Aquatics

SUMMER 2023

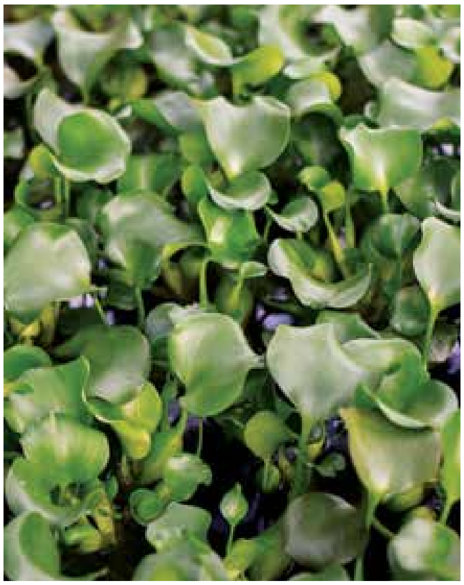
A Publication of the Florida Aquatic Plant Management Society

Aquatics

SUMMER 2023

Volume 45, Number 3

Florida Aquatic Plant Management Society
FAPMS
Established in 1976



Contents

To become a member of FAPMS and receive Aquatics magazine, please visit the website at: www.fapms.org

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 Aquatics Readers,

This is my first issue as Editor of *Aquatics*, and I am very excited to bring you this and future issues featuring the latest in the world of aquatics. Throughout my career I have worked for agricultural and natural resource organizations in the nonprofit and research sector. Serving FAPMS brings me great joy and I look forward to the future of this the organization and this publication!

This issue brings you a variety of updates. Mosquito control is a major concern of Floridians. The East Volusia Mosquito Control District is collaborating with Bethune-Cookman University to work toward integrated management of both aquatic plants and mosquitos in stormwater drainage systems. Read more about this project on page 7.

This issue also features a glimpse into the next generation of aquatic and invasive systems researchers as the UF/IFAS Center for Aquatic and Invasive Plants introduces their current graduate students on page 5.

Dr. Candice Prince gives a research update from her lab including native plant restoration following hydrilla removal and Cuban Bulrush reproduction. To read the full update flip to page 15.

On page 12 Applicator's Corner features a piece by Dr. Jason Ferrell of the UF/IFAS Center for Aquatic and Invasive Plants discussing muck, why it's bad and how to prevent excessive muck development.

Another article takes a look into Lake Okeechobee over the last 123 years of progress and repetition from the aquatic plant management community. On page 18 you will find an examination of a past article written by Langeland in 1987 and a discussion of where we have come since then.

The world of aquatic plant management requires a large group of people and organizations to work together to keep the work compliant with regulations and ensure water quality, wildlife, and native habitats are preserved. This issue includes a piece explaining the process and roles of each organization involved in oversight of this seemingly complicated practice. Flip to page 21 to read the full outline.

Thank you again for the opportunity to serve as your Editor. I look forward to bringing you the latest information and features from our industry. Interested in being featured or writing for Aquatics, email Shelby Thomas at aquaticsmagazine@gmail.com.

CAIP Graduate Students

Hannah Brown

Cape Coral, FL
PI: Dr. Prince and co-advised by Dr. Sperry

Research Area: Subsurface herbicide treatments for floating plant management

Before I started a graduate program at CAIP, I had an internship under Dr. Prince which introduced me to the field of plant management. After the internship, I felt like there was still so much to learn and wanted to continue to explore this field so I accepted a position at CAIP as a graduate research assistant.

My favorite thing that I've learned so far is that an X-ray machine can be used for seed and propagule analysis. X-ray analysis gives us beautiful images of what's inside these structures without opening them.

My favorite thing about my role as a graduate student is being exposed to a wide variety of different topics that allows me to gain new experience. Since I've become a graduate student, I've had the opportunity to develop a wide range of skills such as backing in a trailer, sharpening communication skills, obtaining my pesticide applicators license, and of course being able to use the X-ray machine.

Daniel Canfield

Gainesville Florida
PI: Dr. Prince and Dr. Sperry (co-advised)

Research Area: Hydrilla: Studying the new Connecticut strain, herbicide applications to control hydrilla is high water exchange systems, and the cause of tuber dormancy release.

I knew I wanted to do research on lake management. Aquatic plant management was the next logical step because amount of plants in a lake has such a huge impact on how a lake functions and what we use it for.

As someone coming from a geology background, I'm constantly amazed at how complex and adaptable plants are. If I had to pick one fact, it would be the ability of plants to grow from tiny fragments is still mind-blowing to me. It's crazy to me that we can just rip plants apart and not only will they survive, but those fragments can spread to create more plants.

The fact that I get to meet people all across the country all interested in lake management! It's exciting to see all the new ideas people are coming up with to manage lakes.

Minjin Choi

South Korea,
PI: Dr. Stephen F. Enloe

Research Area: The biology and ecology of *Lygodiium microphyllum* and how to control them.

UF/IFAS CAIP has a great environment to learn ecology and environment and to do experiments. Especially, I like that it has several greenhouses to do different experiments at the same time. This is why I chose a graduate program with UF/IFAS CAIP.

There are many things I have learned so far, but my favorite parts are how to cultivate plants and how to deliver my message from research through presentation. Also, when I find out the meaning of research, I am glad and excited since I feel I do something meaningful which is the reason why I come to the US.

Even though I still need more practice and experience, one of my favorite things about my role as a graduate student is to do presentation, informing audiences of my research and its meaning, because it could help people to have an interest in the necessity of understanding *Lygodium microphyllum* gametophyte ecology.

Amber Riner

Orlando, Florida
PI: Dr. James Leary

Research Area: Integrating Unmanned Aerial Systems into the Maintenance Control of Water Hyacinth

I enjoyed working for CAIP as an undergraduate, so I decided to pursue a master's with CAIP! My favorite thing I've learned so far would be how to fly a drone. I really like problem solving which I've had to do a lot of for my research project.

Corrina Vuillequez

Originally upstate NY, but did my undergrad here at UF studying plant sciences
PI: Dr. Ben Sperry

Research Area: Crested floating heart biology and management

I chose a graduate program with UF/IFAS CAIP because I'm passionate about invasive plant management, and I love the community here!

My favorite thing I've learned so far is how resilient and prolific plants can be. At first glance, invasive plants seem like nothing more than an evil nuisance. But when you consider that these plants are just growing their best in the environment they were placed in, it's pretty amazing how quickly they can grow. Each species has many unique ways of reproducing that gives them an advantage in the environment. For example, hydrilla can reproduce by fragments, tubers, and turions, and can grow exponentially! We have to thoroughly understand the biology in order to control these plants, and even though they are a nuisance, I have grown an appreciation for their abilities.

My favorite thing about my role as a graduate student is that I get to learn and explore new things every day. Rather than having a regular job where you might do the same things every day that you're told to do, I get to ask new questions and investigate them. It's been really interesting to get to be a part of the research process, from designing the studies, setting them up, collecting the data, and I'm excited to learn data analysis soon too!

East Volusia Collaborative Initiation toward Integrated Management of Aquatic Plants and Mosquitoes in Stormwater Drainage Systems

Hyun Jung Cho[1], Miranda Tressler[2], Savannah Stura[2], Imani Ford[1], Anna Ponce[1]

Heavy precipitation can generate a large quantity of surface stormwater runoff within a short time period. The peak runoff volume and the time to reach the peak vary with land surface permeability and soil capacity to hold water. Impervious surfaces such as rooftops, paved streets, highways, and parking lots impede the infiltration of water into the soil. More than 75% of precipitation can become surface runoff in a highly urbanized area, causing low areas to flood quickly after heavy rains (Federal Interagency Stream Restoration Working Group, 1998). The pollutant concentration of untreated stormwater runoff often exceeds the concentration of treated water in the receiving water (LeFevre et al., 2015), causing the degradation of surface water quality and ecosystems (Chang et al., 2018; Wang et al., 2000). To relieve the surrounding areas from potential flooding and flood-induced problems (e.g. mosquito production, pollutant discharges, etc.), retention and detention ponds as well as drainage ditches and canals have become common components of development.

