

# Aquatics

SPRING 2009

Publication of the Florida Aquatic Plant Management Society

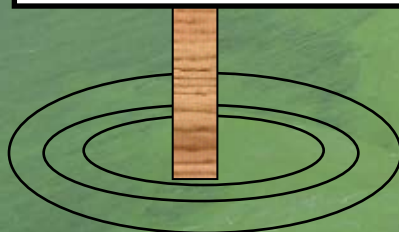
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Founder of FAPMS**





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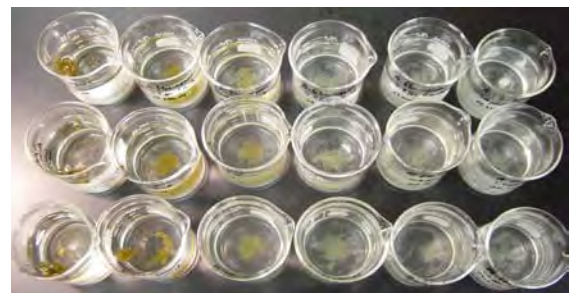
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Les operating a dragline to move canals on the Plantation Golf Course prior to its 15 Dec 1950 opening. (Burghard 146) (Photograph provided by Pat O'Quinn)

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## Leslie E. Bitting, Sr.

Vernon V. Vandiver, Jr.<sup>1</sup>, H.C. (Pat) O'Quinn<sup>2</sup>, and William H. Moore<sup>3</sup>



Les at work in his Old Plantation Water Control District office. (Photograph provided by Pat O'Quinn)

This winter many of us lost a good friend with the passing of Leslie E. (Les) Bitting, Sr. on Sunday, 30 November 2008 in Saint Augustine, Florida. Les was instrumental in the founding of the Florida Aquatic Plant Management Society (FAPMS), serving as its first President in 1977, and a second term as President in 1978. Les was also one of the founding members of the Florida Association of Special Districts; he served as the fourth President of that association which was originally created in 1976 as the Association of Water Control Districts, and served as a Board member until his retirement in 1995.

Many of the FAPMS members knew Les through his service with the Old Plantation Water Control District. He assisted with the creation of the District in 1946 which was chartered by the State of Florida in 1947, and served as Superintendent with the District from 19 November 1946 until his retirement on 1 March 1995.

Ben Bitting, Les' father who was a cattleman all his life, moved his wife and five chil-

dren from Nebraska to Hialeah in the fall of 1939 (1). After moving to South Florida, Les began helping Frederick C. Peters with his farming operations in south Dade County (2). Mr. Peters grew potatoes and had a packing house in Goulds (3).

The Everglades Plantation Company had owned land in Broward County which is now the City of Plantation. In the 1920's part of this historical name was used when the Old Plantation Drainage District was formed (4). In 1941 Mr. Peters purchased 10,000 acres in that area for farm and ranch land. Then, in 1942, Mr. Peters started moving cattle under Les' supervision from Goulds to Plantation to start his Broward County ranch (5).

Mr. Peters and others were instrumental in the establishment in 1953 of the Plantation Field Laboratory, a unit administered under the University of Florida, Everglades Experiment Station, Belle Glade, Florida. (6) The Plantation Field Laboratory was located on the north side of what is now known as Peters Road, just west of the current location of the Florida's Turnpike. The 90-acre site which Mr. Peters leased to the State for the facility surrounded the area where the Peters' ranch house and barn were located.

The Laboratory was established to conduct research on vegetable and forage production on the sandy soils of the lower East Coast of Florida. (7)

Located with the University of Florida in 1954, the United States Department of Agriculture (USDA), Agricultural Research Service (ARS), Soil and Water Conservation Research unit started a project to investigate the hydrology of several Florida watersheds. John C. "Jake" Stephens headed this project. He also started the first research projects in the area to control aquatic weeds in ditches and canals which seriously restricted water movement needed for agricultural irrigation and drainage. The aquatic weed research program continued to increase in size as other ARS scientists were assigned to the location. (8) Later, University of Florida, Institute of Food and Agricultural Sciences faculty were appointed to the aquatic weed research effort following the joint research program's move to its present location in Davie on a 100-acre site; this representing approximately one-fifth of what was commonly called the former Forman Field, depicted in the 1944 US Army/Navy Directory of Airfields as "Forman OLF, Navy," a satellite training airfield of NAS Fort



Les and Bill Moore, at the time with Elf Atochem North America, checking endothall plots on *Hygrophila* in an Old Plantation Water Control District canal in 1993. (Photograph provided by Pat O'Quinn)

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Les designed innovative equipment to treat efficiently the District's urban canals. The crane truck quickly and safely launched the airboat. Les hinged the airboat cage and engine so they would tilt down and allow the airboat to pass under many of the bridges in the District. Photo by Bill Moore.

Lauderdale. (9) The "OLF" was an abbreviation for "Outlying Landing Field".

The above two background paragraphs are included to illustrate one point. Les was very innovative in his work and was always quick to support and cooperate in research projects; he and the Peters family cooperated with the two organizations from their inception. This held true for many years. Bob Blackburn recalls that Les cooperated and assisted with the initial aquatic weed research conducted by the ARS in Plantation. The Old Plantation Water Control District airboat was used to treat *Najas guadalupensis* (Spreng.) Magnus. (Southern Naiad) with aromatic solvents. Southern Naiad caused major submersed aquatic weed problems for agriculture in South Florida prior to the introduction of *Hydrilla verticillata* (L. f.) Royle (Hydrilla). Les also cooperated in the early research that resulted in diquat and endothall products being labeled as aquatic weed herbicides. (10)

Researchers from around Florida and the entire United States who work on aquatic weed problems have always been blessed with numerous invaluable cooperators from the industry in Florida. Les was no exception; his early support is described above, and he continued to be a valuable supporter of the industry until he retired.

As many who had the privilege to know him will tell you he never liked to bring attention to himself. Les liked to work quickly and get things done very efficiently. I will always remember when we had flown on the commuter airline, Gulfstream, from Fort

Lauderdale to Gainesville for a meeting at the University of Florida, Institute of Food and Agricultural Sciences (UF/IFAS), Center for Aquatic Plants with Dr. Bill Haller. Les was as economical as possible for the District, so typically, he had made a reservation with an automobile rental company that had given us a very good rate. However, the rental company happened to be a bit short of cars that morning.

While Les and I waited at the car rental customer service counter, the agent kept looking through the available keys to find us a

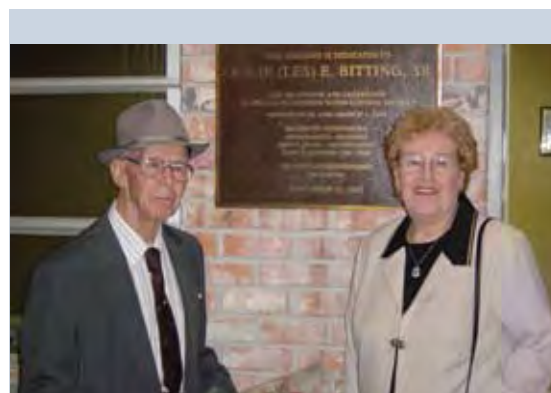
suitable car. Finally while he was still looking through the drawer, he said, "Mr. Bitting, can you drive a stick shift?" Les just smiled and replied, "Yes sir." I could not resist. I asked Les in a voice loud enough that I was sure could be heard by the car rental agent, "Les, why don't you ask him if he can run a dragline?" Good old super-polite, shy Les just smiled, bowed his head somewhat and blushed. The rental agent just paused a few seconds with his mouth open somewhat, and then got us some keys. But there were no more questions about what kind of car we needed.

With Les' passing, Bill Moore sent an email notification to the FAPMS Past Presidents for whom he had an address. To illustrate the high regard in which Les was held by the industry, we will share a few of the comments Bill received. Dan Thayer: "Thanks for sharing. What a great man!!" Eddie Knight: "Thanks for passing this along Bill. Les was truly one of a kind with his kind and giving manner. He is ever etched in my mind. Eddie Knight." Wendy Andrew: "Thanks for letting me know. He was such a grand gentleman. Wendy." I will also pass along Bill

Moore's comment he shared with me: "Les was indeed a great man, admired by all who knew him. Bill."

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- (10) Robert D. Blackburn, telephone interview with the author, 31 March 2009.



Les and his wife Catherine at the dedication of the Old Plantation Water Control District building to Leslie (Les) E. Bitting, Sr. on 21 Nov 2002. (Photograph provided by Pat O'Quinn)



Les helping the crew prepare for an herbicide application. Photograph by Bill Moore.



# A Manager's DEFINITION of Aquatic Plant Control

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and

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## Defining Aquatic Plant Control:

During the past few decades demand for access and use of U.S. surface waters has increased. This is evident in freshwater systems where human activities have expanded. These uses include real estate, recreation, irrigation, hydropower, potable water, navigation, and efforts to conserve environmental attributes such as fish and wildlife habitat. Aquatic plants are a natural and important component of many freshwater systems, and resource managers consider a diverse assemblage and a moderate level of aquatic vegetation to be beneficial for numerous ecosystem functions. Nonetheless, an overabundance of aquatic plants, particularly invasive non-native plants, can impair freshwater systems, requiring some level of aquatic plant management to conserve water body uses and functions. These aquatic plant management activities routinely take place on water bodies ranging in size from small private ponds to large public multi-purpose lakes and reservoirs.

