Radio-Tagging Studies with Grass Carp in Two Texas Reservoirs

by
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Introduction

In many areas, particularly Southern States such as Florida and Texas, aquatic plant growth has become a serious problem. Hydrilla (*Hydrilla verticillata*), Eurasian watermilfoil (*Myriophyllum spicatum*), waterhyacinth (*Eichhornia crassipes*), and others disrupt fishing and boating, and decaying plant material adversely affects the taste of public drinking water. Grass carp (*Ctenopharyngodon idella* Val.) have been effective as biological control agents for aquatic macrophytes in many situations (Van Dyke, Leslie, and Nall 1984; Noble et al. 1986; Thompson, Underwood, and Hestand 1988). Chilton and Muoneke (1992) provide an extensive review of grass carp use and biology. Movement is an important factor in any evaluation of grass carp effectiveness. Fish that move extensively over time may be more likely to emigrate to areas where they are unwanted and less likely to remain in targeted areas.

To assess triploid grass carp movement, radio-tracking studies were conducted in two Texas mainstream reservoirs. Few detailed observations of grass carp movement patterns are published, and those usually report on a limited number of fish (Nixon and Miller 1978; Hockin, O'Hara, and Eaton 1989; Bain et al. 1990; Clapp et al. 1993), or provide only short-term tracking information (Nixon and Miller 1978). For example, data from Hockin, O'Hara, and Eaton (1989) and Beyers and Carlson (1993) included only 5 and 14 fish, respectively, whereas Nixon and Miller's (1978) study only lasted 1.5 months because of the battery life of the radio tags used.

Information about diurnal movements is necessary to determine if fish are visiting secondary feeding areas at night. Only two studies, Hockin, O'Hara, and Eaton (1989) and Beyers and Carlson (1993), have reported on grass carp movements over 24 hr, and both were conducted under very limited conditions. Both studies were conducted in canals; without further investigation, it is difficult to assess their usefulness in predicting grass carp diurnal behavior in larger water bodies, where greater movement is possible such as in mainstream reservoirs.

Objectives of this study were to determine the following: (a) magnitude of triploid grass carp movements within each reservoir, (b) distribution of grass carp relative to aquatic vegetation within each reservoir, and (c) diurnal changes in magnitude of grass carp movements.

Study Sites

Lake Texana is formed by the impoundment of the Navidad River (with significant inflows from Sandy and Mustang creeks (Figure 1)) about 50 km east of Victoria, TX, and covers an area of 4,453 ha. Mean depth is 4.7 m, and maximum depth is 13.4 m. The plant community is dominated by hydrilla, coontail (*Ceratophyllum demersum*), and water hyacinth. American lotus (*Nelumbo lutea*), cattail (*Typha latifolia*), smartweed (*Polygonum hydropiperoides*), and pondweed *Potamogeton* spp.) are present and abundant in places. Lake Weatherford is formed by impoundment of the Clear Fork of the Trinity River about 50 km west of the Dallas-Fort Worth area and covers an area of 445 ha.

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Mean depth is 4.6 m, and maximum depth is 12.5 m. Except for pondweed, American lotus, and coontail, found inside cages during an exclosure study, and 1 g of pondweed found outside cages, bulrush (*Scirpus* spp.), is the only macrophyte found in Lake Weatherford (Poarch and Chilton 1992).

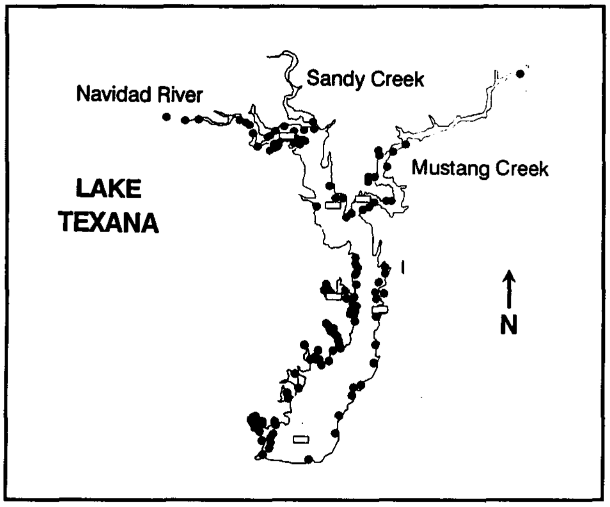

Figure 1. Map of Lake Texana indicating all locations where triploid grass carp stocked in 1990 were found during course of radio-tracking studies (circles) and triploid grass carp stocking sites (rectangles)

