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Application of Early Detection and Rapid Response Management Techniques to Control Hydrilla

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INTRODUCTION: Over the last decade an effective hydrilla (*Hydrilla verticillata* (L. f.) Royle) management strategy that minimizes herbicide and the use of triploid grass (*Ctenopharyngodon idella* Valenciennes) has been in development. This strategy, called early detection and rapid response, relies on early detection of hydrilla infestations, prompt suppression with registered herbicides, stocking of triploid grass carp at 20 fish per vegetated acre, and maintaining grass carp densities of approximately one fish per every eight surface acres of the reservoir (for at least a decade) to prevent regrowth.

To make the triploid grass carp component of this approach more acceptable, a better knowledge of stocking densities sufficient to control hydrilla, prevent regrowth, and minimally impact non-target aquatic vegetation is required. Information is also lacking on population trends of grass carp stocked into reservoirs as well as latitudinal differences in population attributes. These linkages, unfortunately, have not been well-studied but should be remedied by a newly initiated work unit in the Aquatic Plant Control Research Program.

BACKGROUND: Hydrilla originated in Florida during the 1950's (Blackburn et al. 1969, Schmitz et al. 1991, Hoyer et al. 2005) and ranges from coast to coast and as far north as Washington and Maine (U.S. Army Engineer Research and Development Center (ERDC) 2009). As a problem aquatic plant, hydrilla has been managed using registered herbicides, mechanical harvesting, winter drawdowns, insect pests specific to hydrilla, native aquatic vegetation, diploid and triploid grass carp, or some combination of these approaches. In Lake Guntersville, Alabama, a minimalist approach of doing nothing other than herbicide spot treatments for lake access has been implemented.[1]

Symposia held during 1994 (Grass Carp Symposium) and 2004 (Hydrilla Management in Florida) summarized hydrilla management strategies as well as the potential of grass carp as a management tool (U.S. Army Corp of Engineers 1994, Hoyer et al. 2005). Additional studies that evaluated grass carp stockings in major reservoirs include: Lake Conroe, Texas (Klussman et al. 1988, Webb et al. 1994a, Elder and Murphy 1997, Chilton et al. 2008), Lake Guntersville, Alabama (Bain et al. 1990, Webb et al. 1994b, Morrow and Kirk 1995), and the Santee Cooper Reservoirs in South Carolina (Foltz and Kirk 1994; Morrow et al. 1997; Kirk et al. 2000, 2001; Kirk and Socha 2003; Henderson et al. 2003; Kirk and Henderson 2006). It is generally agreed that triploid grass carp are a cost-effective method for long-term control of hydrilla but with a major limitation: triploid grass carp are

[1] Personal Communication. 2008. David Webb, Aquatic Botonist, Tennessee Valley Authority, Guntersville, AL.

best used where loss of all palatable submersed vegetation is acceptable for an extended period of time (Noble et al. 1986, Allen and Wattendorf 1987, Bain 1993, Hanlon et al. 2000, Hoyer et al. 2005, Cassani et al. 2008). However, this paradigm may rapidly be changing with early detection and rapid response management strategies, which eliminate hydrilla early during the infestation.

Stocking densities are an important consideration when employing triploid grass carp to manage aquatic vegetation. Across the country, stocking rates have varied widely (from 1 to 250 grass carp per vegetated acre) depending upon the length of the growing season, desired rate of control, and the type of vegetation (Stocker and Hagstrom 1985, Bates and Webb 1986, Bonar et al. 1993) In general, the longer the growing season, the lower the stocking rate (Wiley et al. 1984). Stocking rates used to manage hydrilla have varied somewhat less. In the Santee Cooper Reservoirs, the target density of 15 fish per vegetated acre controlled a 48,000-acre infestation, but only after an 8-year period (Kirk and Henderson 2006). A stocking density of 10 fish per vegetated acre eliminated, over a two-year period, 6,400 acres of hydrilla in Lake Murray, South Carolina.[1] Very high stocking rates (at least 50 fish per vegetated acre) applied twice rapidly (about one calendar year) eliminated hydrilla in Lake Conroe, Texas between the 1980's and 2008 (Klussman et al. 1988, Chilton et al. 2008). Little is known about maintenance stocking densities or duration for the purpose of preventing hydrilla regrowth from tuber banks in the hydrosoil.

