# Grass Carp Movement and Persistence in Felsenthal Reservoir, Arkansas

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*Abstract:* Excessive coverage of aquatic vegetation has reduced aesthetic quality and recreational value in Felsenthal Reservoir, Arkansas. A large portion of the 6,000-ha impoundment of the Ouachita River, located within the Felsenthal National Wildlife Refuge, is covered by dense aquatic vegetation. Grass carp are commonly used to control aquatic vegetation in closed systems, but results of stocking grass carp for vegetation control in open systems is less certain. Radio transmitters were implanted in 48 adult triploid grass carp. Grass carp were released in the reservoir during fall 2006. Radio-tagged grass carp were relocated approximately semi-monthly during a 12-mo period. Of the 48 fish that were stocked, 39 (82%) were consistently located in Felsenthal Reservoir. Three fish (6%) were never relocated, one fish (2%) moved upstream of Felsenthal Reservoir then returned, and five fish (10%) were located upstream of Felsenthal Reservoir in both the Ouachita and Saline Rivers. Average (SD) home range was 576 (638) ha. Maximum movement from release site averaged 5.7 and 51.4 km for grass carp that remained in and left Felsenthal Reservoir, respectively. The greatest amount of movement occurred during the fall season, with an average daily movement of 238 m/d. Grass carp stocked into Felsenthal Reservoir were not likely to emigrate, and if they did, they were more likely to move upstream than downstream.

*Key words:* grass carp, telemetry, home range

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Because primary production is the first level of a trophic pyramid, aquatic plants are crucial to a healthy ecosystem (Smart et al. 1996). They provide important sources of oxygen and perform such functions as sediment stabilization and provision of refuges for juvenile fish (Caraco et al. 2006). Rooted macrophytes take up nutrients from sediment, which are later released when the plants die. The leaves of submerged macrophytes provide substrate for the attachment of epiphytic plants and animals. Phytoplankton provides food for herbivorous forage fish that are in turn consumed by carnivores. Therefore, plants are an integral part of aquatic systems.

A moderate (~30% coverage) amount of vegetation in aquatic systems is optimal (Savino and Stein 1982). Too few plants may result in low productivity, and too much vegetation can have a negative impact. Dense growth of aquatic vegetation limits fish predator/prey interactions, which could lead to reduced growth rates of predators (Bain and Boltz 1992) and stunting of prey (Savino and Stein 1982, Bettoli et al. 1992). Excessive vegetation can also lead to low oxygen levels due to macrophyte decay (Caraco et al. 2006). Wiley et al. (1984) concluded that an intermediate macrophyte standing stock maximized largemouth bass production in Illinois ponds.

Aquatic vegetation is abundant in Felsenthal Reservoir, covering a large portion of the 6,000-ha impoundment. Due to the shallow nature of the reservoir, native aquatic vegetation became established soon after impoundment. Coverage increased slowly during the first 10 years following impoundment (1985–1995). During the late 1990s and early 2000s, macrophytes such as fanwort (*Cabomba caroliniana*), American lotus (*Nelumbo lutea)*, fragrant water-lily (*Nymphaea odorata*), duckweeds (*Lemna* spp), and various marginal plant species began to spread rapidly throughout the reservoir. By 2004, almost all of the additional 4,047 ha impounded in 1985 was covered by aquatic vegetation. In 2004, hydrilla (*Hydrilla verticillata*) was discovered, and it began to colonize deeper water than the native species. Hydrilla became established in backwater areas, as well as along the Ouachita River channel.

Excessive vegetation in Felsenthal Reservoir has had negative ecological and economic consequences. Anglers, waterfowl hunters, and birdwatchers are unable to utilize densely vegetated portions of the reservoir. Usage of reservoir boating access facilities has declined by 40% since vegetation became a problem in the early 2000s (Williams 2009). As a result, much attention has been placed on controlling aquatic vegetation in Felsenthal Reservoir.

Control of aquatic vegetation may be undertaken by mechani-

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cal, chemical, or biological methods. Biological control is a cost-effective means of managing over-abundant vegetation (Sanders et al. 1991, Chilton and Muoneke 1992). Grass carp (*Ctenopharyngodon idella*) are the most commonly used fish species for biological aquatic vegetation control in the United States (Chilton and Muoneke 1992). The cost of aquatic plant control using grass carp in small water bodies is somewhat less than US$250/ha (Shireman et al. 1985, Beyers and Carlson 1993). Additionally, biological control does not require re-application on a regular basis. Shireman et al. (1985) showed that benefits of stocking grass carp extended more than seven years. Mechanical or chemical control of vegetation is generally less cost-effective (Morris and Clayton 2006), especially in large systems. Stott et al. (1971) and Shireman (1982) reported that the use of herbicides to control nuisance, submerged aquatic vegetation was 6 and 14 times more expensive than using grass carp.

