Movements and Habitat Use of Triploid Grass Carp in Lake Marion, South Carolina

by
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Introduction

Lake Marion is a 44,000-ha impoundment composed of open water as well as dense cypress swamps. Aquatic vegetation had become a serious problem in upper Lake Marion north of the Interstate-95 bridge (I-95) (Inabinette 1985). Upper Lake Marion's shallowness is conducive to aquatic plant growth. Many areas of the lake had limited access because of dense aquatic vegetation. This hampered use of the lake by recreational hunters and anglers. Herbicides were used extensively in order to control the vegetation problem, but a more feasible and long-term solution was needed. Mechanical removal and herbicide treatment can be costly, time-consuming, and works on a limited basis for a limited time. One possible solution was the release of triploid grass carp (*Ctenopharyngodon idella*). Grass carp were effective in eliminating *Hydrilla verticillata* in several large lakes in Florida (Beach et al. 1976; Miley, Leslie, and Van Dyke 1979). Advantages of biological control, such as the use of triploid grass carp, include longevity of the method, constant fish-feeding activity against growing vegetation, low long-term cost, and high effectiveness on selected plants (Sutton and Vandiver 1986). A potential disadvantage of use of triploid grass carp would be overexploitation of aquatic vegetation and the consequent reduction in habitat for nongame fishes, other nongame wildlife, and waterfowl.

Three hundred thousand triploid grass carp were released between 1989 and 1991 at various locations in upper Lake Marion to control nuisance aquatic vegetation (South Carolina Aquatic Plant Management Council and South Carolina Water Resources Commission 1989). Subsequent supplemental stockings were being considered. Water temperature is known to cause migrational movement in grass carp once water reaches 15 to 17 °C (Aliev 1976). A rise in water level or increased flow rates have also caused grass carp to exhibit migrational movement (Stanley, Miley, and Sutton 1978). If triploid grass carp were to migrate up the rivers and away from aquatic weed-infested areas, they would be ineffective for weed control. Objectives of this study were to (a) determine the magnitude and direction of grass carp movements, (b) determine if grass carp remain in the targeted vegetation areas, and (c) examine characteristics of habitats utilized by triploid grass carp.

Study Site

Lake Marion, South Carolina, is a 44,000-ha lake formed by the impoundment of the Santee River. Lake Marion has an average depth of only 5 m and a maximum depth of 12 m. Immediately upstream of Lake Marion, the Santee River is formed by the confluence of the Wateree and Congaree rivers. The Wateree River originates at the Wateree Dam about 100 km upstream from Lake Marion. The Congaree River originates at the Saluda Dam on Lake Murray and flows 85 km before joining the Wateree. The Wateree and Congaree rivers average 183 m^3/sec and 266 m^3/sec discharge, respectively. Lake Marion is connected to Lake Moultrie by an unobstructed canal known as the diversion canal. Together, the two reservoirs comprise the "Santee-Cooper" system (Figure 1). When Lake Marion was constructed in 1941, it impounded