APPROACH: Five reservoirs managed by Duke Energy Corporation (Figure 1) were used to develop this management strategy. Four reservoirs impound the Catawba River (from north to south): Lake James, Lake Norman, Mountain Island Lake, and Lake Wylie. Belews Lake is a 3,663-acre impoundment created in 1973 by impounding Belews Creek (Figure 1).

Mosquito control crews continually surveyed Duke Energy Corporation reservoirs during the growing season to locate and control mosquito breeding areas. These crews also sought invasive aquatic vegetation and routinely visited all potential areas of infestation. Once nuisance vegetation, and especially hydrilla, was located, plant beds were mapped from ground truthing and control was initiated with registered aquatic herbicides (usually Komeen® or Cutrine® at rates not exceeding 1 ppm copper). In some cases the infestation was treated for several years (Table 1) until stakeholder groups (including state agencies, utility companies, marine commissions, and interested citizens) could be assembled to develop, approve, and fund an integrated approach using both herbicide applications and grass carp stocking.

In all cases, an initial stocking rate of 20 triploid grass carp per vegetated acre of hydrilla was used. After hydrilla was controlled (i.e., hydrilla could not be located in systematic surveys using rakes attached to a rope), triploid grass carp were stocked as needed to maintain a minimum density of one fish per every eight surface acres of the entire reservoir. The initial recommendation of one triploid grass carp per every 8 surface acres of the reservoir was based upon estimated grass carp densities that prevented hydrilla regrowth in the Santee Cooper Reservoirs. To account for the presence of those fish, maintenance stockings were based upon a total annual mortality rate of 32% developed in the Santee Cooper Reservoirs (Kirk et al. 2000, Kirk and Henderson 2006).

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[1] Personal Communication. 2009. Chris Page, Biologist, South Carolina Department of Natural Resources, Columbia, SC.