With increasing demands and values associated with surface waters has come a greater need for aquatic plant control. Nonetheless, the term “control” can take on many meanings depending upon the type and amount of use of each water body, the species of plants present, the responsibilities of resource managers, and the objectives of various stakeholder groups associated with the water body. A quick review of reference materials provides the reader with dozens of descriptions and synonyms for “control,” and yet for various reasons none of these efforts would provide a meaningful definition for aquatic plant management. The Aquatic

Plant Management Society (APMS) looks to address this deficiency by providing an aquatic plant manager's working definition of aquatic plant control.

While the terms aquatic plant control and aquatic plant management are often considered synonymous, many resource managers consider control efforts as being operational in nature, and management as a process more aligned with program goals and objectives.

The APMS defines aquatic plant control as **techniques used alone or in combination that result in a timely, consistent, and substantial reduction of a target plant population to levels that alleviate an existing or potential impairment to the uses or functions of the water body.**

The above definition best applies to management techniques that directly target a reduction in plant biomass. It is recognized that some management strategies seek to impact factors such as plant reproductive capacity (e.g., production of flowers, seeds, tubers, etc.) or nutrient availability, and while these techniques are often recognized as a valuable component of an integrated management program, physical reduction of plant biomass may not result for many years. Moreover, in our definition, the use of the term “substantial” may seem ambiguous; however, we feel there is an inherent problem with using quantitative guidelines (e.g., a 70 percent biomass reduction results in acceptable control) to define what is in most cases a series of qualitative field observations by the aquatic resource manager and stakeholders to determine the success of the management activity. Aquatic resource managers should always consider if the proposed management technique has a successful track record, and know the limitations of the potential strategy. Claims that a product or technique can provide control should be supported by peer-reviewed literature, experiences from other resource managers with similar management objectives, or current research and demonstration efforts.

No single definition of aquatic plant control can cover each specific contingency therefore good communication on the front end is a key. **The resource manager and**

**stakeholders must first establish expectations for the amount and duration of plant control prior to the initiation of a control activity, and then implement a management strategy to meet these expectations.** This definition and the attached white paper are intended to address factors that relate directly and indirectly to aquatic plant control. Numerous variables influence aquatic plant control operations and many of these parameters, including water body uses, environmental conditions, and available management tools are presented in Appendix 1, along with the influences they may have on the planning or outcomes of aquatic plant control operations. The white paper and Appendix may be useful to managers responsible for conserving identified uses and functions of public waterways, and who must explain to stakeholders the reasoning behind management plan selection and the ultimate results.

## Linking Management Decisions to Aquatic Plant Control Expectations: Factors that Influence Decisions and Outcomes

Aquatic plants have been controlled in U.S. surface freshwaters under organized programs for more than a century, so it is natural to ask why it is necessary to provide a definition of aquatic plant control at this point in time. In questioning a number of managers, researchers, and other stakeholders, it became obvious that opinions on what constituted acceptable control of an aquatic plant population were widely varied. While agricultural managers have been using terms such as “weed free periods” and “crop yield reductions” to define the economic benefits of weed control in cropping systems, aquatic plant managers have a different focus than their terrestrial counterparts. Agricultural weed managers usually attempt to control a broad-spectrum of weeds in order to enhance one or more crop species in a fairly controlled environment with a specific function. Aquatic plant managers usually try to control one or two weeds (usually invasive



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exotic species) to conserve or enhance perhaps dozens of desirable plants as well as multiple uses of aquatic systems. In essence, an agricultural definition of “weed control” does not encompass many of the issues associated with aquatic plant management.

In developing a manager’s definition for control, it was initially tempting to utilize the language of research to provide a quantitative definition. Both the amount and duration of plant control can be readily quantified within the framework of an experimental study or demonstration project. Nonetheless, many experimental studies result in destructive sampling of the target plants at a given point in time (e.g. 90 percent reduction at 8 weeks after treatment), and they often don’t allow us to determine if even better control or subsequent recovery would result at a later point in time. While this efficacy information can be very useful to managers regarding the expected performance of a specific management technique, the uses, functions, and environmental conditions can vary widely among water bodies and within water bodies through time. This will influence not only the level of management that may be attempted, but also the outcomes of each control operation. While research projects utilize methods that allow for quantification of control, the vast majority of aquatic plant control operations are ultimately judged by fairly subjective visual observations and qualitative means (e.g. the target plants are near the bottom, difficult to find, and the current level of control is rated as good). Therefore, plant control or lack thereof is largely based on whether or not the resource manager and stakeholder expectations have been met.

As noted above, there are numerous issues that either directly or indirectly influence aquatic plant control and management strategies. Before selecting control tools or developing management strategies, three key elements should be addressed that will ultimately influence the manager’s decision making process.

## Native vs. Non-native, vs. Invasive Aquatic Plant Control:

The National Invasive Species Council defines an invasive species as: “an alien species whose introduction does or is likely to cause economic or environmental harm or harm to human health.”

While there are major distinctions between invasive exotic and native species, the main objective of this white paper is to clarify the term “control” and as such will not

make significant distinctions between managing invasive exotic species and nuisance growths of native plants. Whether a plant is a native or exotic, it can cause problems for given water uses (e.g., water conveyance, access). Nevertheless, two key distinctions between nuisance native and invasive plants deserve further discussion. First, problems associated with nuisance native vegetation are typically site specific while invasive plants can impair uses and functions of waters across a broad spectrum of conditions and on a regional scale. The vast majority of large-scale aquatic plant control efforts in the U.S. target invasive species. These plants have the potential to spread and dominate new ecosystems and they also have demonstrated the ability to become established in relatively stable aquatic systems. The philosophy behind invasive plant management programs often is to reduce the potential for spread within and among water bodies by reducing the plant biomass to the greatest extent practicable. The second distinction involves early detection and rapid response (EDRR) programs. These efforts are typically unique to invasive exotic species. A significant and costly multi-agency effort may be initiated to control a very small infestation; however, given the potential negative properties of many invasive exotic plant species, these front-end efforts are viewed as necessary and cost-effective.

## Efficacy vs. Control

It is tempting to define aquatic plant control in terms of an expected percent reduction in coverage or biomass of a target plant population. Some regulatory agencies (e.g., California EPA, Canada Pest Management Regulatory Agency) require that herbicide manufacturers prove the efficacy of their products prior to registration. In this regulatory scenario, a product must reduce a target pest population by greater than 70 or 80 percent to provide efficacy. Within the discipline of aquatic plant management, numerous techniques can provide both a rapid and significant reduction in a target plant population (>70 percent), but these results may only be sustained for a few weeks or months. Therefore, depending upon when the efficacy of a management technique is measured, one assessment may suggest that control was achieved, while a subsequent assessment conducted weeks, months, or a season later may lead to the conclusion that the management effort failed to provide any level of control.

If resource managers and stakeholders have agreed to implement a strategy to provide an entire season of biomass reduction

and the target plants recover within one or two months, then by our definition, control has not been achieved. In contrast, some methods may result in slow initial impact on a target plant population, but may ultimately provide one or more seasons of control. To complicate matters, many stakeholders fail to grasp that an aquatic plant problem may require more than one treatment or strategy. It is incumbent upon resource managers to understand the strengths and weaknesses of the various management techniques and then convey this information to the stakeholders. If expectations are not defined properly, the stakeholder may lose confidence in the management program. When managers do not establish clear expectations, they are often questioned if control was achieved. Attempting to assess aquatic plant control when clear expectations were not established on the front end is one of the biggest challenges in coming up with a meaningful definition or even assessment of control.

## Environmental Controls

Managers must be careful not to confuse slow-acting control methods with natural variations in plant populations. While it is often tempting to link a prior control effort with the large-scale decline of a target plant population, environmental events (e.g. droughts, floods, hurricanes, seasonal senescence, etc.) often are largely responsible for these declines. If empirical data do not exist to support a cause and effect relationship between a control effort and plant biomass decline, managers should avoid making claims that can not be supported by evidence. Some managers rely on environmental events (e.g. flooding events that scour submersed plants or move floating vegetation, and prolonged periods of high dark water that prevent light penetration for submersed plants) to provide control. While this can be effective, in order to be considered an aquatic plant management technique, there should be some level of predictability associated with the environmental event. From a management perspective there is a big difference in relying on routine seasonal flooding events to control a given plant population versus relying on 100-year floods or droughts to provide plant control.

## Levels of Aquatic Plant Control

At the most basic level there are three possible aquatic plant control approaches: 1) no attempt to control, 2) control efforts to eradicate a plant species, or 3) some level of intermediate control that is either incomplete or temporary.



## No Attempt to Control

Despite its connotation, the “no control” option is a valid management decision whose potential outcomes must be considered by managers and explained to stakeholders. Factors that influence a manager not taking active control measures may include:

**Plant species** - Is the plant invasive? Is it a native plant impairing water body uses or is it just unwanted by stakeholders?

**Size of infestation** - Is this a pioneer infestation consisting of a few plants? Is it an established, but stable, population? Is it an established population or starting to approach problematic thresholds?

**Plant location** - Is the infestation in an isolated location? Is the location conducive to spreading the pest plant by fragmentation, flow, etc? Are there important nearby water bodies that are prone to becoming infested?

**Plant biology** - Is there a likelihood of a rapid population expansion? Would “no control” permit the plant to produce viable seed or vegetative propagules that could make later control efforts more difficult and expensive?

**Exploitation** - Is the plant species providing an ecological service (e.g. nutrient uptake, food source for waterfowl, habitat for fisheries, etc.)

**Managerial will** - Managers may be under pressure to not control a plant because

it provides benefits (perceived or real) to a user group. Stakeholders may oppose control because they are not familiar with proposed methods.

