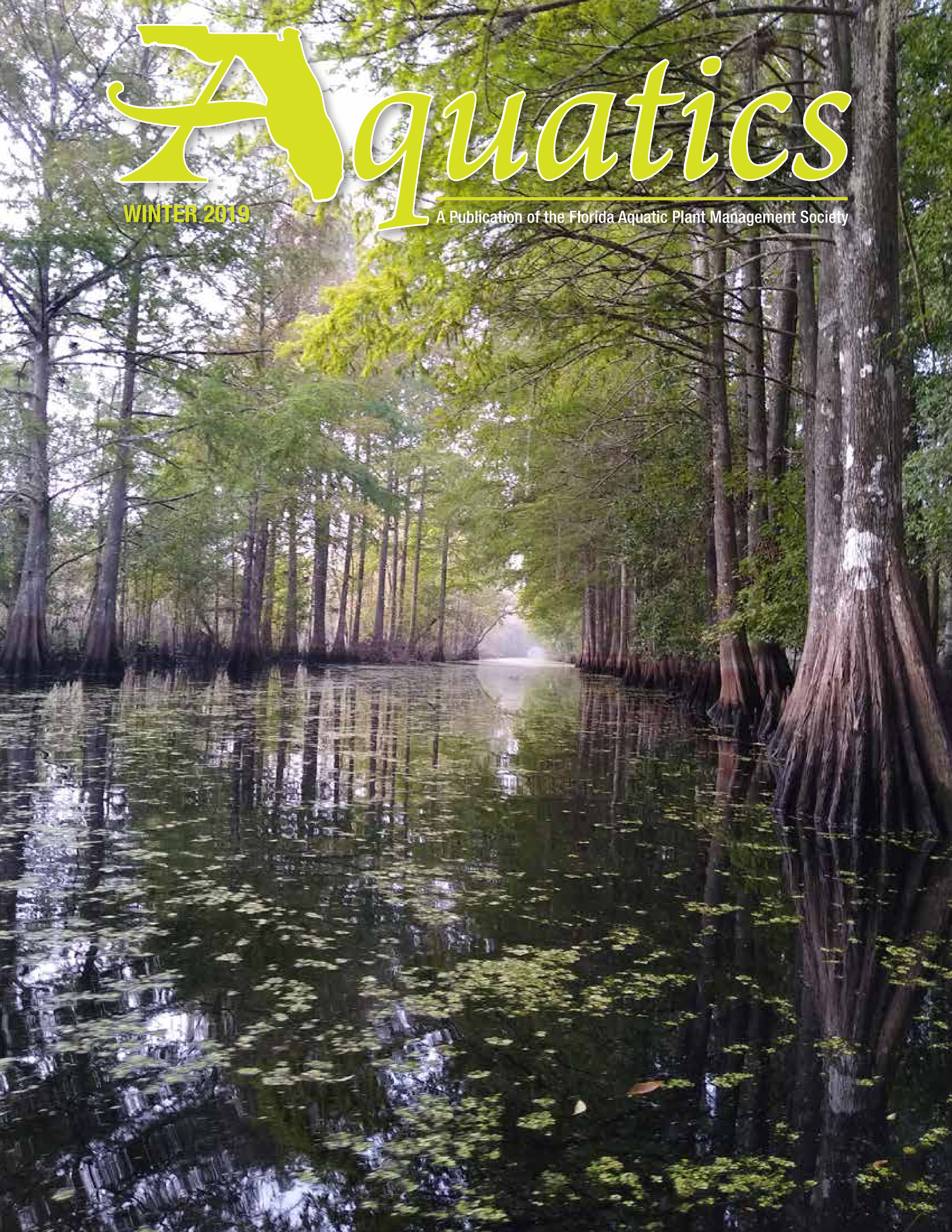
Aquatics

WINTER 2019

A Publication of the Florida Aquatic Plant Management Society



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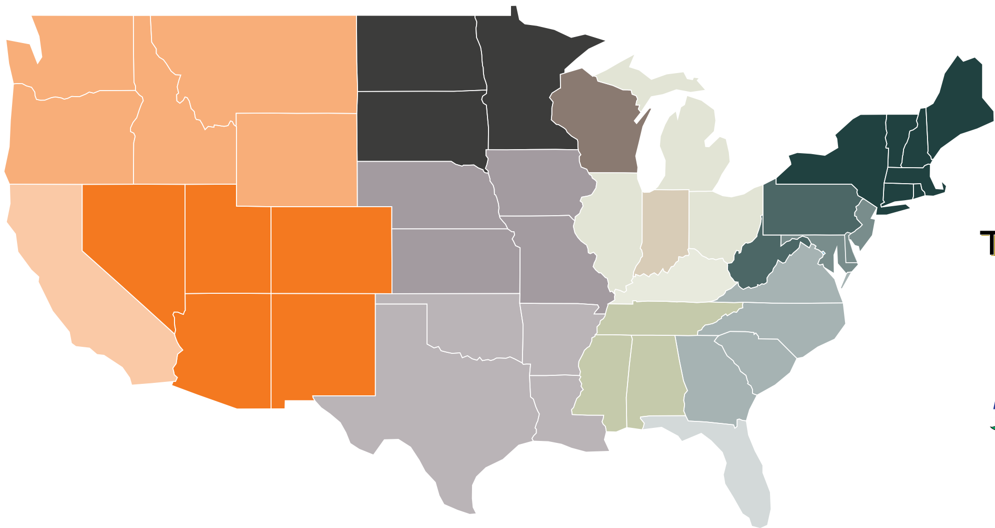

OR, WA ID, MT, WY
Scott Tweedy | 509.961.2621
TweedyS@HelenaAgri.com

CA
Shaney Emerson | 530.434.3381
EmersonS@HelenaAgri.com

AZ, CO, NM, NV, UT
Dave Cromley | 970.481.1885
CromleyD@HelenaAgri.com

MN, ND, SD
Tom Jameson | 320.241.3258
JamesonT@HelenaAgri.com

WI
Shawn Hilliard | 608.516.4006
HilliardS@HelenaAgri.com

IA, KS, NE, MO
Mark Person | 816.560.5448
PersonM@HelenaAgri.com

AR, LA, OK, TX
Kelly Duffie | 281.415.7301
DuffieK@HelenaAgri.com

IL, KY, MI, OH
Greg Ward | 616.340.9557
WardG@HelenaAgri.com

IN
Jeff Parker | 765.635.6311
ParkerJ@HelenaAgri.com

AL, MS, TN
Greg Wall | 662.312.0510
WallG@HelenaAgri.com

CT, NH, NY, MA, ME, RI, VT
Lou Bettencourt | 978.580.8166
BettencourtL@HelenaAgri.comWIWI

PA, WV
Dan Dillman | 724.290.5511
DillmanD@HelenaAgri.com

DE, NJ, MD
Roy Petters | 856.981.9209
PettersL@HelenaAgri.com

GA, KY, NC, SC, VA
Geer Dubose | 803.480.1425
DuboseG@HelenaAgri.com

FL
James Boggs | 863.557.0076
BoggsJ@HelenaAgri.com

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Aquatics

WINTER 2019 Volume 41, Number 4

Looking down the Orange State Canal in Floral City of Lake Tsala Apopka Cover photo taken and submitted by Tim Mullin, Lead Aquatic Plant Technician, Aquatics Division, Citrus County Public Works Department

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

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

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Aquatics

LETTER FROM THE EDITOR

Dear FAPMS Members,

It has been my pleasure to serve as Editor of Aquatics this past year, and I hope you like the content provided. I have enjoyed working with each of you and welcome your ideas and suggestions for the magazine.

First, I want to clarify how the submission process works and what the requirements are. A call for articles is distributed quarterly in preparation for the next issue. Submitted articles are generally around 1,000-2,000 words in length, and they should be targeted for the general public as a wide variety of readers subscribe to our publication. Images that accompany the articles should be at least 3 MB in size, and they should include a caption and proper photo credit (and permission) where necessary. General images taken from the internet will not be considered for publication. A short bio including the author's email for contact is encouraged. While all submissions are welcomed, not all submissions will be published. In some cases, publication may be delayed due to number of submissions received, requests for additional information, content focus in a particular issue, or needed revisions.

Second, I am always looking for images to use on the cover. Cover photos need to be taken vertically and at least 3 MB (preferably higher resolution) in size. We have access to some of the most beautiful scenery in Florida, and I would love to feature where you work! Please submit your name, location of the photo, and your title.

"… if you have ideas or suggestions for content, upcoming meetings, events, etc, please feel free to send them to aquaticsmagazine@ gmail.com."

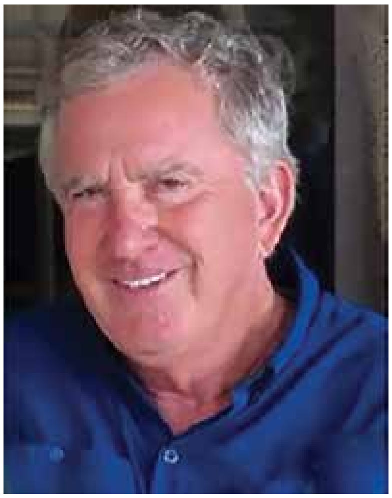
And, if you have ideas or suggestions for content, upcoming meetings, events, etc, please feel free to send them to aquaticsmagazine@gmail.com. I will be happy to include any information to raise awareness and educate about aquatic plant management initiatives.

Many thanks for your support!

Amy L. Giannotti, M.S., C.L.M.
Editor

In Remembrance of David Tarver

February 16, 1951 - October 2, 2019



David Paul Tarver, age 68, of Tallahassee Florida, passed away October 2, 2019 after a lengthy battle with cancer. Many knew him as David, others knew him as Paul.

David joined the Aquatic Plant Management Society (APMS) in 1973 after graduating from Northwestern State University in Louisiana with a BS degree in Wildlife Management. He received a master's degree in Botany from NSU in 1974 and joined the Florida Department of Natural Resources where he provided aquatic plant management extension services and law enforcement duties while serving as the Northwest Florida regional biologist.

David was hired by Eli Lily and Dow to work in Sonar herbicide product development from 1981-1994, and SePRO from 1995-2011 to become Director of Technical Development. During this period, David was a leader in developing strategies to apply fluridone herbicide alone and in combination with other tools to bring hydrilla under maintenance control in Florida public lakes and rivers.

He served on the FAPMS Board of Directors from 1983-1987 and the APMS Board from 1995-2003. David was the publisher of *Aquatics* magazine from 1985-2009. He worked in APMS Education and Outreach where he co-authored the "Understanding Invasive Aquatic Weeds" workbook distributed to more than a half million students. For his many years of service to aquatic resource management, APMS bestowed Honorary Membership to David in 2012.

For more than four decades, David Tarver personified innovation and customer service—both with regulatory agencies and the private sector, spending countless hours on Florida lakes and elsewhere in the country; assessing problems and creating management solutions, then passing that information to managers and stakeholders. Few have shown David's relentless passion to improve the science and management of invasive aquatic plants or had such positive impacts restoring and maintaining t he uses and functions of lakes and rivers as David Tarver.

David Paul was a devoted husband, father, and grandfather. He loved, protected, and cherished his family above all else. Paul married his high school sweetheart, Debra Gallien in 1973. Together, they shared a lifetime of experiences including traveling, raising two boys and loving their precious grandchildren. He shared his vast knowledge of science with his grandchildren through countless hours helping them with homework and teaching them how to study. Paul shared his passion and skills as an Eagle Scout and Boy Scout volunteer with his two sons, Dusty, Josh, and many of their friends. He supported their endeavors in sports, hunting and fishing, and taught them to value education and have respect for our country.

He was preceded in death by his father Lee Tarver, mother Lucille Pope Tarver, and daughter-in- law, Elizabeth Marie Evans Tarver. He is survived in his immediate family by his wife of 46 years Debra Gallien Tarver, son Dustin and wife Selena; grandchildren Presley Tarver and Bristol Tarver, and Sterling Moon, Asher Moon, and Luciano Moon, and son Josh and grandson, Colby.

Donations can be made to :

University of Florida Health
Shands Cancer Hospital
1515 Southwest Archer Road
Gainesville, FL 32608.

In Remembrance of David Tarver

- APMS Member 1973
- **FAPMS Charter Member 1976**
- FAPMS BOD 1983-1987
- APMS BOD 1995-2003
- FAPMS President 1986
- APMS President 2002
- APMS Honorary Member 2012
- *Aquatics* Magazine publisher from 1985-2009

43rd Annual FAPMS Training Conference

For the first time in many years, St. Petersburg, "The sunset capital of Florida", was the host city of the Florida Aquatic Plant Management Society's (FAPMS) 43rd Annual Training Conference. With a wide-ranging variety of eateries and businesses nearby, it was the perfect site for this year's conference. A record attendance of several hundred people attended the conference listened to the keynote address from Carlton Layne of Aquatic Ecosystem Restoration Foundation (AERF) kickoff the conference and discuss the peculiarities of the times we currently experience, underscoring the need to exhibit professionalism and realize that we are all ambassadors of the science we practice. Following in the spirit of changing times, Shelby Oesterreicher, communications manager at the University of Florida Center for Aquatic Invasive Plants (CAIP), discussed public communication strategies for applicators today, providing applicators with key strategies to effectively convey information to the public. Mark Hoyer of the University of Florida's Lakewatch program, presented the results of relevant study concerning long term fish and plant data as it relates to aquatic plant management actions. Dr. James Leary of CAIP, outlined some of the current efforts to examine and study aquatic plant harvesting around the state. The diverse program also had topics concerning, but not limited to, harmful algal blooms (HAB), invasive upland plants, drones, driving safety and heat related stress factors and prevention. Quite the variety of informative and helpful topics!

2019 President's Award Winners

President Kelli Gladding selected two recipients for the 2019 President's Awards; Jackie Smith of Florida Fish and Wildlife Conservation Commission (FWC) and Brian Nelson of the Southwest Florida Water Management District (SWFWMD). Jackie Smith graduated from University of Florida with degrees in Natural Resource Management and Natural Resource Economics. She has worked over 30 years in both aquatic and upland plant management. Currently, she is the South Regional Biologist for the Upland Plant Management Section. Brian is a past president of FAPMS ('90) and will be retiring soon from SWFMD. Brian has been with the District since 1993 and has more than 37 years of vegetation management experience including positions with the Florida Department of Natural Resources. He has also served as secretary of the Florida Exotic Pest Plant Council and chaired the statewide Florida Invasive Species Task Force and has a B.S. degree in Limnology from the University of Central Florida. Thank you both for your support of FAPMS!

