Aquatics

WINTER 2024

A Publication of the Florida Aquatic Plant Management Society

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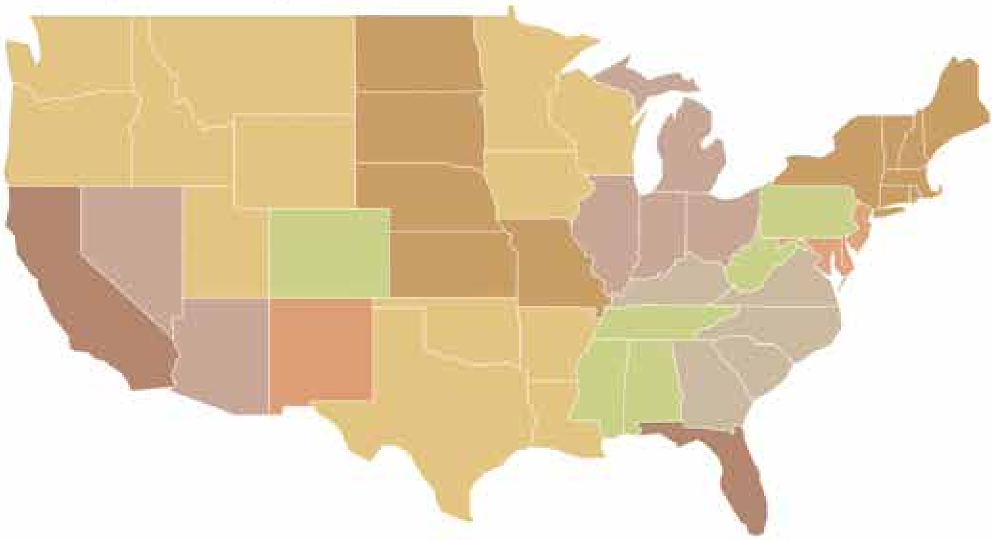

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Aquatics

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The vision of FAPMS is to be a leading resource for promoting excellence in the stewardship of Florida's aquatic ecosystems.

Letter from the Editor

Shelby Thomas

Dear Readers,

As stewards of aquatic environments, we understand that the challenges we face are both complex and ever-changing. In this issue of *Aquatics Magazine*, we explore key issues affecting our water resources and the innovative solutions being developed to address them. Our lineup of features highlights the intersection of research, management, and conservation, offering valuable insights for all who are passionate about preserving our aquatic ecosystems.

We begin with "Combating Crested Floating Heart: Biological Insights and Innovative Control Approaches" by Corrina Vuillequez and Benjamin Sperry. This article dives into the biology of this invasive species and introduces cutting-edge management strategies that could redefine how we combat persistent aquatic invaders.

The team at The Center for Aquatic and Invasive Plants provides an engaging explanation of "How Do Aquatic Herbicides Work?" By unpacking the science behind these tools with an infographic that empowers managers to make informed decisions in their use of herbicides to protect native flora and fauna.

In Part 2 of the AERF Florida Aquatic Plant Management and Mosquito Control Tour, we continue our journey through Florida's unique aquatic landscapes, showcasing the collaborative efforts of researchers, managers, and stakeholders in tackling aquatic plant and mosquito challenges.

Amy L. Giannotti addresses an emerging concern in "Invasive Aquatic Plants and Climate Change: A Growing Threat to Our Waters…and Wallets." This piece explores the interplay between climate change and invasive species, emphasizing the economic and ecological stakes of taking decisive action.

Lastly, "The Value of Vouchers" by Samuel A. Schmid and Gray Turnage highlights the critical role of voucher specimens in research and management. The article sheds light on how these tools contribute to long-term ecological understanding and successful resource management strategies.

As you explore this issue, I hope you find inspiration in the knowledge shared by our contributors and a renewed sense of purpose in your own work. Whether you're in the field, in the lab, or advocating for policy changes, your efforts make a tangible difference in protecting the aquatic environments we all cherish.

Thank you for your continued dedication to our shared mission. As always, we welcome your feedback, ideas, and stories as we work together to foster healthier waters for generations to come.

Warm regards,
Shelby Thomas
Editor, *Aquatics Magazine*

Combating Crested Floating Heart:
Biological Insights and Innovative Control Approaches

Corrina Vuillequez[1], Benjamin Sperry[2]

Photo 1. Crested floating heart can spread to completely cover water surfaces. Photo credit: Corrina Vuillequez.

Background, Biology, and Impacts

Crested floating heart (CFH; *Nymphoides cristata)* is an aquatic invasive plant in the *Menyanthaceae* family that is native to Southeast Asia. In its native range, CFH is a weed in rice production systems and rapidly covers the water surface with its floating leaves (Burks 2002). Despite its weedy reputation, the species' showy white flowers made it desirable in the aquarium and pond trades. Marketed as "water snowflake", CFH quickly became popular for ornamental use in the US in the 1990s (Willey et al. 2014). Unfortunately, the species was not contained in ornamental settings and was observed in canals throughout Central and South Florida shortly after introduction (Burks 2002; Gettys et al. 2017). Currently, significant CFH infestations have been reported in Florida, South Carolina, Texas, and Louisiana (Willey et al. 2014).

Crested floating heart has a unique biology which contributes to its invasiveness. Like true water lily species (*Nymphaeaceae*), CFH exhibits a rooted-floating growth form, meaning it is rooted in sediment and has floating leaves that extend to the water's surface (Gettys et al. 2017). While the plant is known for blanketing the water with its white flowers (Photo 1), seeds produced by the species in the US are thought to be sterile (Willey et al. 2014). However, CFH primarily reproduces asexually through ramets, which are tuberous root clusters produced at leaf-petiole junctions (Photo 2A, Gettys et al. 2017). Crested floating heart ramets easily detach and float away, remaining just beneath the water's surface and out of reach from foliar-applied herbicides (Photo 2B, Burks 2002). In some cases, detached ramets can sink and remain dormant on the hydrosoil until the following season, but this dormancy is not well understood (Ornduff 1966). Ultimately, the clusters of roots on ramets will elongate to establish a new stand. A single mother plant can produce up to 500 ramets in 6 months and 40% are likely to detach and sprout (Markovich et al. 2021).

While the foliage of the species contributes to its reproduction and spread, the root system adds to its resilience. Crested floating heart produces extensive underground root systems which can anchor the plant quite deep into the substrate (Photo 3). Mature CFH plants develop a significant root crown with a starchy base that aids in energy storage. Vegetation managers in South Florida have reported CFH roots remaining viable for over a year in dry soil, sprouting new foliage once they become re-hydrated. Herbicide applications that initially kill off visible leaves often result in regrowth of the plant only weeks later, likely due to its robust root systems surviving the treatment.

