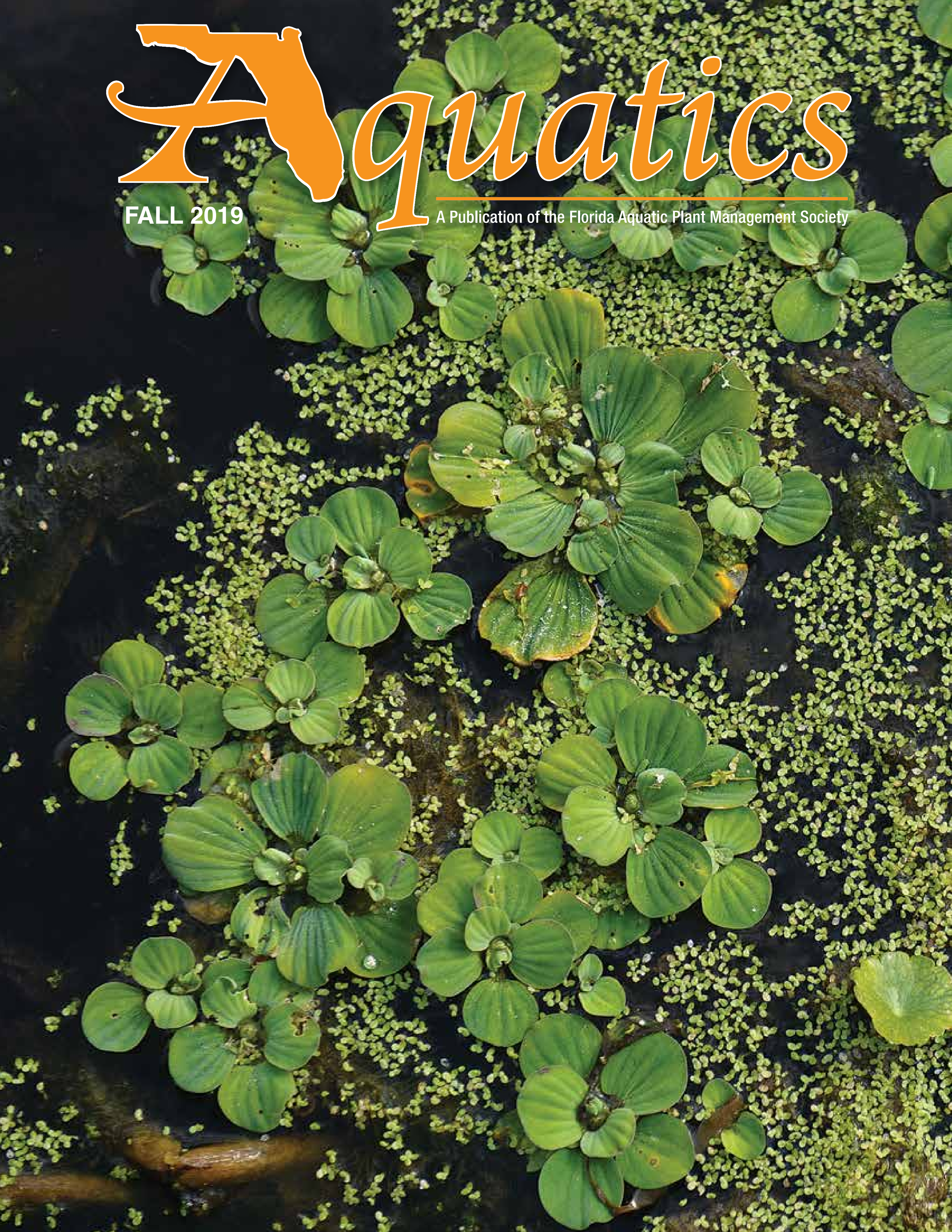
Aquatics

FALL 2019

A Publication of the Florida Aquatic Plant Management Society



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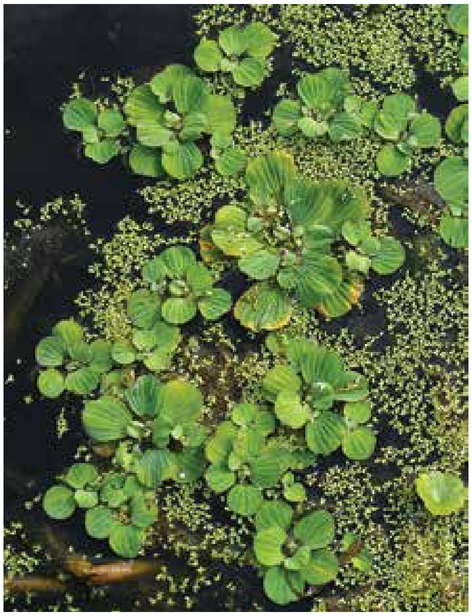

Water lettuce (Pistia stratiotes) plants hiding amongst a patch of duckweed (Lemna spp.) in the waters of Deleon Springs State Park. Water lettuce is one of the most prolific and rapidly reproducing plants in the world. Although its history is well-documented in Florida, it behaves much like an exotic species, quickly overtaking freshwater habitats, outcompeting native plants, and ultimately establishing a monoculture that shades out submersed species below and serves as a breeding ground for mosquitos. Photo by Amy Giannotti

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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.

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LETTER FROM 2019 FAPMS PRESIDENT

Dear FAPMS Members:

It has been my honor to serve as the FAPMS president for 2019. This year has certainly been an eventful one for the history books with the Florida Fish and Wildlife Conservation Commission (FWC) "Pause" in the aquatic plant management program and the challenges that came with social media interactions on this issue. It is said that challenging times often create opportunities for collaboration, and I certainly witnessed that among our aquatic plant community with respect to the statewide "pause". I would like to commend the FAPMS BOD, the Society, and the entire aquatic plant management industry for coming together to provide an honest and open level of communication, and to support the many years of research that illustrate the need to control invasive aquatic plants. The FAPMS BOD worked diligently to develop the first "Resolution Position Statement" regarding the FWC State Funded Program for Aquatic Plants". This resolution, accompanied by several scientific publications, was shared with the FWC Commissioners, the Water Management District Administrators, and our newly elected Governor DeSantis.

I'm also extremely proud to have been part of the inaugural Dr. Michael D. Netherland Exemplary Colleague Award. Dr. Netherland has left a legacy for our industry, and the committee did an incredible job working on developing this new award in remembrance of our colleague.

As members of FAPMS, we are professionals and strive to be leaders here in Florida and beyond. We are passionate about caring for our environment because we live on the water, fish on the lakes, hunt on the shorelines and play in the waves.

I'm humbled and proud to have served this last year and am grateful to the FAMPS members for your continued support.

"Individually, we are one drop. Together, we are an ocean." -Ryunosuke Satoro

Kelli Gladding
2019 FAPMS President

"As members of FAPMS… We are passionate about caring for our environment because we live on the water, fish on the lakes, hunt on the shorelines and play in the waves."

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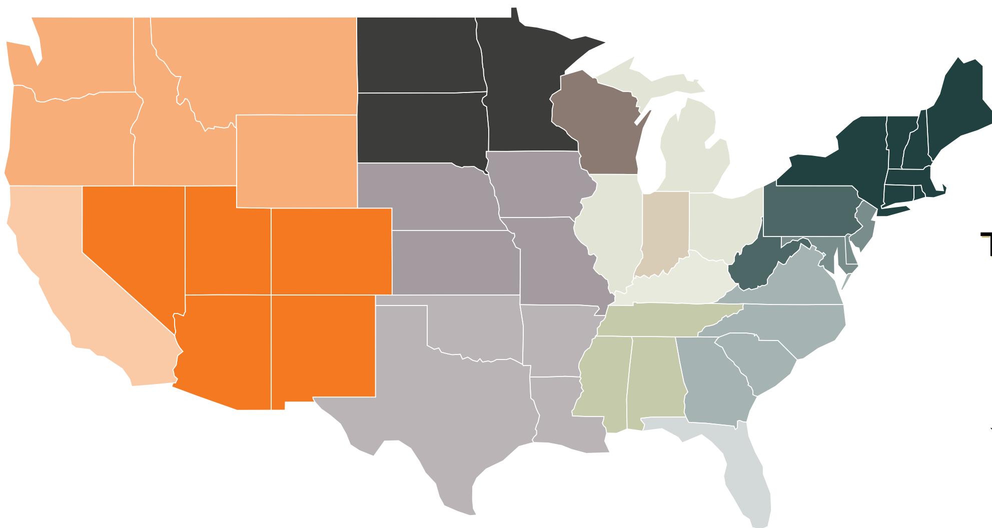

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APPLICATORS' CORNER

A short quiz on water hyacinth appeared in the spring 2019 issue and was followed by answers and some discussion on hyacinths in the summer issue (2019). This issue we will once again test your knowledge on another non-native invasive aquatic plant, the submersed hydrilla, now probably the most costly plant being controlled in aquatic habitats in this country since it is under eradication efforts in several states and is being battled in many other large lakes and reservoirs all over the country. Most aquatic weed managers in the southeast have experience with hydrilla and others around the country are likely to gain this experience in the future considering how fast hydrilla has and continues to spread since its introduction.

Hydrilla was first discovered in a canal near Miami, FL and in the spring fed Crystal River (Citrus County, FL) in about ________________(year?) and it's pretty certain to have been introduced into this country by the ______________________ industry. Its current global distribution includes ________ (number) of the 7 continents and it's believed to be native to _____________ (continent or large region). If you Google "USDA plant database" and search the common name "hydrilla" you will note that this weed now occurs in about _____________ (proportion, 10%? 70%?) of the states in the US.

Historically, native submersed plants growing in naturally nutrient rich and shallow Florida lakes occurred in 5 to 6 ft. of water or less and covered maybe 10 to 20% of the lake. However, when introduced into a lake, hydrilla found an open niche with no competition and grew in much deeper waters, often to water 10 to 12 ft. or greater in depth and often covering 80 to 90% of our shallow lakes. In a sentence, why can hydrilla do this? Hint: what is the most limiting factor to submersed weed growth in lakes?

Hydrilla in Florida (as far as is known) only reproduces by asexual or vegetative means since only the dioecious _________ (male or female?) plant has been found in the state. A second hydrilla introduction apparently occurred in the more

temperate areas of North America since the ____________________ northern hydrilla plant is characterized by sexual reproduction and produces viable seeds in addition to reproducing by vegetative means. Vegetative reproduction in both northern and southern hydrilla is similar since both can reproduce by fragmentation and growth can occur from a single node. They also both produce green-colored _______________

In the leaf axils which look like compact pine cones and white or brownish _____________________

at the ends of underground rhizomes. Northern hydrilla produces these latter two vegetative structures in mid-summer to fall under relatively __________ daylight conditions and hydrilla in Florida produces these in October to March/April or under what is termed __________ day conditions. Day length in combination with water temperatures clearly regulates production of these specialized reproductive structures which allows hydrilla to survive drought, herbicide treatments and other adverse conditions. These structures likely remain viable in or on the hydrosoil for up to (circle one): *a. 2 years, b. 5 years, c. 10 years*

The production of the reproductive structures at the ends of the underground rhizomes likely plays the greatest role in long-term survival. It is hard to conduct research on these structures, since they are usually in the bottom sediment to depths of 3 to 5 inches and at the same time are under 4, 6, 8, or even 12 feet of water. The moment they are collected and removed from the sediment (for example, for laboratory studies), all environmental conditions change and therefore our knowledge of these and what controls their sprouting, etc. is tenuous at best. Even getting good population estimates is difficult and usually conducted via a 4-inch diameter core sampler, BUT we know from drawdown studies that these structures are not randomly distributed. Regardless, research at the Ft. Lauderdale Research and Education Center by Dave Sutton showed that one plant growing under ideal conditions in a pan in shallow water could produce (circle one): *a. 100-500, b. 500-1,000, c. 1,000-5,000, d. >5,000 propagules per square meter in a single year.*

Stakeholders often mention in private and public setting that hydrilla is good for the lake and "cleans the water up". Hard to argue or dispute what one sees, but also sometimes what you see might not be factual. We have all noted this… if a lake has a low (10, 20, 30%) coverage of hydrilla or other submersed vegetation, Secchi disc readings or visibility into the water may be 12 to 18 inches and as the submersed plant coverage increases to 60, 70, or 80%, the water clears noticeably and is now "clean". Several factors contribute to this greater visibility when submersed plant populations are high. For example, surface-matted hydrilla reduces wave and wind action, causing less suspended____________________ in the water column; growth of algae and other organisms on the vegetation, called ______________, temporarily absorb and utilize nutrients; and maybe most important, the forever-moving lake water is under hydrilla mats 60, 70, or 80% of the time where the lack of _________________ prevents or greatly reduces the growth of phytoplankton. Thought question for next issue: where do hydrilla and other submersed plants obtain the nitrogen and phosphorus nutrients they require for plant growth? *a. the water column, b. the sediment, c. both sources*

If you can't wait until next issue for the answers to the above, most can be dug out of an excellent paper written and published in 1996 by Ken Langeland. Here is the full citation:

Langeland, K.A. 1996. *Hydrilla verticillata* (L.F.) Royle (Hydrocharitaceae), "The Perfect Aquatic Weed". *Castanea* 61(3):293-304. Available online at https://www.jstor.org/stable/4033682

Finally, the attached mystery photo (previous page) was taken by Dean Jones while working on a project in south Florida. What plant is this, what are the structures, and what month or months of the year was the photo taken?

Use of Alum to Improve Water Clarity And Plant Communities in Lakes

Coagulation and clarification of water using metal salts has been practiced since at least Roman times to reduce turbidity and improve the appearance of drinking water and surface water. The predominant chemical agent used in these processes has been aluminum sulfate [$Al_2(SO_4)_3$], commonly referred to as alum, which is made by dissolving aluminum ore in sulfuric acid. Powdered alum was used by the ancient Romans beginning around 2000 BC as a coagulant which was mixed with lime to make bitter water potable. The first scientific investigation into the use of alum for coagulation in the United States was conducted by Rutgers University in 1885. Today, alum is used in a multitude of everyday products such as antacids, deodorants, pickles, vaccines, and even in making baseballs.