The 2019 President's Awards recipients were Jackie Smith and Brian Nelson, seen here with 2019 FAPMS President Kelli Gladding.

2019 Honorary Lifetime Membership– None

2019 Inaugural Dr. Michael D. Netherland Exemplary Colleague Award

Dr. Mike Netherland was a highly respected scientist, friend, mentor and collaborator. Nearly everyone in the aquatic plant management community was influenced by his work and his benevolence through the years. In Mike's memory FAPMS created the Dr. Michael D. Netherland Exemplary Colleague Award with the following criteria in mind:

- A special recognition given to a current or former APMS affiliate member who personifies Michael Netherland's positive attitude, outgoing and inquisitive personality, and genuine selfless giving friendship qualities.
- A person that displays a love and pursuit of gaining and sharing knowledge within the APM community.
- A person that exhibits sincerity and friendship towards all FAPMS members, including providing guidance in all forms of aquatic plant management and professional activities.

Several nominations for this award were received, all worthy of recognition for this award. However, FAPMS Charter Member, Honorary Lifetime Member and Past President Joe Joyce ('81) nominated fellow similarly decorated colleague Dr. Bill Haller ('80) for this inaugural award. In Joe's nomination letter, he cited Dr. Haller's, "unique ability to share his knowledge with persons of any skill or education level." He further referenced Dr. Haller's, "sincerity and friendship" understating that there is, "no greater friend to our industry…"

In a fitting gesture of admiration and deservedness, Joe Joyce flew in for the emotional award ceremony and presented

Dr. William Haller, the inaugural recipient of the Michael D. Netherland Exemplary Colleague Award. Pictured here: 2019 FAPMS President Kelli Gladding, Dr. Haller, and Dr. Joe Joyce.

his friend Dr. Bill Haller with the Inaugural Dr. Michael D. Netherland Exemplary Colleague Award in a ceremony appropriately honoring Mike's legacy and impact on the aquatic plant management community.

Applicator of the Year– None

Aquatic Plant Manager Presentation Winners

In what is becoming, the signature event for FAPMS with dedicated and thoughtful participation, four managers took part in this year's Aquatic Plant Manager Presentation Competition. Presenters received an initial $100 for participating in the competition, and in addition, winners also took home $300 for 1st place, $200 for 2nd place and $100 for 3rd place. The presentations were very well done, and they are going home a little heavier in the pocket!

1st– Colin Lewis, Lee County Hyacinth Control District (LCHCD) discussed new technologies involving Unmanned Aircraft Systems (UAS's), more commonly known as drones in aquatic plant management and have the potential to revolutionize the way in which aquatic plant applicators manage their waterbodies. As technology continues to improve, UAS's have become more versatile in their functions and can perform a wide array of tasks. Beginning this year, LCHCD has begun integrating drones into their program to aid in plant surveillance, water quality assessment, and aerial herbicide applications. The use of drones in aquatic plant management can allow applicators to see farther, plan smarter, and manage more efficiently.

2nd–Jim Schultz, Lake Worth Drainage District (LWDD) presented a talk focusing on new processes and improvements in chemical inventory, spray reports and mapping.

3rd–Jackie Keller, Palm Beach County Parks & Recreation (PBCPR) talked about *The benefits and effects of prescribed burning***.** Use of photo surveys and selected observation points prior to and after a prescribed burn in a pine flatwood aided in the execution of the burn and the interpretation of the results. Findings revealed the benefits and effects of fire on nuisance weeds and allowed for optimal integration into a pest management plan for best management practices.

Poster Presentation Competition

FAPMS introduced a new poster competition in 2018, which was open to the existing membership and students. This was designed to encourage applicator observations from the field while integrating that with and supporting student research. Financial awards were distributed to the best posters, with prize money valued at $150, $100, and $50. This an ideal opportunity to present ideas if you are not inclined to do so speaking in front of an audience. Please consider joining us next year by submitting your field observations and/or research!

1st– Colin Lewis
2nd– Shelby Oesterricher

2019 Paul C. Myers Applicator Dependent Scholarship

The Paul C. Myers Applicator Dependent Scholarship provides funds to deserving undergraduate students whose parent or guardian has been a FAPMS member in good standing for at least three consecutive years. A total of $10,000 was awarded in 2019 to several worthy recipients; Molly Lovestrand, Jeremiah Lovestrand, Abigail Farr, Kaylie Mangus, Adrianna Rose, Abigail Campbell, and Jeffrey Olson. This scholarship is funded primarily through monies raised at the annual conference, including $5 for every registration, as well as additional funds from the sale of raffle tickets and Duck Race entrants. At the ban

Duck Races

Likely the most anticipated and heralded event, the FAPMS Annual Duck Races produced several happy winners with the Outdoor prize a weekend stay at Joe Joyce's Chokoloskee camp. In the Yeti race, the first place winner was the recipient of a Yeti cooler:

Outdoor Ducks
1st–Theresia Cluts
2nd–Paul Dampier
3rd–Dan Thayer

Yeti Ducks
1st–Timothy Keene
2nd–Cliff Peeno
3rd–Daniel Pitts

Vic Ramey Photo Contest

This year's winners of the annual Vic Ramey Photo Contest were awarded cash prizes for their winning photos. Winners took home $150 for 1st place, $100 for 2nd place, and $50 for 3rd place in each category. Congratulations, photographers! Also, special credit goes to Colin Lewis who participated in the photo contest, applicator paper and poster session, he netted a cool $700 for doing some extra work. Way to go Colin! Next year, be like Colin and make the most of what the society has to offer!

Aquatic Scene
1st– Colin Lewis
2nd– Colin Lewis
3rd– Mandy D'Andrea

Operations
1st–Justin Edmund
2nd–Steve Salkolar
3rd–Charles Burn

First Annual Fishing Tournament

The fish weren't huge, but the stories were!! Bragging rights from this year's fishing tournament are as follows:

1st–Charles Burn
2nd–Skippy Fair & Mitchel Blankenship

2019 FAPMS Inaugural Fishing Tournament Participants

At the awards banquet, the cooler full of joyous libations was raffled off to Shane Foster of Applied Aquatic Management (AAM).

To end our meeting, President Kelli Gladding, SePRO passed the gavel to the incoming President, Scott Jackson, Syngenta and they jointly announced the grand prize drawing of a Big Green Egg cooker, sponsored by AAM, Nutrien, UPL and Syngenta; won by Mike Coffee of AAM.

Next year the annual training conference returns to Daytona Beach, October 5–8, hope to see you there!

APPLICATORS' CORNER

The Fall 2019 issue of *Aquatics* featured a quiz and discussion on the reproductive biology of hydrilla as well as a "mystery photo". This issue will provide additional discussion on hydrilla and answers to the quiz **(in bold letters)** and introduces the topic of P uptake by aquatic plants. There is a lot of interest in phosphorus recently so we'll try to sort out fact from fiction if we can in the next issue of *Aquatics*.

Likely introduced by the aquarium trade into Florida in **the late 1950s**, hydrilla is believed to be native to **southern Asia/ India,** but the exact origin is controversial since some botanists consider it to also be native to Africa and northern Australia. Regardless, it is now found on **6 of the 7 continents** with the exception, so far, of Antarctica. It is currently most problematic in the western hemisphere, North, Central and South America. The question of nativity of this species has made the search for biocontrol agents more difficult and lengthy since entomologists seek insects or other biotic agents in an exotic invasive plant's native range. However, extensive research has been conducted in all areas in which hydrilla might be native.

Hydrilla has been reported or is currently present in about **50% of the states in the U.S.** and generally grows in deeper water than our native submersed species due to its photosynthetic ability to utilize about ¼ of the light needed by our native plants. **Light is considered the most limiting factor in submersed plant growth and distribution**, but other factors such as sediment type and water flow (velocity) may also impact plant distribution. Only about 2 to 4% of the biomass of hydrilla is devoted to root production and some submersed plants such as bladderwort and coontail, and the macrophytic algae *Chara* and *Nitella* have even less root mass or hold-fast tissues and are easily uprooted in even slow-moving water.

To date, only the dioecious **female** hydrilla plant is found in Florida. Dioecious plants have the male and female flowers on separate plants and therefore sexual or seed production in Florida is not possible (no pollen!). The **monoecious** biotype of hydrilla, found in central and northern U.S., has male and female flowers on the same plant and reportedly produces viable seeds. Both hydrilla biotypes can produce green **turions** in their leaf axils and are generated from axillary buds adjacent to the stems. Turions seem to form more readily on floating hydrilla stems (stems that are not attached to the sediment), but how does a plant know "Hey, we're just floating around so we need to produce turions"???. Apparently one of the mysteries of life!!! See "*Turion production by dioecious hydrilla in North Florida*" in the *Journal of Aquatic Plant Management* 31:101-105 (available online at http://www.apms.org/wp/wp-content/uploads/2012/10/v31p101.pdf).

Regardless, as the turions mature, they detach from the floating stem and sink to the lake bottom to develop into new plants. Both hydrilla biotypes also produce **white or brownish tubers** at the ends of rhizomes growing down into the hydrosoil. Monoecious hydrilla **develops tubers under relatively long-day (longer daylength) conditions** in July through September and hydrilla **in Florida produces tubers under short-day conditions** from about October through April as long as water temperatures are greater than 45 to 50 °F. Both turions and tubers are compact buds in which a short stem is surrounded by greatly reduced fleshy leaves. The terms "turions" and "tubers" are not botanically correct. "Axillary turions" and "subterranean turions" are botanically more accurate, but for simplicity's sake, biologists usually use the informal turions/tuber terminology.

The longevity – or how long tubers and turions survive – and what environmental conditions break their dormancy and promote sprouting are logical questions with no answers. How do you conduct research on hydrilla tubers growing under 6 feet of water and formed under 3 inches of hydrosoil? Quite easy you might say; just take a post-hole digger or other means and dig them up, bring them to the lab and study them… and what you get is 100% sprouting. But they have not sprouted in their natural environment where they were just excavated a week or so ago and those that remain under natural conditions have not sprouted! Hmm...

Much of the following discussion is based on what we believe is happening and have little or no data to confirm or deny! Turions seem to germinate readily on the hydrosoil surface in shallow pans but may have lower sprouting rates under natural conditions and some may survive for maybe 2 to 3 years. Tubers are usually found in much greater numbers than turions and some work suggests the tubers may have a sprouting rate of 3 to 5% of the population per month. So if you start with 300 to 400 tubers per square meter, it will take several years or even decades to deplete the tuber supply, provided no new tubers are formed. Therefore, tubers probably remain in the hydrosoil for much longer periods of time than turions, maybe 10 or more years, but we do not know. Hydrilla has been informally reported to rapidly regrow after grass carp have been removed or their populations depleted from ponds or lakes a decade or more after they were stocked (grass carp survival is believed to be 8 to 12 years). Since these ponds were not closely monitored, the question remains as to whether the return of the hydrilla to problem levels was the result of tuber sprouting, or the re-introduction of hydrilla from other outside sources.

Hydrilla tuber populations collected from hydrilla-infested areas during drawdown of Rodman Reservoir in North Florida showed higher tuber numbers in highly organic soil and lower numbers in sandy soil, with numbers in the neighborhood of 200 to 500 tubers per square meter. A number of years ago, David Sutton planted one sprouted tuber in a dishpan under shallow, warm-water conditions in tanks at the south Florida AREC (now the UF/IFAS Ft. Lauderdale Research and Education Center) and harvested tubers one year later. He found that the plant derived from that initial single tuber produced **3,000 to 4,000 tubers per square meter.**

We have all noted the clear water that

commonly occurs when submersed plants such as hydrilla cover a large portion of a lake. A 50% or greater coverage of submersed plants cause many changes (most temporary) to a lake when its littoral or vegetated area has historically been 10 to 20%. All airboaters know to run the plants on windy days since there are less waves there. This is a major factor in clearing the water, as reductions in wind and wave action in a highly covered, vegetated lake result in less **suspended solids**. **Phytoplankton are also suspended solids and need light to survive and grow, so the lack of light under dense hydrilla or other submersed weeds causes less phytoplankton**, less green coloration, and clearer water as well. In addition, many different species of algae, bacteria, animals, and insects that also absorb nutrients are attached to and live on submersed plants, rocks and other non-living structures. **The terms for these organisms include epiphyton, periphyton and the German term "aufwuchs".** The German term is often used in scientific publications.

The mystery photo on page 6 of the Fall 2019 issue of *Aquatics* was taken by Dean Jones and shows the extensive production of tubers by hydrilla. This photo is of the bottom of a 12-quart dishpan, tipped upside down and rinsed briefly with water. The pan, containing washed builders sand amended with fertilizer, was planted with 5 apical hydrilla meristems in December 2018, grown for 12 weeks under short-day conditions under 3 feet of water in a SFWMD pond in south Florida, and harvested in March 2019. Hydrilla roots are the small, white, thread-like structures and the larger white rhizomes have nodes and tan or brown bands that are about ¼ to ½″ apart. The swollen buds at the terminal ends of the rhizomes are tubers. Some of the tubers were already fully mature and detached from their parent rhizome, and those tubers that were nearly mature are distinguished by their larger size and the black abscission zone at the base of the tuber (two of these can be seen left of center at the 9 o'clock position). There are also numerous smaller, immature tubers of various sizes that have not formed abscission layers yet. The tubers were not counted, but we believe there are close to 75 in this photo and the area of the dishpan is about one square foot. To convert that from 75 tubers per square foot to number of tubers per acre, just multiply 75 tubers by 43,560 square feet… which gives us about 3.25 million tubers per acre in 12 weeks. This is a phenomenal number and just one example of how hydrilla has evolved and developed an extensive means of vegetation reproduction!

The final question in the Fall 2019 issue of *Aquatics* asked the reader to consider where hydrilla and other submersed aquatic plants obtain their primary nutrients, particularly nitrogen (N) and phosphorus (P). Obviously the source of nutrients for the growth of terrestrial plants is limited to the soil where all the required nutrients are moved into plant tissues via root uptake. Algae, growing in water or other wet locations, have no roots and absorb nutrients into their cells from the surrounding water. Nutrient uptake by submersed aquatic plants is not so clearly defined. It is believed that the majority of nutrient (N and P) uptake is via root absorption from the hydrosoil, but some physiologists believe that there is additional nutrient uptake from the water column. This topic will be discussed in the Spring 2020 issue of *Aquatics*.