Unmanaged infestations of crested floating heart can overtake waterbodies in a matter of weeks, impeding navigation, flood control, and recreational opportunities (Burks 2002, Willey et al. 2014). Large mats of CFH can outcompete native submersed plants by blocking sunlight penetration into the water column, ultimately leading to habitat degradation for fish and wildlife (Willey et al. 2014). Crested floating heart has disrupted flood control in south Florida by obstructing water flow in canals

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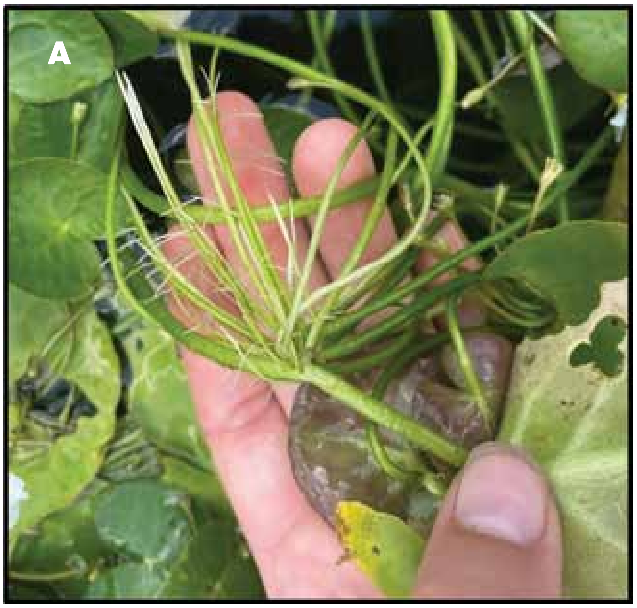

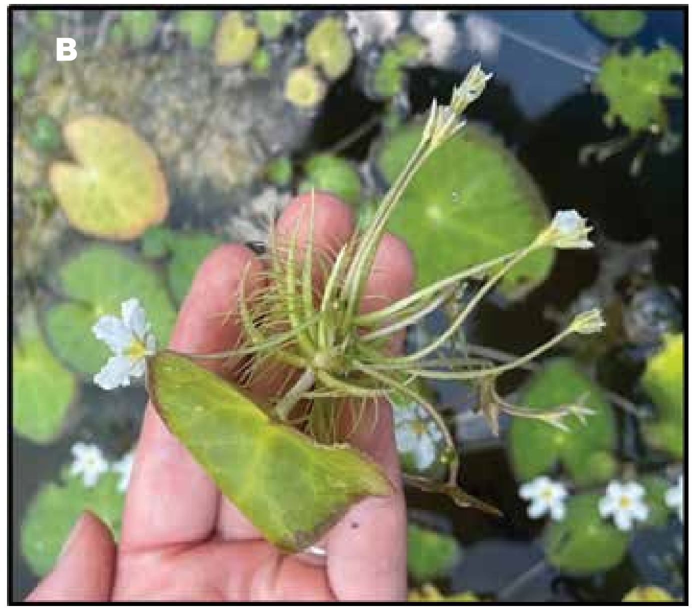

Photo 2. Crested floating heart ramets are produced at the leaf-petiole junctions while still attached to the mother plant (A), and eventually break off and spread (B). Photo credit: Corrina Vuillequez.

(Markovich et al. 2021). In 2012, CFH occupied nearly 6,000 acres of water in the Santee Cooper reservoir system in South Carolina (Willey et al. 2014). The invader has also been impacting the functionality of the stormwater treatment areas (STAs) in South Florida. The STAs comprise 57,000 acres south of Lake Okeechobee and rely on key aquatic plant species to remove excess phosphorous from incoming stormwater runoff before the water reaches the Everglades. Unfortunately, many of the treatment areas have been invaded by CFH, which is outcompeting these key species and poses a threat to the ecology of the everglades if introduced.

In 2009, CFH was classified as a Category 1 invasive species by the Florida Exotic Pest Plant Council (Gettys et al. 2017). This means that CFH can alter native plant communities by displacing natives, and by changing community structures and ecological functions (Gettys et al. 2017). Additionally, in 2014 the species was added to the Noxious Weed List by the Florida Department of Agriculture and Consumer Services, making it illegal to "introduce, multiply, possess, move, or release" CFH without a state permit in Florida (Gettys et al. 2017). This species also poses risk outside of Florida. The weed risk assessment for CFH published by the US Department of Agriculture's Animal and Plant Health Inspection Service (USDA-APHIS) in 2012 estimated that 11% of the US contains suitable habitat for CFH, especially in southeastern systems (USDA APHIS 2012). The assessment deemed CFH to be a high-risk invader, due to its impact and spread potential; however, CFH is not currently a listed federal noxious weed (USDA APHIS 2012).

Photo 3. Mature crested floating heart plants develop a starchy base to their extensive underground roots, called a root crown. Photo credit: Corrina Vuillequez.

Current Research

Natural resource managers have continued to report an ongoing struggle with controlling CFH. Published research on ramet biology and long-term control measures for the species is limited. Thus, we are currently investigating novel management techniques to improve resource manager efforts in controlling CFH.

First, studies are underway aimed toward further understanding CFH's reproductive biology dynamics. In some plant species, such as cassava (*Manihotesculenta* Crantz), added stressors such as pruning can increase seed production (Qiu et al. 2023). Consequently, plant stressors such as mechanical disturbance or sublethal herbicide exposure may have the potential to stimulate CFH ramet production to compensate for suppressed growth. Therefore, if CFH control methods are not 100% effective, increased ramet production may result leading to persistent and expanded CFH populations.

Next, we are looking into how reduced carrier volume in foliar herbicide applications impact CFH control. In other aquatic species, reduced carrier volume (gallons per acre of spray mix) applications with some herbicides resulted in increased plant control (Sperry and Ferrell 2021). However, optimal herbicide carrier volume is species- and active ingredient-specific (Sperry et al. 2021). Therefore, to address this objective for CFH, we are testing a range of herbicides, rates, and carrier volumes. Another strategy we are currently examining is the role of foliar and submersed herbicide exposures. Due to the growth habit of CFH, a two-pronged approach targeting both the floating leaves and its extensive submersed biomass may lead to more effective and longer-term control.

Through our research, we hope to uncover the most effective strategies for long-term control of crested floating heart. Results will be communicated to natural resource managers in various platforms such as *Aquatics* Magazine. Stay tuned for updates!

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Aquatic Ecosystem Restoration Foundation, Inc.

Florida Aquatic Plant Management and Mosquito Control Tour

Part 2
June 3-7, 2024

The first post-COVID AERF tour of aquatic/wetland systems was held in south-central Florida to demonstrate typical weed management and mosquito control activities operated by the various responsible public agencies. The primary purpose of these field trips is to provide an educational opportunity for pesticide regulators to learn about the objectives, coordination, and daily operations of the numerous governmental entities that utilize pesticides in public health and ecosystem management programs.

