Joint Annual Meeting

59th Meeting of the
Aquatic Plant
Management Society

38th Meeting of the
Western Aquatic Plant
Management Society

Program & Abstracts

DoubleTree San Diego
Mission Valley, California
July 14-17, 2019

Meeting Sponsors

The Aquatic Plant Management Society appreciates the generous support of the following meeting sponsors. Through their support and contributions, we can conduct a successful and enjoyable meeting.

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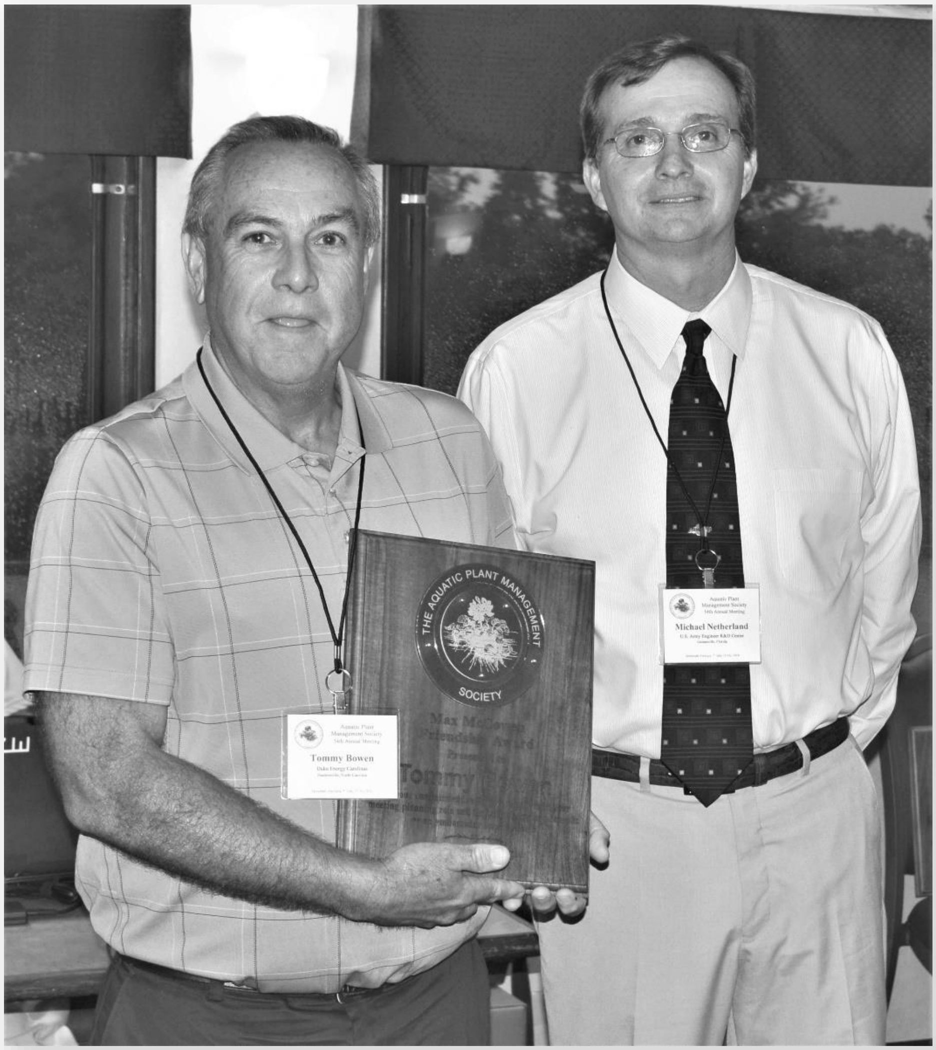
Raleigh, North Carolina

The Aquatic Plant Management Society dedicates the 2019 Annual Meeting to the memories of:

Tommy Wade Bowen and **Michael Dyer Netherland**

Both are cherished long-term and long-active members of the Society.



Tommy Bowen was a 32-year member of APMS. He excelled at coordinating the APMS annual meeting as Meeting Planning Committee Chair from 2011 through the 2018 meeting last summer in Buffalo, NY. He received the Max McCowen Friendship Award in 2014 for his outgoing, friendly and humble demeanor, and the T. Wayne Miller Distinguished Service Award in 2017 for his long-term service to the Aquatic Plant Management Society and to the field of aquatic plant management.

Mike Netherland joined APMS in 1996. He served on the Board for 11 years; as Editor and as President in 2014. He was also President of FAPMS in 2009. Mike was caring, dedicated, and passionate about science and education, interacting with the scientific community across the U.S. and around the world. Mike was a recipient of the first APMS Research and Technical Contributor Award in 2010. All that knew Mike will miss his wit and ability to inject humor to any situation.

Table of Contents

APMS Board of Directors

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Clemson, South Carolina

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Committee Chairs

Awards	Jason Ferrell
Bylaws and Resolutions	Vernon V. Vandiver, Jr.
Education and Outreach	Brett Hartis
Exhibits	Dean Jones
Finance	Andy Fuhrman
Legislative	Robert Richardson
Meeting Planning	Bill Torres
Membership	Mark Heilman
Nominating	John Rodgers
Past President's Advisory	John Rodgers
Program	Mark Heilman
Publications	Jay Ferrell
Regional Chapters	Ryan Wersal
Scholastic Endowment	Tom Warmuth
Strategic Planning	Mark Heilman
Student Affairs	Chris Mudge
Website	Ken Manuel

Special Representatives

AERF	Carlton Layne
BASS	Gerald Adrian
CAST	Lyn Gettys
NALMS	Terry McNabb
RISE	Sam Barrick
Science Policy Director	Lee Van Wychen
Women in Aquatics	Amy Kay
WSSA	Robert Richardson

WAPMS Board of Directors

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Albany, California

The objectives of the Western Aquatic Plant Management Society shall be to:

1. Establish a forum for the exchange of information on aquatic vegetation management techniques, strategies, and research through periodic meetings and other appropriate means.
2. Cooperate with local, state, regional, and national agencies, both public and private, in the identification of and solution to aquatic vegetation problems.
3. Promote uniformity and coordination of activities among agencies concerned with the regulatory aspects of aquatic plant management.
4. Encourage scientific research and assist in promoting the control and management of aquatic plants through scientifically sound procedure.
5. Recognize and promote scientific advancement of the members and facilitate the education of aquatic plant scientists through scholarship and other assistance programs.
6. Extend and develop public interest in, and understanding of, aquatic plant management problems and solutions.
7. Cooperate with local chapters and other organizations with similar and related interests.

The Western Aquatic Plant Management Society geographic region includes the states of:

Alaska, Arizona, California, Colorado, Hawaii, Idaho, Oregon, Nevada,
New Mexico, Montana, Utah, Washington, and Wyoming

APMS Presidents and Meeting Sites

1961	T. Wayne Miller, Jr.	Fort Lauderdale, FL
1962	T. Wayne Miller, Jr.	Fort Lauderdale, FL
1963	William Dryden	Tampa, FL
1964	Herbert J. Friedman	Tallahassee, FL
1965	John W. Woods	Palm Beach, FL
1966	Zeb Grant	Lakeland, FL
1967	James D. Gorman	Fort Myers, FL
1968	Robert D. Blackburn	Winter Park, FL
1969	Frank L. Wilson	West Palm Beach, FL
1970	Paul R. Cohee	Huntsville, AL
1971	Stanley C. Abramson	Tampa, FL
1972	Robert J. Gates	Miami Springs, FL
1973	Brandt G. Watson	New Orleans, LA
1974	Alva P. Burkhalter	Winter Park, FL
1975	Luciano Val Guerra	San Antonio, TX
1976	Ray A. Spirnock	Fort Lauderdale, FL
1977	Robert W. Geiger	Minneapolis, MN
1978	Donald V. Lee	Jacksonville, FL
1979	Julian J. Raynes	Chattanooga, TN
1980	William N. Rushing	Sarasota, FL
1981	Nelson Virden	Jackson, MS
1982	Roy L. Clark	Las Vegas, NV
1983	Emory E. McKeithen	Lake Buena Vista, FL
1984	A. Leon Bates	Richmond, VA
1985	Max C. McCowen	Vancouver, BC
1986	Lars W. J. Anderson	Sarasota, FL
1987	Dean F. Martin	Savannah, GA
1988	Richard D. Comes	New Orleans, LA
1989	Richard Couch	Scottsdale, AZ
1990	David L. Sutton	Mobile, AL
1991	Joseph C. Joyce	Dearborn, MI
1992	Randall K. Stocker	Daytona Beach, FL
1993	Clarke Hudson	Charleston, SC
1994	S. Joseph Zolczynski	San Antonio, TX
1995	Steven J. de Kozlowski	Bellevue, WA
1996	Terence M. McNabb	Burlington, VT
1997	Kurt D. Getsinger	Fort Myers, FL
1998	Alison M. Fox	Memphis, TN
1999	David F. Spencer	Asheville, NC
2000	J. Lewis Decell	San Diego, CA
2001	Jim Schmidt	Minneapolis, MN
2002	David P. Tarver	Keystone, CO
2003	Richard M. Hinterman	Portland, ME
2004	Ken L. Manuel	Tampa, FL
2005	Eric P. Barkemeyer	San Antonio, TX
2006	Jeffrey D. Schardt	Portland, OR
2007	Donald W. Doggett	Nashville, TN
2008	Jim Petta	Charleston, SC
2009	Carlton Layne	Milwaukee, WI
2010	Greg MacDonald	Bonita Springs, FL
2011	Linda S. Nelson	Baltimore, MD
2012	Tyler Koschnick	Salt Lake City, UT
2013	Terry Goldsby	San Antonio, TX
2014	Michael D. Netherland	Savannah, GA
2015	Cody Gray	Myrtle Beach, SC
2016	Rob Richardson	Grand Rapids, MI
2017	John D. Madsen	Daytona Beach, FL
2018	John H. Rodgers, Jr.	Buffalo, NY
2019	Craig Aguillard	San Diego, CA

APMS Award Recipients

Honorary Members

Awarded to persons who have been voting members of the Society for no less than ten years, have contributed significantly to the field of aquatic vegetation management, and must have actively promoted the Society and its affairs during their membership.

William E. Wunderlich	1967
F. L. Timmons	1970
Walter A. Dun	1976
Frank S. Stafford	1981
Robert J. Gates	1984
Herbert J. Friedman	1987
John E. Gallagher	1988
Luciano “Lou” Guerra	1988
Max C. McCowen	1989
James D. Gorman	1995
T. Wayne Miller, Jr.	1995
A. Leon Bates	1997
Richard Couch	1997
N. Rushing	1997
Alva P. Burkhalter	2002
J. Lewis Decell	2004
Paul C. Myers	2005
David L. Sutton	2006
Dean F. Martin	2007
Robert C. Gunkel, Jr.	2008
Allison M. Fox	2010
Randall K. Stocker	2010
Steven J. de Kozlowski	2010
Carole Lembi	2011
Lars W.J. Anderson	2012
David Tarver	2012
Don Doggett	2013
Richard Hinterman	2013
David Spencer	2015
Jim Schmidt	2016
Joseph C. Joyce	2017
Jeffrey D. Schardt	2017
David A. Issacs	2018
Vernon V. Vandiver	2018

President’s Award

An individual, designated by the current President, who has displayed "*Many Years of Dedication and Contributions to the Society and the Field of Aquatic Plant Management*".

T. O. “Dale” Robson	1984
Gloria Rushing	1991
William T. Haller	1999
David Mitchell	1999
Jeffrey D. Schardt	2002
Jim Schmidt	2003
Robert C. Gunkel, Jr.	2004
Victor A. Ramey	2006
William H. Culpepper	2007
Kurt Getsinger	2008
Richard Hinterman	2009
Steve D. Cockreham	2010
Donald W. Doggett	2012
Carlton Layne	2013
Ken Langeland, Jeff Schardt, Dan Thayer, Bill Zattau	2014
Greg MacDonald	2015
Linda Nelson	2015
John Madsen, Mike Netherland	2016
Jason Ferrell	2017
Robert Blackburn	2018
Sherry Whittaker	2018

APMS Award Recipients

Max McCowen Friendship Award

A special recognition given to an APMS member whose demeanor and actions display sincerity and friendship in the spirit of being an ambassador for the APMS. Criteria include warmth and outgoing friendship, sincerity and genuine concern, gracious hospitality, positive attitude and smile.

Judy McCowen	1995
John E. Gallagher	1997
Paul C. Myers	2000
William T. Haller	2002
Bill Moore	2006
Vernon V. Vandiver, Jr.	2012
Tommy Bowen	2014
Steve Hoyle	2015
Ken Manuel	2016
David Isaacs	2017
John Gardner	2018

T. Wayne Miller Distinguished Service Award

An individual recognized for *"Service to the Society and the Profession"*. Considerations include completion of a relatively short-term project taking considerable effort resulting in advancement of aquatic plant management; performance beyond the call of duty as an APMS officer, chair, or representative; or non-member achievement leading to the advancement of APMS goals and objectives.

Gerald Adrian	2005
Linda Nelson	2007
Surrey Jacobs	2009
Amy Richard	2010
Michael Netherland	2011
John H. Rodgers, Jr.	2012
John Madsen	2013
Jim Schmidt	2014
Jeffrey D. Schardt	2015
Craig Aguillard	2016
Tommy Bowen	2017
Tyler Koschnick	2018

Outstanding Graduate Student Award

A student recognized for outstanding achievement during graduate studies in the field of aquatic plant management.

Ryan Wersal	Mississippi State University	2010
Joe Vassios	Colorado State University	2011
Sarah True-Meadows	North Carolina State University	2013
Justin Nawrocki	North Carolina State University	2014
Erika Haug	North Carolina State University	2015
Kyla Iwinski	Clemson University	2016
Alyssa Calomeni	Clemson University	2017
Andrew Howell	North Carolina State University	2018

APMS Award Recipients

Outstanding International Contribution Award

An individual or group recognized for completion of research or outreach activities that is inter-national in nature.

Deborah Hofstra	National Institute of Water & Atmospheric Research	2013
Paul Champion	National Institute of Water & Atmospheric Research	2016
John Clayton	National Institute of Water & Atmospheric Research	2017
Tony Dugdale	Agriculture Victoria	2018

Outstanding Journal of Aquatic Plant Management Article Award

An award voted by the Editor and Associate Editors for research published in the JAPM during the previous year.

James Johnson, Ray Newman	University of Minnesota	2012
Michael D. Netherland and LeeAnn Glomski	U.S. Army Corps of Engineers	2014
Greg Bugbee, M. Gibbons, and M.J. Wells	Connecticut Agricultural Experiment Station	2016
Justin Nawrocki, Robert Richardson and Steve Hoyle	North Carolina State University	2017
Ryan A. Thum, Syndell Parks, James N. Mcnair, Pam Tyning, Paul Hausler, Lindsay Chadderton, Andrew Tucker, and Anna Monfils	Montana State University	2018

Outstanding Research/Technical Contributor Award

An individual or group recognized for completion of a research project or technical contribution related to aquatic plant management that constitutes a significant advance-ment to the field.

Michael Netherland, Dean Jones, and Jeremy Slade	University of Florida	2010
Kurt Getsinger	U.S. Army Corps of Engineers	2011
Mark Heilman	SePRO Corporation	2013
John Rodgers	Clemson University	2015
Rob Richardson	North Carolina State University	2016
Ryan Thum	Montana State University	2017
Scott Nissen	Colorado State University	2018

APMS Graduate Student Research Grant

Student initiatives are among the most important core values of the Aquatic Plant Management Society. High on the list of student support programs is the APMS Graduate Student Research Grant. This $40,000 academic grant, co-sponsored by APMS and the seven regional APMS chapters, provides funding for a full-time graduate student to conduct research in an area involving aquatic plant management techniques (used alone or integrated with other management approaches) or in aquatic ecology related to the biology or management of regionally or nationally recognized nuisance aquatic vegetation.

Recipient	Affiliation	Year	Amount
Mary Bremigan	Michigan State University	1999	$34,000
The Indirect Effects of Sonar Application on Lake Food Webs			
Katia Englehardt	University of Maryland	2001	$40,000
Controlling Non-native Submersed Aquatic Macrophyte Species in Maryland Reservoirs: Plant Competition Mediated by Selective Control			
Susan Wilde	University of South Carolina	2005	$40,000
Investigating the Role of Invasive Aquatic Plants and Epiphytic Cyanobacteria on Expression of Avian Vacuolar Myelinopathy (AVM)			
John Madsen and Ryan Wersal	Mississippi State University	2007	$60,000
The Seasonal Phenology, Ecology and Management of Parrotfeather [Myriophyllum aquaticum (Vellozo) Verdecourt]			
Rob Richardson, Sarah True, Steve Hoyle	North Carolina State University	2010	$40,000
Monoecious Hydrilla: Phenology and Competition			
Ryan Thum	Grand Valley State University	2012	$40,000
A Quantitative Genetics Approach to Identifying the Genetic Architecture of Herbicide Susceptibility, Tolerance, and Resistance in Hybrid Watermilfoils (Myriophyllum spicatum x sibiricum)			
Scott Nissen	Colorado State University	2014	$40,000
Exploring the Physiological Basis of 2,4-D Tolerance in Northern Watermilfoil x Eurasian Watermilfoil Hybrids			
Rob Richardson	North Carolina State University	2015	$40,000
Aspects of Monoecious Hydrilla Physiology and Response to Herbicide Combination Treatments			
Christopher R. Mudge and Bradley T. Sartain	Louisiana State University	2016	$40,000
Exploring Alternative Giant Salvinia (Salvinia molesta D.S. Mitchell) Management Strategies			
John Rodgers and Tyler Geer	Clemson University	2017	$60,000
Evaluation of Management Options for Nitellopsis obtusa (Desvaux in Loiseleur) J. Groves, (1919) (Starry Stonewort) in the United States			
Ryan A. Thum and Greg M. Chorak	Montana State University	2018	$40,000
Identifying Eurasian and Hybrid Watermilfoil Gene Expression Differences in Response to Frequently Used Herbicides for Improved Adaptive Management			

Sustaining Members

Alligare, a global leader in post-patent herbicide solutions and vegetation management, serves clients in the aquatic, forestry, range/pasture, roadway, utility/pipeline, and railroad markets. As an ADAMA Company, Alligare is connected to one of the largest chemical supply chains in the world, giving our customers access to the best active ingredients available at the best pricing possible. Alligare's field sales team provides technical expertise, training and ongoing support for clients. Alligare makes Vegetation Management Simple!

Since 1981, **Applied Aquatic Management, Inc.**, (AAM) has provided innovative and effective water management services, selective vegetation control, wetland management and exotic weed control. AAM has clients throughout Florida including developers, homeowners associations, golf courses, mobile home communities, utilities, local, state and federal government agencies and industry. Our experienced professional staff provides unique knowledge along with advanced equipment to manage all types of waterway, right-of-way, wetland, and upland systems.

Applied Biochemists is proud of its active membership and participation with the APMS for over 40 years. As a manufacturer and supplier of algaecides, aquatic herbicides and other water management products, we highly value the science and integrity the APMS brings to our industry. We are a leading life sciences company, dedicated to the development, production and application of a wide variety of products to improve the recreational and functional value of water, and quality of life throughout the world.

Aqua Services, Inc. is a full-service, aquatic resource management company that specializes in aquatic vegetation management. Established in 1983, the company has provided aquatic plant management for entities in the southeastern U.S. that include the Corps of Engineers, Tennessee Valley Authority, Southern Company, and the Tennessee Wildlife Resource Agency. Aqua Services also provides lake management consulting including electro-fishing assessments, water quality analysis and enhancement, and recreational lake design.

AquaTechnex, LLC is a lake and aquatic plant management firm that operates in the Western United States. The company is expert in the use of aerial and boat GIS/GPS technologies to assess aquatic environments. The firm is also expert in the management of invasive aquatic weed species and phosphorous mitigation to suppress toxic cyanobacteria blooms. Our web site is www.aquatechnex.com; please drop by regularly to get news updates as we have moved our blog onto the site.

Aquatic Control, Inc. has been managing aquatic resources since 1966. As a distributor of lake management supplies, floating fountain aerators, and diffused aeration systems, Aquatic Control represents Applied Biochemists, AquaBlok, BioSafe Systems, Brewer International, SePRO, Syngenta, United Phosphorus, AquaMaster, Kasco, and Otterbine. Aquatic Control has five offices that offer aquatic vegetation management plans including vegetation mapping and application services, fountain and aeration system installation, maintenance, and service throughout the Midwest.

Aquatic Vegetation Control, Inc. (AVC) is a Florida corporation founded in 1986 offering vegetation management and general environmental consulting services throughout the southeast. Since its establishment as an exotic/nuisance vegetation management company specializing in the control of invasive wetland, aquatic and upland species, AVC has broadened its scope of capabilities to include; certified lake management, fish stocking, re-vegetation, mitigation and restoration services, mitigation monitoring services, aquatic, roadside, forestry and utility vegetation management, and environmental/ecological consulting. https://www.avcaquatic.com/

Sustaining Members

BioSafe Systems LLC has been offering sustainable and effective solutions for lake management, municipal and wastewater treatments and other water resources since 1998. Our uniquely balanced, broad-spectrum chemistries are designed to enhance your water's health, quality and appearance. Alternatives to products that utilize copper, or other harsh and sometimes toxic chemicals, BioSafe Systems' complete line of products are EPA registered, USDA NOP compliant, OMRI listed and effectively alleviate algal issues with minimal impact on the environment.

Brewer International, located in Vero Beach, Florida, has been a chemical manufacturer since 1973. This location is perfect because the company purchases limonene, a low viscosity oil derived from the peel of citrus fruit. This natural ingredient is used in many of Brewer's formulations including two OMRI Listed Organic surfactants: Organic-Kick and Vin-Kick. The company offers aquatic surfactants Cide-Kick, Cide-Kick II, Cygnet Plus, I'Vod, Sun Wet, and Poly Control 2. Check out our web site at www.brewerint.com and visit us on our Facebook page.

Chem One is a national leader of Organic Copper Sulfate for aquatic management. With eight standard EPA label grades; Fine 20, 25, 30, 100, 200, Small, Medium and Large. Chem One has a grade to meet every customer's needs. With our corporate offices and 78,000+ square foot warehouse in Houston, Texas, Chem One is a national wholesale company that is certified to ISO 9001, ISO 14001, OHSAS 18001.

Clarke Aquatic Services is a global environmental products and services company. Our mission is to make communities around the world more livable, safe, and comfortable. By understanding our customers' needs, we tailor service programs that draw on our unmatched breadth of industry experience, expertise, and resources. We pioneer, develop and deliver environmentally responsible mosquito control and aquatic services to help control nuisances, prevent disease, and create healthy waterways.

Cygnet Enterprises, Inc. is a national single source distributor of aquatic management products with offices and warehouses in Michigan, Indiana, Pennsylvania, North Carolina, California and Idaho. Cygnet is proud of its reputation for outstanding service, friendly, knowledgeable staff and our unmatched support of the aquatics industry. Cygnet Enterprises is the only aquatic distributor at the Charter Gold Member level in the Aquatic Ecosystem Restoration Foundation (AERF). Please visit www.cygnetenterprises.com.

Diversified Waterscapes, Inc. (DWI) has an extensive knowledge base that includes experienced personnel and seasoned professionals in the management of lakes and ponds. We are dedicated to continually improving our technical and distributor support service, attitude, communication and innovative development of new products and are consistently expanding our knowledge by investigating industry trends, laws and regulations. DWI also manufactures a line of aquatic treatment products that are formulated to be environmentally safe, biodegradable, and non-toxic to aquatic environments.

Duke Energy is one of the largest electric power holding companies in the U.S. Its regulated utility operations serve approximately 7.4 million electric customers located in six states in the Southeast and Midwest, representing a population of approximately 24 million people. Its Commercial Portfolio and International business segments own and operate diverse power generation assets in North America and Latin America, including a growing portfolio of renewable energy assets in the U.S. Headquartered in Charlotte, NC, Duke Energy is an S&P 100 Stock Index company traded on the New York Stock Exchange under the symbol DUK. Visit us at duke-energy.com.

