Aquatic Vegetation Monitoring and Management of the Invasive Weed Hydrilla

Background Information

Because of its clear water, White Lake has always had a healthy population of native aquatic vegetation, and the abundance and distribution of vegetation has varied over time, as is the case in most shallow lakes.

In the late 1950s, the dominant genera (in order of abundance) were: Sagittaria (arrowhead), the filamentous green alga Spirogyra, Cabomba (fanwort), Utricularia (bladderwort) and Eleocharis (spikerush) (Tebo 1961).

Survey work in 1978-79 indicated that densities of vegetation varied noticeably in different regions of the lake, with the primary species being the bladderwort Utricularia and the spikerush Eleocharis, both of which are low-growing (1 to 8 inches in height) (Nichols, 1979).

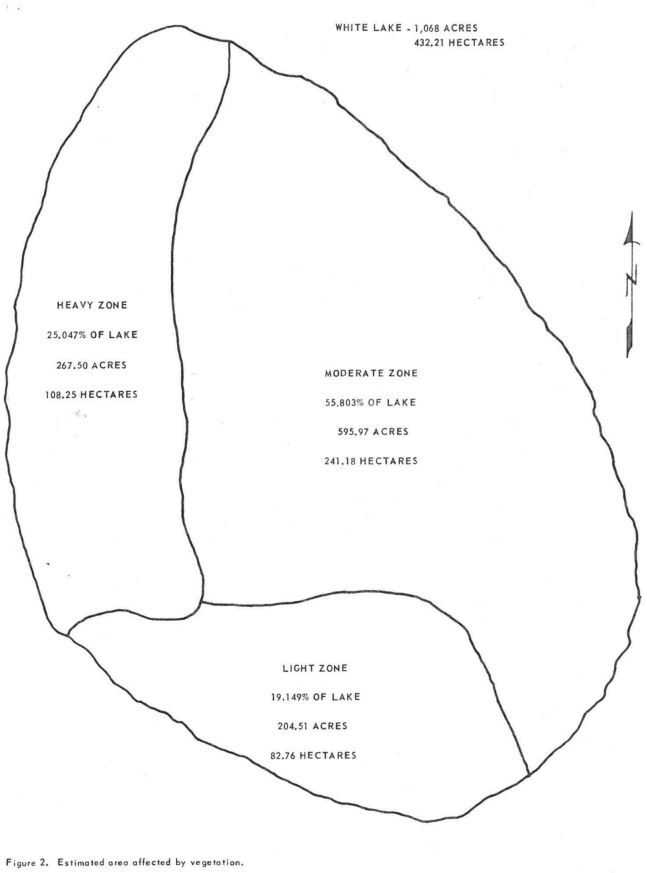

Figure 1. Relative abundance zones for aquatic vegetation in White Lake, from Nichols 1979 Wildlife Resources Commission Report on White Lake.

The Nichols report also includes detailed information on the macroinvertebrates and fishes found in the lake and noted the importance of the vegetation as habitat for fish food organisms.

A 2014 survey of the lake found that the majority of the lake had plant growth, with the dominant species being low watermilfoil (Myriophyllum humile), followed by aquatic moss, spikerush (Eleocharis), the macroalgae Chara, and bladderwort (Utricularia) (2014, NCSU White Lake Aquatic Vegetation Survey Report).