Grass carp are commonly used to control submerged vegetation in lakes and ponds. Grass carp reduced densities of *Potamogeton*, *Elodea*, *Ceratophyllum*, and *Najas* in an Iowa lake by an order of magnitude (Mitzner 1978). Leslie et al. (1983) successfully controlled hydrilla in central Florida lakes with grass carp. Bonar et al. (1993) reduced total volume of vegetation in an Oregon lake using grass carp. In these instances, grass carp were stocked into essentially closed systems, where emigration was unlikely.

In open systems, there is a chance that grass carp will emigrate, inhibiting their successful use. For example, Prentice et al. (1998) tagged grass carp and stocked them into a series of reservoirs on the Guadalupe River, Texas. Grass carp migrated downstream, and emigration rates appeared related to flow. Emigration during high-flow conditions was 59% in a 6-mo period. Adult grass carp stocked into a mainstream reservoir of the Tennessee River moved an average of 32.7 km during a 4-mo period, and moved both upstream and downstream (Bain et al. 1990). Conversely, Clapp et al. (1993) found that grass carp did not leave Lake Harris, Florida, an open system with navigable waterways connecting it to a chain of other lakes. Kirk et al. (2001) found no extensive migrations of grass carp stocked into the Cooper River, a coastal river in South Carolina.

Felsenthal Reservoir is an open system and grass carp could emigrate without affecting vegetation. Thus, a radio-telemetry study was undertaken to determine the probability of grass carp remaining long enough to affect vegetation. The first objective of this study was to determine the proportion of recently-stocked grass carp that persisted in or near Felsenthal Reservoir for a 12-mo period, while the second objective was to evaluate movement and dispersion of radio-tagged grass carp in Felsenthal Reservoir.

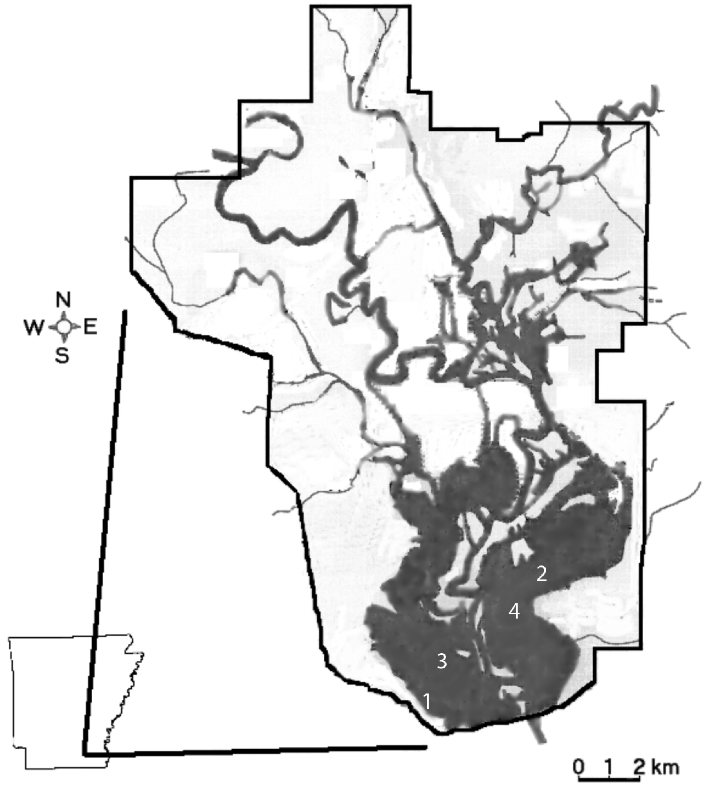


**Figure 1.** Map of Felsenthal Reservoir. Numbers indicate stocking locations. Boundary lines of Felsenthal National Wildlife Refuge are shown.