Sustaining Members

Lake Restoration, located in MN, has specialized in controlling pond weeds, lake weeds, and nuisance algae since 1977. Lake Restoration's product line-up includes: Mizzen, a copper based algaecide, Spritflo and Dibrox herbicides, a variety of pond dyes and nutrient reducers. Lake Restoration also manufactures the TORMADA product application boat, Vitaflume floating fountains, the retractable Goose D-Fence system, and the patented LAKEMAID to eliminate lake weeds automatically. For more information, visit our website www.lakerestoration.com.

The **Lee County Hyacinth Control District** was formed by the Florida Legislature in June 1961to curtail excessive growths of water hyacinth. That same year, water managers from across the state convened in Lee County and formed the Hyacinth Control Society, now APMS, to share control strategies and develop a comprehensive management approach to Florida's most prolific aquatic plant. T. Wayne Miller, Jr. of Lee County served as the Society's President for the first two years and Lee County has been a supporting member of APMS since its inception.

Maxunitech is an integrated enterprise focusing on the Research and Development, production, sales of agrochemicals, and relevant intermediates and other fine chemicals. Established in 2000, under the principles of "people oriented, united for innovation and pursue excellence", we have been researching and developing new products, solving commercial issues from the perspective of technology, and fulfilling enterprise value with value added for our clients.

Valent Corporation signed a formal agreement with **Nufarm Americas** giving them exclusive distributorship of its products. All of Valent's Professional Products, including its aquatics products, Clipper and Tradewind, will now be sold by Nufarm. This allows Nufarm to offer a portfolio of 10 products labeled for aquatics. Nufarm provides a wide variety of products labeled for aquatics, both systemic and contact, that can be used selectively or broad spectrum depending on their use.

Nutrien Solutions is a full-service vegetation management company, providing innovative solutions and quality products for the aquatic plant management industry. The cornerstone of our success is our highly educated and trained field staff. With strong commitments to environmental stewardship, innovation, and technology, Nutrien Solutions provides customized programs tailored to specific locations throughout the U.S. We are the country's leading vegetation management provider, and we're excited to introduce you to everything Nutrien Solutions has to offer. Visit: NutrienAgSolutions.com/Specialty.

For 25 years, **SePRO Corporation** has developed innovative technologies to advance the science of water management. The SePRO team provides comprehensive assessment, planning and implementation solutions. Our focused disciplines include aquatic plant and algae management, water quality restoration, laboratory analysis, mapping and data management. Whether you are looking to assess a water resource, design a prescription plan or implement a restoration program, SePRO provides expertise and solutions to preserve our most precious natural resource – water. www.sepro.com

SOLitude Lake Management is an environmental firm committed to providing sustainable solutions that improve water quality, enhance beauty, preserve natural resources, educate communities and reduce our environmental footprint. SOLitude's team of Aquatic Biologists, Ecologists and Environmental Scientists specializes in the execution of customized lake, pond, wetland and fisheries management programs that include algae and aquatic weed control, water quality testing and restoration, nutrient remediation, vegetation studies and biological assessments for clients across the United States.

Sustaining Members

SOX Erosion Solutions™ has mastered erosion control and restoration of living shorelines and hillsides. SOX manufactures and distributes a suite of patented, bioengineered erosion control solutions that are stable, long-lasting and compliant with all BMP's (Best Management Practices) of Living Shoreline erosion control systems. SOX uses environmentally-focused methodology that gets high marks from engineers and environmentalists alike and is a cost-efficient and long-lasting solution to shoreline & hillside erosion.

Invasive weeds can devastate both natural and commercial habitats. **Syngenta** provides high performance products to control destructive weeds while helping to restore the habitat of aquatic environments. Syngenta offers proven aquatic herbicides like Reward® and Tribune™ that provide fast burn-down, work well in cool weather and are rainfast in as little as 30 minutes. The active ingredient, diquat dibromide, has been used successfully in sensitive aquatic areas for over 25 years.

For over 30 years, **UPL** has been a premier supplier of crop protection products and plant technologies designed for agricultural, specialty and aquatics markets. UPL manufactures aquatic herbicides and algaecides for lakes, ponds, rivers and irrigation canals. These products are marketed as Aquathol®, Hydrothol®, AquaStrike®, Chinook®, Current®, Cascade®, and Teton®. UPL is an industry leader with time-tested and trusted products and a strong commitment to product stewardship, including research and development of new uses, techniques, and formulations. Visit us at www.upi-usa.com.

Vertex Water Features is a science and engineering-based aeration system manufacturer that provides custom designed water quality solutions distributed through its lake manager dealer network to interested lake owners, lake managers, developers and government agencies throughout North America and internationally. Website: www.vertexwaterfeatures.com. Phone: 1-844-432-4303 FB: https//www.facebook.com/VertexWaterFeatures/ Email: info@vertexwaterfeatures.com

Exhibitors

The Aquatic Plant Management Society thanks the following companies for exhibiting their products and services. This list was current when the Program was submitted for printing on June 11, 2019. Please visit the exhibit hall in the Gallery for all Exhibitors, including not-for-profit organizations.

Alligare, LLC
Davidson, North Carolina

Applied Biochemists
Phoenix, Arizona

AquaMaster Fountains
Kiel, Wisconsin

Aquatic Control, Inc.
Seymour, Indiana

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Marine Taxonomic Services, Ltd.
San Marcos, California

Nufarm Americas
Raleigh, North Carolina

Nutrien Solutions
Oviedo, Florida

Outdoor Water Solutions
Springdale, Arkansas

The Power House, Inc.
Owings Mills, Maryland

SePRO
Carmel, Indiana

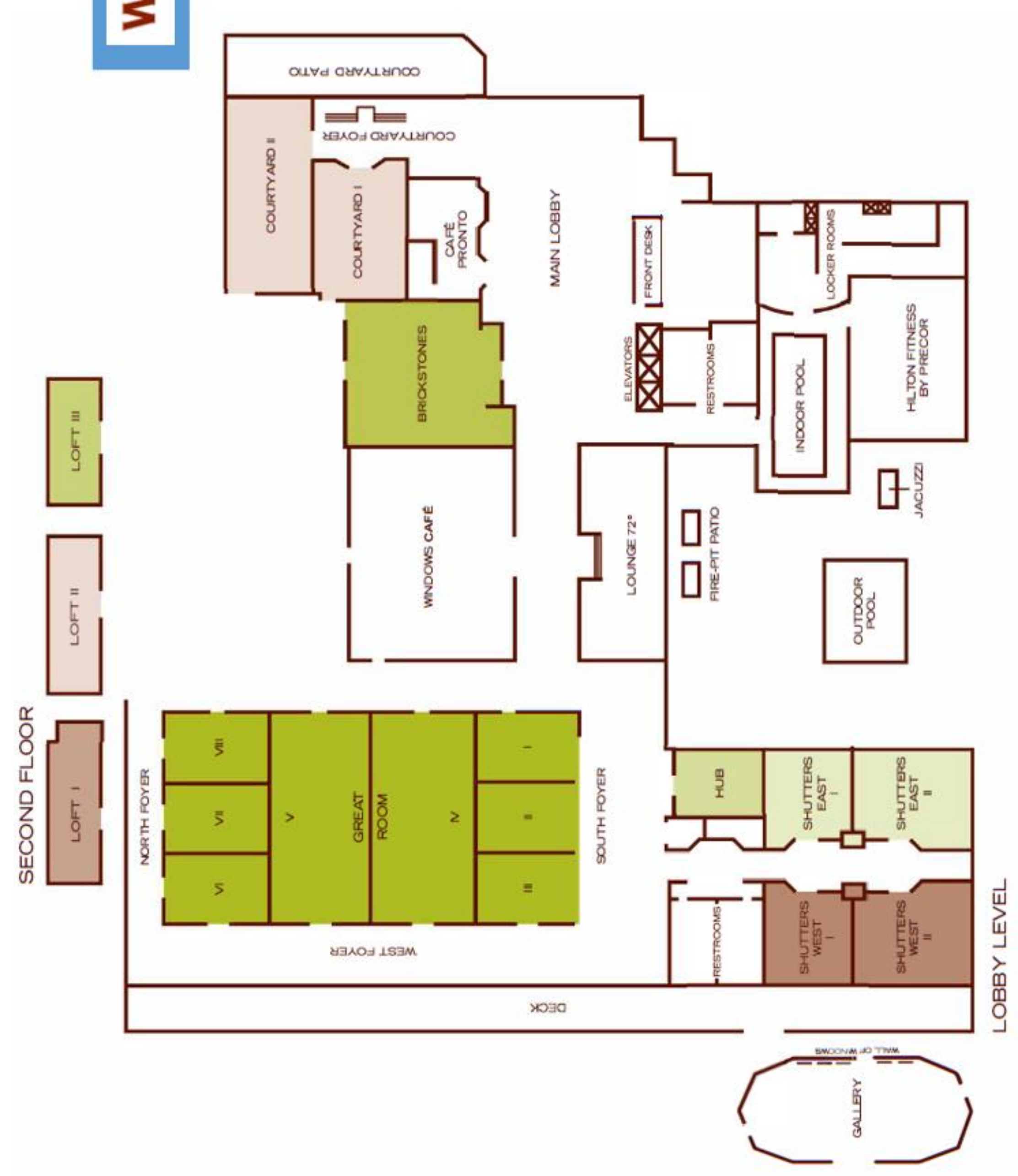
Syngenta
Greensboro, North Carolina

UPL NA Inc.
Exton, Pennsylvania

Vertex Water Features
Pompano Beach, Florida

Winfield United
Ville Platte, Louisiana

WOOD RANCH


SECOND FLOOR
LOFT I
LOFT II
LOFT III
NORTH FOYER
VIII
VII
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GREAT ROOM
IV
I
II
III
SOUTH FOYER
WEST FOYER
DECK
WINDOWS CAFÉ
BRICKSTONES
COURTYARD PATIO
COURTYARD FOYER
COURTYARD II
COURTYARD I
CAFÉ PRONTO
MAIN LOBBY
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ELEVATORS
RESTROOMS
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HILTON FITNESS BY PRECOR
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JACUZZI
LOUNGE 72°
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OUTDOOR POOL
HUB
SHUTTERS EAST I
SHUTTERS EAST II
RESTROOMS
SHUTTERS WEST I
SHUTTERS WEST II
LOBBY LEVEL
WALL OF WINDOWS
GALLERY

General Information and Events

Program Organization

The Agenda is organized by day and time. Posters and abstracts are organized alphabetically by presenting author. For more event information, please see the Agenda-at-a-Glance pages for each day in this Program. Messages will be posted at the meeting registration desk. Most events will take place in the Gallery and Great Room IV-VIII. See the hotel site map on page 13 of the Program for event locations.

Name Badges

Your name badge is your ticket for all events at the meeting. Wear it to all activities during the meeting. All individuals participating in meeting events or activities must be registered and have a name badge. Non-registered guests may purchase tickets for the President's Reception, Poster Session Reception, and Awards Banquet at the meeting registration desk.

Meeting Registration Desk

The meeting registration desk will be in the Courtyard Foyer on Sunday July 14, from 1:00 – 5:00 pm. On Monday, July 15, the registration desk will move to the South Foyer for the duration of the meeting. The registration desk will be open from 7:30 am – 5:00 pm on Monday and Tuesday and from 7:30 am – 12:00 pm on Wednesday.

Exhibits

Exhibits will be open from 7:00 am Monday through 10:00 am Wednesday in the Gallery. Exhibitors may start setting up at noon on Sunday, July 14.

Posters

Posters will be open from 7:00 am Monday through 10:00 am Wednesday in the Gallery. Poster presenters will be on hand during the Monday evening Poster Reception as well as during breaks to answer questions. Poster Presenters may start setting up at noon on Sunday, July 14. All Posters must be set up before 6:00 pm on Monday, July 15.

Continental Breakfasts / Refreshment Breaks

Continental breakfasts and mid-morning and afternoon refreshment breaks will be served each day in the Gallery. Please see the Agenda-at-a-Glance for specific times. Also, take time to visit with Exhibitors in the Gallery while enjoying your breakfast or break.

Spur of the Moment Meeting Room

We have a room set up conference style for 25 guests. Check at the meeting registration desk to reserve.

Student Meet-and-Greet! *Sunday, July 14, 5:00 pm to 6:00 pm, Wood Ranch BBQ*

All students registered for the Annual Meeting are invited to gather at the Wood Ranch BBQ, immediately adjacent to the DoubleTree, to get to know other students prior to the Presidents' Reception. Beverages and light snacks will be provided for this students-only event.

President's Reception: *Sunday, July 14, 6:00 pm to 9:00 pm, Wood Ranch Patio*

Join your APMS friends and colleagues at the Presidents' Reception on the Wood Ranch Patio to "kick-off" our annual meeting while enjoying hors d'oeuvres and beverages. The President's Reception is open to all registered delegates, guests, and students. Non-registered guests may purchase tickets at the meeting registration desk.

Student Affairs Luncheon: *Monday, July 15, 11:30 am to 1:00 pm, Courtyard II*

All students registered for the meeting are invited to attend. This luncheon, provided by our sponsors, is a great opportunity to meet other students, interact with guest speakers and APMS leadership, and learn how to become more involved in the Society. Chis Mudge, Student Affairs Committee Chair, will be the moderator. Please contact Chris by noon Sunday, July 14 to confirm your attendance.

Regional Chapters Presidents' Luncheon: *Monday, July 15, 11:30 am to 1:00 pm, Courtyard I*

Two representatives from each APMS regional chapter are invited to attend the Regional Chapter Presidents' Luncheon, provided by APMS sponsors. Ryan Wersal, APMS Vice President and Regional Chapters Committee Chair will be the moderator for discussions on aquatic plant management activities in each region. Please contact Ryan by noon Sunday, July 14 to confirm your attendance.

APMS Annual Business Meeting: *Monday, July 15, 4:40 pm to 5:10 pm, Great Room IV-VIII*

All APMS members are encouraged to attend the APMS Annual Business Meeting for Society updates as well as electing new Officers and Directors. Members can review details on the Officer and Directors Slate in the June 2019 APMS Newsletter.

WAPMS Annual Business Meeting: *Monday, July 15, 5:10 pm to 5:40 pm Great Room IV-VII*

All WAPMS members are encouraged to attend the WAPMS Annual Business Meeting immediately following the APMS Annual Business Meeting and just before the Poster Reception. Please see the WAPMS web site (www.wapms.org/) for more information.

Poster Session Reception: *Monday, July 15, 6:00 pm to 7:30 pm, Gallery*

This reception provides for the viewing of posters and exhibits along with professional interactions and discussions in a casual setting while enjoying light hors d'oeuvres and beverages. Authors of 29 posters will be on hand to discuss their work. The Poster Session Reception is open to all registered delegates, guests, and students. Non-registered guests may purchase tickets for this event at the meeting registration desk. Enjoy the discussions and refreshments before moving on to dining with colleagues or taking in the sights around the Hotel.

Past Presidents' Luncheon: *Tuesday, July 16, 11:40 am to 1:10 pm, Courtyard I*

All APMS Past Presidents are invited to attend the Past Presidents' Luncheon to provide insight into matters facing APMS and aquatic plant managers. John Rodgers, Immediate Past President, will be the moderator. Please contact John by noon Monday, July 15 to confirm your attendance.

Women of Aquatics Luncheon: *Tuesday, July 16, 11:40 am to 1:10 pm, Loft II*

Amy Kay will host the APMS Women of Aquatics Luncheon to discuss opportunities for women in the field of aquatic plant management. Please contact Amy by noon Monday, July 15 to confirm your attendance.

Awards Reception / Banquet: *Tuesday, July 16, 6:15 pm to 10:00 pm, Great Room*

Registered delegates, guests and students are invited to the Awards Banquet in the Great Room. Join us in the Southwest Foyer outside the Great Room, for a pre-banquet reception from 6:15-7:00 pm. After dinner, we will recognize those who have served APMS, welcome new officers and directors, and this year's student paper and poster award participants. Our evening will conclude with a fund-raising raffle for prizes. The raffle supports APMS student and other education initiatives. Raffle tickets may be purchased at the registration desk and during the Awards Banquet.

Events-at-a-Glance

See daily Agenda-at-a-Glance on pages 17-29 of the Program for event times and locations.

Sunday – July 14:

APMS Board of Directors Meeting – *Courtyard II*
Exhibits and Poster Setup – *Gallery*
Registration – *Courtyard Foyer*
Student Meet-and-Greet – *Wood Ranch BBQ*
Presidents' Reception – *Wood Ranch Patio*

Monday – July 15:

Registration – *South Foyer*
Continental Breakfast & Refreshment Breaks – *Gallery*
Exhibits and Posters – *Gallery*
Opening Remarks, General Session, Special Tribute to Mike Netherland – *Great Room IV-VIII*
Student Affairs Luncheon – *Courtyard II*
Regional Chapters Presidents' Luncheon – *Courtyard I*
Symposium - Delta Region Areawide Aquatic Weed Research Program, General Session, and Student Presentations – *Great Room IV-VIII*
APMS Annual Business Meeting – *Great Room IV-VIII*
WAPMS Annual Business Meeting – *Great Room IV-VIII*
Poster Session & Reception – *Gallery*

Tuesday – July 16:

Registration – *South Foyer*
Continental Breakfast and Breaks – *Gallery*
Exhibits and Posters – *Gallery*
General Sessions, Student Presentations – *Great Room IV-VIII*
APMS Past Presidents' Luncheon – *Courtyard II*
Women of Aquatics Luncheon – *Loft II*
Awards Reception – *Southwest Foyer*
Awards Banquet and APMS Awards Presentations – *Great Room*

Wednesday – July 17:

Registration – *South Foyer*
Continental Breakfast and Breaks – *Gallery*
Exhibits and Posters – *Gallery*
General Session – *Great Room IV-VIII*
Meeting Adjourns – 12:00 p.m.
APMS Board of Directors Meeting – *Shutter East I & II*

Agenda

Sunday, July 14

Sunday's Agenda-at-a-Glance

7:30 am	-	5:00 pm	APMS Board of Directors Meeting *(Courtyard II)*
12:00 pm	-	5:00 pm	Exhibits and Posters Setup *(Gallery)*
1:00 pm	-	5:00 pm	Registration *(Courtyard Foyer)*
5:00 pm	-	6:00 pm	Student Meet-and-Greet *(Wood Ranch BBQ)*
6:00 pm	-	9:00 pm	President's Reception *(Wood Ranch Patio)*

Monday, July 15

Monday's Agenda-at-a-Glance

7:00 am	-	8:00 am	Continental Breakfast *(Gallery)*
7:00 am	-	7:30 pm	Exhibits and Posters Open *(Gallery)*
7:30 am	-	5:00 pm	Registration *(South Foyer)*
8:00 am	-	11:30 am	Session I – Opening Remarks, General Session, Special Tribute *(Great Room IV-VIII)*
10:00 am	-	10:30 am	Refreshment Break *(Gallery)*
11:30 am	-	1:00 pm	Lunch on your own
11:30 am	-	1:00 pm	Student Affairs Luncheon *(Courtyard II)*
11:30 am	-	1:00 pm	Regional Chapters Presidents' Luncheon *(Courtyard I)*
1:00 pm	-	4:40 pm	Session II - Symposium - Delta Region Areawide Aquatic Weed Research Project, General Session, Student Presentations *(Great Room IV-VIII)*
3:00 pm	-	3:20 pm	Refreshment Break *(Gallery)*
4:40 pm	-	5:10 pm	APMS Annual Business Meeting *(Great Room IV-VIII)*
5:10 pm	-	5:40 pm	WAPMS Annual Business Meeting *(Great Room IV-VIII)*
6:00 pm	-	7:30 pm	Poster Session and Reception *(Gallery)*

Session I – Opening Remarks, General Session, Special Tribute
8:00 am - 11:30 am
Great Room IV-VIII

Moderator: Mark Heilman – APMS President Elect
SePRO, Carmel, IN

8:00 am **Call to Order – Announcements and WAPMS Welcome**
Mark Heilman – APMS Program Committee Chair
SePRO, Carmel, IN

Andrea Sealock – WAPMS President
Cygnet Enterprises West, Concord, CA

8:05 am **APMS Presidential Address**
Craig Aguillard
Winfield United, Villa Platte, LA

8:15 am **Sustaining APMS and Chapter Successes: Changing Ecosystems Demand New Collaborative Solutions**
Lars W. Anderson
Waterweed Solutions, Davis, CA

8:40 am **Overview of Risk Assessments: Ecological Risk**
Jean Holmes
U.S. Environmental Protection Agency, Environmental Fate and Effects Division, Office of Pesticide Programs, Arlington, VA

9:00 am **Balancing Invasive Aquatic Plant Management and Environmental Regulation in the Sacramento-San Joaquin Delta (Delta)**
Wendy Pratt
Crowe LLP, Sacramento, CA

9:20 am **On Trial: How Science and Public Perception Are Determining Glyphosate's Future**
Michael S. Blankinship
Blankinship and Associates, Inc., Davis, CA

9:40 am **Lake Tahoe's Aquatic Invasive Species Prevention Program: Ten Years of Success and Planning for the Future**
Dennis Zabaglo
Tahoe Regional Planning Agency, Stateline, NV

10:00 am **Refreshment Break** *(Gallery)*

10:30 am **APMS SPECIAL TRIBUTE: Michael D. Netherland – Scientist, Colleague, Friend**
The technical impact and special character of a unique career

Moderator: Mark Heilman – APMS President Elect

Contributors:

Jason Ferrell	*University of Florida*
Carole Lembi	*Purdue University (retired)*
Kurt Getsinger	*U.S. Army ERDC - Aquatic Plant Control Research Program*
Jeremy Slade	*UPL NA Inc.*
Tyler Koschnick	*SePRO*
Jeff Schardt	*Florida Fish and Wildlife Conservation Commission (retired)*
Ryan Thum	*Montana State University*
Rob Richardson	*North Carolina State University*
John Madsen	*U.S. Department of Agriculture*

11:30 am **Morning Wrap-up and Announcements - Lunch on your own**

Session II – Symposium - Delta Region Areawide Aquatic Weed Research Project, General Session, Student Presentations

1:00 pm – 4:40 pm
Great Room IV-VIII

Moderator: John Madsen
U.S. Department of Agriculture-Agricultural Research Service, Davis, CA

1:00 pm **An Overview of the Delta Region Areawide Aquatic Weed Project for Improved Control of Invasive Aquatic Weeds in the Sacramento-San Joaquin Delta**
Patrick J. Moran[1], Louise Conrad[2], Thomas Jabusch[3], John D. Madsen[4], and Paul Pratt[1]
[1]U.S. Department of Agriculture-Agricultural Research Service, Invasive Species and Pollinator Health Research Unit, Albany, CA
[2]Delta Stewardship Council, Sacramento, CA
[3]Sacramento-San Joaquin Delta Conservancy, West Sacramento, CA
[4]U.S. Department of Agriculture-Agricultural Research Service, Invasive Species and Pollinator Health Research Unit, Davis, CA

1:20 pm **Phenology of Three Invasive Aquatic Weeds in the Delta**
John D. Madsen, Christy M. Morgan, John Miskella
U.S. Department of Agriculture-Agricultural Research Service, Invasive Species and Pollinator Health Research Unit, Davis, CA

1:40 pm **Remote Sensing and Mapping of Floating Aquatic Vegetation in the Sacramento-San Joaquin River Delta**
David Bubenheim[1], Vanessa Genovese[2], Edward Hard[3], and John D. Madsen[4]
[1]*Biospheric Science Branch, Earth Science Division, NASA Ames Research Center, Moffett Field, CA*
[2]*California State University Monterey Bay, Biospheric Science Branch, Earth Science Division, NASA Ames Research Center, Moffett Field, CA*
[3]*California Department of Parks and Recreation, Division of Boating and Waterways, Sacramento, CA*
[4]*U.S. Department of Agriculture-Agricultural Research Service, Invasive Species and Pollinator Health Research Unit, Davis, CA*

2:00 pm **Biological Control of Invasive Aquatic Plants in the California Delta: Past, Present, and Future**
Michael Pitcairn[1], Patrick J. Moran[2], Paul Pratt[2], Angelica M. Reddy[2], and Jon O'Brien[3]
[1]*California Department of Food and Agriculture, Sacramento, CA*
[2]*U.S. Department of Agriculture-Agricultural Research Service, Invasive Species and Pollinator Health Research Unit, Albany, CA*
[3]*California Department of Parks and Recreation, Division of Boating and Waterways, Sacramento, CA*