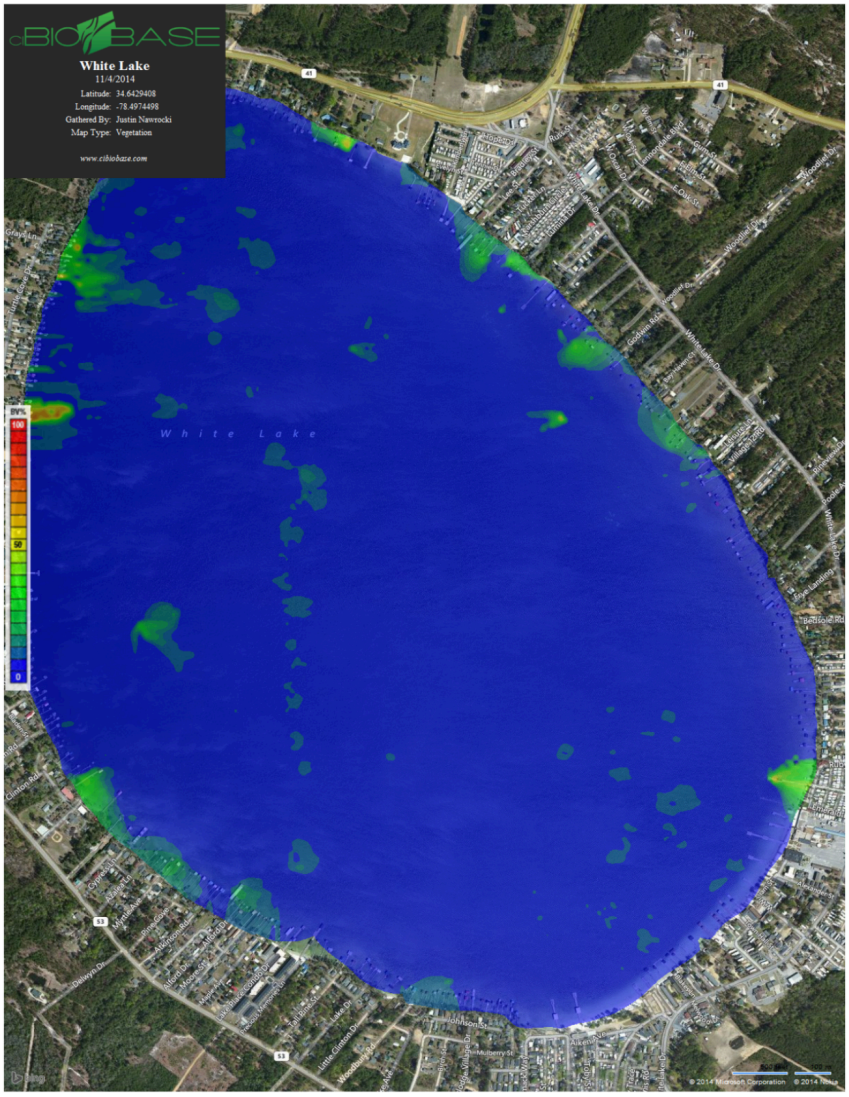

Figure 2. Biovolume of submerged aquatic vegetation in White Lake in November 2014, determined by a hydro-acoustic survey and BioBase software data processing. All vegetation found was low-growing, so that at shallow-water site estimates may be on the high side (Figure from 2014 NCSU Aquatic Vegetation Survey Report).

A 2017 survey of the lake found over 90% of the lake had some plant growth, with the dominant species being Hydrilla verticillata (83% of locations), followed by the macroalgae Chara (66%), and the aquatic moss Fontinalis antipyretica (63%). Dwarf watermilfoil (M. tentellum) was found at 15% of sites, while spikerush (Eleocharis baldwinii) was found at 9%. No Utricularia was found that year (2017 NCSU Report). Floating fragments of Hydrilla were found in all areas of the lake during the survey. A cyanobacterial bloom developed that year, which resulted in elevated pH levels and relatively high water-column total phosphorus levels (NC DEQ 2018).

