 ppm at the dock, 4.10 ppm at the "First turn," 4.13 ppm at "The Ways," 2.14 at "The Osprey Nest," 0.70 ppm at the end of the "Back Jungle," and 1.05 ppm at the CR 365 Bridge. Shortly after this initial application, profound changes occurred in the Wakulla River.

SEDIMENT RESPONSE

Within a month of the initial treatment, the Wakulla River had been altered biologically and physically, and these changes were directly linked. Aquatic vegetation is often the dominant factor influencing flow conditions in riverine systems, and the Wakulla River was no exception. For a long time, a "green dam" of dense submersed vegetation had altered the flow regime of the upper Wakulla River by reducing flow velocities. Decreased flow rates and elevated water levels facilitated the deposition of a thick layer of fine organic sediment in much of the upper river. The rapid decline in the biomass of hydrilla post-treatment greatly reduced hydraulic resistance. From April 1-29 to May 5-23, the average water levels measured at the park declined 1.4 feet. Flow velocity increased enough to scour much of the organic sediment that had accumulated mid-stream leaving an inorganic substrate.



A layer of fine particulate organic sediment approximately 1.5' thick was transported downstream (JVD).



Sediment transport was corroborated by elevated turbidity levels downstream.

AQUATIC PLANT RESPONSE

The immediate effects of the treatment on the aquatic plant community were two fold. First, although emersed plants were relatively unaffected, many submersed plants and their propagules were transported downstream along with the organic sediments. Second, there was direct toxicity to hydrilla, as desired. Control was excellent with approximately 70-80 percent of the hydrilla eliminated, including in areas over 3 miles downstream. Eurasian watermilfoil was controlled six miles downstream. There was also some non-target damage to native plants, including Strap-leaf sagittaria (*Sagittaria kurziana*). In 2004 after three treatments, hydrilla remained under control, the area of Eel-grass or tape-grass (*Vallisneria americana*) had doubled, Muskgrass (*Chara* sp.) began recovering, and half of the spring run had a substrate of sand and shells (Joe Hand, DEP, 2004). Downriver from the park, hydrilla control was excellent and natives recovered. In fact, Southern Naiad (*Najas guadalupensis*) became abundant enough for riparian owners to complain about it in 2007.

WILDLIFE RESPONSE

Wintering American Wigeons on a hydrilla mat at Wakulla Springs in 2001 (JVD).

There is no question that surface mats of hydrilla attract wildlife, especially herbivorous dabbling ducks, such as the American Wigeon (*Mareca americana*). Since hydrilla was effectively controlled, the historically large, wintering widgeon population at Wakulla Springs dramatically declined. Now, these ducks are only “periodically observed in very low numbers.” Based on Bob Thompson’s 20-year summary of wildlife monitoring observations (1997-2016), only three animal species have increased during that period, while the average sightings of twelve have declined. Keep in mind that the quantitatively monitoring of mobile wildlife is difficult; hydrilla mats may have improved visual detection of wildlife; and linking all of wildlife changes to hydrilla control is a stretch given the myriad of factors affecting their numbers and distribution. For instance, a similar decline in widgeons was noted in the St. Marks Wildlife Refuge at that time. However, the extensive physical and biological changes to wildlife habitat in Wakulla Springs subsequent to hydrilla treatment cannot be denied.

Neither can the stated mission of Florida’s state parks: “The primary emphasis is on restoring and maintaining, to the degree practicable, the natural processes that shape the structure, function and species composition of Florida’s diverse natural communities as they occurred in the original domain”. Hydrilla did not infest pre-Columbian Wakulla Springs, so its control may rightfully be viewed as a restoration project. Now that the park is no longer ruled by an exotic plant, perhaps the current wildlife community more closely reflects that of “the original domain.” The restoration Wakulla Springs continues as the native submersed vegetation slowly recovers in areas once dominated by hydrilla monocultures. Thompson’s more recent observations (2012-2016) indicate an increase in sightings of the American Alligator (*Alligator mississippiensis*) and the Yellow-crowned Night-Heron (*Nyctanassa violacea*). With the near extirpation of hydrilla and a steep decline nitrate concentrations, the optimal wildlife population at Wakulla Springs is conjecture. Perhaps, patience is in order.