2:20 pm **Operational Aquatic Invasive Plant Management in the Delta**
Jeffery Caudill[1], Edward Hard[1], John D. Madsen[2]
[1]*California Department of Parks and Recreation, Division of Boating and Waterways, Sacramento, CA*
[2]*U.S. Department of Agriculture-Agricultural Research Service, Invasive Species and Pollinator Health Research Unit, Davis, CA*

2:40 pm **Bio-economic Model of Delta Weed Management**
Karen M. Jetter[1], John D. Madsen[2], David Bubenheim[3], Minghua Zhang[4]
[1]*University of California, Agricultural Issues Center, Davis, CA*
[2]*U.S. Department of Agriculture-Agricultural Research Service, Invasive Species and Pollinator Health Research Unit, Davis, CA*
[3]*Biospheric Science Branch, Earth Science Division, NASA Ames Research Center, Moffett Field, CA*
[4]*University of California-Davis, Land, Air and Water Resources, Davis, CA*

3:00 pm **Refreshment Break** *(Gallery)*

3:20 pm **Platinum Level Sponsor Presentation – UPL NA Inc**
3:30 pm **Gold Level Sponsor Presentation – Applied Biochemists**
3:35 pm **Gold Level Sponsor Presentation – Syngenta**

3:40 pm **The Effects of Invasive Aquatic Weeds on Larval Mosquito Habitat (*Student Presentation*)**
Maribel A. Portilla and Sharon Lawler
University of California, Davis, Department of Entomology, Davis, CA

4:00 pm **Non-Target Impacts of Hydrilla and Lyngbya treatments on Waterwillow (*Justicia americana*) (*Student Presentation*)**
Jens Beets[1], Erika Haug[2], and Robert J. Richardson[2]
[1]*North Carolina State University, Fisheries, Wildlife, and Conservation Biology/Crop Science, Raleigh, NC*
[2]*North Carolina State University, Crop and Soil Sciences, Raleigh, NC*

4:20 pm **Estimating *Lyngbya wollei* Biomass Using Non-destructive Echosounding Measures (*Student Presentation*)**
Andrew Howell, Tyler Harris, and Robert J. Richardson
North Carolina State University, Crop and Soil Sciences, Raleigh, NC

4:40 pm **APMS Annual Business Meeting** *(Great Room IV-VIII)*

5:10 pm **WAPMS Annual Business Meeting** *(Great Room IV-VIII)*

6:00 pm **Poster Session and Reception** (*Gallery)*

Poster Session

6:00 pm - 7:30 pm
Gallery

Systematic Identification and Ecology of *Chara* (Charales) in Stormwater Treatment Areas of South Florida: A Preliminary Study (*Student Presentation*)

Maximiliano Barbosa[1], David E. Berthold[1], Forrest Lefler[1], Eric Crawford[2], and H. Dail Laughinghouse[1]
[1]*University of Florida, Agronomy Department, Fort Lauderdale Research and Education Center, Davie, FL*
[2]*South Florida Water Management District, West Palm Beach, FL*

Can Phoslock® Be Used to Bind and Sediment Microsystin-LR in Aquatic Systems? (*Student Presentation)*

David E. Berthold[1], Forrest Lefler[1], West M. Bishop[2], and H. Dail Laughinghouse[1]
[1]*University of Florida, Agronomy Department, Fort Lauderdale Research and Education Center, Davie, FL*
[2]*SePRO Research and Technology Campus, Whitakers, NC*

Air and Water Temperature Relationship and Growth of Hyacinth and Primrose

David Bubenheim[1], Greg Schlick[2], David Wilson[2], and John D. Madsen[3]
[1]*Biospheric Science Branch, Earth Science Division, NASA Ames Research Center, Moffett Field, CA*
[2]*Bay Area Environmental Research Institute, Biospheric Science Branch, Earth Science Division, NASA Ames Research Center, Moffett Field, CA*
[3]*U.S. Department of Agriculture-Agricultural Research Service, Invasive Species and Pollinator Health Research Unit, Davis, CA*

Growth Response of Water Hyacinth to Environmental Ranges in the California Sacramento-San Joaquin River Delta

David Bubenheim[1], Greg Schlick[2], David Wilson[2], and John D. Madsen[3]
[1]*Biospheric Science Branch, Earth Science Division, NASA Ames Research Center, Moffett Field, CA*
[2]*Bay Area Environmental Research Institute, Biospheric Science Branch, Earth Science Division, NASA Ames Research Center, Moffett Field, CA*
[3]*U.S. Department of Agriculture-Agricultural Research Service, Invasive Species and Pollinator Health Research Unit, Davis, CA*

Sediment Copper Concentrations, *in situ* Benthic Abundance, and Sediment Toxicity: Comparison of Coves Treated with Copper-Based Algaecides and Untreated Coves in a Southern Reservoir (*Student Presentation*)

Tyler Geer[1], Andrew McQueen[2], Alyssa Calomeni[3], Ciera K. Baird[4], Kyla I. Wood[5], and John H. Rodgers[1]
[1]*Clemson University, Department of Forestry and Environmental Conservation, Clemson, SC*
[2]*U.S. Army Engineer Research and Development Center, Environmental Laboratory, Vicksburg, MS*
[3]*EA Engineering, Science, and Technology, Inc., PBC, Hunt Valley, MD*
[4]*Aquatic Control Inc., Seymour, IN*
[5]*Applied Polymer Systems, Inc., Marquette, MI*

An Update on the Development of Hydrilla Biological Control in the U.S.

Nathan E. Harms[1], Dean Williams[2], Matthew Purcell[3], Al Cofrancesco[4], Jialiang Zhang[5], Hong Sun-Hee[6], and Graham McCulloch[7]
[1]*U.S. Army Engineer Research and Development Center, Aquatic Ecology and Invasive Species Branch, Vicksburg, MS*
[2]*Texas Christian University, Department of Biology, Fort Worth, TX*
[3]*Commonwealth Scientific and Industrial Research Organisation, Brisbane, Australia*
[4]*U.S. Army Engineer Research and Development Center, Vicksburg, MS*
[5]*Wuhan Botanical Institute, Invasion Biology and Biocontrol Lab, Wuhan, Peoples Republic*
[6]*HanKyong National University, Anseong, South Korea*
[7]*The University of Queensland, School of Biological Sciences, Saint Lucia, Australia*

Increased Ploidy is not Associated with Higher Phenotypic Plasticity in Response to N and P in the Wetland Invader, *Butomus umbellatus* L.

Nathan E. Harms[1], John Gaskin[2], James T. Cronin[3], and Ashton B. DeRossette[1]
[1]*U.S. Army Engineer Research and Development Center, Aquatic Ecology and Invasive Species Branch, Vicksburg, MS*
[2]*U.S. Department of Agriculture, Agricultural Research Service, Sidney, MT*
[3]*Louisiana State University, Biological Sciences, Baton Rouge, LA*

Herbicide Concentration Exposure Time Evaluations for Loon Lake, WA: Invasive Watermilfoil Genotypes
Erika Haug[1], Kurt D. Getsinger[2], Ryan Thum[3], Terry M. McNabb[4], Steve T. Hoyle[1], and Robert J. Richardson[1]
[1]*North Carolina State University, Crop and Soil Sciences, Raleigh, NC*
[2]*U.S. Army Engineer Research and Development Center, Environmental Laboratory, Vicksburg, MS*
[3]*Montana State University, Bozeman, MT*
[4]*AquaTechnex, LLC, Bellingham, WA*

Successful Eradication of Monoecious Hydrilla from a Northern Indiana Lake
Mark A. Heilman[1], Eric D. Fischer[2], Doug Keller[2], J.T. Gravelie[3], Nathan Long[4], David Keister[5], and Tyler J. Koschnick[1]
[1]*SePRO, Carmel, IN*
[2]*Indiana Department of Natural Resources, Indianapolis, IN*
[3]*SePRO, Traverse City, MI*
[4]*Aquatic Control, Inc., Seymour, IN*
[5]*Aquatic Weed Control, Inc., Goshen, IN*

Establishment of Aquatic Macrophytes in Mission District of the San Antonio River
Jeffrey T. Hutchinson
University of Texas at San Antonio, Department of Environmental Science and Ecology, San Antonio, TX

The Cost of Invasive Weed Management in the California Bay-Delta, 2013 – 2018
Karen M. Jetter
University of California, Agricultural Issues Center, Davis, CA

Aquatic Plant Community Restoration Following the Long-term Control of Invasive *Egeria densa* with Fluridone Treatments
Ajay R. Jones[1], Jeffery Caudill[2], John D. Madsen[3], Lars Anderson[4], Patricia Gilbert[2], Scott Shuler[5], and Mark A. Heilman[5]
[1]*SePRO, Elk Grove, CA*
[2]*California Department of Parks and Recreation, Division of Boating and Waterways, Sacramento, CA*
[3]*U.S. Department of Agriculture-Agricultural Research Service, Invasive Species and Pollinator Health Research Unit, Davis, CA*
[4]*Waterweed Solutions, Davis, CA*
[5]*SePRO, Carmel, IN*

New Chemicals and Tank Mixes for Control of Waterhyacinth in the Sacramento-San Joaquin Delta
Guy B. Kyser[1], John D. Madsen[2], John Miskella[2], and Jon O'Brien[3]
[1]*University of California, Plant Sciences, Davis, CA*
[2]*U.S. Department of Agriculture-Agricultural Research Service, Invasive Species and Pollinator Health Research Unit, Davis, CA*
[3]*California Department of Parks and Recreation, Division of Boating and Waterways, Sacramento, CA*

Herbicide Trials with Brazilian Egeria (*Egeria densa)* for Management in the Sacramento / San Joaquin River Delta
John D. Madsen[1], Christy M. Morgan[1], John Miskella[1], Guy B. Kyser[2], Patricia Gilbert[3], Jon O'Brien[3], and Kurt D. Getsinger[4]
[1]*U.S. Department of Agriculture-Agricultural Research Service, Invasive Species and Pollinator Health Research Unit, Davis, CA*
[2]*University of California, Davis, CA*
[3]*California Department of Parks and Recreation, Division of Boating and Waterways, Sacramento, CA*
[4]*U.S. Army Engineer Research and Development Center, Environmental Laboratory, Vicksburg, MS*

Effect of Herbicide Application on Dissolved Oxygen Dynamics under Canopies of Waterhyacinth (*Eichhornia crassipes*)
John Miskella[1], John D. Madsen[1], Angela Llaban[2], and Edward Hard[3]
[1]*U.S. Department of Agriculture-Agricultural Research Service, Invasive Species and Pollinator Health Research Unit, Davis, CA*
[2]*California Department of Fish and Wildlife, Sacramento, CA*
[3]*California Department of Parks and Recreation, Division of Boating and Waterways, Sacramento, CA*

Release and Establishment of the Shoot-Galling Wasp *Tetramesa romana* and the Armored Scale *Rhizaspidiotus donacis* for Biological Control of Arundo (*Arundo donax*) in the Sacramento and San Joaquin River Watersheds of Northern California

Patrick J. Moran[1], Ellyn Bitume[2], and John Goolsby[3]
[1]U.S. Department of Agriculture-Agricultural Research Service, Invasive Species and Pollinator Health Research Unit, Albany, CA
[2]University of Hawaii and U.S. Department of Agriculture-U.S. Forest Service, Hilo, HI
[3]U.S. Department of Agriculture-Agricultural Research Service, Cattle Fever Tick Research Lab, Edinburg, TX

Water Temperature and the Growth of Spongeplant (*Limnobium laevigatum*)

Christy M. Morgan and John D. Madsen
U.S. Department of Agriculture-Agricultural Research Service, Invasive Species and Pollinator Health Research Unit, Davis, CA

Response of Algal Assemblage to Fertilizer (Nitrogen and Phosphorous) Application Rate in California Rice

Sara Ohadi[1], John D. Madsen[2], and Kassim Al-Khatib[1]
[1]University of California, Davis, CA
[2]U.S. Department of Agriculture-Agricultural Research Service, Invasive Species and Pollinator Health Research Unit,

Interaction of Florpyrauxifen-benzyl with Four Herbicides for Curlyleaf Pondweed Control (*Student Presentation)*

Mirella F. Ortiz[1], Mark A. Heilman[2], and Franck E. Dayan[1]
[1]Colorado State University, Fort Collins, CO
[2]SePRO, Carmel, IN

Variation in Cool Temperature Performance Between Populations of *Neochetina eichhorniae* and Implications for the Biological Control of Water Hyacinth in a Temperate Climate

Angelica M. Reddy[1], Paul Pratt[1], Julie V. Hopper[2], Ximena Cibils-Stewart[3], Guillermo Cabrera Walsh[4], and Fernando McKay[4]
[1]U.S. Department of Agriculture-Agricultural Research Service, Invasive Species and Pollinator Health Research Unit, Albany, CA
[2]University of Southern California, Caron Lab, Los Angeles, CA
[3]Instituto Nacional de Investigación Agropecuaria, La Estanzuela, Uruguay
[4]Fundación para el Estudio de Especies Invasivas, Hurlingham, Argentina

Establishment of the Mike Netherland and Steve Hoyle Outstanding Aquatic Weed Science Graduate Student Award Endowment

Robert J. Richardson
North Carolina State University, Crop and Soil Sciences, Raleigh, NC

Metsulfuron Methyl as a Potential Control for Southern Naiad in Arkansas Baitfish Culture Ponds

George Selden
University of Arkansas at Pine Bluff, Aquaculture/Fisheries Center, Pine Bluff, AR

Digging Deep into the Benthic Layer: Factors Threatening Its Vital Role in Lake Ecosystems

Patrick A. Simmsgeiger
Diversified Waterscapes, Inc., Laguna Niguel, CA

Spatial and Temporal Patterns of Genetic Variation in Lakes with Eurasian and Hybrid Watermilfoil in the Upper Midwest

Ryan A. Thum[1], Greg Chorak[1], Ray Newman[2], Jasmine Eltawely[2]
[1]Montana State University, Plant Sciences and Plant Pathology, Bozeman, MT
[2]University of Minnesota, Fisheries, Wildlife, and Conservation Biology, Saint Paul, MN

Torpedograss Control Via Submersed Applications of Systemic and Contact Herbicides (*Student Presentation*)
Lee G. Turnage[1], Ryan M. Wersal[2], and John D. Madsen[3]
[1]*Mississippi State University, Geosystems Research Institute, Starkville, MS*
[2]*Minnesota State University, Mankato, Biological Sciences, Mankato, MN*
[3]*U.S. Department of Agriculture-Agricultural Research Service, Invasive Species and Pollinator Health Research Unit, Davis, CA*

Evaluation of Selected Algaecides on *Lyngbya wollei* Control (*Student Presentation*)
Emily Vulgamore, Erika Haug, and Robert J. Richardson
North Carolina State University, Crop and Soil Sciences, Raleigh, NC

SWAT Modeling of Nitrogen Exports to the Bay-Delta from Sacramento and San Joaquin River Basins
Ruoyu Wang[1], Huajing Chen[1], David Bubenheim[2], Patrick J. Moran[3], and Minghua Zhang[1]
[1]*University of California-Davis, Land, Air and Water Resources, Davis, CA*
[2]*Biospheric Science Branch, Earth Science Division, NASA Ames Research Center, Moffett Field, CA*
[3]*U.S. Department of Agriculture-Agricultural Research Service, Invasive Species and Pollinator Health Research Unit, Albany, CA*

Florpyrauxifen-benzyl Impact on Non-target Emergent Aquatic Plants under Various Concentration Exposure Time Scenarios (*Student Presentation*)
Rachel A. Watson[1] and Christopher R. Mudge[2]
[1]*Louisiana State University, Department of Entomology, Baton Rouge, LA*
[2]*U.S. Army Engineer Research and Development Center, Environmental Laboratory, Baton Rouge, LA*

Use of Copper EDA Granular for Hydrilla Control in Texas
Paul Westcott[1], Kelly Duffie[2], David Bass[3], Bill Ratajczyk[4], and Ryan M. Wersal[5]
[1]*Applied Biochemists, Phoenix, AZ*
[2]*Helena Agri-Enterprises, Cypress, TX*
[3]*Lower Colorado River Authority, Austin, TX*
[4]*Applied Biochemists, Reedsburg, WI*
[5]*Minnesota State University, Mankato, MN*

Tuesday, July 16

Tuesday's Agenda-at-a-Glance

7:00 am	-	7:40 am	Continental Breakfast *(Gallery)*
7:00 am	-	5:30 pm	Exhibits and Posters Open *(Gallery)*
7:10 am	-	5:00 pm	Registration *(South Foyer)*
7:40 am	-	11:40 am	Session III – General Session and Student Presentations *(Great Room IV-VIII)*
10:00 am	-	10:20 am	Refreshment Break *(Gallery)*
11:40 am	-	1:10 pm	Lunch on your own
11:40 am	-	1:10 pm	Past Presidents' Luncheon *(Courtyard I)*
11:40 am	-	1:10 pm	Women of Aquatics Luncheon *(Loft II)*
1:10 pm	-	5:30 pm	Session IV – General Session and Student Presentations *(Great Room IV-VIII)*
2:50 pm	-	3:10 pm	Refreshment Break *(Gallery)*
6:15 pm	-	7:00 pm	Awards Reception *(Southwest Foyer)*
7:00 pm	-	10:00 pm	Awards Banquet *(Great Room)*
8:30 pm	-	10:00 pm	APMS Awards Presentations – Raffle *(Great Room)*

Session III – General Session and Student Presentations
7:40 am - 11:40 am
Great Room IV-VIII

Moderator: Marc Bellaud
SOLitude Lake Management, Shrewsbury, MA

7:40 am **Understanding How USACE Manages Plants, Mussels, and Research**
Jeremy Crossland
U.S. Army Corps of Engineers, Washington, D.C.

8:00 am **Understanding the Growth Requirements of the Invasive Macroalga *Nitellopsis obtusa* (Starry Stonewort) in a Controlled Environment: A Management Perspective**
Kaytee L. Pokrzywinski[1], Bradley T. Sartain[1], Michael Greer[2], Kurt D. Getsinger[1], Morris P. Fields[1], and Christopher R. Grasso[3]
[1]U.S. Army Engineer Research and Development Center, Environmental Laboratory, Vicksburg, MS
[2]U.S. Army Corps of Engineers, Buffalo District, Buffalo, NY
[3]Oak Ridge Institute for Science and Education, Oak Ridge Associated Universities, Vicksburg, MS

8:20 am **Management of *Nitellopsis obtusa* (Starry Stonewort) in Lake Sylvia, Minnesota, Using a Copper-Based Algaecide (*Student Presentation*)**
Tyler Geer[1], John H. Rodgers[1], and Steve McComas[2]
[1]Clemson University, Department of Forestry and Environmental Conservation, Clemson, SC
[2]Blue Water Science, Saint Paul, MN

8:40 am **Identifying Gene Expression Differences to Improve Adaptive Management Outcomes of Eurasian Watermilfoil (*Student Presentation*)**
Gregory M. Chorak and Ryan A. Thum
Montana State University, Plant Sciences and Plant Pathology, Bozeman, MT

9:00 am **Distribution of Eurasian (*Myriophyllum spicatum*) and Eurasian x Northern (*M. sibiricum*) Hybrid Watermilfoil in Minnesota**
Raymond M. Newman[1], Jasmine A. Eltawely[1], and Ryan A. Thum[2]
[1]University of Minnesota, Fisheries, Wildlife, and Conservation Biology, Minneapolis, MN
[2]Montana State University, Plant Sciences and Plant Pathology, Bozeman, MT

9:20 am **2,4-D Amine and 2,4-D Butoxyethyl Ester Behavior in Eurasian and Hybrid Watermilfoil (*Student Presentation*)**
Mirella F. Ortiz[1], Marcelo de Figueiredo[1], Scott J. Nissen[1], Franck E. Dayan[1], Ryan M. Wersal[2], and William Ratajczyk[3]
[1]Colorado State University, Fort Collins, CO
[2]Minnesota State University, Mankato, Biological Sciences, Mankato, MN
[3]Applied BioChemists, Alpharetta, GA

9:40 am **Learning to Control Hybrid Milfoils in the Pacific Northwest**
Terry M. McNabb
Aquatechnex, LLC, Bellingham, WA

10:00 am **Refreshment Break** *(Gallery)*

10:20 am **Responding Rapidly to Elodea - The First Freshwater Invasive Plant in Alaska**
John M. Morton
U.S. Fish and Wildlife Service, Kenai National Wildlife Refuge, Soldotna, AK

10:40 am **Eradication Economics for Freshwater Pest Plants**
Deborah E. Hofstra, Carla Muller, and Paul D. Champion
National Institute of Water and Atmospheric Research, Freshwater and Estuaries Centre, Hamilton, NZ

11:00 am **Beyond Park Boundaries: Early Detection and Rapid Response to *Hydrilla verticillata* in Ohio's Lake Erie Basin**
Mark J. Warman
Cleveland Metroparks, Natural Resources, Fairview Park, OH

11:20 am **Comparing Vegetative Propagule Sprouting Dynamics of Northern and Southern Populations of Dioecious *Hydrilla verticillata* in the United States (*Student Presentation*)**
Kara Foley, Ramon Leon-Gonzalez, Tyler Harris, and Robert J. Richardson
North Carolina State University, Crop and Soil Sciences, Raleigh, NC

11:40 am **Morning Wrap-up and Announcements - Lunch on your own**

Session IV – General Session and Student Presentations

1:10 pm - 5:30 pm
Great Room IV-VIII

Moderator: Amy Ferriter
Nutrien Solutions, Gainesville, FL

1:10 pm **Screening of Metsulfuron for Control of Giant Salvinia (*Student Presentation*)**
William J. Prevost[1] and Christopher R. Mudge[2]
[1]Louisiana State University, School of Plant, Environmental, and Soil Sciences, Baton Rouge, LA
[2]U.S. Army Engineer Research and Development Center, Environmental Laboratory, Baton Rouge, LA

1:30 pm **Herbicide Studies for Brazilian Peppertree Control in Mangrove Communities**
Stephen F. Enloe[1], MacKenzie Bell[2], and Jessica L. Solomon[2]
[1]University of Florida, Center for Aquatic and Invasive Plants, Gainesville, FL
[2]University of Florida, Agronomy Department, Gainesville, FL

1:50 pm **Multi-scale Brazilian Peppertree (*Schinus terebinthifolia*) Research from IPT Studies to Contractor Field Trials in South Florida (*Student Presentation*)**
Mackenzie E. Bell[1] and Stephen F. Enloe[2]
[1]University of Florida, Agronomy Department, Gainesville, FL
[2]University of Florida, Center for Aquatic and Invasive Plants, Gainesville, FL

2:10 pm **Effects of Grass-specific Herbicides on Twelve Grass Species in Florida (*Student Presentation*)**
Kaitlyn H. Quincy[1] and Stephen F. Enloe[2]
[1]*University of Florida, Agronomy Department, Gainesville, FL*
[2]*University of Florida, Center for Aquatic and Invasive Plants, Gainesville, FL*

2:30 pm **Evaluation of New Herbicide Technologies for the Management of Old World Climbing Fern (*Lygodium microphyllum)* on Tree Islands of the Everglades (*Student Presentation*)**
Jonathan S. Glueckert[1] and Stephen F. Enloe[2]
[1]*University of Florida, Center for Aquatic and Invasive Plants, Boynton Beach, FL*
[2]*University of Florida, Center for Aquatic and Invasive Plants, Gainesville, FL*

2:50 pm **Refreshment Break** *(Gallery)*

3:10 pm **Selective Control of Flowering Rush in Mesocosms and Field Sites (*Student Presentation*)**
Lee G. Turnage[1], John D. Madsen[2], Ryan M. Wersal[3], John D. Byrd[4], Brent Alcott[5], and Tera Guetter[5]
[1]*Mississippi State University, Geosystems Research Institute, Starkville, MS*
[2]*U.S. Department of Agriculture-Agricultural Research Service, Invasive Species and Pollinator Health Research Unit, Davis, CA*
[3]*Minnesota State University, Mankato, Biological Sciences, Mankato, MN*
[4]*Mississippi State University, Plant and Soil Sciences, Starkville, MS*
[5]*Pelican River Watershed District, Detroit Lakes, MN*