Both native and non-native aquatic plants occur in the stormwater drainage systems (e.g. ditches and canals). These macrophytes supply food to consumers in trophic chains and provide habitats and refuge for fish and invertebrate species (Bornette & Puijalon, 2011). Aquatic plants are also frequently used for living shorelines and phytoremediation as a cost effective and resourceful way to reduce the amount of contaminants in projects

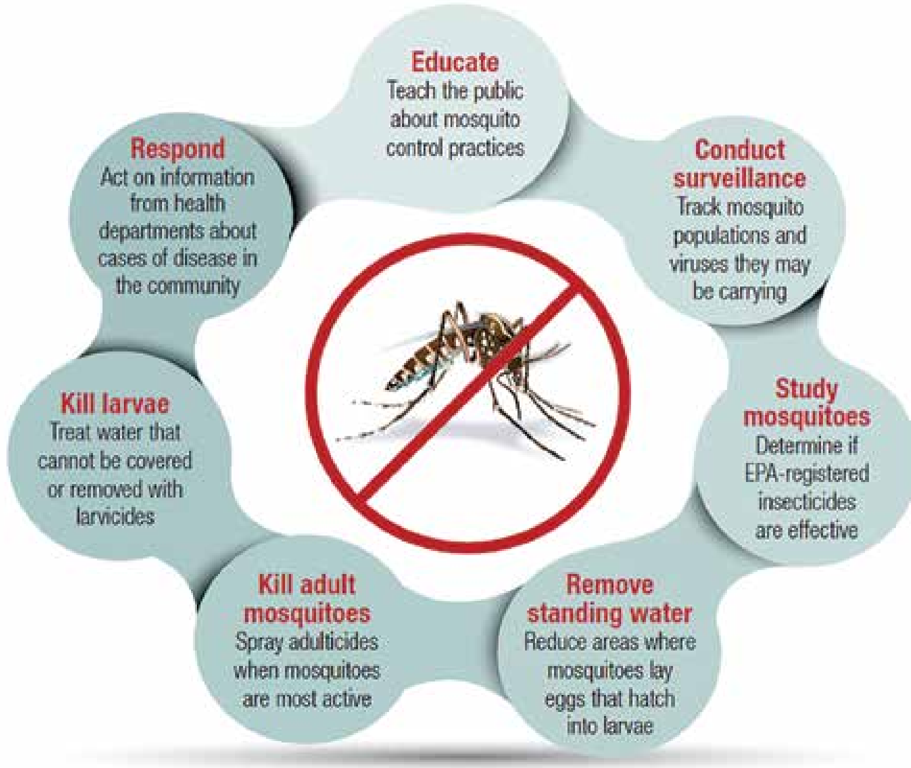


Figure 1. Components of Integrated Mosquito Control Management (source: Centers for Disease Control and Prevention; https://www.cdc.gov/)

implementing Low Impact Development (LID) and Green Infrastructure (Ali et al., 2020). Nevertheless, fast growing aquatic plants can become problematic in the areas of excessive nutrient concentrations and slow waterflow. Floating and canopy-forming aquatics also provide habitats for mosquito eggs and larvae.

Mosquito Control programs employ integrated mosquito management strategies to effectively manage mosquito populations and protect public health (Fig. 1). The foundation of an integrated program is to use real-time surveillance data, such as data collected from mosquito traps, landing rate counts, sentinel chickens, and larval dipping, to make the appropriate targeted treatment decisions and to reduce risk of mosquito-borne illnesses in the community. Mosquito control treatment operations are planned in areas where surveillance data confirms a justification for treatment as per Florida State Statute Chapter 388 and Florida Administrative Code Chapter 5E-13. Larvicide operations target mosquito larvae present in water and prevent emergence into adult mosquitoes. These operations are generally prioritized, over adulticiding operations that target flying adult mosquitoes. Larviciding can more efficiently control mosquitoes in confined water habitats and break the life cycle leading to less need for adulticide applications.

The East Volusia Mosquito Control District (EVMCD) is located along the coast of Volusia County and was established on June 12, 1937 (Fig. 2). The program's primary service area is the eastern section of the county where residents pay a tax

[1]Bethune-Cookman University; [2]East Volusia County Mosquito Control District

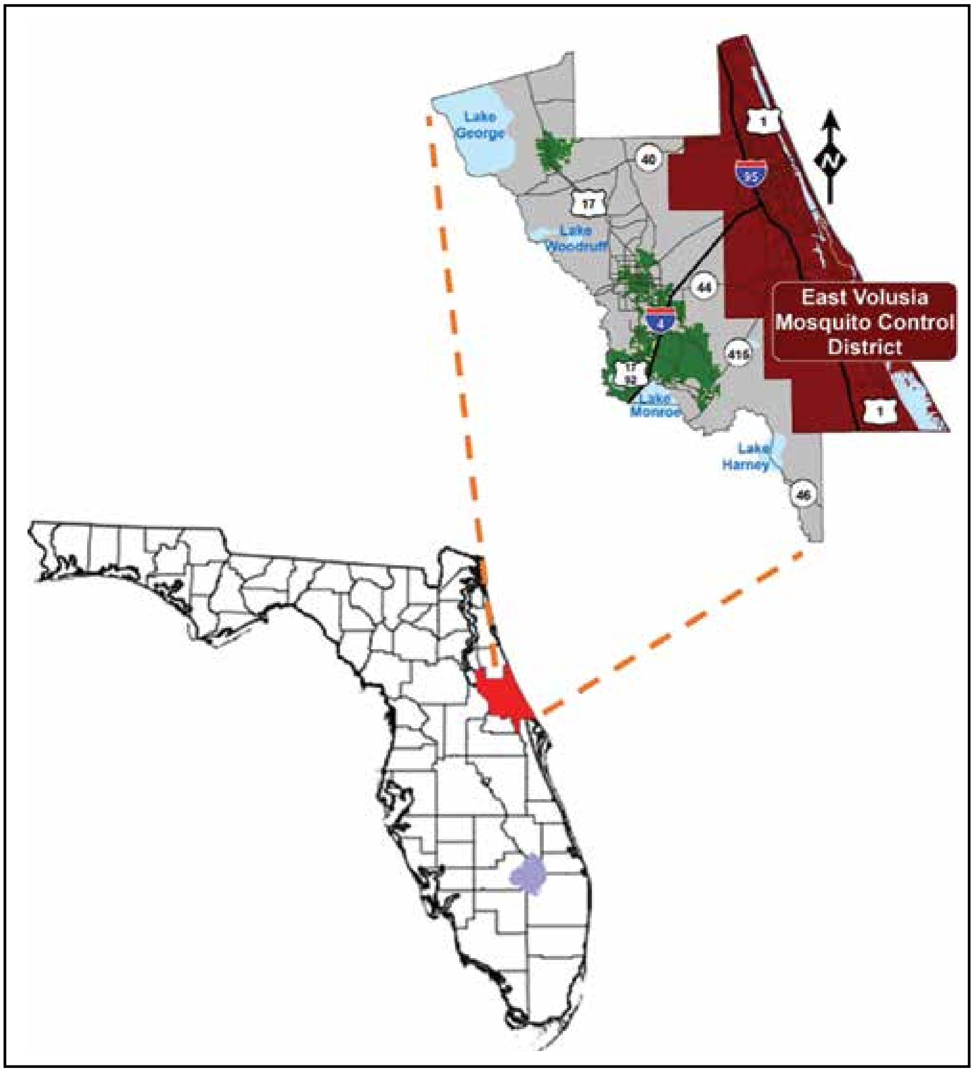


Figure. 2 Reference map of Volusia County located on east coast of Florida. East Volusia Mosquito Control District (EVMCD) located in maroon shaded area.

directly to the East Volusia Mosquito Control District. The western area of the county outside of the taxing district receives mosquito control services at a lesser level paid for by other funding sources. The EVMCD's integrated mosquito management program currently serves a population of just over 500,000 residents throughout the county.

Bethune-Cookman University (B-CU) has been surveying floating, submerged, and littoral aquatic and wetland plants in retention ponds, drainage ditches, and stormwater canals since 2012 within Volusia County (Cho et al., 2015). Thus far, over 120 wetland/aquatic plant species were documented in the surveyed areas, with less than 10% of them being non-native or prohibited plants in Florida. The number and frequency of non-native aquatic plants are lower in regularly-managed (i.e. regular mowing and chemical treatments) ponds and ditches, however, the total species diversity tends to be lower in those that are regularly managed.