In lakes, alum is typically used to reduce the amount of phosphorus in the water column and to bind with phosphorus in lake sediments. When alum is added to water, a fluffy white precipitate is formed which settles slowly through the water column and attracts particles, bacteria, algae, dissolved phosphorus, and metals. The precipitate ultimately settles onto the lake bottom, becoming part of the sediments, leaving a clear water column which is low in nutrients. Once the floc enters the sediments, it forms extremely stable bonds with phosphorus which permanently retains the phosphorus in the sediments, making it unavailable for release. The amount of floc produced and the effectiveness for improving water quality and phosphorus removal increase with increasing alum dose. The addition of alum to water consumes alkalinity and decreases pH, so laboratory jar tests are also used to evaluate potential changes following addition to the lake. An example of a typical jar test used to predict water quality changes at various alum doses is given in Figure 1. Alum treatment typically removes 85-95% of total phosphorus, 30-60% of total nitrogen, 95-99%

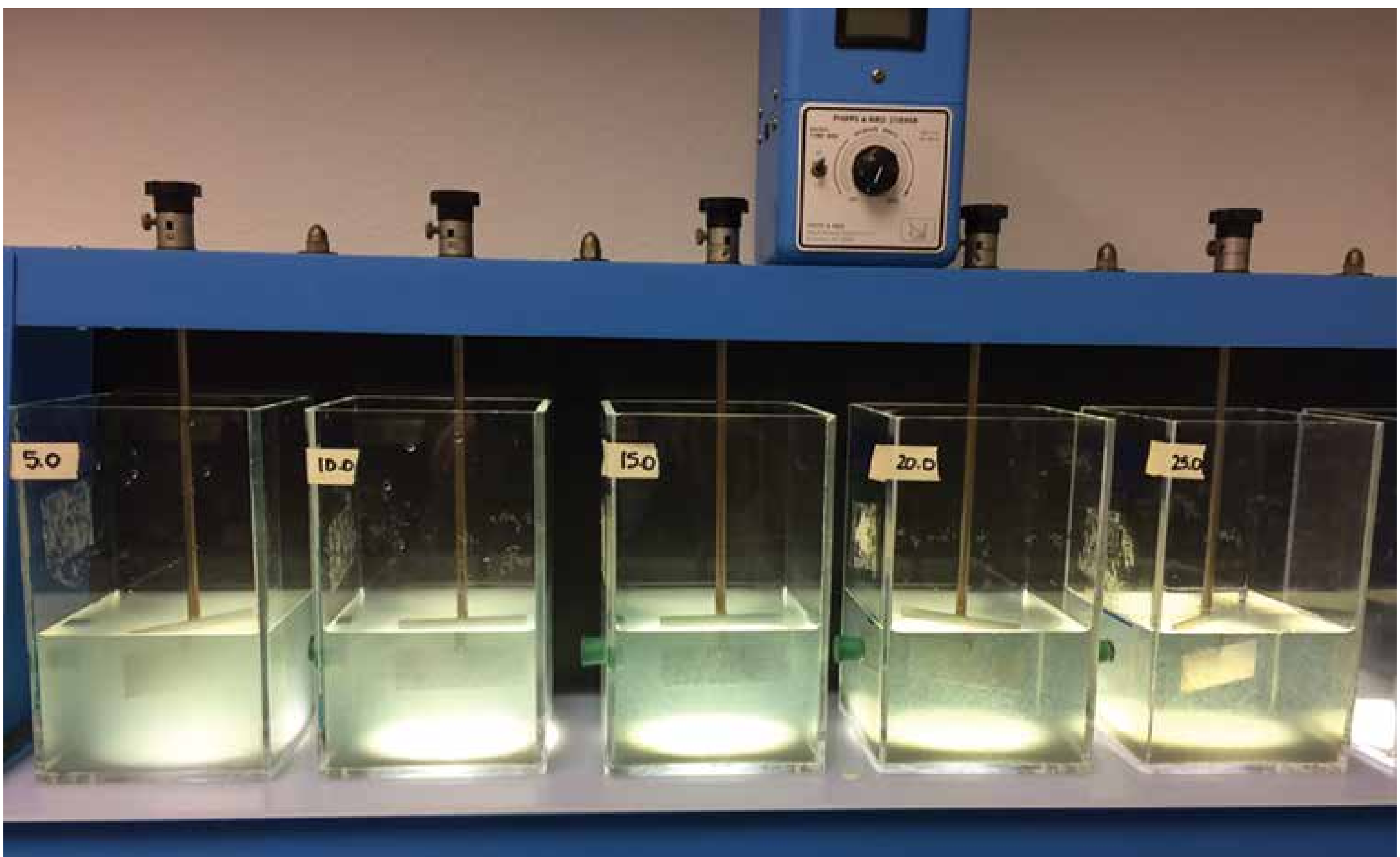


Figure 1. Typical Jar Test to Evaluate Alum Treatment.
(The clarity of the water increases with increasing alum dose. Alum floc is visible on the bottom of the containers.)

a. Application Equipment

b. Alum Mixing into Lake Water

c. Visible Floc in Water Column

d. Water Following Floc Settling

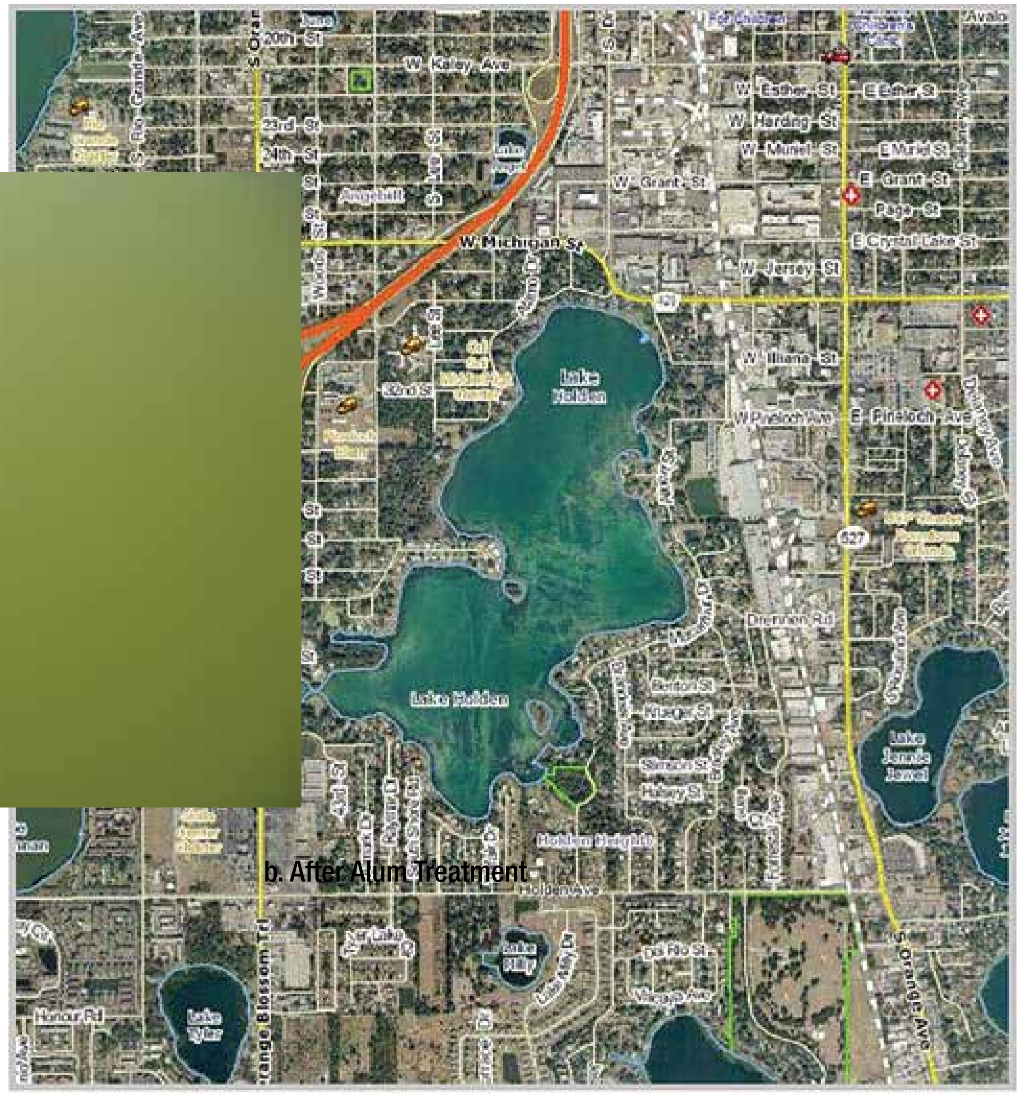
Figure 2. Photographs of a Typical Alum Application Process.

of bacteria, 70-95% of metals, and 85-98% of suspended solids.

After formation, alum floc undergoes an aging process, ultimately forming a crystalline mineral called gibbsite, and any material bound into the floc becomes inert under a wide range of environmental conditions, rendering the attached phosphorus no longer available as food for algae. Many studies have indicated that alum floc decreases the toxicity of lake sediments receiving urban runoff. The floc is non-toxic to benthic organisms, and multiple studies have indicated that alum addition to sediments improves the benthic community over a 3-year cycle -resulting in a new community type with a higher density and diversity that is dominated by clean-water indicator species.

Nutrient loadings to lakes originate from both external sources (e.g., runoff, groundwater seepage, precipitation) and internal sediment recycling. Many Florida lakes today are impacted by elevated nutrient loadings which cause excessive algal growth, harmful algal blooms, and under extreme conditions, fish kills and odors. The dense algal growth absorbs incoming solar radiation within upper portions of the water column, eliminating light that can reach submerged plant species. This causes changes in the physical and chemical characteristics of the water and also

a. Before Alum Treatment



b. After Alum Treatment

Figure 3. Photographs of Lake Holden Before and After Alum Addition.

impacts fish populations and food supplies. The continuous algal growth creates a constant deposition of organic matter to the sediments, and sediment accumulation increases and often becomes anoxic. Under anoxic conditions, phosphorus stored in the sediments can be recycled back into the water column, creating an internal loading source for phosphorus which in many cases exceeds external loadings and is often sufficient by itself to maintain eutrophic conditions in a lake even if the external loadings are eliminated.

Alum has been used in lake management to both inactivate release of phosphorus from anoxic lake sediments and to remove phosphorus from external inflows (Harper, et.al, 1988) although sediment inactivation is more common. During a sediment inactivation treatment, alum is applied at the lake surface using a boat and barge according to the concentration of available sediment phosphorus throughout the lake, determined by collection and analysis of sediment core samples. The alum rapidly forms a precipitate which settles slowly through the water column absorbing particles, algae, bacteria, dissolved phosphorus, and metals before settling into the sediments. The alum application rate varies throughout the lake, depending on variability in available sediment phosphorus. Photographs of a typical alum treatment are provided in Figure 2.

In 1970, Jernelov was apparently the first to use alum to remove phosphorus from the water column of a lake in a whole-lake alum application conducted as part of a lake restoration project on Lake Langsjon in Sweden. The first U.S. lake to be treated with a whole-lake alum application was Horseshoe Lake in Wisconsin which received a surface application of 2.6 mg Al/liter in May 1970. Twelve years later, phosphorus concentrations were still below the pre-treatment level (Garrison and Knauer, 1984). To date, approximately 55 whole-lake alum applications have been conducted in Florida, with approximately 240 conducted world-wide. Water quality benefits of alum sediment inactivation projects have ranged from 5 to more than 20 years.

The most visible impact of an alum addition project is the immediate and long-lasting improvement in water clarity. As the water clears, light penetration increases, and photosynthetic activity can extend to deeper portions of the lake. Virtually every alum application has resulted in a dramatic increase in plant coverage and bio-volume for both submerged and emergent shoreline vegetation which initially begins in shallow areas and extends to deeper areas. A large variety of species have been observed colonizing alum treated lakes.

A good example of a Florida lake that exhibited improved water quality using alum is Lake Holden, a 252-acre lake located in Orange County, Florida. During the 1970s, Lake Holden was one of the most polluted lakes in Central Florida, second only to Lake Apopka, with constant algal blooms, elevated phosphorus concentrations, extremely poor water clarity, and periodic fish kills. Lakefront homeowners invested in multiple remediation techniques, including aeration, with no improvement in water quality. During the 1990s, the homeowners funded construction of alum stormwater treatment systems for the 3 most significant stormsewer inflows which measure the rate of stormwater discharge and add alum into the stormwater on a flow-proportional basis during storm events. Alum floc is generated during travel through the stormsewer system, attracting particulate and dissolved pollutants, and the floc settles into the lake sediments. These stormwater treatment systems reduced in-lake phosphorus concentrations by approximately 50%, but the lake remained in a eutrophic state.

During 2005-2010, Lake Holden received multiple whole-lake treatments to reduce internal recycling of phosphorus. Water clarity in the lake improved with each successive alum treatment, and submerged vegetation began to colonize within the lake for the first time in over 30 years. By the time the alum applications were completed in 2010, Lake Holden had been converted from hyper-eutrophic to oligotrophic conditions, and much of the lake bottom had been colonized by a large variety and density of submerged vegetation. Photographs of Lake Holden water before and after the alum additions are given in Figure 3. The "after" photo is taken during 2016, and the lake bottom is visible over most of the lake. Large areas of submerged vegetation are also visible at virtually all depths. Maximum water depth in the lake is approximately 25-30 feet.

An Eco-Summary evaluation was conducted on Lake Holden by the FDEP Central District Office during 2012. Separate field visits were conducted to Lake Holden during January, May and October to evaluate water chemistry, field parameters, LVI (Lake Vegetation Index), LCI (Lake Condition Index), and benthic macroinvertebrates. Results of the study are summarized below with quotes from the report indicated in *italics*.