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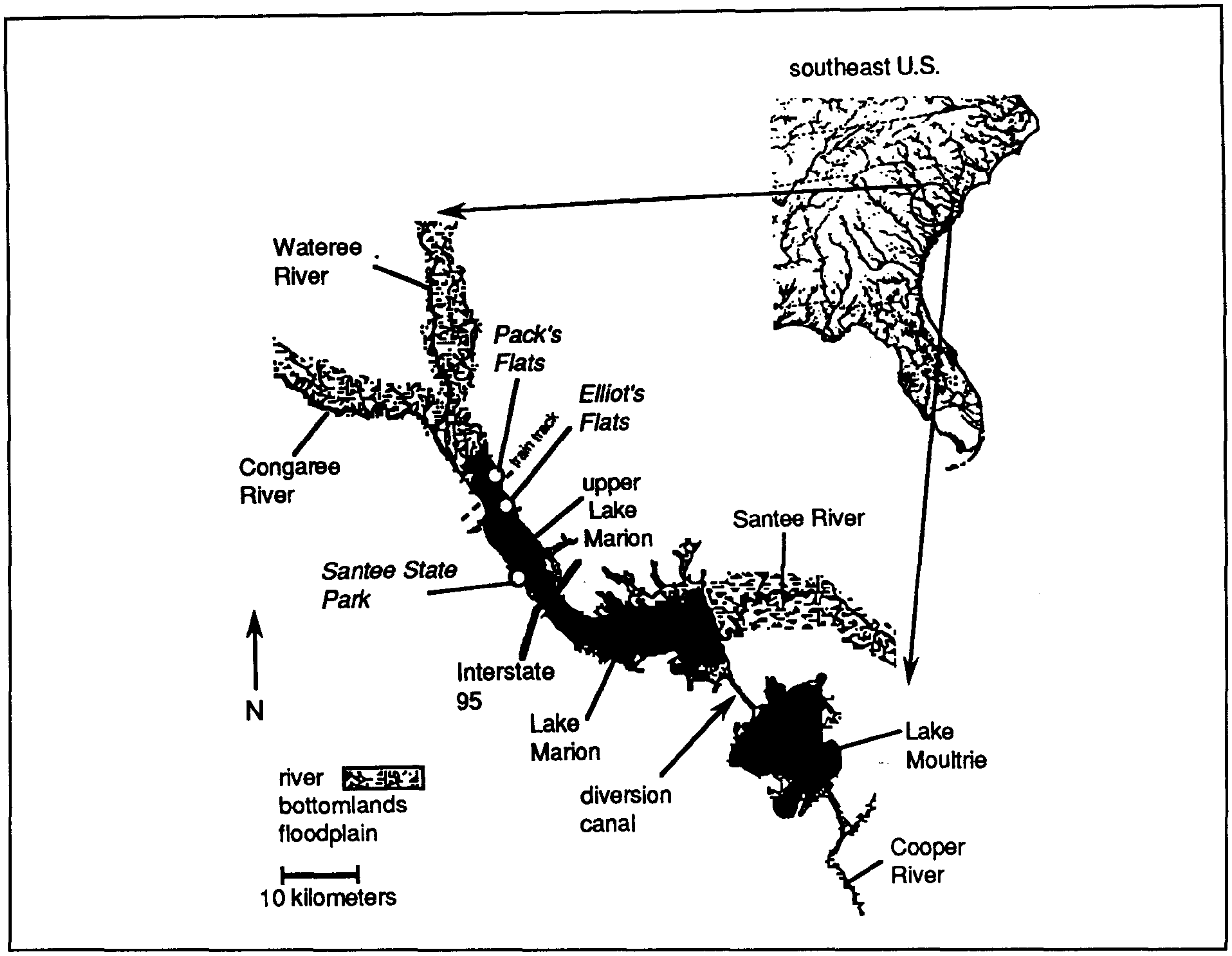

Figure 1. Study areas of upper Lake Marion in relation to the Santee-Cooper (Lakes Marion and Moultrie) system

6,500 ha in its headwater section, which was known as the Santee Swamp. The swamp is anaerobic most of the year and hence influences water quality in upper Lake Marion (Bates and Marcus 1989). Vegetated areas of the lake targeted for control have an estimated 4,800 ha of submerged vegetation, mostly upstream from the I-95 bridge. Habitats in upper Lake Marion can be categorized into five types: (a) Santee River channel (2 to 8 m deep), (b) open water with creek channels running through it (1 to 2 m deep), (c) open water with scattered cypress trees (2 to 3 m deep), (d) open-water shallow flats (1 to 2 m deep), and (e) thick cypress swamp (2 to 3 m deep). All types but the Santee River channel support dense stands of nuisance aquatic vegetation. No assessment of the proportion of upper Lake Marion that each habitat type comprises has been made. Likewise, no assessment of the magnitude of the swamp's influence on downstream water quality has been made, although fish kills because of anaerobic conditions are a common summer phenomenon in upper Lake Marion's swamps.