3:30 pm **Flowering Rush Biocontrol Research Progress**
Jenifer Parsons[1], Jennifer Andreas[2], Hariet L. Hinz[3], Patrick Haefliger[3], and Peter Rice[4]
[1]*Washington Department of Ecology, Yakima, WA*
[2]*Washington State University, Puyallup, WA*
[3]*Centre for Agriculture and Bioscience International, Delemont, Switzerland*
[4]*University of Montana, Missoula, MT*

3:50 pm **Evaluation of Endothall Alone and Pre-mixed with Diquat for Flowering Rush Control (*Student Presentation*)**
Giuliana Piccirilli Soufia, Mirella F. Ortiz, and Scott J. Nissen
Colorado State University, Fort Collins, CO

4:10 pm **Flowering Rush Control in Hydrodynamic Systems: Water Exchange Processes and Herbicide Contact Time**
Bradley T. Sartain[1], Kurt D. Getsinger[1], Damian J. Walter[2], John D. Madsen[3], Shayne Levoy[4], and Terry M. McNabb[5]
[1]*U.S. Army Engineer Research and Development Center, Environmental Laboratory, Vicksburg, MS*
[2]*U.S. Army Corps of Engineers, Walla Walla District, Walla Walla, WA*
[3]*U.S. Department of Agriculture-Agricultural Research Service, Invasive Species and Pollinator Health Research Unit, Davis, CA*
[4]*Canadianpond.ca, Knowlton, QC, Canada*
[5]*AquaTechnex, LLC, Bellingham, WA*

4:30 pm **Sequential Dry Substrate/Foliar Herbicide Applications for Suppression of Flowering Rush**
Peter M. Rice[1], Virgil Dupuis[2], and Ian McRyhew[2]
[1]*University of Montana, Division of Biological Sciences, Missoula, MT*
[2]*Salish Kootenai College, Pablo, MT*

4:50 pm **Managing Aquatic Plants and Algae in Irrigation Canals with Endothall - The First Ten Years**
Cory Greer[1] and Robert C. Smith[2]
[1]*UPL NA Inc., King of Prussia, PA*
[2]*UPL NA Inc., Meridian, ID*

5:10 pm **Flumigard™ (ai: flumioxazin): A Novel Chemistry for Pre-Emergent Canal Treatments**

Andrew Z. Skibo[1], Carl Della Torre III[2], Terry Corbett[3]
[1]*Alligare LLC, Aquatics - Pacific Northwest District, Missoula, MT*
[2]*Orion Solutions LLC, Birmingham, AL*
[3]*Lower Neches Valley Authority, Environmental Stewardship, Beaumont, TX*

5:30 pm **Afternoon Wrap-up and Announcements**

6:15 pm **Awards Reception** *(Southwest Foyer – Outside Great Room)*

7:00 pm **Awards Banquet** *(Great Room)*

8:30 pm **Awards Presentations and Fund-Raising Raffle** *(Great Room)*

10:00 pm **Adjourn Awards Banquet**

Wednesday, July 17

Wednesday's Agenda-at-a-Glance

7:00 am	-	8:00 am	Continental Breakfast *(Gallery)*
7:00 am	-	10:00 pm	Exhibits and Posters Open *(Gallery)*
7:30 am	-	12:00 pm	Registration *(South Foyer)*
8:00 am	-	12:00 pm	Session V – General Session *(Great Room IV-VIII)*
9:40 am	-	10:00 am	Refreshment Break *(Gallery)*
12:00 pm	-	12:10 pm	Closing Remarks - Wrap-up and Adjourn 59th Annual Meeting
12:45 pm	-	1:30 pm	APMS Board of Directors Lunch *(Shutter East I & II)*
1:30 pm	-	5:00 pm	APMS Board of Directors Meeting *(Shutter East I & II)*

Session V – General Session

8:00 am - 12:00 pm
Great Room IV-VIII

Moderator: Amy Kay
Clean Lakes Midwest, Oakwood Hills, IL

8:00 am **A Comparative Review of Management Tactics for HABs**
John H. Rodgers and Tyler Geer
Clemson University, Department of Forestry and Environmental Conservation, Clemson, SC

8:20 am **Managing Urban Lakes with *Prymnesium parvum* (Golden Algae) Infestations**
Frederick Amalfi and Zachary Hache
Aquatic Consulting and Testing, Inc., Tempe, AZ

8:40 am **Accurate Risk Assessment of Copper-Based Algaecides**
West M. Bishop
SePRO Research and Technology Campus, Whitakers, NC

9:00 am **Line Vs. Point Aeration Designs: A Cost-Benefit Analysis**
Patrick Goodwin
Aquatic Systems Inc., Pompano Beach, FL

9:20 am **Evaluating Herbicide Efficacy on Floating Aquatic Invaders**
Lyn A. Gettys, Kyle L. Thayer, Ian J. Markovich, Joseph W. Sigmon, and Mohsen Tootoonchi
University of Florida, Institute of Food and Agricultural Sciences, Fort Lauderdale Research and Education Center, Davie, FL

9:40 am **Refreshment Break** *(Gallery)*

10:00 am **Seasonal Variation in Growth, Biomass and Carbon Storage Allocation of *Ludwigia hexapetala* along Water Depth Gradients in the Russian River Watershed**
Brenda J. Grewell[1], Caryn J. Futrell[1], and Michael D. Netherland[2]
[1]*U.S. Department of Agriculture-Agricultural Research Service, Invasive Species and Pollinator Health Research Unit, Davis, CA*
[2]*U.S. Army Engineer Research and Development Center, Environmental Laboratory, Gainesville, FL*

10:20 am **Interactions of *Hygrophila polysperma* and *Ludwigia repens* Grown in Saturated Soil and Shallow Water**
Jeffrey T. Hutchinson
University of Texas at San Antonio, Department of Environmental Science and Ecology, San Antonio, TX

10:40 am **Effective Removal of *Hygrophila polysperma* and Reintroduction of Native Aquatic Plants to Improve Habitat for an Endangered Fish Species: Results after Seven Years**

Casey R. Williams[1], Robert Doyle[2], Kristina Tolman[3], and Kristy Kollaus[3]
[1]BIO-WEST, Inc., Ecology, San Marcos, TX
[2]Baylor University, Center for Reservoir and Aquatic Systems Research, Waco, TX
[3]Edwards Aquifer Authority, San Antonio, TX

11:00 am **Aquatic Invasive Plants: Battle on a New Front for Alberta**

Nicole L. Kimmel and Grace M. Young
Alberta Environment and Parks, Edmonton, AB, Canada

11:20 am **Evaluation of Concentration and Exposure Time Requirements of Florpyrauxifen-benzyl for Managing Hydrilla and Hybrid Watermilfoil**

Christopher R. Mudge[1], Kurt D. Getsinger[2], Bradley T. Sartain[2], and Michael D. Netherland[3]
[1]U.S. Army Engineer Research and Development Center, Environmental Laboratory, Baton Rouge, LA
[2]U.S. Army Engineer Research and Development Center, Environmental Laboratory, Vicksburg, MS
[3]U.S. Army Engineer Research and Development Center, Environmental Laboratory, Gainesville, FL

11:40 am **Field Demonstration of Hydrilla Management with Florpyrauxifen-benzyl**

Jason Ferrell[1], Dean Jones[2], Mark A. Heilman[3], Kelly Gladding[4], and James Leary[1]
[1]University of Florida, Center for Aquatic and Invasive Plants, Gainesville, FL
[2]University of Florida, Center for Aquatic and Invasive Plants, Lake Alfred, FL
[3]SePRO, Carmel, IN
[4]SePRO, Edgewater, FL

12:00 pm **Wrap-up and Adjourn 59th Annual Meeting**

60th Annual Meeting
Hyatt Regency San Antonio Riverwalk
San Antonio, Texas
July 18-23, 2020

61st Annual Meeting
New Orleans Riverside Hilton
New Orleans, Louisiana
July 11-14, 2021

Abstracts - General Sessions and Poster Session

Abstracts are listed alphabetically by presenting author - appears in **bold.**

Managing Urban Lakes with *Prymnesium parvum* (Golden Algae) Infestations

Frederick Amalfi and Zachary Hache
Aquatic Consulting and Testing, Inc., Tempe, AZ

Prymnesium parvum (golden algae) is a toxin producing algae that is becoming more prevalent throughout the southern and southwestern U.S. Originally favoring a saline and estuarial environment, the alga has expanded its environmental niche into higher salinity reservoirs and urban lakes and ponds and has become an endemic algae in a number of lakes and reservoirs in the southwest. Management of urban lakes and ponds that have active golden algae populations presents unique challenges. Dealing with massive fish kills, stocking challenges, algaecide applications, toxin neutralization, and management of public opinion become routine activities. A comprehensive approach of management techniques is needed in order to mitigate problems.

Sustaining APMS and Chapter Successes: Changing Ecosystems Demand New Collaborative Solutions

Lars W. Anderson
WaterweedSolutions, Davis, CA

The last day of this 2019 APMS/WAPMS meeting- July 17-marks exactly 58 years from the "official" formation of APMS in 1961 (The Hyacinth Control Society). The Western Aquatic Plant Management Society chapter was formed only 34 years ago, when other chapters were beginning as well. This 20+ year gap from the 1960s to 1980's reflects the initially slow but accelerating environmental and socioeconomic and political processes: US-wide spread of invasive aquatic plants into more diverse aquatic sites, coupled with increased recognition of their impacts on agriculture, health, recreation and local economies; and the lack of effective control methods to counter these varied impacts. APMS, with its chapters responded to these increased environmental and economic threats by providing site-specific focal points for basic and applied research on key target species including hydrilla, Eurasian watermilfoil, water hyacinth, curlyleaf pondweed, Brazilian waterweed, cabomba and others. APMS and chapter collaborations with agrochemical industry as well as mechanical engineering sectors, entomologists, fish biologists, microbiologist, molecular geneticists, and aquatic ecologists have resulted in products, methods and strategies used successfully to reduce impacts and spread of invasive aquatic plants. But we have already entered another dramatic shift in environmental and social conditions that demands new approaches and creative thinking to arrive at solutions if we are to sustain viable aquatic and riparian habitats and the ecosystems services. Climate change affects physical habitat suitability, but also phenology (e.g. reproductive and dispersal capacities), and interspecies responses (native/invasive species interaction). New questions arise: What is happening in the sediment microbiome and plant rhizosphere? This area has been nearly ignored in aquatic plants. How will macroinvertebrate and fish /plant interactions change? Can we predict responses to temperature and water cycling in the "new" latitude and elevation conditions? How will sea level rise affect native and problematic species in our important estuaries and river delta biomes? As an approach, APMS and its chapters might consider a series of workshops with allied academic, federal and state agency scientists and professional societies to discuss and identify other looming issues with the aim of prioritizing collaborative research that may help lessen future AIS problems.

Systematic Identification and Ecology of *Chara* (Charales) in Stormwater Treatment Areas of South Florida: A Preliminary Study (*Student Poster Presentation*)

Maximiliano Barbosa[1], David E. Berthold[1], Forrest Lefler[1], Eric Crawford[2], and H. Dail Laughinghouse[1]
[1]University of Florida, Agronomy Department, Fort Lauderdale Research and Education Center, Davie, FL
[2]South Florida Water Management District, West Palm Beach, FL

Chara (aka stoneworts and muskgrass) is a genus of green algae in the class Charophyceae. This alga is generally associated with clean waters and can serve as a bioindicator of water quality. The genus is widespread in South Florida and is planted and used for nutrient uptake (especially phosphorus) in the Storm Water Treatment Areas (STAs) of the South Florida Water Management District (SFWMD). In the STAs, massive die-offs of *Chara* can occur that undermine the efficacy of the water treatment process. In order to attain a better understanding of these die offs, research on the phylogenetic and ecological characteristics is necessary. We conducted morphological, phylogenetic and ecological analyses to further our understanding of *Chara* in the STAs. Two species were found in our investigation: *Chara haitensis* Turpin and *C. zeylanica* Klein ex Willdenow. These species are morphologically similar and appear cryptic, which complicates field identification. We were able to identify that both species were co-occurring, even in single beds, by phylogenetic analyses of the *rbc*L and *mat*K genes. *Chara* growth patterns were analyzed using mesocosms. From these experiments, we observed that the flow and depth of water has a major role in the success of *Chara* growth. Future work is directed at analyzing the physiological responses of these species under varying nutrient, pH and flow scenarios.

Non-Target Impacts of Hydrilla and Lyngbya treatments on Waterwillow (*Justicia americana*) (*Student Presentation*)

Jens Beets[1], Erika Haug[2], and Robert J. Richardson[2]
[1]*North Carolina State University, Fisheries, Wildlife, and Conservation Biology/Crop Science, Raleigh, NC*
[2]*North Carolina State University, Crop and Soil Sciences, Raleigh, NC*

Best management practices in aquatic plant management call for the selective control of nuisance species, while limiting impacts to beneficial native species. Waterwillow (*Justicia americana*) is a desirable native plant species in North Carolina Piedmont reservoirs. Monoecious hydrilla (*Hydrilla verticillata*) is a non-native nuisance invasive species in many reservoirs and readily infests waterwillow populations. Lyngbya (*Lyngbya wollei)* is a filamentous cyanobacteria that is rapidly spreading in NC reservoirs, as well as throughout the southeastern U.S. Lyngbya provides little to no ecosystem services and herbicide/algaecide applications are the only cost-effective management option. There is a need for management programs to control hydrilla and lyngbya while avoiding significant non-target impacts to waterwillow populations. Monoecious hydrilla tubers collected from NCSU stock culture were sprouted and established in 14-L mesocosms before being planted in 1-L pots with established waterwillow to imitate co-existing populations. Herbicide rates and exposures were selected based on current hydrilla or lyngbya treatment regimes and were as follows: endothall (3 ppm; 48 hours and static with follow- up treatment), copper (1 ppm; 24 hours and static), copper (1ppm) + diquat (0.5 ppm; static), fluridone (5 ppb; static), and endothall (0.3 ppm) + peroxide (5 GPA; static). Treatments were replicated four times and the trial will be repeated in space and time. Plants were harvested 30 day after treatment and data was analyzed in R statistical software package. Results and implications for selective management for waterwillow will be discussed.

Multi-scale Brazilian Peppertree (*Schinus terebinthifolia*) Research from IPT Studies to Contractor Field Trials in South Florida (*Student Presentation*)

Mackenzie E. Bell[1] and Stephen F. Enloe[2]
[1]*University of Florida, Agronomy Department, Gainesville, FL*
[2]*University of Florida, Center for Aquatic and Invasive Plants, Gainesville, FL*

Brazilian peppertree is a highly invasive species that is found primarily in Florida, Texas, Hawaii, and Australia. It can grow up to 30 feet in height and has multistemmed trunks with lateral branches that form dense, impenetrable thickets. State agencies in Florida aggressively manage peppertree at an annual cost of one to two million dollars per year. Given the costs of management and the intensity of individual plant treatments (IPT), our overall goal was to improve IPT approaches for Brazilian peppertree control. To accomplish this, a series of field studies were conducted in south Florida that included novel herbicide treatments for IPT including cut stump, basal bark, and hack and squirt approaches. Using individual trees as experimental units, we found multiple herbicide options that effectively controlled Brazilian peppertree for cut stump and basal bark treatments at rates lower than the current commercial standards. For the hack and squirt study, we found both aminocyclopyrachlor and aminopyralid provided good control when applied with a reduced hack and squirt (RHS) approach which includes making a single hack and applying 1mL of a 50% v/v herbicide solution per four-inch diameter stem. From these studies, we scaled up research efforts to 0.5-acre replicate plots and utilized contractor crews to test efficacy of IPT treatments including reduced hack and squirt and basal bark treatment with two formulations of triclopyr. We found that compared to the basal bark applications the RHS approach took a similar amount of time to apply, provided a similar amount of control, and significantly reduced the amount of herbicide applied. These results indicate that there are novel herbicide treatments and techniques that could improve control efforts on Brazilian peppertree. In addition, this unique multi-scale research approach has accelerated our understanding of a novel invasive plant treatment strategy and its implementation in the field.

Can Phoslock® Be Used to Bind and Sediment Microsystin-LR in Aquatic Systems? (*Student Poster Presentation*)

David E. Berthold[1], Forrest Lefler[1], West M. Bishop[2], and H. Dail Laughinghouse[1]
[1]*University of Florida, Agronomy Department, Fort Lauderdale Research and Education Center, Davie, FL*
[2]*SePRO Research and Technology Campus, Whitakers, NC*

Microcystins [and its congener microcystin-LR (MC-LR)] are considered the most common cyanotoxin produced by cyanobacterial harmful algal blooms. The intracellular MC-LR is released into the water column upon cell lysis during treatment or senescence, where it can remain stable for weeks and lead to adverse health effects. The ideal treatment method for MC-LR-producing strains is one that can remove or degrade both cells and toxins from the water column. We tested the hypothesis that MC-LR can bind to Phoslock®, removing it from the water column by sedimentation. In order to test this, MC-LR was dissolved in deionized water and diluted to 5, 20, 50, 100, and 500 ppb. A stock solution of Phoslock® (1 gL-1) was used and kept homogenized on a magnetic stirrer and applied into solutions containing MC-LR at concentrations of 50, 100, and 150 ppm (in triplicate) including a control without Phoslock®. The tubes were incubated at room temperature for 24-48hr, and then processed for MC concentration using ELISA. Results indicate that MC-LR is removed from the water column when higher concentrations of both Phoslock® (100 and 150ppm) and MC-LR (100 and 500ppb) are present. Future work aims at deciphering the in-situ effects of Phoslock®, in combination with other algaecides and flocculants to improve the efficacy of toxin removal.

Accurate Risk Assessment of Copper-Based Algaecides

West M. Bishop
SePRO Research and Technology Campus, Whitakers, NC

Standard toxicity testing data with copper suggest that typical copper algaecide application concentrations can cause deleterious acute impacts to non-target organisms. These standard studies do not contain measurable amounts of algae or other particulate organic matter and are designed to show a maximum potential for risk, but they are not representative of field scenarios. Copper formulations differ in their impact on non-target organisms as well as affinity and efficacy of toward the target algal species/strain. Few studies have assessed the impact of specific binding of copper to target ligands, and the subsequent alteration of risks to non-targets species. Copper algaecides are often applied directly to an algal bloom and often the copper concentration is greatly decreased rapidly in the water column. This needs to be accounted for in order to support realistic risk management decisions in the field. Information presented herein will assist regulatory personnel and stakeholders to make informed decisions based on accurate risk regarding copper algaecide exposures in field applications.

On Trial: How Science and Public Perception Are Determining Glyphosate's Future

Michael S. Blankinship
Blankinship and Associates, Inc., Davis, CA

The recent attention focused on Glyphosate-based herbicides (GBH) and the associated adverse health claims have resulted in large initial judgements against the manufacturer Monsanto. Although scientific literature rightly has its place is assessing the cause-effect relationship between GBHs and health, lay jurors are left to decide this causal relationship based on a deluge of technical information presented during brief court proceedings. Available data will be explored along with the concept of risk perception and what the vegetation management community should expect in the future.

Air and Water Temperature Relationship and Growth of Hyacinth and Primrose (*Poster Presentation*)

David Bubenheim[1], Greg Schlick[2], David Wilson[2], and John D. Madsen[3]
[1]*Biospheric Science Branch, Earth Science Division, NASA Ames Research Center, Moffett Field, CA*
[2]*Bay Area Environmental Research Institute, Biospheric Science Branch, Earth Science Division, NASA Ames Research Center, Moffett Field, CA*
[3]*U.S. Department of Agriculture-Agricultural Research Service, Invasive Species and Pollinator Health Research Unit, Davis, CA*

Temperature is a primary determining factor for plant growth and development so providing an appropriate temperature input is critically important for developing growth models. The Delta Region Areawide Aquatic Weed Project (DRAAWP), a USDA sponsored area-wide project including NASA Ames Research Center and State of California Department of Boating and Waterways, uses modeling to assess invasive aquatic plant impacts on ecosystem services in the Delta. Availability of continuous records for monitored temperature is limited and particularly in the case of water temperature the distribution of monitoring is inadequate. This work quantitatively defines the influence of air and water temperature in determining dominant growth rate processes for important floating aquatic invasive plants in the Delta. Since these plants function with portions submerged and above water, we wanted to understand the relationship between root zone and shoot zone temperature and ability to use a single temperature inputs in DRAAWP models. Water hyacinth and primrose were grown in multiple controlled environment chamber studies with various combinations of root zone and shoot zone temperatures. Long-term growth studies provided integrated response of biomass accumulation and distribution within the canopy. Short-term gas exchange studies provide a time scale for responsiveness to temperature and a short-term study approach to evaluate temperature responses at various stages of canopy development.

Growth Response of Water Hyacinth to Environmental Ranges in the California Sacramento-San Joaquin River Delta (*Poster Presentation*)

David Bubenheim[1], Greg Schlick[2], David Wilson[2], and John D. Madsen[3]
[1]*Biospheric Science Branch, Earth Science Division, NASA Ames Research Center, Moffett Field, CA*
[2]*Bay Area Environmental Research Institute, Biospheric Science Branch, Earth Science Division, NASA Ames Research Center, Moffett Field, CA*
[3]*U.S. Department of Agriculture-Agricultural Research Service, Invasive Species and Pollinator Health Research Unit, Davis, CA*

Management of aquatic weeds in complex watersheds and river systems present many challenges to assessment, planning, and implementation of management for aquatic invasive plants. The Delta Region Areawide Aquatic Weed Project (DRAAWP), a USDA sponsored area-wide project including NASA Ames Research Center and State of California Department of Boating and Waterways, is working to enhance decision-making and operational efficiency of invasive plant management in the California Sacramento-San Joaquin Delta. Expansion of invasive aquatic plants has been detrimental to water management and the ecosystem complex in the San Francisco Bay/California Delta. The portion of DRAAWP reported here focuses on parametrizing the environmental response inputs for the Delta models for prominent invasive aquatic plants. Changing climate, long-term drought, shifts in land use, and variation in water flow and quality from input watersheds lead to wide and unique variation in environmental conditions. Environmental variability occurs across a range of time scales from long-term climate and seasonal trends to short-term water flow mediated variations. Response of invasive aquatic plants are examined using controlled environment growth facilities at time scales of weeks, day, and hours using a combination of study duration and growth assessment techniques to assess water quality, temperature, nutrient, and light effects. These provide response parameters for plant growth models in response to the variation and interact with management and economic models associated with aquatic weed management. Plant growth models are informed by remote sensing and applied spatially across the Delta to balance location and type of aquatic plant, growth response to altered environments and phenology.

Remote Sensing and Mapping of Floating Aquatic Vegetation in the Sacramento-San Joaquin River Delta

David Bubenheim[1], Vanessa Genovese[2], Edward Hard[3], and John D. Madsen[4]
[1]Biospheric Science Branch, Earth Science Division, NASA Ames Research Center, Moffett Field, CA
[2]California State University Monterey Bay, Biospheric Science Branch, Earth Science Division, NASA Ames Research Center, Moffett Field, CA
[3]California Department of Parks and Recreation, Division of Boating and Waterways, Sacramento, CA
[4]U.S. Department of Agriculture-Agricultural Research Service, Invasive Species and Pollinator Health Research Unit, Davis, CA

The California Sacramento-San Joaquin River Delta is the hub for California's water supply and supports ecosystem services, agriculture, and Northern to Southern California communities. Expansion of invasive aquatic plants and impacts of changing climate, long-term drought, land use, and water flow and quality are detrimental to water management and the ecosystem complex in the San Francisco Bay/California Delta. The California Division of Boating and Waterways (DBW) has management responsibility for invasive aquatic plants and has partnered with NASA Ames Research Center and USDA-Agricultural Research Service to develop science-based, adaptive-management strategies. Satellite-based, remote sensing methods have been developed to provide, for the first time, a comprehensive view of floating aquatic vegetation (FAV) population dynamics on a landscape scale and support operations, assessment and strategic planning. An initial mapping tool used Landsat imaging, available at 14-day intervals with 30 m^2 pixel size, to map FAV and proved to significantly enhance operations and management assessment. Continued development and added satellite platforms now provides improved temporal, spatial, and spectral resolution enabled development of new Floating Aquatic Vegetative Indices (FAVI) to accentuate particular canopy features. Improvements include the identification and mapping of prominent floating species and their distribution within a complex aquatic community, estimation of biomass and canopy features, estimation of growth rate and floating patch movements, and assessment of local and comprehensive landscape-scale management practice effectiveness. Localized plant distribution and environmental monitoring coupled with customize plant response models provide assessment of aquatic plant ecosystem function. This effort supports operational decision making, enables assessment of management practices effectiveness, and provides new tools for planning and verification. A first-ever, comprehensive, quantitative view of floating aquatic plant populations in the California Delta and linkage with operational decision making and enhanced assessment capabilities increases the efficiency of resource management efforts in the region.