- ☐ The LVI score corresponded with a Category II "Healthy" designation. "*Lake Holden has a stable, healthy plant community, dominated by beneficial, submersed aquatic plants*"
- ☐ Substantial reductions were observed in the proportion of cyanobacteria present in the algal community. "*Phytoplankton data indicate stability and balance in the algal community with low potential for armful (sic.) algal blooms*"
- ☐ The LCI score was 59, corresponding to a "*very good*" designation.
- ☐ The encountered benthic species were indicators of good water quality. Mayflies and caddisflies were encountered – both are pollution sensitive "*Overall, the benthic community appears to be balanced and stable and has shown considerable improvement from past conditions.*"

Alum treatment is a rapid and efficient method of removing large amounts of phosphorus from a lake budget and reversing the eutrophication process. As phosphorus is removed from the lake, algal growth declines and water clarity improves which promotes growth of submerged vegetation, enhances habitat and fisheries, and converts the lake from an algae-dominated system to a macrophyte-dominated system. Alum surface treatments are substantially less expensive than stormwater management projects (Harper, 1995) and produce long term improvements in lake water quality.

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Dr. Harvey H. Harper (hharper@erd.org) is currently President of Environmental Research & Design, Inc. (www.erd.org) and a former faculty member in the Department of Civil and Environmental Engineering at the University of Central Florida. Dr. Harper has over 35 years of experience in water quality projects related to lakes and stormwater management and has conducted more than 50 sponsored research projects on the performance efficiencies of common and innovative BMPs. He originated the concept of chemical stormwater treatment in 1986 and has received multiple awards for his work in innovative stormwater treatment. He is a current Board member for the UCF Stormwater Academy, a former Director for the North American Lake Management Society, a former Director and Officer of the Florida Lake Management Society, and a current member of the Florida Stormwater Association.

CAIP Faculty Staff Updates

The University of Florida Institute of Food and Agricultural Sciences Center for Aquatic and Invasive Plants (UF/IFAS CAIP) welcomed two new faculty and two new staff members into the fold this summer, Dr. Benjamin P. Sperry, Dr. Candice Prince, Lara Colley and Shelby Oesterreicher.

Dr. Benjamin P. Sperry began at UF/IFAS CAIP in June of 2019 as an Assistant Research Scientist. He received his bachelor's and master's from the University of Florida in Plant Science and Agronomy – Weed Science, respectively. He then went on to earn his Ph.D. from Mississippi State University in Agronomic Weed Science in May of 2019. While his formal training is weed science in agricultural systems, Dr. Sperry has held several positions prior to graduate school related to terrestrial invasive plant management. He is an avid outdoorsman who became familiar with aquatic invasive plants and their associated problems at an early age. He is most excited about the opportunity to develop more effective aquatic plant management practices and strategies in order to positively impact both the unique ecosystem and people of Florida.

"My interest in agronomic weed science came from work experiences related to crop production where I observed weed control as often the most troublesome component to any production systems," Sperry said. "My interest in aquatic invasive plants stemmed from my childhood and hobbies."

Dr. Candice Prince was recently hired as an assistant professor with the Agronomy Department and the UF/IFAS CAIP in August 2019. She earned her bachelor's and Ph.D. from the University of Florida College of Agriculture and Life Sciences. She received her bachelor's degree in Plant Science in 2014 where she specialized in Restoration Horticulture. In 2019, she completed her Ph.D. in Horticultural Sciences with a concentration in Environmental Horticulture. Prior to graduating, Dr. Prince worked with UF/IFAS CAIP as a graduate student. Her research interests place an emphasis on understanding the ecology and physiology of an invasive species and using that information to create more targeted management plans.

Dr. Prince is conducting research for UF/IFAS CAIP as well as teaching courses in the Agronomy Department within the UF/IFAS College of Agricultural and Life Sciences. Her hope is to use emerging technologies and innovation to actively engage students and teach them how dynamic the scientific field can be.

"I feel that I can make a difference by investigating the science behind plant invasions, and then using that knowledge to develop practical solutions for land managers," Dr. Prince said.

Lara Colley was recently hired as the education coordinator for the UF/IFAS Florida Invasive Plant Education Initiative (UF/IFAS IPEI) at the UF/IFAS CAIP in February of 2019. She earned a bachelor's degree in natural resource conservation and master's in forestry and environmental education from the University of Florida College of Agricultural and Life Sciences.

She helps develop, evaluate and implement education outreach materials and programs for UF/IFAS IPEI. Her passion is to encourage individuals to adopt conservation behaviors and positive attitudes about nature. She has environmental experience with her previous positions as a park ranger, nature interpreter and small business owner.

"I love learning and teaching others about nature, as I have always been inspired by the natural world. Having a career that gives me the opportunity to help instill folks with a sense of environmental stewardship is, quite frankly, a dream," Lara said.

Shelby Oesterreicher was recently hired as the communications manager for the UF/IFAS CAIP in June 2019. Shelby received her bachelor's and master's from the University of Florida College of Agricultural and Life Sciences in Agricultural Education and Communication with a specialization in communication and leadership development. She has since served as a communications coordinator for the Florida Farm Bureau Federation and a public information specialist for the Florida Department of Agriculture and Consumer Services Division of Plant Industry. Shelby manages communication for UF/IFAS CAIP by creating video, design and print media and content regarding research, events and education conducted by the Center.

"I am enjoying the opportunity to use translational communications in order to inform our stakeholders about the science happening at UF/IFAS CAIP and affiliated organizations," Shelby said.

The University of Florida Institute of Food and Agricultural Sciences Center for Aquatic and Invasive Plants strives to inform and educate all stakeholders about the impacts and management of invasive plants. To learn more about UF/IFAS CAIP visit https://plants.ifas.ufl.edu or follow @UFIFASCAIP on Facebook, Instagram and Twitter.

Cyanobacterial Blooms in Florida's Fresh Waters

Forrest W. Lefler[1], David E. Berthold[1], Maximiliano Barbosa[1], H. Dail Laughinghouse IV[1]

What is an algal bloom? An algal bloom occurs when there is an increase in the concentration of cells within the water column. These blooms are typically visible with the naked eye as either a greenish scum or a sheet of green slime covering the surface of the water. Blooms are not only found on the water's surface, they can also occur within the water column or on the lake bottom, known as the benthos. Freshwater cyanobacterial blooms (cyanoHABs) occur widespread and are frequent in lakes worldwide. Harmful algal blooms (HABs) aren't limited to cyanobacteria, nor are they bound by fresh waters. For example, HABs can also occur in marine environments, and in Florida, the red tide caused by the dinoflagellate Karenia brevis, is of major concern. CyanoHABs are not new phenomena either, as there are records of blooms occurring back to at least the 12th century, as well as documented livestock deaths attributed to these blooms beginning in the 19th century. Algal blooms can be harmful and a nuisance. Nuisance blooms are typically referred as those that do not produce toxins, posing little harm to human health, but may still cause damage to the ecosystem. The blooms that produce toxins are known as harmful algal blooms and are a threat to both public and environmental health. Depending on the toxin produced, accumulation may occur in the water, sediments, and potentially bioaccumulate in the food web. Blooms can be triggered by many factors, but the main sources are eutrophication of waters, increasing temperatures, stratified waters, and light intensity. Eutrophication is an increase in nutrient load in the water column typically in the form of nitrogen, phosphorus, and organic matter. Sources of eutrophication are many times from human activity, such as fertilizer application, livestock waste, sewage, and septic discharge. Freshwater systems are typically phosphorus limited, and thus an influx of phosphorus provides the nutrients needed for rapid algal growth. With combined eutrophication and sunny, hot summers, Florida offers a perfect breeding ground for cyanoHABs.

Figure 1 Field image of cyanobacterial bloom occuring in Lake Okeechobee during Summer 2018.

Cyanobacteria (blue-green algae) are ancient photosynthetic microrganisms that evolved around 3.5 billion years ago. These organisms are some of the most crucial on the planet, as they form the base of the food chain and generate oxygen. In addition, they are capable of producing many toxic secondary compounds (cyanotoxins) and taste and odor compounds, such as geosmin. There are hundreds of different classes of these compounds, and many can harm the nervous system, liver, and/or kidneys, as well as cause developmental issues in both animals, including humans, and plants. Cyanotoxins are produced by many species and can be found from low to high concentrations in the water. While acute toxicity is a serious concern and can be lethal, chronic exposure to cyanotoxins has been linked to tumor and cancer development. During cyanobacterial blooms, toxin concentrations can be produced at dangerous rates.

Besides toxin production, surface blooms can block light from entering the water column, depriving subsurface vegetation of the light needed to carry out photosynthesis, which can lead to a loss of submerged vegetation. Blooms can also deplete oxygen in the water, which can cause fish kills. Death of both the vegetation and fish have negative effects on the ecosystem long-term, and in the short-term, provide cyanobacteria with more nutrients due to decomposition and subsequent release of the organic matter and nutrients. Cyanobacteria aren't all bad, as not all species produce toxins or form blooms. You may be familiar with the dietary supplement Arthrospira, which is commercially sold as Spirulina, and cited as having many benefits to human health. Other cyanobacteria can be used for the production of biofuels or omega-3 dietary supplements.

However, there are some bad cyanobacteria here in our backyards. Florida is home to many toxin-producing taxa, such as Aphanizomenon, Dolichospermum, formally known as Anabaena, Microcystis, Planktothrix, and the invasive Raphidiopsis raciborskii, formally known as Cylindrospermopsis raciborskii. These species produce different toxins, including variants of microcystins and anatoxins, each with

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varying toxic effects. Currently, there are around 157 different described classes of cyanobacterial bioactive compounds, each with numerous variants. Here we will discuss three commonly occurring toxic bioactive compounds (cyanotoxins) in Florida's freshwaters: anatoxins, microcystins, and cylindrospermopsins. Anatoxins are mainly attributed to Aphanizomenon and Dolichospermum, and are a powerful neurotoxin with a quick onset that can cause tingling in hands and feet, or in more extreme cases, paralysis or death. Fortunately, this toxin is unstable and degrades quickly in the water due to exposure to light. With the invasion of Raphidiopsis raciborskii, there is a risk of exposure to cylindrospermopsins, which are hepatotoxic, affecting the liver and kidneys and can lead to vomiting, blood in stool or urine, as well as dehydration; these effects can last up to one week. Cylindrospermopsins have not been documented as lethal to humans; however, livestock deaths have been attributed to this toxin. Cylindrospermopsins also degrade by sunlight, but can be present in the water for a few weeks when there is limited light exposure. The big 'bad guy' of cyanotoxins in our fresh waters are the microcystins, which are produced by common bloom-forming taxa, such as Dolichospermum and Planktothrix, as well as its namesake, Microcystis. Microcystins are the most frequent cyanotoxin found with 256 different variants, each with varying degreed of toxicity. They affect the liver and cause many ailments such as vomiting, liver damage, and in some cases death. They are linked to tumor formation in animals and developmental effects in plant tissues. One reason this toxin gets the most attention is due to its frequency and stability in the environment. While other cyanotoxins will degrade fairly quickly in the environment, microcystins can remain intact for several weeks.

What does this mean for us? These cyanoHABs can handicap our way of life and economy, and in the summers of 2016 and 2018, Florida experienced firsthand troubles with cyanoHABs enveloping Lake Okeechobee and its tributaries. Due to changes in climate and eutrophication, cyanoHABs are becoming more commonplace, and with more public awareness, there has been increased reporting from concerned and informed citizens. With an uptick in the frequency and/or intensity of toxic blooms, the risk of exposure to these toxins increases. This can be due to exposure of crops to toxins via contaminated irrigation waters, exposure to contaminated drinking water, and bioaccumulation in the food web. In the U.S., the Environmental Protection Agency (EPA) has guidelines for concentrations of microcystins and cylindrospermopsins in both drinking and recreational waters, and some U.S. states have additional guidelines for other cyanotoxins. The World Health Organization has also issued guidelines for cyanotoxin levels in drinking and recreational waters.

Figure 2 Microscopic image of *Microcystis aeruginosa* using black ink to visualize colony mucilage

Where do we go from here? Collaborative efforts are being made around the state to find ways to mitigate and treat these blooms, sequester nutrients, and remove these toxins from the environment. Earlier this year, the governor of Florida pledged $2.5 billion for Everglades restoration and water resources. This includes the creation of a Blue-Green Algae Task Force with the goal of reducing their impacts now and over the next five years, as well as an increase in efforts to reduce nutrient loads entering Lake Okeechobee. There is no short-term fix for this endeavor, but statewide efforts are being made to preserve our waterways.

Table 1 Features of select cyanotoxins common to Florida

Toxin	Produced by	Variants	Target Organ	Health Effects
Anatoxins	*Anabaena, Aphanizomenon, Dolichospermum, Raphidiopsis, Planktothrix, Oscillatoria*	6+	Neurotoxin	Numbness in extremities, dizziness, paralysis, death
Microcystins	*Microcystis, Planktothrix, Nostoc*	256	Hepatotoxin	Nausea, vomiting, diarrhea, death
Cylindrospermopsins	*Raphidiopsis, Aphanizomenon*	3	Hepatotoxin	Nausea, vomiting, diarrhea, blood in urine or stool, dehydration,
Saxitoxins	*Anabaena, Aphanizomenon, Planktothrix, Raphidiopsis, Lyngbya, Scytonema*	50+	Neurotoxin	Numbness around mouth, difficulty breathing, paralysis, death

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Empirical analyses of water quality, long-term fish, and aquatic plant population data in relation to aquatic plant management actions

Final Report, June 2019

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Introduction:

Florida LAKEWATCH is a citizen volunteer lake monitoring program that facilitates "hands-on" citizen participation in the management of Florida lakes, rivers, and coastal sites through monthly monitoring activities (Hoyer *et al.* 2014). LAKEWATCH staff keep records of all the questions that volunteers ask during individual years allowing LAKEWATCH to direct research and extension activities toward current issues of concern. Throughout the years, aquatic plant management and ecology continue to be major areas of interest, accounting for almost 40% of all questions during the last five years. The use of herbicides and their impacts to fish and wildlife are a continual concern. Thus, LAKEWATCH put this proposal together to determine if long-term data were available to address some of these stakeholder concerns.