The mystery photo in the last issue raised considerable interest among readers, so this will become a standard feature of the APPLICATORS' CORNER. This one is easy…

What the heck are THOSE?

These odd structures stay viable for many years and allow this invasive plant to recover after "adverse events" like herbicide treatments. Answer these questions for a chance to win a FLORIDA WEED SCIENCE t-shirt!

1. What is the full Latin name (genus and specific epithet) of the plant that produces these?

2. What are the white structures called and where on the plant are they produced?

3. What are the green structures called and where on the plant are they produced?

Email your answers by February 1 to Dr. Lyn Gettys at lgettys@ufl.edu with the subject line "Aquatics mystery plant entry". Entries that correctly answer all three questions by the deadline will be entered into a drawing and one lucky winner will be randomly selected to receive the much-coveted shirt. The winner will be announced in the next issue of Aquatics magazine.

Good luck!

Alum Revisited

In the past few years, as cyanobacteria (formerly known as blue-green algae) detections and Harmful Algae Blooms (HABs) have increased in frequency, I have watched with concern the variety of fixes that have creeped onto the scene – everything from vacuums and skimmers; ultraviolet and ultrasonic devices; bubblers, aerators, and water flow devices of all sorts; bacteria; and alum. In addition, the so-called "pause" of 2019 created a forum for anti-pesticide activists and those who object to an integrated approach to aquatic plant management. From those public meetings, suggestions and recommendations continue to flow that regulators must now consider and address as they arise. There is nothing inherently evil about any of these ideas, but the devil is always in the details. Many of the methods and suggestions appearing regularly in the media and on the internet are simply illegal.

One of the documents I'll keep referring to is the U.S. Environmental Protection Agency's Label Review Manual. This manual, which you can obtain by Googling "EPA Pesticides Label Review Manual", is a wonderful reference work and is used as an EPA internal training tool. It is recommended for use by state regulators, pesticide registrants and anyone else interested in how pesticide labels are developed and evolve. In a shameless plug, I also refer you to the upcoming 4th Edition of the Aquatic Ecosystem Restoration Foundation's Best Management Practices Manual. You'll find a chapter therein that covers pesticide registration and enforcement in more depth than is presented here.

There are two federal statutes that aquatic plant managers must deal with in their planned activities – The Federal Insecticide, Fungicide, and Rodenticide Act, as Amended (FIFRA), and the Clean Water Act (CWA) and its provisions under the National Pollution Discharge Elimination System (NPDES). You have heard me expound upon these laws and rules for over forty years. Even so, we must continue to preach the message over and over and still some people don't get it. Enforcement becomes the only viable response at some point. We'll start with the basics.

FIFRA is the federal statute that regulates the manufacture, distribution, sale and use of pesticides and pesticide devices in the United States. In general, products are considered to be pesticides if they are **intended** for preventing, destroying, repelling, or mitigating any pest. The key word is "intent". In the aquatic world, intent can be determined by examining the claims associated with the product. The Label Review Manual in Chapter 2 addresses the claims:

If a person who distributes or sells the product claims, states or implies by labeling or otherwise (such as, advertising, collateral literature, or **verbal statements** [emphasis added]), that the product can or should be used as a pesticide … then the product is a pesticide. 40 CFR 152.15(a).

In addition, the EPA considers:

> Even if pesticidal claims are not made for the product, if the person who distributes or sells the substance has actual or constructive knowledge that the substance will be used, or is intended to be used, for a pesticidal purpose, the product is a pesticide product required to be registered. 40 CFR 152.15(c).

As stated above, more and more aquatic-related issues such as harmful algae blooms, invasive species, and unusual environmental circumstances continue to appear. In response to the rise of new and creative aquatic products, the EPA has tried to address some of these in Chapter 12 of the Label Review Manual:

> For certain aquatic use products, claims to reduce sludge and unpleasant odors in water or to clean, clarify or deodorize ponds and lakes are not considered pesticidal claims; nor are claims regarding the reduction of nutrients and organic matter in water, **provided no claim is directly made or implied that the reductions will result in reduced pest populations** [emphasis added]. The claims "Reduces critical nutrients for cleaner, clearer ponds", "Ponds with algae need to reduce nutrients", and "Bacterial Product to Control Excess Nutrients for Clear, Clean Ponds" **imply pesticidal use and therefore require registration** [emphasis added].

Slime and odor control agents and other products expressly claiming control of microorganisms of economic or aesthetic significance are not considered to be public health-related but should bear accurate pesticide labeling claims. Registrants are still responsible for ensuring that these products perform as intended by developing efficacy data, which must be kept on file by the registrant.

EPA's policy does not permit the use of the terms "natural" or "naturally" in the labeling of any registered product, including biopesticide products, both microbials and biochemicals. These terms cannot be well defined and may possibly be misconstrued by consumers as a safety claim.

Aquatic dyes intended to reduce UV light or to otherwise reduce or control aquatic plants, algae or cyanobacteria are considered to be pesticides and must be registered with the EPA prior to distribution and sale. It's all about the claims.

Another area of increasing concern for EPA and state enforcement offices involves pesticide devices. In general, if an article is an instrument or contrivance that uses physical or mechanical means to trap, destroy, repel or mitigate any plant or animal life, it is considered to be a device and is subject to regulation under FIFRA. Devices are not subject to the registration requirements that apply to pesticides under FIFRA Section 3. Pesticide devices must, however, be produced in a registered pesticide-producing establishment and that number must appear on the labeling of all pesticide devices.

EPA has identified many types of devices subject to FIFRA jurisdiction. Some aquatic-related devices include, but are not limited to, certain ultraviolet light systems, ozone generators, water filters and ultrasonic devices for which claims are made to kill, inactivate, entrap or suppress the growth of pests in various sites. Aerators, nano-bubblers, water circulators and similar products which are marketed with claims to control algae, cyanobacteria or aquatic life in general, would all be considered to be pesticide devices. It has also been noted recently that devices utilizing fire, steam and lasers along with skimmers, vacuums and the like - all claiming to manage or control aquatic pests - are making a comeback. They are still regulated as pesticide devices under FIFRA.

Harvesters, cookie cutters and similar devices are not regulated by the EPA even though they clearly are devices intended to manage aquatic plants. These types of devices fall under an exemption from regulation because the effectiveness of the device depends more on the performance of the operator than the performance of the device itself. A flyswatter is another good example of a pesticide device exempt from regulation because its efficacy depends on the skill of the user and not the device itself.

The EPA also regulates the labeling of pesticide devices to some degree. In brief, the device is considered to be misbranded and subject to prosecution if the labeling fails to comply with the following requirements and others not listed here:

- The labeling bears any statements, designs or graphic representations that are false or misleading;
- The label fails to bear the establishment number of the establishment where it was produced;
- It lacks adequate directions for use; or
- It lacks an adequate warning or caution statement.

While, as stated above, no registration of the device is required by the EPA, a manufacturer is barred from making any false or misleading claims for the device. In practice, that means, should the EPA ask for it, the manufacturer must be able to satisfactorily prove with scientific evidence that their product does what it claims.

As indicated above, products that directly state or imply claims to reduce, control or manage plants, algae or cyanobacteria populations when used are thus considered to be pesticides. And "The claims 'Reduces critical nutrients for cleaner, clearer ponds', 'Ponds with algae need to reduce nutrients', and 'Bacterial Product to Control Excess Nutrients for Clear, Clean Ponds' imply pesticidal use and therefore require registration." What is occurring more and more often these days is companies or individuals will use a product known to reduce nutrients and either directly or by implications as described above, make claims to customers that the treatment will control a pest such as algae or cyanobacteria. Frequently such claims are associated with alum treatments, although there are other products that are used as well. The original manufacturer usually is not making claims. Rather, the user is the entity implying or actually claiming pesticide activity.

FIFRA Compliance Policy No. 3.5 states, in part:

> The Agency considers any application of an unregistered pesticide for other than personal use to be distribution or sale of an unregistered pesticide, a violation under Section 12(a)(1)(A) of FIFRA. This includes applying an unregistered pesticide to another person's property for other than monetary consideration. Furthermore, a person applying an unregistered pesticide for hire, only to provide a service of controlling pests without delivering any unapplied pesticide to any person so served, would be considered a distributor and is therefore subject to the higher penalties set forth in Section 14(a)(1) and 14(b)(1) of FIFRA.

The use of alum, lanthanum and other nutrient reducers, flocculants, etc., absent any additional claim, is perfectly legal and constitutes a viable option for water management. Once an expressed or implied claim to reduce, control, or manage an aquatic organism has been made in association with the application, however, the applicator/operator is in clear violation of FIFRA. In addition, because the application of the unregistered pesticide is to, over, or near waters of the U.S. or waters of the State, the provisions of the Clean Water Act are also triggered and compliance with that statute is required as well.

Pesticide registrants spend literally millions of dollars to provide data to the EPA to prove to a scientific certainty that their product can be used as directed and cause no unreasonable adverse effect on human health or the environment. What I hear when I raise objections to alum treatments is "It's not a pesticide!", Well, that's just wrong. All products intended to be used to manage aquatic pests such as vascular plants and algae are, in fact, pesticides. If allowed to continue unabated, you, the citizens, homeowners, recreators, and water users all, will be exposed to unregistered pesticides used in the waters of your state. That just seems contrary to all the complaints and objections I've heard during and since "The Pause". Perhaps these products which make pesticide claims are safe. Perhaps there's no adverse effect on human health or the environment. But how do we know? Which independent agency, like the EPA, has vetted the data to determine the risk to the environment? What are the adverse effects of layering floc on the benthic zone of lakes? What effect is there on nontarget organisms? Indeed – what is the risk to human health of exposure to a metal? The state of Florida doesn't even allow EPA-registered copper products to be used in public waters, yet they turn a blind eye to the use of an unregistered product for algae and cyanobacteria control. Does that make any sense at all?

So what about using alum as a means of managing HAB? In my opinion, the treatment of a lake with alum to control algae and bacteria constitutes the distribution and sale of an unregistered pesticide under FIFRA. In addition, and also in my opinion, the application would be in violation of the Clean Water Act and its NPDES provisions. Applications of pesticides in, near, and over waters of the United States must be in compliance with FIFRA to also be in compliance with the state NPDES Pesticides General Permit.

We must apply the standards required of all pesticides to alum treatments which either express or imply pesticide activity. Don't be charmed by "But it's not a pesticide."

Mr. Carlton Layne was a Law Enforcement Officer for EPA, Office of Pesticide Programs, Region 5, and is now retired. Carlton is particularly skilled in the investigation of pesticide incidents to determine compliance with federal, state and/or tribal requirements under applicable statutes and ordinances. In particular, he has expertise in both label interpretation and development in terms of applicability in the field by users, legal requirements and enforcement. He is currently Executive Director of the Aquatics Ecosystem Restoration Foundation.

Update from FWC – Invasive Plant Management Section

Here are some of the most recent developments within IPM:

- Instituted new schedule of operations that better clarifies exactly where treatments will occur.
- Developed additional higher-level management approval process for treatments to be conducted.
- Developed scopes of work to better integrate mechanical harvesting into the funded program. Some examples include:
    - Toho summer hydrilla management project
    - Toho fall, winter, spring hydrilla management project and comparison with herbicide application.
    - Lake Okeechobee hyacinth removal project
    - Request for information on alternatives to herbicide control of aquatic plants
- Testing near-real time monitoring of herbicide applications to better get treatment data (Ag-terra system).
- Formed a Technical Assistance Group to promote dialogue and mutual understanding among key stakeholder groups and agencies that share a common interest in the FWC's Aquatic Plant Management Program.
- Developing strategies with partners to better communicate what we do and why to give stakeholders a better understanding of the complexities involved in invasive plant management.
- Developing habitat management plans to help guide management on a lake-by-lake basis.
- We have a Legislative Budget Request for an additional $4 million to integrate mechanical methods into the program and to address expanding invasive plant issues.
- Rick Clark has left the FWC for the Department of Health. Rob Kipker assumed the role of Aquatics Sub-Section Administrator.

The FWC is committed to making these and other improvements that meet the desires of our stakeholders and provide our fish and wildlife with the habitats they need to flourish. We will continue to use science to guide our decision-making process and to answer current and future management questions or issues. Engagement with stakeholders is a key component of our management philosophy, and we will continue to solicit opinions from our diverse group of stakeholders.

Matt Phillips (mattv.phillips@myfwc.com) is the Section leader of Invasive Plant Management for the Florida Fish and Wildlife Conservation Commission (FWC) and is located in Tallahassee, Florida. He has a Bachelor of Science degree (with emphasis on aquatic systems) from Florida State University and has been working in the invasive plant management field for nearly 28 years. In his current role he oversees the management of invasive and nuisance vegetation through two management programs. An Uplands program that funds the control of invasive vegetation on all state of Florida public conservation lands which includes local, county, regional and state parks as well as all Wildlife Management Areas. An Aquatics program that funds the management of invasive and nuisance plants on approximately 1.25 million acres of public waters. The Section oversees a roughly $40 million dollar annual budget and has a staff of 32.5 FTEs located around the state. The Section also oversees two permitting programs that regulate the control of aquatic plants and the use of grass carp for plant control. Matt has memberships in several professional societies and sits on several committees including the National Aquatic Plant Management Society (APMS), Florida Aquatic Plant Management Society (FAPMS), Florida Prescribed Fire Council and Gulf and Atlantic States Resource Panel (GSARP) and is currently on the Board of FAPMS, as government affairs chair, and the Coffeen Nature Preserve. He has conducted various presentations on a variety of invasive plant issues and has several publications on invasive plant management including the use of prescribed fire for aquatic plant management. In a past life he was a semi-professional bass fisherman and member of the Bass Anglers Sportsman Society (BASS) and FLW, fishing tournaments throughout the Southeastern United States. He also dabbled as a soccer coach and announcer for his boys' middle and high school soccer teams and tries to spend as much time, outdoors, with his family as possible.