**Managerial experience** - Inexperienced resource managers are often uncomfortable with making aquatic plant management decisions (especially on a large-scale). Until a manager understands the issues and situation, the “no control” option may be viewed as the safest and least controversial.

The consideration of these factors and others may justify a “no control” decision. There are consequences associated with all management decisions and “no control” is not exempt. As previously addressed, plant reductions related to environmental factors could be included within the realm of the “no control” option. While environmental events such as floods, droughts, freezes, or severe algae blooms can be quite effective in controlling aquatic plants, these events are not typically predictable and they are not initiated by managers. Nonetheless, the fact that some managers tend to rely on seasonal or weather events to provide effective control suggests the term “no control” may be a misnomer in these situations.

## Eradication

Much like defining control, eradication

has proven to have numerous meanings to various managers, researchers, and stakeholders. In a strict sense, eradication means the complete and permanent removal of all viable propagules of a plant population. This is confounded when a population is removed and then reintroduced at a later time. Some plants may be eradicated following single management efforts (e.g. removal of water hyacinth (*Eichhornia crassipes*) plants prior to seed set) while others such as hydrilla may require years of intense surveillance and management. Eradication efforts are typically employed when a region, state, or watershed is threatened with a new introduction of an invasive species that has potential for significant economic or environmental impact. Based on efforts by various resource management agencies to date, aquatic plant eradication programs are characterized by:

- sustained and multi-year efforts to insure elimination of the plant population;
- small-scale efforts to control relatively few plants,
- control costs on a per acre basis can be quite high;
- the overall impact of repeated control efforts on the infested water body is continually weighed against the regional threat posed by the invasive plant;
- control efforts may eventually be re-

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duced; however, vigilant monitoring remains a key to success.

## Temporary Control

Outside the realm of eradication, all other control efforts are temporary. Temporary control is essentially an acknowledgement that one hundred percent control is either not an economically viable management objective or is not physically achievable. Temporary control is a continuum that can be represented by the short-term reduction of target plants following mechanical harvesting or spot treatments with contact herbicides, to many years of control that may result from grass carp (*Ctenopharyngodon idella*) stocking for submersed plants, or decades of suppression of alligatorweed (*Alternanthera philoxeroides*) by the alligatorweed flea beetle (*Agasicles hygrophila*). Thus, temporary control results when the aquatic plant manager has made the decision that eradication is not a viable endpoint and some level of target plant persistence is acceptable in the management strategy for a given water body.

Temporary control is achievable using a variety of methods. Managers should evaluate each proposed method and the integration of various methods in terms of meeting specific control objectives.

## Maintenance Control

Maintenance control is applied on a lake-wide or regional scale over time, usually to reduce and contain invasive species. Once established, invasive aquatic plants can be extremely difficult, if not impossible, to eradicate. However, managing invasive plants at some prescribed level that does not impair the uses and functions of the water body can reduce environmental and economic impacts. As the term implies, maintenance control indicates that a conscious decision has been made to actively control an aquatic plant problem with the added understanding that a long-term commitment to management rather than eradication is the goal. Simply stated, maintenance control involves routine, recurring control efforts to suppress a problem aquatic plant population at an acceptable level.

Maintenance control encompasses a continuum of control objectives. On one extreme, the goal of maintenance control may be to reduce and sustain a plant population at the lowest feasible level that technology, finances, and conditions will allow. This strategy has proven effective in managing established populations of highly invasive aquatic plants. By managing water hyacinth (*Eichhornia crassipes*) at low levels through

frequent small-scale control operations, there is a corresponding reduction in the overall management effort, especially herbicide use and management costs. There also are environmental gains, such as reductions in sedimentation, and dissolved oxygen depressions. At the other end of the spectrum, maintenance control operations can be applied just prior to plant populations impairing the uses or functions of the water body. This strategy entails allowing plants to grow to the brink of problem levels, and therefore may be best employed in controlling slow growing or otherwise non-invasive plants.

Paradoxically, there is often more stakeholder support for crisis management (allowing plants to reach some problem or impairment level) than maintaining invasive species at low levels. This may be related to stakeholders being unaware of invasive plant growth potential. It also may be related to the public's perceptions of control methods – for example, not understanding that less herbicide may be needed to maintain plants at low levels rather than waiting for an obvious problem to develop.

While the examples of grass carp and alligatorweed flea beetle describe multi-season impacts, it must be recognized that the basis for this extended control is the continued presence of adequate populations of the management tool (i.e. the carp or the beetle). If the carp numbers are reduced below a certain threshold (predation, sportfishing, flooding, escape from the system), the target plant will generally re-colonize the aquatic system. Likewise, a severe winter can have adverse impacts on biological control organisms, and this may allow the target plant population to grow back to nuisance levels. The principle of maintaining a continuous pressure on the target plant is an important concept that is often not discussed when describing maintenance control provided by grass carp or biocontrol organisms. Maintenance control is often used to describe only ongoing herbicide programs, yet it is the integrated use and continuous pressure provided by grass carp, biocontrol organisms, and chemical control tools that best describe a maintenance control approach.

## Adaptive management –

Since maintenance control represents a long-term commitment, it must also encompass a strategy known as adaptive management. Uses and functions of water bodies change through time, as do conditions within water bodies and among plant populations. Examples include target and non-target plant growth stages, water temperature, depth, clarity, and flow. All change several times during the year and can require different control strategies or different expectations for control outcomes. Therefore, integrated management plans for each aquatic plant control operation must account for and adapt to these changes.

## Communicating Control Expectations to User Groups

Many stakeholders view aquatic plant management endeavors as a one-time

control effort with no further need for additional management. This does not reflect the reality of the discipline of aquatic plant management. The vast majority of management programs require a sustained effort over multiple years to keep unwanted vegetation under control. For example, while grass carp can provide long-term control of hydrilla, this result is due to their continuous presence and feeding on existing biomass and propagules. Carp can sustain control for many years, yet removal of the carp due to natural losses or on purpose will typically result in the recovery of the target plant. Likewise, a single treatment with fluridone herbicide may remove or reduce a target invasive plant such as Eurasian watermilfoil (*Myriophyllum spicatum*) within a system for one to several years. Upon discovery of new plants, many stakeholders are dismayed that the treatment did not eradicate the problem. In some cases these plants may have recovered from dormant seed or they may have been introduced from a nearby system that was not managed. Aside from the use of an effective classical biological control organ-

ism (highly selective) or high stocking rates of grass carp (non-selective), user groups must be informed about the importance of maintaining continuity in an aquatic plant management program. Single small-scale efforts that don't address the problem at an adequate scale often lead to claims that "we tried that and it didn't work." A lake full of hydrilla (*Hydrilla verticillata*) or Eurasian watermilfoil may require whole-lake management efforts. The control may last one or two seasons or even longer, but experience suggests that these invasive plants will ultimately return at some level.

One of the bigger challenges facing aquatic resource managers relates to the promotion of unproven and often costly technologies that are packaged as environmentally friendly approaches to aquatic plant management. As noted earlier, claims



of a product or device providing “control” should be supported by published or on-going research, or by another reputable resource manager who has successfully applied that technique or strategy and met similar control objectives.

## APPENDIX A

### Parameters that Influence Aquatic Plant Control Decisions and Outcomes

Aquatic plant management is a complex discipline that blends predictable sciences of chemistry and hydrology with variable parameters of biology and meteorology for application in venues with boundaries defined by human values and economics. Before aquatic plant control activities are initiated, one of the first and most important steps is to identify the various uses and functions of the water body. Identifying uses clarifies environmental and economic values of the water body that may be at risk. It also helps in selecting management tools and strategies that are compatible with, and will help to conserve, the various uses and functions of the water body.

After the uses and functions are identified, a management objective must be developed for the water body that considers

these uses as well as concerns of the various stakeholders with interests in the water body. Management objectives are fairly straightforward for waters with relatively few uses or an emergency plant problem. Conflicts in developing objectives arise more frequently when there are many shared uses, multiple stakeholder groups, and an unclear vision if plants, that currently may be enhancing an identified use, may in time impair this or other uses. After management objectives are developed, managers must list all of the potential control tools and select the best tool or combinations that will achieve the stated objective.

There are direct and indirect environmental and economic costs associated with aquatic plant management activities. Responsible resource managers must understand these consequences and choose options that are proven effective and compatible with the current conditions at the site of interest. This information can be obtained through peer-reviewed literature, from direct experience, or through consulting with reliable sources with successful experiences controlling similar plant problems under similar conditions.

Table 1 lists various parameters to consider in developing an aquatic plant control

program. Many of these considerations or constraints may influence both the scope of the program and the level of control achieved. While immediate and complete removal of a plant problem may be a desired goal or outcome, in practice, the control process may take months and may be temporary in nature; and therefore, will need to be repeated on a routine basis. Water body and plant conditions are constantly changing as are tools available to manage plants. Rarely can one person keep track of all of these changes or become an expert in each control tool; therefore, except for the most basic control situations, aquatic plant management experts should be consulted and stakeholders informed about impending aquatic plant control operations. Paramount in this communication is conveying to the non-technical stakeholder why particular methods were chosen and what are the anticipated or expected outcomes of selected (and perhaps rejected) control options, and a receptiveness of stakeholders to respect the multiple uses and functions that may be associated with each water body and to review control tools and options based on their potential for achieving management objectives rather than from a personal preference or bias.