Methods

Ninety-five triploid grass carp (mean weight = 1.6 kg, mean total length = 503 mm, size range = 0.5 to 4.7 kg, 369 to 813 mm) were surgically implanted with radio tags equipped with internal loop antennas during June 1990. Tag frequencies ranged from 48 to 50 MHz. Often two tags transmitted on the same frequency, but were distinguished by pulse rate differences (40 or 50 pulses per minute). Fish were divided into groups of 15 or 16 and released at six sites (two stocking sites each in the lower, middle, and upper end of the reservoir) (Figure 1). To locate fish, the entire reservoir was searched by boat, including several miles upstream in the three major tributaries, at 1-week intervals for 3 weeks, 2-week intervals for 8 weeks, and 1-month intervals thereafter.

We conducted 24-hr tracking studies in December 1990 and in February 1991. Ten fish were tracked at 4-hr intervals for 24 hr on each occasion.

In April 1991, 26 additional triploid grass carp (mean weight = 3.75 kg, mean total length = 662 mm, size range = 5.34 to 9.31 kg, 586 to 688 mm) were implanted with tags equipped with external whip antennas, and groups of four or five were released at each of the six original stocking sites. Twelve of the newly stocked fish were tracked at 4-hr intervals for the first 24 hr, and again 48 hr after release. Newly stocked fish were tracked after 1 week, at 2-week intervals for 10 weeks and 1-month intervals thereafter. Another 24-hr tracking study using the same 12 fish was conducted 3 months after release.

In August 1990, 10 triploid grass carp (mean weight = 1.5 kg, mean total length = 495 mm, size range = 1.4 to 1.8 kg, 482 to 506 mm) were implanted with internal loop antenna radio tags and released at one stocking site in Lake Weatherford. Tracking intervals were 1 week for 1 month, 2 weeks for 2 months, and 1-month thereafter. Five fish were tracked at 2-hr intervals for 24 hr in October 1990 and in March 1991.

Fish location was marked on a grid map of each reservoir, and average daily movement (ADM), in $m \bullet d^{-1}$, was calculated for each instance of observed movement. ADM was used to analyze movement patterns through time. Data collected during the first 3 months after release were used to compare differences in movement between 1990 and 1991. Only data from fish located at least four times were used (week 1 movement data for 1991 were not used since there were no week 1 data for 1990). Data were log-transformed to stabilize variances. Core use and home range areas were calculated following Kartalia and Foltz (1994, in preparation).

Results

Lake Texana

Only 69 of the 95 radio-tagged fish originally released in Lake Texana were found during the study. Of those, 6 were located once, 8 were located twice, and 10 were located only three times. Eleven of the forty-five fish located four or more times moved almost exclusively during the first few weeks after release.

Fish released in 1990 were always associated with littoral vegetation, primarily in or near beds of hydrilla and secondarily coontail, followed by American lotus, cattail, smartweed, and pondweed. None were associated with water hyacinth, although it was very abundant in certain areas of the reservoir. Grass carp distribution was skewed toward areas with the most abundant submerged vegetation (Figure 1).

Mean ADM for 1990 was 30.7 m•d^{-1}, and mean ADM for the first 3 months after release in 1990 was 28.4 m•d^{-1}. In general, ADM decreased through time (Figure 2).