UF Grad Student Updates

Jonathan Glueckert

Originally from Long Island, Jonathan Glueckert received his undergraduate degree from Siena College in upstate New York where he studied environmental science. After working several seasonal jobs for the Forest Service in Idaho, Jonathan moved to Florida to work with Dr. Stephen Enloe at the UF/IFAS Center for Aquatic and Invasive Plants (CAIP) as a biologist on an interagency project with Florida Fish and Wildlife (FWC), Southwest Florida Water Management District (SWFMD), and US Fish and Wildlife Service. The agencies came together due to highly invasive Lygodium microphyllum, commonly known as Old World climbing fern. In the past decade, research of management practices regarding Old World climbing fern had plateaued, sparking the agencies' desire to research new herbicide technologies as well as new techniques to treat the invasive plant. In the three years Jonathan has worked as a biologist at CAIP, he decided to begin the master's program at the University of Florida Agronomy Department in order to achieve his goal of working in a land management position for a federal or state agency in the future. Majoring in Agronomy, Jonathan has focused his thesis on better management practices for Old World climbing fern. As long as his research makes managing invasive plants easier for land managers and contractors, Jonathan would like to continue researching and managing invasive plants in south Florida and beyond.

Jacob Thayer

Jacob Thayer, originally from Jupiter, Florida, is a graduate assistant with the UF/IFAS Center for Aquatic and Invasive Plants (CAIP) majoring in agronomy with a focus in aquatic plant management. Majoring in Forest Resources and Conservation, Jacob worked for CAIP as an undergraduate student under the supervision of Dr. William Haller. His research interests focus on aquatic soils and their affect on plant colonization. With a minor in soil and water sciences, Jacob has developed an interest in how nutrients interact in the soil as it relates to aquatic plants. He now works under Dr. James Leary and co-advisor Dr. Candice Prince studying herbicide screening. One could say working at CAIP is a family tradition for the Thayer family as Jacob, his brother, father and grandfather have all worked at the Center at one time or another. His future career goals are to eventually move back to Jupiter and work in aquatic plant management. However, as a first semester graduate student in the fall, he is excited to delve deeper into his research for now.

"I think its really fascinating that there is a whole other sphere that plants grow in that have different adaptations, different ways of dealing with stress like underwater oxygen stress, different nutrient species and stuff like that," Jacob said.

Jessica Solomon

Jessica Solomon was born and raised a Florida native. Growing up in Miami and Clearwater, she spent most of her time exploring the outdoors after school. At 18, Jessica moved to Gainesville to begin her education. She received her undergraduate degree in Wildlife Ecology and Conservation from the University of Florida's College of Agricultural and Life Sciences (UF CALS). Following graduation, Jessica moved to Berkeley, California where she worked at the University of California Berkeley's Field Station for the Study of Behavior, Ecology, and Reproduction with their colony of spotted hyenas. She then began working for a private ecological consulting firm as a biological monitor on construction sites. During most weekends, Jessica worked at International Bird Rescue doing medical triage on aquatic and oiled birds. After moving back to Florida to be closer to her family, Jessica began work for the Florida Park Service as a program assistant in the AmeriCorps program Florida

Conservation Corps (FLCC). After two years, she began invasive plant management at Payne's Prairie Preserve State Park. Through the FLCC's collaboration with the Center for Aquatic and Invasive Plant's Florida Invasive Plant Education Initiative (CAIP IPEI) Jessica was introduced to Dr. Stephen Enloe. Jessica majored in Agronomy at UF CALS as a graduate student and studying invasive plant ecology and management in Dr. Enloe's lab at CAIP. Jessica's thesis surrounds the management of the invasive plant known as "Mother-of-millions" (Kalanchoe species). Jessica graduated with her master's degree on December 13, 2019 and she is hoping to head to the eastern part of the US to pursue her career in the invasive plant realm.

"I now get to study invasive plant ecology and management and am very excited for my future in a career in invasive plant ecology," Jessica said.

Kalanchoe hand pull at Butler Beach- Jessie Solomon

Mackenzie Bell

Originally from Palm Desert in southern California, Mackenzie Bell served as a graduate research assistant at UF/IFAS CAIP until her graduation in December of 2019. Her thesis research surrounds improving Brazilian Peppertree management through novel application techniques aiming to reduce herbicide output and improve worker safety. Mackenzie began her education majoring in Biology and minoring in Sustainability at San Diego State University. She spent her final year of her bachelor's studying abroad in Melbourne, Australia at Deakin University. While studying in Australia, Mackenzie became interested in invasive species, experiencing the unique landscapes and wildlife of Australia. In 2016, Mackenzie moved to Florida to learn more about invasive species. The next year, Mackenzie worked for Paynes Prairie Preserve State Park. Through her work at Paynes Prairie, Mackenzie realized the importance of managing invasive species because of their relationship to biodiversity. Mackenzie majored in Agronomy at the University of Florida Agronomy Department and specialized in invasive plant and science m anagement. Brazilian peppertree (Schinus terebinthifolia Raddi) has been the focus of Mackenzie's research during her time in Dr. Enloe's lab. She also enjoys participating in citizen science programs such as the Santa Fe River Turtle Research Project. Since her graduation, Mackenzie has moved to Arizona in hopes of furthering her work with invasive species.

"This experience goes above and beyond what I could've asked for in university and I am grateful to have had the opportunity to be a part of this community at the Center for Aquatic and Invasive Plants and the University of Florida," Mackenzie said.

Katie Ray, UF/IFAS CAIP Communications Intern and Shelby Oesterreicher (soesterreicher@ufl.edu), UF/IFAS CAIP Communication Manager, contributed this article on behalf of UF/IFAS CAIP. The headshots are courtesy of Shelby Oesterreicher, and the field shot was provided by Jessica Solomon.

UF graduate students pictured here received awards at the Texas Aquatic Plant Management Society Annual Conference. Congratulations Mohsen Tootoonchi (PhD student, won a $1000 scholarship), Ian Markovich (MS student, won a $500 scholarship) and Joey Sigmon (MS student, won the best student paper award $250)! Well done! Photo credit Kelly Duffie

A Response to Frequently Asked Questions about the 2018 Algae Blooms in Lake Okeechobee, the Caloosahatchee, and St.Lucie Estuaries[1]

Lisa Krimsky, Ed Phlips, and Karl Havens[2]

The unknown economic and health impacts associated with these algae blooms have resulted in a concerned and sometimes confused citizenry. The well-intentioned,though sometimes misguided, messages from individuals and local advocacy groups have resulted in a chaos of mixed and sometimes questionable information, particularly on social media. The authors of this document compiled a list of frequently asked questions posted in Facebook comment feeds regarding the blooms. The purpose of this document is to address the questions with scientifically backed evidence and to advise when more research is needed.

1. Why is there a massive algae bloom this year in Lake Okeechobee?

To answer this question, we first have to provide some background about algae blooms and Lake Okeechobee. An algae bloom is the rapid and substantial increase in algae biomass in an aquatic system.

Blue-green algae, or cyanobacteria, need a few specific ingredients and conditions to grow: nutrients, most importantly nitrogen and phosphorus, and adequate sunlight.

Lake Okeechobee is a large, shallow, nutrient-enriched lake. A long history of human activities has resulted in a large reserve of nutrients in the watershed soils, wetlands and bottoms of tributaries, as well as in the sediments of the lake (Flaig and Havens 1995, Havens 2013). Increased human development around the watershed has exacerbated the nutrient problem.

The lake's shallow waters, particularly around the south and west shoreline, where light penetration is highest, provide favorable conditions for algae to grow. In addition, the lake experiences a long season of algae-growth-stimulating high water temperatures due to its subtropical location. These conditions are favorable to blue-green algae (Phlips et al. 1993;Havens et al. 1994; Paerland Huisman 2008). As with many lakes and reservoirs in Florida and around the world, blue-green algae are common in Lake Okeechobee. Certain types o blue-green algae have special adaptations that help them dominate blooms. For example, some species have the ability to adjust their position vertically in the water column through buoyancy regulation, which allows them to find the optimal depths for light and nutrient availability.

This allows cyanobacteria to bloom in the open waters of the lake where light limitation can make it difficult for other algae species (Havens et al. 2016).

Lake Okeechobee is most prone to having large blooms of harmful cyanobacteria when the weather is warm and sunny, typically in the spring through early fall. Periods of high rainfall can increase the potential for blooms by elevating the external flow of phosphorus- and nitrogen rich water from the watersheds that feed the lake. Tropical storms, like Hurricane Irma, can also result in the mixing of phosphorus-rich bottom sediments, providing additional fuel for blooms.

Figure 1. A blue-green algae,or cyanobacteria,bloom at Port Mayaca, June 2018. Credits: Forrest Lefler, UF/IFAS

In May 2018, a record amount of rain fell over south Florida, delivering extra nutrients from the local watershed into the lake. These nutrients added to the nutrients that had already been built up from the storm water runoff and perhaps sediment resuspension during Hurricane Irma.

This rainfall, combined with hot summer days and plenty of sunshine, created

1. This document is ED-2, one of a series of the Florida Sea Grant Program, UF/IFAS Extension. Original publication date August 2018. Visit the EDIS website at http://edis.ifas.ufl.edu.

2. Lisa Krimsky, UF/IFAS Extension Florida Sea Grant water resources regional specialized agent Ill, southeast district; Edward Phlips, professor of algal physiology and ecology, School of Forest Resources and Conservation, Program in Fisheries and Aquatic Sciences; and Karl Havens, director, Florida Sea Grant College Program; UF/IFAS Extension, Gainesville, FL 32611.

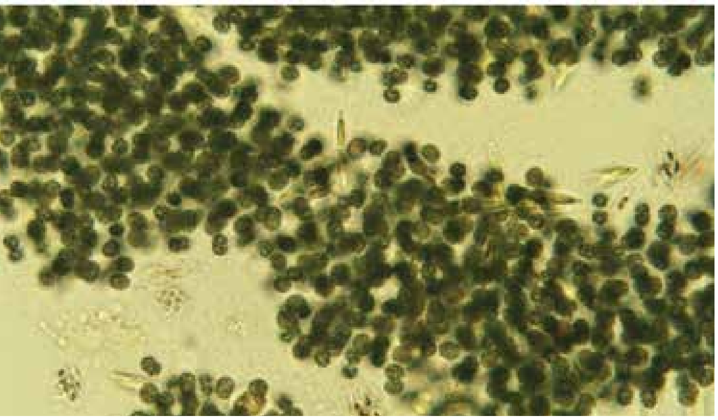


Figure 2. Microscopic image of blue-green algae (Microcystis) collected at Port Mayaca, June 2018. Credits: Forrest Lefler, UF/IFAS

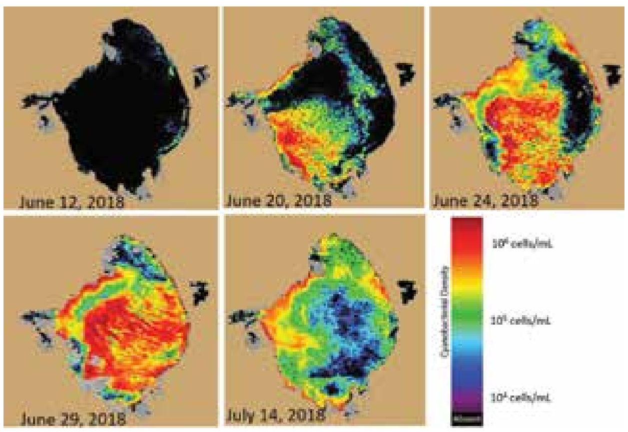


Figure 3. Satellite imagery showing the progression of cyanobacteria concentration in Lake Okeechobee. Scale bar shows the cell concentration in cells/ml where cool colors represent lower concentrations and warm colors show high concentration. Black indicates no bloom, gray is clouds or no data, and brown is land. Credits: NOAA, derived from Copernicus Sentinel-3 data from EUMETSAT

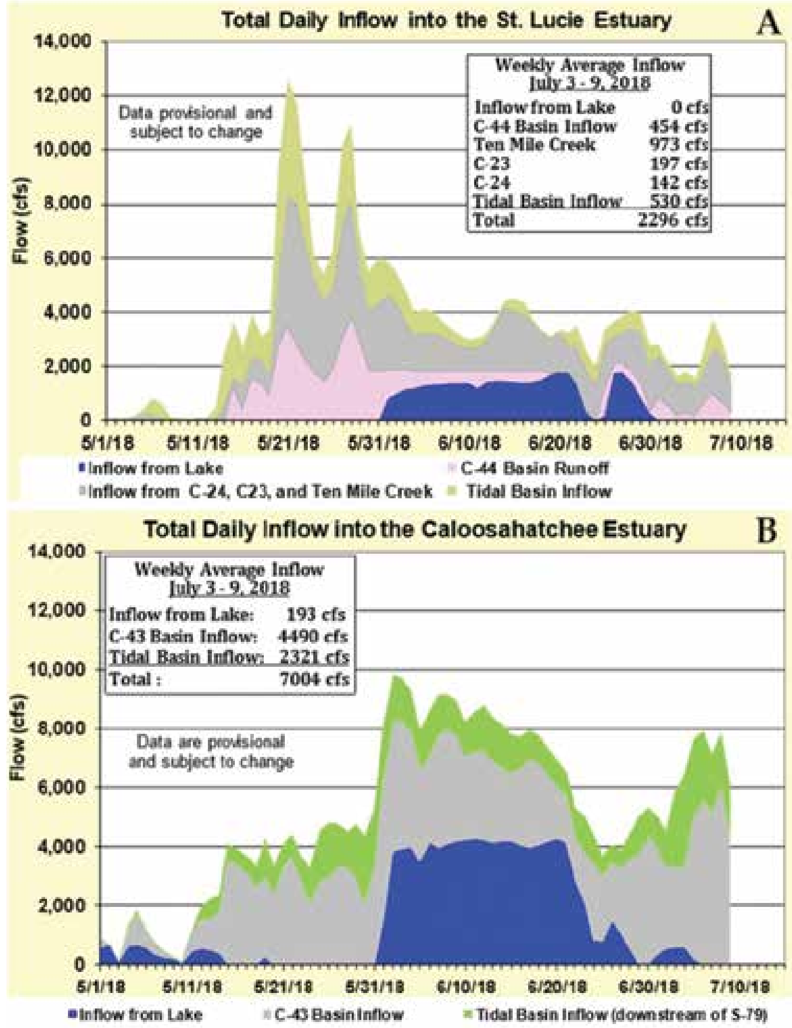


Figure 4. A) Estimated total daily inflow from Lake Okeechobee and runoff from the C-44, C-23, C-24, Ten Mile Creek, and tidal basins into the St. Lucie Estuary. B) Estimated total daily inflow from Lake Okeechobee and run off from the C-44, C-23, C-24, Ten Mile Creek,and tidal basins into the Caloosahatchee Estuary. Credits: SFWMD

conditions that supported an intense algal bloom. June 2018 satellite images produced by NOAA show the development of a cyanobacteria bloom in Lake Okeechobee beginning in the middle of June, then intensifying and spreading to other parts of the lake.