Recently, voices from many additional lake users around Florida showed concerns about the current state of aquatic plant management activities directed by the Florida Fish and Wildlife Conservation Commission (FWC). Based on these concerns, beginning January 28th, FWC paused all aquatic plant herbicide treatment while they held public meetings and collected comments on the aquatic plant management program.

The first five public meetings were held at the following times and locations:

- ☐ February 6 – Kissimmee: County Commission Chambers, fourth-floor Osceola County Administration Building, 1 Courthouse Square, Kissimmee, FL
- ☐ February 7 – Okeechobee: Okeechobee County Civic Center, 1750 U.S. Highway 98 N. Okeechobee, FL
- ☐ February 13 – Sebring: Bert J. Harris, Jr. Agriculture-Civic Center, 4509 George Blvd, Sebring, FL.
- ☐ February 19 at the Alachua County Library Headquarters, 401 E. University Ave., Gainesville, FL.
- ☐ Feb. 26 – Eustis: Eustis Community Center, 601 Northshore Dr., Eustis, FL.

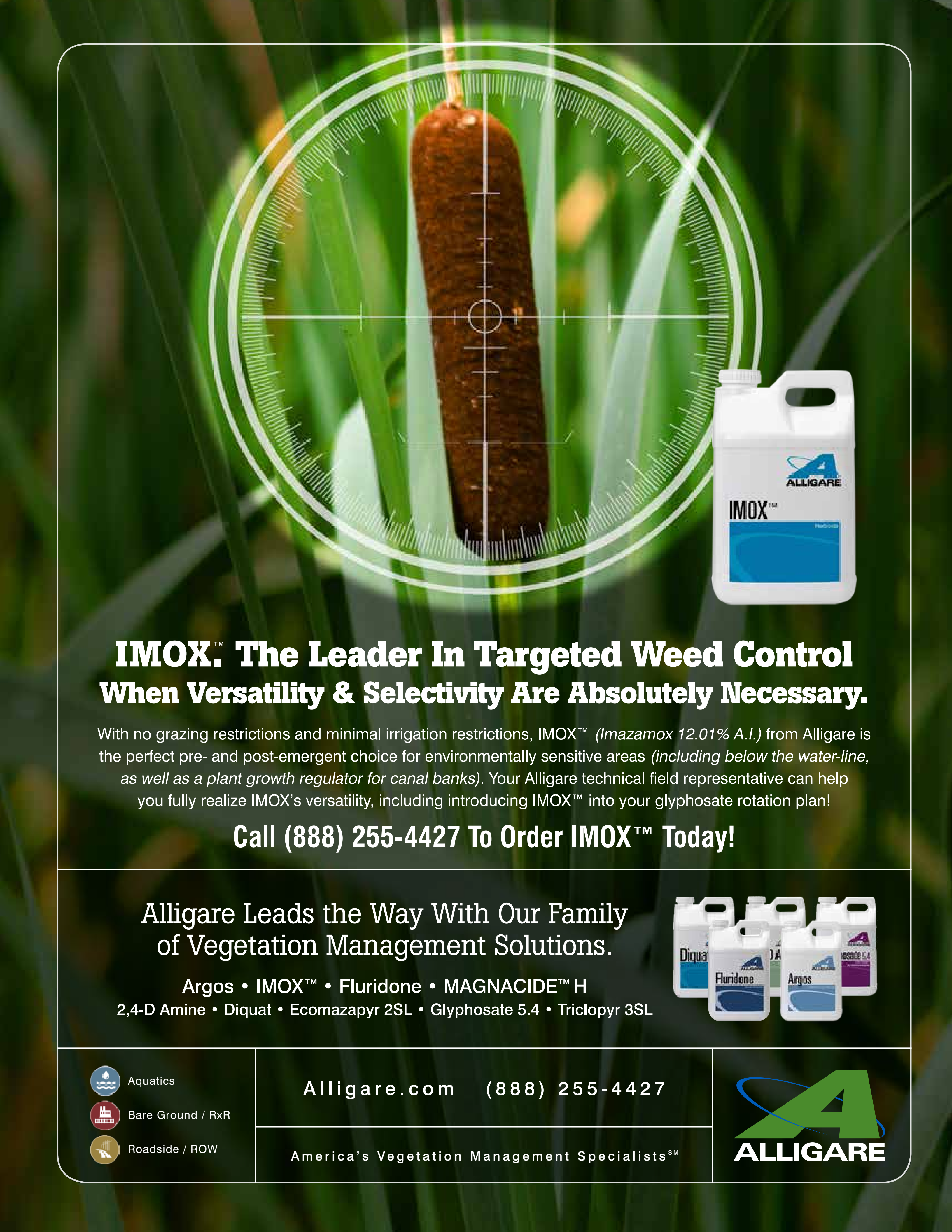
These meetings provided the public with an opportunity to voice concerns about plant management activities on Florida water bodies during the past 12 months. The following is an early summary of the concerns voiced at the public meetings and presented to FWC Commissioners at their annual Commissioners meeting:

- ☐ Dissatisfaction with the condition of lakes:
  - Poor water quality
  - Unhappy with plant management
  - Declining fishing, hunting, and bird watching
- ☐ Contractor oversite, accountability, management
- ☐ Preference for mechanical harvesting versus chemical control
- ☐ Human and ecological safety of herbicides
- ☐ Coordination lacking with other agencies

Based on these preliminary public inputs, FWC Commissioners directed staff to move forward with some of the following changes to the Aquatic Plant Management Program:

- ☐ Expanding the creation of habitat management plans for individual lakes.
- ☐ Forming a Technical Assistance Group consisting of staff, partners, and stakeholders.
- ☐ Improving timing of herbicide-based invasive aquatic plant removal treatments.
- ☐ Increasing coordination with manual invasive aquatic plant harvesting companies.
- ☐ Exploring new methods and technologies to oversee invasive plant herbicide application contractors.
- ☐ Developing pilot projects to explore better integrated plant management tools.

Florida is fortunate to have many long-term data sets that can be used to examine aquatic plant management activities. In 1982, the Florida Department of Natural resources started monitoring aquatic plants, focusing on exotics (hydrilla and floating plants). The responsibility for monitoring and managing aquatic plants was then shifted to Florida Department of Environmental Protection, and finally the responsibility rests with FWC. Throughout all these political changes, the surveys of aquatic plants continued, yielding over three decades of aquatic plant data for Florida's public waters (FWC 2017a). Florida LAKEWATCH was initiated in 1986 yielding over three decades of water quality data on many of the same lakes surveyed for aquatic plants (Hoyer *et al.* 2014). In 1999, Florida LAKEWATCH in cooperation with FWC started a long-term fish monitoring program (Hoyer *et al.* 2011), that was eventually standardized by FWC in 2006 yielding consistent data on over 30 public lakes for the last decade (FWC 2017b). Over the last decade FDEP and FWC also maintained records on all herbicide activity in public waters (location,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target species, amount and type of herbicide, date of application), which are also available (https://public.myfwc.com/HSC/PMARS/LoginForm.aspx).

Much of these data are common to many Florida lakes, thus the major goal of this research effort is to collate these databases into one common database and empirically examine impacts of aquatic plant management activities on water quality, fish population metrics, and aquatic plant metrics among multiple lakes. The primary objectives of this research are to:

To collate available long-term data sets on fish, aquatic plants, water quality, and aquatic plant management activities for empirical analyses.

- Examine collated data for limnological patterns among water quality, fish, and aquatic plant population metrics to describe background relationships and variability.
- Identify subsets of the collated data to test for differences in water quality, fish, and aquatic plant population metrics based on different aquatic plant management strategies.

Monitoring Databases

Invasive Plant Management (IPM) Annual Aquatic Plant Survey:

In 1982 the Aquatic Plant Management Section of the Department of Natural Resources began surveying the lake surface area covered with highly invasive exotic aquatic plants on many public waters. The surface area of these invasive plants was estimated every year, however all plants species were surveyed only every other year. These surveys have continued through multiple agencies and continue today with FWC's Invasive Plant Management section (IPM). Currently, FWC's IPM Biological Administrator publishes a list of survey species for the Regional Biologists to record prior to each survey season. This list serves as the Presence/Absence for species on each waterbody that year. Of those plant species, the biologists record the acreage only for the highly invasive exotic plant species (e.g., *Eichhornia crassipes, Pistia stratiotes*, and *Hydrilla verticillata*) on the survey. The database includes the following parameters:

- Waterbody Name
- Waterbody Acres
- Waterbody Type
- County
- Water Management District
- Survey Year
- Survey Date
- Surveyor
- Species Acres
- Species Name
- Origin (Native, Exotic)
- Habitat (Submersed, Emersed, Floating)

For this project we have obtained the IPM Annual Aquatic Plant Survey raw survey data from 1982 to 2017. The database contains aquatic plants surveyed on 397 lakes from 53 Florida counties. The data include information on over 200 species of aquatic plants. The data are not additive in that the sum of areas for each individual species may exceed 100% because species occurred in mixed habitats. Thus, the data cannot be used to determine a total lake's percent area covered (PAC) with aquatic plants. However, the data are excellent for following abundances of individual species through time, especially the major species of management concern.

IPM Herbicide Application Data:

Aquatic plant control efforts with herbicides have been occurring in Florida for many decades. It is unfortunate that good records of herbicide application were not systematically kept which would have allowed for solid analyses of efficacy as well as impacts to non-target flora and fauna. However, in 2010 FWC began keeping records of herbicide treatments that require permits from IPM.

During spring of each year, FWC IPM Biologists create their annual workplan. Individual biologists estimate the acreage of each plant that will need to be controlled that fiscal year. The workplan serves as an FWC issued permit for contractors and government cooperators that will carry out plant control for FWC. When unexpected work is needed throughout the year, the workplan is amended.

When applicators are performing plant control work, they record the following data:

- Date
- Waterbody
- Plant species controlled
- Crew members and hours worked
- Quantity of herbicide used
- Rate of application of herbicide
- Acreage controlled

Applicators give their data sheets to their administrators, who in turn enter it into FWC's Plant Management and Accounting Retrieval System (PMARS) database.

For this project we have now obtained this raw database, which has a seven year record of herbicide treatments in 419 "Areas of Interest" (lakes, rivers, canals, etc.) from 58 counties. Table 1 shows a list of all control methods applied to lakes sorted by the most frequently used methods over the last seven years.

Table 1. Florida frequency of herbicide treatments by control method recorded in the Plant Management and Accounting Retrieval System (PMARS) from 2010 through 2017.

Control Method	Frequency
Diquat	16864
2,4-D (liquid)	7249
Glyphosate	6335
Flumioxazin	5713
Aquathol K	2445
Mechanical Harvester	2439
Imazamox	1866
Aquathol Super K	1535
Penoxsulam (liquid)	1326
Imazapyr	1204
Carfentrazone	1107
Triclopyr	639
Copper Chelate (liquid)	194
Hydrothol 191	131
Fluridone (liquid)	107
Hydrothol (granular)	55
Fluridone (pellets)	41
Grass Carp	40
Mechanical Shredder	35
Topramezone	29
Bispyribac	23
Hand Removal	23
Mechanical (Other)	10
Penoxsulam (granular)	10
2,4-D (granular)	9
Endothall + Diquat	8
Triclopyr + 2,4-D (liquid)	7
Sethoxydim	4
ProcellaCOR	3
Triclopyr + 2,4-D (granular)	3
Peroxide (granular)	2
Snagging (tree removal)	2
Aquatic Dye (for shading)	1

FWC Long-Term Fish Data:

In 1999, Florida LAKEWATCH, in cooperation with FWC, started a long-term fish monitoring program (Hoyer *et al.* 2011) that was eventually standardized by FWC in 2006 (FWC 2017b), yielding consistent fisheries data on over 34 public lakes for the last decade. These long-term fisheries data include targeted spring time electrofishing data on largemouth bass (LMB), black crappie (BLCR) trawl data, and community sampling data including information on LMB, BLCR, exotic fishes, forage fishes, rough fishes, sunfishes, and game fish. For each sampling methodology FWC staff has calculated standard metrics of importance by year for analyses.

For this project we have now obtained this summarized database, which has a 10-year record of 28 lakes from 18 Florida counties Table 2.

Table 2. Long-Term fish data collected annually from 28 lake systems from 2007 to 2018

Water Body	County
Apopka	Orange
Blue Cypress	Indian River
Crescent	Putnam
Dorr	Lake
George	Volusia
Griffin	Lake
Harris	Lake
Istokpoga	Highlands
Johns	Orange
Kissimmee	Osceola
Lochloosa	Alachua
Minneola	Lake
Monroe	Volusia
Newnan	Alachua
Okeechobee	Palm Beach
Orange	Alachua
Panasoffkee	Sumter
Poinsett	Brevard
Rodman	Putnam
Santa Fe	Alachua
Talquin	Leon
Tarpon	Pinellas
Tohopekaliga	Osceola
Trafford	Collier
Big Henderson	Citrus
Washington	Brevard
Weir	Marion
Weohyakapka	Polk

The long-term fish monitoring program measures and records many metrics that can be used to evaluate the status of entire fish communities and/or individual fish species of concern. The following are groups of metrics that are included in the long-term fish monitoring program:

1) Proportional Stock Density (PSD) and Relative Stock Densities (RSD) metrics (Willis et al. 1993) that evaluate the largemouth bass size structure for each year based on spring electrofishing:

- PSD = #quality/#stock *100
- RSD-16 = #legal/#stock *100
- RSD-P = #preferable/#stock *100
- RSD-M = #memorable/#stock *100
- RSD-T = #trophy/#stock *100
- stock > = 200mm TL
- quality > = 300mm TL
- preferred > = 380mm TL
- memorable > = 510mm TL
- trophy > = 630mm TL
- legal size (16 in) > = 406mm TL

2) Metrics recording the annual spring average electrofishing Catch Per Unit Effort (fish/min) of largemouth bass for each size group and total catch rate. Size groups include:

- stock > = 200mm TL
- quality > = 300mm TL
- preferred > = 380mm TL
- memorable > = 510mm TL
- trophy > = 630mm TL
- legal size (16 in) > = 406mm TL

3) Metrics that lists the annual average relative weight (WR) and total length (TL) of largemouth bass in spring electrofishing samples.