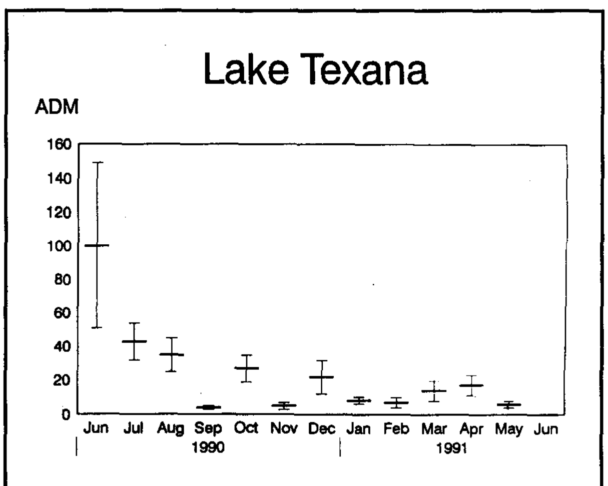

Figure 2. Average daily movement (ADM) (m•d^{-1}) of triploid grass carp stocked in 1990, Lake Texana, Texas. Error bars represent standard errors

Most observed movement of fish released in 1991 occurred within 1 week after release. During the first 3 months, 34.3 percent of movement occurred within the first 2 days after release; 56.4 percent occurred within the first week (movement recorded for the first 2 days after release was not included in this calculation). For the entire study period, 33.1 percent of movement occurred within 2 days, and 47.2 percent occurred within 1 week. ADM was 1,255.4 m•d^{-1} (N = 25, S.E. = 166.4), and 409.3 m•d^{-1} (N = 25, S.E. = 47.9) at 48 hr and 1-week postrelease, respectively. A quiescent period, exhibited by 21 of 26 fish (81 percent) released in 1991, followed initial movement. Mean ADM for the first 3 months after release in 1991 was 116.2 m•d^{-1} (N = 24, S.E. = 15.9).

Fifteen of the twenty-six fish released in 1991 had moved upstream, relative to their initial stocking location, by the last date they were found. In some cases, directionality was difficult to determine.

Average movement during the first 24 hr after release in 1991 was 2.96 km (S.E. = 0.58, range = 0.47 to 7.41 km). However, after 3 months of acclimation, 24-hr tracking studies revealed little diurnal movement for most fish. During the two 24-hr tracking studies with 1990-released fish, 54 percent of our observations indicated zero movement, and 87 percent indicated movement <200 m. Eighty-three percent of movement resulted from fish moving back and forth between stable sites. Fifty-seven percent of observed movement occurred between 0400 and 1200 hr, but was not correlated to water temperature. Similar results were obtained in 1991 (after fish had acclimated) when 78.6 percent of all observations indicated zero movement. Forty-four percent of movement was the result of fish traveling back and forth, and 56 percent of all recorded movement was during 0800 to 1200 hr.

Lake Weatherford

All fish were located at least once. At each location, fish were associated with bulrush, primarily in the upstream portion of the reservoir (Figure 3). As in Lake Texana,

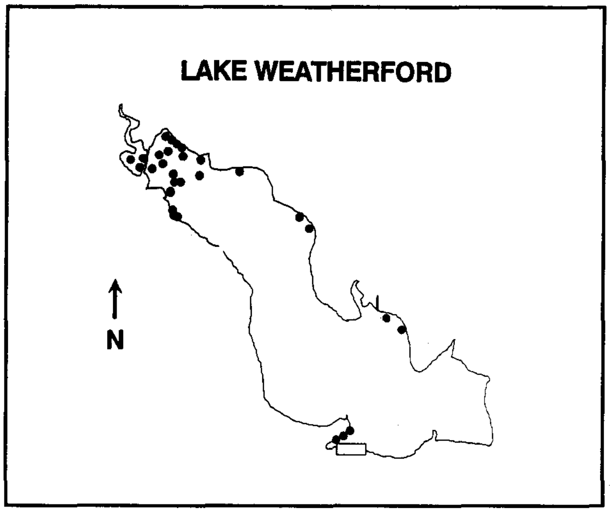

Figure 3. Map of Lake Weatherford indicating stocking site (rectangle) and all locations where triploid grass carp were found during course of radio-tracking studies in 1990 and 1991