Bethune-Cookman University and the East Volusia Mosquito Control District initiated collaborative surveys of aquatic plants and mosquito larvae in the stormwater and drainage systems in 2022. This project uses adult mosquito surveillance data collected from routine CO_2 baited light traps to generate a range of possible larval sites and aquatic plants that are known for their association with mosquito species.

Extensive historical surveillance data exists regarding primary vector and pest species found in Volusia such as *Culex nigripalpus* (West Nile Virus vector), *Aedes aegypti* (Dengue, Zika, ChikV vector), and *Aedes taeniorhynchus* (severe salt marsh pest). A limited amount of information is known regarding the current larval sites for *Mansonia* spp. and *Coquillettidia perturbans* mosquitoes which have a relationship in their larval stage to specific aquatic plants found throughout the county. Both genera of mosquitoes have a modified siphon that pierces into the roots of the aquatic plants during most of their life in water. Their larval siphon and pupal trumpets pierce and remain attached in the plant tissues for drawing oxygen from the plant's aerenchyma. Water lettuce (*Pistia stratiotes*) and Water hyacinth (*Eichhornia crassipes*) are well known host plants of *Mansonia* larvae, while other aquatic plants (*Salvinia* spp., *Limnobium* spp., *Paspalum* spp., and *Typha* spp.) also have been found or speculated as potential hosts (Amorim, 2022; Gil et al., 2021; Rojas et al., 2021). These mosquitoes are currently generally treated by adulticide operations when populations exceed thresholds in surveillance traps due to a void of data regarding their current larval sites.

Mosquito control should be achieved through understanding widest possible range of host plant species; and it is essential to understand the diversity of macrophyte species that can serve a host for immature mosquitos. *Mansonia* oviposition is also known to vary seasonally and has been correlated with the abundance/growth season of the aquatic plants, particularly, Water lettuce (Lounibos and Linley, 1987). Therefore, the collaborative project goal is to assess the urban stormwater and drainage system's role as potential habitats of mosquito production by studying occurrence and phenology of aquatic plants and associated mosquito larvae.

Retention ponds, ditches, and canals within the East Mosquito Control district of Volusia County are surveyed for documenting growth and phenology of aquatic plants that are known to potentially host mosquito eggs and larvae (Fig. 3). The areas are being investigated for the presence of all aquatic plants and sampled to document the larval species harboring in these plants. Plant species, mosquito species, abundance, photos, field notes, and geographic coordinates are recorded; and the information

Figure 3. Photography of field surveys.

Figure 4. Microscopic photos epidermis with stomata of *Eichhornia crassipes* (top), aerenchyma of *Salivia minima* (middle), and multicellular trichome tip of *Salivia minima* (bottom).

is uploaded to ArcGIS Survey123 (ESRI. Redlands, CA). Some specimens of the plants are taken to both B-CU and EVMCD for laboratory observation. At B-CU, anatomical sections and prints of epidermis of the plant leaves are being used to examine anatomy of potential mosquito host plants including, but not limited to Water lettuce, Water hyacinth, Water spangles, and Sponge plants (*Limnobium* spp.) (Fig.4). Anatomical structures of aquatic plant leaves are plausibly the factors for selection of the location for laying eggs of this species, thus facilitating development of the larvae. At EVMCD, the presence of mosquito larvae is documented. When larval species identification is not possible, aquatic plants collected with mosquito eggs and/or attached larvae will be reared to identify mosquito species.

Non-native floating aquatics such as Parrot feather (*Myriophyllum aquaticum*), *Salvinia minima* and *Hydrilla verticillata* were found in cold months of January and February in narrow ditches. While Parrot feather was predominant in February, *S. minima* overtook the areas by April. Abundance of Water lettuce and Water hyacinth increased in April and outgrow in some ditches in the summer months (Figs. 5 and 6). Mosquito larvae of *Anopheles*, *Uranotaenia*, *Culex* spp. were found throughout the survey periods (December 2022 – July 2023), *Mansonia titillans* larvae were first confirmed in July 2023 within the area thickly infested by Water lettuce (Figs. 6). The data collected from this evaluation will be used to develop larvicide operational plans to target these mosquitoes in the larval stages before they become flying adult mosquitoes.


Figure 5. July 20, 2023 Inspection of Water hyacinth in roadside ditches in Daytona Beach and examination of root structure in the field for mosquito larvae presence.

Author bios/emails

Hyun Jung ("J.") Cho, choh@cookman.edu, Professor of Integrated Environmental Science at Bethune-Cookman University. She received her Ph.D. in Conservation


Figure 6. August 3, 2023 Inspection of water lettuce in a large ditch in Edgewater. A floating trap is set on top of the plants to monitor adult *Mansonia spp.* mosquito emergence (left). *Mansonia titillans* larva collected from Edgewater being reared on *Salvinia minima* in the insectary (right).

Biology and M.S. in Biological Sciences from University of New Orleans and B.S. in Biology from Sung-shin Women's University, Seoul, Korea. Her research involves habitats from urban waterways, freshwater wetlands, estuarine waters, saltmarshes, and seagrass beds.

Miranda Tressler, mtressler@volusia.org, Environmental Program Manager at Volusia County Mosquito Control (VCMC). She received a B.S. from Embry-Riddle Aeronautical University in Computational Mathematics and is currently enrolled in the M.S. program of Entomology and Nematology at University of Florida. She is responsible for managing the surveillance, research, and laboratory operations at VCMC.

Savannah Stura, sstura@volusia.org, Environmental Specialist I at Volusia County Mosquito Control. She received a B.S. from University of Florida and M.S. in Natural Resource Management from Unity College. She is responsible for the management of mosquito surveillance equipment and supplies, identification of field collections, and laboratory analysis at VCMC.

Imani Ford, Imani.J.Ford@students.cookman.edu, Graduate Assistant at Bethune-Cookman University. She received a Bachelor's degree at University of South Florida in Physical Sciences. She is currently enrolled in the MS program of Integrated Environmental Science at B-CU.

Anna Bozena Ponce, poncea@cookman.edu, Assistant Professor of Natural Sciences at Bethune-Cookman University. She earned her Ph.D. in Agriculture from Warsaw University of Life Sciences - SGGW, Poland, and holds an M.S. in Biology from Silesian University, Poland. Her research specializes in plant anatomy and morphogeneticss.

References

Ali, S., Abbas, Z., Rizwan, M., Zaheer, I. E., Yavaş, İ., Ünay, A., ... & Kalderis, D., 2020. Application of floating aquatic plants in phytoremediation of heavy metals polluted water: A review. Sustainability, 12(5), 1927.

Amorim, J.A., Sa, I.L.R., Rojas, M.V.R., Santos Neto, N.F., Galardo, A.K.R., Carvalho, D.P., Ribeiro, K.A.N. and Sallum, M.A.M., 2022. Aquatic Macrophytes Hosting Immature Mansonia (Mansonia) Blanchard, 1901 (Diptera, Culicidae) in Porto Velho, Rondonia State, Brazil. Journal of Medical Entomology, 59(2), pp.631-637.

Bornette, G., & Puijalon, S., 2011. Response of aquatic plants to abiotic factors: a review. Aquatic sciences, 73, 1-14.

Chang, N.-B., Lu, J.-W., Chui, T.F.M., & Hartshorn, N., (2018). Global policy analysis of low impact development for stormwater management in urban regions. Land Use Pol. 70, 368–383.

Cho, H.J., D. Spence, (Eds.) 2015. Plants of Retentions Ponds and Drainage Ditches: the Greater Daytona Beach area. Bethune-Cookman University. Daytona Beach, FL. 194 pp. https://bugwoodcloud.org/CDN/fleppc/AquaticPlantsOfTheGreaterDaytonaBeachAreaREDUCED.pdf

Federal Interagency Stream Restoration Working Group, 1998, Stream corridor restoration: Principles, processes, and practices: GPO Item No. 0120-A; SuDocs No. A 57.6/2:EN 3/PT.653. ISBN-0-934213-59-3, 648 p.

LeFevre, G. H., Paus, K. H., Natarajan, P., Gulliver, J. S., Novak, P. J., & Hozalski, R. M., 2015. Review of Dissolved Pollutants in Urban Storm Water and Their Removal and Fate in Bioretention Cells. Journal of Environmental Engineering, 141(1), 1.