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Parameter	Consideration/Constraint	Influence	Plant type
<b>Water uses and functions</b>	identify uses, values or functions of each water body to determine which if any may be at risk from invasive aquatic plants or nuisance growths of native and non-native plants - control tools and management strategies must be compatible with water body uses - water uses and conditions change and must be considered during the planning for each control operation	the uses of each water body must be identified and prioritized in order to develop management objectives - management objectives and water uses influence the tools and strategies best suited for aquatic plant control which in turn influence the spatial extent and duration of control	E = emergent S = submersed F = floating  Plant types are listed if their control is a primary consideration or influenced by this control consideration
<b>Navigation and access</b>	river channels or boat ramps blocked, areas of lakes inaccessible	frequent inspections and rapid response are necessary to sustain commercial navigation in rivers and canals - frequent inspections and control as necessary to conserve recreational access and navigation	E, S, F
<b>Transportation</b>	floating plant masses jam against bridges and may cause structural damage or erosion around pilings	frequent inspections and rapid response are necessary to prevent damage associated with aquatic vegetation, especially tussocks and floating islands	E, S, F
<b>Flood control</b>	plant masses can block or impede water flow in river channels, canals, lake outfalls, or flood control structures	frequent inspections and control of invasive plants that may impact flood control to the lowest feasible level - control native and non-invasive plants as necessary to conserve flood control	E, S, F
<b>Potable water</b>	plants clog water intakes	frequent inspections and control of plants as necessary to prevent disruption of water supply - herbicides must have potable water tolerance, set-back distance, or concentration limit	S, F
<b>Irrigation</b>	plants clog water intakes, impede water flow in ditches, canals, and rivers	ensure herbicides are compatible with irrigated crops, may need to treat when crops not in field, find alternate irrigation supply -notify homeowners of any lawn or ornamental plant watering restrictions after herbicide use	E, S, F
<b>Livestock watering</b>	plants do not usually impact ability for watering livestock from water bodies	if herbicides used, may need to remove livestock from water body shoreline, find alternate watering source	E, S, F
<b>Downstream uses and needs</b>	plant masses prevent water releases for downstream uses like drinking, irrigation, wetland restoration, estuaries	control plants to provide downstream water - herbicides must be compatible with downstream uses - coordinate control with water releases - frequent releases may dilute or draw off herbicide concentrations	E, S, F
<b>Recreation</b>	identify and assess recreational uses within the system	aquatic plants may enhance or hinder recreational activities within a water body that may be seasonal or year-round	
Boating	plants can restrict access and boating activities	select control methods and frequency to accommodate types and amounts of boating - inboard/outboard motor, sailing, canoe/kayak, rowing shell, etc.	E, S, F
Fishing	plants can block access to fishing areas - plants provide habitat to support fisheries but at high densities and cover can impair fish and wildlife habitat	manage invasive plants to conserve or enhance native plants - select herbicides that are compatible with fishery – try to time control to minimize impacts with bedding and increased activities like tournaments, weekends, holidays, etc.	E, S, F
Hunting	plants can block access to hunting areas - plants provide habitat and food source, especially for some waterfowl	manage invasive plants to conserve or enhance native plant habitat - plan control to minimize impacts with hunting	E, S, F
Swimming	plants can cover swimming areas, increase danger of entanglement and drowning	select control method compatible with swimming or control during low or no swimming periods	E, S, F
Skiing	plants can impede boat operation and increase danger of entanglement and drowning	keep designated ski / boating areas free of aquatic plants	S, F
Wildlife viewing	plants can block access to wildlife viewing areas and view of wildlife	work with wildlife management agencies to ensure access to wildlife areas is acceptable - keep designated areas open for boat access	E, S, F
<b>Fish and wildlife management</b>	identify and assess wildlife uses and needs within the system - while moderate levels of plants may provide essential habitat or forage, too many plants may cover nesting, bedding and forage areas	aquatic plants and control operations may enhance or hinder wildlife management activities within a water body that may be seasonal or year round	



Endangered species, including habitat and forage/prey	plants may provide essential habitat for endangered species - conversely, plants can cover nesting, bedding and forage sites as well as impair habitat for forage animals - ex: in Florida, waterhyacinth may outcompete native plants essential for Everglades Kite nesting as well as cover their prey (apple snails) causing them to abandon nests	understand types and seasonality of endangered species as well as forage/prey habitat requirements, select control tools and timing compatible with endangered species	E, S, F
Fishery	moderate levels of diverse plant communities are generally viewed as favorable for many sport fish populations - monocultures of nuisance or invasive plants can crowd out beneficial native plants, cover bedding sites, stunt or eliminate some fish populations, reduce dissolved oxygen leading to fish kills	select control methods compatible with fish management objectives for water body - ex: do not drawdown during spawn; repeated harvesting may reduce young of year sport fish, ensure herbicide is compatible with primary fish management objective, avoid formation of extensive surface mats of submersed or floating plants and large submersed plant treatments with contact-type herbicides during hot water/low oxygen periods	E, S, F
Waterfowl hunting	plant monocultures can crowd out or cover beneficial native plants	if possible, control plants well in advance of or after hunting season	E, S, F
Non-game wildlife	plant monocultures can crowd out or cover beneficial native plants or cover nesting and foraging sites	identify areas or species of concern with wildlife management agency and select control tools and timing compatible with non-game species managed in the water body	E, S, F
Habitat	plant monocultures can crowd out or cover beneficial native plants	control invasive or nuisance plant populations to conserve or enhance diverse beneficial native plant assemblages	E, S, F
Nesting / foraging	plant monocultures can cover fish bedding sites, interfere with rookeries, cover or exclude prey or forage animals and plants	control invasive or nuisance plant populations to conserve nesting and foraging sites, ensure control tools are compatible with important forage plants and animals	E, S, F
Vegetation planting project	invasive and nuisance plant growth can cover or crowd out newly planted vegetation	prevent invasive or nuisance plants from covering revegetation projects, select control tools and timing that are compatible with planted species	E, S, F
<b>Mosquito control</b>	invasive floating plants and surface mats of submersed plants are ideal mosquito breeding sites	control invasive and nuisance plant mats, especially in quiescent waters in urban areas to reduce mosquito habitat	S, F
<b>Control feasibility</b>	various parameters influence whether or not a plant can be effectively controlled including; available tools, water body physical and chemical conditions, and plant susceptibility and growth stage	list and consider all control tools that have been proven successful in the water body in question or in similar waters and conditions - integrate the best tool or tools compatible with water body uses, functions, and conditions, that meet management objectives into the control program	
<b>Potential for control</b>			
Available methods	list all plant control tools that have been demonstrated effective in controlling plant(s) in question - demonstrated through documentation, contact with experienced managers that have effectively applied that control strategy	integrate tools into control plan that have been demonstrated to be effective - if tool is new, unproven, experimental, etc., approach implementation as operational research and convey to stakeholders the level of control anticipated and level of confidence in achieving control	E, S, F
Biological	usually refers to releasing an animal species including fish, arthropods, or pathogens to suppress or control target aquatic plants to some extent	effectiveness may vary from suppression to complete control so target plant susceptibility and management objectives must be clearly evaluated and conveyed to stakeholders	E, S, F
Fish – grass carp	generalist feeder that may control target and non-target plants - prefer some plant species over others - sterile, triploid chromosome variety available - mobile river fish that may need to be contained with physical or electric barrier - may control plants for up to a decade - may require permit from fish and game agency - extremely difficult to remove and determine population size in system after stocked (easier to add more if needed than to remove after stocking)	test to ensure that only sterile triploid carp are released - ensure target plant is susceptible to grass carp, stock at the lowest feasible level - consider controlling target plants with other methods first to reduce biomass - install containment strategy - identify non-target susceptible plants - develop integrated strategy to augment control - stock 10"-12" fish in cooler months to reduce losses from predation, heat stress, and low dissolved oxygen - stocking rate can change significantly, ex: if water levels increase or decrease after stocking or sudden natural declines in vegetation (shading, etc.) can cause "overstocked" situation	S, F
Arthropods	most classical biological control is conducted with insects - agents must be approved by the USDA as well as state regulatory agencies prior to release to ensure host specificity - agents may reproduce in self-sustaining populations or may need additional releases to sustain sufficient levels to suppress or control plants	impacts from insects may range from no observable control to decimation of target plant depending on insect species, plant type and climate at release site - predation from native animals (birds, fish, wasps, etc.) may influence the biocontrol population size and therefore the level of stress, suppression, or control achieved	E, S, F
Pathogens	some plant pathogens, especially fungi can stress aquatic plants - commercially available pathogens (bioherbicides) are under research evaluation	naturally occurring outbreaks may increase efficacy of herbicide treatments, ex: water hyacinth control in some Florida waters	E, S, F