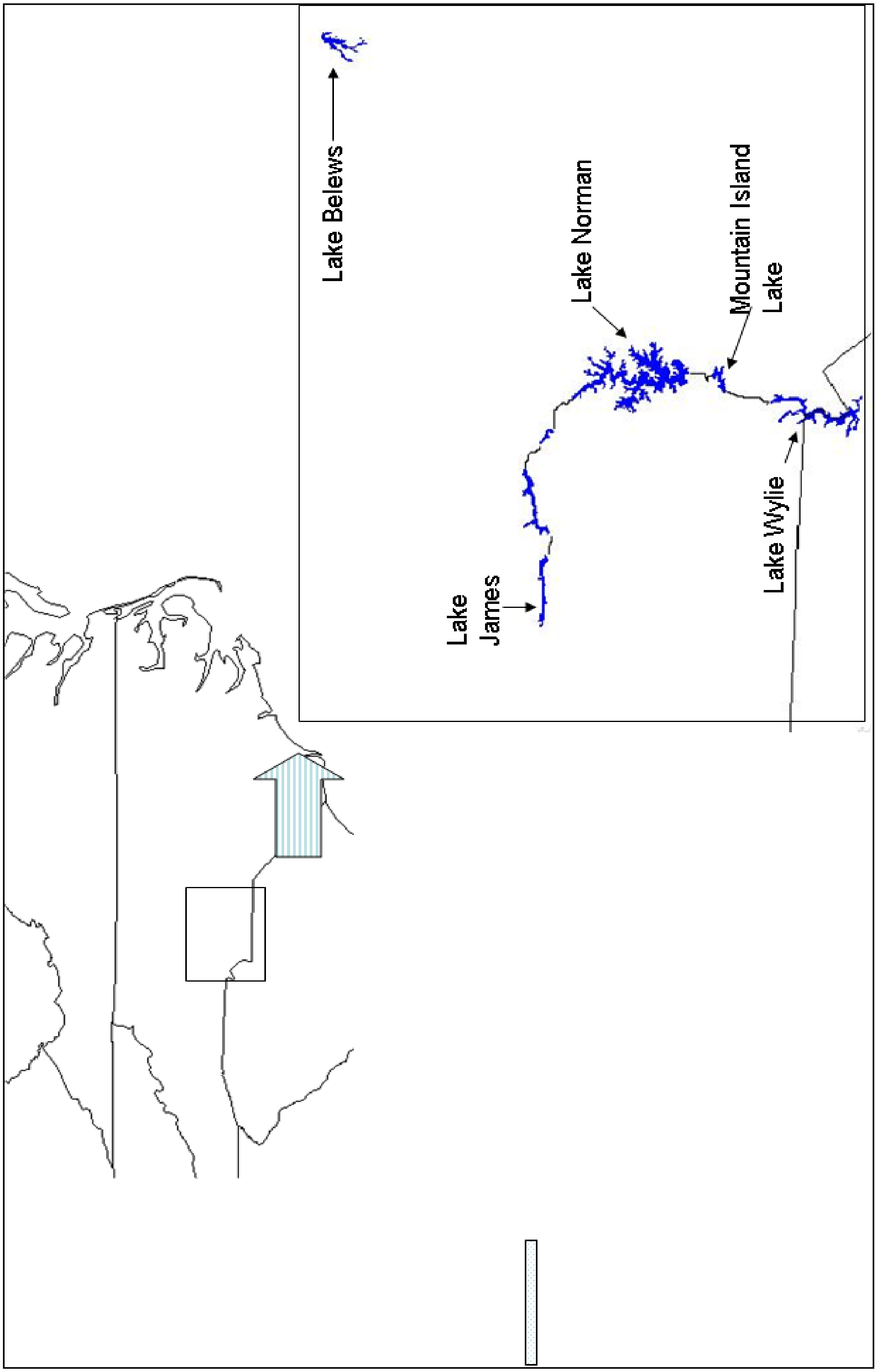

Figure 1. The study site.

RESULTS AND DISCUSSION: The five reservoirs total 59,674 surface acres, of which 14,920 are vulnerable to infestation (Table 1). The surface area of the reservoirs varies markedly in scale: from Lake Norman (32,475 acres) to Mountain Island Lake (3,281acres). Hydrilla was first discovered in Lakes James and Belews in 1999 and last discovered in Lake Wylie during 2006.

Table 1. Characteristics and management chronology of reservoirs using early detection and rapid response strategies to manage hydrilla.

Reservoir	Area (acres)	Area infested (acres)	Potential infestation (acres)	Year infested	Grass carp stocked	Control achieved
Norman	32,475	400	8,000	2000	2004	2005
Mountain Island	3,281	1,000	1,200	2000	2000	2003
James	6,812	1,050	1,400	1999	2002	2003
Belews	3,663	106	920	1999	2005	2006
Wylie	13,443	90	3,400	2006	2009	2009

Triploid grass carp were stocked at a rate of 20 fish per surface acre of hydrilla. Within one calendar year after stocking triploid grass carp, complete control (at a minimum, hydrilla was not observed during routine surveys) was achieved in all reservoirs, except Mountain Island Lake, where hydrilla was intermingled with other nuisance vegetation. Based upon the response of hydrilla in the Santee Cooper reservoirs (15 fish per vegetated acre) and Lake Murray (10 fish per vegetated acre) in which control lagged, stocking at a rate of 20 fish per vegetated acre, when combined with herbicide application, may be an acceptable minimum density for rapid elimination of hydrilla in the water column. During 2002, a total of 1,000 and 1,050 acres of hydrilla were first controlled using this approach in Mountain Island Lake and Lake James, respectively (Table 1). A 400-acre infestation was controlled in Lake Norman during 2004 and a 106-acre infestation in Belews Lake was controlled the following year.