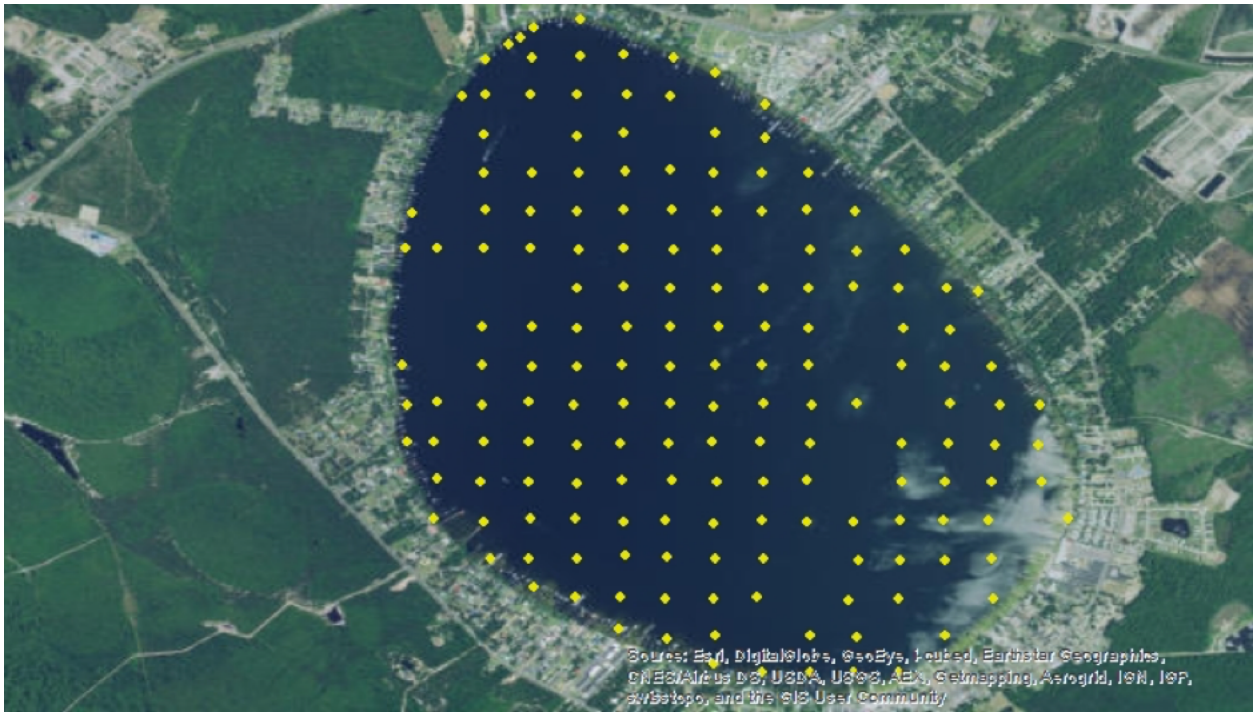

Figure 3. Presence of the aquatic weed Hydrilla (points in yellow) in White Lake in October 2017. (Figure from 2017 NCSU Aquatic Vegetation Survey Report).

A provisional checklist of the littoral zone vegetation of White Lake was published in 2016 as part of a more comprehensive survey of the natural littoral vegetation of the Bay Lakes. The authors did not survey the lake due to the level of development of the lakeshore, and relied on historical vouchers, personal observations and literature reviews (Howell et al., 2016). Two species of Myriophyllum (low watermilfoil, M. humile, and dwarf milfoil, M. tentellum) have been reported from the lake, and vouchered specimens are found in two herbarium collections (one at NCSU and one at Duke). Myriophyllum tentellum has been classified as a rare species in the state by the NC Natural Heritage Program.

A 2018 survey of White Lake found the biomass of aquatic vegetation was much lower than in 2017; this was best illustrated by comparison photos included with the survey report that year:

2017

2018

Only one Hydrilla plant was found as part of the survey (a tuber with sprouted growth), although several plants were found growing adjacent to the marina boat ramp at the northern lakeshore (2018 NCSU Aquatic Vegetation Survey Report). The rare Myriophyllum tentellum was found in more locations than in previous surveys, generally in shallower areas, along with the spikerush Eleocharis baldwinii. Overall lake conditions changed as a result of a low-dose alum treatment in May of that year, which resulted in lower pH levels, lower water-column phosphorus levels, and elimination of filamentous cyanobacteria (which resulted in gradually improving water

clarity). Hurricane Florence in September added substantial amounts of rainwater to the lake, and annual precipitation was much above average (89 inches for 2018, compared to the long-term average for the region of 49 inches).

The 2019 survey at White Lake found an increase in the percentage occurrence of aquatic vegetation, with two species—dwarf milfoil and spikerush—constituting the majority of the biomass:

White Lake % Occurrence				
Species	**2014**	**2017**	**2018**	**2019**
Hydrilla	0%	84%	0.5%	1.5%
Dwarf Milfoil	0%	15%	20%	34%
Spikerush	40%	9%	56%	68%
Aquatic Moss	43%	63%	32%	6%
Chara	29%	66%	0%	0%
Low Milfoil	54%	0%	0.5%	0%
Bladderwort	14%	0%	0%	0%
No Vegetation	11%	6%	36%	16%
Vegetation	89%	93%	65%	84%

Table 1. Aquatic vegetation found in annual whole-lake surveys of White Lake. Percentage occurrence is determined as the number of survey points in which each vegetation species is found divided by the total number of survey points (202) sampled (Table from 2019 NCSU White Lake Aquatic Vegetation Survey Report).

Hydrilla was found at three locations in 2019 at very low densities, with no floating fragments found. The pH levels in the lake ranged from 6.2 to 7.0 su, while the annual mean total phosphorus in the water column was 0.018 mg/L. Chlorophyll a monthly means ranged from 1.8 to 10.3 ug/L.

In addition to the annual aquatic vegetation surveys, an intensive monthly monitoring program was initiated in 2018 with the objective of detecting Hydrilla in the lake so that "rapid response" spot treatments with herbicide could be made. No Hydrilla has been found in monthly monitoring of the lake in 2018 and 2019. Tuber surveys of sediments have also been conducted but no tuber banks, or concentrations of tubers have been found—single tubers have been found at several sites only.