Methods

Eighty-two triploid grass carp were surgically implanted with radio transmitters (45 fish in the 1989/1990 study and 37 fish in the 1990/1991 study). Life spans of transmitters were 9 months, and transmitter frequencies ranged from 48.036 to 49.527 kHz. Each fish was identified by a distinct frequency. Fish were anesthetized using a bath containing 100-mg/L MS-222 and 25-mg/L Furacin. Each fish was weighed to the nearest 0.01 kg and measured to the nearest millimeter. Anesthetized fish were placed in a V-shaped operating trough so that the fish excluding its abdomen was submersed in water containing MS-222 and Furacin. A small aquarium aerator was used to maintain adequate oxygen levels in the operating trough. A radio transmitter was then surgically implanted using the procedure described by Schramm and Black (1984). Surgical gloves were worn, and instruments and transmitters were disinfected prior to use.

Scales were removed from the incision area, and a 5-cm longitudinal incision was made in the ventral wall 6 cm anterior to the pelvic girdle. A transmitter was then inserted into the body cavity and the incision closed with non-absorbable silk sutures. Oxytetracycline (50-mg/kg body weight) was injected into the body cavity before the last suture was stitched. Fish were then immediately released into the lake at Pack's or Elliot's Flats (1989/90 study) or approximately 1 km north of Santee State Park during the 1990/91 study (Figure 1).

An Advanced Telemetry Systems (Model 2000) radio receiver was used. Boat searches for implanted grass carp were conducted 3 days per week for 18 months. Signals were received while boating with a Telex Communications (Model 64 B-S) four element yagi antenna. Once a signal was picked up by the receiver, the antenna was rotated to ascertain direction, and the boat was motored in that direction. Signal strength increased as the fish was approached. The coax cable was then disconnected from the antenna and dropped in the water beside the boat. Intensity of the signal indicated when the boat was within 25 m of the fish. Air searches of the Santee-Cooper system were conducted monthly during the initial study in order to locate any fish that had not been located in 14 days. Air searches were not conducted during the second study because all fish were regularly located.

Once a fish was located, date, water depth, and Loran latitude and longitude coordinates were taken. Water temperature and dissolved oxygen were measured at the surface and on the bottom with a YSI dissolved oxygen meter (Model 51B) to the nearest 0.1 °C and 0.1-mg/L, respectively. Mean dissolved oxygen was calculated from the surface and bottom value. An aquatic vegetation sample was taken from the surface and bottom with a rake. Aquatic vegetation was identified (Pennwalt 1984) in the field. The species that comprised the largest proportion of a sample was categorized as primary vegetation, and the species that comprised the next largest proportion was categorized as secondary. Vegetation density in the general vicinity of the fish location was categorized into one of four categories: (a) vegetation covers ≥50 percent of the surface, (b) vegetation covers <50 percent of the surface, (c) vegetation present but submersed, or (d) vegetation sparse. Habitat type was categorized as one of five types (see Study Site): (a) river channel (Santee, Congaree, or Wateree), (b) open water with creek channels (OWCC), (c) open-water shallow flats (OWSF), (d) thick cypress swamp (TCS), and (e) open water with scattered cypress trees (OWCS).

Fish locations were plotted on a digitized map that indicated the Santee River channel. Days elapsed and distance moved (to nearest 0.01 km) between readings were computed for each fish. Minimum net daily movement was then computed as net kilometers/elapsed days. Linear and nonlinear regressions were employed to describe seasonal changes in minimum net daily movement. Distance from the river channel to the fish was computed along a line perpendicular to the fish and the river channel. Distances were recorded to the nearest 0.01 km. Distance of grass carp from the river channel was tested with a t-test (null hypothesis that the distance = zero).

Core-use area and home-range estimates were calculated for individual fish using the bivariate scatterpoints (Longitude = Y_1 and Latitude = Y_2) of grass carp locations. Core-use areas were computed as the 95-percent confidence region (i.e., ellipse) to each fish's mean location, whereas home ranges were based on a 95-percent confidence region to each fish's observations (Sokal and Rohlf 1969). Average core-use and home-range areas were computed from log10 transformed values. Similarly, the statistical center of distribution for both studies was computed as the 95-percent confidence region (i.e., ellipse) to the sample mean.