4) Metrics that record the percent composition of different species and groups of species (by number and weight). Calculated species diversity and species richness values are also reported. Species lists and groups include:

- Sum of percent composition for groupings = 100.
- Group 1 = BLCR (black crappie), Catfish, Exotic (non-native species), Forage, LMB (largemouth bass), Other (primarily marine species), Rough, and Sunfishes
- Group 2 = Gamefish and Nongame
- 1/D = diversity metric; Simpson's Diversity Index
- R = number of species observed in samples
- Total number of species observed for all years is also listed (cum)

5) Metrics that record the annual average trawl catch rates (fish/min) of black crappie for each size group and total catch rate. The size groups include:

- stock > = 130mm TL
- quality > = 200mm TL
- preferred > = 250mm TL
- memorable > = 300mm TL
- trophy > = 380mm TL

6) Metrics that record information from interviews with anglers (creel census data) focusing on black crappie, largemouth bass and sunfish species. The data include:

- Effort (angler hr.)
- Success harvest (fish/angler hr.)
- Success catch (fish/angler hr.)

7) The FWC TrophyCatch Program provides another database that can be used to inform management decisions. TrophyCatch is an incentive-based conservation program designed for anglers who catch-and-release largemouth bass heavier than eight pounds in Florida. FWC's goals are:

- Collect valid information through citizen-science about trophy bass to help the FWC better enhance, conserve and promote trophy bass fishing
- Encourage catch-and-release of the biggest, oldest, most valuable bass
- Excite anglers about Florida freshwater fishing encouraging them to purchase licenses and fish more resulting in benefits to anglers, fishing-related businesses, local communities and the fisheries by having more support and funding for conservation
- Share information about fishing opportunities and destinations to make fishing more enjoyable

Anglers are encouraged to follow catch-and-release guidelines for these big bass and to document the catch through a photograph of the entire bass on a scale with the weight clearly legible (https://www.trophycatchflorida.com/). From 2012 to 2018, the TrophyCatch Program has collected data from approximately 900 systems from 62 Florida Counties.

Florida LAKEWATCH Data:

Florida LAKEWATCH, a volunteer water quality monitoring program, was initiated in 1986 yielding over three decades of water quality data (Hoyer *et al.* 2014). The following parameters have been monitored monthly on lakes in the database: total phosphorus, total nitrogen, chlorophyll, and water clarity. Because research has shown the importance of water color and specific conductance to lake limnology, and Florida Department of Environmental Protection (FDEP) has incorporated these two parameters in the EPA approved Numeric Nutrient Criteria, Florida LAKEWATCH has been measuring these additional parameters quarterly for the last decade.

For this project, Florida LAKEWATCH staff has calculated annual lake means of all water quality parameters for later data analyses. This includes data from 20 Coastal Dune Lakes, 405 Estuary Sites, 1731 Lakes and 414 River/Stream Sites (Table 3).

Table 3. Number of LAKEWATCH systems by Florida County sampled since August 1986.

County	Dune Lake	Estuary	Lake	River/Stream
Alachua			42	15
Bay	2	36	3	11
Bradford			10	
Brevard			14	
Broward			42	3
Calhoun				3
Charlotte		10	40	5
Citrus		3	27	61
Clay			30	6
Collier		26	9	1
Columbia			4	13
DeSoto			1	
Dixie			1	
Duval			8	3
Escambia		14	5	2
Flagler		1	36	
Franklin		16		3
Gadsden			4	
Gilchrist				3
Gulf		11	4	
Hamilton			5	
Hardee				8
Hernando			10	3
Highlands			69	10
Hillsborough		4	211	84
Holmes			2	3
Indian River			4	
Jackson			4	2
Jefferson			4	3
Lake			128	13
Lee		13	27	8
Leon			74	3
Levy		3	1	10
Liberty			1	
Marion			36	19
Martin			1	
Miami-Dade		9	38	
Monroe		107	3	
Nassau			1	
Okaloosa		61	10	15
Orange			192	6
Osceola			43	9
Palm Beach		12	23	4
Pasco			51	
Pinellas		12	45	3
Polk			125	3
Putnam			89	4
Santa Rosa		9	4	
Sarasota			13	4
Seminole			122	9
St John's			1	3
St Lucie			25	
Sumter			7	
Suwannee			3	
Taylor			2	
Union			2	
Volusia		11	49	10
Wakulla		4	4	22
Walton	18	43	16	27
Washington			6	
Total Systems	20	405	1731	414

Data Merging:

Electronic copies of all the above mention databases were obtained for this research project. A common lake identifier to each database was developed so they could all be merged for analyses. This was a difficult task because each data provider uses a different name or name spelling for identifying individual lakes. Florida County designations for individual lakes can be listed differently on lakes bordering more than one county. Also the same name can be used for many different lakes in different counties (Spring Lake, Blue Lake and others) requiring identification through latitude and longitude. In some cases lake names are even spelled differently within the same database over the historical record of that database. Once a common name was established for each database they were merged for Future analyses.

To facilitate the future merging of many aquatic resource monitoring databases available in Florida, LAKEWATCH is currently working with the United States Geological Service (USGS). The USGS supports a system called Geographic Names Information System (GNIS) that records a unique identification number to geographical entities including lakes (https://geonames.usgs.gov/).

The U.S. Board on Geographic Names is a Federal body created in 1890 and established in its present form by Public Law in 1947 to maintain uniform geographic name usage throughout the Federal Government. The Board comprises representatives of Federal agencies concerned with geographic information, population, ecology, and management of public lands. Sharing its responsibilities with the Secretary of the Interior, the Board promulgates official geographic feature names with locative attributes as well as principles, policies, and procedures governing the use of domestic names, foreign names, Antarctic names, and undersea feature names.

The original program of names standardization addressed the complex issues of domestic geographic feature names during the surge of exploration, mining, and settlement of western territories after the American Civil War. Inconsistencies and contradictions among many names, spellings, and applications became a serious problem to surveyors, map makers, and scientists who required uniform, non-conflicting geographic nomenclature. President Benjamin Harrison signed an Executive Order establishing the Board and giving it authority to resolve unsettled geographic names questions. Decisions of the Board were accepted as binding by all departments and agencies of the Federal Government.

The Board gradually expanded its interests to include foreign names and other areas of interest to the United States, a process that accelerated during World War II. In 1947, the Board was recreated by Congress in Public Law 80-242. The Bylaws of the Board have been in place since 1948 and have been revised when needed. The usefulness of standardizing (not regulating) geographic names has been proven time and again, and today more than 50 nations have some type of national names authority. The United Nations stated that "the best method to achieve international standardization is through strong programs of national standardization." Numerous nations established policies relevant to toponomy (the study of names) in their respective countries.

In this age of geographic information systems, the Internet, and homeland defense, geographic names data are even more important and more challenging. Applying the latest technology, the Board on Geographic Names continues its mission. It serves the Federal Government and the public as a central authority to which name problems, name inquiries, name changes, and new name proposals can be directed. In partnership with Federal, State, and local agencies, the Board provides a conduit through which uniform geographic name usage is applied and current names data are promulgated.

LAKEWATCH is working with the USGS to define GNIS identifiers for all lakes in the LAKEWATCH database (>1700) and is recommending that other monitoring entities add a column to their respective databases and use the GNIS identifiers that LAKEWATCH is developing. After this effort, if there is still no GNIS identifier an individual lake that an agency is monitoring there is a process that can be used to add it to the USGS list. To begin that process you can contact:

Jennifer Runyon, research staff
U.S. Board on Geographic Names
U.S. Geological Survey
12201 Sunrise Valley Dr., MS 523
Reston, VA 20192-0523
(703) 648-4550
jrunyon@usgs.gov
https://geonames.usgs.gov

Results and Discussion

Data available from the large number of systems, variables, and years in the databases presented above show that there are an unlimited number of correlations, comparisons and statistics that could be conducted. Also there are multiple additional databases available (e.g., Florida Climate Center Data: https://climatecenter.fsu.edu/) that could also be merged and used to address specific management questions and inform management actions.

As a proof-of-concept for this project, we will use data common to lakes sampled by FWC for the long-term fish monitoring program. We will use these merged data to address two major comments voiced by multiple stakeholders concerning the current management of aquatic plants with herbicides that lead to the statewide pause in herbicide spraying.

Glyphosate is a synthetic phosphonate herbicide and Cyanobacteria can use the phosphorus portion of the glyphosate molecule for growth thus causing harmful algal blooms.

Herbicides are toxic to fish and when used in lakes herbicides hurt largemouth bass populations.

Water Chemistry of the Long-Term Fish Monitoring Lakes:

The selection of the Long-Term Fish Monitoring lakes was based on the lakes being distributed throughout Florida, the individual lakes must be public and the lake must be a major angling resource. These selection parameters resulted in a group of lakes that are mostly productive with long-term chlorophyll values averaging in eutrophic or hypereutrophic ranges (Figure 1, Table 4). The basic water chemistry for the Long-Term Fish Monitoring Lakes has been monitored, in most cases, for over 15 years (Table 4 and Table 5). In addition to

Table 4. Florida LAKEWATCH water chemistry monitoring data (total phosphorus TP, total nitrogen TN, and chlorophyll CHL) for the Long-Term Fish Monitoring Lakes. The whole lake mean is recorded along with the minimum and maximum annual averages for each lake.

		TP (µg/L)			TN (µg/L)			CHL (µg/L)		
Water Body	Years	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Apopka	6	92	58	117	3906	3112	4722	69	45	112
Big Henderson	24	24	17	57	1050	733	1833	10	5	18
Blue Cypress	13	133	94	185	1351	1036	1609	7	4	11
Crescent	8	82	66	115	1475	1254	1814	34	16	63
Dorr	29	18	14	25	500	388	651	11	4	16
Floral City Pool	14	46	16	120	1132	734	1912	15	2	34
Griffin	27	62	40	97	2505	1540	4433	91	22	297
Harris	29	32	21	42	1660	1179	2172	48	15	85
Hernando Pool	18	17	7	33	947	517	1709	7	2	12
Istokpoga	23	63	44	77	1375	1035	1614	41	17	55
Johns	29	39	14	77	999	750	1406	13	3	29
Kissimmee	19	53	36	76	1323	998	1691	34	13	58
Lochloosa	24	68	37	117	2191	1299	5275	77	11	254
Minneola	20	21	6	42	861	417	1877	5	1	11
Monroe	15	79	57	140	1625	1205	1951	21	3	68
Newnan	22	144	66	298	3437	1863	11500	167	23	467
Orange	23	94	28	303	1978	1048	5483	52	14	282
Panasoffkee	28	35	12	72	903	499	1572	15	3	31
Poinsett	9	106	49	139	1950	1353	2620	19	12	29
Rodman	18	29	12	60	739	445	1025	8	3	16
Santa Fe	33	13	7	26	533	356	781	9	3	23
Talquin	17	57	47	71	858	527	1129	32	8	49
Tarpon	5	31	27	44	1016	805	1144	32	20	44
Tohopekaliga	22	47	32	67	1105	879	1344	27	17	43
Trafford	13	169	86	304	3004	2108	5563	67	38	135
Washington	4	124	74	214	1419	1288	1659	10	6	17
Weir	28	13	8	20	814	632	1090	13	9	19
Weohyakapka	26	29	17	45	846	520	1224	17	6	36

being productive the majority of the lakes can also be classified as colored (Pt-Co units > 40) and/or clear hardwater lakes (Pt-Co units < 40 and specific conductance > 100 µS/cm @ 25 C) (Table 5). These water chemistry characteristics can explain why the lakes selected for the Long-term Fish Monitoring Lakes have productive fisheries. Lakes with greater chlorophyll levels generally support larger food bases for lake systems and maintain larger fish populations than lakes with low chlorophyll levels (Jones and Hoyer 1982, Hoyer *et al.* 2011).

Glyphosate and Algal Blooms:

The molecular formula of glyphosate is $C_3H_8NO_5P$ and it has a total molecular weight of 169.073 g/mole (https://pubchem.ncbi.nlm.nih.gov/compound/glyphosate#section=Top). The molecular weight of phosphorus is 30.974 g/mole making phosphorus approximately 18 % of the total weight of Glyphosate (active ingredient). The Plant Management and Accounting Retrieval System (PMARS) database can be used to determine which lakes have been sprayed with glyphosate and how much is sprayed in a given year. Table 6 shows the average annual amount of glyphosate used to control aquatic plants in 21 lakes monitored in the long-term fish monitoring program. Multiplying the annual average glyphosate used within individual lakes by 18% shows that that amount of phosphorus incorporated in glyphosate applied to individual lakes ranged from 1.1 kg in Johns Lake to 5798 kg in Lake Okeechobee.

The surface area of these lakes can be obtained from IPM Annual Aquatic Plant Survey database and the mean depth of each lake can be obtained from the IPM BioBase database (Table 6). Surface areas ranged from 605 ha in Lake Trafford to 188,995 ha in Lake Okeechobee. Mean depth ranged from 1.0 m in Lake Panasoffkee to 4.6 m in Lake Talquin. Multiplying mean depth by surface area will determine the total volume of water in each lake. Dividing the total amount of phosphorus added with the treatments of glyphosate by the volume of water yields the potential phosphorus concentration of each lake assuming the glyphosate phosphorus added to the lakes was evenly mixed throughout the lakes. The LAKEWATCH program has the measured total phosphorus concentrations for these lakes that can then be compared with the estimated concentration of phosphorus added with glyphosate treatments.

In 18 of the 21 lakes, glyphosate phosphorus added to the water column was less than 1% of the concentration already in the water column. The phosphorus added to Lakes Istokpoga, Talquin and Tohopekaliga would add 1.2%, 1.2% and 2.5 % more phosphorus than was already in the lakes, respectively. These values are extremely low and if all the phosphorus incorporated into the glyphosate molecule were available for algal growth they would not be sufficient to cause a major Cyanobacteria bloom. Additionally, phosphorus in glyphosate is bound tightly and not readily available for algal growth until bacteria break it down. Glyphosate also binds quickly with any sediment particle again making it difficult to be used for algal growth (Hove-Jensen *et al.* 2014).