Day 3 (Wednesday, June 5, 2024): The group met at the COE South Florida Operations Office, Jacksonville District, conference room in Clewiston, Florida, located on the southwest side of Lake Okeechobee. The mission of the COE was established by the River and Harbors Act, first passed by the U.S. Congress in 1899 and since amended. This act authorized the COE to manage aquatic plants and other hinderances to navigation. The Jacksonville District provides services to other COE Districts under the Invasive Species Branch and is the designated Operations Support Center for COE efforts in protection of natural resources in the United States.

The COE aquatic weed management program is conducted in part under the Removal of Aquatic Growth (RAG) program, which is federally funded and responsible for weed control in navigable waterways. In

Florida, that includes the St. Johns, Chattahoochee, and Kissimmee Rivers and the Okeechobee Waterway. The Aquatic Plant Control (APC) program matches state funding in other selected tributaries and state waters connected to Federal waters. The COE also cooperates extensively with Florida's Water Management Districts, particularly the SFWMD, under the Comprehensive Everglades Restoration Project (CERP).

The COE has in-house crews to manage aquatic weeds, principally floating plants, on the St. Johns River; however, management of plants in the Lake Okeechobee waterway is conducted by private contractors. The COE weed control projects involve extensive interagency coordination and keeping the public informed about future operations. The federal waterways in Florida, particularly the 450,000-acre Lake Okeechobee, are multi-use systems popular for fishing, hunting and boating while also serving as a source of potable water, irrigation water and water storage. Lake Okeechobee is critically important to some 10 million residents on Florida's east and west coasts and not only provides potable water, but also protects the coastal aquifers from saltwater intrusion.

The COE has provided funds for research to identify biological control agents for aquatic plants and was one of the lead agencies involved in the release and establishment of the alligatorweed flea beetle (*Agasicles hygrophila*) for control of alligatorweed (*Alternathera philoxeroides*) in the mid-1960s. The COE also worked with the USDA-ARS Invasive Plants Research Laboratory in Ft. Lauderdale to seek successful biocontrol agents for melaleuca trees. The major weeds controlled in Lake Okeechobee are the floating plants waterhyacinth and waterlettuce. Mechanical harvesting of these floating weeds is mostly impractical on Lake Okeechobee since off-loading sites are far apart and plants may be in one location today and 30 miles away tomorrow. Control of these species is funded by the COE who work closely with FWC and SFWMD to avoid interference with major fishing tournaments or other potentially impacted water users. The COE/FWC-monitored private contractors

are expected to cease operations when winds exceed 10 mph. All applicators have restricted use pesticide licenses issued by the Florida Department of Agriculture and Consumer Services (FDACS) and regularly attend training programs. Experience on the lake has clearly shown that maintenance control (maintaining floating plants at the lowest feasible level) results in long-term reductions in both total cost and herbicide use. An airboat tour along the Rim Canal and onto the lake allowed tour participants to interview an applicator who described a typical tank mix and demonstrated use of a hand-held spray gun. There were very few floating invasive plants seen, which is to be expected this time of year. The objective of maintenance control is to reduce plant populations to the lowest feasible level before the rainy season, wind season and high growth season, when exponential growth of waterhyacinth and waterlettuce can result in doubled population size in 6 to 8 days.

A discussion of endangered species revealed that the COE and FWC have extensive experience with the Everglades snail kite (Rostrhamus sociabilis) and the Okeechobee gourd (Cucurbita okeechobeensis). The COE has worked with FWC and U.S. Fish and Wildlife Service (USFWS) and together they have developed the following general guidelines:

a. Applicators must be cautious around nesting Everglades snail kites and must remain 500 m away from the nests during nesting season
b. The foraging zone around Everglades snail kite nests is 1500 m and only selective herbicides may be used in these areas
c. Growth of the Okeechobee gourd, also rare and endangered, seems to benefit from the management of invasive aquatic plants

The endangered species protection plans are being developed; in the meantime, applicators abide by the current USFWS guidelines.

The next stop on the way to Ft. Myers was the Clewiston Airport, where tour attendees visited Agricultural Air Services. This company is an aerial contractor for the SFWMD and has conducted much of the aerial melaleuca treatment work over the past 20 years. Company staff demonstrated several control droplet nozzles, described the micro-foil/through-flow controlled droplet booms and outlined the areas that are treated, ranging from natural areas to agricultural operations. Safety and drift control is paramount in aerial applications. The "nurse truck" that supplies tank-mixed products to the helicopter has a large water-carrying capacity and, in a few hours, can utilize many 2.5-gallon pesticide containers. Triple-rinsing and re-using the rinsate from these containers would normally be time-consuming and tedious, but these managers have developed a system that rapidly punctures and cuts the empty container, then injects a strong water stream into the container to rinse it. The rinsate is collected in the same process and used to dilute the next mix batch that is loaded into the helicopter. Highlights of Day 3 include:

The COE and their contractors have done an excellent job of reducing floating plants on Lake Okeechobee to very low maintenance levels going into the summer growing season. We saw very few floating plants in the Rim Canal or in the marsh on the south side of the lake; however, we only saw a small portion of the lake! The cooperating agencies agree that maintenance control of floating weeds occurs when the total area of these plants in the lake is less than 500 acres. Submersed weeds have historically not been a major problem on the lake

Despite concerted efforts to increase public education and information sharing, Lake Okeechobee's stakeholders still have major concerns over governmental regulation of water levels, weed control programs, water quality, endangered species, fish and duck populations, etc. Spray moratoriums in 1986 and 2019 caused the agencies to stop treating invasive weeds for several weeks. Following the most recent moratorium, it took 2 years and an estimated additional $2 million to return floating plants back to maintenance control levels

In Florida (and likely elsewhere), the vast majority of aquatic weed control herbicide use is undertaken by governmental agencies with in-house weed control staff or through contracts with private applicator companies. Although there are no restricted use herbicides labelled for aquatic use, essentially all of these applicators are trained and licensed. Licensure is typically required as a condition of government contracts and is also required by the management companies' insurance carriers to limit liability and ensure that potential environmental damage in avoided

The registration of new herbicide modes of action (MOAs) for aquatic use in the past two to three decades has not only addressed the resistance issues of some aquatic weeds, but has also greatly improved selective control of many of the most serious weeds throughout the country. However, due to low market value and perceived high risk, the major agrichemical companies are reluctant to develop products solely to meet the needs of the aquatic plant management industry