Chemical herbicides	chemical herbicides must be registered for aquatic use by the USEPA and state regulatory agency - permits may be required from state or local governments before using registered herbicides	sites and maximum rates are regulated by the federal and state label - susceptible plant species and lower than maximum use rates are determined through laboratory and operational research	E, S, F
Contact/systemic	herbicides fall into two general categories, faster acting contact type herbicides that kill the portion of the plant to which they are applied, and slower acting systemic type herbicides that translocate within the plant killing the entire plant including the roots	faster acting or contact type herbicides may be more conducive to controlling submersed plants in flowing waters - slower systemic herbicides may be more suited to large-scale treatments to minimize oxygen consumption during plant decomposition	E, S, F
Liquid/pellet formulation	herbicide formulations fall into two basic formulations; liquid or aqueous, and solid pellets, flakes, wettable powders, or granules	liquid formulations are usually less expensive and are a better choice in waters with thick soft sediments where pellets can sink, diminishing effectiveness - pellets applied in slow flowing waters with firm substrates sustain prescribed concentrations for longer periods	E, S, F
Plant growth regulators	PGRs do not kill, but rather suppress growth of target aquatic plant	herbicides at low rates may provide some plant growth regulation - may lead to increased resistance in plants if not killed - application of this control strategy not well developed	S
Mechanical			
Harvester	removal of plant mass from water body - may control non-target plants and animals - various designs, sizes, and hauling capacity available - may provide immediate control of small scale plant problems	may fragment and spread target plant - must find disposal sites - removes target and non-target plants and animals - more efficient harvesters may harvest larger fish and wildlife that cannot escape path - efficiency may be increased with barges to shuttle plants to disposal site - may create turbidity in shallow waters	E, S, F
Barge mounted hoe/dragline	removal of dense mats of plants and floating islands	removes dense masses of vegetation and other material from canals and river channels as well as bridges and flood control structures - may fragment and spread target plant - must find disposal sites - may remove target and non-target plants and animals	E, S, F
Shredder	various designs are available to shred floating masses of herbaceous and woody plants and floating masses or islands of sediments	used for emergency restoration of access, navigation, or flood control attributes as well as around bridges - generates fragments that may spread invasive plants - controls all plants and animals in control area - may require additional shredding or harvesting of materials that float back to the surface - may generate temporary turbidity in immediate control area - drops mater on bottom - not advisable for repeated use at boat ramps, navigation channels, residential shorelines, etc.	E, S, F
Rotovator	underwater apparatus or arm extending from barge with rotating tines to tear plants from sediments	generates fragments and may spread invasive plant infestation - may need to harvest uprooted plants - disturbs sediments and may generate turbidity	E, S
Cultural/Physical			
Barriers	passive devices to cover target plants, or to contain plant fragments, turbidity, herbicide-treated water - may be highly labor intensive to install/remove	may be used in small areas where other options are less practical	E, S
Benthic	fabric laid over plants on substrate - must anchor to bottom - place over live plants or control plants to substrate and place barrier to control re-growth	evaluate potential impacts to target and non-target plants and animals - may need to clean barrier to prevent plant growth on top	E, S
Curtains	vertical barrier in the water column to minimize water exchange from one site to another - can either be manufactured curtain to prevent water exchange to contain herbicides, or a strip of plants left on the edge of harvest or shredding sites to contain fragments or turbidity	prevent or reduce herbicide dilution and turbidity in flowing or open waters	E, S
Benthic rollers	device usually anchored to a piling or dock to roll over plants and sediments	may be effective on small scale - needs power source and frequent monitoring	E, S
Drawdown	water control structure must be available - reducing water levels to accommodate aquatic plant control must be compatible with other uses and functions of the water body - consider ability to refill water body after drawdown	drawdowns need to last for several months - must be complete to desiccate plants - best applied in winter to include impacts from freezing - compatible with prescribed fire for emergent plant control - try to avoid during fish spawn, waterfowl hunting, endangered species nesting foraging - partial drawdowns during growing season may allow invasive or nuisance submersed plants to colonize into deeper waters expanding the problem - incomplete drawdowns may allow wetland plants like cattail or willow to reach nuisance levels	E, S, F



Desiccation	extreme drawdown must be of sufficient duration to dry target plants and preferably sediments - not appropriate during wet or growing season	plants that produce underground tubers (hydrilla) or extensive seed bank (water hyacinth) are not well suited to control by drawdown - floating islands may develop upon re-flooding and may need to be controlled	E, S, F
Freezing	freezing enhances desiccation and amount of control	drawdown needs to expose sediment to reduce insulating effect from water - conversely, summer drawdowns can increase spread of invasive (torpedograss) or native plants (willow) can expand to nuisance levels	E, S, F
Prescribed fire	planned burning of emergent vegetation to reduce standing crop - burning must be compatible with surrounding land use	reduces standing crop and stimulates re-growth in some species - be prepared to follow up with other methods including herbicides upon re-flooding - may not be practical in urban areas or near high traffic highways	E
Flooding	flush floating plants or mats of plants out of system or into upland areas, - increase water level to shade and stress submersed plants	raising the water level to flush and strand floating plants or mats of plants into uplands is an option in waters with flood control structure and few to no houses or structures along shoreline - other flooding methods include lowering water levels to treat submersed plants, then re-flooding to reduce light and further stress plants - some emergent plants (torpedograss) can be controlled by dewatering, burning, and re-flooding to suppress re-growth	E, S, F
Dredge – barge mounted	large-scale dredging operation that removes rooted plants and sediments - sediments returned to water column or pumped to settling basin	may miss plants - may fragment and spread plants - may increase turbidity	S
Dredge – diver assisted	hand-held suction device controlled by underwater diver using snorkel or SCUBA - dislodge plants by hand and place into suction lift to screen plants onshore or on attending barge	labor intensive - effective in small areas where other methods are not practical - may cause or may be impeded by siltation / turbidity	S
Dyes	artificial dyes like natural tannins color water, reducing light penetration to control or suppress submersed plant growth	may provide submersed plant and algae suppression in small areas where water flow, volume, and exchange are low	S
Hand pulling	removing plants by hand - includes tossing rakes or hand-held cutting blades to shear plants	immediate control - labor intensive - may be suitable for new infestations around boat ramps, docks, trash rakes at water intakes, pumps, etc. - may use rakes and cutting blades to clear small areas of plant material - creates fragments that may spread plants to other areas	E, S, F
Shearing - chains, etc.	includes any of a number of devices that are dragged through rooted stands of plants including chains pulled by hand or steel bars towed by boat or barge	labor intensive - disturbs sediments - creates fragments and turbidity - may need to clear obstructions - used in some canal systems where most plants may be considered undesirable and substrate habitat is a low concern	E, S
<b>Waterbody parameters</b>			
<b>Hydrology</b>			
Water depth	water depth can influence the cost and duration of control - water control structures can give the flexibility of reducing and increasing water depths to accommodate control	re-growth of submersed plants to the surface is faster in shallow waters - do control costs, methods, etc. warrant short term control? - control of submersed plants with herbicides requires treating much or all of the water column - shallow water should be less costly to treat than deep water - increasing the water depth after a submersed plant herbicide treatment reduces light penetration enhancing the amount and duration of control	E, S
Water volume	important for herbicide control since effectiveness of many herbicides is dependent upon sustaining a prescribed concentration	reducing water volumes before herbicide treatments for submersed plant control can save money and increase efficacy - increasing water volume before use of herbicides to control submersed plants can dilute concentration and reduce or negate control efficacy	S
Water flow	static vs. moving water can play an important role in selecting control methods	important in determining pelletized vs. liquid formulation herbicides - dilution from flow may be too great to apply herbicides, especially slow acting systemic compounds - flow may dictate urgency of control, ex: to keep floating plants from clogging flood control structures or jamming against bridges - keeping flow unimpeded may impact ability to contain grass carp with conventional physical barrier	S, F
Springs / sinkholes	related to flow	groundwater may dilute or dissipate herbicides	S

Tidal influence	tides can raise or lower water levels and volumes, can flush herbicides, and regulate plant growth	may dilute herbicide concentrations by adding water volume at high tide or flush herbicides out of treatment area as tide recedes - depending on salt content, may preclude use of some herbicides not registered for use in brackish or marine waters - may restrict access for herbicide spray boats, harvesters, barges, etc. due to low (grounding) or high (bridge clearance) water level - invasive plants may not reach problem level if salt content sufficiently high - ex: hydrilla in brackish water - may favor invasive species tolerant to low salinities - ex: Eurasian watermilfoil	S
<b>Water chemistry</b>			
Dissolved oxygen	oxygen is needed to sustain aquatic life and decompose organic sediments and detritus - warmer water holds less dissolved oxygen than cooler water	check oxygen level prior to herbicide use - slow acting or systemic herbicides or treating smaller areas with contact type herbicides can reduce amount of plant decomposition and demand on oxygen to avoid stressing or killing fish - try to conduct large-scale plant management in cooler months before plants reach peak biomass (more oxygen / less decomposition)	S, F
pH, alkalinity, and hardness	these parameters may be important in determining invasiveness of plants in certain waters - ex: water hyacinth and hydrilla do not grow as well in low pH waters - pH, alkalinity, and hardness modify performance of certain herbicides	low alkalinity and pH increase copper toxicity to fish - high pH decreases efficacy of flumioxazin herbicide for submersed plant control - hard water binds with glyphosate and reduces efficacy	S
Nutrient content	nutrient content in aquatic macrophytes and in the sediments may be re-suspended in the water column after controlling aquatic plants - nutrients are released from decomposing plants and in shallow waters, sediments may be stirred by waves and water currents	nutrient content may be a concern when planning large-scale management - some nutrients are released by decomposing plants - removing plants from the system to remove nutrients may not be cost-effective since aquatic plants are mostly water - sediment nutrient re-suspension may be significant after the calming effects of plant cover is removed	S, F
<b>Water transparency</b>			
Color / tannic content	highly colored or tannic water limits light penetration and can suppress submersed plant growth	generally, submersed plants grow faster in waters with higher transparency with all other factors being equal - conversely, lower transparency can retard growth of submersed plant shoots	S
Turbidity / suspended particles	turbid water limits light and suppresses submersed plant growth	submersed plant recovery after control can be retarded in highly colored or tannic waters - anticipate increased submersed plant control duration	S
Algal type and concentration	some algal blooms can suppress submersed plant growth either through light attenuation or perhaps allelopathy with blue-green blooms	submersed plant recovery after control may be retarded in highly turbid waters - suspended clays and organics can neutralize diquat and fluridone herbicides	S
<b>Sediment characteristics</b>			
Composition - sand, clay, organics	sediment type plays an important role in plant growth as well as control, especially chemical options	treating large areas of submersed plants during a planktonic algae bloom may perpetuate or enhance the bloom	S
Sediment depth / location	check sediment type and thickness prior to herbicide treatments	clay sediments inactivate diquat herbicide, high levels of organic sediments can adsorb fluridone herbicide	S
Potential for re-suspension	extensive plant cover, especially submersed plants, can retard organic sediment decomposition or allow suspended particles to settle out of flowing water forming thick flocculent layer	thick soft sediment layers can reduce or negate pelletized herbicide formulation efficacy - harvesting in shallow waters above flocculent sediments may result in turbidity problems	S
<b>Plant physiology</b>			
Plant origin/growth characteristics	problem plants in a proposed control area should be characterized as native or exotic, and if exotic, they should be characterized as either a nuisance under the conditions present in the water body, or an invasive species in that region	diquat herbicide is inactivated by suspended clay particles - high suspended organic particle content can reduce fluridone herbicide efficacy - removing calming effect of plants (after control) may allow water flow or waves to agitate sediments, especially in shallow waters, re-suspending sediments and associated nutrients - result may be increased turbidity or algae bloom - agitation from harvester paddle wheels can increase turbidity in shallow waters with flocculent sediments	S
<b>Plant physiology</b>			
Plant origin/growth characteristics	problem plants in a proposed control area should be characterized as native or exotic, and if exotic, they should be characterized as either a nuisance under the conditions present in the water body, or an invasive species in that region	the invasiveness and extent of the plant in the region influences the intensity of control - ex: a newly discovered plant that may be invasive in waters across the region may trigger eradication efforts - a native plant that interferes with boat ramp access may be beneficial throughout the rest of the water body triggering only local control	E, S, F