movement was most intense during the first week after release; ADM was only about half as great if the first week is treated as an acclimation period (Table 1). Only two fish exhibited movement >200 m after that time, whereas, seven fish began a quiescent period. The period lasted an average of 54.6 days (S.E. = 14.7, range = 6 to 116 days; some fish never moved after the initial period; in those cases, for purposes of calculation, the quiescent period ended at the end of the calendar year).

During 24-hr radio-tracking studies, only one fish moved, and it moved less than 15 m.

Discussion

Our data indicate that upon release, grass carp undergo a period of rapid movement and dispersal, followed by a time of relative inactivity. Nixon and Miller (1978) and Kartalia and Foltz (Personal Communication, Clemson University) reported similar results. A period of inactivity by grass carp, after acclimation, is consistent with their behavior in native habitats. Gorbach and Krykhtin (1988) reported juvenile grass carp may feed for years in the lower reaches of the Amur River. After this period of growth and relatively little long-range movement in the lower portions of the river, they begin an upstream migration to their spawning grounds, traveling as much as 500 km in the first 2 years of the migration. In our study, the fish released in 1991 (mean length 662 mm) were already well within the size range of fish that would have begun their normal upstream migration, and it is not surprising that some exhibited a strong upstream component in their movements.

At least 60 percent of the fish released into Lake Weatherford exhibited upstream movements. However, the data are somewhat difficult to interpret; since virtually all of the plant biomass was found in the upper portions of the reservoir, fish may have been simply going where the food was.

Several fish were found several miles upstream in both the Navidad River and Mustang

Table 1
Average Daily Movement (ADM) of Triploid Grass Carp in Lake Weatherford, Texas

Fish	Overall			Excluding Week 1		
	ADM, $m \cdot d^{-1}$	S.E.	N	ADM, $m \cdot d^{-1}$	S.E.	N
1	64.2	24.6	12	43.1	13.8	11
2	37.6	25.2	12	14.4	10.7	11
3	37.5	22.2	14	16.5	8.1	13
4	0.3	0.3	7	0.3	0.3	7
5	1.7	1.1	14	0.9	0.7	13
6	13.2	10.0	13	3.9	3.9	12
7	53.5	34.4	12	46.3	36.9	11
8	32.9	27.7	13	5.2	1.8	12
9	1.0	1.0	11	0.0	0.0	10
10	117.6	55.6	4	64.8	24.5	3

Note: Overall mean ADM was 36.0 (S.E = 11.5, N = 10), and mean ADM excluding movement during the first week was 19.5 (S.E. = 7.4, N = 10).

Creek, but no fish were located more than 200 m upstream in Sandy Creek. Fish found upstream generally remained in one location over an extended period of time or traveled back down into the main body of Lake Texana. However, movement back into the reservoir was probably precipitated by lack of food in the tributaries where vegetation was sparse. Movement via tributaries could be significant in certain areas of Florida where vegetated lakes are connected by relatively short water courses. After vegetation removal in one lake, it is probable that fish will migrate via such courses if a barrier is not present.

The only instance of significant movement over a 24-hr period was immediately following grass carp release in 1991. All other 24-hr studies indicated minimal diurnal movement, usually during the morning. This result is consistent with data reported by Hockin, O'Hara, and Eaton (1989), who investigated grass carp movement in an unnavigated portion of the Lancaster Canal, Great Britain, and found, although fish moved and fed at all times, activity was greatest around dawn and remained high until noon. As in our study, Hockin, O'Hara, and Eaton (1989) reported diurnal movement was uncorrelated with water temperature; Cassani and Maloney (1991) found that water temperature, 22.2 to 30.3 °C, did not significantly affect grass carp average speed. In general, temperature shifts over 24-hr are probably not sufficient to significantly affect activity.

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