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Effects of Triploid Grass Carp on Aquatic Plants, Water Quality, and Public Satisfaction in Washington State

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Abstract.—We investigated effects of triploid grass carp *Ctenopharyngodon idella* on aquatic macrophyte communities, water quality, and public satisfaction for 98 lakes and ponds in Washington State stocked with grass carp between 1990 and 1995. Grass carp had few noticeable effects on macrophyte communities until 19 months following stocking. After 19 months, submersed macrophytes were either completely eradicated (39% of the lakes) or not controlled (42% of the lakes) in most lakes. Intermediate control of submersed macrophytes occurred in 18% of lakes at a median stocking rate of 24 fish per vegetated surface acre. Most of the landowners interviewed (83%) were satisfied with the results of introducing grass carp. For sites where all submersed macrophytes were eradicated, average turbidity was higher (11 nephelometric turbidity units, NTU) than at sites where macrophytes were controlled to intermediate levels (4 NTU) or unaffected by grass carp grazing (5 NTU). Chlorophyll *a* was not significantly different between levels of macrophyte control; therefore, we concluded that most of this turbidity was abiotic and not algal. Triploid grass carp were a popular control option and effectively grazed most submersed macrophytes in Washington State. However, calculating stocking rates based on landowner estimates of aquatic plant coverage rarely resulted in intermediate levels of aquatic plant control. Additionally, the effects of particular stocking rates varied considerably. We recommend against using grass carp in Washington lakes where eradication of submersed vegetation cannot be tolerated.

Triploid grass carp *Ctenopharyngodon idella* were legalized for aquatic macrophyte control in Washington State in 1990. Since then, numerous lakes and ponds have been stocked with these fish to control nuisance aquatic vegetation, but little work has been done to assess their efficacy statewide, albeit a few individual lakes and ponds have been intensively studied (Bonar 1990; Pauley and Bonar 1995; Scherer et al. 1995; Pauley et al. 1998).

Several questions regarding the use of grass carp for management of aquatic macrophytes in the Pacific Northwest remain unanswered. These include their ability to control but not eliminate all submersed macrophytes when used under routine management conditions; the suitability of the current grass carp stocking rates used in Washington; effects of grass carp on Washington's water quality; and public satisfaction associated with grass carp introductions.

Because many researchers have found that moderate levels of aquatic vegetation can be important for fish (Durocher et al. 1984; Wiley et al. 1984) and wildlife (Gasaway et al. 1979) populations, the goal of most grass carp users is to stock at densities that will control, but not eradicate, all submersed macrophytes. Although intermediate levels of macrophytes were achieved 2–4 years after stocking grass carp in some Pacific Northwest sites (Bonar 1990; Bonar et al. 1993; Pauley and Bonar 1995), other sites exhibited either little control (Pauley et al. 1998) or eradication of submersed macrophytes (Scherer et al. 1995; Pauley et al. 1998).

Grass carp stocking rates are usually expressed in numbers of fish of a specific size per unit of lake surface area or per unit of aquatic vegetation abundance (surface area or biomass). Stocking rates based on aquatic vegetation abundance are usually considered more accurate if the goal is to suppress but not eliminate aquatic macrophytes (Cassani et al. 1995). In some experimental studies and large systems, aquatic plant abundance for stocking rate calculations is carefully estimated by measuring aquatic plant biomass (Bonar 1990; Bonar et al. 1993; Cassani et al. 1995; Blackwell and Murphy 1996) or coverage as derived from aerial photographs (Martyn et al. 1986; Bonar 1990) or hydroacoustic techniques (Maceina and Shireman 1980; Thomas et al. 1990). However,

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under routine management, such as in statewide programs where dozens of smaller lakes and ponds are stocked, these techniques are often too costly. Therefore, if aquatic plant abundance is used in stocking-rate calculations, it is often based on a visual estimate of the area of the lake occupied by submersed aquatic plants, usually made by the landowner. Determining if stocking rates estimated by this common method result in aquatic macrophyte suppression or elimination is important for those programs that have macrophyte suppression as their goal.