Results

Triploid grass carp used in this study averaged 704 mm total length (SE = 15) and 4.42-kg live weight (SE = 0.20) at the time of release. Fish were located on 225 occasions in the first study and 180 occasions during the later study. Average elapsed time between locations of an individual fish was 10 and 17 days for the first and second study, respectively. The longest distance moved by a fish was 10.6 km over 4 days, while the averages were 0.29 km/day (SE = 0.01) and 0.10 km/day (SE = 0.01) for the 1989/90 and 1990/91 studies, respectively. Grass carp in this study did not demonstrate a preference for the river channel in Lake Marion (Figure 1). Mean distance of grass carp from the river channel was 1.75 km (SE = 0.08) and 1.01 km (SE = 0.07) for the first and second studies, respectively. These mean distances was significantly different from zero ($t = 22.84$, $p = 0.0001$; $t = 14.21$, $p = 0.0001$). Grass carp in the 1989/90 study showed an average individual core-use area of 49 km^2 and an individual home range of 165 km^2. As a group, they were distributed from Pack's Flats to Santee State Park (Figure 2). Grass carp in the second study had an average individual core-use area of 9 km^2 and only 49 km^2 for average individual home range (Figure 2). As a group, fish in the second study were located principally in an area known as Stumphole Flats about 3 km north of Santee State Park (Figure 2). Surface dissolved oxygen concentrations at fish locations remained above 8 mg/L most of the year, but bottom concentrations averaged less than 1 mg/L in May. Water temperatures at fish locations were similar to the pattern that occurs in the upper lake: winter temperatures of 10 °C and summer high temperatures of 29 °C. There was a 2 to 5 °C difference between surface and bottom temperatures at fish locations, which ranged in depth from 2 to 3 m.

No studies to date have quantified the different proportions of habitat and aquatic vegetation types in upper Lake Marion. Fish were located in open-water shallow flats or adjacent open water-cypress stands 66 and 70 percent of the time during the 1989/90 and 1990/91 studies (Figure 3). Depths averaged 2 to 3 m. Grass carp locations in thick cypress swamps accounted for only 19 and 25 percent of the locations. Seventy-two and fifty-three percent of recorded grass carp locations were in areas with aquatic vegetation at the water's surface (Figure 4). Over the two studies, 66 and 70 percent of fish locations were in areas dominated by *Hydrilla* (Figure 5). *Egeria densa* was the predominate vegetation type in only 11 and 6 percent of fish locations. Other vegetation types that included duckweed, *Nitella*, and coontail accounted for 20 and 19 percent of the locations, but no single species exceeded 2 percent.

Discussion

Magnitude of movements were comparable but less than those reported for adult fish by Bain et al. (1990). Bain et al. (1990) reported that adult fish movement averaged 33 km over a 4-month period (i.e., about 0.27 km/day) and that one fish traveled 6 km/day. It is difficult to make direct comparisons between studies without knowledge of the frequency of observation. For example, a fish could travel 1 km each day for 10 successive days, but if it finished at its origin and had not been observed for 10 days, net daily movement would compute as zero. Higher movement rates reported for the first study (1989/90) were for grass carp released at two widely separated points in upper Lake Marion, South Carolina. Also, fish probably moved to avoid widespread low dissolved oxygen events that occurred during 1989 and 1990 in the uppermost cypress swamps and adjacent flats. In the 1990/91 study, grass carp generally remained in the shallow flats located within 2 km of their release site. Core-use areas traveled by grass carp were very close to values reported by Chilton (in this symposium) for triploid grass carp in a Texas reservoir.