Day 4 (Thursday, June 6, 2024): We visited Florida's east coast on Tuesday and the central southern region of the state on Wednesday, so Thursday's focus was Florida's west coast, where attendees visited the Lee County (Ft. Myers) Mosquito and Hyacinth Control District. The Mosquito Control District (LCMCD) was formed

in 1958 and the Hyacinth Control section (LCHCD) was added in 1961. This program has been a pioneer and is well-known for providing leadership to the entire industry since its formation. Historically, aquatic weed control was the responsibility of county mosquito control agencies since the two disciplines are closely related, but state funding for, and oversight of, weed control in Florida's waters is now the responsibility of the FWC. Primary plants controlled by LCHCD include waterhyacinth, waterlettuce and some emergent plants, all of which are preferred habitats for *Mansonia* sp. mosquitoes. Similar to other agencies, LCHCD uses all of the tools available to accomplish their goals. Sterile triploid grass carp (*Ctenopharyngodon idella*) are raised at the District and stocked at appropriate sites for submersed weed control, and mechanical removal is occasionally used following heavy rains or other events that cause accumulation of vegetation in locations needing immediate control. Lee County recognized that floating aquatic plants grow very quickly in waters with high levels of nutrients and these conditions also promote algae blooms; consequently, the county started a "Pondwatch" program where riparian owners send water samples to the District for nutrient analyses. Lee County also enacted a law banning the application of lawn fertilizers during the rainy season, generally June through October. Data from the Pondwatch program has shown significant decreases in primary nutrients in county waters. LCHCD staff are experimenting with drones for use in their treatment programs and also are investigating and increasing the use of invert herbicide application techniques. Inverts are an oil emulsion made by combining vegetable oil and herbicide mix in a "blender" as the mix is sprayed by a handgun onto the foliage of vegetation. This technique allows spraying under higher pressure and treating over a longer distance without the production of excessive "fines" (very small particles), thus reducing potential drift.

There are 54 species of mosquitoes in Lee County, but only around 15 species are targeted for control due to their aggressive nature and/or concern about their ability to transmit diseases of public health concern. LCMCD has several methods to sample mosquito populations and assess disease potential. For example, mosquitoes are captured in traps of various kinds, collected in large truck mounted net traps, landing rates are counted, and sentinel chickens are monitored for various diseases. Public phone calls (complaints), some 4,400 a year, are logged by GPS, and hot spots for sampling and determining whether control activities are needed can be assessed. Larvicide applications are the preferred method of mosquito control and can be done at any time of the day. Around 10% (56,000 acres) of Lee County consists of salt marshes, which are a primary breeding site for black saltmarsh mosquitoes (*Aedes taeniorhynchus*), which produce huge populations and are aggressive biters. Other species of particular concern are *Aedes aegypti*, *A. solicitans*, and *A. albopictus*, which transmit dengue, West Nile virus, encephalitis, Zika, and other diseases. A decade ago, there were fewer than 10 cases of dengue in humans annually, but recently, for unknown reasons, between 30 to 50 cases have been reported per year.

Applications of adulticides are done in the evening in areas where potential populations reach designated threshold levels. These adulticides include dibrom and various permethrins applied by truck or aerially. Both methods of application utilize sophisticated means of turning the spray system on or off when entering or leaving treatment polygons. In addition to chemical mosquito control, LCMCD has pioneered methods for sterilization and release of sterile male mosquitoes to reduce overall populations.

The District also has an active, aggressive educational program for school children called "Ponds, Puddles and People" which has already reached over 100,000 K-12 students. Children in early classes learn about mosquitoes and their life cycles, whereas later classes focus on mosquito identification, transmission of various diseases, monitoring, pesticides, resistance and even the availability of summer internships.

Afternoon travel to Olando included a 2-hour break at the 13,000-acre Audubon Corkscrew Sanctuary, which was one of the first Audubon properties in Florida. Highlights of Day 4 include:

1. The adoption of technology by LCMCD has certainly been praiseworthy. The automation of spray systems turning on and off as the aircraft or truck enters and exits a target polygon should minimize application errors, as well as improve safety to the equipment operators
2. Disease detection in mosquitoes is also a major advancement
3. The use of drones, once the details are worked out, are also likely to be very useful in certain situations for managing mosquitoes and invasive aquatic plants

Day 5 (Friday, June 7, 2024): The final day of the tour began with attendees boarding airboats to visit West Lake Tohopekaliga (Toho), the 23,000-acre headwaters of the Kissimmee River which drains 80 miles south to Lake Okeechobee. This lake is a COE-designated Federal Flood Control and Navigation Project and a world class sport fishery, ecotourism destination and home to populations of the endangered Everglades snail kite. The lake is managed by the FWC, which has kept floating plants under control but has lacked funds for the past two years to conduct significant amounts of submersed weed (hydrilla) control. The maximum depth of the lake is 12 to 13 feet, but the average depth is around 6 to 8 feet in the winter and 5 to 6 feet in summer, when it is lowered by the COE for water storage in case of a hurricane. Hydrilla can likely grow in water as deep as 9 to 10 feet, which allows growth in about 80% of the lake. These values are typical for most Florida lakes, particularly those in peninsular Florida.

Water levels on West Lake Toho are managed by the COE and SFWMD as part of the Okeechobee Waterway. There is a lock and spillway on the south end of the lake, which is the beginning of the Kissimmee River. Since lake levels have been held lower in summer than "normal" for many years, the littoral fringe of the native species Kissimmeegrass (*Paspalidium geminatum*), spatterdock (*Nuphar advena*), cattails and bulrush, along with the invasive plant torpedograss (*Panicum repens*), have grown into deeper waters during peak growth in the summer and tolerate the higher water in winter when they produce less growth. Consequently, the lake has a very large and noticeable littoral fringe of emergent vegetation and provides excellent conditions for fish and wildlife. As mentioned above, Lake Toho does have an Everglades snail

kite population and the rules for treating aquatic weeds in nesting and forage areas for the kite are the same as those noted for lake Okeechobee.

The FWC contractor demonstrated a typical submersed weed application method by applying a water/herbicide mixture from a tank into weighted trailing hoses that are dragged below the airboat at near idle speeds. The group also saw a snail kite sitting on a post feeding on an apple snail (*Pomacea* sp.). The primary submersed weeds in the south portion of the lake were a mixture of native Illinois pondweed (*Potamogeton illinoensis*) and hydrilla; both were growing to the water surface and very dense.

After the tour of West Lake Toho concluded, tour attendees were taken to the Orlando Airport for travel home.

Tour highlights include:

1. The maintenance control concept for floating aquatic weeds appears to be working well in Florida. We saw very few waterhyacinth or waterlettuce plants in STA-1, Lake Okeechobee or in West Lake Toho, although we only saw a small portion of each system
2. The dense submersed plant biomass in the Southport area of Lake Toho, if it is similar in coverage and density in other parts of the lake, certainly indicates potential oxygen problems. Summer's hot temperatures and a cloudy, tropical depression with heavy rainfall could produce a major fish kill
3. This was a fun trip with a great group of people. It looks like we have work to do; we need clarification on drone usage, resolution of endangered species issues, and ways to manage crested floatingheart!!!