2. Why are there blooms in the estuaries?

Algae blooms in estuaries are dependent on the same basic ingredients as blooms in lakes, including high nutrient levels and sufficient light availability. The SLE and CE are subject to blooms of both freshwater and saltwater algae.

The conditions leading to the two types of blooms are different. Saltwater blooms typically occur when salinities in the estuaries are greater than 5 ppt. Both estuaries have sufficient nutrient inputs to support blooms, but relatively high tidal flushing rates often limit the intensity of saltwater blooms because of continuous dilution with coastal waters. For example, in the SLE the North Fork region of the estu ary has the slowest flushing rates (7-14 days for 50% water turnover), allowing blooms of diatoms and dinoflagellates to build (Phlips et al. 2012), but not long enough to sustain the type of massive freshwater algae blooms observed in 2016 and 2018. Freshwater cyanobacteria blooms, such as those observed in 2016 and 2018, typically occur during periods of high rainfall, when nutrient-rich discharges of water from the watershed are large, resulting in very low salinities in the estuary. During some extreme rainfall periods, the US Army Corps of Engineers, also known as the Corps, discharge water from Lake Okeechobee into the SLE and CE as required by the Lake Okeechobee Regulation Schedule to prevent the Herbert Hoover Dike from being compromised. When an intense algal bloom is occurring in the lake, these discharges can introduce fresh water and nutrients into the estuaries, precipitating intense bloom conditions. Cyanobacteria many also be flushed out of the lake and into the estuaries, though

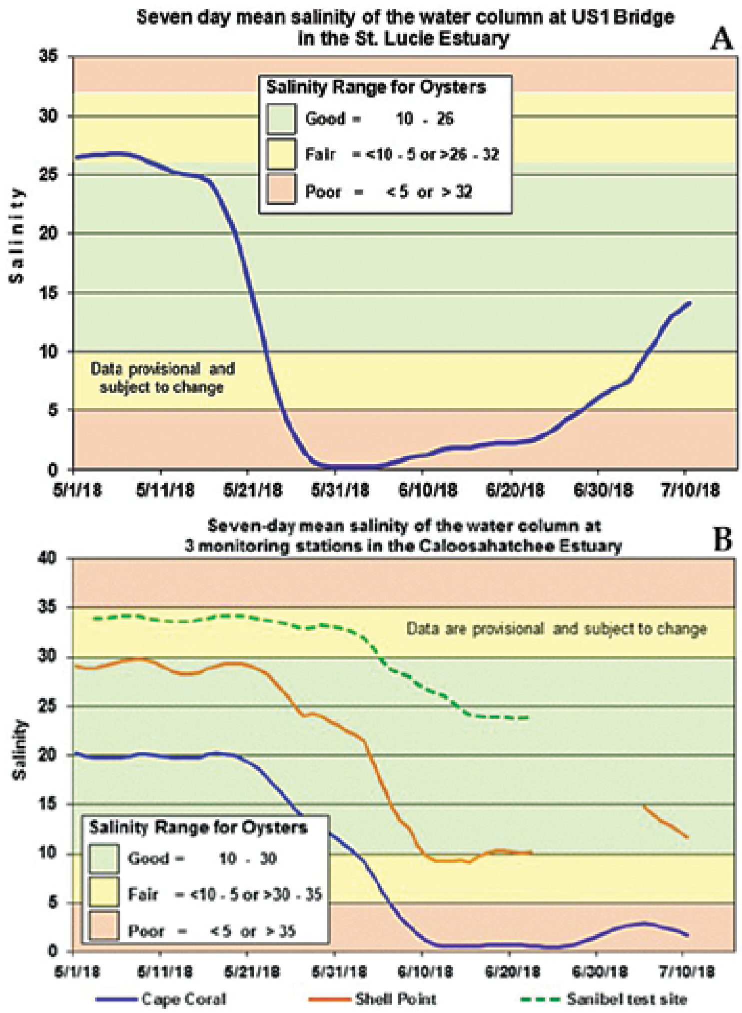


Figure 5. A) Seven-day mean salinity of the water column at the US Highway 1 Bridge. B) Seven-day mean salinity of the water column at 3 monitoring stations in the Caloosahatchee Estuary. Credits: SFWMD

direct evidence of this during the 2018 blooms does not exist. Refer to question 3 for further discussion.

3. Are the algae in the estuaries from the lake?

Anecdotal and pictorial evidence of algae-bloom water flowing through the St. Lucie and Caloosahatchee canal systems has led people to speculate that Lake Okeechobee was a direct contributor to at least some of the algae blooms that have sprung up in the estuaries in 2016 and 2018.

In terms of the St. Lucie Estuary, a three-year study from 2005-2008 of algae blooms showed that the large toxic freshwater Microcystis bloom in 2005 was strongly connected to discharges from Lake Okeechobee into the South Fork region of the estuary, necessitated by very high rainfall levels (Phlips et al. 2012). Since the overall structure of the St. Lucie Estuary and Lake Okeechobee has not changed dramatically since 2005-2008, it is possible to suggest that the blue-green algae blooms of 2016 and 2018 may share at least some of the basic characteristics of the 2005 bloom. However, there appears to be insufficient scientific evidence currently available to test this hypothesis.

In 2018, most of the water that flowed into the two estuaries came from their own basins, and in the St. Lucie estuary salinity was reduced to zero, which is favorable for blue-green blooms, before lake discharges began.

4. What kind of algae make up the blooms?

The Florida Department of Environmental Protection (DEP) has been collecting water samples at sites with visual indication of a surface water algae bloom throughout the St. Lucie and Caloosahatchee estuaries. Data from Lake Okeechobee water samples are limited to a few sites along the shoreline. The blue-green algae Microcystis aeruginosa was identified as the dominant taxon in 45 of 87 total samples collected throughout the entire region since July 17, 2018 (DEP 2018). The US Geological Survey recently conducted an independent sampling program and found two species of Microcystis, both with the potential to produce toxins. The scope and results of the research associated with the 2018 blooms in Lake Okeechobee have not yet been fully reported by the groups involved, so further details will likely be forthcoming.

5. Is the algae toxic? Is it harmful to people?

Some, though not all, blue-green algae can produce toxins. Microcystis aeruginosa, one of the dominant bloomforming species in Lake Okeechobee, has been shown to produce the hepatotoxin microcystin, which can result in gastrointestinal problems, and, in extreme cases, liver damage, if people ingest untreated contaminated water. Impacted water sources used for human consumption are typically treated to destroy the toxin. Some blue-green algae can produce other types of toxins such as neurotoxins, which affect the nervous system and can cause respiratory distress and eye irritation. Some blue-green algae, including Microcystis aeruginosa, can cause skin irritation in a small proportion of otherwise healthy individuals. These reactions are often mild and are less of a concern than the more prominent and toxic hepatotoxins in Florida (Phlips et al. 2003; Pilotto et al. 2004).

In Florida, DEP coordinates water sampling and tests for algal species and toxicity in both freshwater and marine environments, and the Florida Department of Health takes the lead in determining if an algae bloom presents a human health risk. To avoid possible adverse symptoms and effects of exposure to toxins, humans and pets should avoid direct contact with water contaminated with intense blue-green algae blooms.

6. Why do toxin levels vary?

Concentrations of algae toxins in ecosystems are often roughly proportional to the amount of toxin-producing algae present. However, environmental conditions, including nutrient and light levels, and the age and health of algae cells can also affect toxin levels. For example, blooms of Microcystis aeruginosa frequently form surface scums that can be driven by wind onto shorelines, resulting in massive accumulations of biomass and very high, but spatially restricted, toxin levels. Methods used to collect samples for analysis can also affect the level of toxins detected. For example, monitoring efforts focusing on the collection of samples from hot spots in algae biomass accumulation can result in much higher concentrations than the average toxin levels in an ecosystem. While sampling methodology might result in overestimation of total toxin levels in ecosystems, accumulations of high levels of toxins can pose local health issues, as described in the answer to question 5.

7. Is this a wider-spread issue right now in the United States?

Algae blooms, including cyanobacteria blooms, are a growing problem not only in Florida but throughout the United States and world. Although algae blooms are naturally occurring, human activities and nutrient inputs from stormwater, agriculture, urban landscapes, and sewer and septic systems have significantly increased the amount of nutrients available for bloom formation in many environments around the world.

In addition to Florida, algae blooms have been reported this year in Utah, Lake Erie, New York, North Carolina, Oregon and as far away as New Zealand, Australia, the Philippines and the Middle Eastern country of Oman. The problem of harmful algal blooms is expected to grow with continuing increases in nutrient loads and a warmer, more extreme climate with prolonged periods of heavy rainfall and drought. This is particularly true for blooms involving cyanobacteria, which are known to favor hot weather

(Havens 2018a, Havens 2018b, Paerl and Huisman 2008, and Phlips 2015).

8. What is being done to stop this from happening over and over?

The existing 2018 bloom in Lake Okeechobee could continue through the summer, although changing environmental conditions can alter the course of a bloom. Freshwater releases were temporarily stopped at the end of June. The Corps initiated releases again on July 13. Future releases of water from the lake could happen if the summer rainy season brings heavy rainfall to the watershed north of the lake.

In a longer-term context, there are numerous efforts underway to control nutrient inputs to the lake and estuaries, and to reduce harmful freshwater discharges from the lake to the estuaries. An in-depth description of all these efforts is beyond the scope of this response, so we provide a general overview of the issue and solutions.

As noted, there are two main challenges that need to be addressed to prevent the reoccurrence of lake and estuary blue-green algae blooms. First, reductions in both nitrogen and phosphorus inputs are needed in the watersheds around the lake and estuaries, as well as within lake sediments. (Havens and Frazer 2012; Paerl et al. 2016). This reduction includes direct inputs into and from Lake Okeechobee as well as inputs from lands that surround the St. Lucie and Caloosahatchee Rivers and Estuaries.

Algae blooms in Lake Okeechobee in the 1980s were the impetus for the Surface Water Improvement and Management Plan (SFWMD 1989). Certain sectors, such as agriculture, have made significant reductions in nutrient exports. Today, Lake Okeechobee, the Caloosahatchee Estuary Basin and the St. Lucie River and Estuary are all under Basin Management Action Plans (BMAPs) that provide a blueprint for reducing pollutant loadings. Even with these significant nutrient reductions, numerous challenges to reducing inputs to the lake still remain.

In fact, there has been no reduction in total nutrient loading to Lake Okeechobee since nutrient-control programs began in the 1980s. Much of the watershed soils are so saturated with phosphorus that even if all sources were stopped today, scientists estimate that the current load of residual nutrients into the lake would last more than 50 years. For this reason, the South Florida Water Management District (SFWMD) has been pursuing regional nutrient-control programs along with controls at the sources of the nutrients to stop the sources and also capture the residual legacy nutrients from soils, wetlands, and other places before they reach the lake. The watersheds around the two estuaries also have this same problem with residual nutrients in soils, wetlands, and creek bottoms.

For the lake, an additional challenge is the large accumulation of phosphorus in its sediments, which is called the internal phosphorus load. Studies indicate that the phosphorus-enriched sediments in the central region of the lake are a source of phosphorus to the water column and thus, to algae (Moore et al. 1998). Over the course of a year, the internal load of phosphorus in the lake is approximately equal to the external load. Modeling indicates that even with an immediate cessation of phosphorus inputs to the lake, internal loading from sediments would increase until the depletion of the internal phosphorus store, which would keep phosphorus concentrations high for many decades.

The second challenge that needs to be addressed is that of water quantity. Lake Okeechobee is engineered to act as a reservoir rather than a natural lake with fluid boundaries. Water levels in the lake are managed for flood control, water supply, navigation and the health of the lake's littoral zone. There are numerous existing constraints to moving the water south out of Lake Okeechobee. To reduce or eliminate excess discharges to the west and east coasts, we must complete alternative water storage and water flow projects.

9. Will the EAA reservoir help?

The Everglades Agricultural Area (EAA) reservoir is one of a number of water storage tools that will help, though not solve, the problem of algae blooms in the lake. Florida's 2017 Water Resources Law directed the expedited design and construction of the EAA reservoir. The current proposal will be designed to hold at least 240,000 acre-feet of water and include water-quality features necessary to meet state and federal water-quality standards. An acre-foot of water is the volume of water necessary to cover one acre of land, an area roughly the size of a football field, one foot deep.

The SFWMD estimates that the EAA project would reduce the number of high-flow freshwater discharges, the same that are detrimental to oyster populations, by 40 percent for the St. Lucie Estuary and 55 percent for the Caloosahatchee. It is important to note that the environmental benefits from the EAA reservoir are modeled with the assumption that all currently constructed and authorized Central Everglades Planning Project and Comprehensive Everglades Restoration Plan (CERP) projects in the area will be operational. According to the project schedule, the EAA reservoir project will be submitted for congressional authorization by December 2019.

10. Will CERP solve this problem?

The Comprehensive Everglades Restoration Plan (CERP) is a 35-plus-year plan to "restore, preserve, and protect the south Florida ecosystem while providing for other water related needs of the region, including water supply and flood protection." The 68 project components within the plan address the quality, quantity, timing and distribution of fresh water in the natural system. There are a number of projects within CERP that will have direct impacts on Lake Okeechobee and the coastal estuaries. These are some of the ongoing and proposed projects most pertinent to the issue of freshwater discharges.

Reservoirs – In addition to the EAA reservoir, CERP includes construction of the C-43 western basin reservoir, the Indian River Lagoon-South Project, which includes the C-44 eastern basin reservoir, C-23, 24, and 25 reservoirs, and a northern Kissimmee River reservoir.

Aquifer Storage and Recovery (ASR) – ASR technology may provide the ability to store and recover large volumes of water over longer periods of time. ASR facilities inject treated and untreated groundwater, partially treated surface water, and reclaimed wastewater into the Floridan Aquifer. The water is injected in areas where the aquifer is brackish.

This creates a freshwater bubble that may allow for water to be recovered and returned to the lake for use during drought years. CERP originally planned for 333 wells at 5 million gallons per day. A groundwater modeling study identified numerous constraints to ASR and the number of possible ASR wells has been modified to 130. This change greatly reduces the storage capacity of CERP compared to what originally was planned. CERP also included a system of interconnected rock quarry lakes (the Lake Belt) in southeast Florida, and those also have been dropped from the plan, meaning a further loss of regional storage.