Lounibos, L.P. and Linley, J.R., 1987. A quantitative analysis of underwater oviposition by the mosquito Mansonia titillans. Physiological entomology, 12(4), pp.435-443.

Rojas-Araya, D., Mathias, D. and Burkett-Cadena, N., 2021. A Mosquito Mansonia titillans (Walker)(Insecta: Diptera: Culicidae: Culicinae: Mansoniini): EENY-765/IN1314, 10/2020. EDIS, 2021(2), pp.6-6.

Gil, L.H.S., Mello, C.F., Silva, J.D.S., Oliveira, J.D.S., Freitas Silva, S.O., Rodríguez-Planes, L., Da Costa, F.M. and Alencar, J., 2021. Evaluation of Mansonia spp. Infestation on Aquatic Plants in Lentic and Lotic Environments of the Madeira River Basin in Porto Velho, Rondônia, Brazil. Journal of the American Mosquito Control Association, 37(3), pp.143-151.

Wang, L., Lyons, J., Kanehi, P., Bannerman, R., & Emmons, E. 2000. Watershed urbanization and changes in fish communities in southeastern Wisconsin streams. Journal of the American Water Resources Association, 36(5), 1173–1189.

Why does everyone ask about lake

muck?

By Dr. Jason Ferrell

Whenever you talk about aquatic plant management, regardless of where you are in the country, you always get a few of the same questions and concerns from stakeholders. One of the most common, whether you are in Florida, Connecticut, or somewhere in between, "Doesn't spraying aquatic plants just send toxic muck to the bottom of the lake"? This is a great question. So, let's try to answer this in parts.

What is muck?

"Muck" is a catch-all term that refers to all the dead organic matter that settles to a lake bottom. This organic matter is a collection of decaying plants, fish, algae, or any other critters that have settled to the bottom. Said another way, muck is natural. It is an unavoidable part of lake aging and, in and of itself, it is not bad. Honestly, a little muck, in the right places, is actually a very good thing since it helps support a wide variety of insect larvae, worms, snails, and other species that are critical to a healthy-lake food chain.

So, why do people think muck is bad?

Unfortunately, like most parts of life, too much of a good thing can become a bad thing. When muck buildup becomes excessive, it essentially begins to rot on the lake bottom. As bacteria start to consume this organic matter, they also consume all the oxygen. With the oxygen gone, the helpful critters that once lived in the muck must leave. Moreover, the lack of oxygen means the organic matter starts to ferment and this process causes methane and hydrogen sulfide (sewer gas) to form, which further creates an environment that is unhealthy for fish, plants, and other desirable lake creatures.

What causes muck levels to go from good to bad?

A healthy lake is a diverse lake. It has a wide variety of native plants, fish of various types and sizes, and a well-established food chain to support all these organisms' needs. In this scenario, the diversity of life helps keep everything in check. No one species dominates and the lake system becomes well-balanced.

However, things can become unbalanced when invasive plants are introduced. These plants, with few natural predators to check their growth, will often grow very rapidly and attempt to overwhelm the lake. They then drop tons (literally tons!) of leaves into the water as part of their growth and development process. The leaf drop starts building muck on the lake bottom and decreasing oxygen. Furthermore, these overgrown plants block sunlight that is required by native submersed plants and algae, both of which release oxygen as part of photosynthesis. As native plants and algae decline, oxygen in the water decreases further, while the invasive plants are growing at full speed and continue to drop leaves. This process quickly leads to excessive muck and conditions that nobody wants on their lake.

How can we prevent excessive muck development?

One of the best ways to promote a lake with a healthy level of organic matter is to keep invasive plants at a manageable level. By preventing the overgrowth of invasive plants, organic matter deposition is reduced, the water remains open and well-oxygenated, and critters that live in and consume the organic matter remain active. This restores the balance of the lake and creates a diverse system that supports a wide variety of plant and animal life.

Doesn't spraying herbicide for plant management create more, and possibly toxic, muck?

It stands to reason that spraying invasive plants, and killing them in one fell swoop, would simply accelerate the muck problem. But there are a couple of things to consider before discounting herbicides altogether.

1. Invasive plants are dropping leaves every day. If that plant is sprayed, 100% of the plant will drop to the bottom. However, water hyacinth has been documented to drop 60% of its leaves every month. If that plant is allowed to persist for five months, it can theoretically drop 300%, or three plants worth of biomass, over that time period. So

MUCK AND INVASIVE PLANTS

WHAT IS MUCK?

- Muck is a brown to black substance created by decaying organic materials, like leaves and algae
- Muck naturally occurs at the bottom of water bodies like lakes, ponds, and other depressions
- A small amount of muck is normal in an aquatic ecosystem

THE PROBLEM

- Muck levels are all about balance, and too much muck is often tied to poor water quality and increased algae blooms
- Invasive plants can create an anaerobic environment and decrease sunlight under the water's surface, leading to a challenging environment for native plants and animals

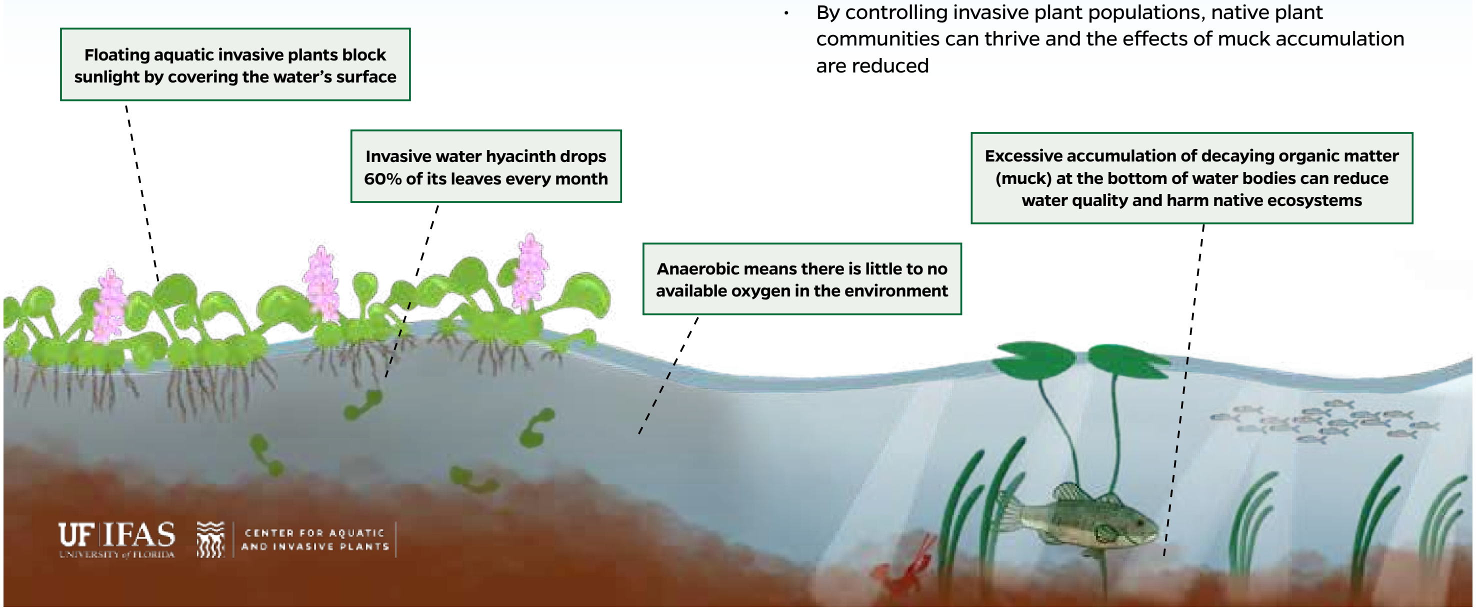
INVASIVE PLANTS AND MUCK

- Invasive plants grow rapidly, leaving little time for organic material to decay, resulting in muck accumulation
- Floating aquatic plants, in particular, create an abundance of muck

THE SOLUTION

PROACTIVE MANAGEMENT

- Proactive management of invasive plants is an approach that involves continuous, routine monitoring and management to maintain invasive or nuisance plant populations at low levels
- By controlling invasive plant populations, native plant communities can thrive and the effects of muck accumulation are reduced



timely spraying, and stopping future leaf development/drop, reduces overall muck biomass.

