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Population Response of Triploid Grass Carp to Declining Levels of Hydrilla in the Santee Cooper Reservoirs, South Carolina

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ABSTRACT

Approximately 768,500 triploid grass carp (*Ctenopharyngodon idella* Valenciennes) were stocked into the Santee Cooper reservoirs, South Carolina between 1989 and 1996 to control hydrilla (*Hydrilla verticillata* (L.f.) Royle). Hydrilla coverage was reduced from a high of 17,272 ha during 1994 to a few ha by 1998. During 1997, 1998 and 1999, at least 98 triploid grass carp were collected yearly for population monitoring. Estimates of age, growth, and mortality, as well as population models, were used in the study to monitor triploid grass carp and predict population trends. Condition declined from that measured during a previous study in 1994. The annual mortality rate was estimated at 28% in 1997, 32% in 1998 and 39% in 1999; however, only the 1999 mortality rate was significantly different. Few (2 out of 98) of the triploid grass carp collected during 1999 were older than age 9. We expect increased mortality due to an aging population and sparse hydrilla coverage. During 1999, we estimated about 63,000 triploid grass carp system wide and project less than 3,000 fish by 2004, assuming no future stocking.

Key words: Aquatic plants, growth, mortality, aquatic plant management, population size *Ctenopharyngodon idella, Hydrilla verticillata.*

INTRODUCTION

Grass carp (*Ctenopharyngodon idella* Valenciennes) are used to control noxious aquatic plants, primarily hydrilla (*Hydrilla verticillata* (L.f.) Royle), a plant these fish consume preferentially and can economically control for long periods (Wattendorf and Anderson 1986, Leslie et al. 1987, Allen and Wattendorf 1987). Although sterile triploid grass carp are commonly used, there are still concerns that effective stocking densities cannot be achieved without impacting non-target vegetation and animals (Stott and Robson 1970, Fedorenko and Fraser 1978, Gasaway 1978, Ware and Gasaway 1978, Shireman and Maceina 1981, Leslie et al. 1987, Klussman et al. 1988, Bain 1993). Stocking rates for large water bodies were thought problematic because of difficulties in achieving proper densities, variable plant coverage, and emigration potential of grass carp (Guillory and Gasaway 1978, Noble et al. 1986, Bain et al. 1990, Bain 1993, Chilton and Poarch 1997).

The Santee Cooper system in South Carolina, which encompasses 70,000 ha and includes Lakes Marion and Moultrie, was stocked with over 768,500 triploid grass carp between 1989 to 1996 to control hydrilla. Although grass carp have been stocked in other large water bodies (Noble et al. 1986, Klussman et al. 1988, Bain et al. 1990), the Santee Cooper stocking was the largest release of triploid grass carp in North America.

The target density of approximately 20 to 30 triploid grass carp per vegetated ha was achieved by incremental stocking. From 1992 to 1994, Morrow et al. (1997) monitored the grass carp population in the Santee Cooper system and determined that the annual mortality rate was 22% with a population size of approximately 350,000 fish (17 fish per vegetated ha). Our studies (conducted in 1997 through 1999) were initiated, after an interval of three years, to evaluate population trends and to determine stocking requirements.

METHODS

Hydrilla coverage was estimated several ways depending upon yearly funding. When funding was sufficient, aerial infrared photography was used and aquatic vegetation types were verified by ground truthing. At other times, small aircraft, flying at approximately 300 meters altitude, were used to map aquatic vegetation. Observers mapped topped out aquatic vegetation and ground crews subsequently identified the species of aquatic vegetation. Once mapped and identified, the area of hydrilla coverage was estimated with a planimeter (John Inabinette, pers. comm.).