Additional smaller-scale water storage opportunities outside of those in CERP are being implemented when available. For example, dispersed water management, or water farming, distributes shallow water across parcel landscapes such as fallow citrus land. Even with all of these water storage projects, the entirety of CERP will take decades to implement. In addition, because of the shortfall of ASR, Lake Belt and other storage, CERP is projected to fall short of the amount of water storage needed to substantially reduce estuary discharges and rehydrate the Everglades by over one million acre feet of water (NASEM2016).

11. Are deep-injection wells a good short-term solution to stop releases of water?

Deep well injection (DWI) is the permanent disposal of water deep below the earth's surface. DWI is currently being considered as an option to use when discharges to the estuaries are necessary. Proposed use of wells would occur only when fresh water would otherwise be lost to the ocean, causing harm to the estuaries on the way. There is debate about the use of DWI because disposed water is not recoverable. Deep well injection is not a new technology, and there are currently 180 Class I wells in operation in Florida, most for wastewater disposal into the Boulder Zone. Deep injection wells alone will not entirely eliminate freshwater discharges to the estuaries. An internal SFWMD analysis of future conditions suggests that the use of 50 deep-injection wells in combination with proposed restoration projects reduces the annual volume of lake discharge by 67 percent and 77 percent for the St. Lucie and Caloosahatchee estuaries, respectively.

Additional Resources

- Options to Reduce High Volume Freshwater Flows to the St. Lucie and Caloosahatchee Estuaries and Move More Water from Lake Okeechobee to the Southern Everglades: An Independent Technical Review by the University of Florida Water Institute
- Central Everglades Planning Project Post Authorization Change Report Feasibility Study and Draft Environmental Impact Statement
- Florida Sea Grant Algae Bloom webpage

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A re-examination of mechanical harvesting hydrilla on Lake Tohopekaliga: Is it what we thought it was?

James Leary[1], Alex Dew[2], Ed Harris[2], Dean Jones[1], Candice Prince[1] and Ben Sperry[1]

Fresh hydrilla harvested on to the conveyor into the hopper of a commercial aquatic harvester boat.

Background

Many of our readers will recall January 2019 when the Florida Fish and Wildlife Conservation Commission (FWC) called for a pause to their Aquatic Plant Management (APM) Program, coinciding with a statewide series of public listening sessions regarding their management of public waterbodies. In these sessions, strong voices from individual stakeholders of the general public raised concerns about the over-reliance of herbicides. In March 2019, the FWC responded with the establishment of an enhancement plan which included exploring ways to better integrate mechanical aquatic plant harvesting. Soon after, in June 2019, a contractor bid was awarded to initiate a pilot program deploying mechanical harvesters to remove submersed hydrilla (*Hydrilla verticillata* (L.f.) Royle) from designated plots on Lake Tohopekaliga (Lake Toho).

Hydrilla is a submersed aquatic monocot, native to South Asia. Since being introduced in the late 1950's, it is now one of the most dominant aquatic plants in Florida. The dioicous female form is a perennial that also produces copious propagative tubers and turions for recruitment and colonization of whole lake systems (Haller et al. 1976). It can develop dense monotypic populations that "top-out" reaching fresh weights equal to 11-13 tons acre^{-1} (Haller et al. 1980, Mericas et al. 1990) causing several effects: (i) exclusion of native vegetation, (ii) reduction in water storage capacity, (iii) impeding flood conveyance (iv) disruption of boat access and navigation and (v) impairment of the aquatic environment (Langeland 1996). Since 2008, The FWC has been given the mandate to manage hydrilla using a risk-based decision process that balances the hazards described above against the derived benefits of low to moderate hydrilla coverage (e.g., fish and wildlife habitat) (Hoyer et al. 2004, Johnson et al. 2014). In short, hydrilla cannot be feasibly eradicated from any of Florida's lakes where established.

Whole-lake fluridone treatments became the standard for managing hydrilla in the mid-1980s through the mid-2000s with 115,000 acres treated (Feller et al. 1999). At low doses (i.e., 5-15 ppb), fluridone was a highly effective, selective and economical option until plant tolerance to the herbicide was discovered across many lakes (Getsinger et al. 2008, Michal et al. 2004). As a result, management abruptly transitioned to an alternate herbicide, endothall. Since 2010, over 188,000 acres of hydrilla have been managed across 229 public lakes with 97% of the management actions being in-water herbicide treatments and 88% of those treatments with endothall as the proven standard. Intensive use of this herbicide over the last decade is starting to show signs of tolerance development (Berger and MacDonald 2011). The over-reliance of a single active ingredient continues to be a vulnerability of a feasible hydrilla maintenance strategy.

Mechanical harvesters are a century-old technology used for cutting and collecting aquatic vegetation. The typical harvester is an aluminum hull watercraft with side- or aft-mounted paddle wheels for propulsion; reciprocating cutter bars are mounted on the bow and coupled to an inclined, porous conveyor table able to cut several feet below the water surface (Koegel et al. 1973). The

[1] Center for Aquatic and Invasive Plants, University of Florida/Institute of Food and Agricultural Sciences

[2] Invasive Plant Management Section, Florida Fish and Wildlife Conservation Commission

conveyor table transfers the cut materials into hoppers of varying capacities (Bowes et al 1973). This physical control system is generally regarded as environmentally neutral by the public and can benefit a lake system by removing biomass instead of leaving it in the water column to decompose (Haller 2014). However, mechanical harvesters are inherently non-selective and may also have a direct impact due to bycatch of fish and other fauna. Furthermore, mechanical harvesting is also considered less efficient and more cost-prohibitive when compared to standard chemical control options (e.g., Langeland 1996; Hoyer et al., 2005). Previous research has estimated machines to harvest 0.5-2.0 acres hr^{-1}, being influenced by the type of aquatic vegetation, the density of standing biomass per unit area and transport distance from the disposal site (Koegel et al. 1973, McGehee 1979, Sabol 1987, Sassic 1982). Over the last decade, mechanical harvesting has been utilized by the FWC to manage just over 2700 acres with 76% of the tasks relegated to removal of tussocks and filamentous algae. Only 48 acres of hydrilla were harvested in the same time period, which suggests a very limited role in the institutionalized maintenance strategy.

In support of this new FWC enhancement mission, we are re-examining the potential of mechanical harvesting to become a more integrated component of hydrilla management in Lake Toho. It is the second largest lake in Osceola County at >18,000 acres, with an average depth <7 ft, for a total estimated volume between 30-50 billion gallons. It is valued for its boating, fishing and wildlife habitat. This lake was once severely impaired by municipal waste discharges starting in the 1950s, with peak phosphorous (P) loading in 1980. This hyper-eutrophic system was succumbing to algal blooms, organic sedimentation and lake succession (Williams 2001). Once waste discharge ceased, total P declined significantly from >200 ppb to <100 ppb by 1992 (James et al. 1994). Since then total P loads have averaged <40 ppb (LakeWatch.org). Toho has progressed from a hyper-eutrophic state to a more natural mid-eutrophic state.

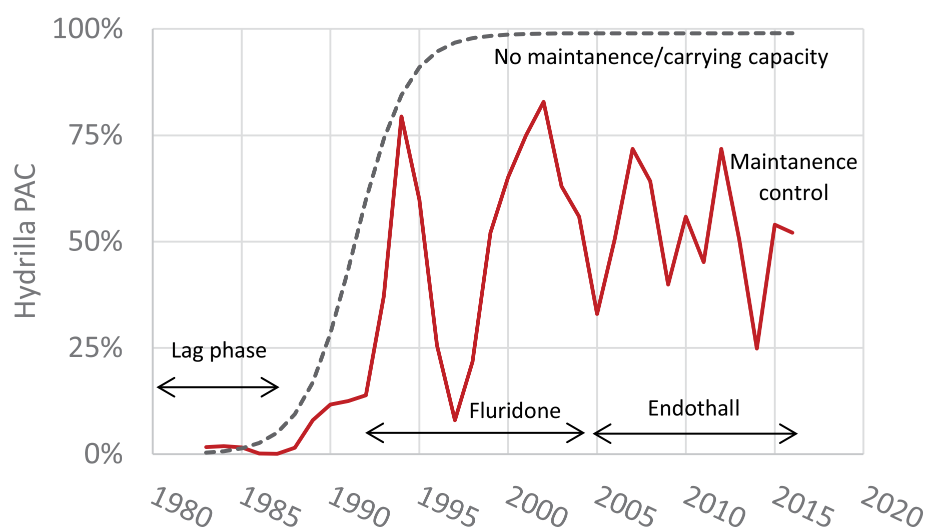
Coincidently, hydrilla was first documented in Lake Toho in 1983. It was likely introduced before then and established undetected. The lag phase of an invasion when a species begins propagating is often regarded as the best opportunity for eradication. For many species this period could last several decades. For hydrilla in Lake Toho it took less than 10 years from first report to go from <2% percent area cover to >75% (Feller et al. 1999). The window of opportunity to eradicate hydrilla from Lake Toho has most certainly closed and in its place a herbicide maintenance strategy over the last three decades has kept hydrilla from infesting the entire lake; stabilizing the population at ~50% cover (i.e., ~9,000 acres). Since 2010, Lake Toho has received 17% of all statewide hydrilla treatments, more than any other single lake in the state, and more than lakes Istokpoga and Kissimmee combined. With these allocations, FWC treats on average >3500 infested acres every year on Lake Toho; this is a large undertaking that would quickly transition to an expensive recovery with any disruption in the current strategy.

If the herbicide maintenance program is to be offset with mechanical harvesting operations, an optimal harvesting strategy is needed to compensate for managing large scale infestations (Finnegan et al., 2014). In accordance with the FWC plan to enhance their APM program, we devised a research plan in coordination with the harvesting contract on Lake Toho during the summer of 2019 to re-evaluate the feasibility of harvesting in an operational situation. The purpose of this research was to update technologies that would generate new data analytics calibrating operational efficiency and efficacy of mechanical harvest operations to be considered in future strategic planning of a more integrated approach to hydrilla management.

Methods

A task agreement was established with a vendor to remove hydrilla biomass from three feet below the water surface during the period of June 14 through August 30 (77 days). The vendor deployed four Kelpin 800 harvesters. These harvesters have 9.5 ft cutter/conveyor tables with a holding capacity of 800 ft^3. The cutter bar can harvest to a depth of 5.5 ft. Harvesters were networked to multiple platform barges, airboats and tugs for separate transport and offload of harvested materials to spoil islands designated near the harvest plot areas.

A total of three plots were established



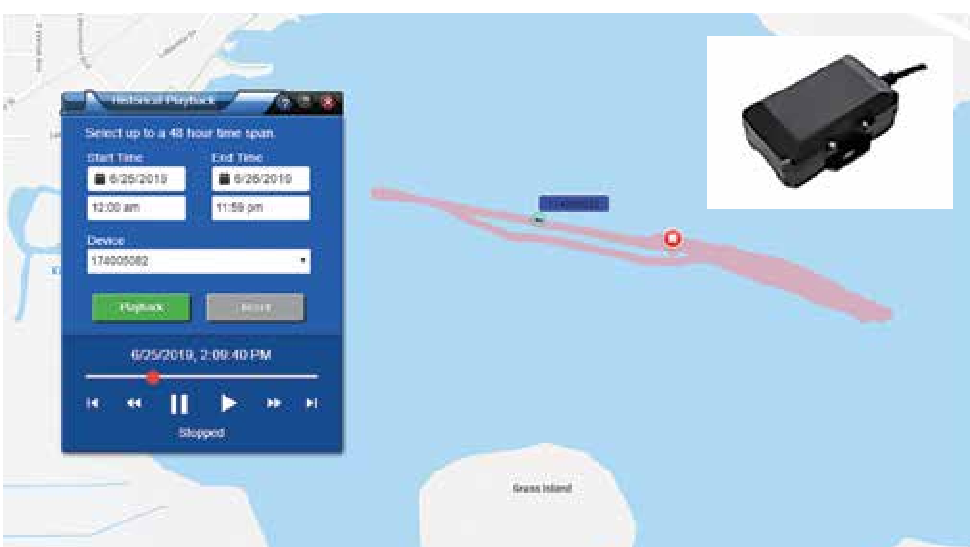
Percent area cover (PAC) of hydrilla on Lake Toho from 1983-2016 (red) with a simulated invasion curve (black dash) depicting the short lag phase and the carrying capacity of Lake Toho up to 99% of the total area.

The three harvest plots displayed; rectangular shallow plot in the north cove; two square plots in the south cove designated A and B, respectively. Recorded track data of the harvesters ferrying between plots and during the contract period of 06/14-08/30.

in heavily infested sections of Lake Toho for contract harvesting. The north cove had a long rectangular plot that was 85 acres. Water depth of this shallow plot started at 3.5 ft and increased 5 ft in that two-month period. This is a major boat access connecting with the Kissimmee boat ramp. It is marshy with thick sediment layers and well-established emergent vegetation communities including Kissimmee grass (*Paspalidium geminatum*), American lotus (*Nelumbo lutea*) and spatterdock (*Nuphar advena*) among others. Two more square plots, each 125 acres, were established in the south cove. The water depth in this section of the lake started at 6 ft and increased to over 7 ft in this same period. These plots were in open water further away from the littoral zones and not typically prioritized for management. For the purpose of this article, these plots have been designated A and B, respectively.

Each harvester was retrofitted with AT-V4 Pro GPS trackers (www.usfleettracking.com) simultaneously connected to the North American cellular network and GNSS. Each device was programmed to record position and timestamp on 10-sec intervals for 24-hr monitoring in real time. Data is being stored on remote servers and is retrievable as comma separated value (.csv) files observable in multiple software (e.g., Arcmap®, Excel®, Notepad, etc.). The spatial and temporal point data collected were translated to interpret efficiency metrics including harvester speed, area covered and harvest intensity (i.e., time per unit area).

A total of seven hydroacoustic surveys were conducted over the 77-day period to monitor harvesting progress. A 200-kHz transducer with 20° beam width integrated with WAAS GPS (Lowrance Electronics; Tulsa, OK) was mounted on the transom of a 15 ft jon boat to a depth 6 in below the water surface, recording 10-15 pings s^{-1} at boat speeds ≤ 7 mph. Transects were spaced 165 ft apart. Scan log data (.sl2) files were post-processed with BioBase® cloud-based data processing to create spatial data layers with depth and aquatic plant height to calculate biovolume ratios of all georeferenced locations (Radomski and Holbrook 2015, Valley et al. 2015 and 2016). Changes in biovolume over time were interpreted as a measure of efficacy.