2. Waiting to manage "until there is a problem" will create more muck. Allowing invasive plants to proliferate to crisis levels before action is taken means there will be a significant amount of organic matter dropping at one time and this is negative for a number of reasons. However, proactively managing to keep the invasive plant populations low, prevents mass decay of organic matter while keeping the water open and well-oxygenated.
3. Herbicides do not create "toxic" muck. All herbicides are required to **pass hundreds of tests** before the EPA will approve them for use. One of these tests ensures that the herbicide breaks down and dissipates in aquatic environments. After the herbicide is sprayed, sunlight and/or microbes in the water will cause that herbicide to break down and become inactive in the environment very soon after application.

Conclusion

Muck is natural and necessary for a healthy lake, but too much muck shifts the lake to an unhealthy balance of low oxygen and stressful conditions for aquatic wildlife. Therefore, it is important to manage these lakes to prevent plant overgrowth and excessive biomass production/loss. The best way to do this is by proactively managing invasive plants and encouraging a wide diversity of native aquatic species. Doing this will provide a proper balance in the lake that benefits not only our aquatic friends, but our human friends as well.

Learn More About Florida's Lakes

To learn more about Florida's lakes, check out our podcast, "Working In The Weeds," where we talk about all things aquatic and invasive plants. In our "Florida Lakes and Landscapes" episode, we discuss how Florida lakes are created, what makes a lake "healthy," and what makes Florida's environment prone to invasive species.

Subscribe to our **podcast** for more episodes on all things invasive and aquatic plants.

*This article was originally written for the UF/IFAS Blogs Community on July 14, 2023 by **Dr. Jason Ferrell**, UF/IFAS CAIP director and professor. Questions or comments can be sent to the UF/IFAS CAIP communications manager at caip@ifas.ufl.edu. Follow UF/IFAS CAIP on Instagram, Facebook, and Twitter. UF/IFAS Center for Aquatic and Invasive Plants. Turning Science Into Solutions.*

Research Updates from the Prince Lab

Dr. Candice Prince,

University of Florida, Center for Aquatic and Invasive Plants

There are many exciting research projects happening at the University of Florida's Center for Aquatic and Invasive Plants (CAIP). Dr. Candice Prince has been a faculty member at CAIP for four years and is diving into all aspects of aquatic plant management research. Here are snapshots of two current research projects with her lab:

Figure 1. Hydrilla (*Hydrilla verticillata*) tubers are underground reproductive structures. They can remain dormant in the sediment for up to four years, allowing hydrilla to recolonize following management activities. Photo credit: Shelby Thomas, UF/IFAS Center for Aquatic and Invasive Plants.

Native Plant Restoration Following Hydrilla Removal

Hydrilla (*Hydrilla verticillata*) tubers (Figure 1) may remain viable in the sediment for over four years (Langeland 1996, Van and Steward 1990), making eradication of this submersed aquatic plant difficult. Chemical control efforts can effectively reduce hydrilla's population, but often result in empty space that is vulnerable to reinvasion from tubers and stem fragments. In addition, submersed aquatic vegetation (SAV) species have the ability to improve water clarity through competition for nutrients with phytoplankton, while also mitigating the effects of wind and wave action that might otherwise disrupt the bottom sediments (Gu and Hoyer 2005).

Invasive plant management efforts often rely on passive restoration, where native species are allowed to recover naturally following the removal of the invader (Ruwanza et al. 2013). However, active restoration (i.e., planting seeds and/or vegetative propagules) may be necessary in situations where the invasive species has been present for a long period of time or has altered the ecosystem past a particular threshold (Holmes et al. 2008, Ruwanza et al. 2013). Active revegetation of native SAV species may help to maintain ecosystem services such as fish habitat and sediment stabilization. In addition, having diverse native plant communities may allow ecosystems to resist further invasions (Beaury et al. 2020).

The Prince lab at the University of Florida's Center for Aquatic and Invasive Plants seeks to address these issues with ongoing research. We are collaborating with Dr. Ben Sperry and Mike Durham (CAIP and US Army Corps of Engineers), as well as UF seed biologist Dr. Hector Perez, to understand how key native species such as Illinois pondweed (*Potamogeton illinoensis*) (Figure 2) grow, reproduce, and can be used in restoration projects. We are also working to understand if native plantings can outcompete hydrilla tubers following chemical control. We hope that this research will improve long-term management success for hydrilla in Florida.

Figure 2. An Illinois pondweed (*Potamogeton illinoensis*) inflorescence emerging from a mesocosm at the UF/IFAS Center for Aquatic and Invasive Plants, where a research team is investigating its phenology, seed production, and germination characteristics.

Cuban Bulrush Reproduction

Cuban bulrush (*Oxycaryum cubense*, or sometimes referred to as *Cyperus blepharoleptos*) is an aggressive invasive sedge that forms dense floating mats in Florida's waterbodies (Bryson et al. 2008) (Figure 3). It was introduced to the United States in the 1800's, possibly through ship ballast or migratory birds (GBIF Secretariat 2022,

Figure 3. A) A floating mat of Cuban bulrush at Cross Creek (Alachua County, FL). B) A section of a floating Cuban bulrush tussock, demonstrating the thickness of the sediment layer (~25.4 cm) and the length of the roots (~127 cm).

Watson and Madsen 2014). Cuban bulrush has been present in Florida since 1945 and has been vouchered in 30 counties (Wunderlin et al. 2023). It has spread from 8 to 278 waterbodies between 1982 and 2022 (Figure 4), suggesting that it may have been in a lag phase until relatively recently.

Tussocks of Cuban bulrush can block access to waterbodies, shade out native SAV species, and impact water quality (Alam et al. 1996, Mallison et al. 2001). Short-term control has been achieved in Florida using diquat, glyphosate, and 2,4-D (FWC 2021) but retreatment is required for regrowth. One obstacle to controlling Cuban bulrush has been the lack of information on its reproductive strategy. The species has an extensive stolon system and produces seeds, which have been observed germinating on top of other floating plant species (Bryson et al. 2008). However, the relative contribution of these reproductive methods to its recruitment is unknown.

We are collaborating with UF researchers Jackson Jablonski and Drs. Stephen Enloe, Greg MacDonald, and Hector Perez, as well as Dr. Benjamin Sperry with the US Army Corps of Engineers, to better understand Cuban bulrush's seed biology. This work will establish the viability and germination requirements for Cuban bulrush in Florida, which have not been well established. We are especially focused on potential seed dormancy, a property of some species that allows their seeds to remain ungerminated in the seedbank until environmental conditions are favorable. As with hydrilla tubers, seeds that can remain dormant for long periods of time pose significant management challenges. This research will provide information for biologists about the viability of Cuban bulrush seeds, how long they are able to remain dormant, and when they are most likely to germinate in Florida.

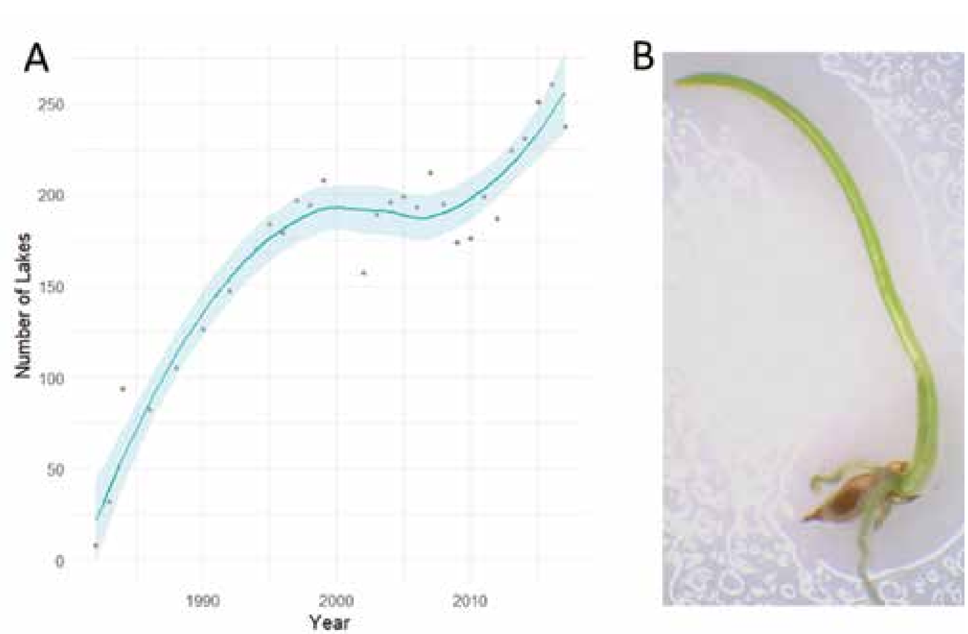


Figure 4. A) The number of waterbodies in which Cuban bulrush (Oxycaryum cubense) was detected by Florida Fish and Wildlife Conservation Commission (FWC) biologists from 1982 to 2022. Data were provided by FWC's Invasive Plant Management Section. B) A Cuban bulrush seedling that germinated during a dormancy experiment.