Operational Aquatic Invasive Plant Management in the Delta

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Aquatic weed management in the California Sacramento-San Joaquin Delta (Delta) and its tributaries has been conducted since 1982 by the California Parks and Recreation Division of Boating and Waterways (DBW). This year, the program will utilize chemical, physical and biological control methods as a part of Integrated Pest Management (IPM) in the Delta, which is approximately 101,000 acres. DBW targets eight invasive aquatic plant species including *Eichhornia crassipes* and *Egeria densa*. Increased number of target invasive plants, trends in target plants and environmental conditions such as high or low water flow years have further emphasized the importance of IPM and a flexible toolset to control target invasive plants in the Delta.

Identifying Gene Expression Differences to Improve Adaptive Management Outcomes of Eurasian Watermilfoil (*Student Presentation*)

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Aquatic plant managers are increasingly concerned about herbicide resistance and methods for identifying it could become an important tool for managers. However, identifying the genetic basis of herbicide resistance is challenging because it can be due to genetic mutations in either the target enzyme, or "non-target" genes that affect herbicide uptake, translocation, metabolism, or detoxification. In addition, herbicide resistance may be influenced by up- or

down-regulating gene expression (how much of an enzyme is produced). RNA-Seq is a method to quantify the expression levels of all genes actively being used by an organism in a set of conditions and is therefore a promising approach to identify mechanisms associated with resistance that are a result of gene expression differences between resistant and susceptible individuals. This project focused specifically on Eurasian watermilfoil *(Myriophyllum spicatum* L.; including hybrids with northern watermilfoil, *Myriophyllum sibiricum* Komarov), one of the most heavily managed invasive aquatic weeds in the U.S. We compared gene expression differences between control and 2,4-D treated plants (500 ppb) at several times after treatment for two different genotypes previously shown to differ in their sensitivity to 2,4-D. In addition to insights from these comparisons, this study performed a *de novo* assembly of the Eurasian watermilfoil transcriptome (i.e., the DNA sequences for most genes), which includes 334,917 unique genes and will serve as a critical genomic resource for genetic studies of Eurasian watermilfoil.

Understanding How USACE Manages Plants, Mussels, and Research
Jeremy Crossland
U.S. Army Corps of Engineers, Washington, D.C.

Overview of current programs and operations at U.S. Army Corps of Engineers (USACE) related to aquatic plant management, invasive mussels, and research related to these subjects. The presentation will provide an overview of current aquatic plant management activities across the country, expansion of the authorities under the Aquatic Plant Control Program, update on impacts and management activities related to Harmful Algal Blooms at USACE projects, and overview of current and future research activities.

Herbicide Studies for Brazilian Peppertree Control in Mangrove Communities
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Mangroves are a critical component of many coastal ecosystems in South Florida. As a diverse group of species, they provide numerous ecosystem services that benefit a wide array of other species. Unfortunately, Brazilian peppertree is an increasing problem in mangrove communities and selective control options are greatly needed. To address this, studies were conducted to assess the utility of novel herbicide treatments for Brazilian peppertree control and mangrove selectivity. Brazilian peppertree and red, white, black and buttonwood mangroves were established in greenhouse conditions in the spring of 2018 at the UF Center for Aquatic and Invasive Plants in Gainesville, Florida. In study one, foliar treatments of aminopyralid, aminocyclopyrachlor, and florpyrauxifen-benzyl were applied at maximum and one-half maximum label rates. In study two, imazamox and carfentrazone were applied alone or in tank mixes. Treated plants were subsequently grown for 180 days. Visual estimates of defoliation were conducted at 30, 60, 90, and 180 days after treatment and quantitative estimates of mortality and live shoot heights were conducted at 180 DAT for each of the five species tested. There was considerable variation in both peppertree efficacy and mangrove tolerance among auxin type treatments. Both aminopyralid and aminocyclopyrachlor provided very good control of peppertree but were highly injurious to most mangroves. Florpyrauxifen-benzyl did not effectively control Brazilian peppertree but was still injurious to mangroves. Imazamox and the imazamox + carfentrazone tank mix provided good control of peppertree but resulted in excessive mangrove injury. Carfentrazone alone did not control peppertree and resulted in significant mangrove injury. These results indicate multiple herbicides have very useful activity on peppertree. However, the critical selectivity on the four mangrove species is still generally lacking.

Field Demonstration of Hydrilla Management with Florpyrauxifen-benzyl
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Selective management of dioecious hydrilla is an ongoing struggle for many lakes in the southern U.S. Therefore, learning how to use florpyrauxifen-benzyl at the field level is important to the future of hydrilla management. Fish Lake is a 230-acre lake (5 ft avg) in Osceola County, Florida. Prior to treatment, hydrilla persisted in a near continuous ring with 46% of the lake infested. Florpyrauxifen-benzyl, in the form of ProcellaCOR SC, was applied at the maximum use rate of 48.3 µg ai L^{-1}(5 PDU per acre-foot) on August 14, 2018. The treatment area was a 50-acre U-shaped block on the south end of the lake. Aquatic vegetation response was monitored using hydroacoustics and point-intercept verification. Submersed vegetation in the treatment block declined from a biovolume of 65% with hydrilla dominance at time of application to 15% after 5 months, representing a 77% reduction. The dominant plant at 5 months was vallisneria, which increased from 24 to 43% frequency. A significant amount of hydrilla outside the treatment plot was also affected with hydrilla in the southern two-thirds of the lake declining from 54 to 21% frequency. The floating leaf plants American lotus and fragrant waterlily were negatively impacted within the management area and some untreated areas where hydrilla injury was observed. Spatterdock was impacted after the application and auxin symptoms were obvious. However, within 5 months of treatment, all new leaves had emerged without symptoms and no rhizomes floated. Dissolved oxygen showed minimal decline following treatment. Herbicide concentrations were measured the day of application and 1, 2, 3, and 7 days after. By day 7, florpyrauxifen-benzyl concentrations were below 1 ppb. In summary, while some floating-leaved species were sensitive and showed injury based on rate and placement of treatment, results indicate that florpyrauxifen-benzyl can be an effective tool for hydrilla management.

Comparing Vegetative Propagule Sprouting Dynamics of Northern and Southern Populations of Dioecious *Hydrilla verticillata* in the United States (*Student Presentation*)

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The dioecious biotype of hydrilla (*Hydrilla verticillata* (L.f.) Royle) is a submerged aquatic plant species native to Asia but was introduced to the U.S. in the 1960's where it has negatively impacted freshwater systems due to its invasive nature. Today, dioecious hydrilla has continued to persist in Florida and in the nearby southern states which include Georgia, Alabama, South Carolina, Louisiana, and Texas. These observations agree with the literature that states that dioecious hydrilla is more reproductively successful in southern climates due to longer growing seasons and more time to form reproductive propagules. The northern-most recorded population of dioecious hydrilla within Atlantic Coast states exists in Philpott Lake (Martinsville, VA) and little is known about the ecological factors that drive its growth. It was hypothesized that this more northern population of dioecious hydrilla has been selected for additional cold-hardiness when compared to southern populations and research was conducted to test this hypothesis. The spouting rate of tubers produced by this northern population was compared to the sprouting rate of tubers produced by southern populations of dioecious hydrilla on a temperature gradient ranging from 9.4 ± 0.8°C to 36.0 ± 0.8°C. By the end of the two-week study, sprouted tubers produced by southern populations of dioecious hydrilla had significantly longer stem lengths at cooler water temperatures (25°C) than sprouted tubers produced by northern populations of dioecious hydrilla ($p < 0.0002$; $\alpha = 0.05$). Results of this research suggest that there may be differences in sprouting and growth dynamics between northern and southern populations of dioecious hydrilla which could have implications on its future spread throughout the U.S.

Management of *Nitellopsis obtusa* (Starry Stonewort) in Lake Sylvia, Minnesota, Using a Copper-Based Algaecide (*Student Presentation*)

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Nitellopsis obtusa (starry stonewort) is an invasive characean species of Eurasian origin that has spread rapidly among inland lakes in the Great Lakes region of the U.S. Initiating an aggressive control plan as soon as possible after discovery of *N. obtusa* is important for efficient and effective management. In West Lake Sylvia (Wright Co. MN), *N. obtusa* was first confirmed in September of 2016 in the vicinity of the public boat access. In response, algaecide applications to control *N. obtusa* began early in the summer of 2017 and continued throughout the year to control and contain regrowth and potential recolonization or re-infestation of the area. This situation provided an opportunity to measure the effectiveness of algaecide applications as a tactic for rapidly responding to an infestation of *N. obtusa*. To target growth and regrowth of *N. obtusa*, the copper-based algaecide Cutrine®-Plus was applied four times between June and October 2017 in the initially colonized area adjacent to the public boat access. Post-treatment *N. obtusa* surveys by an independent auditor confirmed that the spatial extent of *N. obtusa* and the frequency of *N. obtusa* at sample sites declined in the treated area from June to December. In 2018, management of

N. obtusa in the immediate vicinity of the boat access was continued: four applications of Cutrine®-Plus targeting growth and regrowth of *N. obtusa* occurred in the infested area between July and October 2018. Results from this study indicate that algaecide treatments are effective for control of incipient *N. obtusa* infestations.

Sediment Copper Concentrations, *in situ* Benthic Abundance, and Sediment Toxicity: Comparison of Coves Treated with Copper-Based Algaecides and Untreated Coves in a Southern Reservoir (*Student Poster Presentation*)

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Copper-based algaecides are frequently used to control noxious algae blooms that compromise uses of lakes and reservoirs. However, there are concerns regarding potential adverse effects to benthic aquatic biota following long-term applications. Multiple lines of evidence are useful for evaluating potential ecological risks. These lines of evidence are encompassed in the sediment quality triad (SQT) and include measured copper concentrations in sediments, *in situ* benthic invertebrate data, and sediment toxicity testing results. The overall objective of this study was to measure potential ecological risks associated with long-term (i.e. years to decades) applications of copper algaecides in coves in Lay Lake, Alabama. Sediment samples from three coves that had been treated for approximately 7, 10 and 20 years were compared to samples from three untreated coves within Lay Lake in terms of sediment copper concentrations, *in situ* benthic macroinvertebrate total abundance, and results from laboratory sediment toxicity assays using naïve cultured *Hyalella azteca* and *Chironomus dilutus.* In general, sediment copper concentrations were not significantly different between treated and untreated coves, with the exception of one treated cove (PC-1S) that contained elevated sediment copper concentrations compared to all other coves, likely due to a copper algaecide application on the sampling day (prior to sediment sampling). However, the copper was not bioavailable to organisms based on *in situ* macroinvertebrate abundance and laboratory toxicity analyses. *In situ* benthic invertebrate abundance was not different between treated and untreated coves. In all sediments tested, there were no measurable adverse effects (survival greater than 80%) to *H. azteca* and there were no significant differences in the survival of *C. dilutus* between treated and untreated coves. Based on this weight-of-evidence approach, there were no adverse effects to benthic invertebrates in copper treated coves in Lay Lake as compared to untreated coves.

Evaluating Herbicide Efficacy on Floating Aquatic Invaders

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Florida's waters are routinely invaded by new exotic plants. Two new invaders are redroot floater (*Phyllanthus fluitans*) and feathered mosquitofern (*Azolla pinnata*). Redroot floater, a dicot, was first reported in a Desoto County canal attached to the Peace River in 2010. Feathered mosquitofern, a true fern, was first collected in Florida's waters in Palm Beach County in 2007. Despite their very different botanical classifications, both species can survive out of the water on damp soil, form floating dense mats and cause ecosystem harm by attenuating light and oxygen in the water column. They also interfere with boating, fishing and swimming. Current distribution of both species is primarily southern Florida, but range expansion is likely, so it is critical to identify control methods for these species. We evaluated efficacy of 35 foliar herbicide treatments (single aquatic herbicides or combinations of two herbicides) in greenhouse trials with four replicates per treatment. We applied treatments to robust populations of plants in 68L mesocosms and monitored them for 6 weeks after treatment, then recorded percent coverage and conducted destructive harvests. Dried plant material was weighed to determine reduction in biomass compared to untreated controls (UTC). Most treatments resulted in > 90% reduction in biomass compared to UTC. These results suggest that feathered mosquitofern and redroot floater are susceptible to most chemical control tools and that failure to eradicate nascent populations of these weeds is likely due to plants escaping treatment and recolonizing treated areas vs. poor herbicide efficacy.

Evaluation of New Herbicide Technologies for the Management of Old World Climbing Fern (*Lygodium microphyllum)* on Tree Islands of the Everglades (*Student Presentation*)

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Old World climbing fern (OWCF) (*Lygodium microphyllum*) is one of the most aggressive invasive plants in South and Central Florida. This highly invasive fern smothers native vegetation in mesic upland and forested wetland ecosystems in the Everglades, blanketing the canopy of tree islands and dominating understory communities with thick rachis mats. OWCF is an incredibly difficult invasive plant to manage due to its wind dispersed spores, tolerance to flooding, and tendency to grow in areas with extremely challenging access. In 2016, a multi-faceted research project was initiated to improve OWCF management approaches. In the first phase, six small scale herbicide screening studies were conducted at multiple locations across south Florida to assess over 30 different herbicide treatments in comparison to the standard foliar glyphosate treatment approach. From these studies, multiple formulations of triclopyr and the new aquatic herbicide florpyrauxifen-benzyl showed very promising activity on OWCF at twelve months after treatment. These treatments were subsequently incorporated into tree island studies in the Loxahatchee National Wildlife Refuge in south Florida. For the triclopyr treatments, ground based studies utilized contractor crews for “poodle cutting” and subsequent foliar treatments. For the florpyrauxifen-benzyl treatments, both ground based and aerial treatments were applied. A total of sixty islands were incorporated into all studies. Post treatment OWCF cover evaluations indicated multiple triclopyr formulations provided effective OWCF control 12 MAT. For florpyrauxifen-benzyl, shorter term data collected to date indicates significantly better OWCF control with higher rates. These studies indicate that both triclopyr and florpyrauxifen-benzyl may be useful for OWCF management. Future work will examine the influence of hydrology on the treatment outcomes as hydroperiod appears to be a major driver in OWCF recruitment.

Line Vs. Point Aeration Designs: A Cost-Benefit Analysis

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In this study, a cost-benefit analysis is presented for line and point aeration designs. The metrics compared include per cent water moved or turnover per day, oxygen transfer efficiency, chlorophyll *a* (chl. a) reduction, labor, capital costs, and operation costs. Published equations for calculating turnover and oxygen transfer were used to compare the efficacy of line and point aeration diffusers at varying depths and densities. Current aeration models were used to assess the efficacy of line and point aeration designs concerning lake chl. *a*. Case studies were used to compare labor, capital, and operational costs. Results indicate that both line and point aeration designs can meet desired aeration objectives. Turnover and oxygen transfer were superior with line diffusers at shallow depths (< 3 m), while point diffusers were superior at deeper depths (> 3 m). Point aeration designs provided greater reductions in chl. *a* at lesser airflow than line aeration designs. Initial capital savings may be provided using line aeration, but long-term maintenance and electrical costs are likely greater. Both line and point aeration designs should be considered on a site by site basis and should account for lakes’ physical attributes and the aeration objectives at hand. Multiple designs should be presented to stakeholders such that best management practices can be fostered.

Managing Aquatic Plants and Algae in Irrigation Canals with Endothall - The First Ten Years

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After decades of use in lakes, ponds, streams, and other traditional aquatic sites, the active ingredient endothall received USEPA registration for a new use site in 2009. Through extensive collaborative research, endothall was registered for the control of aquatic plants and algae in irrigation canals. This talk will detail the vast infrastructure of irrigation canal systems in the Western U.S. and outline the historical and current maintenance control options being employed. The evolution of endothall treatment protocols for individual species, and how they have been implemented by canal managers for improved control will be discussed. The most recent of these treatment advances is the Quick S.E.T. (short exposure time) method. This method utilized higher rates at shorter exposure times and has shown excellent efficacy on weeds and algae, while significantly reducing the time required for a treatment.

Seasonal Variation in Growth, Biomass and Carbon Storage Allocation of *Ludwigia hexapetala* along Water Depth Gradients in the Russian River Watershed

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Seasonal growth and allocation of biomass and carbon storage reserves are fundamental aspects of plant competitiveness and invasiveness. Understanding variation of these factors across environmental gradients can inform development of effective management strategies by targeting weak points in weed life cycles. We evaluated seasonal growth, biomass and total nonstructural carbohydrate storage (TNC) of *Ludwigia hexapetala* and its variation with water depth at three contrasting river sites in the Russian River Watershed, California. The field study included five randomly located transects with biomass sampling through plant phenological stages for 18 months at four water depths (0, 25, 50, 100cm) at each site. Plant biomass core samples above and below the water surface, and root/rhizome samples from sediment were oven dried and weighed. Lower woody stem and below ground tissues were analyzed for TNC. Growth and biomass allocation varied with water depth and by site. In all cases, total live biomass was lowest in winter (semi-dormant stage), increased progressively through spring (pre-reproduction) and summer (flowering), with peak biomass attained in autumn (seed maturation and dispersal). Total biomass production was highest in shallow water, ranging from 1.5-6.8 ± 0.3 kg m^{-2} at 25 cm depth to 1.0-4.5 ± 0.2 kg m^{-2} at 50 cm depth in autumn. The percentage of total floating biomass where water was 25 cm deep increased from winter (9.7 ± 2.0 %) and spring (24.6 ± 4.4 %) to peak values in summer (43.6 ± 1.8 %) and autumn (45.2 ± 2.8 %). TNC reserves in lower woody stems and rhizomes varied by location and life stage, but in all cases were highest in fall - winter with depletion to lowest levels pre-reproductive and flowering stages. These results suggest targeted management actions at flowering stage when floating biomass exceeds submersed biomass could be most effective for foliar herbicide applications.

An Update on the Development of Hydrilla Biological Control in the U.S. (*Poster Presentation*)

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Biological control of hydrilla (*Hydrilla verticillata*) has been ongoing in the U.S. since the 1980's but has not yet provided consistent results across the introduced distribution. Additionally, at least two hydrilla genotypes occur in the U.S., but genetic identity was not known early on and thus not used to inform selection of the control agents that are currently available. Although worldwide surveys for biological control agents of hydrilla throughout its native range have been conducted since the 1970's, recent surveys for dioecious agents between 1996 and 2013 focused on China, Southeast Asia and Australia. To inform native range exploration for agents of monoecious hydrilla, China and South Korea were widely sampled for molecular analysis during 2013-2016, leading to identification of at least six sites with genetic matches to U.S. monoecious plants. Since 2016 regular surveys of native range monoecious hydrilla has been ongoing but visual identification of plants and common herbivore species (i.e. chironomids, *Hydrellia* spp.) has been difficult, and taxonomic expertise in these groups is rare. Using DNA barcoding on samples collected during 2013-2016, a number of new associations between herbivore species and hydrilla haplotypes were made, including a *Hydrellia* sp. and *Dicrotendipes* sp. that were collected from the U.S. monoecious genotype in Korea. Current focus is on quarantine biology and host-specificity of the *Hydrellia* sp. from the monoecious hydrilla genotype in South Korea. An unidentified defoliating moth species was also collected from the U.S. monoecious genotype in China and will be evaluated. Further surveys are also recommended in China and South Korea where

biotypes/genotypes exist that match those found in the U.S. New areas in the native range were also identified for future sampling, based on unique taxa identified through DNA barcoding.

Increased Ploidy is not Associated with Higher Phenotypic Plasticity in Response to N and P in the Wetland Invader, *Butomus umbellatus* L. (*Poster Presentation*)

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Genetic variation in invading populations due to separate introductions or post-introduction evolutionary processes may generate multiple genotypes of varying ploidies that vary in their response (phenotype) to a range of environments, requiring spatially unique preventative or management approaches to limit their spread. Increased ploidy may be positively related to phenotypic plasticity, but this relationship has conflicting support. Positive response to sediment N or P enrichment varies between species but may contribute to invasiveness if a species (or genotype) has greater plasticity to increased resource availability. The way in which genetic variation and associated phenotypic plasticity between introduced plant populations determines response to N or P is unknown for most invaders but could be important in explaining variability in the spread and subsequent impacts by invaders with multiple introduced lineages. We conducted a common garden experiment using ten populations (diploid and triploid cytotypes) of the Eurasian invasive plant, *Butomus umbellatus*, and nutrient solutions of varying N or P (4, 40, 200, 400 mg/L N; 0.4, 4, 40 mg/L P), to measure phenotypic response (biomass accumulation, vegetative reproduction, nutrient allocation) to N and P. Diploid populations produced, on average, 300% more aboveground biomass and 250% more reproductive biomass at high [N] and 200% more aboveground biomass and 250% more reproductive biomass across [P]. In contrast, triploid plants produced 30% and 150% more underground biomass than diploid plants, in response to N and P, respectively. Consistently, diploid plants outperformed triploid plants at all [P] and all but the lowest [N] in all phenotypic measures except underground biomass, a feature which may be key to the successful invasion of the triploid cytotype in the U.S. Pacific Northwest.

Herbicide Concentration Exposure Time Evaluations for Loon Lake, WA: Invasive Watermilfoil Genotypes (*Poster Presentation*)

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Loon Lake is a 450-hectare lake located in Stevens County, Washington. For over twenty years the residents of Loon Lake have managed a population of invasive presumed Eurasian watermilfoil (*Myriophyllum spicatum*). In more recent years, 2,4-D herbicide treatments have become less and less efficacious. In the spring of 2018, representative plants collected from seven different locations around the lake were subjected to a series of treatments in order determine the most effective herbicide for the watermilfoil in Loon Lake. Treatments included 6- and 12-hour exposure to 6 ppb flurpyrauxifen-benzyl, 12 ppb flurpyrauxifen-benzyl, 1.25 ppm triclopyr and 2.5 ppm triclopyr. Plants were visually inspected at 3, 6 and 12 days after treatment (DAT), and 3, 4 and 6 weeks after treatment (WAT). A final destructive harvest of the above-ground biomass was conducted at 6 WAT for dry weight analysis. Complete control was achieved with all products regardless of rate or exposure length for plants collected from these seven Loon Lake locations. Samples of the seven clones used in this treatment protocol were sent to Montana State University for genotypic analysis and found to include two genotypes (genotypes 1 and 4). Additional samples sent directly to Montana State University from Loon Lake indicated that two other genotypes exist in the lake (genotypes 2 and 3). More extensive genotypic analysis and mapping of these hybrid watermilfoil populations is needed as well as an additional efficacy screening for genotypes 2 and 3 to predict lake-wide efficacy of these products on the hybrid watermilfoils present in Loon Lake.