The rare plant (dwarf milfoil) was propagated at NCSU in 2018, as any Hydrilla management actions could potentially impact this species; it was found to be easy to propagate and maintain. In 2019, some of the propagated plants were used to test different herbicides (ProcellaCor, endothall, fluridone, and Diquat) at different concentrations; the results of this study indicated that fluridone and endothall had the least effect on the dwarf milfoil (T. Harris, NCSU, personal communication).

Conclusions and Recommendations:

The Hydrilla Technical Advisory Group that was formed in early 2018 was faced with what appeared to be a worst-case scenario for White Lake: a broad-scale Hydrilla infestation and a cyanobacterial bloom which had persisted through the winter of 2017-2018.

The Town of White Lake and NC State Parks determined that addressing the cyanobacterial bloom was the first priority in 2018, while the Hydrilla Group discussed the options for management in a system that included a rare plant species (see Appendix 1). One of the options, stocking the lake with triploid grass carp, was considered as risky, given the possibility of fish escape, but also because the carp would likely feed on all of the vegetation types, including the rare species, and could potentially eliminate it from the lake. A whole-lake herbicide treatment was a similarly daunting prospect.

The intensive monitoring and whole lake surveys that have been done in recent years indicate that the presence and relative abundance of natural vegetation in the lake is similar to what has been seen in earlier surveys, despite the increase in the pH of the lake from its previously acidic levels (pH around 4.5 su). The presence and relative abundance of Hydrilla in the lake has varied considerably since it was first detected: in 2017 it was found in most of the lake, but in subsequent years it has been found in only a few areas at very low densities It remains low-growing rather than exhibiting the vigorous, rapid growth that results in it "topping out" in other water bodies (Lake Waccamaw in 2012, for example). Site-specific environmental factors such as nutrient availability, inorganic carbon, pH and sediment composition can influence growth (e.g., Barko et al., 1986, Steward, 1991, Song et al., 2018), and it would seem prudent to conduct additional research to better understand what factor(s) control Hydrilla growth in this lake.

A comprehensive early detection rapid response program for White Lake will consist of the following elements:

1. Monitoring: Intensive Vegetation monitoring and annual lake-wide surveys will be needed over the long-term for this lake. The monthly monitoring protocols developed over the past two years will be implemented again in 2020, and additional monitoring around boat ramps will be conducted by the White Lake Stewardship Officer. An annual whole lake aquatic vegetation survey will be conducted in the fall by NCSU. The monitoring protocols are described in more detail in Appendix 2.

2. Management: Two herbicides have been identified as causing the least harm to non-target rare plants, and Aquatic Weed Program personnel would be able to treat small areas of infestation

if necessary. As no larger-scale treatment programs are being pursued at this time, the management objective would be control, rather than eradication.

3. Communications: A "No Aquatic Hitchhikers" sign has been posted at the White Lake Marina and other boat ramps for a number of years. Hydrilla brochures have also been provided to the Town, for placement at Town Hall and the Marina. The Town now has a Communications Team which is helping to develop and implement educational efforts for lake issues, including participation in events such as the Harvest Festival in October and the Water Festival in May. The White Lake Watch web site has also provided a platform for education and outreach about the lake and State Parks also has the ability to post information to their Singletary/White Lake site. The Communications Team has requested more information on Hydrilla, including where it is presently found in the state, and what living plant material looks like.

4. Preventing Introductions: Developing an inspection program for White Lake will be a priority for 2020, as there are other invasives, such as the filamentous cyanobacteria Lyngbya, which could become problems in the lake if introduced. This will include training and organizing volunteer inspectors who can visit the two primary boat ramps at the lake (marina and Camp Clearwater) during peak usage periods such as the Fourth of July holiday. All personnel at White Lake Marine will also be trained, so that they can do inspections of the boats that they are bringing in for servicing, prior to putting them into the lake. In addition, the installation a boat decontamination station at the marina/marine dealership should be evaluated. These actions would form the basis for a long-term aquatic invasive species (AIS) prevention program for this lake.

5. Further Studies: Developing additional research projects with NCSU to identify factors controlling Hydrilla growth in White Lake should be a priority for 2020.

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Appendix 1. Hydrilla in the U.S. – EDRR Fact Sheet.