MANATEE RESPONSE

Sixteen Florida manatees (*Trichechus manatus latirostris*) were observed on March 7, 2019 (JVD)

"On August 8, 1997, a group of four manatees was observed in the Wakulla Spring basin. The three adults and one calf were the first documented sighting of manatees in the spring basin. They stayed in the area for three days before returning to the lower part of the Wakulla River. In December of 2000, a single young manatee was observed in the spring basin. The manatee remained in the spring and upper portion of the river for 4 days before it left park waters. In December of 2002, three manatees were sighted in the spring and stayed for 2 days. 2003 showed a tremendous increase in manatee use of the spring and upper Wakulla River. A total of 16 different sightings were recorded," according to the Park Unit Management Plan.

What changed in the Wakulla River to facilitate movement of manatees into the park after the hydrilla treatment in 2002? As mentioned previously, the rapid decline in hydrilla biomass resulted in sufficient flow velocity to scour channels through accumulated organic sediments. Regarding manatee access, a crucial channel was created was just north of the CR 365 Bridge. Prior to the treatment, this area was shallow, occupied by a dense stand of hydrilla, and impassable. After treatment, a channel was created that was sufficient for manatee to gain access to the park, and it remains to this day.

North of the CR 365 Bridge, dense vegetation formed an impassable barrier to manatees in 2001 (JVD).

The treatment in 2002 created a channel sufficient for manatee access to the park (JVD).

CRAWFISH RESPONSE

Red Crawfish (*Procambarus peninsulanus*)

Aquathol Drip Treatments:

Begin Date	Begin Time	End Date	End Time	Duration (hrs)	Flow (cfs)	Gals used	PPM*
April 15, 2002	6PM	April 17, 2002	5PM	47	145	1750	4.24
November 19, 2002	2PM	November 21, 2002	4PM	50	355	2000	2.09
November 12, 2003	10AM	November 14, 2003	12N	50	261	1500	2.07
May 3, 2004	5PM	May 5, 2004	6PM	49	415	1500	1.41
April 27, 2005	10AM	April 29, 2005	11AM	49	356	1500	1.65
April 17, 2006	3PM	April 19, 2006	3PM	47	265	1500	2.23
March 26, 2007	3PM	March 28, 2007	2PM	47	183	1000	2.14
							*calculated

Given the extent of the hydrilla problem, the initial treatment in 2002 was intentionally aggressive at 4.24 ppm. Subsequent concentrations were reduced by more than half, averaging only 1.93 ppm. The primary reason for that reduction was sensitivity about non-target damage to native plants and animals. Of particular concern was the Red Crawfish (*Procambarus peninsulanus*) which suffered mortality during the first treatment. The Invasive Plant Management team addressed this matter by monitoring caged crawfish during a subsequent treatment. Twenty cages containing crawfish were deployed immediately prior to herbicide application and retrieved after four days. Another twenty chambers were deployed nine days after the herbicide application and again retrieved four days later. Dissolved oxygen dropped from as high as 4.3 ppm to approximately 2.0 ppm after the herbicide treatment. Aquathol concentrations ranged from 0.41 to 2.06 ppm, well below toxic levels for crayfish. Despite the lower oxygen levels, only one crayfish death was observed among the forty replicates during the experiment. The prevailing theory is that the oxygen depletion was greater during the initial treatment because of the massive reduction in hydrilla. Most importantly, no crawfish mortality was observed during subsequent treatments and the crawfish population recovered quickly. Subsequent hydrilla treatments at lower rates also resulted in less turbidity and damage to native plants.