Successful Eradication of Monoecious Hydrilla from a Northern Indiana Lake (*Poster Presentation*)

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[5]Aquatic Weed Control, Inc., Goshen, IN

In August 2006, the Indiana Department of Natural Resources (IDNR) discovered the monoecious biotype of hydrilla in Lake Manitou, a 327-ha lake located in northcentral Indiana. In response to this first discovery of hydrilla in the Midwest U.S., IDNR implemented rapid response actions followed by an eradication program utilizing season-long application strategies of the systemic herbicide fluridone (Sonar®). Point-intercept rake surveys in the late spring and mid-summer of each year failed to detect hydrilla after the start of fluridone treatments in 2007. Sediment core sampling documented hydrilla tuber decline from an average of 73 m^{-2} (732,339 ha^{-1}) in 2007 to undetectable levels by 2011. SCUBA diver surveys were adaptively implemented from 2011 through 2018 to detect trace hydrilla with the last detection of hydrilla by diver in 2013. From 2014 - 2016, fluridone treatments were gradually reduced in scale and intensity to promote native aquatic plant growth while aggressively controlling any trace hydrilla. No management was conducted in 2017 and 2018. Ongoing vegetation assessments and diver reconnaissance failed to detect hydrilla through 2018, the 5th consecutive year without detection. Native plant presence and diversity decreased during the most intensive treatment years (7 native species found in 2005 – 2006 versus 2 – 6 from 2007 – 2013) but increased from 2014 – 2018 to equal or greater levels (7 – 12 species) than pre-eradication. The successful selective eradication of hydrilla and recovery of a native-dominant aquatic plant community can inform potential efforts in other U.S. lakes.

Eradication Economics for Freshwater Pest Plants

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There is a belief across science experts in freshwater biosecurity that if an eradication programme is implemented at the earliest possible intervention point, the cheaper the cost of intervention, the lower the impact (social, cultural, environmental and economic) of the organism and the higher the chance of success. Given the inherent complexity in making intervention decisions, responses are often decided in relation to specific incursions as they happen in their particular context. However, there are common themes that contribute to eradication success across invasive macrophyte incursions. Analysing New Zealand examples of control programmes for key invasive aquatic weeds at differing stages of abundance and impact, allow common themes to emerge that support the hypothesis that the sooner eradication is selected the lower the total cost (including impacts on values) is likely to be, and the higher the chance of a successful eradication. The analysis also improves the understanding of what economic elements contribute to success at a macro-level, and improves our ability to forecast costs, benefits and the predictability of intervention outcomes at different intervention points.

Estimating *Lyngbya wollei* Biomass Using Non-destructive Echosounding Measures (*Student Presentation*)

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Mat-forming populations of *Lyngbya wollei* (lyngbya), a nuisance cyanobacteria, continue to gain recognition among southeastern U.S. waterways due to rapid biomass development, increasing spatial abundance, and mysterious temporal trends. Waterbodies claiming lyngbya presence often report negative impacts on recreation, property, and native macrophyte growth. While factors of lyngbya presence and abundance have been studied, researchers still seek to identify the unique biological, chemical, and physiological processes which promote lyngbya progression, and thus successful management. Detecting and quantifying lyngbya has proven challenging for studying, as populations may be found stratified throughout the water column. Further, potentially deleterious populations may go undetected until surface mats emerge, and benthic or other subsurface populations are difficult to measure using traditional rake-toss survey strategies. Several echosounding techniques have successfully quantified submersed vascular species for decades, though none have documented the ability to identify and quantify cyanobacteria populations over time. However, preliminary research results from 2018 suggest the ability to sense and provide a measure of lyngbya water column occupancy using a high frequency, scientific-grade echosounding unit (Biosonics MX). Current research efforts are being conducted at Lake Gaston, North Carolina to develop a method which would allow quantifying lyngbya abundance using non-destructive biomass estimates and provide a repeatable, timely survey option for management.

Establishment of Aquatic Macrophytes in Mission District of the San Antonio River *(Poster Presentation*)

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Aquatic macrophytes are rare in the Missions District of the San Antonio River except along the shoreline. In this study, macrophytes were planted in different water velocities in static and flowing water using monoculture and polyculture (n = 5 species) 0.25 m^2 plots. The goals of the study were to determine resilient macrophytes that can withstand extreme discharge and utilize these species to establish macrophytes in other areas of the river. Species were planted using 20 cm apical tips in eight sites from May-August 2018. Initial plantings included *Bacopa monnieri, Heteranthera dubia*, *Hydrocotyle umbellate*, *Ludwigia repens*, and *Potomogeten illinoensis*. Heavy rainfall during September 2018 resulted in high discharge rates for over 30 days, and no species survived. Base flow in the river averaged 1.4 $m^3\ s^{-1}$ (50.8 $ft^3\ s^{-1}$) from May-August but reached a maximum of 94.3 $m^3\ s^{-1}$ (3330 $ft^3\ s^{-1}$) on September 4. In addition to extreme high discharge, preliminary evaluation of the sediment in planting areas indicated it was comprised primarily of sand, gravel and rocks and less than 1% organic matter. Additional plantings of *Justicia americana, Sagittaria platyphylla, Paspalum distichum, and Eleocharis rostellata* from bare roots occurred during July 2018, and survival of these species ranged from 0.5 to 22.5% following the high discharge events. Planting apical tips was unsuccessful due to limited root development prior to high discharge events. Additional plantings in 2019 will include bare root stock of *J*. *americana*, *S*. *platyphylla*, and *P*. *distichum* intermixed with submerged species, and planting at the water's edge. Future hypotheses to be tested include: 1) the establishment of plants such as *J*. *americana* will serve as nursery plants and result in increased organic matter, and 2) bare root plants established at edge where more organic matter is present will allow their spread and establishment into deeper water.

Interactions of *Hygrophila polysperma* and *Ludwigia repens* Grown in Saturated Soil and Shallow Water

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Ludwigia repens, a native, and *Hygrophila polysperma*, an invasive, are morphologically similar amphibious macrophytes that occur in spring runs of Central Texas and other aquatic environments in Florida. *Hygrophila polysperma* is a dominant species in flowing waters > 20 cm while *L*. *repens* occurs sporadically in static and shallow water < 20 cm in Texas. Planting efforts to restore *L*. *repens* in flowing water > 20 cm were unsuccessful where *H*. *polysperma* was manually removed. In an interaction study between *Ludwigia repens* and *Hygrophila polysperma* subjected to different planting ratios, *L*. *repens* exhibited greater growth in shallow static water at a depth of 15 cm when grown in equal or higher ratios compared to *H*. *polysperma*. Photosynthetic rates were greater for *L*. *repens* in saturated soils and shallow water indicating this species is more tolerant of sunlight than *H*. *polysperma*. *Hygrophila polysperma* allocated greater biomass to its roots indicating this species may be more adaptable to scouring from floods and extended droughts by greater regrowth from roots. Moreover, *Hygrophila polysperma* exhibited lower light saturation rates indicating this species is more tolerant of lower light levels. The results of this study indicate that *L*. *repens* will be competitive in restoration efforts if grown in shallow static or minimal flows in areas where *H*. *polysperma* has been removed but will be out-competed by *H*. *polysperma* in deeper flowing water.

Bio-economic Model of Delta Weed Management

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We present the results of a simulation on alternative timing for weed management using a bioeconomic model of floating aquatic vegetation in the California Bay-Delta (Delta). The Delta has experienced increased aquatic weed infestations over the past decades. Widespread infestations of water hyacinth caused significant economic costs to different agencies in 2014-2016. With improved management and more rainfall these costs have declined but outbreaks of other aquatic weeds including pennywort, and the recent identification of alligator weed makes effective management of aquatic weeds an ongoing concern. The cost of alternative management of aquatic weeds, using the example of water hyacinth, will be estimated using a bioeconomic model. This model consists of three parts: a weed growth model based on temperature, a spread model based on water and air flows, and an economic model that includes cost to the public agencies that manage weeds as well as private marinas.

The Cost of Invasive Weed Management in the California Bay-Delta, 2013 – 2018 (*Poster Presentation*)

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This poster will present a summary of the costs to different agencies to manage invasive aquatic weeds in the California Bay-Delta (Delta) for six years from 2013 through 2018. During the height of the drought years (2013 – 2015) the costs to manage invasive aquatic weeds increased from $8 million a year to $15.8 million. Costs to the California Division of Boating and Waterways (DBW) about doubled from $7 million to $13.7 million while costs to other agencies such as the U.S. Bureau of Reclamations nearly tripled from $343 thousand to $921 thousand. Costs incurred by other groups such as the Port of Stockton, or marina owners more than tripled during this same time period. DBW is the main agency charged with areawide management of both floating and submerged aquatic weeds. The effectiveness of weed management by this agency is a factor in the costs to control aquatic weeds by other agencies. From 2016 to 2018, the budget for DBW fell by about one million. However, aquatic weed management costs by other groups fell by over 75% to levels not seen since before the start of the drought period. While costs are down for all groups, the composition of where costs are allocated changed. With improved management of floating aquatic weeds such as water hyacinth, greater infestations of submerged aquatic weeds were identified. There are now more costs incurred for the management of submerged aquatic weeds and less for floating aquatic weeds.

Aquatic Plant Community Restoration Following the Long-term Control of Invasive *Egeria densa* with Fluridone Treatments (*Poster Presentation*)

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The Sacramento-San Joaquin Delta is one of the largest estuaries in North America, providing water for more than 700,000 acres of agriculture, recreation and fisheries habitat. The Delta is home to hundreds of native plants and animals, including the endangered delta smelt (*Hypeomesus transpacificus*). For decades, the exotic invasive plant, *Egeria densa* has negatively impacted native habitat and navigation of vessels. Native to South America, *Egeria densa* is a warm-water submerged plant that exhibits invasive traits, such as quick growth, canopy formation and the ability to establish a monoculture. Covering 3,500 acres, Franks Tract is the largest single body of water within the San Joaquin Delta and has been infested with *Egeria densa* since the mid 1990's. Originally used for agriculture,

Franks Tract was flooded in 1936 and is a popular spot for fishing and waterfowl hunting. In 2006 Franks Tract began to be managed at operational scale utilizing fluridone. *Egeria densa* frequency of occurrence was variable throughout the decade but was reduced in the last 5 years of treatment, while species richness doubled during the same time period. In addition to the increases in species richness, *Potamogeton richardsonii*, a native, has become the most widespread species. The shift of a monoculture of a non-native species to a more diverse native assemblage, following management with fluridone, is likely to improve fisheries, native species habitat, and waterway traffic.

New Chemicals and Tank Mixes for Control of Waterhyacinth in the Sacramento-San Joaquin Delta (*Poster Presentation*)

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The Sacramento-San Joaquin Delta is the largest freshwater estuary on the west coast of the U.S. and comprises a critical environmental and economic resource. Delta habitat and economic utility are compromised by invasive species including waterhyacinth, a floating aquatic weed. Standard control measures for waterhyacinth include foliar treatment with glyphosate or 2,4-D, both of which are subject to increasing public and regulatory concern. To address this, we have conducted trials over three seasons to evaluate efficacy of newly registered aquatic herbicides that are applied at much lower rates of active ingredient than glyphosate or 2,4-D. In 2017, we evaluated waterhyacinth control using carfentrazone (133 g ai ha^{-1}), flumioxazin (322 g ai ha^{-1}), imazamox (280 g ae ha^{-1}), and florpyrauxifen-benzyl (350 and 701 g ai ha^{-1}), as well as various tank mixes, compared with a standard rate of glyphosate (1681 g ae ha^{-1}). Plots were established in floating 1-m^2 quadrats, and treatments were replicated four times in randomized complete blocks. All treatments were applied in 935 L ha^{-1} solution with 3.5 L ha^{-1} *Agridex* surfactant. We also included treatments with glyphosate (1681 g ae ha^{-1}) in lower spray volumes of 234 and 468 L ha^{-1} to evaluate whether spray volume had any influence on efficacy. We treated plots 6/13/17 and took biomass samples 8 WAT (two 0.1-m^2 quadrats per plot). Three treatments resulted in better than 95% reduction in waterhyacinth biomass: florpyrauxifen-benzyl (701 g ai ha^{-1}), the tank mix of flumioxazin + imazamox (322 + 280 g ai/ae ha^{-1}), and the 468 L ha^{-1} application of glyphosate (1681 g ae ha^{-1}). Flumioxazin + imazamox gave somewhat synergistic control (better than additive), while other tank mixes (carfentrazone + imazamox, carfentrazone + glyphosate, flumioxazin + glyphosate) gave less than additive control. These results suggest that florpyrauxifen-benzyl and flumioxazin + imazamox may be effective alternatives to glyphosate for controlling waterhyacinth with reduced rates of active ingredient. Their availability also will facilitate management for herbicide resistance. The fact that glyphosate applied in a spray volume of 468 L ha^{-1} produced better control than the same rate of glyphosate in 234 or 935 L ha^{-1} suggests that spray volume optimization may be a useful topic for future research.

Aquatic Invasive Plants: Battle on a New Front for Alberta

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Through rapidly expanding global trade, travel and tourism, many new pathways have rendered our landscapes vulnerable to invasive plants, sometimes beyond the realm of containment. These invasions threaten our environment, economy and in some cases our health and safety. While invasive plants have been under siege for nearly 150 years on land, aquatic invasive plants are just beginning their battle in Canadian waters. Herbicide use for plant control in water is in its preliminary stages in Canada. Aquatic herbicide registrations are limited with no economic drivers and very strict guidelines on use. Approvals from both the provincial and federal departments, that oversee herbicide use, are required just to attempt use in water. While herbicide use might be intimidating to some resource managers unfortunately this is the new reality. Rapid response when aquatic invasive plants are detected in the country is very challenging, but we cannot afford to ignore their presence either. In Alberta, two extremely challenging species, flowering rush (*Butomus umbellatus*) and invasive Phragmites (*Phragmites australis* spp. *australis*) are rapidly expanding their stronghold. Find out what Alberta is doing in response despite the barriers that presently exist.

Herbicide Trials with Brazilian Egeria (*Egeria densa*) for Management in the Sacramento / San Joaquin River Delta (*Poster Presentation*)

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The nonnative Brazilian egeria (*Egeria densa*) is the dominant submersed plant in the Sacramento / San Joaquin River Delta, displacing native plant species and degrading habitat for endangered fish species. A mesocosm study was conducted at the USDA Aquatic Weed Research Laboratory in Davis, CA to determine efficacy of aquatic herbicides. Fifty mesocosm tanks of 167 L capacity were planted with four 4.2 L pots of Brazilian egeria and allowed to establish for four weeks before treatment. All pots were harvested from two tanks before treatment for an initial biomass estimate. Four tanks each were treated with bispyribac sodium (45 ppb), carfentrazone-ethyl (200 ppb), ethylenediamine complex of copper (1000 ppb), diquat (390 ppb), dipotassium salt of endothall (5000 ppb), dimethylalkylamine salt of endothall (5000 ppb), florpyrauxifen-benzyl (50 ppb), flumioxazin (400 ppb), fluridone (60 ppb), imazamox (500 ppb), penoxsulam (60 ppb), and four tanks were conserved as an untreated reference. All exposures were single treatments, static exposures for ten weeks. Weekly, a visual percent control was estimated for each tank. At the end of ten weeks, all pots were harvested, and the shoots were dried at 70C for 48 hours. All herbicides produced some statistically significant reduction in biomass. Copper, diquat, endothall dimethylalkylamine, and fluridone produced 90% or better control. Carfentrazone (69%) and the potassium salt of endothall (62%) provided better than 50% control, with other herbicides producing somewhat less than 50% control. Field demonstration has substantiated some of these findings. A study of three treatment plots in 2016 found an 85% reduction in biomass in fluridone-treated plots, compared to a 26% increase in biomass in untreated plots. A field trial on two plots treated with diquat found 98% and 80% control, respectively. A field trial with the dipotassium salt of endothall resulted in 43% control after one treatment.

Phenology of Three Invasive Aquatic Weeds in the Delta

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The Sacramento / San Joaquin River Delta (hereafter the "Delta") is a 65,000-acre network of waterways that constitute the transition of the free-flowing Sacramento River and San Joaquin River to the brackish Suisun Bay. A freshwater tidal estuary, the Delta is a critical habitat for numerous freshwater and migratory species. The Delta has a diverse assemblage of native aquatic plant species, as well as several invasive aquatic plants. As part of ongoing aquatic plant management in the Delta, the seasonal growth of waterhyacinth (*Eichhornia crassipes* (Mart.) Solms), Brazilian elodea (*Egeria densa* Planch.), and curlyleaf pondweed (*Potamogeton crispus* L.) were studied. For each species, three separate sites were sampled monthly from May 2015 through December 2017. At each site, twelve biomass samples were taken with either a 0.1 m^2 quadrat (floating plants) or a 0.023 m^2 Eckman dredge (submersed plants). Air and water temperature were recorded continuously at 15-minute intervals using a Hobo temperature sonde. Samples were sorted to relevant plant parts, dried at 70C, and weighed to determine plant biomass. Growth data was analyzed by calculating biomass, and density of either stembases (waterhyacinth) or turions (curlyleaf pondweed). Water temperature is an important driver for plant growth of all three species. Low flow years tend to have more plant growth in part because of the earlier onset of adequate temperature for growth, and higher water temperatures throughout the growing season. Curlyleaf pondweed total nonstructural carbohydrates (TNC) ranged from 20 to 60% in the turions, with a distinct peak in July and a consistent low point in February. Egeria shoot TNC was consistently lowest in late spring (April or May). Waterhyacinth stembase TNC ranged from almost 0 to 30%, with a distinct minima in June of each year.

Learning to Control Hybrid Milfoils in the Pacific Northwest

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Eurasian milfoil has been a serious problem in Northwest waters for a number of decades. In recent years there has been a noticeable occurrence of hybrid strains of Eurasian crossed with native milfoil species. These plants are not as susceptible to many common herbicide treatment practices. As it is often hard to differentiate these plants without DNA analysis and DNA analysis options are limited, many treatments are not delivering optimal results. In 2016, AquaTechnex was contracted mid-season by the Loon Lake LMD (Lake Management District) to perform a standard treatment for Eurasian milfoil. This treatment had somewhat less than optimal results. Plants showed symptoms and many dropped as expected, but others withstood control. We sampled plants from 10 locations in the treatment area for DNA analysis and all came back as hybrid cross. At that point we prepared a grant application to the Washington Department of Ecology to develop a strategy to effectively define and target hybrid milfoil species. This grant was approved and funded. During the fall of 2017 and spring of 2018 our team collected milfoil plants from Loon Lake, submitted them for DNA analysis and contracted with North Carolina State University to conduct concentration exposure time studies with triclopyr and florpyrauxifen-benzyl herbicides. This work developed treatment profiles that are to be applied operationally in the lake in the spring of 2019 and prior to the APMS meeting. This paper will discuss the methodology that will be used in future control programs where hybrid milfoils are suspected.

Effect of Herbicide Application on Dissolved Oxygen Dynamics under Canopies of Waterhyacinth (*Eichhornia crassipes*) (*Poster Presentation*)

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The California State Parks Division of Boating and Waterways (DBW) manages waterhyacinth in the Sacramento-San Joaquin River Delta to ensure navigation and fish habitat. Decreasing the amount of waterhyacinth in the Delta should increase fast-moving, highly oxygenated water for fish habitat and migration. However, plant decomposition following herbicide treatment could temporarily lower the dissolved oxygen in the water under the plant canopy. The USDA-ARS and the DBW conducted two trials in the summer of 2016 to monitor dissolved oxygen following herbicide treatment relative to untreated waterhyacinth canopies and in open water. The first trial was along channels subject to tidal fluctuations and mass flow, and the second trial was in backend sloughs where there was little water movement. Three channel-side sites were chosen and three 30.5m by 9.1m treatment plots were chosen for each site. A PME minDO$_2$T Logger (Precision Measurement Engineering, Inc., Vista, CA) was deployed under waterhyacinth canopy in each treatment plot. One plot was treated with glyphosate, one with 2,4-D, and one left untreated at each site. Dissolved oxygen levels were collected every 30 minutes in each plot through six WAT. The same protocol was followed for the backend slough trial, except that each site also had a plot treated with imazamox, in addition to the other treatments. Two minDO$_2$T Loggers were deployed in the open water, away from water hyacinth canopy, in each experiment. The dissolved oxygen levels PRE and POST treatment were compared for each treatment, using ANOVA ($P \leq 0.05$). For the channel-side trial, there was no significant difference in dissolved oxygen levels for any of the treatments ($P > 0.18$). In the backend sloughs, there was no significant difference in dissolved oxygen levels for any of the treatments ($P > 0.92$ for all comparisons).

An Overview of the Delta Region Areawide Aquatic Weed Project for Improved Control of Invasive Aquatic Weeds in the Sacramento-San Joaquin Delta

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The 68,000-acre San Joaquin-Sacramento River Delta of northern California is the largest freshwater estuary on the U.S West Coast. The Delta is of great value environmentally and economically, irrigating over $35 billion in crops in the Delta and Central Valley. The Delta provides drinking water for 25 million people. Recreational boating supports a $300 million economy. The ports of Stockton and Sacramento handle million tons of cargo per year. The Delta's sloughs, wetlands and riparian habitats host 56 listed species. Invasions by non-native species are a major environmental challenge. The USDA-ARS Areawide Pest Management Program focuses on integrated, adaptive control of major weeds and pests, by supporting implementation of new, science-based control solutions and improved communication and coordination among agencies and stakeholders. The USDA-ARS Delta Region Areawide Aquatic Weed Project (DRAAWP) was funded in 2014 to improve control of floating water hyacinth (*Eichhornia crassipes*), submersed Brazilian waterweed (*Egeria densa*), and riparian arundo (*Arundo donax*) in the Delta. Outputs from the DRAAWP are now informing control of nine aquatic weeds and arundo using chemical, mechanical, and in some cases biological methods. The DRAAWP project addresses critical Delta attributes, including water resource use and protection, conservation of native species, habitat restoration, and protection of economic activities and human communities. The development of decision support tools for the lead control agency (Division of Boating and Waterways, California Department of Parks and Recreation) has led to new knowledge on aquatic weed growth and dispersal in the Delta, models of watershed nutrients and flow, remote sensing data, efficacy information for new herbicides, and release of new biological control agents. Project benefits include reduced weed coverage and lower control costs for stakeholders.

Release and Establishment of the Shoot-Galling Wasp *Tetramesa romana* and the Armored Scale *Rhizaspidiotus donacis* for Biological Control of Arundo (*Arundo donax*) in the Sacramento and San Joaquin River Watersheds of Northern California (*Poster Presentation*)

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The grass known as arundo or giant reed *(Arundo donax* L.) (Poaceae) is invasive in the Sacramento and San Joaquin River watersheds of northern California, and arid riparian habitats throughout the southwestern U.S. Arundo consumes water, blocks flood control channels, fuels fires, and displaces native plants. We released the shoot tip-galling wasp *Tetramesa romana* (Hymenoptera: Eurytomidae) and the rhizome and shoot-feeding armored scale *Rhizaspidiotus donacis* (Hemiptera: Diaspidae) as biological control agents. Releases were made in the summer of 2017 at six sites, three each in the Northern Sacramento and southern San Joaquin watersheds. At each site, three plots were pretreated with mechanical topping of shoots at 1 m height, ground cutting, or no pretreatment. In 2018, wasps were present in 9 of 9 plots at one site in the Sacramento River watershed, and in 6 of 9 plots at one site in the San Joaquin watershed, with no effect of plot pre-treatment on establishment. Wasp gall exit holes, made by emerging adults, were used as indicators of overwintering and reproduction. About one in seven side shoots had exit holes, and their density ranged from 1 to 3 holes per m main shoot length. No exit holes were found at the other sites. The armored scale was released by planting potted infested plants at five sites in the fall of 2017. One year later, armored scales were found on resident plants in 1 to 5 plots per site, and females isolated from ½ of these plots produced crawlers, demonstrating that reproductive populations of the scale are present at all five sites. In future studies we will use baseline shoot biomass data to evaluate dispersal and impact of arundo biocontrol agents.

