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Longevity and Persistence of Triploid Grass Carp Stocked into the Santee Cooper Reservoirs of South Carolina

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ABSTRACT

This study evaluated longevity and population persistence of 768,500 triploid grass carp (*Ctenopharyngodon idella* Valenciennes) stocked in the 70,000-ha Santee Cooper system in South Carolina from 1989 through 1996 to control hydrilla (*Hydrilla verticillata* (L.f.) Royle). Collected from 1998 through 2002, the oldest of 477 fish were age 11. Total annual mortality rates ranged from 22% to 39% meaning 10% of a cohort could persist for 5 to 9 years. Longevity and persistence measured in this study demonstrate that benefits of aquatic plant control and risks to non-target organisms need to be carefully balanced. Annual stocking of as many as 150,000 could potentially leave numerous fish in this system for almost a decade. Conversely, control of hydrilla, achieved since 1997, is unlikely to last more than few more years.

Key words: mortality, biological impacts, *Ctenopharyngodon idella*, weed control.

INTRODUCTION

Triploid grass carp have been used to control nuisance aquatic vegetation in both large and small impoundments for almost 20 years (Sutton and Vandiver 1986, Wattendorf and Anderson 1986). However, use of triploid grass carp in large reservoir systems is still limited and controversial. Improving this aquatic plant management tool will depend on resolving issues related to stocking densities, migration, impacts to non-target organisms, and population dynamics (Bain 1993).

Cassani et al. (1995) and Schramm and Brice (1998) developed stocking densities resulting in an intermediate level of aquatic plant control in small impoundments. Similar results have not been achieved consistently in large reservoir systems despite some recent advances in assessment (Morrow et al. 1997). Consequently, triploid grass carp have been stocked where risks of use were outweighed by either herbicide costs or label restrictions. Examples include Lakes Murray, Moultrie, and Marion in South Carolina.

Movement of triploid grass carp out of the target areas or entirely out of open reservoir systems is considered to be a serious limitation (Bain 1993). Maceina et al. (1999) stated the likelihood of emigration prevented the use of triploid grass carp in Lake Seminole, Florida. Other studies have revealed movements from reservoirs into coastal rivers and es-

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tuaries (Jacobson and Kartalia 1994, Webb et al. 1994, Elder and Murphy 1997). Conversely, telemetry studies by Foltz et al. (1994) suggested that triploid grass carp stocked in a reservoir moved to sites with abundant forage and remained there. Kirk et al. (2001) examined movements in a coastal river and found that triploid grass carp did not migrate into brackish water and remained year around near stands of hydrilla. The study concluded, based upon a review of the literature, that migrations were possible and recommended performing site specific assessments before using triploid grass carp in large systems.

Collection and aging techniques to assess population dynamics of grass carp in large reservoir systems were developed during the 1990s. Diploid grass carp stocked into Lake Guntersville, Alabama (Morrow and Kirk 1995), as well as triploid fish in the Santee Cooper Reservoirs, South Carolina, were evaluated (Morrow et al. 1997, Kirk et al. 2000). These studies attempted to estimate growth, mortality, condition parameters, and project population decline. However, information developed from these assessments has not been used to determine subsequent stocking requirements.

The ability to predict longevity and persistence of stocked fish is essential in addressing the limitations of triploid grass carp used for aquatic plant control. Unfortunately, little published information deals with either longevity or persistence of stocked triploid grass carp. Earlier studies in the Santee Cooper reservoirs suggested few fish survived beyond age 9 (Kirk et al. 2000). Sutton and Vandiver (1986) stated grass carp had a life span in Florida of about 10 years, and Gorbach (1971) estimated a life span of 21 years in the Amur River. Allen and Wattendorf (1987) reported longevity ranged from 10 to 15 years. Aging techniques improved in the 1990s when lapillar otoliths were validated as an aging structure (Morrow et al. 1997) and this refinement allowed biologists to better estimate longevity.

In this study, we used age structure and total mortality estimates of triploid grass carp, collected for population assessments from 1998 through 2002 in the Santee Cooper system, South Carolina, to estimate longevity and population persistence. In that regard, "longevity" was defined as the maximum age of fish collected in routine sampling and "persistence" as the number of years that 10% of a cohort would remain. A value of 10% was chosen since, during some years, 150,000 triploid grass carp were stocked system-wide, and in our judgment, even 10% of that stocking could still have biologically significant impacts upon aquatic vegetation or non-target organisms.

METHODS

The Santee Cooper system (70,000 ha) in South Carolina consists of Lake Marion, Lake Moultrie, and a diversion canal connecting the reservoirs. The system has a long history of aquatic plant infestations culminating with the invasion of hydrilla during the 1980s (Morrow et al. 1997). A total of 768,500 triploid grass carp were stocked from 1989 through 1996, hydrilla coverage peaked in 1994 at 17,272 ha, and submersed aquatic vegetation was eliminated by 1997 (Kirk et al. 2000).

