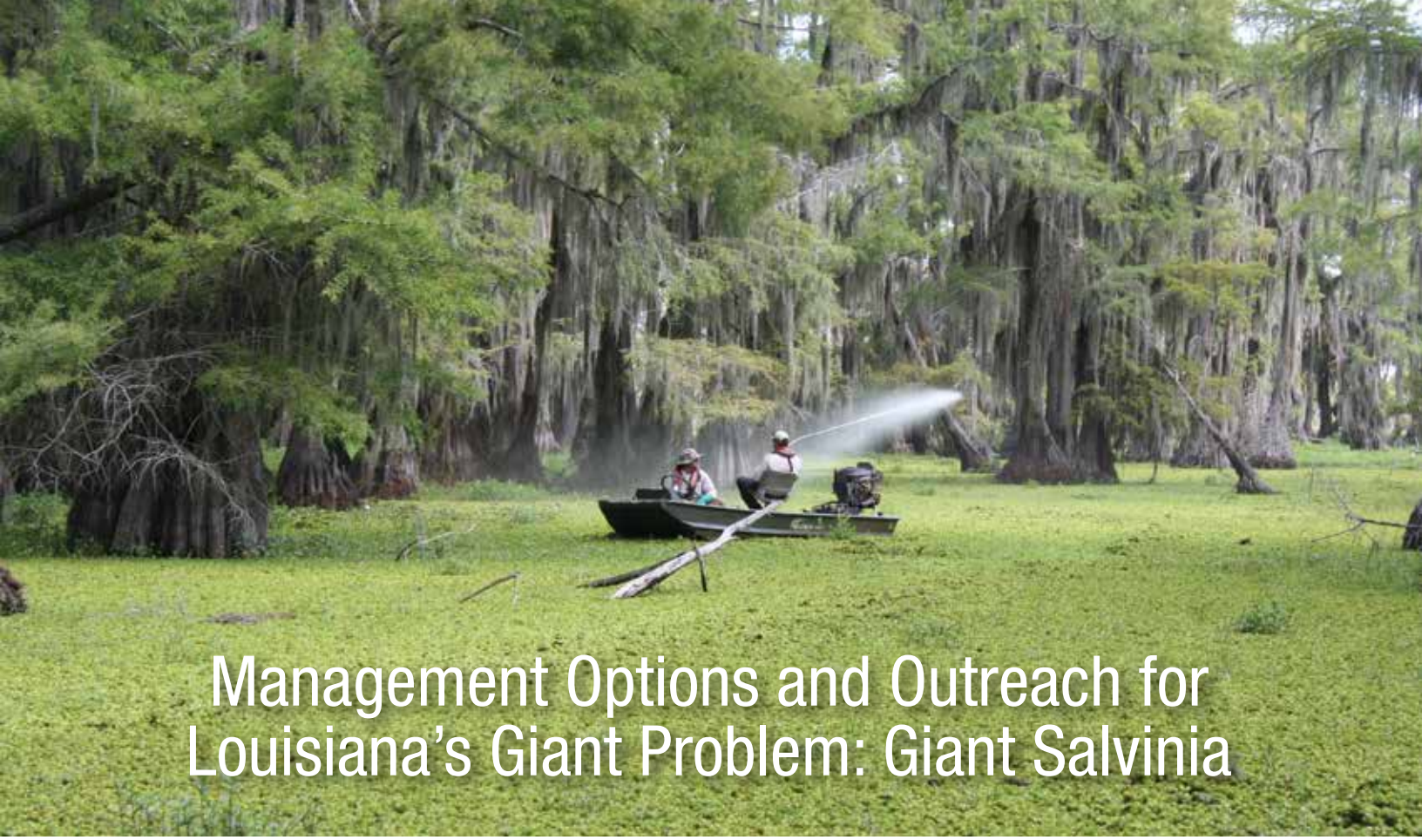

Management Options and Outreach for Louisiana's Giant Problem: Giant Salvinia

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Giant salvinia (*Salvinia molesta* Mitchell, Salviniaceae) is a free-floating aquatic fern native to Brazil and is considered one of the worst aquatic weeds in the southeastern U.S. (Wahl *et al*. 2020). It invades tropical and subtropical freshwater habitats across the southeastern U.S. including Louisiana, Texas, and neighboring states (Figure 1). Freshwater systems provide critical ecosystem services including carbon sequestration, wildlife habitat, water filtration, and storm surge protection. Additionally, Louisiana waterways provide essential cultural and economic services such as recreational opportunities, Acadian history, tourism development, and wildlife observation (Board *et al*. 2013).

Giant salvinia negatively impacts water quality, prevents sunlight from reaching the water column, displaces native plants and wildlife, and hinders function of the waterways (McFarland *et al*. 2004). During summer months, the plant thrives in the Louisiana's tropical and subtropical climates by rapidly spreading via asexual reproduction from rhizomes and plant fragments (McFarland *et al*. 2004). Under favorable conditions, the plant can quickly increase biomass, cover large waterbodies, and create a dense mat several plant layers thick (up to one foot). However, plant growth slows substantially in cold weather from November to February with

Figure 1. Giant salvinia has three growth stages: primary, secondary, and tertiary. This aquatic fern grows vertically in the tertiary growth stage. Photo taken by Korey Pham.

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winter growth variation dependent upon latitude. Furthermore, growth in thick mats protects the plant from frost damage and freezing temperatures resulting in the top layer turning brown while the bottom layer remains healthy and green (Russell 2017) (Figure 2).

Controlling giant salvinia is a challenge due to its rapid growth and lack of native enemies. In Louisiana, there are several methods of control including mechanical, chemical, and biological control. Mechanical control, including hand removal and machine grinding, is limited due to the plants ability to reproduce quickly from plant fragments. This method is also cost-prohibitive for large infestations and not effective for areas with limited access such as cypress swamps (Wahl *et al.* 2020).