Acknowledgements

Collaborators in the research discussed here: Dr. Ben Sperry (US Army Corps of Engineers), Dr. Stephen Enloe (UF/IFAS Center for Aquatic and Invasive Plants), Michael Durham (US Army Corps of Engineers), Corrina Vuillequez (UF Center for Aquatic and Invasive Plants), Dr. Hector Perez (UF Environmental Horticulture Department, Dr. Greg MacDonald (UF Agronomy Department), and Jackson Jablonski (UF Agronomy Department)
Funding: Funding for the research discussed in this article is provided by the Florida Fish and Wildlife Conservation Commission (FWC) Invasive Plant Management Section

Literature Cited

Alam SK, Ager LA, Rosegger TM, Lange TR (1996) The effects of mechanical harvesting of floating plant tussock communities on water quality in Lake Istokpoga, Florida. Lake Reserv Manag 12:455–461

Beaury EM, Finn JT, Corbin JD, Barr V, Bradley BA (2020) Biotic resistance to invasion is ubiquitous across ecosystems of the United States. Ecol Lett 23:476–482

Bryson CT, Maddox VL, Carter R (2008) Spread of Cuban Club-Rush (*Oxycaryum cubense*) in the Southeastern United States. Invasive Plant Sci Manag 1:326–329

FWC (2021) Annual report of activities conducted under the Cooperative Aquatic Plant Control Program in Florida public waters for fiscal year

2019-2020. Page 29. Florida Fish and Wildlife Conservation Commission Invasive Plant Management Section

GBIF Secretariat (2022) Cyperus blepharoleptos Steud. https://doi.org/10.15468/39omei. Accessed February 28, 2023

Gu B, Hoyer MV (2005) Community Structure and Environmental Conditions in Florida Shallow Lakes Dominated by Submerged Aquatic Vegetation. Lake Reserv Manag 21:403–410

Holmes PM, Esler KJ, Richardson DM, Witkowski ETF (2008) Guidelines for improved management of riparian zones invaded by alien plants in South Africa. South Afr J Bot 74:538–552

Langeland KA (1996) Hydrilla verticillata (L.F.) Royle (*Hydrocharitaceae*), "The Perfect Aquatic Weed." Castanea 61:293–304

Mallison CT, Stocker RK, Cichra CE (2001) Physical and vegetative characteristics of floating islands. J Aquat Plant Manag 39:107–111

Ruwanza S, Gaertner M, Esler KJ, Richardson DM (2013) The effectiveness of active and passive restoration on recovery of indigenous vegetation in riparian zones in the Western Cape, South Africa: A preliminary assessment. South Afr J Bot 88:132–141

Van TK, Steward KK (1990) Longevity of monecious hydrilla propagules. J Aquat Plant Manag 28:74–76

Watson AF, Madsen JD (2014) The effect of herbicide and growth stage on Cuban club-rush (Oxycaryum cubense) control. J Aquat Plant Manage:4

Wunderlin R, Hansen B, Franck A, Essig F (2023) Atlas of Florida Plants. http://florida.plantatlas.usf.edu/. Accessed February 28, 2023

1899 - 2022
Where Are We Now? 123 Years of Progress and Repetition on Lake Okeechobee.

The *Aquatics article* written by Langeland in September of 1987 described the immense battle that Florida had taken since the introduction of water hyacinth (*Eichhornia crassipes*) in the 1880's. A battle where canals, lakes and other means of aquatic federal navigation were blocked by this green menace. Years ago, options for defense against invasive aquatic plants were much more limited. Harvesters were giant machines as large as the canal they were in, lifting and tossing the plants out of the waterways. Dangerous nonregulated chemicals were sprayed on the plants in hopes they would melt away. Large, indiscriminate "destroyer" boats ripped and tore through the foliage just to make a path for other boats. It took enormous effort and manpower to get these plants under control. This battle took place over 100 years ago, after the Rivers and Harbors act of 1899 was enacted. Although today our waterways may seem like we have won the war against this invasive plant, state and federal agencies continue to fight every day to keep our lakes, rivers and canals clear and navigable. Exactly how far has aquatic plant management come since then?

The goal in aquatic plant management has been the same since the initiation of Florida Statute Chapter 369.22: "maintain plant populations at the lowest feasible level." This goal is commonly referred to as "maintenance control". Over the past 123 years, managers have innovated in many ways to achieve the same goal; some resulting in success, and others not so much. Keeping plants at the lowest feasible level has many benefits, including the reduction of chemical usage, cost reduction for agency members and prevention of native plant communities from being overtaken by nonnatives. Despite these benefits, however, the same issue has been reoccurring time and time again: negative public perception. A common question that arises among members of the public is, "If the plants are not causing a problem, why manage them?" Bill Haller, now retired Director of the University of Florida Center for Aquatic and Invasive Plants, wrote in the 1981 Summer Aquatics article, "Influx of new residents, human forgetfulness and a current lack of hyacinth problems add up to 'why waste time on our lakes.'" A trend seems to have formed over the years that when there is a low level of plants to treat on Lake Okeechobee or an algae bloom appears, members of the public direct their attention to preventing all aquatic plant management. They blame the poor condition of the lake on the aquatic plant management, rather than seeking for answers rooted in science. In February 2019 this exact situation occurred. An algae bloom after hurricane Irma caused public pressure and this led to a three-month herbicide moratorium throughout the state. Water hyacinth quickly increased to record numbers throughout Lake Okeechobee. It has taken three years since the moratorium to get the plants on the lake back under maintenance control.

To return to maintenance control, a variety of "tools" in the plant management toolbox need to be used. The toolbox, in this context, is the concept of Integrated Pest Management (IPM). IPM is a pest management strategy that uses mechanical, biological, and cultural control methods in addition to chemical control to manage invasive species. In 1898, many agencies were using chemicals such as carbolic acid, sulfuric acid and even kerosene to burn the plants (Langeland, 1987). Today, the Environmental Protection Agency protects not only the environment but also its users from these negligent actions. Currently on Lake Okeechobee plant management agencies are only using a handful of aquatic herbicides. Some have been applied since the 1940s such as 2-4D, while others like PorcellaCOR and Penoxsulam have been added more recently. Systemic herbicides have allowed managers the ability to treat certain invasive species while also reducing non-target damage to native plants. Despite all of this, public perception of herbicides has remained the same.

In addition to chemical control,

mechanical control (harvesting) is another viable option for helping to control aquatic plants in certain scenarios. Harvesters have been around for decades, and these giant machines have not changed much over the years. Paddle wheels, conveyer belts, and shedders are all still being utilized today on Lake Okeechobee. These machines have great use in small canal systems and in areas where disposal is close by but continue to be a costly option for a larger lake system. Since the Langland article was written, WEEDOOs have been added to the IPM toolbox. These small shallow water harvesters allow managers to remove floating vegetation from small tight spaces like boat ramps and have helped in adjacent tributaries. Their small size, however, does have limitations when disposal is far from the treatment site. Other innovations such as a "juicing machine" that is attached to a barge, allows for the transportation of blended hyacinth and lettuce to be pumped out of the system to a location in need of nutrients such as a farmland. This process is successful but has proven to be extremely costly, and ineffective in a large shallow water system like Lake Okeechobee.