Randy G. Westbrooks, Invasive Species Prevention Specialist
Steven Manning, President
Invasive Plant Control, Inc., Whiteville, North Carolina. USA.
(Dr. Westbrooks has retired since drafting this document in late 2012)

Common Name: Hydrilla
Scientific Name: *Hydrilla verticillata* (L.) F. Royle
Family: Hydrocharitaceae

Description: A submersed, rooted aquatic plant that can grow at depths of 20'. **Stems** slender branched, up to 25' long. **Leaves** strap-like and pointed, in bottle-brush whorls of 3-8, up to 0.8" long, 0.1" wide, with serrated margins. **Leaf midribs** reddish in color, undersides with small sharp teeth. **Flowers** tiny, white, with 6 petals, on long stalks. **Reproduction** occurs sexually through the production of seeds, and also vegetatively by fragmentation of the stem, or by sprouting of axillary turions (in the leaf axils) and subterranean tubers (attached to the roots).

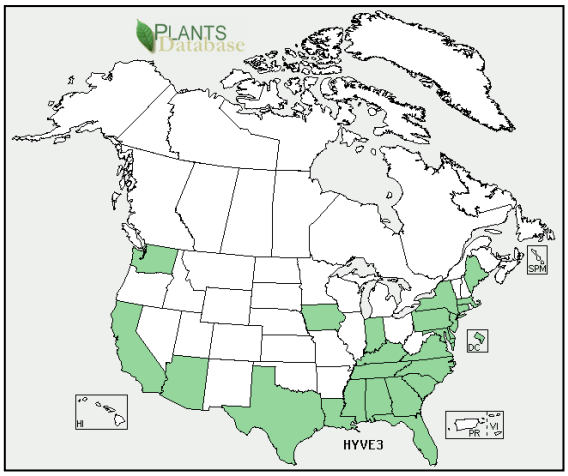
Genetic Forms: Hydrilla occurs in both monoecious (both male and female flowers on the same plant) and dioecious (male and female flowers on different plant) forms. The dioecious form occurs in the southeastern U.S. (South Carolina and southward), California, Poland, Malaysia, Indonesia, and Panama. The monoecious form has been found in the Mid-Atlantic Region of the U.S. (North Carolina and northward), in India, and Indonesia.

Similar Plants: Hydrilla can be confused with Brazilian elodea (*Egeria densa* Planch.) and Canadian waterweed (*Elodea canadensis* Michx.). The leaf midrib of Brazilian elodea is smooth; the leaf midrib of Hydrilla is toothed. The leaves of Canadian waterweed occur in whorls of three along the stem and are up to 0.2" wide.

Habitat: Hydrilla invades slow-moving or still water systems, such as ditches, ponds, lakes, rivers, and tidal zones (up to 7% salinity). It can grow in water a few inches deep, to water that is more than 20' deep. It can grow in low to high nutrient conditions. In the U.S., southern populations overwinter as perennials; northern populations (e.g., Connecticut) die back and re-grow from turions and tubers in the hydrosoil. It can also grow in very low light conditions (1% of full sunlight). This last characteristic gives is a distinct competitive advantage over most other aquatic plants.

Native Range: Africa or Asia – now widespread around the globe.

Pathways of Introduction and Spread: Hydrilla was first introduced into the U.S. in the late 1940s as an aquarium plant from Ceylon (now Sri Lanka). It is now spread primarily as fragments on boats and boat trailers.



Reported U.S. Distribution (USDA Plants Database:

URL: http://plants.usda.gov/java/profile?symbol=HYVE3

Ecological and Economic Impacts: Hydrilla is one of the worst aquatic weeds in the United States. It forms dense submersed mats at the surface of the water that can cover hundreds of acres. The dense mats reduce water flow, clog irrigation and hydroelectric equipment, interfere with recreation (boating, fishing, swimming), outcompete native aquatic plants, alter water chemistry, and reduce oxygen levels. In Florida, *millions of dollars* are spent annually in efforts to keep Hydrilla under "maintenance control".

Regulatory Status: Hydrilla is listed as a U.S. Federal Noxious Weed. It is regulated as a state noxious weed in Alabama, Arizona, California, Colorado, Connecticut, Florida, Maine, Massachusetts, Mississippi, Nevada, New Mexico, North Carolina, Oregon, South Carolina, Texas, Vermont, and Washington.

Online Resources:

Hydrilla Fact Sheet – USDA Forest Service – Weed of the Week Series.
URL: http://na.fs.fed.us/fhp/invasive_plants/weeds/hydrilla.pdf

Hydrilla Images - U-GA Bugwood Image Gallery.
URL: http://www.invasive.org/weedcd/species/3028.htm

Hydrilla Profile – Center for Aquatic and Invasive Plants – University of Florida.
URL: http://plants.ifas.ufl.edu/node/183

Hydrilla Profile - USDA Plants Database.
URL: http://plants.usda.gov/java/profile?symbol=HYVE3

Control Methods: A number of methods have been developed to control the establishment and spread of Hydrilla. These include **manual and mechanical control** to keep impacted waterways open, **chemical control** to kill the plant in the water column and associated roots and tubers in the hydrosoil, **biological control** with sterile grass carp to feed on the plant and prevent energy storage in the tubers, **water drawdowns** to desiccate and kill the plant in impounded lakes and other waterways, and **benthic barriers** that prevent plant fragments from rooting and rooted plants from growing up into the water column.