Giant salvinia was first reported in U.S. in South Carolina in 1995, but this population was eradicated. Since its re-introduction into the U.S. in the Toledo Bend Reservoir (Texas/Louisiana border), giant salvinia has been managed with aquatic herbicides. Glyphosate and diquat are the primary active ingredients used on giant salvinia during the past two decades. These products are used alone or in combination to treat the foliage, but other herbicides including penoxsulam, flumioxazin, carfentrazone, and fluridone have been evaluated as foliar and subsurface applications with mixed results. As an effort to rotate herbicides with different modes of action to alleviate future issues with selection pressure (e.g., herbicide resistance), herbicide screening trials were initiated by former LSU graduate students (William Prevost and Dr. Bradley Sartain) as well by Dr. Mudge. In particular, the slow-acting, systemic acetolactate synthase (ALS) inhibiting herbicide metsulfuron-methyl was found to be highly active at 0.5 to 1 oz/A (98 to 100% control) when applied to mature, tertiary growth stage plants (Sartain and Mudge 2018b, Prevost *et al.* 2021). A Section 24(c) registration [Special Local Need (SLN) label] was recently granted for Alligare's PRO MSM 60 (Louisiana and Texas) and Bayer's Cimarron Max Part (Louisiana and South Carolina) to control plants in public managed and/or regulated waterways (no private land use or application).

Traditionally, herbicide treatments are applied during the growing season—March/April through October/November—in the deep south. Until recently, only limited number of giant salvinia acres were chemically treated during the winter. The idea of applying herbicides to slow growing or frost/freeze damaged plants was deemed not necessary or wasteful since most agencies felt giant salvinia would not respond to herbicides during the cold months. Mesocosm research determined control could be achieved, especially if foliar applications were administered prior to a freezing event (Mudge and Sartain 2018, Sartain and Mudge 2018, Sartain and Mudge 2019). The practice of year-round or maintenance spraying has increased and aided in reducing the total number of plant acres found during the spring.