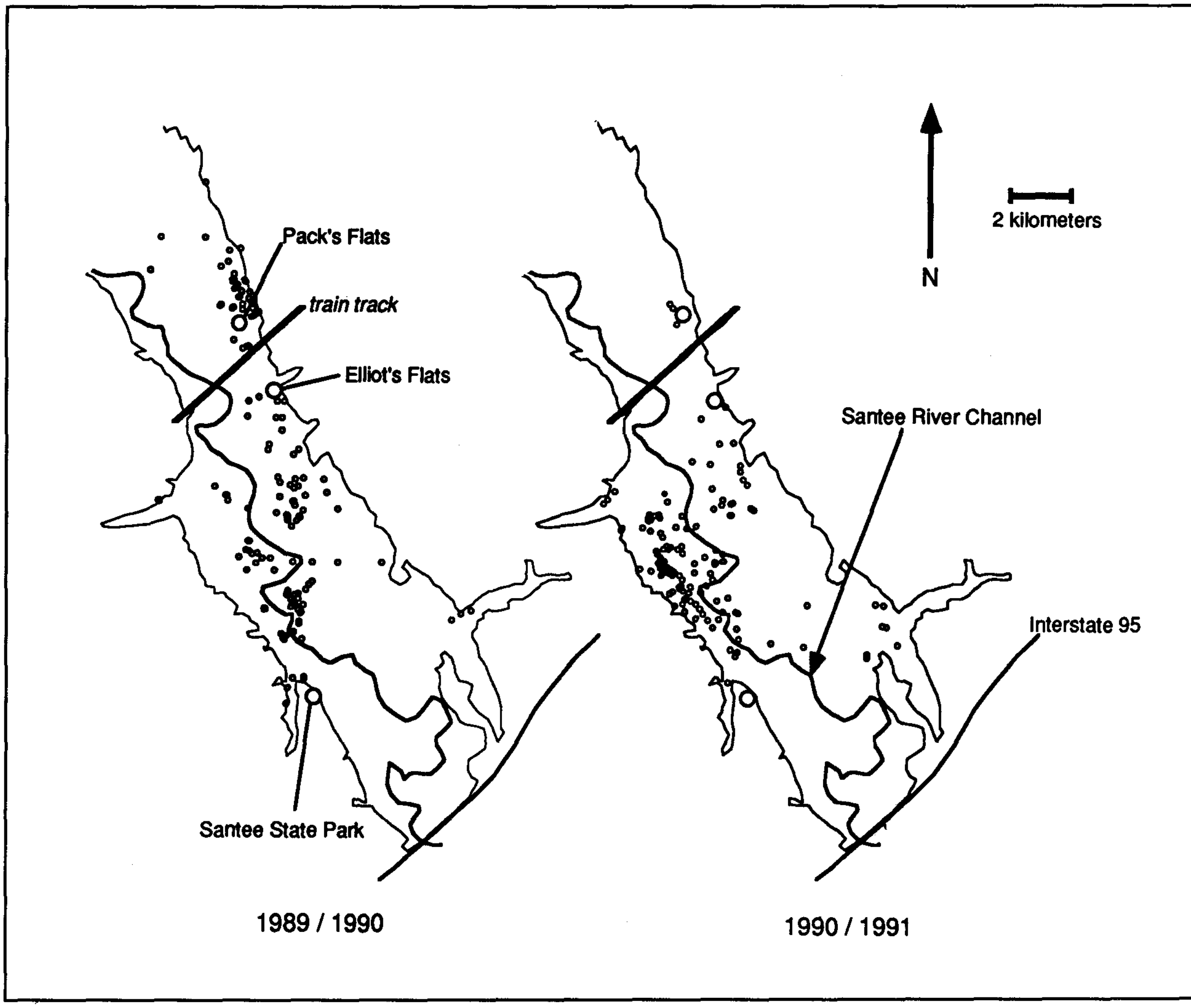

Figure 2. Locations of radio-tagged adult triploid grass carp in upper Lake Marion, South Carolina. Each dot represents one or more individual fish locations