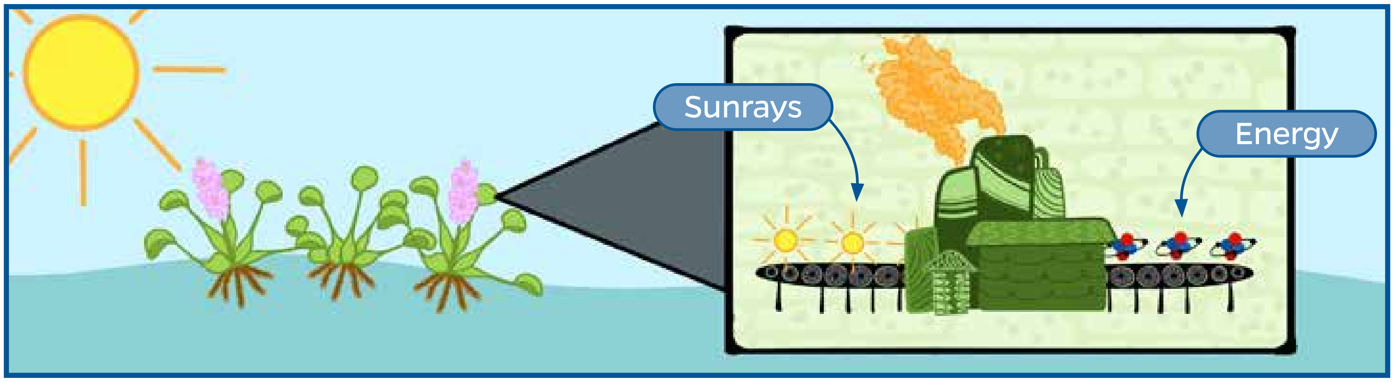
Presenters for days three, four, and five included: *Ian Markovich, Jessica "Skippy" Fair, Tyler Green, Jesse Hall, Alyssa Jordan, Al Brady, Hunter Parker, Jenifer McBride, Jason Cull, Ernesto Lasso, De La Vega, Keith Andreu, Jamie Fowler, Brittany Lay, Alex Holmes*

Attendees included: *Cristina Giuseppina Inglis, Gillian Elizabeth Manning, Leanne Yee Yan Bikai, Scott Johnstone Couture, Nicole Kimmel, Ken Bao, Sergio Santiago, Kelly Kulhanek, Hannah Dean, Michael Piombino, Lindy Caffo, Meghann Niesen, Jerrett Fowler, Daniel Aboagye, Cassi Walls, Victoria Oliver, Jeremy Leonard, Samantha Thomas, DeMariah Koger, Lindsay Roe, Sayed Islam, Lydia Crawford, Carlton Layne, William Haller, Lyn Gettys*

HOW DO AQUATIC HERBICIDES WORK?

FOUR COMMON WAYS AQUATIC HERBICIDES WORK IN PLANTS

Aquatic herbicides are a **helpful tool** when it comes to **controlling problematic plants** in our waterways. They are designed to target a **specific plant part** and prevent it from growing.



All plants are little factories that use sunlight to make their food so they can grow. This process is called photosynthesis. The first step in photosynthesis is to harvest sunlight, and turn it into energy that can be used by the plant. This is done when the green pigments in the leaves (chlorophyll) absorb the sun's rays. This energy is converted to electrons that race through the leaf in a very specific way, creating a lot of chemical energy that powers the plant.

There are currently **17 herbicides** registered by the U.S. Environmental Protection Agency for use in Florida's waters. These aquatic herbicides work in **four common ways**:

PHOTOSYSTEM 1 INHIBITORS

These PS1 herbicides work like a magnet to pull tiny electron particles off their regular path. These electrons get confused and can't do their job. Energy then builds up in the wrong place and the cells explode.

ENZYME INHIBITORS

Enzyme inhibitors work like a lock and key. They attach to enzymes and block them from converting sugar into energy for the plant. When enzymes are blocked, energy is not converted and the plant stops growing.

CAROTENOID INHIBITORS

Carotenoid inhibitors sneak into the plant and stop carotenoids from collecting the extra sunlight. The plant doesn't realize the carotenoids are stopped by the herbicides, so the chlorophyll continues to process the sunlight energy and becomes overwhelmed.

SYNTHETIC AUXINS

Synthetic auxins, also known as plant growth regulators, change the hormone messaging in plants. When these herbicides enter, they overwhelm the plant with different hormone messages until they get confused, which will ultimately stop the plant from growing.

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Invasive Aquatic Plants and Climate Change: A Growing Threat to Our Waters… and Wallets

North American Lake Management Society's 44th International Symposium in South Lake Tahoe, NV/CA. The theme for this year's conference was "Flood and Drought, Fire and Ice: Managing Lakes Under Changing Climates."

I just returned from attending the North American Lake Management Society's 44th International Symposium in South Lake Tahoe, NV/CA. The theme for this year's conference was "Flood and Drought, Fire and Ice: Managing lakes under changing climates." Several presentations explored aquatic plant management problems and strategies from various regions across North America. A few focused on the economic, environmental, and stakeholder challenges associated with managing Hydrilla (*Hydrilla verticillata*) in Lake Apopka, Florida. There were talks addressing harmful algal blooms, and the increased intensity, duration, and frequency of cyanobacteria with respect to a changing climate. And there was a session dedicated to addressing the difficulties of managing Eurasian watermilfoil (*Myriophyllum spicatum*) and curly-leaf pondweed (*Potamogeton crispus*) in Lake Tahoe, which spans both Nevada and California and is designated an Outstanding National Resource Water under the federal government's Clean Water Act. It was an excellent meeting with so much relevant information, agency and research university input, useful scientific data, and practical applications for lake management. It got me thinking a lot more…about the implications for aquatic plant management in a warming world.

As climate change reshapes our planet, our aquatic ecosystems face increasing threats. Rising temperatures, changes in rainfall, and more frequent extreme weather events are providing an opening for invasive aquatic plants to not only thrive, but also to expand to new areas. These aggressive species outcompete native vegetation, altering water quality and hydrology, and significantly changing the habitats on which native fish, wildlife, and plants depend. Understanding the connection between climate change and invasive aquatic plants is essential for protecting our waterways and preserving biodiversity. It is also vital for anticipating and managing the financial costs associated with climate change impacts.

What Are Invasive Aquatic Plants?

Invasive aquatic plants are non-native species introduced — often unintentionally — into new ecosystems where they proliferate rapidly, taking over space and using up resources critical for native species' survival. In their native range, aquatic plants are kept in check by native predators, herbivores, pathogens, and environmental conditions. However, once transported to a new area without these natural controls in place, they grow and spread quickly, outcompeting native plants and drastically changing the landscape. Invasive aquatic plants are frequently introduced through human activity, like discarding aquarium contents into natural water bodies, neglecting to properly clean, drain, and dry fishing and hunting gear, or releasing ornamental plants thought to be 'harmless'. Once invasive plants establish themselves, they can spread further via flooding, wildlife movement, storm events, and recreational activities.