We used methods similar to those of an earlier study of triploid grass carp in the Santee Cooper reservoirs (Morrow et al. 1997). Skilled bowfishers collected at least 98 triploid grass carp yearly for a bounty of US$50.00 per fish using methods described by Kirk et al. (1992). Collected fish were measured for total length (TL) to the nearest mm and weighed to the nearest 10 g. Utricular otoliths (lapilli) were removed, cleaned, and stored in 95% isopropanol. Scales were removed from the area near the posterior tip of the pectoral fin when laid flat against the body, and stored in ziplock® bags. We estimated condition (Ricker 1975) to compare plumpness of fish among years and evaluate the effects

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of decreasing hydrilla coverage. Fish collected during 1994, a period of time when hydrilla was abundant, were used as the standard for determining condition.

To estimate age, lapilli were examined as described by Morrow and Kirk (1995). After age determination using otoliths, scales were examined using a Ken-O-Vision microfiche projector. Annuli on scales were identified that corresponded to annuli on otoliths and distance from the focus to each annulus and to the scale margin were measured using a sonic digitizer mounted on top of the microfiche projector. The Frazer-Lee method was used to back-calculate lengths at annulus formation (Carlander 1982). Growth (in length) of triploid grass carp was described by fitting a von Bertalanffy growth equation (von Bertalanffy 1938) using lengths back-calculated with scale measurements.

A catch curve (Ricker 1975), adjusted for yearly stocking rates (Morrow et al. 1997), was used to estimate mortality. Weight-length relations were estimated using a power function (Ricker 1975). To use population models (Beamesderfer 1991) age structures, weight-length relations, mortality rates, and a growth equations were required as input for forecasting population trends. Comparisons of total mortality and condition were performed using GLM procedures in SAS (SAS 1985). The statistical level of significance selected was $P < 0.05$.

RESULTS

Hydrilla coverage between 1989 and 1997 is presented in Figure 1. Coverage peaked at over 17,272 ha in 1994 but declined rapidly starting in 1995; after 1997, essentially no topped out hydrilla existed.

At least 98 triploid grass carp were collected yearly by bowfishers; however during 1999 collection was difficult and the last fish was not collected until 25 September 1999. Condition, as measured from 1994, declined significantly to 0.91 in 1997 (Table 1). Condition measured in 1998 was 0.83 and 0.87 in 1999; these estimates were not significantly different but were less than condition measured in 1994 and 1997 (Table 1).

We estimated total annual mortality as 28% during 1997, 32% during 1998, and 39% measured in 1999 (Table 1).

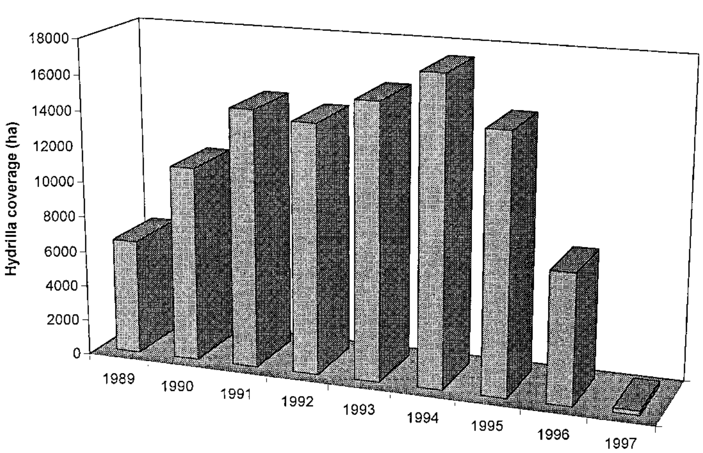

Figure 1. Estimated coverage of hydrilla in the Santee Cooper reservoirs, South Carolina from 1989 through 1997.

Table 1. Survival, condition, total annual mortality, as well as population predictions for triploid grass carp stocked into the Santee Cooper reservoirs, South Carolina.

Year	Condition	Total mortality	Estimated population[1]
1994	1.0 a	22% a	
1997	0.91 b	28% a	
1998	0.83 c	32% a	
1999	0.87 c	39% b	63,000
2000			37,000
2001			21,000
2002			11,000
2003			6,000
2004			3,000

[a, b, c]Condition and mortality estimates with the same letter are not statistically different.