Native plant	a plant species that evolved in the general region where it is now found	a diverse assemblage of native plants is generally viewed as favorable - native plants do not generally impair natural waters, they may present problems to various uses and functions of the water body on a local scale - problems associated with native plants are often generated by watershed alterations including stabilized water levels and increased nutrient content - plants native to a region can cause problems in man-made waters like shallow canals or aqueducts where presence of any plant species may be considered undesirable or problematic	E, S, F
Exotic / alien	a plant that has been transported to a region in which it did not evolve	exotic plants do not necessarily cause problems in the ecosystems in which they have been introduced - causes of problems may be similar to those associated with native plants and therefore may be localized	E, S, F
Invasive	a plant that is non-native to the ecosystem under consideration and whose introduction causes or is likely to cause economic or environmental harm or harm to human health – even if an invasive plant species does not cause problems in one waterbody, it may serve as a contamination source for adjacent waters that may be more conducive to invasion	newly discovered populations of invasive plants should be considered for eradication or containment - delays may allow spread within infested waters or to additional waters - invasive plants may not be invasive in all cases - ex: water milfoil may cause problems in clear, shallow, stabilized waters, but may not be problematic in deep or turbid lakes or reservoirs with widely fluctuating water levels	E, S, F
Plant growth stage	plants are susceptible to various control methods based on current weather and growth conditions	most herbicides need actively growing plants to be effective - new growth is generally easier to control with herbicides than mature plants with high starch reserves and larger rhizome / root mass	E, S, F
Target plant / non-target	it is important to understand the growth stage of target plants as well as commingled non-target plants	consider cost-effective control measures that selectively control target plants while conserving or enhancing non-target species - evaluate cost-effectiveness of proposed control - ex: controlling a new infestation of hydrilla or Eurasian watermilfoil in two feet of water in an attempt to eradicate may be cost-effective - controlling widely dispersed and established hydrilla in two feet of water where re-growth to the surface may take 1-2 months may not be cost-effective management	E, S, F
Plant susceptibility	plants must be susceptible to control tools to avoid wasting valuable time and money	evaluate effectiveness of control tools through literature reviews or contact with managers with similar problems and conditions - plant susceptibility may change from one control event to the next related to such parameters as plant growth stage or water conditions	E, S, F
Target plant / non-target	prior to initiating aquatic plant control in systems where a diverse native plant community is desired, it is important to identify non-target plants to develop control programs that conserve or enhance these species	impacts to non-target plants can be reduced through selection of control methods, timing of control, using lowest feasible herbicide rates, and controlling target plants, especially invasive plants, before they become widespread and require large-scale control efforts - ex: stocking sterile grass carp early after an infestation of susceptible plants or reducing plant biomass prior to stocking allows the lowest number of fish to be released lessening non-target plant control	E, S, F
Potential for re-growth			E, S, F
Target / non-target	control operations may be expensive - evaluate the potential for re-growth for proposed control methods or strategies	consider cost-effective control measures that selectively control target plants while conserving or enhancing non-target species - evaluate cost-effectiveness of proposed control - ex: controlling a new infestation of hydrilla or Eurasian watermilfoil in two feet of water in an attempt to eradicate may be cost-effective - controlling widely dispersed and established hydrilla or EWM in two feet of water where re-growth to the surface may take 1-2 months may not be cost-effective management	E, S, F
<b>Climate</b>			
Weather	daily weather conditions	rain may wash off herbicides before they are effective - treat early in day during summer months in thunderstorm prone areas - check weather report prior to herbicide applications for wind and rain forecast - several cloudy or rainy days after a large submersed plant treatment with contact herbicides may result in substantial dissolved oxygen reductions	E, F, S
	seasonal weather conditions	use caution applying systemic herbicides requiring 2-3 months of contact in areas impacted by tropical or seasonal monsoonal weather - take advantage of winter dieback by controlling plants before they become a problem in spring or summer	S

Light intensity	an important plant growth factor along with temperature	some herbicides' primary breakdown pathway is via photolysis; efficacy may be reduced in the summer or in shallow clear waters - consider with water transparency for predicting submersed plant growth along with herbicide selection and treatment timing - light intensity triggers tuber production in hydrilla	S
Water temperature	temperature influences plant growth and the amount of dissolved oxygen in the water column as well as microbial activity important for decomposing plant material and degrading some herbicide compounds	warming winter and spring temperatures can trigger plant growth, important for herbicide uptake especially in submersed plants - warmer water holds less dissolved oxygen than cooler; important for planning size of herbicide treatment and mode of action (fast acting contact vs. slower systemic)	S, F
Other considerations	in addition to physical parameters, there are human values to consider when deciding the level of aquatic plant control to attempt on a water body	these influences do not necessarily reflect the level of control that may be achieved, but rather the will of stakeholders to commit to attempting some level of control effort	
Cost	value judgment - does the anticipated outcome of controlling or not controlling plants justify expenditure?	the benefits of control must justify control expenditures - control must meet reasonable management objectives, including duration of control, restore or conserve uses and functions of water body, protect public health and safety, etc.	E, S, F
Anticipated amount of control	aquatic plant control is complex and many stakeholders have a rudimentary understanding of available tools and realistic control expectations - the public usually expects control to resolve impaired uses or functions of water bodies - responsible aquatic plant managers and researchers must clearly convey to stakeholders why they select or support control options as well as the anticipated amount and duration of control	management objectives should address anticipated extent of control - control includes the level of impact to the standing crop as well as underground roots, rhizomes, tubers etc. that influence ability of the plant to recover; therefore, control also includes the degree of impact to the problem-causing plant, the time to alleviate impaired uses, and the expected amount of time control will last; i.e. time until water uses may again be impaired	E, S, F

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Spatial – acres, % of water column	control area includes the coverage of plants to be controlled, expressed in acreage, square meters, etc. - also includes the percent of the water column in which plants are controlled, expressed as percent volume infested - can also include the below ground portion controlled (runners, roots, corms, tubers, etc.)	control using different tools or applied to different plant species provides variable results - managers must select tools that provide a level of control that satisfies management objectives and convey this reasoning or expectations to stakeholders	E, S, F
<b>Duration</b>			
Time to achieve control	depending on the method(s), the amount of time to achieve control may be immediate or may take months or longer, if achieved at all	control methods may provide immediate relief of a problem (ex: harvesting adjacent to flood control structures or bridge pilings) or take months (ex: systemic herbicides, biological controls)	E, S, F
Length of control in time	the applied control method(s) as well as environmental parameters impact the duration of control achieved - ex: control may be achieved in a matter of a few days to a few weeks, but plants may re-grow to problem levels within a month	control may last a few days to several years depending on method and water body conditions - ex: a summer contact type herbicide treatment of hydrilla or torpedograss growing in 1-2ft of water may only last a few weeks before plants refill the water column while a winter fluridone treatment in 12-15 feet of water may prevent hydrilla from growing back to the water surface for 18-24 months	E, S, F
Suppression	includes reducing plant vigor as well as flowering, seed production	many biological controls as well as plant growth regulators stress plants but by themselves may not provide a level of control that meets management objectives or stakeholder expectations	E, S, F
<b>Water body values at risk</b>	assess various uses of water bodies and estimate economic and environmental costs as well as impacts to human health if plants are controlled or not controlled	assists in establishing management objectives as well as level of control and choosing control options	E, S, F
<b>Alternative water body</b>	if plant control cannot be achieved in a water body, identify any alternative waters to serve the uses and functions	this is a temporary solution while eradication or management efforts are being devised or applied in a water body - access to the infested water body may be closed during eradication efforts or control delayed in infested waters while higher priority waters are managed, especially if other nearby waters are available - efforts should be made to resume use of water body as soon as possible	E, S, F
<b>Contractor / equipment availability</b>	ensure availability of contractor and equipment to address all anticipated control possibilities	have back-up labor and equipment contractors available - securing contracts can take time which may be critical for eradication or in emergency situations – large-scale control operations or operations in waters with multiple uses and functions may have very narrow windows of opportunity to implement	E, S, F
<b>Control history in similar waters</b>	apply control tools or management strategies with proven or demonstrated effectiveness and compatibility with uses and functions of system	monitor efficacy of each control event - determine causes of poor or no control and avoid repeating - for new infestations look to successes or failures with various control options in waters as similar as possible to proposed control site	E, S, F
<b>Coordinate with stakeholders</b>	control operations should be developed with stakeholders that have expressed interest in understanding the intricacies of aquatic plant control - the public should be notified through some means of any use restriction of impending herbicide control operations	stakeholders may view aquatic plant control and control tools from a single or less than holistic perspective - education and outreach efforts are important in addressing public concerns	E, S, F
<b>Support – verbal, financial, in-kind</b>	important tiebreaker for waters of equal importance when factors such as funding, technology, contractor availability, or cost/benefit ratios are insufficient to implement control projects in all water bodies - especially for lower priority uses or waters	work with all stakeholders to clarify management objectives - in low priority management waters, if support is high, then elevate to higher priority than equal priority waters where support is low or stakeholders oppose control	E, S, F
Public	level of verbal support from homeowner or public or private stakeholders or associations	for equally ranked control project priorities, public support may elevate control projects, especially above projects where there is no support or open stakeholder opposition to control	E, S, F
Agency – federal, state, local	level of verbal, financial, or in-kind service support for controlling aquatic plants	external funding or services may elevate a control project to a higher priority above otherwise equally evaluated projects with no external assistance	E, S, F