There is another nutrient issue to consider when aquatic macrophytes are treated (Xiong and Hoyer 2019). There are three mechanisms that can cause increases in nutrient concentrations of a lake when significant aquatic plants are treated (> 30% area covered with aquatic Plants; Canfield *et al.* 1984). First, nutrients within the plant and attached algae (periphyton) are released, making it available to open water algae. Additionally, when macrophytes are removed wave action increases, potentially increasing resuspension of nutrients to the water column. Without calm water, particles containing nutrients are not allowed to settle. The percentage of a lake treated with glyphosate can be calculated

Table 5. Florida LAKEWATCH water chemistry monitoring data (Secchi depth, color, specific conductance) for the Long-Term Fish Monitoring Lakes. The whole lake mean is recorded along with the minimum and maximum annual averages for each lake.

		Secchi (m)			Color (Pt-Co Units)			Conductance (µS/cm)		
Water Body	Years	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Apopka	6	0.9	0.6	1.4	27	24	31	410	380	468
Big Henderson	24	5.1	1.3	7.9	96	17	423	173	125	206
Blue Cypress	13	1.8	1.3	2.3	193	122	261	164	116	194
Crescent	8	1.9	1.2	2.4	125	44	290	720	429	925
Dorr	29	3.0	1.7	4.2	69	19	131	67	61	83
Floral City Pool	14	3.3	1.5	5.2	183	65	421	138	112	163
Griffin	27	1.9	0.8	3.2	102	31	267	259	169	313
Harris	29	2.3	1.3	4.5	26	10	134	254	220	283
Hernando Pool	18	5.5	2.6	7.7	76	19	188	133	110	155
Istokpoga	23	2.2	1.6	3.8	87	41	123	155	105	195
Johns	29	4.4	1.6	7.1	77	50	150	188	168	214
Kissimmee	19	2.7	1.9	4.4	79	29	132	169	143	192
Lochloosa	24	1.8	0.7	2.5	128	37	278	114	90	147
Minneola	20	5.3	1.9	10.3	108	6	329	130	79	202
Monroe	15	2.1	1.6	2.6	137	53	213	1151	539	1641
Newnan	22	1.1	0.7	2.0	141	40	307	93	70	135
Orange	23	2.4	1.3	4.1	137	35	292	99	67	125
Panasoffkee	28	3.6	2.2	4.5	45	17	80	259	221	327
Poinsett	9	1.9	1.1	3.5	154	110	200	694	292	1057
Rodman	18	5.9	2.8	13.8	69	11	132	347	238	420
Santa Fe	33	6.9	3.7	12.1	39	12	92	84	72	93
Talquin	17	2.7	2.3	3.2	44	18	65	70	51	90
Tarpon	5	3.2	2.0	4.4	38	13	56	518	488	555
Tohopekaliga	22	2.9	1.8	4.1	62	36	118	171	145	197
Trafford	13	1.3	0.8	1.6	51	32	77	294	239	370
Washington	4	2.0	1.4	2.5	181	104	275	347	278	443
Weir	28	5.6	3.6	8.0	8	5	12	205	169	244
Weohyakapka	26	3.8	2.0	7.2	46	28	81	110	85	138

Table 6. Data from multiple monitoring databases used to calculate the amount of phosphorus in glyphosate treatments added to lakes comparing it to the amount of phosphorus naturally in the water.

Lake	Years Treated	Annual Mean Glyphosate Used (kg)	Surface Area (ha)	Mean Area Treated (ha)	Mean Depth (m)	Herbicide TP Concentration (µg/L)	Lake Mean TP (µg/L)	Glyphosate Percent of Lake TP (%)
Apopka	9	119.9	12413	0.6	1.1	0.16	85	0.19
Blue Cypress	4	38.8	2653	8.5	2.3	0.12	152	0.08
Griffin	8	28.5	7034	5.8	1.7	0.04	52	0.08
Harris	7	3.7	5580	0.7	2.5	0.00	23	0.02
Istokpoga	9	624.1	11207	111.0	1.4	0.73	62	1.18
Johns	2	1.1	978	0.2	2.6	0.01	26	0.03
Kissimmee	9	745.1	14143	157.9	2.0	0.46	49	0.94
Lochloosa	5	11.6	2309	2.4	1.8	0.05	53	0.09
Newnan	3	6.0	3006	1.0	1.6	0.02	95	0.02
Okeechobee	9	5798.3	188995	1180.3	2.7	0.20	100	0.20
Orange	7	75.2	5142	15.3	1.7	0.15	122	0.13
Panasoffkee	3	13.6	1805	2.5	1.0	0.13	43	0.31
Poinsett	7	24.8	1754	4.5	1.1	0.23	120	0.19
Rodman	3	18.9	3885	3.2	2.4	0.04	27	0.13
Talquin	2	572.9	3582	101.7	4.6	0.63	54	1.16
Tarpon	9	35.6	1026	6.5	2.8	0.22	28	0.81
Tohopekaliga	7	733.5	7612	130.8	1.4	1.24	50	2.47
Trafford	5	20.8	605	3.2	1.9	0.33	139	0.24
Washington	9	64.4	1765	14.2	4.0	0.17	124	0.13
Weir	3	3.5	2301	0.6	3.9	0.01	16	0.04
Weohyakapka	9	34.4	3048	9.3	1.2	0.16	35	0.46

by dividing the area treated from the PMARS database by the lake surface areas data from the LAKEWATCH database. The percent lake areas treated with glyphosate ranged from 0.005 % in Lake Apopka to 2.8 % in Lake Talquin. These percentages are much too low (< 30% PAC) to cause whole lake nutrient increase that might contribute to significant algal blooms.

These empirical analyses using multiple merged databases suggest that glyphosate treatments are not responsible for creating significant algal blooms in lakes. Thus, the analyses do not support the following stakeholder statement: "Glyphosate is a synthetic phosphonate herbicide and Cyanobacteria can use the phosphorus portion of the glyphosate molecule for growth thus causing harmful algal blooms."

Herbicides and Largemouth Bass

To examine potential herbicides impacts to largemouth bass populations, the PMARS database was used to calculate the total amount of herbicide (all compounds) used annually in lakes that are part of FWC's Long-Term Fish Monitoring program. These lakes were then ranked into three even groups for later analyses; lakes with low, medium, and high herbicide usage (Figure 2). The lakes with low, medium, and high herbicide usages averaged annual herbicide applications of 26 gm/ha, 90 gm/ha and 2872 gm/ha and each group was significantly different from each other (Figure 2).

The lakes with low, medium, and high herbicide usage also had group average lake mean depths of 2.9 m, 2.6 m, and 1.8 m, respectively. The lakes with high herbicide usage had significantly shallower mean depths (analysis of variance, $p < 0.05$) than low and medium herbicide usage lakes. This suggest the shallow lakes would have more light reaching lakes substrate allowing for more aquatic plant growth (Caffery *et al.* 2007) and thus the need for more aquatic plant management (herbicide applications). Indeed, the IPM annual aquatic plant survey data showed that the percent of a lakes surface area covered with hydrilla was significantly higher in lakes with high herbicide usage (Figure 3).

Largemouth bass metrics estimated from data collected in the Long-Term Fish Monitoring program were compared among the three herbicide usage groups to empirically examine the statement that "Herbicides are toxic to fish and when used in lakes herbicides hurt largemouth bass populations." If herbicides are collectively harmful to fish and thus detrimental to largemouth bass populations then the groups of lakes with the high herbicide usage should have the lowest estimates of largemouth bass metrics measured.

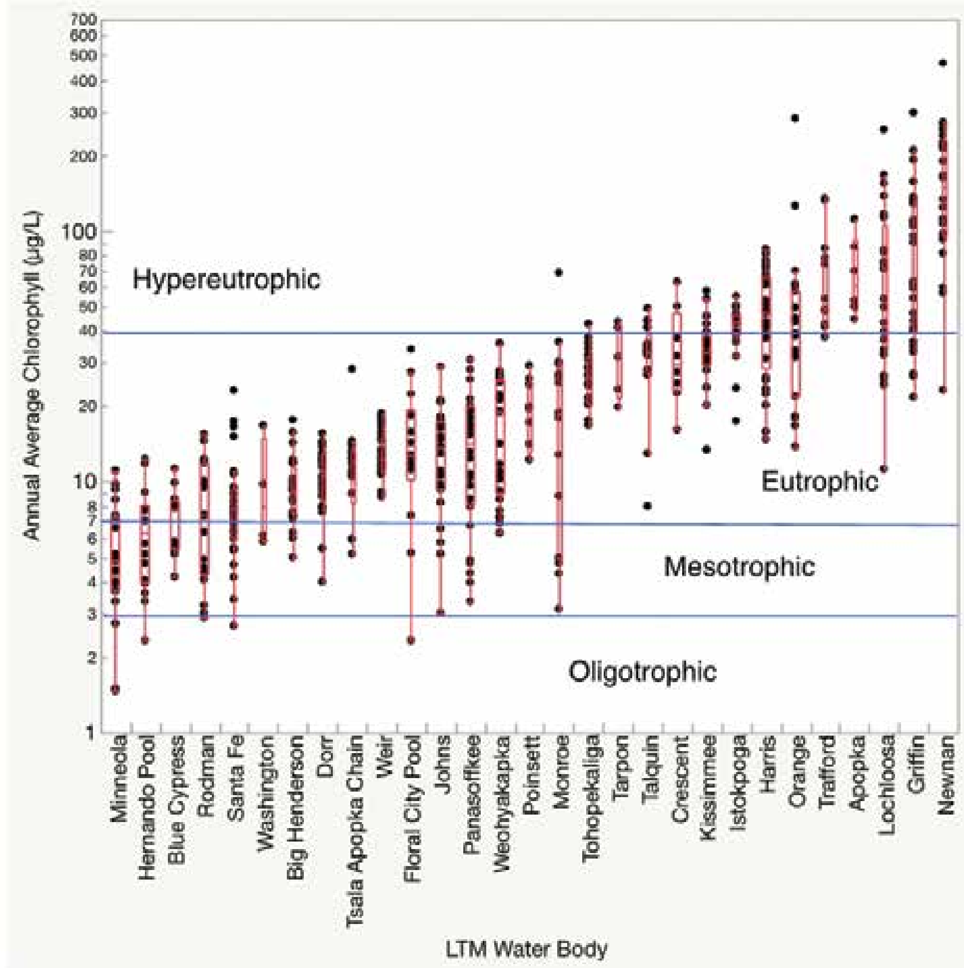

Figure 1. Quantile box plots for annual average chlorophyll concentrations. Each point is the value for an individual year, the box represents the 25th and 75th percentile using multiple years of data for individual lakes. Lake trophic state designations were based on the lake trophic classification system developed by Forsberg and Ryding (1980).

Spring electrofishing data collected during the Long-Term Fish Monitoring program yielded catch per unit effort (CPUE) data for substock largemouth bass (total length < 200mm). The substock fish can also be referred to as young-of-the year fish, having generally been produced less than one year ago. These young fish are generally more susceptible than adult fish to issues related to water chemistry such as low dissolved oxygen and thus probably any toxicity issues potentially related to herbicide treatments. Figure 4 shows that largemouth bass substock CPUE in low, medium, and high herbicide groups averaged 0.19 fish/min, 0.20 fish/min and 0.23 fish/min, respectively. An analysis of variance showed no significant differences among all herbicide groups.

Spring electrofishing data collected during the Long-Term Fish Monitoring program yielded catch per unit effort (CPUE) data for legally harvestable sized largemouth bass (total length < 406 mm). Figure 5 shows that legal largemouth bass CPUE in low, medium and high herbicide groups averaged 0.14 fish/min, 0.13 fish/min and 0.12 fish/min, respectively. An analysis of variance showed no significant differences among all herbicide groups.

Spring electrofishing data collected during the Long-Term Fish Monitoring program yielded catch per unit effort (CPUE) data for total largemouth bass (all sizes caught). Figure 6 shows that total largemouth bass CPUE in low, medium, and high herbicide groups averaged 0.94 fish/min, 0.73 fish/min and 0.98 fish/min, respectively. An analysis of variance showed that CPUE for the group of lakes with medium herbicide usage was significantly less than the mean CPUE of lakes with high herbicide usage.

Creel survey data is used by FWC to monitor the actual success rates (fish/angler hr.) anglers have while fishing on individual lakes. The largemouth bass creel estimated success rate for low, medium, and high herbicide usage lakes averaged 0.48 fish/angler hr., 0.72 fish/

angler hr., and 0.60 fish/angler hr., respectively (Figure 7). An analysis of variance showed no significant difference between average success rates in lakes with high herbicide usage and average success rates in groups with low or medium herbicide usage.

FWC's Trophy Catch program is a Citizen Science based program where anglers can report trophy catches (fish greater than eight pounds) caught, recording date, lake name, and the fish weight. Totaling the number of trophy fish recorded on an individual lake by year and dividing by the lake's surface area yields an estimated annual catch rate for trophy largemouth bass. The annual average trophy largemouth bass catch rate for lakes with low, medium, and high herbicide usages were 0.44 fish/km^2, 0.33 fish/km^2 and 0.49 fish/km^2, respectively (Figure 8). An analysis of variance showed that lakes with high herbicide usage had significantly larger trophy catch rates than lakes with medium herbicide usage.

All six largemouth bass metrics examined in these empirical analyses suggests that lakes with the highest herbicide usage showed no suppressed largemouth bass population characteristics. Therefore the following statement made by multiple stakeholders is not supported with the available data: "Herbicides are toxic to fish and when used in lakes herbicides hurt largemouth bass populations."

Conclusions

Aquatic plant management has been, is, and will continue to be a major issue in Florida. LAKEWATCH has worked and collaborated with FWC for decades and understands that FWC's aquatic plant management program is sound and based on the best available science, much of which has been conducted by the University of Florida. However, the difficulty comes with the diversity of stakeholders utilizing individual lake systems and that there is no one size fits all lakes management plans. For example, Harris Chain of Lakes Restoration Council and local stakeholders are communicating with the State Legislature and County Government to acquire more funding for herbicides to control the hydrilla in the Harris Chain of Lakes. At the same time stakeholders from Lake Istokpoga are screaming to University of Florida staff, who are currently developing a habitat management plan for the lake, to stop all herbicide work on the lake.