Climate Change: A Catalyst for Invasion

Climate change amplifies the challenges of managing invasive aquatic plants in several ways:

1. **Warmer Water Temperatures**
   Aquatic plants are sensitive to water temperature. Many invasive species can thrive in warmer conditions, while native plants struggle with warmer waters, more intense sunlight, or severe storms. As climate change raises temperatures, invasive plants are often the first to

adapt and flourish. Research by Glomski and Netherland (2012) showed that Hydrilla can grow up to 191 inches per day, allowing a single cutting to expand dramatically in all dimensions in just 24 hours - far surpassing the commonly cited growth rate of "an inch per day." This rapid spread is due to Hydrilla's remarkable ability to generate multiple new stems, branches, and stolons within a very short time period. Its dense growth can blanket entire lakes, rapidly blocking sunlight, halting photosynthesis, and reducing oxygen levels….and ultimately suffocating aquatic life.

2. **Extended Growing Seasons**
   Warmer temperatures mean longer growing seasons, giving invasive aquatic plants more time to establish in new locations….and more time to reproduce. This extended period allows invasive vegetation to spread faster and increases the difficulty and expense associated with aquatic plant control efforts. The majority of invasive aquatic plants reproduce by fragmentation, so the longer that the plant tissue remains viable, the greater the potential for the plant to grow and to be moved from place to place. For example, Eurasian watermilfoil can grow more densely and spread its root system across larger areas when winter temperatures are milder, making it harder for native species to re-establish in spring.

3. **Changes in Precipitation Patterns**
   Extreme weather events, including heavy rains, intense storm events and droughts, alter the natural water flow in rivers, lakes, and wetlands. Flooding can transport fragments of invasive aquatic plants to new areas, enabling rapid colonization. Hurricanes can further spread invasive aquatic vegetation via stormwater, high winds, and by displacing wildlife — like birds that may carry plant fragments and be blown into habitats beyond their usual range. On the other hand, droughts can lower water levels, providing newly exposed shoreline for invasive plants to establish

Coontail (*Ceratophyllum demersum*) in Spooner Lake, Nevada.

Lake Tahoe, Nevada/California. Surface elevation is 6,225 feet; deepest point 1,645 feet; 72 miles around, and 12 miles across, and 22 miles long. Average clarity in 2023 winter = 91.9 feet, summer 53.5 feet. (Data from University of California, Davis – Tahoe Environmental Research Center).

FWC Biological Administrator, Nathalie Visscher, gives a presentation on selective control of Hydrilla and littoral vegetation restoration in Lake Apopka for the NALMS attendees in South Lake Tahoe, NV

and take over once the water returns. And there are a number of aquatic plant species that remain viable even after being high and dry for weeks.

4. **Increased Carbon Dioxide Levels**

Elevated carbon dioxide (CO_2) in the atmosphere doesn't just impact land plants. It can also benefit aquatic plants by increasing photosynthesis rates, giving invasives that reproduce quickly and have no natural controls, a further advantage over native aquatic plants. These changes may enable invasive plants to grow faster, spread more aggressively, and resist control efforts.

The Impact on Ecosystems and Biodiversity

Invasive aquatic plants can transform entire ecosystems. By outcompeting native plants, they reduce biodiversity, disrupt food chains, degrade water quality, and displace wildlife that rely on native habitats.

When invasive aquatic plants invade and establish, these species can form dense mats that block sunlight from reaching other native submersed aquatic vegetation. This shading effect causes native plants to die off, removing essential food sources and places of refuge for fish, macroinvertebrates, and other wildlife.

Floating mats of invasive aquatic plants, like water hyacinth, can trap sediment and nutrients, leading to water stagnation, increased algae blooms, and concerns

Robbins' pondweed (*Potamogeton robinsii*), at an alpine lake in CA. Native, but listed as rare/threatened/endangered in CA.

Broad leaved pondweed (*Potamogeton amplifolius*) in a creek at an alpine lake in CA. Native.

for mosquito-borne disease as mosquito populations thrive in these conditions.

Dense patches of invasive plants can make water activities, like boating, fishing, waterskiing, and swimming, challenging and sometimes dangerous. And if invasive aquatic plants are left unmanaged, the recreational and tourism industries suffer resulting in economic impacts to a community.

Rising Costs for Management Initiatives

The cost of managing invasive species is rising sharply as climate change creates conditions that favor their spread and persistence. Additionally, climate-related shifts in *native* species populations can reduce the resilience of ecosystems, further encouraging invasive aquatic plants to recruit and dominate a new habitat or ecosystem. When invasive aquatic plants can thrive and colonize larger areas and over longer periods of time, containment and attempted control efforts both become more complex and more costly.

Increased flooding potential is linked not only to storm intensity but also to invasive aquatic plants blocking flood control structures. Obstruction can be costly, as it reduces the effectiveness of flood management systems and increases the effort and expenses required for stormwater maintenance.

In some locations, costs are also exacerbated by climate change when it comes to the use of herbicides in water. For the chemical control of invasive aquatic plants, herbicide treatments are typically calculated based on the water volume in areas where the invasive aquatic plants are growing. In subtropical and temperate regions, warmer climates mean extended growing seasons, and herbicides must be used more often. But in alpine regions and colder areas, as temperatures rise and climate change intensifies, increased snowmelt results in greater runoff, leading to deeper lakes and ponds. This added water volume makes herbicide treatments more costly, as larger quantities of chemicals are required to achieve effective control. And in many cases, herbicides are more effective in cooler waters since microbes can't degrade the chemicals as easily. So with a warmer climate, herbicide efficacy is a real concern.

As a result, management budgets are being stretched thin, requiring increased funding to develop and implement new control strategies, conduct repeated treatments throughout an extended growing season, monitor at-risk habitats, successfully maintain stormwater and flood control structures, and conduct public outreach and prevention programs. These rising costs highlight the urgent need for educational awareness and management practices that *anticipate and mitigate* the compounding effects of climate change on invasive aquatic plants.

Myriophyllum sp. in Donner Lake, NV.

What Can WE Do?