## Study Site

Felsenthal Reservoir is a 6,000-ha impoundment on the Ouachita River, Arkansas (Figure 1). The reservoir is part of the U.S. Army Corps of Engineers' (USACOE) Ouachita-Black River Navigation Project (OBNP), and is the third of four navigation pools going upstream on the Ouachita River. The OBNP provides a minimum 2.74-m navigation channel year-round. The reservoir, as it presently exists, was impounded in 1985, when a new lock and dam was constructed, replacing an old navigation system and raising the water level of the impoundment by 1.04 m to 19.8 m above mean sea level. Because of the level terrain in what is known as the Felsenthal Basin, raising the water level increased the size of the reservoir from 2,023 ha to its current size (Turman and Olive 2008). Most of the 4,047 ha impounded by the creation of the OBNP is less than 1m in depth, making it ideal for growth of aquatic vegetation. The Ouachita River channel bisects the reservoir, with large backwater areas on both the east and west sides, connected to the river channel via small artificial cuts and sloughs.

As mitigation for the OBNP, the Felsenthal National Wildlife Refuge was created. This 26,305-ha refuge completely encompasses Felsenthal Reservoir, giving the U.S. Fish and Wildlife Service (USFWS) primary authority over reservoir management. The USACOE and the Arkansas Game and Fish Commission (AGFC) also have authority over some aspects of reservoir management (Turman and Olive 2008). The USACOE is charged with maintaining a 2.74-m navigation channel at all times, which prevents the reservoir from being drawn down as a means of controlling unwanted vegetation. Water levels are dependent upon releases from three headwater impoundments, as well as H. K. Thatcher Lock and Dam, which is the headwater of Felsenthal Reservoir. The four dams on the OBNP have navigation passes which allow boats to bypass the locks during periods of high flows, but also allows for unimpeded fish passage.

## Methods

On 12–13 October 2006, radio transmitters (Lotek MBFT-3A; 16 g in air; 16 x 46 mm) were surgically implanted in 48 triploid grass carp. Mean total length was 496 mm (range 425–702 mm), and mean weight was 1.31 kg (range 0.75–3.85 kg). Surgeries were performed at the Andrew Hulsey State Fish Hatchery in Hot Springs, Arkansas, by researchers from the University of Arkansas at Pine Bluff (UAPB) Aquaculture and Fisheries Center using methods described by Schramm and Black (1984). Each transmitter had a unique frequency and was inserted through an incision near the pelvic fin base with the antenna protruding from a point ~15 mm posterior to the original incision. Estimated life span of the transmitters was 430 d. Detection distance under the conditions in Felsenthal Reservoir probably ranged from 700 to 1500 m. Transmitter weight did not exceed 2% body weight of any fish.

Forty-four of the transmitter equipped grass carp were stocked in Felsenthal Reservoir on 20 October 2006. Immediately prior to stocking, the transmitter in each fish was checked to ensure proper functioning. Four transmitters failed to work properly, so those fish were not stocked. Grass carp were stocked by boat in four locations—two sites each on the east and west sides of the reservoir. Four additional fish were obtained in November 2006 and surgeries were performed using the same procedure as before to implant replacement transmitters from Lotek. The four additional fish were stocked on 4 December 2006.

Surveys to locate radio-tagged grass carp began 3 d after stocking the initial 44 fish. Boat surveys were conducted 1–4 times each month during the 344-d study ($n = 24$ surveys). A standard survey route through the reservoir was established to maintain consistent effort over the course of the study. Surveys were conducted most frequently during the first 180 d post stocking (October–April). In addition, four aerial surveys were conducted during the study to locate fish not located by boat. Aerial surveys were concentrated primarily during high-water periods when the reservoir more than doubled in size and tracking by boat was inefficient. Aerial surveys followed the Ouachita River from just north of Calion, Arkansas (approximately 95-km upstream of Felsenthal Lock and Dam); downstream to Monroe, Louisiana (approximately 88-km downstream of Felsenthal Lock and Dam); as well as up the Saline River from its mouth to near Rye, Arkansas (approximately 110-km upstream from the mouth). Fish locations were recorded using a global positioning system (GPS).

GPS location data were entered into a database, which was imported into ArcMap 9.1 and ArcGIS 9.0 (ESRI, Inc., Redland, California) for analyses. Data from both boat and aerial surveys were used to determine the proportion of fish that remained in or near Felsenthal Reservoir for 344 d post stocking. Home range was determined with Home Range Tool, an extension of ArcGIS 9.0 (Rodgers et al. 2005). Home range was calculated using the fixed arithmetic mean method. This method creates a polygon that contains 95% of the locations closest to the geographic mean of the center of the home range. After calculating home range for each fish, these polygons were placed individually over a base map, and the terrestrial portions within each home range were subtracted from the home range area.