VALLISNERIA AUGMENTATION

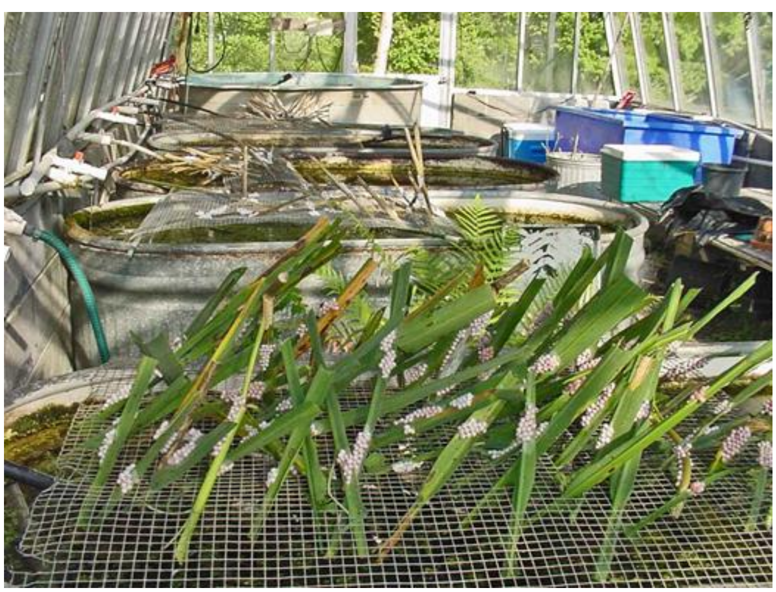
Dense stand of Vallisneria adjacent to the boat dock in 2006 (JVD).

Hydrilla is a fierce competitor. One hydrilla plant is the completive equivalent to over seven *Vallisneria* plants. When rooted together in nutrient-rich substrates, hydrilla grows three times faster than *Vallisneria*. Add to that hydrilla's propensity to form light-blocking canopies, and there is little wonder why *Vallisneria* lost its traditional dominance in the upper Wakulla River subsequent to the exotic invasion. One year after the initial herbicide treatment, much of the bottom exposed due to sediment scouring and the absence of the hydrilla. Biologist seized the opportunity by augmenting the expansion of herbicide-resistant Vallisneria. In 2004, two-hundred-and-six *Vallisneria* plants were transported from Merritt's Millpond and planted near the boat dock. This vegetated area has expanded and is still obvious today. Other efforts followed, however, the expansion of native submersed plants in the upper river has been gradual in the absence of hydrilla. More planting efforts may be warranted.