In Lake Wylie, small infestations (estimated at 5 acres) were treated with Komeen® beginning in 2006. Despite herbicide treatment, hydrilla continued to spread to multiple sites comprising 90 acres by November 2008. A total of 1800 triploid grass carp (20 fish per acre) were stocked in April and May 2009 and had controlled hydrilla by October.

Maintenance densities estimated that a rate of at least one fish per every 8 surface acres controlled hydrilla regrowth at all reservoirs, except in Lake James. During October 2009, a topped-out patch of hydrilla (approximately 100 ft^2) was found during a routine survey conducted seven years after achieving initial control. The infestation was subsequently eliminated that year with herbicides, and hydrilla has not since been detected in the reservoir as of 2011. Maintenance stocking densities developed in the study reservoirs may or may not be sufficient to prevent hydrilla regrowth from tuber banks in larger reservoir systems (e.g., the Santee Cooper Reservoirs totaling 170,000 surface acres) or systems that have hydrilla interspersed with stands of submersed native vegetation.

Studies during the next 3 years will continue to monitor the Duke Energy Reservoirs and evaluate more long-term success of control. These studies will be used to refine the early detection and rapid response approach and will include population modeling and expanded geographic coverage. Recommendations will be developed on both short- and long-term stocking strategies, based on known population attributes and responses to latitudinal gradients (e.g. average water temperature and growing season) that meet various aquatic plant management objectives. Other study sites will include southeastern reservoirs (Lakes Moutrie and Marion) where hydrilla is beginning to re-colonize littoral zones. Geographic locations that have sufficient baseline information on plant coverage and stocking densities to compare long-term latitudinal trends (e.g., Texas, Arizona, or the Pacific Northwest) may also be included. Changes in plant coverage will be analyzed to determine grass carp impacts on native and exotic plants based upon their palatability.

Triploid grass carp will be collected, otoliths will be extracted, and age will be determined in the laboratory. Back-calculated lengths will be determined, when possible, to reconstruct rates of growth. Age-structured and population viability models will be developed for each study reservoir using estimated rates of total mortality. These models will be used to evaluate the relationship between stocking approaches and coverage of hydrilla and other submersed aquatic species. Recommendations will be developed on both short- and long-term stocking strategies, based on known population attributes and responses to latitudinal gradients that meet various aquatic plant management objectives. Results will be summarized as guidelines for early detection and rapid response management actions.

RECOMMENDATIONS: Recommendations developed from this study are applicable to mid-size reservoirs: (up to 32,000 surface acres), and are as follows:

- Monitor the reservoir during the growing season to detect hydrilla early in the colonization phase.
- If patches of hydrilla are detected, immediately treat with an approved herbicide.
- Immediately stock triploid grass carp no less than 12 in. long at a rate of 20 fish per vegetated acre.
- Assuming a 32% annual mortality rate, maintain grass carp densities at 8 fish per surface acre of the water body for at least a decade after elimination of hydrilla in the water column.
- Monitor mortality rates using sectioned otoliths (Morrow et al. 1997) and catch curve analysis.
- Continue annual monitoring and adjust stocking rates accordingly based upon the area of infestation and changes in the annual mortality rates of triploid grass carp.

POINTS OF CONTACT: For additional information, contact James P. Kirk (601-634-3060, *James.P.Kirk@usace.army.mil*) or the Program Manager of the Aquatic Plant Control Research Program, Dr. Linda S. Nelson (601-634-2956, *Linda.S.Nelson@usace.army.mil*), or Dr. Al Cofrancesco, Technical Director, Civil Works Environmental Engineering and Science (601-634-3182, *Al.F.Cofrancesco@usace.army.mil*). This technical note should be cited as follows:

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