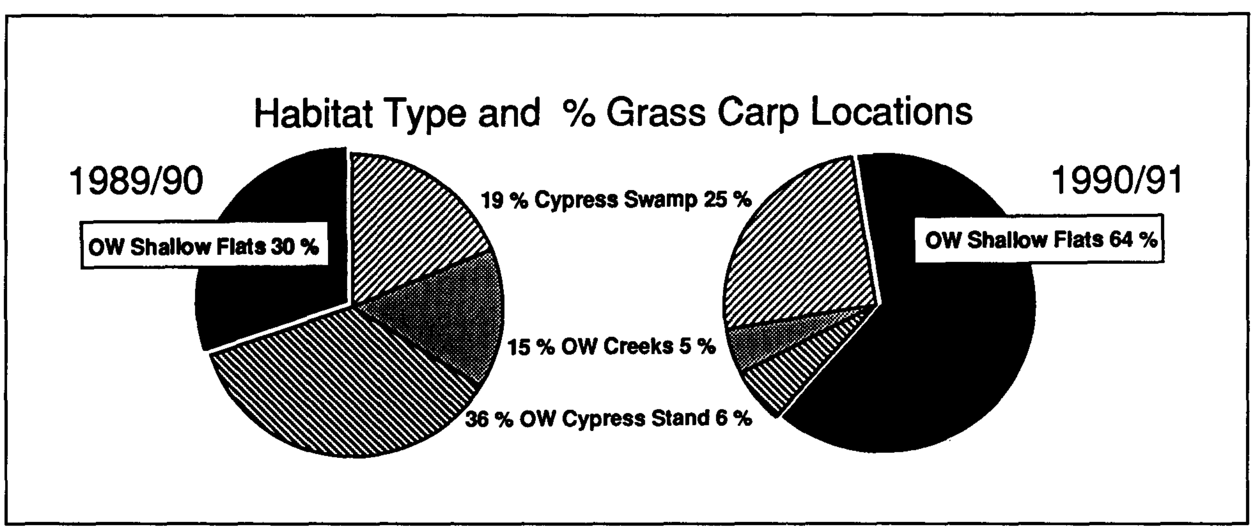

Figure 3. Habitats utilized by radio-tagged adult triploid grass carp in upper Lake Marion, South Carolina

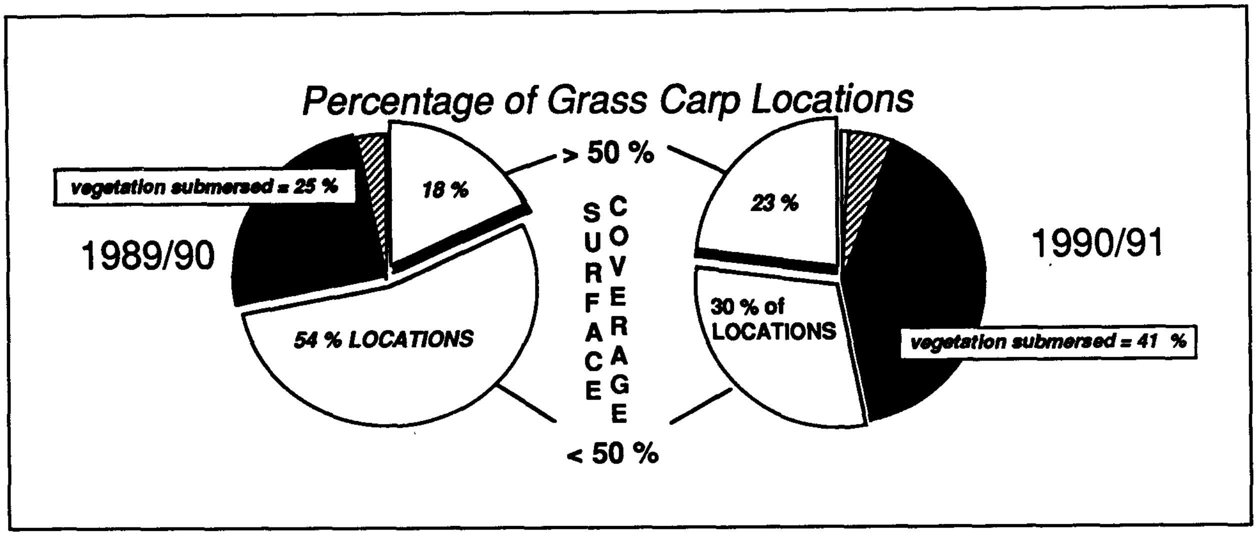

Figure 4. Aquatic vegetation relative abundances at locations utilized by radio-tagged adult triploid grass carp in upper Lake Marion, South Carolina