The most cost-efficient option for controlling aquatic plants is biological control. Biological control, or biocontrol, is the planned use of one organism (i.e., an insect) to control or suppress the growth of another organism, like a weedy plant species. For water hyacinth, biocontrol has been an important tool in the IPM toolbox. Since the Langeland 1987 article, USDA scientists approved and released the water hyacinth planthopper (*Megamalus scutellaris*) in Florida. This insect feeds on the sap of water hyacinth and females deposit eggs into the leaf tissue. Studies are still being completed to understand the impact this insect is causing on water hyacinth and its integrated potential with herbicides. Today, water hyacinth has five biocontrol species that have been approved and released to help control this nuisance plant including the native mite (*Orthogalumna terebrantis*), released water hyacinth moth (*Niphograpta albiguttalis*) and two weevils: (*Neochetina eichhorniae* and *N. bruchi*). Having these insects as a treatment option makes treating remote and hard to access areas much easier, because sites do not have to be accessed for treatment to continue once the insects are established. Biological control is often the most cost-effective option for plant management, but it is extremely difficult for scientists to find viable candidates for release.

Since the introduction of water hyacinth, managers from all over the state continue to battle this green beast in Florida waterways. Keeping the plants at the lowest feasible level remains the best and most affordable option for all lake and riverine systems. Over the years, innovations and continued research has added to the IPM toolbox to better manage these pests. However, as we have seen time and time again, public perception and forgetfulness overtake the rationale and researched processes. Managers must continue to strive for a more informed perspective among the general public to ensure the health and safety of our aquatic ecosystems in the years to come.

Invasive Plant Management, Who is Involved?

Amy L. Giannotti, MS, CLM

AquaSTEM Consulting

Managing invasive species is a multifaceted endeavor that requires a comprehensive scientific approach, a well-coordinated strategy, and involves various responsible entities. Regrettably, the general understanding of aquatic plant management in Florida is often skewed, as many individuals incorrectly believe the process merely involves attaching a chemical tank to a boat and haphazardly spraying chemicals. This article is intended to explain how the process works and what role different organizations, agencies, and levels of government play in the oversight for controlling invasive aquatic plants.

Aquatic plant management begins with a technical understanding of the biology and ecology of invasive vegetation. Scientific research helps identify the species' impact on native ecosystems, the potential pathways of introduction, and vulnerabilities in the plant's physiology that help determine which management efforts are most effective and economical. For example, knowing which metabolic pathway a herbicide targets is necessary for evaluating the potential control a herbicide has (or doesn't have) on a plant. Similarly, if the plant isn't palatable (tasty) to the fish or insects we hope will feed on it, then biocontrol options may not be effective. For aquatic plants that reproduce by fragmentation, mechanical harvesting may make the infestation worse as each time the plant is cut, new growth occurs from each stem's tip.

Once research is conducted, peer-review, and published, this information is disseminated to resource professionals who are tasked with formulating management plans. These conclusions are shared in scientific journals, white paper publications, and at professional conferences and symposia – many of which are open to the public. Management plans outline specific actions to control or eradicate the invasive plants and are built on a foundation of integrated plant management practices. Depending on the nature of the targeted species and the physiology and abundance of non-target species, control methods will utilize an integrated approach – where biocontrol, physical, mechanical, cultural, and chemical actions are implemented either in rotation or in combination.

Public engagement and education are vital components of invasive aquatic plant management. Educating communities and waterfront enthusiasts about the ecological and economic impact of invasive aquatic plants fosters awareness and cooperation for protecting the resource, its wildlife, water quality, and associated property values. Public support and involvement can aid in the early detection and reporting – both of which are crucial for preventing the spread of invasive aquatic vegetation. Obtaining reliable and credible scientific information holds significance, and such information is derived from research universities, government agencies, and reputable scientific consulting firms. While social media can be a great way to connect with others and share ideas, it's important to approach it with a critical mindset and not solely rely on it for disseminating accurate and complex information. Unfortunately, social media provides a platform for anonymous and unqualified users to spread mis and disinformation without scientific merit and credibility.

Invasive species management requires financial resources for research, program development and implementation, ongoing monitoring, and outreach. Budgeting and securing funding from various sources – like government agencies, grants, private organizations, etc. are essential for guaranteeing long-term management efforts.

Managing aquatic vegetation involves navigating a complex web of regulations and policies at different levels – local, regional, state, and federal. Regulations dictate which species are prohibited to possess or transport, which species can be controlled, control methods allowed, and reporting requirements. Complying with these regulations ensures a coordinated and legally sound approach to management that protects the resource over the long-term.

Aquatic plant management projects require careful planning, communication, and consultation with various stakeholders to ensure their success and minimize any negative impacts. Managing invasive aquatic vegetation is necessary for protecting native plant biodiversity, habitat for native fish and wildlife, water quality, flood control, navigation, recreation, sediment stabilization, and utilities. Here are some of the key layers of oversight involved in aquatic plant management in Florida waters:

Federal Oversight

The United States Environmental Protection Agency (EPA) is concerned with the regulatory compliance of pesticide use and mandates that all pesticides distributed or sold in the United States must be registered (licensed) by the EPA. Applicants intending to register a pesticide for distribution, sale, and use must do so under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), and show that the pesticide will not adversely affect the environment. This includes identifying risks to public health, economic, social, and environmental impacts as well as any dietary risks from pesticides that may end up in the food supply. The Office of Pesticide Programs (OPP) is the entity that regulates the manufacture and use of pesticides and determines risk assessments.

The United States Department of Agriculture (USDA) is responsible for scientific research, communicating how invasive species are officially defined, and helping to coordinate research and management efforts at the federal level. The USDA creates the Federal Noxious Weed Program which is designed to prevent the introduction and spread of non-native invasive plants in the United States.

Implementation of aquatic plant management activities in Florida falls to one federal agency – the United States Army Corps of Engineers (USACE). USACE manages floating invasive aquatic plants and tussocks in Federal Navigable Channels.

This includes Lake Okeechobee, the Okeechobee Waterway, and associated tributaries for Navigation and Flood Risk Management where designated vegetation is managed to protect navigation and water control structures. It also includes the management of the Federal Navigable Channel of the St. Johns River. In addition, USACE manages floating aquatic and submersed species for Comprehensive Everglades Restoration Projects. The management of the plants happens during the Construction Phase and the Operational, Testing and Monitoring Period (OTMP).

State of Florida

In the state of Florida, the Florida Department of Agriculture and Consumer Services (FDACS) has several important functions related to the management of aquatic plants. First, FDACS is the agency charged with registering pesticides before they can be used in the State of Florida. Primary considerations for registration include the proposed chemistry and how that relates to the unique environmental and climate conditions in Florida. Second, FDACS is also the state agency responsible for implementing laws, regulations, and management programs pertaining to the transport and possession of aquatic plants. And lastly, granting pesticide licenses to qualified herbicide applicators who fulfill the requirements and successfully complete a sequence of exams covering overall pesticide safety and proper application in various environments is another responsibility of FDACS. These environments include but are not limited to aquatics, natural areas, rights of way, turf, and ornamentals, and others.

The Florida Fish and Wildlife Conservation Commission (FWC) directs the research, planning, control, and regulation of aquatic plant management activities via their Invasive Plant Management Section. This includes permitting for aquatic plant control activities on waters larger than 160 acres with more than one waterfront owner (Chapter 68F-20), and/or on those waters with public access that meet the statutory criteria under Chapter 68F-54, Florida Administrative Code. Public waterbodies that meet legislative criteria are eligible for funding from the FWC for invasive plant management efforts. FWC's Regional Biologists conduct surveys and continuously monitor these waters and collaborate with designated partners – or cooperators – who implement the strategies outlined by the Biologists in accordance with habitat preservation, flood prevention, recreation, and stakeholder need.

The Florida Department of Environmental Protection (FDEP) regulates the removal or addition of sediment to any waterfront area. In most cases, the movement of sediment requires a Dredge and Fill Permit; however, there is an exemption for the removal of a limited amount of submerged sediment that is done in accordance with the removal of permitted aquatic plants.

Regional

FDEP is responsible for management of water resources at the state level, and as such, supervises the activities of the state's five water management districts at a regional level – some of which are involved in aquatic plant management. Water Management Districts (WMDs) provide aquatic plant control in designated wetland areas, canals, and flood control structures throughout the State to safeguard property and protect public safety.