Thus, chemical control is recommended, particularly in the northern tier of the state where the cold weather makes it easier for chemical management strategies since the plant is not as resilient. Continued use of aquatic herbicides and mechanical interventions (where appropriate and cost effective) is suggested to control giant salvinia infestations even if the plant appears to be unhealthy (Mudge and Sartain 2018, Sartain and Mudge 2018, Sartain and Mudge 2019). For more information, please watch our winter management video on the LSU AgCenter's YouTube Channel (https://youtu.be/sOQutvI_08ghttps://youtu.be/sOQutvI_08g).

A cost-effective method for controlling giant salvinia is biological control (Maluleke *et al.* 2021). The salvinia weevil, *Cyrtobagous salviniae* (Figure 3), is a host-specific insect native to Brazil. Since 2001, the weevil has been used as a biological control agent in Louisiana and has been successful at reducing giant salvinia coverage in tropical and subtropical regions across the world (Tipping *et al.* 2008, Wahl *et al.* 2020). Since chemical control can be up 20-fold more costly than biological control (Maluleke *et al.* 2021), the later has become the cornerstone of management programs across the world. Thus, the salvinia weevil is recommended especially in the southern portion of

Figure 2. Top layer of giant salvinia protects the bottom layer after exposure to frost damage and freezing temperatures. Photo taken by Jeff Sibley.

Figure 3. Giant salvinia weevils are beetles about the size of a kiwi seed. Imaging of the giant salvinia weevil by Dr. Katherine Parys.

Figure 4. Giant salvinia infestation in Cameron Parish, Louisiana, before and after release of giant salvinia weevils. Weevil feeding disrupts nutrient flow and plants turn brown, begin to decompose, and eventually sink. Photo by LSU AgCenter.

Louisiana where the winters are milder.

Salvinia weevil adults feed on the new buds and larvae tunnel the rhizomes resulting in a drastic reduction of nutrient uptake (Knutson and Mukherjee 2012). Over time, severe feeding damage reduces the plant growth, increases the browning, and eventually sinks the plant. Salvinia infestations were reduced by 99% within two years in Louisiana and Texas (Tipping *et al.* 2008). Moreover, salvinia mat collapse was observed within one summer after introduction of the salvinia weevil (Figure 4). However, depending on the size of the giant salvinia infestation, this process may take longer. Since biological control may take time to control an area, an Integrated Pest Management (IPM) plan should be developed to supplement the weevil's effort.

Weevil cold tolerance is one limiting factor for the biological control program with the insects failing to establish in northern latitudes (Russell *et al.* 2017). Efforts have been made to develop populations of the salvinia weevil tolerant to harsh winters. A population from Argentina is currently being evaluated for use in temperate regions of central and north Louisiana and Texas (Russel *et al.* 2017). Understanding the weevil population dynamics over the seasons will improve management strategies for giant salvinia. Future establishment of more cold tolerant populations of the salvinia weevil could increase their winter survival, increase population growth in spring and summer, and subsequently reduce the aggressiveness of salvinia in temperate regions (Mukherjee *et al.* 2014). The LSU AgCenter has developed a program that rears weevils in six earthen ponds in St. Gabriel and St. Martinville, Louisiana (Figure 5). Along with the sponsoring agencies, Louisiana Department of Wildlife and Fisheries, United States Fish and Wildlife Services, United States Geological Survey, and Coastal Wetlands Planning, Protection and Restoration Act, weevils are distributed to south Louisiana landowners (Figure 6). Water level, water quality (nutrients, pH, conductivity, etc.), and presence of other aquatic pests (insects and weeds) are monitored weekly. The mean weevil population density, number of weevils per kilogram of salvinia, are recorded and pond maintenance decisions are made. In addition, salvinia infestations are monitored across the state including Cane Bayou, Delcambre, and Cameron, Louisiana. Each location has permanent sampling sites where the weevils were previously released and other control sites where weevils were not released. Giant salvinia percent coverage, plant health, weevil population density (number of weevils per kilogram of salvinia) weevil distribution, and water quality data are recorded during site visits (Figure 7). This longitudinal study plays a key role in how giant salvinia infestations are impacted by the weevil and extreme weather and environmental events.