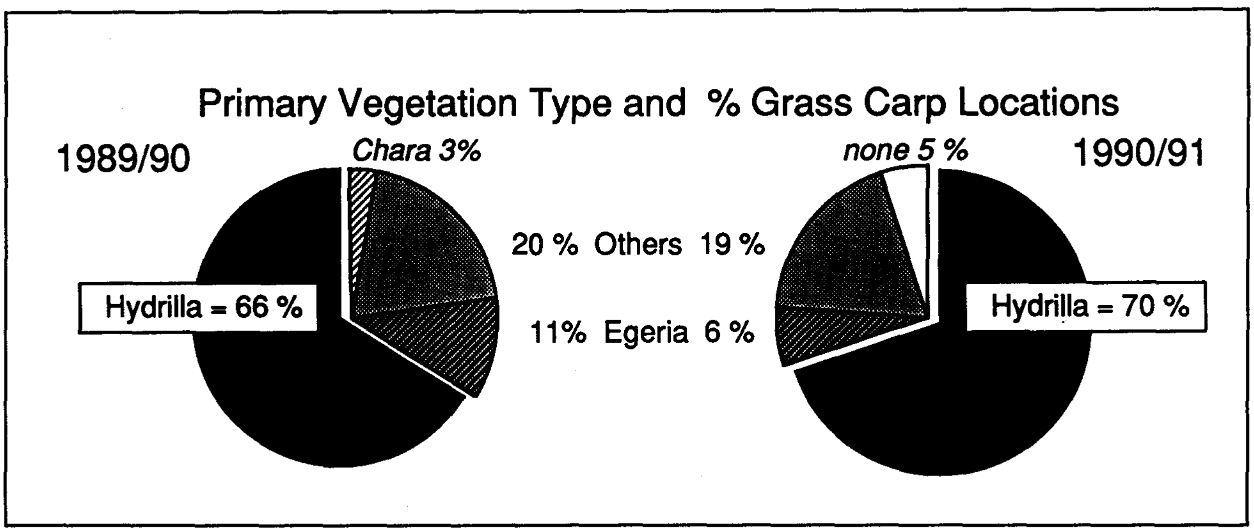

Figure 5. Predominate aquatic vegetation at locations utilized by radio-tagged adult triploid grass carp in upper Lake Marion, South Carolina

Shallow flats and adjacent areas were most frequented by grass carp, probably because of higher dissolved oxygen and abundant submersed vegetation. Thick cypress swamps in contrast are characterized by low summer dissolved oxygen concentrations (Bates and Marcus 1989). Utilization of more open areas probably provides grass carp with a suitable combination of food density and dissolved oxygen concentrations.

Locations predominated by *Hydrilla* constituted the majority of grass carp locations. *Hydrilla* is an excellent food for grass carp because of the soft nature of the plant and high ash content (Tan 1970; Rottman 1977). Grass carp used in this study were large (704-mm TL), and according to Sutton and Vandiver (1986), *Hydrilla* would be their preferred food. No data exist concerning the percentage of Lake Marion's total nuisance aquatic weeds that the individual species comprise. Thus, no preferences for *Hydrilla* can be inferred in the present study.

Summary

No long distance migrations were observed, and fish showed no affinity for the Santee River channel. Triploid grass carp remained in the upper part of Lake Marion, and these fish did not leave areas targeted for aquatic vegetation control. Dissolved oxygen levels appeared to play an important part in the location and movement of fish. In addition, water quality and aquatic vegetation distribution for upper Lake Marion are needed in order to interpret movements relative to available habitat.

Acknowledgments

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