# Native *Bacopa* Species in Florida



Figure 1. *Bacopa caroliniana* covered in periphyton at Florida Panther National Wildlife Refuge, Naples, FL. Photo by Karen Villazon.

**Kathryn Villazon**  
University of Florida

There are approximately 100 known species of *Bacopa* in the world, of which 18 exist in the United States according to the USDA. This genus is found mostly in tropical and subtropical regions. *Bacopa* is an aquatic plant which serves as food, habitat and protection for many fish and invertebrate species. Extensive research has been performed on the genus *Bacopa*. For medicinal purposes, *Bacopa* can enhance the body's antioxidant defenses, decreases anxiety, protects gastrointestinal health, and can improve the preservation of new information for amnesiac people. There are three known species of *Bacopa* native to Florida: *Bacopa caroliniana* (Walt.) Robins. (Blue hyssop or Lemon Bacopa), *Bacopa monnieri* (L.) Pennell (Coastal water hyssop), and *Bacopa innominata* (Gómez Maza) Alain. (Nameless water hyssop).

The genus *Bacopa* was transferred into the Plantaginaceae (Plantain family) from the Scrophulariaceae (Figwort family) as a result of differences in genetic coding and floral and foliar morphological characteristics. Similar characteristics among the three species of *Bacopa* include: mat-

forming growth habit, submersed and emergent plant parts, and the requirement of moist soil for growth (obligate wetland species according to Florida DEP).

One characteristic that distinguishes *Bacopa caroliniana* (Figure 1) from the

“There are three known species of *Bacopa* native to Florida: *Bacopa caroliniana* (Walt.) Robins. (Blue hyssop or Lemon Bacopa), *Bacopa monnieri* (L.) Pennell (Coastal water hyssop), and *Bacopa innominata* (Gómez Maza) Alain. (Nameless water hyssop).”

other *Bacopa* spp. is its pungent lemon aroma, hence its common name, lemon bacopa. When the leaves are crushed, a strong lemon-scented aroma is always pro-

duced from *B. caroliniana*. *B. caroliniana* is a perennial species. It has a bright blue flower with four stamens and can produce flowers throughout the year. It is found in at least 102 lakes throughout Florida and does not seem to occur in any specific watersheds, therefore it is a generalist. It apparently can grow in a wide range of soil and water conditions. The flowers are subtended by two linear green bracts, are solitary, and sit on short stems which are 3-15 mm long. The leaves are opposite, simple, deltoid to obelliptic with an acute apex, clasping, reddish-brown to lime green with an undulating margin, 10-30 mm long and 7-15 mm wide. The leaves can either be submersed or emergent. The fruit is a capsule with minute seeds covered by the sepals. It can reproduce both sexually (by seeds) and asexually (fragments).

Although *B. caroliniana* is a mat-forming, repent grower, it usually poses few problems to boaters or other recreational activities. However, in south Florida, it has been reported that pH ranges from 6 to 9 encourage this species to grow out of control and recent reports indicate some waterways in north Florida are also producing prolific growth. Although, *B. caroliniana* acts as a niche for many invertebrates as well as forage for water fowl, most commonly it is found at the edges



and shallow water of ponds, streams, and swamps. This species is usually grown in water gardens for both aesthetic and aromatic value.

*Bacopa monnieri* is a creeping perennial with smooth, glabrous stems and often white, solitary flowers, but flower color can also be light purple to blue to light pink (Figure 2). The leaves are opposite, cuneate to elliptic-cuneate, clasping, light to dark green in color, and 7-15 mm long by 3-7 mm wide. A distinguishing characteristic of the leaves of *B. monnieri* is the single, more prominent midrib which is usually found on each leaf. The stems can reach up to 30 mm in length and contain white flowers with five green sepals. Unlike *B. caroliniana*, *B. monnieri* does not emit an aromatic scent when its leaves are crushed. Also, *B. monnieri* tends to grow in more alkaline, hard-water, eutrophic lakes.

*B. monnieri* has been extensively studied for both medicinal and heavy-metal absorption properties. Over a 15 day period, *B. monnieri* can absorb greater than 90% of copper accumulated in the soil and water column and can also reduce cadmium, chromium, manganese, zinc and lead concentrations in a body of water. Mercury is also absorbed by *B. monnieri* and maximum mercury concentrations occur in its roots. This *Bacopa* species is also used for medicinal purposes for treatment of insanity, epilepsy, nerve tonic, cardiogenic, and as a diuretic. *B. monnieri* is commonly found on sandy shores of rivers and ponds and also grows in areas of tidal influence near the coast.

*Bacopa innominata* is rarely found in Florida and is in fact listed as a threatened species. It is a multi-stemmed, much-branched low growing perennial. The



Figure 2. *Bacopa monnieri* flowers and stamens, leaves, and growth habit.

leaves are oval to rounded-ovate and approximately 0.5-1.3 cm long with very fine pubescence. The leaves are deltoid with the widest part of the leaf blade toward the clasping base. Flower stalks are also finely pubescent and approximately 2-8 mm long. The flowers are white with two stamens. *B. innominata* flowers during the summer and produces a fruit capsule that is 2-2.5 mm long. The seeds are dark brown. This species of *Bacopa* is rare and only found from Hillsborough County northward in Florida.

In summary, the three species of *Bacopa* native to Florida have several differ-

ent uses as well as distinguishing characteristics. *B. caroliniana* always produces a fragrant lemon aroma. *B. monnieri* has no fragrance and is used for medicinal purposes. *B. innominata* is scarcely found throughout Florida. These three species can add aesthetic value and even aromatic value to water gardens.

Refer to Table 1 for more information on the identifying characteristics of the three *Bacopa* species native to Florida.

For more information or a list of references, please contact Kathryn Villazon at email: villazon@ufl.edu.

**Table 1.** Identifying characteristics of the three native *Bacopa* species in Florida.

Species	Leaf shape	Leaf pubescence	Leaf color	Fruit type	Flower color
<i>B. caroliniana</i>	Simple, deltoid to obelliptic with an acute apex	yes	Reddish brown to lime green	Capsule: 4-5 mm long	Bright blue
<i>B. monnieri</i>	Cuneate to elliptic-cuneate	no	Light to dark green	Capsule: 4-5 mm long	Often white, can be light purple to blue to light pink
<i>B. innominata</i>	Oval or rounded-ovate	Finely pubescent	Light to dark green	Capsule: 2-2.5 mm long	white



Figure 1: Hydrilla and Hygrophila Demonstration Project Homepage

# Hydrilla and Hygrophila Demonstration Project Website

By Stacia Hetrick

Interested in controlling hydrilla and hygrophila? Want to learn more about the current research being done to find new and alternative methods to manage these troublesome weeds? Visit our newly updated website on the “Demonstration Project on Hydrilla and Hygrophila in the Upper Kissimmee Chain of Lakes” (Demonstration Project) at <http://plants.ifas.ufl.edu/osceola>.

The goal of this website is to keep stakeholders informed of the current demonstrations that are being conducted on hydrilla and hygrophila and to provide information about these weeds and the problems they cause. The website (Figure 1) is updated on

a continual basis so tracking the progress of the project is easy!

## Hydrilla and Hygrophila Demonstration Project

This website is just one component of the Demonstration Project that is being conducted by means of a \$2.881 million grant awarded to Osceola County, Florida by the Environmental Protection Agency (EPA). The purpose of the Demonstration Project is to discover new herbicides, develop new technology processes or practices, or a new combination of these for the purpose of providing more successful and cost effective ways to control hydrilla and hygrophila. Demonstrating the results of the project to

applicators, non-scientific public, government partners and other stakeholders is another important role of the project and the website is one of the many tools that we have developed in order to accomplish this task.

### The Problem:

“The Problem” page (Figure 2) provides basic information about hydrilla and hygrophila, such as how they got to Florida, what their impacts are, their management, and ways to stop their spread. View more at <http://plants.ifas.ufl.edu/osceola/about.html>.