Note: an additional control method, **biomanipulation**, was considered by the technical group.

Appendix 2.

Hydrilla Detection, Response and Communication Plan for White Lake

I. Hydrilla Detection and Monitoring Protocols

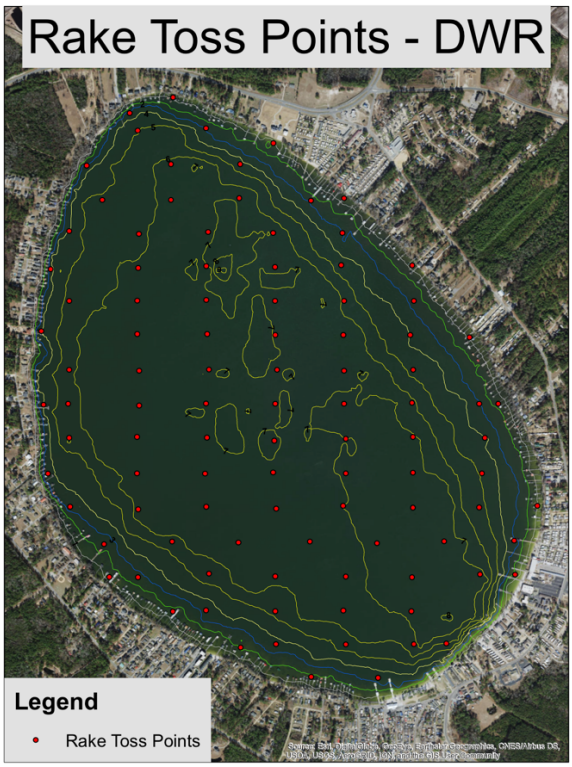
Early detection activities can be implemented by a variety of informed agency staff (State Parks, Wildlife Resources Commission, DEQ) and volunteers/interested residents, including the White Lake Stewardship Officer. To report a possible infestation:

- Note the location in the waterbody where the suspected Hydrilla was found (landmark, GPS point, photos)
- Take a picture of the plant (digital photos with a smartphone are ideal; place a coin or other object near the plant to provide scale before taking photos).
- Provide the information to: stewardshipofficer@whitelakenc.org

Monthly monitoring responsibilities will alternate between NC DWR Aquatic Weed Program personnel and NCSU Extension personnel, and will include the following methods:

Sample Points/Rake Toss Collections

Sampling will occur at 110 pre-determined points (Fig. M1) each month. A set of three rake toss actions will be performed at each sample point, tossing the rake the full distance of the rope, and pulling it in slowly once it has reached the lake bottom. The relative density of the overall plant mass will be assessed and then the mass will be separated into different species, and relative density will be assessed and recorded as field notes; photos of representative samples will be taken, and voucher specimens will be collected for less-certain species (the two Myrophyllum species, for example).



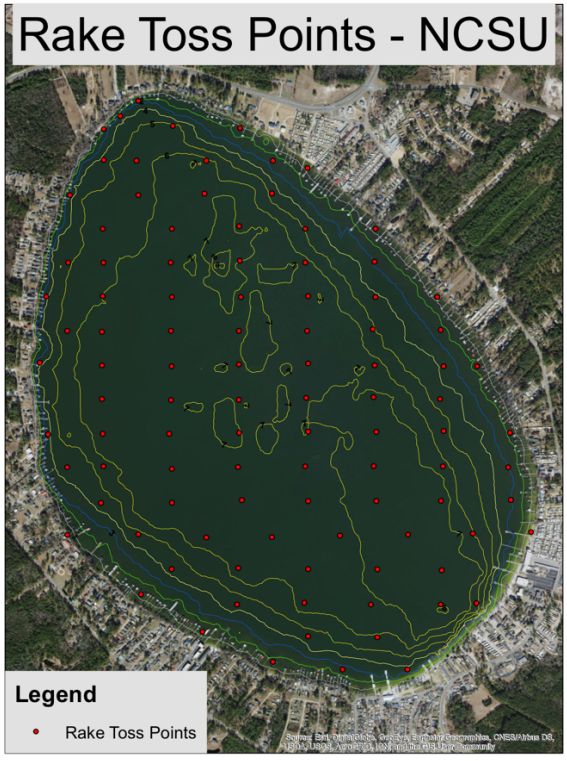


Figure M1. Point-intercept sampling locations for monthly vegetation sampling in White Lake. Three rake tosses are made at each point.