Water Temperature and the Growth of Spongeplant (*Limnobium laevigatum*) (*Poster Presentation*)

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South American spongeplant (*Limnobium laevigatum* (Humb. & Bonpl. Ex Willd.) Heine, hereafter spongeplant), native to southern Mexico, Central America, South America, and the Caribbean, was first detected in California in 2003. Since then, it has been found in numerous locations including the Sacramento / San Joaquin River Delta. It reproduces from both seed and child plant production. Very little has been published on the biology or management of spongeplant, including its capability to grow and spread. We studied the growth of spongeplant in a greenhouse under conditions of controlled water temperature to evaluate the potential role of temperature to regulate growth and documented the relative growth rate of this free-floating species. Spongeplant was grown in 16 tanks, with four tanks assigned to a given temperature. Water temperatures selected were 15, 20, 25, and 30C. The tanks were subdivided into six cells per tank, and one cell was harvested each week. When harvested, the number of rosettes was counted, and all plants were dried for 48 hours at 70C. Relative growth rates (RGR) were calculated from both density and biomass data using a standard equation. By 28 DAI (days after initiation), spongeplant biomass was greatest in tanks grown at 25 and 30C (157 and 167 gDW m^{-2}, respectively), with lower biomass for 20C (120 gDW m^{-2}) and 15C (22 gDW m^{-2}). Density by 28 DAI was statistically the same at 20, 25, and 30C (2740, 3000, and 2570 rosettes m^{-2}, respectively), and lower at 15C (307 rosettes m^{-2}). The optimal temperature for growth is approximately 25C. The relative growth rates were highest at 7 DAI and declined afterwards due to density-dependence. Relative growth rate for density was statistically highest at 30C (0.330 d^{-1}). Relative growth rate for biomass was not statistically different for the four temperatures at 7 DAI, with the RGR at 30C being 0.234 d^{-1}. Spongeplant demonstrates a sensitivity to water temperature in growth, requires temperatures at 15C or above to grow, and has a rapid growth rate similar to other nonnative free-floating plants.

Responding Rapidly to Elodea - The First Freshwater Invasive Plant in Alaska

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Elodea spp. is the first submersed freshwater invasive plant to establish in Alaska. Although initially detected in Cordova in 1982, it was ignored until “rediscovered” in Fairbanks in 2009. Shortly thereafter, Elodea was found in waterbodies in Anchorage (2011), the Kenai Peninsula (2012), and the MatSu Borough (2014). Partners in the Kenai Peninsula Cooperative Weed Management Area (CWMA) were the first in Alaska to apply aquatic herbicides (fluridone, diquat) and the first to report successful eradication, all within three years of initial detection. When two new infestations were found on the Kenai Peninsula in 2017, the CWMA acquired permits and applied first treatments within the same year. At this point, all known infestations on the Kenai Peninsula have been eradicated or are in treatment. We attribute the early success of this management partnership to several critical factors: articulating a clear management goal, dedicated interagency project team, eliciting the support of the right experts, an adaptive Integrated Pest Management plan, sustained outreach to generate support, and early recognition that planning, fund raising, and permitting are the hard work (not field aspects of management).

Evaluation of Concentration and Exposure Time Requirements of Florpyrauxifen-benzyl for Managing Hydrilla and Hybrid Watermilfoil

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In 2018, the synthetic auxin herbicide florpyrauxifen-benzyl was registered in the U.S. to control submersed, floating, and emergent aquatic plants. Due to limited concentration exposure time (CET) data, small-scale trials were conducted under various CET scenarios to investigate efficacy against dioecious hydrilla (*Hydrilla verticillata* L.f. Royle) and hybrid watermilfoil (*Myriophyllum spicatum x M. sibiricum*) as well as selectivity against the non-target species water stargrass (*Heteranthera dubia* (Jacq.) MacMill) and elodea (*Elodea canadensis* Michx.). Hydrilla exposed to florpyrauxifen-benzyl at 12, 24, or 36 µg a.i. L^{-1} for 12, 24, or 48 hr during the summer (August) was reduced by 30 to 75% 8 weeks after treatment (WAT). A follow up trial in the spring (May) evaluated florpyrauxifen-benzyl against immature (recently established) and mature (overwintered) hydrilla. The results indicated no differences in efficacy between the two plant growth stages and 33 to 85% control was achieved. In a growth chamber trial, hybrid watermilfoil dry weight biomass was reduced 98 to 100% when florpyrauxifen-benzyl was applied at 3 to 12 µg a.i. L^{-1} at 3 to 24 hr exposure times 4 WAT. In a follow up trial, plant control ranged from 50 to 100% with 3 to 9 µg a.i. L^{-1} at 0.5 to 4 hr exposure periods. In particular, florpyrauxifen-benzyl at 6 and 9 µg a.i. L^{-1}, regardless of exposure period, provided ≥95% control. In addition, water stargrass and elodea demonstrated relative tolerance to the herbicide at concentrations up to 6 µg a.i. L^{-1} for 4 hr and 9 µg a.i. L^{-1} for 1 hr. These results provide evidence that florpyrauxifen-benzyl possess utility for selectively managing difficult to control invasive species that hinder our Nation's waterways.

Distribution of Eurasian (*Myriophyllum spicatum*) and Eurasian x Northern (*M. sibiricum*) Hybrid Watermilfoil in Minnesota

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Eurasian watermilfoil (*Myriophyllum spicatum*) is an invasive and intensively managed weed across much of North America. It hybridizes with the native northern watermilfoil (*M. sibiricum*), and previous studies indicate that some genotypes of the hybrid are more invasive and some are more tolerant of various herbicides. Although hybrid watermilfoil has been identified from Minnesota since the late 1990s, the geographic distribution of hybrid watermilfoil in Minnesota has not been assessed. To determine the distribution of hybrid (HWM, and coincidentally Eurasian EWM, and northern NWM) watermilfoil in Minnesota, 62 lakes across the state with a range of sizes and duration of invasion, were sampled for milfoil at 100 points in each lake. Plants were identified to taxon using ITS (internal transcribed spacer DNA sequence) markers or microsatellites. Genotypes were identified with microsatellite fingerprints. Based on genetic identification, 43 lakes contained EWM, 27 lakes HWM, and 23 lakes NWM. Hybrid was most common within the Twin Cities Metro; only 5 of 20 lakes sampled outside the metro had HWM. Most lakes either contained just EWM (29%) or just HWM (21%). Among lakes that contained HWM and a parent taxon (12 lakes), we found that HWM was more often in lakes that contained EWM (9 lakes) compared to those that contain NWM (3 lakes). We identified 8 EWM genotypes, 57 HWM genotypes, and 81 NWM genotypes. There was little within-lake diversity for EWM (3 lakes had >1 genotype), and we found one genotype to be the most common and widespread (in 38 lakes). Most lakes with HWM had only one genotype, but 10 lakes contained multiple HWM genotypes. Four HWM genotypes were found in multiple lakes; the most common one was found in 7 lakes across the northeast metro area. We are currently assessing geographic, environmental and human factors that may explain these patterns.

Response of Algal Assemblage to Fertilizer (Nitrogen and Phosphorous) Application Rate in California Rice (*Poster Presentation*)

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The early season rapid growth of nuisance algae in water-seeded California rice can interfere with the establishment of newly emerged rice seedlings. This rapid growth of algae is stimulated by the presence of nutrients in the water; adaptation of fertilizer management practices may reduce the negative effects of the algae on the early establishment of rice. A field and two controlled experiments were conducted to understand the responses of the algae growth to the amount of nitrogen (urea) and phosphorus (triple super phosphate) during the summer 2018. The field experiment was set up using PVC pipes (80 cm diameter), inserted into the soil and algae coverage were visually scored every second day for a month during the field experiment. In the controlled experiments, 19 L buckets were utilized as experimental unit and algae fresh and dry biomass and water chlorophyll *a* content were measured during the two weeks of experiment. Nitrogen was applied at 0, 50 and 150 kg ha^{-1} at field experiment and at 0, 60, 120, 180, 240 and 300 kg ha^{-1} in controlled experiment in combination with phosphorus rates of 0, 35 and 75 kg ha^{-1} under field conditions and 0, 20, 40, 60, 80 and 100 kg ha^{-1} in the controlled experiment, respectively. The growth of algae was maximal when the two fertilizers were applied together (75: 150 N: P kg ha^{-1}) under the field. On the contrary, the increased growth of algae was only stimulated by each fertilizer separately and not their interaction under the controlled condition. The initial results suggest that manipulation of the amount of fertilizer may change the growth of algae; however, such a change could be environmentally controlled. Further studies are needed for a better understanding of the algae growth dynamics and its impact on rice seedling establishment.

Interaction of Florpyrauxifen-benzyl with Four Herbicides for Curlyleaf Pondweed Control (*Student Poster Presentation*)

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Invasions of non-native aquatic plants such as curlyleaf pondweed (*Potamogeton crispus*) (CLP) can have wide-ranging negative effects on native biodiversity and the uses and values of freshwaters. CLP can thrive in a wide range of growing conditions, from very warm summer temperatures to ice-covered water with very low light intensities. Among the tools available for invasive aquatic plants control, herbicides have provided the most economical control of aquatic weeds over the years; however, the use of herbicides has always been controversial. ProcellaCOR® (florpyrauxifen-benzyl) is a new reduced-risk synthetic auxin herbicide that has a unique, low-rate, short-exposure, systemic activity for selective control of invasive aquatic plants. In this study we compared the efficacy of ProcellaCOR® alone or in mixtures with penoxsulam (Galleon® SC), endothall (Aquathol® K), flumioxazin (Clipper™) and copper (Komeen®) for CLP control.

2,4-D Amine and 2,4-D Butoxyethyl Ester Behavior in Eurasian and Hybrid Watermilfoil (*Student Presentation*)

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Hybrid watermilfoil is becoming more prevalent in many lakes where Eurasian (*Myriophyllum spicatum*) and Northern watermilfoil (*M. sibiricum*) co-occur. These hybrids between Eurasian and the native Northern watermilfoil have a 30% faster growth rate and in many cases are less sensitive to 2,4-D than either parent. In order to understand why these hybrids are less sensitive to 2,4-D we investigated 2,4-D acid and 2,4-D butoxyethyl ester (BEE) absorption, translocation, metabolism, and desorption in Eurasian and hybrid watermilfoil. The hybrid watermilfoil was from Hayden Lake, ID and is known to have reduced 2,4-D sensitivity. Herbicide absorption, translocation, and metabolism were evaluated over a 192-h time course, while herbicide desorption was evaluated over a time course of 72 h. The mathematical function that best fit these experimental data were the same for both 2,4-D formulations and both watermilfoils; however, 2,4-D BEE was more rapidly absorbed and reached a higher concentration in the plant compared to 2,4-D acid. We anticipated this result since 2,4-D BEE has a much higher log K_{ow} than 2,4-D acid. 2,4-D BEE was rapidly metabolized and by 12 HAT 100% of the absorbed 2,4-D BEE was metabolized to the free acid. The rate of 2,4-D metabolism to a primary unknown metabolite was similar for Eurasian and hybrid watermilfoil. Herbicide desorbed when treated plant tissue was transferred to clean water and 2,4-D BEE desorption was higher based on the initial herbicide absorption compared to 2,4-D acid. These data suggest that 2,4-D acid and 2,4-D BEE absorption, translocation, metabolism, and desorption do not account for reduced 2,4-D sensitivity in hybrid watermilfoil.

Flowering Rush Biocontrol Research Progress

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Flowering rush, *Butomus umbellatus* L., is an aggressive invasive plant that rapidly colonizes freshwater aquatic systems. It is becoming an increasing concern in many North American states and provinces and is poised to become a substantial problem in several major waterways, even in areas with active control efforts. Although chemical and mechanical control methods continue to be explored, they may not prove practical in regions where flowering rush is widespread, creating concerns that the flowering rush populations will continue to expand and spread without restriction. In looking for possible alternative control methods, the Flowering Rush Biocontrol Consortium (FRBC) was formed and a biocontrol research and development program was initiated in 2013. Flowering rush is an excellent candidate for biocontrol because it is the sole genus and species within the family Butomaceae. This increases the probability of finding a host-specific biocontrol agent, and likely reduces the number of test plant species required for host-specificity testing. The FRBC consists of many federal, state and provincial partners that have pooled resources to fund CABI Europe-Switzerland to conduct field surveys, host-specificity tests, and impact studies of potential biocontrol agents. Three potential biocontrol agents have been identified, including a rhizome- and leaf-mining weevil (*Bagous nodulosus*), stem/leaf-mining fly (*Phytoliriomyza ornata*), and white smut (*Doassansia niesslii*). Host-specificity tests have thus far indicated that *B. nodulosus* has a very narrow host range and final testing will likely be completed in 2019.

Biological Control of Invasive Aquatic Plants in the California Delta: Past, Present, and Future

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Weed biological control in the Sacramento-San Joaquin River Delta (Delta) began in 1982 with the introduction of three agents targeting water hyacinth. The weevil *Neochetina bruchi* is widely distributed throughout the Delta, a second weevil is rare, and a moth failed to establish. Continued outbreaks and limits to control methods has led to renewed interest in biological control. The water hyacinth planthopper *Megamelus scutellaris* was released at 19 Delta sites in 2018, with evidence of initial establishment. Current research focuses on testing and permitting of cold-hardy biotypes of the weevil *Neochetina eichhorniae* and the moth *Niphograpta albiguttalis*, host range studies of the stem-mining flies *Thrypticus* spp., and the leaf-mining mite *Orthogalumna terebrantis*. Testing of the *Ludwigia* thrips *Liothirps ludwigi* revealed that the insect's diet was too broad. Surveys in 2019 resulted in quarantine colonization of *Tyloderma* weevils from Uruguay, which will undergo host range testing. *Alternanthera philoxeroides* was recently discovered in the Delta and efforts are underway to introduce the beetle *Agasicles hygrophila* and the thrips *Amynothrips andersoni* from the southern U.S. Research on a native weevil (*Bagous lunatoides*) to control *Limnobium laevigatum* is also underway. A leaf-mining fly (*Hydrellia egeriae*) that attacks *Egeria densa* was tested but the fly also reproduced on native elodea and was rejected. Surveys for *E. densa* natural enemies are continuing. Biological control of *Arundo donax* includes the release of a shoot-galling wasp, *Tetramesa romana*, and a scale, *Rhizaspidiotus donacis*. Both insects established upstream of the Delta. A leaf-mining midge (*Lasioptera donacis*) may be permitted for release in the near future. The importance of biological control of aquatic weeds in the Delta is expected to increase over time.

Evaluation of Endothall Alone and Pre-mixed with Diquat for Flowering Rush Control (*Student Presentation*)

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Flowering rush (*Butomus umbellatus* L.) (FR) is an invasive weed that infests many northern states and nearly all adjacent Canadian provinces. It forms dense infestations that can compete with native species, affects the use of the water bodies, and alters wildlife habitats. FR plants were grown from rhizomes for 2 weeks and the most uniform plants with at least 30 cm of shoot growth were treated with either endothall alone or pre mixed with diquat. Endothall alone was evaluate as either the amine (Teton) or the dipotassium (Cascade) formulation at 5ppm, and the premix (AquaStrike) at 1.8 ppm of the dipotassium salt of endothall and 0.36 ppm of diquat. Healthy, fully submerged FR plants were exposed to herbicide treatments for 12, 24 or 48 h. Visual control ratings were collected weekly for 4 weeks, then aboveground biomass was harvested, and pots were kept in the cold room at 3C for 6 weeks. After the period of vernalization, the pots were moved back to the greenhouse and allowed to regrow. Teton and AquaStrike significantly reduced the plants ability to regrow from exposed rhizomes, while rhizomes from the Cascade treatments regrew even in the higher CET. Between the three treatments, Teton and AquaStrike controlled FR and significantly impacted the plants ability to regrow from treated rhizomes.

Understanding the Growth Requirements of the Invasive Macroalga *Nitellopsis obtusa* (Starry Stonewort) in a Controlled Environment: A Management Perspective

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Increased attention has focused on understanding the growth of *Nitellopsis obtusa* (starry stonewort) through chemical drivers with limited information on light availability and soil classification. This is important as water chemistry, soil content and light type/availability largely control the distribution, abundance and growth of macroalgae. Therefore, the objective of this study was to expand our knowledge on the growth and biology of *N. obtusa* in response to various light, soil and nutrient scenarios. The purpose was to determine optimum *ex-situ* germination and cultivation conditions for *N. obtusa*. Information from these efforts will aid in the development of standardized *ex-situ* growth protocols that will compliment *in-situ* growth data, which can be utilized for replicated, small-scale management trials. Results of this study demonstrate that *N. obtusa* can be sub-optimally cultivated under a variety of conditions in the laboratory. Ideal growth conditions were heavily dependent on light and soil types as determined by main axis length, shoot number, colorimetric changes as a relative indication of physiological health (hyperspectral imaging) and overall morphology (stereomicroscopy). This information can help guide field studies and determine the role of nutrients, soil and light in *N. obtusa* growth and physiology. Cultivated *N. obtusa* can also provide a setting for the detailed and replicated evaluations of management strategies in the absence of confounding variables. Such a tiered evaluation approach (growth chamber, outdoor mesocosms and field verifications) has proven invaluable in developing techniques for successfully managing other problematic submersed plants including Eurasian watermilfoil and hydrilla.

The Effects of Invasive Aquatic Weeds on Larval Mosquito Habitat (*Student Presentation*)

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Mosquitoes are dangerous vectors of disease, capable of transmitting West Nile Virus and other pathogens to humans and animals. A lot of effort is made to control these pests, particularly by targeting larvae in their aquatic environment. Unfortunately, invasive aquatic weeds can massively modify and dominate the aquatic landscape, resulting in obstructed boat passages, blocked water pumps, and interrupted natural ecosystems. Although some invasive aquatic weeds are known to harbor mosquito species, others are thought to repress them, and most relationships are unexplored. In this study, we measured wild larval mosquito abundances, along with the number of naturally-recruited predators and competitors, in three different aquatic habitats in pond mesocosms: no plants, water hyacinth (*Eichhornia crassipes*), or Brazilian waterweed (*Egeria densa*). We found high number of larval mosquitoes in open water, fewer in water hyacinth, and very low numbers of larval mosquitoes present in Brazilian waterweed. Few, if any, differences were found in the number of predators or competitors between treatments. This highlights a difference in habitat quality to larval mosquitoes caused by the presence or absence of invasive weeds. By improving our understanding and identification of larval mosquito habitat, we can develop better and more targeted control.

Balancing Invasive Aquatic Plant Management and Environmental Regulation in the Sacramento-San Joaquin Delta (Delta)

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The California Department of Parks and Recreation, Division of Boating and Waterways (DBW), is tasked with controlling the growth and spread of aquatic invasive plants (AIPs) in the Delta, tributaries, and Suisun Marsh in support of the environment, economy, and public health. The Delta is the largest estuary on the West Coast, a network of sloughs and waterways, hub of the State Water Project and Central Valley Project, and source of drinking water for 25 million Californians, as well as irrigation for 4.5 million acres of agriculture. An objective of the program is to conduct effective management actions to control AIPs while at the same time striving to minimize non-target species impacts and to prevent environmental degradation in Delta waterways. The two components of this objective can be in contradiction with one another. This presentation will describe the regulatory framework that DBW operates within (Clean Water Act, Federal Endangered Species Act, California Endangered Species Act, California Environmental Quality Act, Section 10 of the Rivers and Harbors Act, Delta Plan, Lake and Streambed Alteration Agreement, and California Pesticide Laws), outline the resulting management and operational challenges, and present DBW's approach to maximizing effectiveness within the complex regulatory and political environment of the Delta.

Screening of Metsulfuron for Control of Giant Salvinia (*Student Presentation*)

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Giant salvinia (*Salvinia molesta*) continues to spread throughout Louisiana, Texas, and the southeastern U.S. Aquatic herbicides are the most cost-effective treatment used to manage the invasive floating fern. Most infestations are chemically managed with a combination of the systemic and contact herbicides glyphosate and diquat. Due to the limited number of herbicides available for aquatic use and herbicide resistance management, additional herbicides are needed to control this highly invasive plant. Recently, the non-aquatic herbicide metsulfuron-methyl was screened for giant salvinia activity and results indicated 98 to 100% control at 21 to 84 g a.i. ha^{-1}. As a follow up, mesocosm trials were conducted in 2018 at the LSU AgCenter Aquaculture Research Facility in Baton Rouge, Louisiana, to determine the efficacy of foliar applied metsulfuron at 2.6, 5.3, 10.5, 21.1, 42.1, 84.1, and 168.2 g a.i. ha^{-1} against giant salvinia in the tertiary growth stage. Metsulfuron reduced plant dry weight 94 to 100% at 5.3 to 168.2 g a.i. ha^{-1} at 8 WAT. Also, the calculated LD_{90}, or lethal dose to kill 90% of the test population, was 3.8 g a.i. ha^{-1}. An additional trial was conducted to evaluate the efficacy of metsulfuron alone and in combination with glyphosate, carfentrazone-ethyl, diquat, or flumioxazin in comparison to glyphosate + diquat and glyphosate + flumioxazin. Metsulfuron (42.1 g a.i. ha^{-1}) was compatible with all herbicide tank mix partners and provided ≥98% giant salvinia control regardless of treatment. Based on this data, metsulfuron alone or in combination with previously registered aquatic herbicides is highly efficacious against giant salvinia when applied as a foliar application.

Effects of Grass-specific Herbicides on Twelve Grass Species in Florida (*Student Presentation*)

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The broad-spectrum herbicides glyphosate and imazapyr are typically used for emergent invasive grass control. However, these herbicides can negatively impact native plant communities. Grass-specific herbicides (graminicides) are currently being developed as an alternative that could provide increased selectivity, but their impact on many native grass species is still uncertain. To address this issue, mesocosm and greenhouse studies were conducted to evaluate graminicide impacts on ten native and two nonnative grass species. Seven aquatic grasses were propagated and placed in 900L mesocosm tanks at the University of Florida Center for Aquatic and Invasive Plants to compare the impacts of glyphosate sethoxydim, and fluazifop-p-butyl on above-water, below-water, and root biomass. Treatments were applied in the summer of 2018 and included an untreated control, 2% v/v glyphosate, 24 oz/A fluazifop, and 40 oz/A and 3% v/v sethoxydim. The experiment was designed in a completely randomized design with four replicate mesocosms per treatment per species. Additionally, five terrestrial native grass species were treated with the same treatments and an additional 0.5% v/v fluazifop-p-butyl treatment in the Spring of 2019 in an RCBD. Shoot harvests were conducted at 30 DAT and shoot regrowth and root biomass harvests occurred at 60 DAT. For the aquatic and terrestrial grasses, the low rate of sethoxydim tended to be relatively safe across most species compared to the higher spot treatment concentration. Regrowth from grasses treated with glyphosate was generally lower than that from sethoxydim and the low rate of fluazifop-p-butyl. These results indicate the lower broadcast rates of the graminicides may fit well for invasive grass management with improved selectivity over glyphosate on many native grasses. However, the higher graminicide concentrations used for spot treatments may cause substantial injury to many native grass species tested and care should be taken when treating mixed stands of native and invasive grasses.

Variation in Cool Temperature Performance Between Populations of *Neochetina eichhorniae* and Implications for the Biological Control of Water Hyacinth in a Temperate Climate (*Poster Presentation*)

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Biological control of water hyacinth, *Eichhornia crassipes*, has resulted in variable outcomes in temperate regions where cool climates are thought to limit population growth and performance of the biological control agents. The weevil, *Neochetina eichhorniae* (Coleoptera: Curculionidae), originating from Argentina, was introduced into northern California, USA, in 1982. The realized distribution and abundance of this weevil is limited, and the exotic weed remains a problem. In this study, we tested populations of *N. eichhorniae* from northern California, Australia, South Africa, and Uruguay to examine the effects of low temperature on life-history performance to determine if cold hardiness differs between populations. We measured the development time, fecundity, survivorship, and thermal tolerance (chill coma: CTmin and supercooling point: SCP) of the four *N. eichhorniae* populations under two temperature treatments simulating fall and winter seasons of northern California. Results suggest that immature stages of all populations tested failed to survive and females did not reproduce in the winter treatment. In the fall treatment, all populations showed similar performance in most of the measured life history traits. The Australian population had the highest intrinsic rate of increase, net reproductive rate and doubling time, due to its longer oviposition period, and higher daily fecundity (2.1 ± 0.2 eggs per day), twice that of the California population (1.0 ± 0.2 eggs per day). Thus, the introduction of *N. eichhorniae* from Australia into northern California may increase weevil densities, distribution, and improve biological control of water hyacinth.