Despite the success of the rearing and distribution program, the program needs to adapt to account for climate change and for the northern expansion of giant salvinia. Hurricanes, summer flooding, and other coastal changes are expected to strengthen and increase in frequency as the climate changes. These frequent disturbances can impact the spread of giant salvinia, which makes it imperative to improve detection of new plant infestations. More research is needed to understand how giant salvinia and the salvinia weevil are impacted by saltwater intrusion (via hurricanes and sea level rise). Currently, it is unknown whether the salvinia weevil can survive in higher saline

Figure 5. Earthen weevil rearing ponds are managed to maintain plant quality in St. Martinville, Louisiana. Photo by Rodrigo Diaz.

Figure 6. Every year the LSU AgCenter hosts a 'Weevil Harvest Event' where landowners participate in the collection of weevil-infested salvinia from our ponds in south Louisiana. Photo by the LSU AgCenter.

environments. Thus, it is imperative that the biological control program is approached differently in coastal wetland ecosystems.

Moreover, reliance on stand-alone technologies, primarily weevils and herbicides, has proven a slow task to remove giant salvinia from Louisiana and neighboring states. Integrated pest management (IPM) has been investigated in a small-scale setting with favorable results (Cozad et al. 2019) and direct toxicity is not an issue with some of the registered herbicides (Wahl 2018, Mudge et al. 2013), but these efforts need to be evaluated in an operational setting. Weevil releases and herbicide applications have been occurring simultaneously throughout Louisiana for over a decade; however, their collective impact on large field populations is unknown. Selective placement of herbicides and weevils followed by extensive field sampling is a must going forward.

Currently, the U.S. Army Engineer Research & Development Center and the LSU AgCenter are screening non-aquatic herbicides for activity on giant salvinia. Industry partners are contacted if efficacious products are found to pursue an aquatic label (e.g. Section 3 or SLN). Additionally, improving the use of the current registered herbicides by evaluating application timing, combination treatments, IPM, other refinements are ongoing tasks needed to restore aquatic ecosystems. Graduate students are also being sought to assist with applied and basic research of this plant at the small-scale (mesocosm, greenhouse, and laboratory) and field/operational settings. As this floating fern spreads across the U.S. into Corps, state, and private waterbodies, rapid response assistance is being deployed to limit its impact on our Nation's most valuable resource.

Our mission at the LSU AgCenter is to combat giant salvinia infestations across the state of Louisiana. An outreach program was implemented to increase public awareness and knowledge of this invasive species. Important content about invasive species, biological control, and chemical control is continually developed and published. The media created includes short videos, pictures, articles, and manuals. The most successful tool has been social media where tens of thousands of people have been reached. For more information about our outreach program please visit our Instagram account (https://www.instagram.com/weevil_rock_you/), Facebook account (https://www.facebook.com/weevilrockyou/), and our invasive species website (http://www.lsuagcenter.com/giantsalvinia).

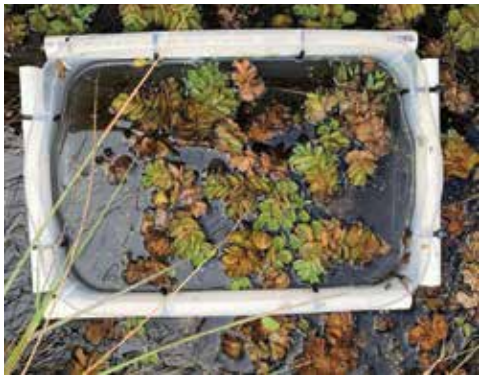

Figure 7. Giant salvinia percent coverage is measured with a small quadrat at a permanent monitoring site. Photo by Korey Pham.