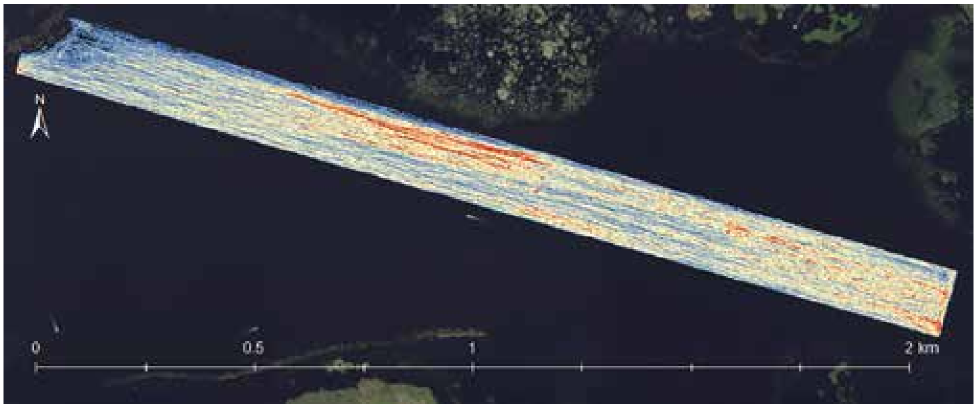
The network display of the GPS tracker monitoring the harvester in real time

Results

A total of 1022 boat-hours was recorded for all three plots (i.e., 254, 435 and 333 hrs for SouthA, SouthB and North, respectively). The average speed of the harvesters was 1.6 mph; with a 9.5 ft cutting bar, this translates to a harvesting rate of 1.9 acres hr^{-1} when boats are operating. Harvest operations were conducted during day light hours (i.e., 0700-1900) with a slight skew towards morning operations due to likely suspensions during afternoon thunderstorms in the summer months. Typically, 2-3 harvesters were operating in unison on different sections of each plot for an average of 12.7 boat-hrs per day. The average daily harvest was 18 acres for an average rate of 1.4 acres per boat-hr. This is less than the rate of speed calculated above, suggesting that ~75% of boat operations were dedicated to harvesting with the remaining 25% used for unload and ferry. As mentioned above, these were heavy infestations that

Harvester Efficiency Metrics for the Three Plots

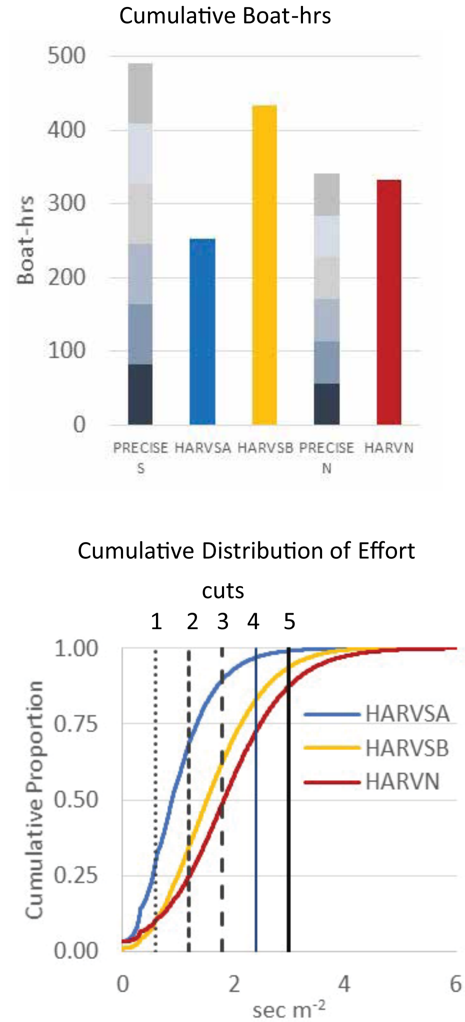
Plot	Boat-hrs day^{-1}	Acre day^{-1}	Speed (mph)
SOUTH A	12.3	18.0	1.7
SOUTH B	12.5	16.8	1.5
NORTH	13.1	18.8	1.5



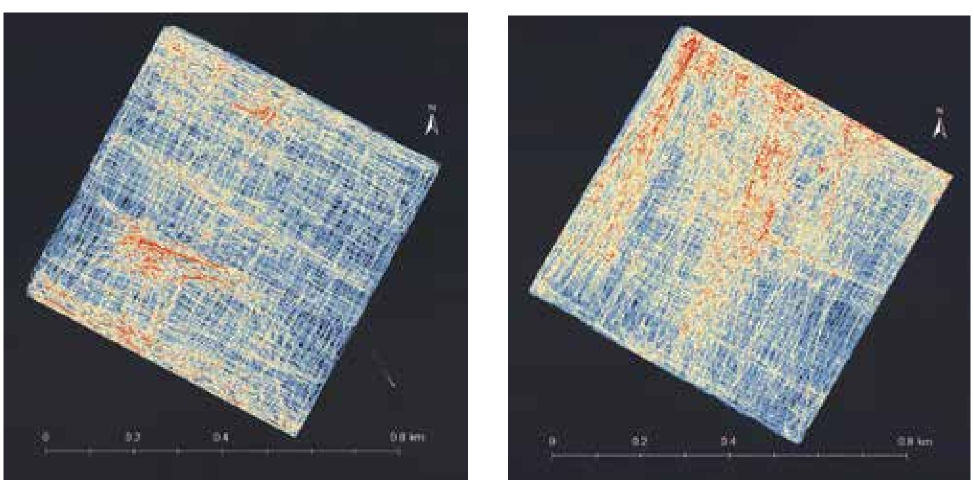
would influence the number of loads to be transported to strategically placed barges. These harvester efficiency metrics using current GPS technologies corroborate closely with the previous reports cited (Koegel et al. 1973, McGehee 1979, Sabol 1987, Sassic 1982).

Harvest tracks covered 97-99% of the plot areas with buoys placed in the corners of each plot to serve as a visible navigational aid. Based on calculated speeds (i.e., 1.6 mph) a precision harvest with parallel tracks and 20% overlap could harvest the entire north and south plots with a single cut in ~57 and 82 boat-hrs, respectively. The total effort (i.e., boat-hrs) recorded in south A plot was enough to cut the entire area over three times but the median, (i.e., interquartile) range of the plot area was only harvested between 1-2 times. The harvest south B and north plots were less precise. Accumulated efforts exceeded five cuts each, while the median range of the areas were harvested approximately between 2-4 cuts, respectively. The low harvest precision could be attributed to operator bias towards topped-out (visible) hydrilla and the lack of GPS navigation to maintain straight lines with effective overlap. This highlights one of the primary challenges to harvesting hydrilla and other submersed aquatic vegetation. Customarily, most harvest operations are contracted to remove more apparent tussocks and emergent vegetations, where visual acuity produces acceptable precision.

Baseline surveys of the three plots were conducted on 05/30/2019, two weeks before harvesting. Average percent area cover (PAC) and biovolume (BV) ranged from 54-98% and 35-54%, respectively. This is the time of year when hydrilla is actively growing but has not yet reached the surface. The average BV exhibited large standard deviations resulting from the heterogeneity of hydrilla occupying each of the plots. The south A plot exhibited the lowest PAC and BV. In the first month of



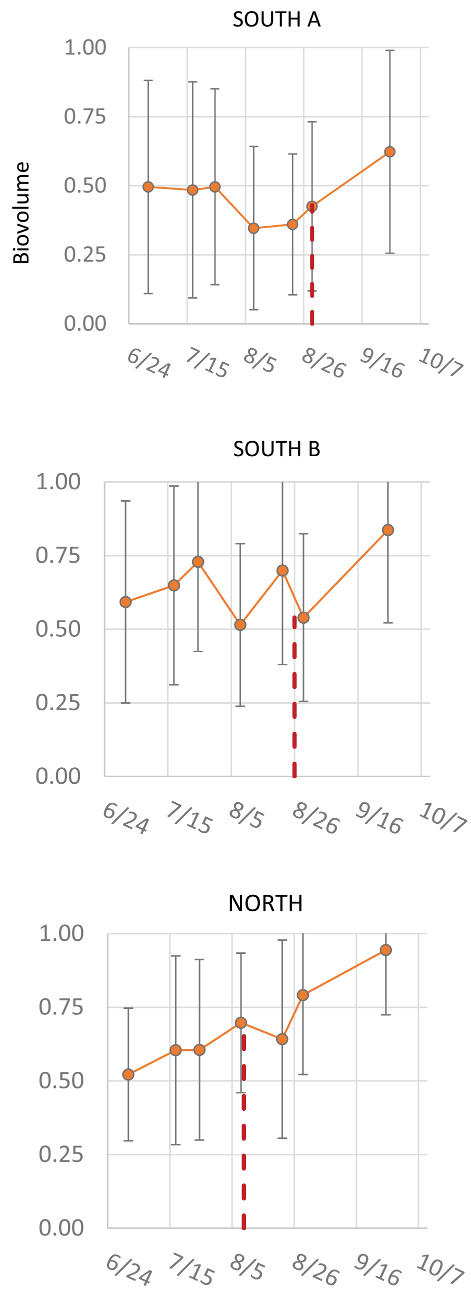
Cumulative boat-hrs for multiple precision cuts in the south (S) and north (N) plots (gray scale) versus the cumulative boat-hrs in each of the harvest plots (A) and the uniform time efforts (sec m^{-2}) for precision cuts versus the cumulative proportion of intensity (sec m^{-2}) assigned to each of the respective plot areas (B)



A raster translating harvester track lines to effort (i.e., time per unit area) for each of the three plots. Harvest operations covered 97-99% of the designated plot area within the contract time period. However, note the lack of uniformity in the distribution of effort.

harvesting (06/14-07/17) BV increased in all plots. In the final 6 weeks of the harvest contract (07/17-08/30) the south A plot showed modest reduction from 0.48 to 0.43 BV at final harvest. Strong reciprocal regrowth was exhibited in the south B plot (e.g., growth spikes on 07/25 and 08/22), but was still reduced from 0.65 to 0.54 BV at final harvest. This was incidentally the plot with the highest harvest effort in boat-hrs. Biovolume continued to increase in the north plot from 0.60 to 0.70. The depth of this plot was < 4 ft and several feet lower than the south plots, where we would expect higher temperatures and light penetration conducive to faster growth. Bowes et al. (1977) identified both seasonality and regionality as influencers of hydrilla growth. Furthermore, the water column in a shallow depth simply fills up faster.

A final survey was conducted for each of the plots one month after the harvest contract was terminated (09/26). Biovolume sharply increased by an average of 40% across all plots once harvesting ceased. This clearly demonstrates how harvesting is a non-lethal action and where suppression could only be achieved while harvesting was constantly administered. The harvest efforts in the south plots appeared to match hydrilla growth responses while harvest efforts in the north plot was being outpaced by regrowth. It cannot be over-emphasized the challenges of managing hydrilla during peak summer months. Harvesting in summer can result in regrowth to pre-harvest weights in a matter of weeks (Engel 1990, McGehee 1979). Thus, as demonstrated in this pilot study, multiple harvests become necessary during the summer growing season to keep hydrilla suppressed. This is not exclusive to mechanical harvesting, where it is known that herbicide efficacy can be compromised during the summer. Records from 2010-2018 show 75% of all herbicide treatments to hydrilla have occurred in early Spring (Feb-April) and late Fall (Oct-Dec), while only 12% of herbicide treatments have been applied during the same period as this pilot study (June-Aug).

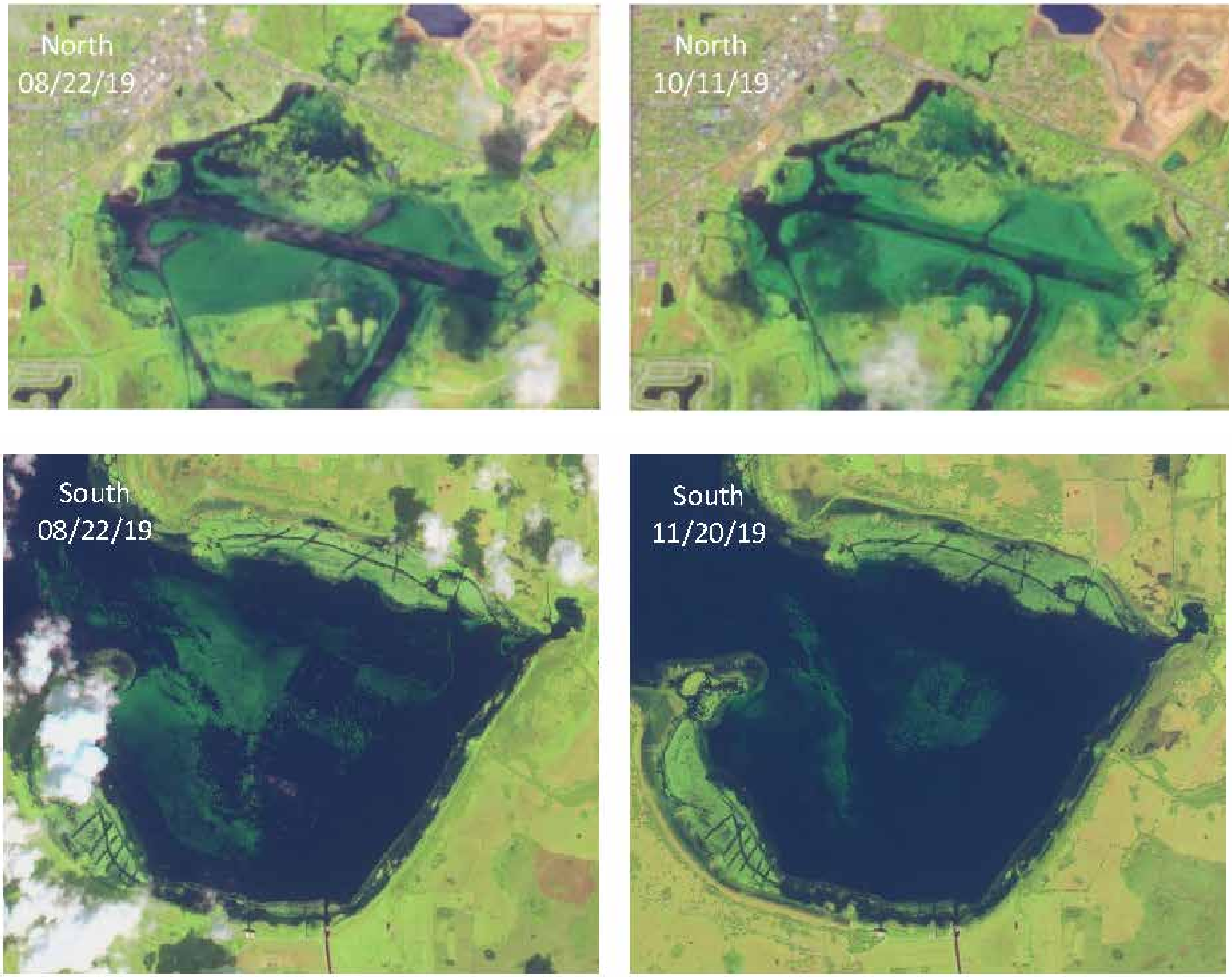


Average biovolume (±SD) reported as a proportion during the harvest contract and one month after harvest. The final harvest is designated by the red dash

Is harvesting the future of aquatic plant management? That was the question asked by Nicholas Sassic in this very publication back in 1982. Back then, there was increasing scrutiny of herbicides used in APM precipitated such an idea (a history we've been doomed to repeat). In the article, he takes the position that mechanical harvesting can be competitive with the cost of an herbicide application in the right situation. He highlights how the logistics of disposal can dramatically influence the cost. Disposal is a factor that does not encumber on herbicide management but can double the cost of a harvest operation (Sabol 1987). In shallow water, herbicide treatments can cost $400-600 per acre which increases with water depth, where deep water treatments can exceed $1000 per acre. According to FWC, mechanical harvest contracts can be 2-3 times higher at >$1900 acre^{-1}. Assuming a harvest rate of 1.4 acres hr^{-1}, the hourly cost rate would be ~$1400 hr^{-1} if they are referring to single-cut operations.