Complicating things, these two stakeholder viewpoints are moving targets depending on what the aquatic plants in each system have to "say". At one time there was little or no

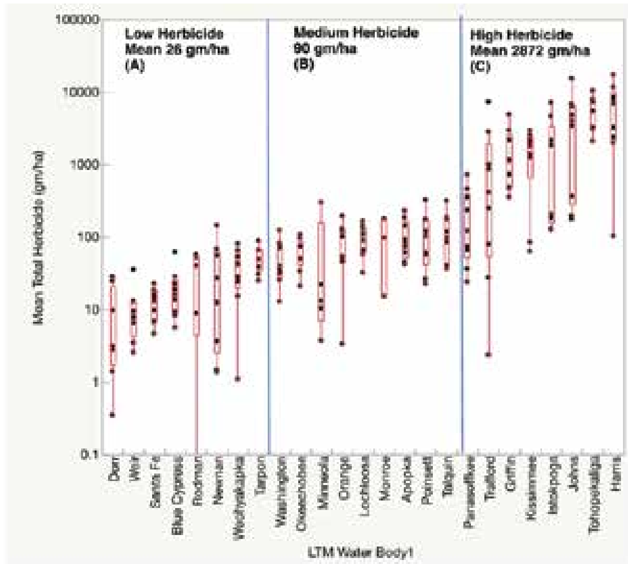

Figure 2. Quantile box plots for total herbicide amounts used in individual lakes over seven years. Each point is the value for an individual year, the box represents the 25th and 75th percentile for individual lakes. An analysis of variance was conducted to determine if herbicide amounts within low, medium, and high herbicide groups were significantly different and group means with different letters indicate significant difference ($p < 0.05$).

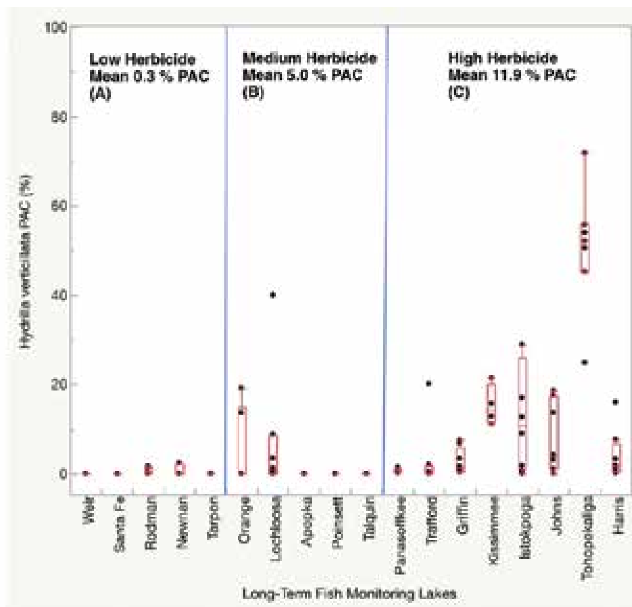

Figure 3. Quantile box plots for hydrilla coverage (% PAC) in individual lakes over multiple years. Each point is the value for an individual year, the box represents the 25th and 75th percentile for individual lakes. An analysis of variance was conducted to determine if hydrilla coverages were different among herbicide groups and group means with different letters indicate significant difference ($p < 0.05$).

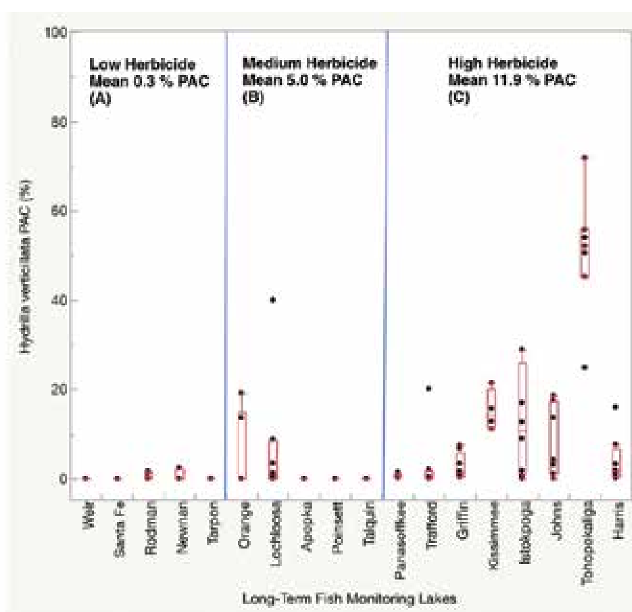

Figure 4. Quantile box plots for annual largemouth bass substock (<200 mm) electrofishing catch rates (fish/min) for individual lakes that experience low, medium and high herbicide usage. Each point is the value for an individual year, the box represents the 25th and 75th percentile for individual lakes. An analysis of variance was conducted to determine if catch rates were significantly different among herbicide groups and group means with different letters indicate significant difference ($p < 0.05$).

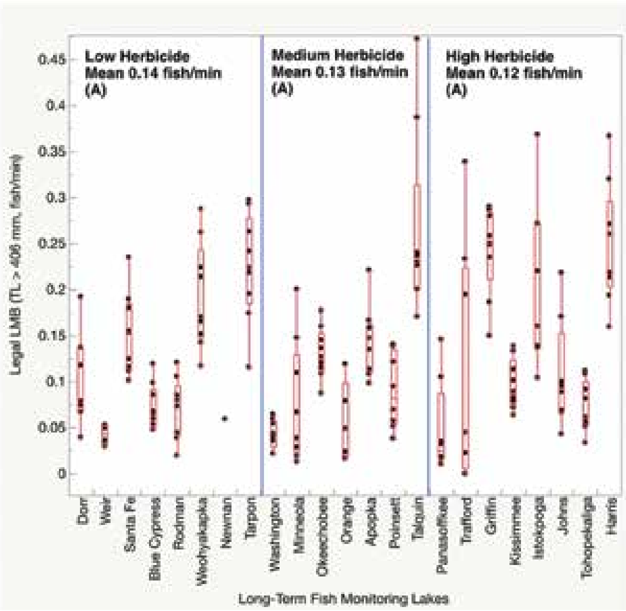

Figure 5. Quantile box plots for annual largemouth bass legal size (> 406 mm) electrofishing catch rates (fish/min) for individual lakes that experience low, medium and high herbicide usage. Each point is the value for an individual year, the box represents the 25th and 75th percentile for individual lakes. An analysis of variance was conducted to determine if catch rates were significantly different among herbicide groups and group means with different letters indicate significant difference ($p < 0.05$).

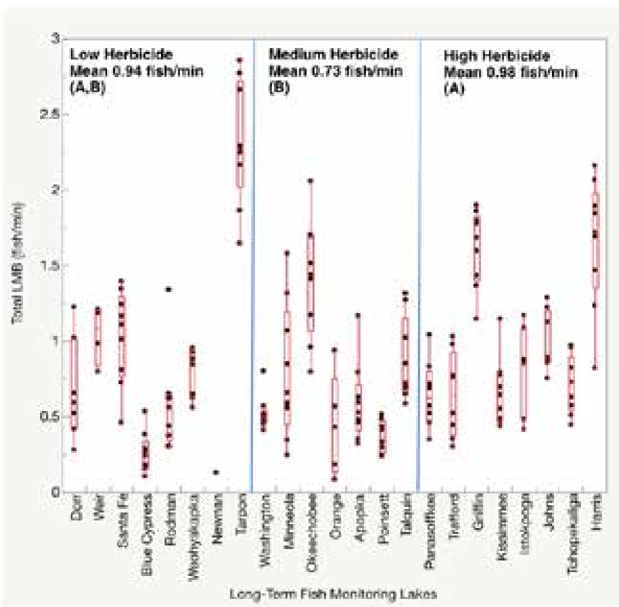

Figure 6. Quantile box plots for annual largemouth bass all sizes electrofishing catch rates (fish/min) for individual lakes that experience low, medium and high herbicide usage. Each point is the value for an individual year, the box represents the 25th and 75th percentile for individual lakes. An analysis of variance was conducted to determine if catch rates were significantly different among herbicide groups and group means with different letters indicate significant difference ($p < 0.05$).

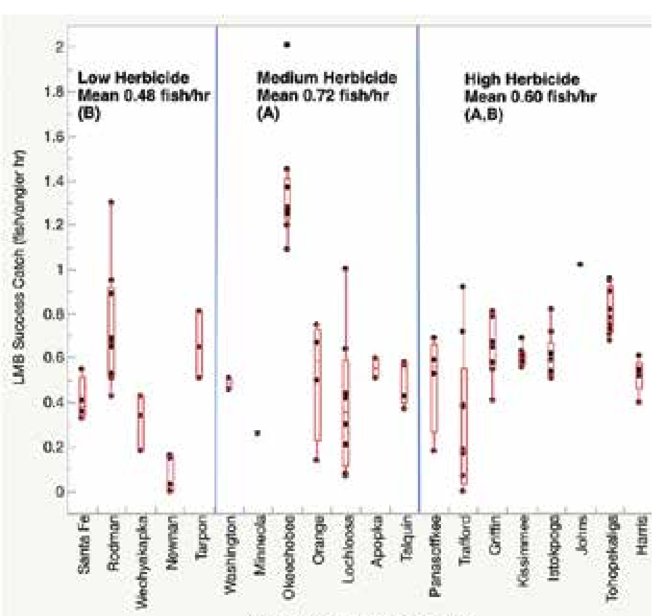

Figure 7. Quantile box plots for annual largemouth catch rates (fish/angler hr.) for individual lakes that experience low, medium and high herbicide usage. Each point is the value for an individual year, the box represents the 25th and 75th percentile for individual lakes. An analysis of variance was conducted to determine if angler success rates were significantly different among herbicide groups and group means with different letters indicate significant difference ($p < 0.05$).

submersed aquatic vegetation in the Harris Chain of lakes and the stakeholders/anglers were screaming to get some for fish habitat. In 1996, Lake Istokpoga was covered with over 25,000 acres of hydrilla and at that time the stakeholders were screaming to spray the hydrilla. Thus, heading in the direction of individual lake management plans that can be adjusted as plants come and go in a system seems to be the best approach.

Data mining efforts from the multiple long-term monitoring programs in Florida is a good approach to informing stakeholders as management plans are developed. This pilot project shows how data mining efforts can address issues/concerns that stakeholders have regarding the management of their lake. If all monitoring groups would use a standardized lake GNIS identifiers then the data mining and merging process would become easy allowing for data analysis to address issues of concern.

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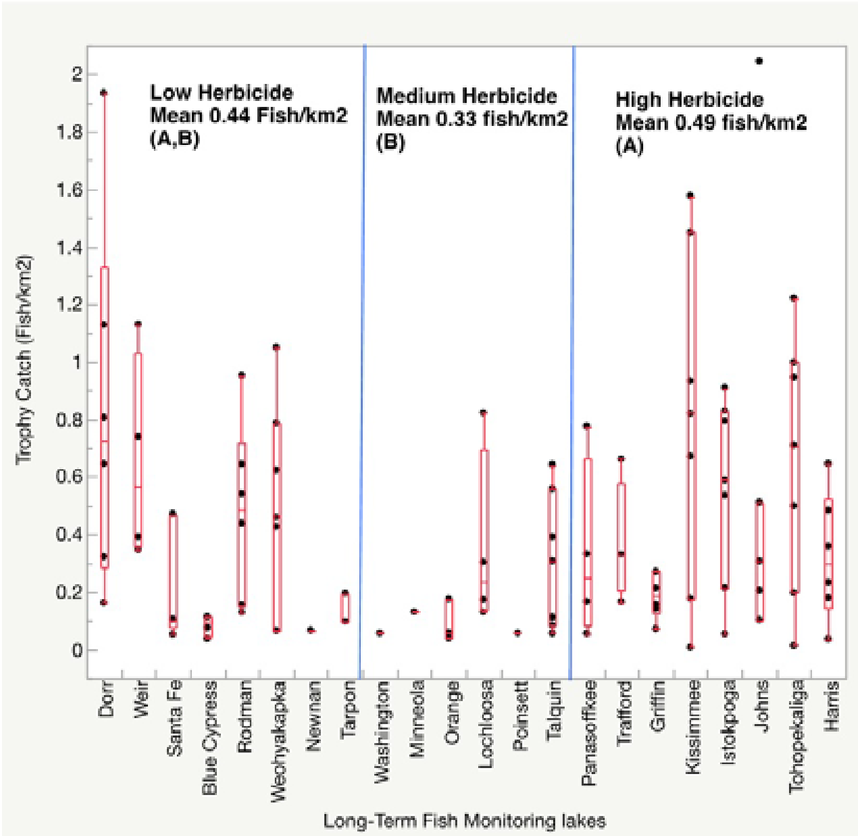

Figure 8. Quantile box plots for Citizen Scientist trophy catch reports (fish/km^2) for individual lakes that experience low, medium and high herbicide usage. Each point is the value for an individual year, the box represents the 25th and 75th percentile for individual lakes. An analysis of variance was conducted to determine if catch rates were significantly different among herbicide groups and group means with different letters indicate significant difference ($p<0.05$).

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2019 Calendar of Events

October 2-4
41st Annual Conference South Carolina Aquatic Plant Management Society (North Myrtle Beach, SC)
http://www.scapms.org/meetings.html

October 14-17
Florida Aquatic Plant Management Society 43rd Annual Training Conference (St. Petersburg, FL)
http://www.fapms.org/

October 27-31
21st International Conference on Aquatic Invasive Species (Montreal, Quebec)
https://www.icais.org/

November 3-6
38th Conference of MidSouth Aquatic Plant Management Society (Baton Rouge, LA)
http://www.msapms.org/conferences/2019/

November 11-15
North American Lake Management Society 39th International Symposium (Burlington, VT)
https://www.nalms.org

November 20-22
Texas Aquatic Plant Management Society Annual Conference (Bryan, TX)
http://www.tapms.org/conference-registration/

Need CEUs but don't see anything that fits your schedule? Visit the FDACS website and search for available CEU classes here: http://aessearch.freshfromflorida.com/AvailableClassSearch.asp. For more information about licensing, certification and finding Florida CEUs, check out "CEUs just for you" in the Summer 2014 issue of Aquatics magazine (http://fapms.org/aquatics/issues/2014summer.pdf)

What do global **regulatory** and **research agencies** conclude about the health impact of GLYPHOSATE?