FLORIDA APPLESNAIL AUGMENTATION

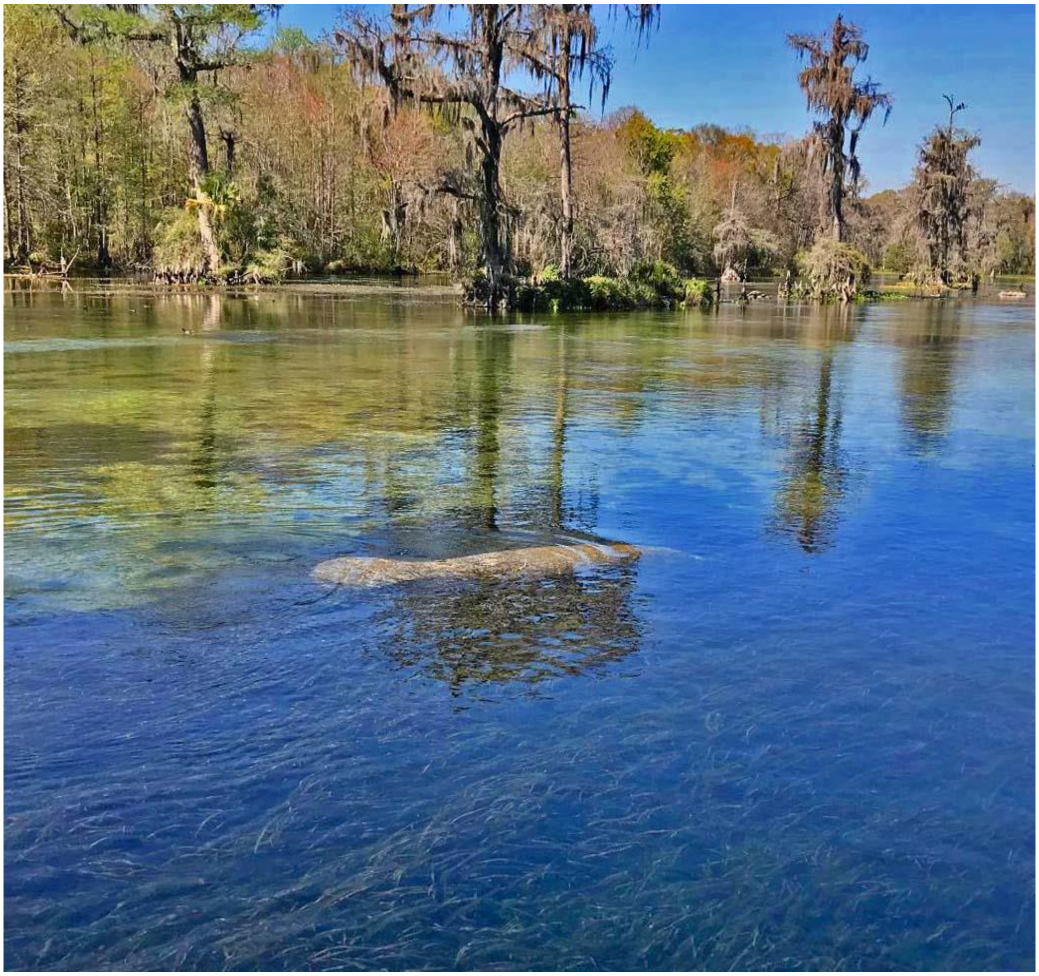
A limpkin prepares to dine on a Florida applesnail (Tom Obrock).

Perhaps because of its haunting cry, the disappearance of Wakulla Spring's avian trademark, the Limpkin (*Aramus guarauna*), has been particularly disappointing. In 1971, seventy-one of these birds were in residence. In 2000, prior to any herbicide treatments, there were none. That loss mirrored a decline of the Limpkin's preferred food item, the Florida Applesnail (*Pomacea paludosa*). In an effort to spur a return of the Limpkin, snail eggs were collected from the Wacissa River. To avoid predation, juvenile snails were reared in a controlled environment to 2 cm in size. Almost 3,000 were transported to the park from 2003 to 2007. The response has been muted based on egg counts, but there is always hope for a rebound of the applesnails and a return of the Limpkin to Wakulla Springs State Park.



Applesnail hatchery in DEP's greenhouse (JVD).

CONCLUSIONS AND RECOMMENDATIONS



A manatee grazing on a bed of Strap-leaf Sagittaria at Wakulla Springs on March 7, 2018 (JVD).

From 1998 to 2001, Wakulla Springs State park had been under siege by an invasive plant. Visitation was down, staff morale was low, and in spite of great effort, there was little hope of the situation returning to normal. Fortunately, Park Manager Sandy Cook and Park Biologist Scott Savery had the courage to take a leap of faith and follow the recommendations of DEP's Bureau of Invasive Plant Management. Employing a herbicide drip system the initial seven times in this carefully protected Outstanding Florida Water was the most awesome responsibility of my career. I considered Wakulla Springs to be a natural wonder and was terrified of making any errors.