Collection, aging, and assessment techniques used in this study were described by Morrow et al. (1997) as follows. About 100 triploid grass carp were collected yearly from 1998 through 2002 by bowfishers paid a bounty. Collected fish were delivered to South Carolina Department of Natural Resources biologists for processing. Fish were weighed, measured for total length, and lipillar otoliths were removed. Sectioned otoliths were aged by two biologists and differences in age reconciled. Mortality was estimated with a catch curve (Ricker 1975) and population trends were simulated with MOCPOP 2.0 software (Beamesderfer 1991)

RESULTS AND DISCUSSION

A total of 477 triploid grass carp collected during 1998 through 2002 were aged and none were older than age 11 (Table 1). The percentage of the fish age 10 or 11 increased as the minimum age of the stocked triploid grass carp increased. Only two of 102 triploid grass carp were age 10 when the youngest fish were age 3 and the oldest age 10. The number in this age group increased to 16 of 72 in 2002 when the youngest fish were age 7 and the oldest would have been age 14.

Total annual mortality rates ranged from 22% to 39%. These rates translate to a range of population persistence (i.e., the period where 10% of a cohort would still survive) of from 5 to 9 years.

The lifespan of triploid grass carp in the Santee Cooper reservoirs, South Carolina (latitude 33°N) is 11 years. This compares well with estimates of 10 years in Florida (Sutton and Vandiver 1986) and 10 to 15 years by Allen and Wattendorf (1987). Triploid grass carp may live longer at higher latitudes with shorter growing seasons and lower water temperatures. For example, maximum lifespan of wild grass carp in the Amur River was 21 years (Gorbach 1961) but Berg (1949) reported most fish in the commercial fishery were ages 5 through 11.

Population persistence is an important consideration in achieving and maintaining desired stocking densities. The levels of mortality estimated in this study suggest population persistence, and therefore some measure of aquatic plant control, of from 5 to 9 years. These estimates are in the range of aquatic plant control described by Mitzner (1978) and Shireman et al. (1985) of 5 years and 7 years, respectively. Additionally, the range of population persistence of 5 to 9 years suggests that small changes in total annual mortality can make a large difference in the persistence of a stocked population. Hence, accurate mortality estimates are impor-

TABLE 1. AGE CHARACTERISTICS AND TOTAL ANNUAL MORTALITY ESTIMATES FOR TRIPLOID GRASS CARP COLLECTED IN THE SANTEE COOPER RESERVOIRS, SOUTH CAROLINA FROM 1998 THROUGH 2002.

Year	Total annual mortality	Number age 10 or 11	Minimum age	Theoretical maximum age[1]
1998	33%	2 of 102	3	10
1999	39%	2 of 98	4	11
2000	35%	4 of 96	5	12
2001	22%	21 of 109	6	13
2002	38%	16 of 72	7	14

[1]The oldest possible age of triploid grass carp during that year. No fish older than age 11 were collected.

tant since a change in total mortality from 39% to 22% almost doubled the persistence of stocked fish.

A maximum lifespan of 11 years and population persistence from 5 to 9 years suggests triploid grass carp have potential to impact non-target aquatic vegetation and organisms for extended periods. The risk triploid grass carp persistence to non-target organisms will largely be determined by the scale of the stocking and the resulting densities. For example, stocking a couple hundred triploid grass carp in an enclosed reservoir embayment may not present a long term risk system wide since only a few dozen fish would be expected to survive more than five years. However, in the case of the Santee Cooper reservoirs, 150,000 fish were stocked one year and as many as 15,000 fish could survive for 5 to 9 years. This many fish could migrate or substantially impact on non-target aquatic vegetation over wide areas since the original stocking density to control established hydrilla was between 20 to 30 fish per vegetated ha (Kirk et al. 2000).

Our estimates of longevity and mortality could be useful in predicting population trends where assessments may not be possible. For example, mortality estimates would be difficult where a single stocking was employed. In such a circumstance, estimates of longevity and mortality developed in this study would be useful in using software such as a MOCPOP 2.0 (Beamesderfer 1991) to project population trends over time.

This study largely confirms previous studies regarding the lifespan and duration of aquatic plant control. Triploid grass carp stocked into southern waters can be expected to live about 11 years. The ranges of mortality estimated in the Santee Cooper reservoirs demonstrate that significant numbers of triploid grass carp will remain for a least 5 years and perhaps as long as 9 years. In that regard, hydrilla which was essentially eliminated in 1997, could rebound anytime in the next few years.

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