FWC also permits Jurisdictional Water Control Districts to control invasive aquatic plants in areas vital for maintaining stormwater flow and reducing risk of flooding. These are primarily located in south Florida and are commonly referred to as Drainage Districts.

Local Municipalities – City and County

In some locations, the municipality (local or county governments) serve as the FWC cooperator for managing aquatic plants in public waterbodies. For these areas, the aquatic plant control activities are funded and permitted by the State and management efforts implemented by local governments. This means that a FWC Regional Biologist surveys, monitors, and oversees the planning and treatment protocols.

On private lakes that don't qualify for state funds, sometimes a local municipality will choose to manage nuisance vegetation….and sometimes not. This varies for each community throughout the state. Funding is usually what prevents the municipality from treating invasive aquatic plants as management efforts can quickly become cost-prohibiting. In some cases, though, funds collected from a stormwater utility, or from a Municipal Service Taxing Unit (MSTU), or from a Municipal Service Benefit Unit (MSBU) help the city or county government to implement aquatic plant control activities.

Stormwater utility fees are typically generated based upon the amount of impervious surface a property has and its subsequent impact on surrounding surface waters. These funds are then used to collect, convey, and manage stormwater runoff, and to support the infrastructure associated with these technologies. Because increased nutrient pollution accelerates aquatic plant growth, the stormwater utility fee in some municipalities is used to cover the costs of aquatic plant management.

Municipalities can also create MSTUs and MSBUs to offset the costs of controlling invasive aquatic plants. These special assessments are created by the municipality, billed directly to property owners within a specific geographic area, and are used for designated purposes.

Additionally, local governments may also have permitting programs in place to regulate the removal and management of waterfront vegetation. These regulations vary by location, and it is always best to check with the municipality or check the Florida Municode library to see if a local ordinance exists for shoreline activities. In cases where there is overlapping jurisdiction between a city/county and FWC, the rule that is most stringent applies.

Waterfront Property Owners

Residential and commercial lakefront properties who own the waterfront can manage aquatic plants in accordance with local, regional, and state regulations that apply. Sometimes this involves permitting from multiple entities and, in some cases, projects are exempt from permitting entirely.

In Summary

This is a broad outline of the roles and responsibilities governing aquatic plant management efforts in Florida. It's always best to consult your local municipality as well as an FWC Regional Biologist, and/or a professional lake management consultant prior to beginning an aquatic plant control or restoration project. This ensures that work is compliant with regulations and that water quality, wildlife, and native habitats are preserved.

Amy L. Giannotti, MS, CLM (amy@aquastemconsulting.com) is an environmental scientist and certified lake manager with over 25 years of experience in freshwater and marine vegetation management. Her background includes extensive work in both state and local governments in Florida, focusing on aquatic plant and lake management efforts. Amy now owns her own consulting firm, and her clients range from municipalities and homeowners' associations (HOAs) to waterfront residents and professional scientific organizations. She holds a Bachelor of Science degree in biology from Marietta College and earned her Master of Science degree in environmental sciences and marine ecology from the University of Virginia.

Calendar of Events

October 9-11, 2023
South Carolina Aquatic Plant Management Society Annual Conference
Ocean Drive Beach and Golf Resort
North Myrtle Beach, SC
http://scapms.org/meetings.html

October 16-19, 2023
47th Annual Florida Aquatic Plant Management Society Annual Training Conference
Hilton St. Petersburg Bayfront
St. Petersburg, FL
https://fapms.org/conference/2023-conference/

October 24-26, 2023
42nd MidSouth Aquatic Plant Management Society Conference
LaGrange, GA
https://msapms.org/conference/

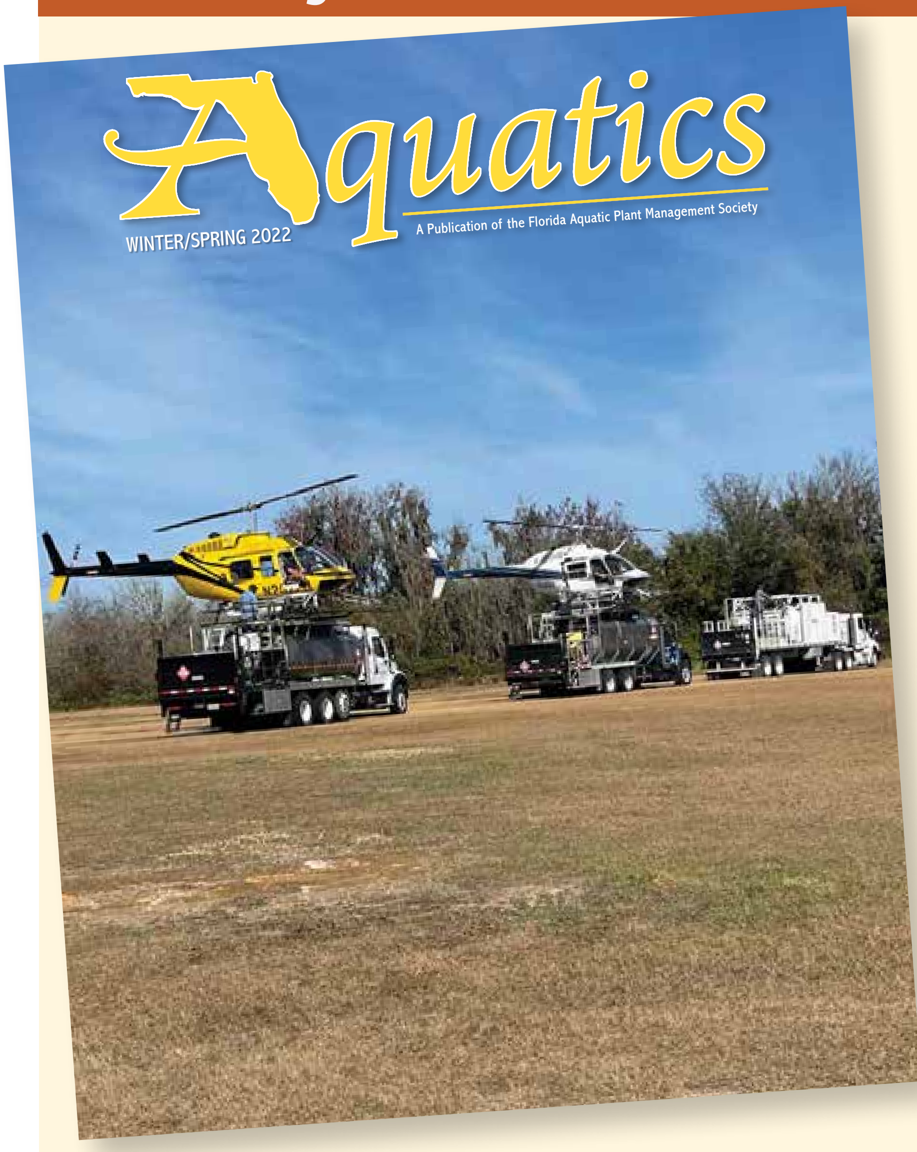
November 13-17, 2023
International Aquatic Plants Group
Antwerp, Belgium
www.internationalaquaticplantsgroup.com

November 15-17, 2023
Texas Aquatic Plant Management Society Annual Conference
Mesquite Convention Center
Mesquite, TX
https://www.tapms.org

February 26-29, 2024
44th Annual Midwest Aquatic Plant Management Society Conference
Hyatt Regency Downtown
Columbus, OH
https://www.mapms.org/conferences/2024-conference/

March 18-22, 2024
Western Aquatic Plant Management Society Annual Conference
Las Vegas, NV
https://wapms.org

It Pays to Advertise



- Aquatics is circulated to approximately 2000 environmental managers, landscape managers, governmental resource managers, and commercial applicators.
- Aquatics is a resource for the people who buy and use aquatic products and services.
- Advertising in Aquatics magazine is a profitable investment compared to other magazines.
- Your advertisement not only provides the reader with pertinent information, but your support helps maintain the quality of this publication.

Aquatics Magazine
Advertising Point of Contact

Angie Huebner
Invasive Plant Management
701 San Marco Blvd, Jacksonville, FL, 32207-8175
863-990-7090
Angie.L.Huebner@usace.army.mil

PRESORT STANDARD
US POSTAGE
PAID
PERMIT #592
PONTIAC, IL