### About the Projects:

Discover in-depth information about the



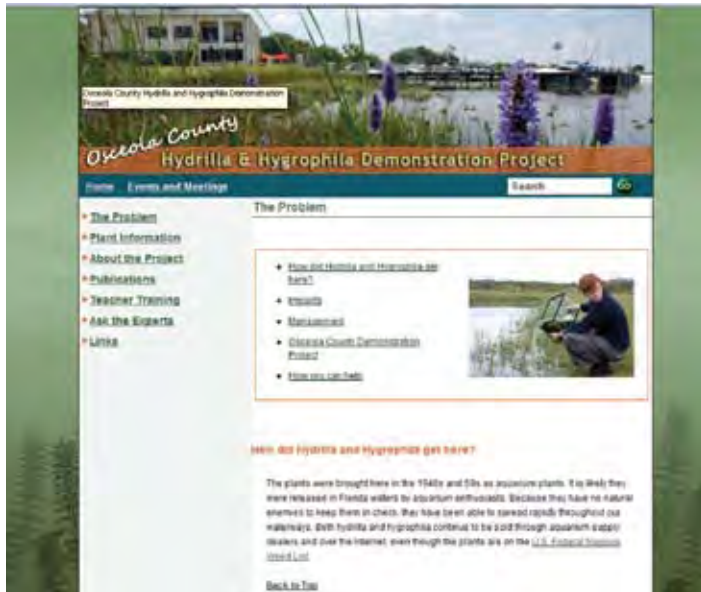


Figure 2: "The Problem" webpage that provides basic information about the plants.



Figure 3: Project Reports webpage.

Demonstration Project, including a description of the specific project components, on the "About the Project" page at [http://plants.ifas.ufl.edu/osceola/project\\_information.html](http://plants.ifas.ufl.edu/osceola/project_information.html).

#### *Project Reports:*

Find up-to-date information about the research being conducted in the "Project Reports" page (Figure 3) which posts quarterly reports on the website. In the first report for 2009, Dr. William A. Overholt of the University of Florida, Biological Control Research and Containment Laboratory, reported that "We are now convinced by our molecular genetic work that hydrilla is not native to Africa, as we had previously thought. The genetic studies clearly point to China as the center of origin." To read more about this discovery and other significant findings, check out the "Project Reports" page at [http://plants.ifas.ufl.edu/osceola/qtr/quarterly\\_reports.html](http://plants.ifas.ufl.edu/osceola/qtr/quarterly_reports.html).

#### *Ask the Experts:*

We have also included an "Ask the Experts" page which provides an introduction to the primary researchers involved in the Demonstration Project as well as their contact information. To view this page, go to <http://plants.ifas.ufl.edu/osceola/bios.html>.

#### *And There's More... :*

The website also provides access to numerous publications that have resulted from the Demonstration Project at <http://plants.ifas.ufl.edu/osceola/publications.html>. Upcoming events and meetings are

also posted, including the annual Demonstration Project Field Days that offer a chance to learn about the results of the project, take boat tours to the demonstration areas and talk to the researchers in person. To find out more about upcoming Field Days and other events and meetings related to this project, go to <http://plants.ifas.ufl.edu/osceola/events.html>.

For more information contact  
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## Editorial

In recent months Americans have experienced a period of dramatic change. Our FAPMS membership has also shown a desire for change by challenging some traditions within our organization. First, members voted by an overwhelming majority to change the society logo. Secondly, the Board voted to produce its trade magazine *Aquatics* in-house, through the use of volunteers, and to return all magazine revenue back to the Society. These changes were significant, as they modified the internal structure and appearance of our organization.

Board members embarked on the year 2009 and immediately faced a new challenge: developing new strategies to pass on information to FAPMS members in view of today's technologically advanced world. Printed newsletters and glossy magazines have fulfilled that duty in the past, however, information from FAPMS needs to spread faster and be more interactive for our organization to gain the interest of future aquatic plant managers.

FAPMS Board members recognize the need to improve the role of FAPMS as a society that provides pertinent and timely information for applicators and managers. Our unique organization

is but one participant in a long-line of professional organizations. What will set FAPMS apart in the future? Partnering with other professional organizations must be considered in order to provide a fundamentally useful society to all members. As an example, FAPMS exchanged website links with the Florida Stormwater Association (FSA), and now FSA members can use their internet webpage to contact FAPMS and gain information about exotic and native plants in their stormwater ponds.

Examine your role as a member and how you interact with FAPMS on a daily basis. Do you contact your Board members and ask questions? Do you visit the FAPMS website to get information? Or are you a member who uses one of the popular internet search engines to find what you need? If the FAPMS website is not fulfilling your immediate needs, please send me an email and let me know how we can improve the site to reach its full potential. In addition, if you have suggestions for improvements to our *Aquatics* Magazine I would encourage you to send them to me along with an informative article for future publications.

*Editor*



## Aquavine

### Final Rule on Aquatic Pesticides

On April 9, 2009, the Department of Justice (DOJ) chose not to seek rehearing on an opinion issued by the U.S. Court of Appeals for the 6th Circuit in *National Cotton Council v. EPA*. DOJ instead filed a motion to stay issuance of the Court's mandate for two years to provide EPA time to develop, propose and issue a final NPDES general permit for pesticide applications, for States to develop permits, and to provide outreach and education to the regulated community.

Reversing EPA's November 2006 *Aquatics* Pesticides rule, the 6th Circuit held that CWA permits are required for all biological pesticide applications and chemical pesticide applications that leave a residue in water when such applications are made in or over, including near, waters of the U.S. EPA estimates that the ruling will affect approximately 365,000 pesticide applicators that

perform 5.6 million pesticide applications annually.

EPA plans to work closely with states and the environmental and regulated communities in developing a general permit that is protective of the environment and public health. Visit the EPA website: <http://cf-pub.epa.gov/npdes/> for details.

### Calibration Challenge Winners

Congratulations to the winners of the "Calibration Challenge" printed in the Winter 2008 issue of *Aquatics* magazine (Vol. 30, No. 4). Craig Mallison won first place (\$75 gift certificate to Outback Steakhouse) by submitting the first set of correct answers, and Kenny Baker won second place (\$50 gift certificate to Outback Steakhouse) by submitting the fifth set of correct answers. Correct answers to the problems are provided below.

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32 ounces of non-ionic surfactant

0.06 ppm

51.2 ounces of herbicide

6.4 ounces of non-ionic surfactant

8.1 ounces/acre

1.9 gallons

2.3 tanks

46000 tons

2300 tons

Herbicide B

52.4 acres

20.9 acres

40%

5 mph

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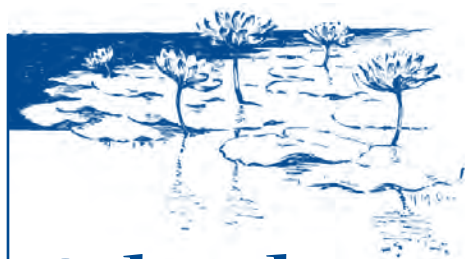
*Editor.*

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## Calendar

**July 12-15, 2009**

**Aquatic Plant Management  
Society 49th Annual Meeting**  
Milwaukee, WI  
<http://www.apms.org>

**Aug 12-14, 2009**

**SCAPMS Annual Conference**  
Clemson, SC  
[www.scapms.org](http://www.scapms.org)

**Aug 30-Sep 3, 2009**

**139th Annual Meeting of the  
American Fisheries Society**  
Nashville, TN  
[www.fisheries.org/afs09](http://www.fisheries.org/afs09)

**Sept 22-24, 2009.**

**Southeast Herbicide Applicator  
Conference.**  
Edgewater Beach Resort,  
Panama City Beach, FL.  
[www.conference.ifas.ufl.edu/sehac](http://www.conference.ifas.ufl.edu/sehac)

**October 12-15, 2009**

**33rd Annual FAPMS  
Training Conference**  
Daytona Beach, FL  
[www.fapms.org](http://www.fapms.org)

**Oct 13-15, 2009**

**MSAPMS Annual Conference**  
Lake Guntersville State Park  
Guntersville, AL  
[www.msapms.org](http://www.msapms.org)

# Too Many Weeds Spoil the Fishing



**Exotic invasive aquatic plants such as Hydrilla, Eurasian Water Milfoil, Curlyleaf Pondweed, Water Chestnut and Water Hyacinth can be detrimental to a healthy fishery in lakes across the country.**

These invasive plants when left unmanaged can alter the ecosystem of lakes and reservoirs, causing a decline in the fishery, as well as interfering with other valued uses of waterbodies.

## **The Authoritative Leader in Aquatic Habitat Management**

Successful aquatic habitat management is all about achieving a balance in the aquatic ecosystem. United Phosphorus, Inc. offers assistance and a full line of aquatic products for properly managing exotic and invasive plants and algae to achieve and maintain a healthy aquatic environment for native aquatic plants.

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**TO OBTAIN A COPY OF OUR VIDEO, *AQUATIC PLANT AND HABITAT MANAGEMENT*, CALL 1-866-287-9190**



**Aquathol® K and Aquathol® Super K Aquatic Herbicide**  
For selective control of Hydrilla, Curlyleaf Pondweed, Coontail and other Invasive and Nuisance aquatic plants.

**Hydrothol® 191 Aquatic Herbicide & Algicide**  
A broad-spectrum herbicide and algicide. Hydrothol® 191 provides a companion product or an alternative to copper algicides when controlling difficult algae species.



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WATCH**



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