Preparing for climate change and preventing the spread of invasive aquatic plants requires awareness, informed decision-making rooted in science, and collective action. Here are some things that we can all do to help:

- **Learn to Identify Local Invasive Species and How to Report:** Many local conservation groups, extension programs, and government agencies offer resources to help you recognize invasive aquatic plants in your area. By learning to identify them, you can report sightings to help with early control efforts. There are a number of apps available like "IveGot1" and reporting websites that collect these data and send a biologist to verify the reports. Managing a small infestation is far more affordable than trying to control a plant that establishes and is successfully reproducing.
- **Follow Guidelines for Boating and Fishing:** Before leaving a water body, clean any visible mud, plants, and animals from your gear and equipment. This includes fishing gear, boats, trailers, dive equipment, jet skis, etc. Let your equipment dry before using it in another location. Follow the Clean, Drain, Dry practices available at https://www.cleandraindry.org. And respectfully avoid any areas posted for treatment or prohibited access.
- **Never Dump Aquarium Contents:** If you have aquatic plants (even fragments!) or animals in an aquarium, never release them into natural waters, ditches, or ponds. Even species that seem harmless in an aquarium can become problematic in a natural environment.
- **Educate and Practice Prevention:** Invest in signage, outreach, and communication efforts to prevent the spread of invasive species by cleaning, draining, and drying boats, gear, and equipment after each use to avoid transporting plant fragments between waterways. Raising awareness within local communities about invasive species and their impacts also helps build collective responsibility.
- **Support Native Vegetation:** Planting and restoring native vegetation along shorelines and in natural areas can strengthen ecosystems, making them more resilient to invasion. This creates an established community of native aquatic plants that provide competition against invasive plants that are 'looking' for a place to land and grow. Healthy, diverse plant communities are better able to resist invasive aquatic plants and adapt to changing conditions.
- **Advocate for Climate-Resilient Management, Policy, and Risk:** Communities can advocate for climate-informed invasive aquatic plant management policies and funding to

support more efficient control measures, like updated herbicide strategies and improved mechanical or biological controls that account for increasing water levels and temperatures. Perhaps biocontrol efforts will be suitable in areas where they weren't previously an option? Risk assessments are also an important part of municipal and community planning — knowing how an invasive aquatic plant invasion may impact tourism dollars, your team, and the working budget is critical. Work with policymakers to make sure that they understand climate change and what that means for management and funding efforts.

- **Promote and Use Green Infrastructure:** Supporting or implementing green infrastructure, such as natural buffers and wetland restoration, helps reduce runoff and manage water levels, mitigating one pathway through which invasive aquatic plants can spread.

Moving Forward

Climate change and invasive aquatic plants form a complex feedback loop that threatens freshwater ecosystems, wildlife, property values, and wallets; but we have plenty of scientific information available to plan and adjust accordingly. As temperatures rise, the threat of invasion grows, compounding the ecological damage and economic costs associated with managing — even to the lowest feasible level. By promoting awareness, relying on scientific data, and taking preventative action, we can take a proactive approach to help protect native waterways, livelihoods, and vegetation. Our efforts today can ensure that these dynamic aquatic ecosystems remain healthy and resilient for future generations….and for the native wildlife who depend on us.

Resources:

Clean, Drain, Dry: National Campaign on Invasive Species. https://www.cleandraindry.org

Glomski, L. M., and M. D. Netherland. 2012. "Does hydrilla grow an inch per day? Measuring short-term changes in shoot length to describe invasive potential." *Journal of Aquatic Plant Management*. 50: 54–57.

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The value of vouchers

Voucher specimens are one of the most important tools in the aquatic scientist's toolkit.

Samuel A. Schmid and Gray Turnage

The neglected aquatic ecosystem

Freshwater is the most important natural resource on the planet and much of this water is housed in natural and artificial aquatic ecosystems. These ecosystems are complex and diverse, and in many of these systems the structure and function are driven by the aquatic plant community. The plants in these systems are specially adapted to aquatic conditions and provide several ecosystems services like improved water quality, flood mitigation, and food and habitat for fish and waterfowl. For the aquatic plant community, a more diverse community is more resilient and provides more ecosystems services.

Despite the importance of a diverse aquatic plant community, much of the plant diversity in aquatic ecosystems remain undescribed. In herbarium collections, there is a systematic bias toward terrestrial ecosystems thus aquatic ecosystems are often neglected. This bias results in a comparatively poorer understanding of our aquatic plant communities which hampers the ability of resource managers to make appropriate management decisions. The remedy for this problem requires more botanists on the water, collecting specimens and documenting aquatic

Figure 1. Population of *Didiplis diandra*, a rare, submersed plant, from northeastern Mississippi. Top: Photo of population on site. Bottom: Digitized voucher specimen from this population [credit: Mississippi State University herbarium (MISSA)].

plant diversity. An increased collection effort not only bolsters our knowledge of native aquatic plant diversity, but also helps scientists and resource managers track the distribution and spread of aquatic invasive species. Voucher specimens are one of the most important tools in the aquatic scientist's toolkit.

What is a voucher specimen?

In this context, plant specimens are any plant material that is preserved and serves as a record of that population (Figure 1). A voucher specimen, specifically, is an herbarium specimen used in a scientific study. The most common method to prepare plants for specimens is to press them with a plant press and dry them in a cool, dry place or with the help of a drying oven set to around 100°F (38°C). An effective specimen will have accompanying information:

- **Determination.** A determination is the identity of the species collected. A specimen can be determined by the collector or expert botanist if necessary. Taxonomic family is also often included.
- **Date and locality.** Locality should include state/province, county, nearby municipality, and GIS coordinates if available.
- **Habitat.** This should be a description of the environment the population was found in. It can include ecosystem type, soil and water properties, geologic and geographic descriptions, and associated taxa.
- **Collector's name and number.** The name of the person who collected the specimen and a number unique to that specimen. The collector's name and number are often used to identify the specimen (e.g., S.A. Schmid 353).

Some botanists will keep their own collection, but most opt to submit their specimens to an herbarium for safe keeping.

An herbarium is essentially a museum filled with plant specimens that act as a public resource for the documentation of floral diversity. Herbaria can range in size from the largest, like the Missouri Botanical Garden with over six million specimens, to collections at small colleges and universities, often with fewer than a thousand specimens. After receiving a specimen, an herbarium will typically make a label with the accompanying information and glue the plant material and label to a sheet of museum-grade paper (Figure 2). In this form, the specimen can be housed indefinitely as a permanent record of that population. Often times, herbaria will digitize their collections by making photos of their specimens available to the public, typically housing them on large data repositories like iDigBio and SERNEC. These herbarium collections act as the primary source of information for the composition

Figure 2. A student researcher affixes specimens and labels to herbarium paper at Mississippi State University Herbarium (MISSA).

Figure 3. Samuel Schmid collecting plant specimens in the field. This ecosystem is a wet pine savanna, a wetland with a fire-adapted plant community.

of our plant communities and are an invaluable public service.