[1]Population model eliminates from the estimate all fish older than age 10.

There were no significant differences in total mortality rates among 1994, 1997, and 1998; however, 39% mortality measured in 1999 was significantly greater than reported in previous years. Most triploid grass carp did not survive to age 10, and in 1999, only 2 of 98 fish were older than age 9. We estimate about 63,000 triploid grass carp were present in the system in 1999 (Table 1). The population (assuming no future stockings) should continue to decline substantially, and by the year 2004, approximately 3,000 fish are predicted to remain in the system (Table 1).

DISCUSSION

This study demonstrates that triploid grass carp populations can be monitored in large reservoirs (Morrow and Kirk 1995, Morrow et al. 1997) allowing a management strategy of incremental stocking (Sutton and Vandiver 1986, Leslie et al. 1987). The significance of monitoring is that managers may now adjust triploid grass carp densities to levels appropriate for maintaining intermediate levels of submersed aquatic vegetation. However, regular estimates of growth, mortality, and population density are essential to determine future stockings.

Estimates of mortality generated by a catch curve are fundamental to monitoring triploid grass carp populations in large water bodies (Ricker 1975). For catch curves to be reliable, assumptions of equal yearly recruitment and no emigration must be met (Ricker 1975). In our studies, we adjusted for yearly stocking (Morrow et al. 1997) and telemetry studies suggested that emigration was minimal (Foltz et al. 1994).

Growth of grass carp can be affected by a number of factors including temperature, density, and food availability (Gasaway 1978, Shireman et al. 1980). Gasaway (1978) reported that growth in weight of grass carp was linear relative to age while hydrilla (a preferred food item) was abundant. Morrow et al. (1997) reported linear tripoloid grass carp growth in the Santee Cooper system during 1994. However, we used condition, rather than age-specific weights, to evaluate food availability because of statistical considerations. Condition declined between 1994 and 1998 (Table 1) but a change in condition could not be detected between 1998 and 1999. We speculate that condition may increase should hydrilla rebound.

We could demonstrate increasing mortality only during 1999. Even if mortality rates are not increasing, our modeling suggests this population will quickly decline, with population levels below 3,000 fish by 2004 (Table 1). We hypothesize that low levels of hydrilla and an increasingly aging population lead to increased mortality. Starting in 2000, the youngest age class will be age 5 and most triploid grass carp in this system die before age 10. In this regard, age 10 was a reasonable choice for maximum life span in our population model.

Recommended stocking rates for grass carp range from 2 to 500 fish per vegetated hectare (Stocker and Hagstrom 1985, Bates and Webb 1986, Bonar et al. 1993). The goal of managers in the Santee Cooper system was reduce hydrilla while allowing some resurgence of submersed aquatic vegetation. As the population of triploid grass carp declines in the Santee Cooper system, the potential for hydrilla regrowth from existing tubers, turions, and rhizomes increases. Rapid regrowth has already been observed in Lake Marion where grass carp exclosures have filled with hydrilla in less than six months (Larry McCord, Santee Cooper, pers. comm.).

In the near future, aquatic plant managers may again need to consider maintenance stocking to achieve an intermediate level of control of submersed aquatic vegetation. This management objective in a large reservoir system may now be practical due to assessment and aging techniques developed during the 1990's (Kirk et al. 1992, Morrow and Kirk 1995, Morrow et al. 1997). Cassani and others (1995) was able to achieve similar goals in small Florida systems and submersed vegetation was never eliminated in Lake Guntersville or Conway (Webb et al. 1994, Leslie et al. 1994). Meeting the management objective of an intermediate level of aquatic vegetation will take diligence and effort. Aquatic plant managers must consider increasing mortality of an aging triploid grass carp population, declining condition as hydrilla coverage decreases as well as the potential of hydrilla to rapidly re-colonize formerly infested areas. Therefore, regular population assessments, such as this one, are necessary for aquatic plant managers to project the need and extent of future stockings.

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