Hydro-Acoustic Survey

The objective is to create a vegetation map of the lake each month. During the hydro-acoustic survey operation, as vegetation is observed on the 'real time' display of the unit, the surveyors will stop to collect samples (via rake toss), identify species and make field notes. Hydro-acoustic (SONAR) data will be submitted to BIOBASE (https://www.biobasemaps.com/) for processing and output will be reviewed by Aquatic Weed Program and staff.

Annual Tuber Monitoring

Sampling will be conducted using a 10.2 cm diameter sediment core puller modified from Sutton (1982). Each core sampled will be roughly 0.008 m^2. Harlan et al. (1985) reported that 93 to 100% of monoecious hydrilla tubers were found in the top 12 cm of hydrosoil; therefore, the target depth for each sample will be approximately 20 cm. All core samples will be sifted through 3 mm wire screen to recover and count all tubers and turions. Sites sampled and found to have tubers will be resampled the following year until no tubers are found at that location. In addition, if warranted, new sites should be sampled to accurately track the decline in tuber bank numbers.

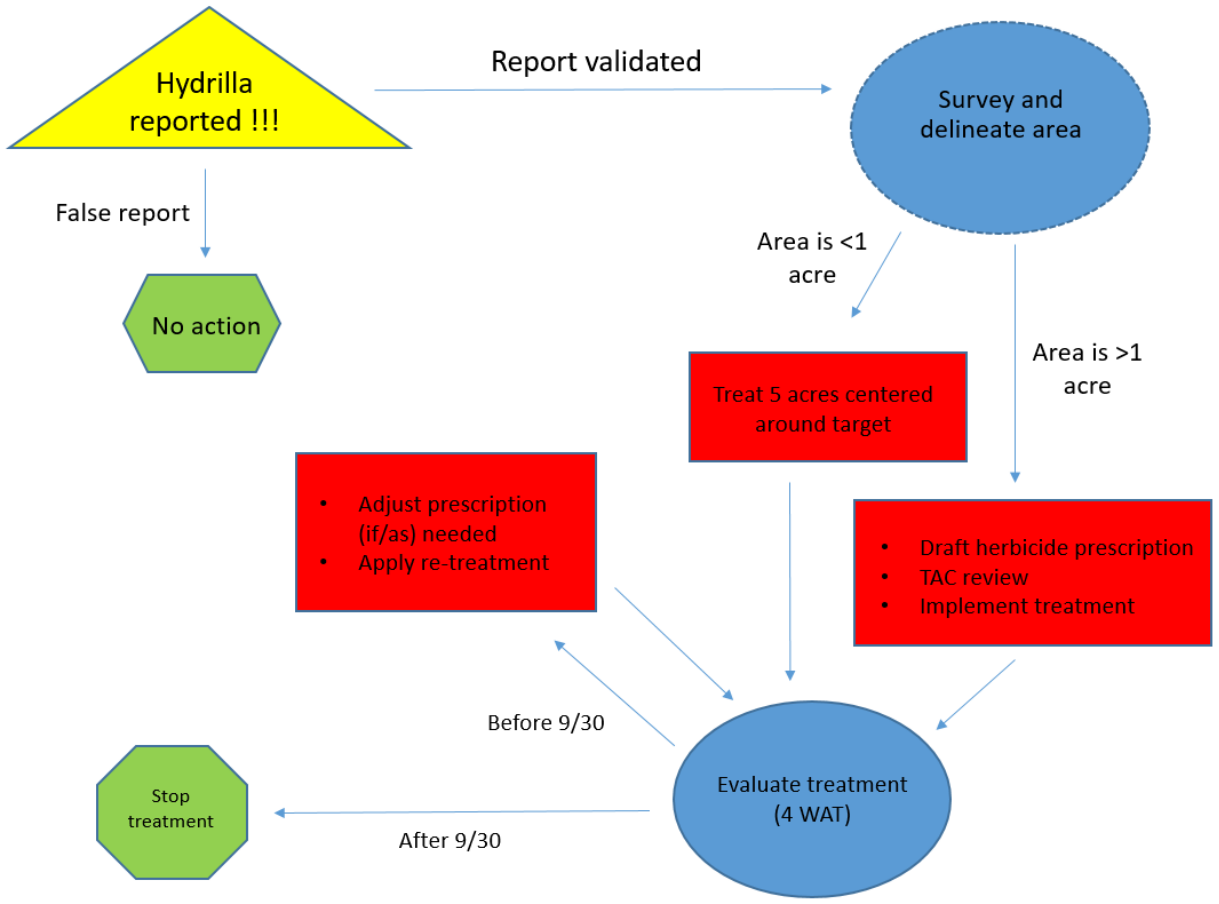
Annual Lake-Wide Survey of Aquatic Vegetation