Collection best practices

Making a good plant specimen can be a blend of art and science (Figure 3). While some botanists prefer to make their specimens aesthetically pleasing, the priority is to convey as much scientific information as possible. To best aid in a correct determination, the collector should include in the plant material, important traits that help identify the species. This is often a combination of reproductive (flower parts, floral arrangement, fruits, etc.) and vegetative (leaf shape, leaf arrangement, root stock form, etc.) characteristics, and which traits are important will depend on the species. Collecting specimens is, ultimately, a destructive form of sampling, so the collector should ensure they minimize harm to the plant community. Species that are protected or only have one representative in the community should be left alone and the collector should employ an alternative form of documentation (like photography). Rare species should also be treated with care; should the collector chose to make a collection, they might consider leaving the roots behind to allow for regeneration. Once the plant material is collected, the collector will need to press it.

To press plant specimens, a collector will need a plant press and newspaper (Figure 4). The press consists of a wooden frame (typically 12” × 18”), blotter paper, corrugated cardboard, and two straps that fit around the press when full. For each specimen, the flattened plant material should be placed inside a sheet of newspaper and then sandwiched between two sheets of blotter paper, then sandwiched again between two pieces of cardboard. The stack can then be bound inside the press until dried. When working with aquatic plants with lots of moist, spongy tissue, it is often necessary to periodically change out the blotter paper as the plant dries to ensure a quick drying process and prevent the growth of mold and other fungi. After they are dried, specimens are often frozen or fumigated to kill any pests, afterward, the specimens are ready to be labeled and affixed to their herbarium paper, and finally added to the collection. While collecting specimens can be quite important, the process is simple and can be easily integrated into existing studies and management activities.

Voucher specimens further our scientific understanding

Although records of plant diversity are valuable in their own right, plant specimens also facilitate important scientific studies. Taxonomists often use herbarium specimens to resolve issues in current taxonomic treatments and describe new species. Many herbaria work directly with researchers and allow them to take morphological measurements of their specimens and sample plant material for molecular analysis. The use of herbaria to describe new species is so prolific, that most new species descriptions are facilitated with the help of herbaria. Biogeography is another discipline that frequently makes use of herbarium specimens. Most herbaria with digitized collections also have their data indexed in large data repositories like GBIF. Biogeography researchers often use these services to build large datasets of occurrence data for their species of interests. These datasets are then used to meet research objectives like modeling the ecological niche of a species or predicting how climate change will affect its distribution. Collecting voucher specimens are valuable in field studies, especially for cryptic species. It can sometimes be too time consuming to identify cryptic species in the field, voucher specimens allow field scientists to make accurate identifications at later times without wasting precious time using a dichotomous key. Also with a physical specimen, determinations can be updated as species are renamed, and taxonomies are rearranged.

> *Several infamous invasives have some of their earliest records as herbarium specimens, including alligatorweed, Eurasian watermilfoil, and water hyacinth.*

The study of aquatic invasive plants greatly benefits from the collection of voucher specimens. These physical records allow researchers to track the spread of invasive species across time, and occurrences of new introductions can be documented and assist in early detection. Plant specimens are valuable for understanding the history of aquatic invasive species. Several infamous invasives have some of their earliest records as herbarium specimens, including alligatorweed, Eurasian watermilfoil, and water hyacinth. These specimens have been instrumental in estimating the point(s) of introduction and the history of their spread. Ultimately, voucher specimens are easy and inexpensive ways to improve the scientific rigor of field studies on aquatic plants and provide valuable information to the public.

Samuel A. Schmid, is a Research Associate and PhD Candidate at Mississippi State University. His research focuses on the ecology and management of several aquatic and wetland plants invasive in the United States. His current study systems include alligatorweed (Alternanthera philoxeroides), Cuban bulrush (Cyperus blepharoleptos), and invasive eelgrass (Vallisneria sp.).

Gray Turnage, PhD, is an ecologist and aquatic weed scientist whose research interests focus on the biology, ecology, and management of aquatic plants at laboratory, mesocosm, and field scales.

Figure 4. Materials used for collecting plant specimens: newspaper and a plant press filled with blotter paper and cardboard.

Calendar of Events

December 1 – 4
9th International Weed Science Congress
Jerusalem, Israel
https://www.iwsc2024.com/

December 9 – 12, 2024
48th Annual Florida Aquatic Plant Management Society Annual Training Conference
Hilton Daytona Beach Oceanfront Resort
Daytona Beach, FL
https://fapms.org/

conference/2023-conference/

January 7 – 8, 2025
26th Annual Northeast Aquatic Plant Management Society
Holiday Inn Saratoga Springs
Saratoga Springs, NY
https://www.neapms.org

February 24 – 27, 2025
45th Annual Midwest Aquatic Plant Management Society Conference
Palmer House Hotel
Chicago, Ill
https://www.mapms.org/conferences/2025-conference/

March 17 – 19, 2025
Western Aquatic Plant Management Society Annual Conference
Sacramento, CA
https://wapms.org

July 14 – 17, 2025
1-15 Aquatic Plant Management Society 65th Annual Meeting
Omni Providence
Providence, RI
https://apms.org/2025-annual-meeting/

Call for Submissions – The Florida Aquatic Plant Management Society is preparing the Spring 2025 Issue of *Aquatics* magazine and is seeking articles from industry professionals, researchers, and other interested authors. Submissions can be directed to aquaticsmagazine@gmail.com.

Articles should be no longer than **2,500 words** in length and include photos, captions, author bio and email.

Want to write for us, but aren't sure what to write about? Below are some topics our readers are always interested in:

- Plant Identification (Native and Invasive)
- Research Updates
- Stories on the people of the aquatic and related industries
- Photo stories – Do you spend a lot of time on the water taking photos that tell a story of some particular plant or a part of Florida? Submit your series of photos with captions and we can share your story!
- Waterbody updates
- Agency Updates

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AERF

Aquatic Ecosystem Restoration Foundation

DID YOU KNOW?

Invasive Aquatic Plants & Harmful Algal Blooms:

- Threaten native aquatic ecosystems
- Degrade water quality, causing health problems for people and animals, loss of habitat for fish and wildlife, and a decrease in property values
- Impacts recreational activities

AQUATIC PLANT MANAGEMENT BEST PRACTICES

SPONSORSHIP OPPORTUNITIES

The Aquatic Ecosystem Restoration Foundation is committed to sustainable water resources through the science of aquatic ecosystem management in collaboration with industry, academia, government and other stakeholders.

Accomplishments & On-Going Efforts

- Best Management Practices Handbook on Biology & Control of Aquatic Plants
- Research partnerships: Private – Government – Academia
- Regulatory Education Tours
- Educational Symposia, Summits, & Seminars
- EPA Liaison
- Science Advisory Panel For Managers & Consultants
- Contributor To Plant Camps For Educators
- White Paper Development
- Graduate Student Assistantships
- Regulatory Engagement & Support
- Connection To World-Leading Scientists In The Discipline
- Webinars For Management & Policy Decision Makers
- Funding For Student Internships
- Travel Assistance For Government & Student Education Opportunities
- B.A.S.S. Alliance & Support

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AQUATIC WEED CONTROL
Short Course

https://go.ufl.edu/awcsc

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