Korey Pham (kpham@agcenter.lsu.edu) is an Entomology PhD student and Research Associate for the Department of Entomology at the LSU AgCenter. She has a B.S. in General Biology from St. Edward's University in Austin, Texas. Her current role at the LSU AgCenter is to rear and distribute salvinia weevils to private landowners in south Louisiana and provide outreach materials to better manage aquatic weeds. Her current research responsibilities include the optimization of salvinia weevil release recommendations and understanding the competitive interactions between giant salvinia and Cuban bulrush and its impact on the salvinia weevil biological control program.

Dr. Christopher Mudge (Christopher.R.Mudge@usace.army.mil) is a Research Biologist for the U.S. Army Engineer Research & Development Center (ERDC) and is stationed in Baton Rouge, Louisiana. His current research responsibilities include the evaluation and development of use patterns for recently registered and experimental herbicides for selective management of invasive aquatic plants that hinder our Nation's waterways. Dr. Mudge has a B.S. and M.S. from Louisiana State University (LSU) in Agronomic Crops and Rice Weed Management, respectively, as well as a Ph.D. in Aquatic Weed Science from the University of Florida. After completing his

Ph.D. in 2007, Dr. Mudge accepted a position on the Chemical Control and Physiological Processes Team at ERDC in Vicksburg, Mississippi. In 2013, he was re-assigned to Baton Rouge where he is an Adjunct Professor in the LSU School of Plant, Environmental and Soil Sciences and serves as an advisor to M.S. and Ph.D. graduate students. He currently serves as a member of the Board of Directors for the Aquatic Plant Management Society (APMS) and the Acting Team Leader of the Aquatic Plant Management Team at ERDC.

Hannah Laville is an undergraduate student at Louisiana State University, studying Natural Resource Ecology and Management. Additionally, she serves as a student worker in the Entomology Department at the LSU AgCenter. In this role, she works closely with Dr. Rodrigo Diaz and Korey Pham to assist in the biological control program that rears and releases the salvinia weevil, as well as assisting with tasks associated with ongoing invasive species research within the lab. In addition, she has conducted research that aims to understand salvinia weevil dispersal from a release site into a surrounding infestation.

Rodrigo Diaz (rdiaz@agcenter.lsu.edu) is an Associate Professor in the Department of Entomology at Louisiana State University. Rodrigo's research focuses on biological control of non-native weeds and insects. Current projects include biological control of giant salvinia, roseau cane scale, elephant ear and air potato. Louisiana. Due to his experience in classical biological control, Rodrigo has developed a network of international partnerships that have resulted in several research agreements, procurements of import/export permits, student exchanges, and scientific publications. In 2020, he became Associate Editor for the Journal of Aquatic Plant Management. Rodrigo obtained his master's degree at Texas A&M University in 2003 and his Ph.D. at the University of Florida in 2008.

Footnotes

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Calendar of Events

January 11-13, 2022
23rd Annual Meeting of the Northeast Aquatic Plant Management Society
The Resort and Conference Center at Hyannis, Cape Cod, MA
http://www.neapms.org/details-original

February 28-March 3, 2022
42nd Annual Midwest Aquatic Plant Management Society Conference
Grand Geneva Resort & Spa, Lake Geneva, WI
https://www.mapms.org/conferences/2022-conference/

March 7-11, 2022
40th Annual Meeting of the Western Aquatic Plant Management Society
DoubleTree Reid Park, Tucson, AZ
https://wapms.org/events

July 18-22, 2022
62nd Annual Meeting of the Aquatic Plant Management Society
Greenville, SC (updates coming soon)

August 22-25, 2022
UF/IFAS Aquatic Weed Control Short Course
DoubleTree by Hilton Orlando at SeaWorld, Orlando, FL
http://sfyl.ifas.ufl.edu/aw/ (updates coming soon)