Data from boat tracking surveys were used to analyze distances traveled by grass carp within the reservoir. Maximum movements from release site were evaluated to assess the magnitude of dispersion. Movement patterns were also evaluated to determine the extent to which movement varied among seasons. Seasons were divided into fall (October–December), winter (January–March), spring (April–June), and summer (July–September). Only those fish that were located at least twice during a season were used to calculate average daily movement (ADM) for that season. Differences in ADM among seasons were examined with repeated measures ANOVA ($\alpha = 0.05$). A Tukey multiple comparison test was used as a post-hoc mean separation test. Both tests were analyzed using the GLM procedure in SAS (SAS 2002).

During high-water events, when water levels below the dam are within one foot of water levels above the dam, the river becomes an open system. Boats, debris, and fish can move freely downstream due to the design of Felsenthal Lock and Dam and the nature of the Ouachita River system. Therefore, gage height readings from Felsenthal Lock and Dam were obtained from the National Weather Service Office in Shreveport, Louisiana, and were examined to determine the number of days during the study that river flow, and thus, fish movement, was unimpeded by the dam.

## Results

Forty-five grass carp were located at both the beginning (immediately following each stocking) and end of the study, and three fish were never located. Thirty-nine grass carp (81%) were relocated in Felsenthal Reservoir throughout the study. One fish moved upstream of Felsenthal Reservoir and then returned. Five fish were located upstream of Felsenthal Reservoir in either the Ouachita or Saline Rivers at the end of the study. No fish were located downstream of Felsenthal Lock and Dam. The mean number of observations by boat for fish that remained in Felsenthal Reservoir was 18 out of a possible 24 (range = 1–24 ). Home range was calculated for forty-five of the grass carp. Minimum and maximum home ranges were 50 and 3,540 ha, and averaged 576 ha. Home range was less than 600 ha for most of the grass carp (Figure 2).

The maximum movement from release site averaged 5.7 km (range = 1.2–15.0 km) during the study for fish consistently located within the reservoir. Fish that left Felsenthal Reservoir traveled the farthest distances from their release location, and their maximum movement averaged 51.4 km (range = 39.9–54.9 km; Table 1). Grass carp movement appeared variable among seasons. Fall ADM was significantly greater than ADM in other seasons ($P < 0.001$). Fall ADM was 238 m ($n = 46$ SD = 136 m; Figure 3). The ADM for winter, spring, and summer were 55 m ($n = 40$ SD = 71 m), 28 m ($n = 38$ SD = 32 m), and 17 m ($n = 39$ SD = 18 m), respectively (Figure 3).

The total length of the telemetry study, between the time the fish were stocked, and when the final tracking survey was conducted was 344 d. During this period, Felsenthal Lock and Dam gage-height data indicated that water levels allowed free movement of fish below the dam for 64 d. However, no fish were located below Felsenthal Lock and Dam during the study.

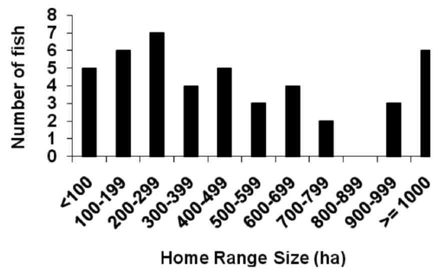


**Figure 2.** Frequency distribution of grass carp home range size (ha) in Felsenthal Reservoir.

**Table 1.** Maximum linear distance traveled from release site for fish that left Felsenthal Reservoir during the 344-d study.

| Fish ID | Max linear distance (km) | Landmark |
|---|---|---|
| 24 | 39.9 | Below Thatcher L&D |
| 29 | 74.6 | Saline R. near Rye |
| 32 | 44.9 | Calion Pool |
| 43 | 42.6 | Saline R. above Longview |
| 47 | 54.9 | Upstream of Calion |

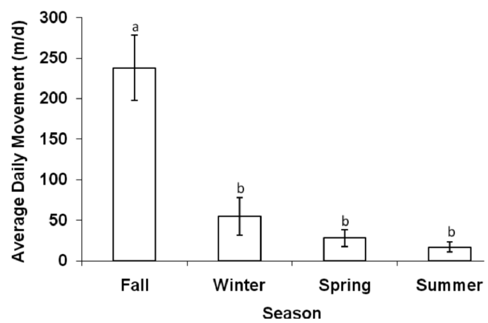


**Figure 3.** Average daily movement of grass carp in Felsenthal Reservoir during 2006–2007 divided into fall (October–December), winter (January–March), spring (April–June), and summer (July–September) seasons. Error bars represent 95% confidence intervals, letters indicate significant differences (Tukey $P < 0.05$).