Risk Assessment

What is the likelihood this will cause harm, based on dose and exposure?

EPA United States Environmental Protection Agency	USA	"Human health risk assessment concludes that glyphosate is **not likely to be carcinogenic** to humans... [and] **no other meaningful risks to human health** when the product is used according to the pesticide label"	2017
EPA United States Environmental Protection Agency, Office of Pesticide Programs	USA	"Not strong support for... 'suggestive evidence of carcinogenic potential...' based on the weight-of-evidence... Even small, non-statistically significant changes... were contradicted by studies of equal or higher quality. The strongest support is for **'not likely to be carcinogenic** to humans'"	2017
NTP National Toxicology Program	USA	"**Little evidence of toxicity**, and there was no evidence of glyphosate causing damage to DNA"	1992
Health Canada	Canada	"Products containing glyphosate **do not present unacceptable risks to human health** or the environment when used according to the revised product label directions... Risks to [occupational] handlers are not of concern for all scenarios"	2017
		"**No pesticide regulatory authority** in the world currently **considers glyphosate to be a cancer risk** to humans at the levels at which humans are currently exposed"	2019
ECHA European Chemicals Agency	Europe	"Based on the epidemiological data as well as on data from long-term studies in rats and mice, taking a weight of evidence approach, **no hazard classification for carcinogenicity** is warranted"	2017
efsa European Food Safety Authority	Europe	"Glyphosate is **unlikely to be genotoxic or to pose a carcinogenic threat to humans**... Neither the epidemiological data nor the evidence from animal studies demonstrated causality between exposure to glyphosate and the development of cancer in humans"	2015
anses	France	"**Level of evidence of carcinogenicity** in animals and humans is considered to be **relatively limited** and does not allow for a 1A or 1B classification (known or suspected carcinogen for humans)"	2016
BfR Risiken erkennen – Gesundheit schützen	Germany	"Available data **do not show carcinogenic or mutagenic properties** of glyphosate nor that glyphosate is toxic to fertility, reproduction or embryonal/fetal development in laboratory animals"	2015
Federal Department of Home Affairs FDHA, Federal Food Safety and Veterinary Office FSVO	Switzerland	"Residues of glyphosate in the foods investigated **do not represent a risk of cancer**"	2018
Australian Government, Australian Pesticides and Veterinary Medicines Authority	Australia	"Glyphosate **does not pose a carcinogenic risk** to humans.... Products containing glyphosate are safe to use as per the label instructions"	2016
Environmental Protection Authority, Te Mana Rauhī Taiao	New Zealand	"**Unlikely to be carcinogenic** to humans or genotoxic (damaging to genetic material or DNA) and should not be classified as a mutagen or carcinogen"	2016
ANVISA Agência Nacional de Vigilância Sanitária	Brazil	"**No evidence** to indicate that the herbicide **glyphosate is carcinogenic**"	2019
Food Safety Commission of Japan	Japan	"**No** neurotoxicity, **carcinogenicity**, reproductive toxicity, teratogenicity, and genotoxicity"	2016
Rural Development Administration	Korea	"Epidemiological studies on glyphosate... found **no cancer** link"	2017
World Health Organization; Food and Agriculture Organization of the United Nations	Global	"Glyphosate is **unlikely to be genotoxic at anticipated dietary exposures**. Glyphosate is unlikely to pose a carcinogenic risk to humans from exposure through the diet"	2016
World Health Organization, Drinking water quality guidelines	Global	"Under usual conditions, the presence of glyphosate and AMPA [aminomethylphosphonic acid, glyphosate's primary metabolite] in drinking-water **does not represent a hazard** to human health"	2004
World Health Organization, International Programme on Chemical Safety	Global	"Available data on occupational exposure for workers applying Roundup indicate **exposure levels far below** the NOAELs [no observed adverse effect levels] from the relevant animal experiments"	1994

Longitudinal Study

How glyphosate impacted 54,251 pesticide applicators since 1993.

Agricultural Health Study	USA	"**No association was apparent between glyphosate and any solid tumors or lymphoid malignancies** overall, including non-Hodgkin's lymphoma and its subtypes... some evidence of increased risk of AML [acute myeloid leukemia] among the highest exposed group that requires confirmation"	2018

Hazard Assessment

What is the potential to cause harm, regardless of dose or exposure?

International Agency for Research on Cancer; World Health Organization	Global	"**Limited evidence in humans for the carcinogenicity** of glyphosate... Evidence in humans is from studies of exposures, mostly agricultural [e.g. not from dietary exposure]... A positive association has been observed for non-Hodgkin lymphoma... There is **'strong' evidence** that exposure to glyphosate or glyphosate-based formulations is **genotoxic**" IARC placed glyphosate in its hazard category "Group 2A: probably carcinogenic to humans" along with red meat, hot beverages, and working as a barber. The evidence on carcinogenicity was less robust than for agents such as bacon, salted fish, oral contraceptives and wine.	2015

Genetic Literacy Project
SCIENCE NOT IDEOLOGY

Click on the bolded conclusions to take you to the document issued by the regulatory or research agency.

Infographic by Kayleen Schreiber, PhD, adapted from infographic by Maxime Pinazzi and Iida Ruishalme. Maxime Pinazzi is a media blogger focusing on skeptical analysis of online science news and author of ChèvrePensante.fr (media analysis, critical thinking). Iida Ruishalme is a biologist specializing in biomedical research and author of Thoughtscapism.com.

Photo 1: A teacher from plant camp got a firsthand look at how large exotic apple snails are.

Established in 2004, Florida's Invasive Plant Education Initiative (IPEI) is the education and outreach department of University of Florida's Institute of Agricultural and Life Sciences' (UF/IFAS) Center for Aquatic and Invasive Plants. The mission of the IPEI is to increase the public's awareness of invasive plants and their understanding of the need for invasive plant management, while fostering environmental literacy and stewardship among the citizens of Florida.

The IPEI uses a variety of means to achieve its goals of invasive plant education, including educator workshops, tabling at conferences and expos and creating high quality print and online education materials. Educators can request free materials for their classrooms from the IPEI website http://plants.ifas.ufl.edu/education/, such as plant identification decks, DVDs, laminated posters, puzzles and activity guides. The website also contains an invasive plant curriculum, which consists of videos, lesson plans and activities that can be used to supplement lessons or can be taught as entire units.

The test-centered nature of today's classrooms can challenge even the most well-intentioned teacher to find the time to include invasive species education in their curricula. The good news is, the online curriculum developed by the IPEI is easy for teachers to adapt to their needs and is aligned to the current educational state standards. One can find activities like The Hydrilla Game, The Alligator Weed Flea Beetle Lab, The Invasive Apple Snail Activity and many others.

In addition to providing educational resources, each year since 2006, the IPEI invites 24 educators from around the state to participate in Plant Camp, a 5-day invasive plant "boot camp". The camp is an immersive experience designed to inspire educators to *want* to include invasive species into their curriculum. Past Plant Campers report thoroughly enjoying this program and many have called Plant Camp the most valuable professional development program they attend during the summer. *"This has been the most interactive and engaging professional development that I have ever participated in. The extensive planning and preparation was apparent daily. Thank you for the opportunity to participate"*, commented one camper.

A recent 2019 Plant Camp participant said, *"I loved today's activities! All of the hands-on… from critter catching (wish there was more time — my favorite in general) to planting (felt as if I was a part of something useful and helpful)… I think learning it and then having to ID it in groups is the best way to actually LEARN it. These hands-on and different ways of learning styles are perfect for this course. All of you who are leading us are*

Photo 2: Plant Camp attendees learn about Hydrilla verticillata during the pond lab.

doing an amazing job! This week is totally worth it! More than worth it!". The IPEI is proud for Plant Camp to be lauded as a superstar by many past participants.

This hands-on education program is designed to provide professional development and materials to educators, so they can confidently introduce their students to the topic of invasive plants. The camp provides 37.5 professional development points to graduates to help them maintain their teaching credentials. The experiences are intended to offer background information, historical context and identification skills necessary to understand the complexities of invasive species plant management. The activities conducted during Plant Camp are taken from the IPEI's online curriculum, so they can be replicated by educators once back in the classroom.

The Florida Fish and Wildlife Commission (FWC) generously sponsors this program each year with additional sponsorship provided by plant management industry and professional organizations. "The FWC is a long-time supporter of the Florida Invasive Plant Education Initiative & Curriculum, which includes Plant Camp. Each year, we are excited for teachers to take these valuable lessons and messages back to their students", says Sam Yuan, Invasive Plant Management - Research and Outreach Manager at Florida Fish & Wildlife Conservation Commission.

Camp Begins…

This year, Plant Camp participants arrived in Gainesville on Monday June 10th and dove right into a week filled with expert guest lectures, plant and organism identification, pond walks, plant morphology and biological control lab activities. The caliber of presenters was extraordinary as was the level of coordination required to shuttle 24 inquisitive, enthusiastic teachers from destination to destination. The schedule for Plant Camp is rigorous with practically every minute of the day accounted for.

Plant Camp 2019 had 27 presenters from 17 different state agencies, university departments, professional organizations and private companies. These professionals provided participants with an in-depth understanding and awareness of the challenges associated with invasive species plant management and ultimately a greater knowledge of plant management methods. Participants were given a substantial amount of education materials to take back to their classrooms and education centers to implement the lessons and activities they experienced throughout the week. Additionally, the presenters serve as a resource for the participants. Those who present during Plant Camp graciously encourage participants to contact them with future questions.

Camp Highlights…

Plant Camp is full of so many amazing experiences, it would be difficult to touch on each of them, but here are few standouts. Expert and world-renowned Botanist, Dr. David Hall led a plant identification walk around the ponds at the UF/IFAS Center for Aquatic and Invasive Plants. His quiet demeanor shrouds an intensely profound knowledge of botany. Yet, his ability to get people genuinely excited about identifying plants is astounding. *"David Hall is a legend in Florida!!"*, exclaimed one participant. Campers huddled around Dr. Hall and a cut clump of cattails in the drizzling rain to get a close look at its dissected flower spike. He showed them how to use their hand lenses to closely examine the center of water lettuce to reveal its tiny, white flowers.

Dr. Chuck Cichra led a pond ecology lab where participants used dip nets to catch

Photo 3: FWC Biologist Ed Harris explains to the Plant Camp students how aquatic plant management works in Florida's large lakes.

dragonfly larvae, water scorpions, crawfish, tadpole, leeches and many other organisms. This activity can be used to teach students how to use a dichotomous key to identify the organisms they have captured. This lab generates a tremendous amount of enthusiasm and eagerness to learn about what life forms exist generally unseen in the water. One participant said, *"I absolutely loved the pond ecology lab!"*. Activities like this help learners foster a curiosity and wonder for the natural world. *"I wish I had more time to learn about the critters from the pond and time to explore their habitats and their names"* and *"This was a fun day. A lot of great stuff and many different ways to go about teaching the concepts"*, two 2019 Plant Camp participants.

The Plant ID Challenge was a fun way to put campers' skills to the test. They split into groups and were tasked with identifying as many aquatic plants as possible in 20 minutes. Dr. Bill Haller spent many months growing plants for this activity, which were housed in large tubs with numbered flags. The participants excitedly flipped through their plant ID decks trying to identify *Sagittaria lancifolia, Utricularia spp.* and *Pontederia cordata,* to name a few. The level of competition became quite fierce as the teacher became the student in this activity. *"I loved the hands-on approach to this week… but my favorite - for the purpose of being here was the ID challenge. I LOVED taking what we had been taught and had to put it to use"*, exclaimed a camper.

Each year the Plant Camp participants take an airboat tour of Lake Toho and it is certainly a fan-favorite! The participants get to see what a prolonged hydrilla infestation looks like and witness the toll it takes on the ecology of the system. Ed Harris, biologist for FWC, discussed the complexities of aquatic plant management and helped students understand what factors led to the infestation. He also pointed out the successes and small wins like the resurgence of eelgrass, the thriving clusters of planted bulrush and the increase in snail kite nesting sites.

"Lake Toho was an amazing experience. Being able to actually see the massive mats of hydrilla had a huge impact in tying everything that we have learned this week together. It shows the importance of supporting research in control and prevention of invasive plants," 2019 Plant Camp participant.

Photo 4: Alligatorweed is one of the few aquatic plants where biocontrol efforts are solely responsible for controlling the spread of this invasive weed. Plant Camp participants learn about this partnership between the alligatorweed flea beetle and the alligatorweed plant.

Plant Camp came to an end, but not before friendships were made, collaborations were forged, and perceptions were changed. Lara Colley, the Education Coordinator for the Education Initiative says, "There are a number of projects in the works between our office and 2019 Plant Camp graduates. The Education Initiative will be helping coordinate an Envirothon project, helping a Plant Camp grad with her enrichment program and hopefully several others."

One of the major focuses of Plant Camp is to demystify aquatic plant management. The IPEI strives to clear up misconceptions, focus on the science and energize educators to take this newfound knowledge back into their classrooms and teach this topic with confidence. The Initiative strives to promote science literacy and increase awareness of invasive plants and the harmful impacts they have on our ecosystems.

Lara Colley *(UF/IFAS CAIP) is the new Education Coordinator for the Invasive Plant Education Initiative. She helps develop, evaluate and implement education outreach materials and programs for CAIP. Her passion is to encourage individuals to adopt conservation behaviors and positive attitudes about nature. She has a colorful background including park ranger, nature interpreter and small business owner. She earned a bachelor's degree in natural resource conservation and master's in forestry and environmental education. She can be reached at laracolley@ufl.edu.*

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