Sequential Dry Substrate/Foliar Herbicide Applications for Suppression of Flowering Rush

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Flathead Lake is at low pool drawdown in late winter through May. This seasonal drawdown regimen provides a dry ground treatment window for soil active herbicide uptake via roots. Two herbicide treatments, 3 qt/ac imazamox & 3 qt/ac imazapyr, both with 2 qt/ac MSO were applied as “dry ground” treatments during the spring (May). The treatments were repeated for five sequential years (2014-2018). The long-term goal was to reduce the regrowth potential from the rhizomes. Imazapyr was consistently more efficacious than imazamox. Control of leaf canopy cover during the summers after spring spraying ranged from 95 to 98% for imazapyr and 62 to 85% for imazamox. This level of summer-long top growth control was commercially acceptable to lakeshore owners. Rhizome weights and density were also reduced. However, after 5 years of spraying the imazamox plots still had 757,774 rhizomes leaf initials per acre and the imazapyr plot had 106,230 rhizomes leaf initials per acre. This density of emergent leaf tips is sufficient to reestablish a dense infestation in one regrowth season without re-spraying.

Establishment of the Mike Netherland and Steve Hoyle Outstanding Aquatic Weed Science Graduate Student Award Endowment (*Poster Presentation*)

Robert J. Richardson
North Carolina State University, Crop and Soil Sciences, Raleigh, NC

The NCSU Aquatic Plant Management Program is excited to announce that an endowed gift agreement has been made between the Aquatic Ecosystem Restoration Foundation and the North Carolina Agricultural Foundation to establish the Mike Netherland and Steve Hoyle Outstanding Aquatic Weed Science Graduate Award Endowment. This fund has been established in recognition of these two exceptional individuals and their historic commitment to furthering the science of aquatic plant management through graduate student guidance and mentorship. The fund has been established in acknowledgement of AERF's donation to the Foundation for the benefit of Aquatic Plant Management at North Carolina State University. Distributions from the Fund will be used to provide financial awards to outstanding graduate student(s) in the weed science program, with an emphasis on aquatic weed science. Dr. Mike Netherland was an Adjunct Professor at NCSU. He served on many graduate student committees and collaborated with NCSU personnel on numerous aquatic plant management research efforts. Mr. Steve Hoyle served NCSU for 35 years, with most of that time spent on aquatic plant management. Steve worked with numerous graduate students to ensure the successful completion of their research projects. We thank both of these outstanding individuals for their contributions to Aquatic Plant Management at NCSU.

A Comparative Review of Management Tactics for HABs

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The objective of this presentation is to strategically review available management tactics for noxious algae. This review is populated from scientific (peer reviewed) literature that provides information regarding critical attributes of the management tactics. Allying the management objectives with the selected tactics that are implemented helps to insure that the appropriate scale in terms of space and time can meet expectations for restoration of water resource uses. In order to accomplish integrated targeted noxious algal management, all available and applicable tactics must be considered for development of an adaptive management plan. This review is an initial effort to synthesize the information required to accomplish this task.

Flowering Rush Control in Hydrodynamic Systems: Water Exchange Processes and Herbicide Contact Time

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In 2018, field trials were conducted to evaluate water exchange processes to develop guidance in the effective management of flowering rush within the McNary Dam and Reservoir located in the Columbia River Basin of eastern Washington State. Evaluations were also conducted to determine the effectiveness of bubble curtains for reducing water exchange within potential flowering rush herbicide treatment areas. Sites of 0.68 to 3.02 hectares were treated with rhodamine WT dye using a submersed application technique to achieve a nominal aqueous concentration of 10 µg/L. Dye readings were collected from multiple sampling points at specific time intervals within each site until a dye half-life could be determined. Dye half-lives represented in-situ water exchange processes under ambient conditions occurring at the time of treatment. Estimated whole plot water-exchange half-lives in non-bubble curtain sites ranged from short (0.56 hours) to moderate (6.7 hours). Estimated water-exchange half-lives in the Yakima River Site #1 (2.6-hour half-life) and Columbia Park Marina Site #2 (6.7-hour half-life) suggested that diquat should have a sufficient contact time to significantly reduce flowering rush shoot biomass. Other sites such as Columbia Park Golf Course Site #3 (0.56-hour half-life) and Port of Pasco Site #4 (1.29-hour half-life) demonstrated more rapid water exchange properties, likely too rapid to effectively control flowering rush using herbicides without the use of a barrier or curtain to slow water exchange. The use of the bubble curtain at Clover Island Site #5 increased the water-exchange half-life from 3.8 hours with no curtain, to 7.6 and 7.1 hours for Bubble Curtain Evaluations #1 and #2, respectively. The ability of the bubble curtain to slow bulk water-exchange processes will provide improved chemical control tactics in flowing water systems, such as the Columbia River. In addition, slowing water-exchange processes may allow for the effective use of other herbicides.

Metsulfuron Methyl as a Potential Control for Southern Naiad in Arkansas Baitfish Culture Ponds (*Poster Presentation*)

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Submersed aquatic vegetation is a continual problem in the Arkansas Aquaculture industry. At present there are only 15 herbicide active ingredients labeled for aquatic use. Because of this, it can be useful to stakeholders to search for unlabeled pesticide active ingredients that can be effective and might be eligible for a 24c SLN label in Arkansas. Metsulfuron methyl (MSM) is one active ingredient that has attracted interest in the past. A small mesocosm demonstration was carried out during the summer of 2018 and spring of 2019 where Southern Naiad was grown in submersed cups and exposed to two different rates of MSM (0.1 oz of product/acre*ft and 0.2 oz of product/acre*ft). The results of this demonstration will be presented.

Digging Deep into the Benthic Layer: Factors Threatening Its Vital Role in Lake Ecosystems (*Poster Presentation*)

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Lakes are living systems with many players shaping the lake from the inside out. It is just like a human body; each part of the lake plays an important role for the overall health. In this presentation we will be looking at the lake's digestive system, the benthic layer. First, we will introduce the details of the benthic layer, along with its significance in the aquatic ecosystem. Next, the factors that threaten the benthic layer such as water runoff, wildlife, chemicals, and harmful algal blooms will be revealed. These harmful algal blooms (HABs) are an increasing concern nationwide as they introduce health hazards not only to humans and wildlife, but to the lake's ecosystem as a whole, including the benthic layer. We then begin to identify the issues of the water system through mapping, sediment analysis, and visual indicators of a system out of balance. From these issues we can derive effective management options whether they be chemical, biological, or physical; along with the benefits and consequences of each. Finally, we can discuss preventative measures that we can utilize in order to keep the entire lake system healthy. When the lake is once again in balance, these simple measures will allow the ecosystem to self-regulate itself for years to come. The benthic layer is a fascinating and vital part of any aquatic ecosystem. It is only with a firm understanding, and careful observations that you can learn to manage your water systems and avoid unhealthy lake imbalance.

Flumigard™ (ai: flumioxazin): A Novel Chemistry for Preëmergent Canal Treatments

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Water stargrass (*Heteranthera dubia*) commonly known as grassleaf mudplantain, is a submersed perennial species in the water hyacinth family (*Pontederiaceae*). This native species of the U.S. and Canada is commonly found in natural waterways and often can become a nuisance species in irrigation conveyance canals. Flumigard[1]™, active ingredient flumioxazin, has utility both as an in-water herbicide for control of submersed aquatic vegetation, as a post-emergent terrestrial and riparian chemistry for control of nuisance broadleaf species and has moderate soil residual activity providing preëmergent control of both terrestrial and aquatic vegetation. Field trials were conducted 2017-2019 within conveyance canals of the Lower Neches Valley Authority examined the utility of preëmergent, bare-ground applications of flumioxazin, fluridone, imazamox and penoxsulam, alone and in various combinations to provide post-flooding control of water stargrass and dioecious hydrilla (*Hydrilla verticillata*). A treatment of flumioxazin (0.21kg ai/ha) plus imazamox (0.28 kg ai/ha) was statistically equivalent to combination treatments of fluridone (2.24 and 1.12 kg ai/ha, respectively) plus imazamox (1.12 and 0.56 kg ai/ha, respectively) and fluridone (2.24 kg ai/ha) plus penoxsulam (0.19 kg ai/ha) the season of application in providing water stargrass and hydrilla control. The inclusion of a contact-type herbicide chemistry such as Flumigard™ into a preëmergent aquatic weed control program will potentially increase overall weed control spectrum, increases apparent activity on submersed aquatic vegetation when combined with systemic active ingredients such as imazamox and fluridone. Additionally, the inclusion of this chemistry into SAV-management programs common to the aquatic and riparian niche market bring several unique advantages to the irrigation canal manager. Further, flumioxazin introduces a new mode of action into a limited portfolio of herbicide active ingredients registered for this niche market use thereby decreasing the potential for resistance development.

Spatial and Temporal Patterns of Genetic Variation in Lakes with Eurasian and Hybrid Watermilfoil in the Upper Midwest (*Poster Presentation*)

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It is clear that Eurasian and hybrid watermilfoils exhibit genetic variation for growth and herbicide response, and this variation is of interest to managers charged with developing and evaluating control tactics. However, it is unclear how much overall genetic variation there is, and how it is structured within and among populations, and over time. For example, do populations consist largely of single genotypes that vegetatively (clonally) propagate, or are they genetically diverse? Similarly, do individual clones have widespread distributions indicative of extensive dispersal of asexual propagules, or do they have restricted, local distributions? For genetically diverse lakes, how much change in genetic composition occurs over time, and how much do management actions influence genetic composition? These questions have important management implications regarding the adaptive potential of populations, and whether the same management tactics will have similar efficacy in the same lakes over time or in different lakes. We studied patterns of within- and among-lake genetic variation in ~50 lakes in Michigan and ~70 lakes Minnesota using a combination of molecular markers. We found that within-lake genetic diversity was generally low, and among-lake genetic diversity was relatively high. However, some lakes were genetically diverse, and some genotypes were shared across multiple lakes. For genetically diverse lakes, we found that genetic composition can change over time. We will discuss alternative explanations for these spatial and temporal patterns, and their implications for Eurasian and hybrid watermilfoil management actions.

Selective Control of Flowering Rush in Mesocosms and Field Sites (*Student Presentation*)

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Flowering rush is an invasive aquatic plant species that is spreading across the northern U.S. and southern Canada. Flowering rush can displace many native aquatic plants species like hardstem bulrush, an emergent aquatic plant that is used as spawning habitat by many native fish species. Previous studies show that repeated applications of contact herbicides can control flowering rush; however, it is unknown if these herbicides can be used to selectively control flowering rush co-occuring with hardstem bulrush. The purpose of this study was to determine if selective control of flowering rush was possible with repeat contact herbicide applications in field and mesocosms trials. In field trials, flowering rush leaf density was reduced 99% and 92% at eight weeks after initial treatment (WAIT) in years one and two, respectively, while hardstem bulrush leaf density was not affected. In mesocosms, flowering rush and hardstem bulrush were exposed to repeat submersed injections of the contact herbicides diquat, endothall, copper, carfentrazone-ethyl, and flumioxazin. Endothall reduced aboveground biomass of flowering rush by 69% compared to reference plants at eight WAIT; no other herbicides affected aboveground biomass of flowering rush. Diquat reduced belowground biomass by 77% compared to reference plants at eight WAIT while the other herbicides had no effect. None of the herbicides tested in mesocosms affected above or belowground biomass of hardstem bulrush when compared to non-treated reference plants at eight WAIT. Future studies should investigate concentration exposure time requirements of endothall and diquat for flowering rush control.

Torpedograss Control Via Submersed Applications of Systemic and Contact Herbicides (*Student Poster Presentation*)

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Torpedograss (*Panicum repens*) is a perennial invasive aquatic plant species that is spreading across the southeastern U.S. Torpedogass can survive in terrestrial and aquatic environments; in aquatic habitats the species can be rooted to hydrosoil or form large floating islands (tussocks) that limit human and wildlife uses of waterbodies. Portions of torpedograss tussocks can break off, float away, and infest new locations thereby making the problem worse. Limited data exists concerning submersed chemical control methods that are effective at controlling torpedograss. This work was conducted to investigate short- and long-term submersed chemical control options of torpedograss grown in outdoor mesocosms. Nine herbicides labeled for use in aquatic environments and a non-treated reference were evaluated. Eight weeks after treatment (WAT), harvested plants were separated into root/rhizome and shoot/leaf tissues, placed in labeled paper bags, dried in a forced air oven for five days at 70C, then weighed. No herbicides significantly reduced torpedograss root/rhizome tissues eight WAT; however, penoxsulam (0.025 ppm), topramezone (0.05 ppm), flumioxazin (0.4 ppm), and carfentrazone-ethyl (0.2 ppm) had reduced root/rhizome tissue by 57%, 64%, 97%, and 62% (respectively) by 52 WAT. Triclopyr (1.5 ppm), diquat (0.37 ppm), flumioxazin, and carfentrazone-ethyl had reduced shoot/leaf tissue by 57%, 47%, 98%, and 49% (respectively) at eight WAT. At 52 WAT, penoxsulam, topramezone, flumioxazin, and carfentrazone-ethyl had reduced shoot/leaf tissues by 49%, 66%, 97%, and 57% (respectively). Based on these findings, additional research should be conducted to determine if operational control of torpedograss is possible using these herbicides.

Evaluation of Selected Algaecides on *Lyngbya wollei* Control (*Student Poster Presentation*)

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Lyngbya wollei is a filamentous, mat-forming cyanobacterium that is increasingly responsible for water quality and habitat degradation in water bodies across the U.S. Benthic filaments proliferate under sub-optimal, environmental conditions and upsurge through the water column, releasing volatile organic compounds that induce taste and odor problems. In addition to potential toxigenic properties that cause safety concerns, dense mats create an anoxic environment and obstruct the water surface, impeding on the native ecosystem and recreational and aesthetic usage of water bodies. Non-heterocystous cells are encompassed by a robust sheath that prevents penetration and degradation, making chemical control difficult and unrepeatable thus far. Research was conducted to evaluate singular and combination algaecides as chemical control options for *L. wollei* populations of Lake Gaston, North Carolina/Virginia. The impounded reservoir has been infested with the nuisance cyanobacteria since the 1990s and serves as an ideal study area due to the persistence and spread of the species despite management efforts. The ultimate goal is to find a chemical or chemical combination that controls *L. wollei*. Samples of *L. wollei* were collected from various coves on Lake Gaston and cultured in Z-8 media. Resultant sub-populations were chemically treated and incubated for 10 days under environmentally replicated conditions. Efficacy was evaluated by biomass, chlorophyll, cell viability and metabolic analysis of filaments. Final results will be discussed, and conclusions will be used to inform management endeavors of Lake Gaston and future research of *L. wollei*.

SWAT Modeling of Nitrogen Exports to the Bay-Delta from Sacramento and San Joaquin River Basins (*Poster Presentation*)

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The Sacramento-San Joaquin Delta and its waterways have recently been infested by invasive aquatic weeds, which impede water flow, impair commercial navigation and recreational activities, degrade water quality, and alter ecosystem community interactions. The Sacramento and San Joaquin River watersheds are located in the upstream regions with intense agricultural activities, and contribute significant amount of nitrogen loadings to the Delta. Since nitrogen is one of the most important abiotic factors to facilitate the rapid growth of invasive aquatic plants, it is important to quantify the total nitrogen loadings entering the Delta, as well as the seasonal patterns, concentration levels, and different contributions from the two upstream watersheds. This study aims to model nitrogen fate and transport from the Sacramento and San Joaquin River basin to the Delta using the USDA Soil and Water Assessment Tool (SWAT) model. We calibrated and validated SWAT in both watersheds, with modifications of default algorithms to better represent complex regional hydrological/water quality conditions (tile drain in San Joaquin River basin, and flood conveyances in Sacramento River basin). Daily continuous N exports (loadings and contributions) were then reconstructed via SWAT simulation. Frequency analysis is employed to compare the distribution pattern of N loadings from two upstream watersheds. Sacramento river basin generates 5 times more nitrogen load than San Joaquin river basin, which are 14.81 and 2.72 thousand tons/yr, respectively. Nitrogen runoff peaks are found in winter months for both watersheds. These results provide insight into the timing of peak growth of aquatic weeds in the Delta, and scientific evidence for the benefits of more efficient watershed management practices in controlling excess nutrient export.

Beyond Park Boundaries: Early Detection and Rapid Response to *Hydrilla verticillata* in Ohio's Lake Erie Basin

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Cleveland Metroparks has been committed to a program of detection and control of *Hydrilla verticillata* (hydrilla) since the invasive aquatic plant was first discovered in 2011. During the formative years, the program incorporated annual park-wide surveillance in aquatic habitats, tuber bank monitoring in five infested waterbodies, and herbicide treatments carried out by contractors. In 2016, the Park District was awarded a two-year grant through Great Lakes Restoration Initiative (GLRI) to expand its hydrilla program throughout Ohio's Lake Erie Basin. The grant-supported work has developed best management practices for fluridone in shallow and hydrologically-dynamic waterbodies, detected four additional hydrilla records among nearly 300 sites surveyed, and has created a strong regional framework for early detection and rapid response to aquatic invasive plants. The presentation includes a discussion of herbicide treatment in shallow, hydrologically-dynamic waterbodies, evidence to halt treatment and monitoring, and the effort to build a regional surveillance network. In 2019 Cleveland Metroparks will expand the program to include additional aquatic invasive plants in Ohio's Lake Erie Basin with a grant from the Ohio Department of Natural Resources.

Florpyrauxifen-benzyl Impact on Non-target Emergent Aquatic Plants under Various Concentration Exposure Time Scenarios (*Student Poster Presentation*)

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Florpyrauxifen-benzyl was registered in the U.S. for aquatic use in 2018. This arylpicolinate herbicide is efficacious against hydrilla (*Hydrilla verticillata*), water hyacinth (*Pontederia crassipes*), and other difficult to control submersed, floating and emergent species when applied subsurface. To date, limited selectivity data has been generated for this new herbicide. Therefore, mesocosm trials were conducted to evaluate the selectivity of florpyrauxifen-benzyl applied subsurface at various concentration exposure times (CET) against the non-target emergent species giant bulrush (*Schoenoplectus californicus*), duck potato (*Sagittaria lancifolia*), jointed spikerush (*Eleocharis interstincta*), pickerelweed (*Pontederia cordata*), soft-stem bulrush (*Schoenoplectus tabernaemontani*), maidencane *(Panicum hemitomon),* and club-rush *(Eleocharis cellulosa).* The non-target species were exposed to florpyrauxifen-benzyl at 12 to 38.7 µg a.i. L^{-1} for 12 to 168 hours, as well as static exposures in a series of trials. Regardless of CET treatment, giant bulrush, soft-stem bulrush, jointed spikerush, maidencane, and club-rush were not reduced in biomass when florpyrauxifen-benzyl was applied subsurface. However, the majority of the florpyrauxifen-benzyl CET treatments were not selective to pickerelweed and reduced plant dry weight by 89 to 98%. Similarly, duck potato biomass was reduced 17 to 50% when plants were exposed for ≥24 hours to concentrations ≥12 µg a.i. L^{-1}. These data provide evidence that florpyrauxifen-benzyl is relatively selective against non-target emergent aquatic plants when applied subsurface.

Use of Copper EDA Granular for Hydrilla Control in Texas (*Poster Presentation*)

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Copper EDA (copper-ethylenediamine complex) has been a tool in aquatic plant management for many years, primarily as a tank mix partner with diquat for control of hydrilla. Though effective, this combination imposes restrictions on water use following application and careful consideration when used in certain diquat-sensitive, mixed plant communities. Over the past several years Applied Biochemists and our cooperators have worked to establish use patterns for copper EDA treatments for hydrilla control in both small- and large-scale applications. Copper EDA treatments offer selectivity, impose no water use restrictions, and typically cost less per acre than combination or systemic herbicide treatments. The 9.87% copper EDA granular formulation offers some unique advantages where currents and water exchange can limit the efficacy of liquid aquatic herbicides. Lake LBJ is a 6,500-acre impoundment of the Colorado River about 45 miles northwest of Austin, TX. A shallow, offshore submerged island, supporting 8 to 10 acres of hydrilla and completely surrounded by deeper water was chosen as a test site. The hydrilla patch was a known boating and jet skiing hazard during the summer. The site's open water location also makes it subject to significant wind and wave action. Treatments using 9.87% copper EDA granular at 240 pounds per acre (1.0 ppm copper in the bottom 3 feet) were completed by LCRA crews on May 18 and June 20, 2017. Partial control was achieved following the first treatment and near 100% control occurred following the second treatment, with no regrowth observed through late October 2017 (4 months AT). Proven efficacy, species selectivity, zero water use restrictions; including application to potable water sources, controlled on-target A.I. release, and a favorable cost per acre make the 9.87% copper EDA granular formulation (Harpoon®) a practical and effective choice for hydrilla control.

Effective Removal of *Hygrophila polysperma* and Reintroduction of Native Aquatic Plants to Improve Habitat for an Endangered Fish Species: Results after Seven Years

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The Comal Springs and Comal River is a short urban river (5km) located entirely in the city limits of New Braunfels, Texas. The Comal River is fed by Comal Springs a karstic spring system that produces an average of 250 cfs in discharge. As many as seven rare and endemic species are found within the Comal system with six species listed as threatened or endangered by the U.S. Fish and Wildlife Service (USFWS). To help better protect these endangered species the USFWS approved a Habitat Conservation Plan to be implemented by the Edwards Aquifer Authority, City of New Braunfels and other stakeholders which identifies multiple goals to improve and increase habitat for target species. One such species is the fountain darter, *Etheostoma fonticola*. To improve habitat for this fish several projects were implemented. These include the removal of *Hygrophila polysperma*, the dominant nonnative aquatic plant, as well as propagation and reintroduction of native aquatic plants including *Ludwigia repens*, *Cabomba* *caroliniana* and *Sagittaria platyphylla*. Monitoring data collected over the previous ten years indicated these species are more suitable for the fountain darter than *Hygrophila polysperma*. Location of restored areas was prioritized based on historical observation of native aquatic plant distribution, sediment and channel characteristics as well as water quality requirements for the fountain darter. In order to provide a reliable source of native aquatic plants several techniques were used including sprigging of stem fragments and in situ nursery propagation. Removal of *Hygrophila polysperma* was carried out by hand. Since 2013 an estimated 4,000 square meters of *Hygrophila polysperma* has been removed with complete eradication in some restoration areas and nearly complete eradication in others. Former areas occupied by *Hygrophila polysperma*, plus some additional area, has been replanted with over 60,000 native aquatic plants.

Lake Tahoe's Aquatic Invasive Species Prevention Program: Ten Years of Success and Planning for the Future

Dennis Zabaglo
Tahoe Regional Planning Agency, Stateline, NV

Lake Tahoe's Aquatic Invasive Species (AIS) Program began in earnest in 2008 after the discovery of quagga mussels (*Dreissena rostriformis bugensis*) in Lake Mead, NV. The Program's success is due to the creation of a dedicated partnership consisting of more than forty private and public entities. A decade later, the Lake Tahoe AIS Program has had tremendous success educating the public about the impacts of AIS, preventing new invaders, and is making progress on controlling existing invasive species. To adequately prepare for the next ten years and beyond, the need to identify and develop tools to sustain the program is critical. There have been many lessons learned which have improved efficiencies and refined the program over time. Unsurprisingly, education has been a critical component to success, but not just with the boating public. Significant effort has been spent ensuring that funders, policy makers and legislatures understand the continued threat and the value added by the program. Partnerships are also vital to the success, not only locally but regionally and nationally as well. Coordination with other programs and the boat industry has proven to be extremely valuable and further investment in partnership fostering is necessary. As the program evolves, current and future challenges are being identified. Solutions to issues like program and staff costs, keeping pace with industry advances, and the threat of new species due to climate change are being sought. Having a solid foundation built by strong partnerships puts the Program in a good place to continue the success and achieve the ultimate goal of protecting Lake Tahoe.

Notes:

The **Aquatic Plant Management Society, Inc.** is an international organization of scientists, educators, students, commercial pesticide applicators, administrators, and concerned individuals interested in the management and study of aquatic plants. The membership reflects a diversity of federal, state, and local agencies, universities and colleges around the world, corporations, and small businesses. Membership applications are available at the meeting registration desk and online at www.apms.org.

The **Vision** of the Aquatic Plant Management Society is to be the leading international organization for scientific information on aquatic plant and algae management.

The **Mission** of the Aquatic Plant Management Society is to provide a forum for the discovery and dissemination of scientific information that advances aquatic plant and algae management policy and practice.

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