Survey procedures will use combined methods of 1) hydroacoustic scans (SONAR); and 2) a standardized point-intercept sampling protocol (rake-tosses at each point) using a grid of 202 points. All survey data is provided to BioBase for processing so that biovolume estimates can be mapped.

II. Rapid Response to the Presence of Hydrilla

A third-party report of Hydrilla would require confirmation by AWP personnel. If a report is validated, a site visit would be scheduled within one week and an intensive delineation survey would be undertaken in the area where the siting was made. If Hydrilla is detected during a scheduled monitoring visit by AWP or NCSU staff, a similar intensive delineation survey would be conducted (Fig. M2).

Figure M2. Flowchart for Hydrilla Response Protocol.



Delineation Surveys

The delineation surveys would start with a 5-acre area (centered on the specific location) around the positive occurrence; if additional Hydrilla is found in this area, these occurrences will be flagged (both physically and with GPS) and the survey zone would continue to be expanded until there is no additional Hydrilla found. If AWP staff respond to a report of Hydrilla being found and are unable to find it with a delineation survey, the area will be incorporated into subsequent monitoring visits as a Delineation Area, and the delineation process will be repeated during these visits. The White Lake Stewardship Officer and Singletary State Park personnel will be informed of any occurrences so that they can assist in monitoring between visits of DWR/NCSU.

Spot Treatment for Small Infestation Area

Two herbicides, fluoridone and endothall have been tested on the rare species found in White Lake. AWP staff should be prepared to use endothall for spot treatment at White Lake and determine whether follow-up treatment with additional endothall or the slower-acting fluridone is warranted.

Endothall acid works by interfering with plant respiration, affecting protein and lipid biosynthesis and disrupting plant cell membranes (Senseman 2007, Madsen et al. 2010, US EPA 2005). It causes cellular breakdown of plants within two to five days. Symptoms of plant damage include defoliation and brown and shriveled tissues will become apparent within a week of herbicide application. Plants will fall out of the water column within three to four weeks after application (taken from Cornell Cooperative Extension Tompkins County's "Endothall: Herbicide Treatment FAQ" http://ccetompkins.org/environment/invasive-species/hydrilla-endothal-treatment-faq).

Fluridone is a systemic herbicide that is absorbed by vegetative tissues and translocated throughout the plant, inhibiting the synthesis of carotenoid pigments. Lack of these protective pigments causes susceptible plants to die slowly through reduced food production and damage by sunlight. Uptake must be nearly continuous over an extended period (>60 days preferred), requiring extended exposure (which means repeated applications, based on FasTEST results [which measures the concentration of fluridone in the water]).

Treatment for Larger Infestation Area

If multiple occurrences of Hydrilla are found within a delineated area of greater than 5 acres, spot treatment will take place at the time of the survey if possible, and a treatment plan will be developed for an area 30-40% larger than the delineated area. Dr. Rob Richardson with NCSU is a recognized expert in Hydrillla management and was instrumental in designing the original treatment plan for Lake Waccamaw, so his ongoing oversight and recommendations will be critical for the White Lake project as well. Any proposal for a larger treatment area would trigger a review by the full Hydrilla TAG and the development of an RFP and contract.

III. Communications of Findings

The following schedule is planned for monitoring in 2020:

Mid-May: DWR

Mid-June: NCSU

Mid-July: DWR

Mid-August: NCSU

Late September: NCSU Annual Vegetation Survey

The Stewardship Officer and State Parks Superintendent will be notified in advance to confirm sample dates and times.

A brief written report (which can be posted to the White Lake Watch web site) will be submitted to the Town and to the administrator of the web site within a week of the monitoring date.

Town contact: Steve Bunn, Lake Stewardship Officer, stewardshipofficer@whitelakenc.org
Web site administrator: Diane Lauritsen, ddlauritsen@gmail.com

The annual whole-lake vegetation survey should include a bathymetric map, mean depth and lake volume from BioBase software. Advance notification of the survey date will ensure that lake elevation data is collected that day as well, which can be correlated to the volume data.