Shortly after the first treatment, I received a scathing call from a U.S. Fish & Wildlife employee who had recently kayaked on the lower Wakulla River. He was appalled by the giant rafts of decaying vegetation floating on the unnaturally murky water. My heart sank as he questioned my judgement, expertise, and environmental concern. Would I be forever known as the man who destroyed the

Wakulla River? As turbidity returned to normal, however, the results of the project on the entire Wakulla River became clear. Invasive submersed species, specifically hydrilla and Eurasian watermilfoil, were successfully controlled six miles downstream to the confluence of the St. Marks River. In hindsight, the first herbicide treatment was a necessary purge of dense exotic vegetation and of the organic sediment produced and trapped those plants. The river and the park had obviously changed for the better, and the Park Manager Sandy Cook and Biologist Scott Savery agreed wholeheartedly.

The first hydrilla treatment changed the river's vegetation, sediments, bathymetry, flow velocity, and elevation in a dramatic fashion. Wildlife habitat was also altered. However, the stated objective of Wakulla Springs State Park is to "protect, restore and maintain native animal diversity and natural relative abundance . . . as they occurred in the original domain," meaning prior to the unnatural stimulating effects of exotic plants and elevated nitrates on fish and wildlife. Fortunately, the conditions of Wakulla Springs may be slowly headed toward that of "the original domain" in terms of wildlife, native plants, and nitrate concentrations.

Data from 1956 to 1973 suggest that a natural level of nitrates at Wakulla Springs was only 0.05 ppm. In the late 1980s to early 1990s, concentrations peaked at 20 times of that background level. At that level (1.00 ppm), the growth rate of hydrilla accelerates by a factor of 2.75 with no positive effects on the growth of *Vallisneria* or *Sagittaria*. No wonder hydrilla dominated these native plants in the park. Progress has been made in stemming nitrate pollution. While the median concentration was 0.89 ppm from 1989 to 2000, the current nitrate concentration is only 0.42 ppm. That is enough to reduce hydrilla's growth rate, but the abatement of filamentous algae species, like *Lyngbya*, may require further nitrate reductions. That is important because robust epiphytic algae can negatively affect the health and expansion native vascular plants.

Regarding the expansion of native plants, the welcomed decline nitrate concentrations in Wakulla Springs may be slowing all plant growth. Also, increased flow velocities may be interfering with plant anchoring. To remain rooted in the substrate, the tape-like leaves of *Vallisneria* and *Sagittaria* have evolved to avoid friction in flowing water. However, anchoring is a challenge when scouring is ongoing. In addition, hydraulic friction is increased when leaves are coated with epiphytic algae and diatoms. Grazing by manatees may also be a factor by uprooting native plants. However, the best explanation for the slow expansion of native vegetation may be light suppression. Photosynthesis is impaired not only by the thick coating epiphytes but also by the tannic color of the spring's water. Over the past 20 years, the frequency of "dark water days" noted by park staff has almost doubled. Gross primary productivity is cut in half during those periods compared to clear water conditions.

In conclusion, an Aquathol "drip system" was implemented to treat a massive hydrilla infestation of Wakulla Springs only after all reasonable alternatives had failed. It was a bold move, but as Park Biologist Scott Savery put it at that time, "The results were remarkable." Hydrilla's grip on the park was finally broken. Along with the biological changes of the upper river, there were physical alterations that may have been more important. The flow of the upper Wakulla River became swifter, the substrate less organic, and flow-adapted native plants regrew. Now, periphyton remains excessive, even at the lower nitrate concentrations. In terms of recommendations, a new nitrate goal of < 0.30 ppm might be considered. Also, additional efforts to augment the applesnail population could prove fruitful. Finally, adding native plants that effectively reproduce via fragmentation, such as Coontail (*Ceratophyllum demersum*), Southern Naiad (*Najas guadalupensis*), and Muskgrass (*Chara* sp.), might be contemplated.

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EDWARD BALL WAKULLA SPRINGS STATE PARK UNIT MANAGEMENT PLAN

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