## Discussion

The first objective of this study was to determine the proportion of grass carp that remained in Felsenthal Reservoir. Of the 45 grass carp observed during the study, 40 (89%) were located within Felsenthal Reservoir at the end of the study. The other five grass carp were all located upstream of Felsenthal Reservoir in Arkansas. During 64 d of the study, water levels were equal above and below Felsenthal Lock and Dam, which allows for the free passage of fish across the dam. Despite high flows, 81% of stocked grass carp were consistently located in the reservoir. These results are contrary to several previous studies, which found that grass carp moved a great deal in open systems, and even emigrate during periods of flooding (Bain et al. 1990, Prentice et al. 1998). Due to the open-system characteristics of Felsenthal Reservoir, the possibility for emigration of grass carp has prevented their use for vegetation control to this point. However, the results of this study suggest that downstream emigration from this system may be unlikely to occur.

Home range in this study was somewhat smaller than home ranges reported in other studies. Average home range in our study was similar to the 378-ha average home range reported by Clapp et al. (1993) for a closed Florida lake. However, Chilton and Poarch (1997) and Clapp et al. (1993) both reported average home ranges greater than 3,000 ha for grass carp in open systems in Texas and Florida. Home ranges of that magnitude were only observed for approximately six grass carp during this study, despite 6,000 ha available for use.

A second objective of this study was to evaluate grass carp dispersion and movement. Average maximum movement from release site for this study was similar to movements from release sites in other grass carp telemetry studies in open systems. Average maximum movement from release site in open systems usually ranges from less than 1 km to about 15 km (Bain et al. 1990, Clapp et al. 1993, Kirk et al. 2001). However, for the small group of grass carp that left Felsenthal Reservoir, average maximum movement was much greater. This is similar to the results of Prentice et al. (1998) for a reservoir chain on the Guadalupe River, Texas, where average maximum movement from release site was as high as 296 km. Some grass carp invariably seem to move great distances in open systems, where there is a possibility of greater movement. As demonstrated in this study, the proportion of grass carp that move large distances may be low.

Average daily movement for this study was similar to ADM in several other grass carp telemetry studies. Average daily movement is typically less than 200 m/d (Bain et al. 1990, Clapp et al. 1993, Chilton and Poarch 1997), but can occasionally be high in open systems such as those reported by Prentice et al. (1998) and Nixon and Miller (1978) that were as high as 517 and 4,457 m/d, respectively. Previous research has shown that grass carp move a great deal during warmer months, but are more sedentary during winter months when water temperatures are typically lower (Nixon and Miller 1978, Bain et al. 1990). Other studies have shown that grass carp move a great deal during the first few weeks post stocking then establish a home range and do not move significantly unless conditions such as water level, flow, or temperature change (Nixon and Miller 1978, Chilton and Poarch 1997). This study indicated that fish dispersed widely during the first 90 d post stocking which coincided with cooler water temperatures during fall and winter. Thereafter, grass carp seemed to establish a home range, and did not move great distances despite warmer water temperatures later in the study. It is possible that daily movement during warmer months was equal to or greater than movement during earlier time periods, but the movements occurred within a confined home range rather than into different areas of the reservoir, as was occurring during the first few months following stocking. Twenty-four hour tracking events were not conducted to determine whether or not this was the case. These results reflect a temporal change in behavior by grass carp, and should not be viewed as an indication of energetic output.

This study showed that the majority of grass carp stocked into Felsenthal Reservoir did not emigrate from the system during their first year. Grass carp were more likely to move upstream than downstream when they did emigrate. Study results also suggest that grass carp may disperse throughout the reservoir from any given stocking site, consistent with the findings of Clapp et al. (1993). Similar to Kirk et al. (2001), it appeared that the grass carp found abundant food resources in relatively small areas, and remained stationary following an initial period of acclimation. These results suggest that grass carp may be a viable option for controlling nuisance aquatic vegetation in Felsenthal Reservoir.

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