If we were to assume south A and B plots were effectively maintained during the term of the contract, the effort accumulated was between 1.6-2.8 boat-min acre^{-1} day^{-1}. It's clear based on the speed of recovery after harvest that the summer growth phase starting in June extends well beyond August and likely up to November (i.e., 183 days). Based on these rough calculations, each acre would require 5-9 boat-hrs for complete summer maintenance. With perspective to the current maintenance strategy, 3500 acres of hydrilla managed on Lake Toho would require 17,000-30,000 boat-hrs, or 93-164 boat-hrs day^{-1} during the summer months. That is over 10 times the fleet capacity utilized in this study and likely not conceivable as a replacement to the herbicide strategy currently in place. There is opportunity however to explore and develop a more integrated strategy to increase contributions of harvesting that can enhance current herbicide-based programs. However, this would dramatically increase complexity requiring a higher order of logistical coordination and legislative commitments to permanent, sustainable support exceeding current funding levels.

Haller and Jones (2012) previously identified GPS-assisted navigation as a critical technological advancement to harvesting operations. Its apparent from this study that the technology has not yet been fully embraced. The data presented in this study support a substantial increase in precision to be achieved with better navigation, resulting in more efficient use of boat-hrs, ultimately improving the cost



North and South coves just before contract termination (0 weeks after treatment; WAT) and reciprocal recovery expressed post treatment at 6 and 12 WAT, respectively. Note rising wate levels in November due to East Lake Toho drawdown. Images provided by Sentinel-2 satellite from European Space Agency (ESA)

effectiveness of mechanically harvesting hydrilla. This study further corroborates deep water harvesting advocated by Haller and Jones (2012). Further research is needed to consider the seasonal conditions influencing growth response. Here we challenged existing harvester technology under the most extreme conditions.

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Informational Web Content

FWC Hydrilla Management Position . https://plants.ifas.ufl.edu/manage/developing-management-plans/fwc-hydrilla-management-position/

FWC implementing enhancements to Aquatic Plant Management Program. https://myfwc.com/news/all-news/aquatic-enhancements/

Debate rages about how to control spread of hydrilla in lakes. https://www.dailycommercial.com/news/20190224/debate-rages-about-how-to-control-spread-of-hydrilla-in-lakes

Harvesters. https://plants.ifas.ufl.edu/manage/developing-management-plans/mechanical-control-considerations/harvesters/

Mechanical Control Considerations. https://plants.ifas.ufl.edu/manage/developing-management-plans/mechanical-control-considerations/

Large-Scale Hydrilla Control Considerations for Lake Toho. https://plants.ifas.ufl.edu/manage/developing-management-plans/large-scale-hydrilla-control-considerations/

Assistant Professor, James Leary, Ph.D., (learyj@ufl.edu) is a Research and Extension Specialist in Aquatic Plant Management at the University of Florida's Center for Aquatic and Invasive Plants. Prior to moving to Florida, Dr. Leary spent over 20 years with the University of Hawaii, where he studied tropical weed science in managed and natural area landscapes.

The University of Florida's New Weed Science Graduate Certificate Program

Are you interested in furthering your education on weed science and invasive plant management? Have you considered going back to school for a graduate degree, but are not sure how to fit it in around your work schedule? If so, a graduate certificate program may be a good fit for you. The University of Florida is offering an online Weed Science Graduate Certificate to provide training on weed ecology and plant interactions, management techniques, and environmental considerations for plant management.

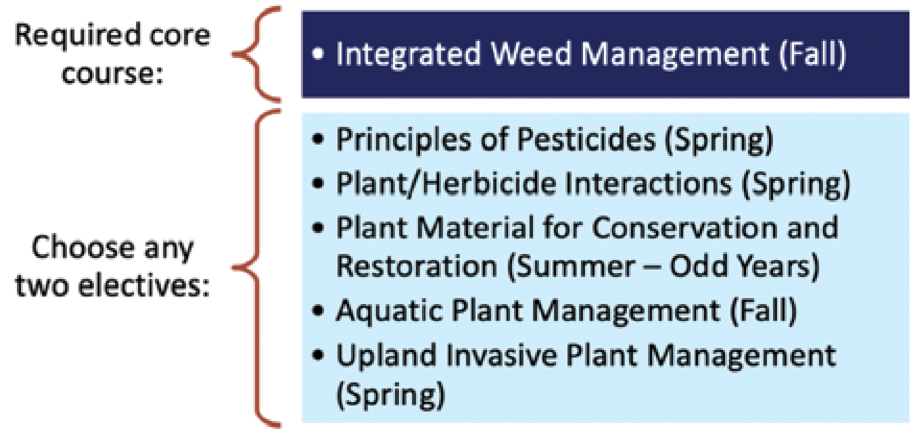


Figure 1. There is one required core course for the certificate program (Integrated Weed Management). In addition, students must choose two electives. Each course is 3 credits each, for a total of 9 credits needed to complete the certificate program.

What is an Online Graduate Certificate?

A graduate certificate is a continuing education and professional development opportunity. Graduate certificates have fewer courses than a graduate degree program (such as a master's degree), and there is no requirement to conduct independent research or defend a thesis. Graduate certificates are designed to focus on a specific topic or skillset, such as weed management. Many graduate certificates, such as the Weed Science Graduate Certificate, are offered 100% online – there is no requirement to come to Gainesville for coursework or exams, making it ideal for students with full-time jobs.

The Weed Science Graduate Certificate

The Weed Science Graduate Certificate is part of the Agronomy Department at UF. It is a graduate-level program, and is ideal for:

- Natural resource managers
- Industry personnel
- Government agency employees
- Agricultural managers
- Extension agents
- Students considering graduate school or a career change

As a weed science certificate student, you will learn about the biology, physiology, and ecology of nuisance plant species. You will also learn about the science behind management techniques and herbicide use, including how to control species in an environmentally responsible way. To complete the certificate, students must complete 9 credits (3 courses) with a minimum 3.0 GPA. There is one required course, Integrated Weed Management, and five electives that you can choose from for your remaining two courses (Figure 1). Students must also pass a final exam with a minimum score of 75%. The exam will include questions from each class you take during the program and may be taken multiple times if necessary.

One of the benefits of a certificate program is its flexibility. For example, there is no strict time limit for completing the program – you can complete your coursework over several years if needed.

Table 1. Applications are due several months prior to the start of the semester. Applications can be submitted online through the UF system. Please contact Dr. Candice Prince (cprince14@ufl.edu) before applying.

Semester	Application Due Date
Spring	November 1st
Summer	March 1st
Fall	May 1st

The courses you take during the certificate program can also count towards a graduate degree at UF if you decide to pursue a master's degree or Ph.D. in the future.

Requirements for Admission

To be admitted into the Weed Science certificate program, students must have completed a Bachelor of Science degree and have taken one prior course in plant science (botany, agronomy, plant physiology, etc.). Students with a Bachelor of Arts degree may also be admitted if they have work experience in plant management or other related fields. There is no requirement for students to take the GRE! Applications can be submitted online through the UF system (see Table 1 for due dates). State employees that are eligible for the State Employee Tuition Waiver Program can have their tuition and fees waived for up to 6 credits (two courses) per semester. For more information on the tuition waiver, the cost of tuition, or the application process, please contact Dr. Candice Prince (cprince14@ufl.edu).

Candice Prince (cprince14@ufl.edu) is an Assistant Professor in the Agronomy Department at the University of Florida. Questions about the certificate and its requirements can be directed her way. She will be happy to assist!

2020 Calendar of Events

February 3-7
Florida Mosquito Control Association Dodd Short Course (Gainesville, FL)
https://floridamosquito.org/Public

February 10-13
40th Annual Meeting of the Midwest Aquatic Plant Management Society (Indianapolis, IN)
http://www.mapms.org/

February 27
South Florida Aquatic Plant Management Society General Meeting (Sunset Lakes Community Center, Miramar, FL)
http://sfapms.org/

March 2-5
Weed Science Society of America Annual Meeting (Maui, HI)
http://wssa.net/

TBD
Florida Weed Science Society (Haines City, FL)
https://sites.google.com/site/floridaweedsciencesociety/

April 22-24
Florida Vegetation Management Association Annual Conference (Daytona Beach, FL)
https://www.myfvma.org/

May 4-7
University of Florida IFAS Aquatic Weed Control Short Course (Coral Springs, FL)
http://conference.ifas.ufl.edu/aw/

June 25
South Florida Aquatic Plant Management Society General Meeting (Holy Cross Hospital, Ft. Lauderdale, FL)
http://sfapms.org/

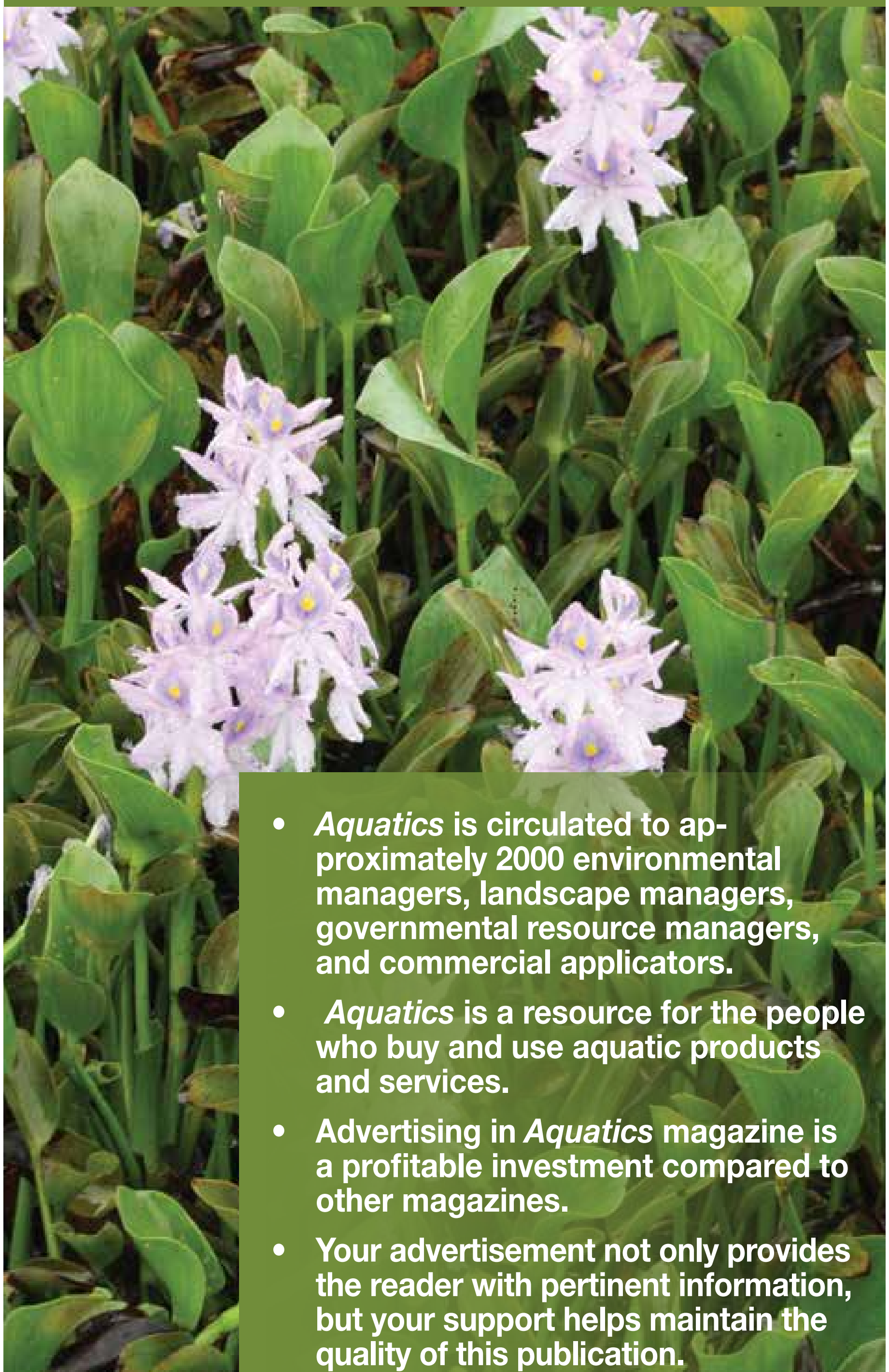
July 19-22
Aquatic Plant Management Society 60th Annual Meeting and Western Aquatic Plant Management Society Joint Meeting (Austin, TX)
http://www.apms.org/

September 24
South Florida Aquatic Plant Management Society General Meeting (location TBA)
http://sfapms.org/

October 5-8
Florida Aquatic Plant Management Society 44rd Annual Training Conference (Daytona Beach, FL)
http://www.fapms.org/

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)

It Pays to Advertise



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