Increased turbidity, either algal or abiotic, has been observed in some lakes following the stocking of grass carp (Lembi et al. 1978; Maceina et al. 1992; Water Environmental Services Incorporated 1994), which can be an undesirable consequence. It is important to determine if grass carp commonly contribute to increased turbidity in statewide programs and under what conditions.

In Washington, grass carp have been used primarily in private lakes and ponds that receive a variety of different uses. Anglers, property owners, bird watchers, boaters, and farmers have all applied for permits to stock grass carp in Washington. Although assessment of public satisfaction has generally been overlooked, it is an important component in evaluating the success of introductions.

Five years after the legalization of triploid grass carp in Washington, we evaluated the three effects of these fish in 98 lakes and ponds statewide: (1) general effects on macrophyte communities and water quality in the cool, north-temperate waters of Washington State; (2) the ability of grass carp to consistently control aquatic macrophytes to intermediate levels (at stocking rates expressed in number of fish per area of vegetation estimated by visual observations); and (3) the public satisfaction with the results of grass carp introductions.

Methods

We contacted all Washington Department of Fish and Wildlife (WDFW) regional offices to obtain copies of grass carp stocking permits. These permits contained lake name, lake size, name and address of pond owner, maps of each lake, the landowner's estimated percent coverage of aquatic plants before stocking, and the primary nuisance plant species. Permits also contained the number of fish (8–12 in) recommended by state biologists, which was based on the amount of vegetated surface acres of the lake.

After we had compiled permit information, we contacted landowners via telephone survey to determine the primary use of their lakes and their overall satisfaction with the grass carp treatments. To evaluate public satisfaction, we determined the following from the landowner: numbers of dead grass carp observed following stocking; magnitude of change in the macrophyte community; and changes they might have noted in angling quality, wildlife populations, and esthetics of the lake. To include only those lakes where grass carp had adequate time (2–5 years) to have an impact, we only included lakes stocked before October 1993. If a landowner had more than one lake on his property stocked with grass carp, we estimated satisfaction for each lake separately.

We visited 98 lakes stocked with grass carp between July 19 and August 22, 1995, to conduct a rapid assessment of current macrophyte community abundance and water quality. At each lake, we visually estimated current surface macrophyte coverage in the same manner as was done for the permit maps before stocking. We also used recording fathometers to assess bottom coverage and volume of submersed macrophytes (Maceina and Shireman 1980; Thomas et al. 1990; Canfield and Hoyer 1992). We measured bottom coverage and macrophyte volume by moving a small boat equipped with a recording fathometer along transects at a constant speed. Because most of the lakes or ponds were small (<10 acres) and circular, we felt that two transects (one running the length of the pond and the other perpendicular to it at the widest point) could provide an index of macrophyte bottom coverage and volume.

We used the cut-and-weigh method (Welch 1948; Lind 1979) to determine the volume occupied by aquatic macrophytes. Chart records were photocopied twice. On one copy we cut out the cross section of the entire lake, while on the other, we cut out the same cross section of the entire lake and then removed all macrophyte tracings. We weighed each cutout on a Mettler balance with a sensitivity of 0.00035 oz. We then divided the weight of the cross section with plants removed by the weight of cross section of the entire lake, multiplied by 100, and subtracted this figure from 100 for an index of percent volume occupied by aquatic macrophytes (PVO). To determine bottom coverage, we first summed the lengths of the two transects occupied by macrophytes. We then summed the total lengths of the two transects. The first quantity was divided by the second and multiplied by 100 for an index of bottom coverage.

Lakes were separated into three categories based on the degree of macrophyte control. Because we

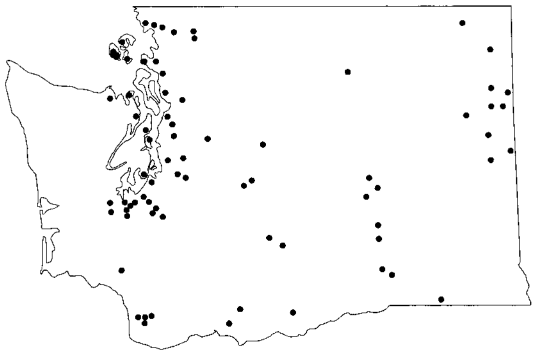

FIGURE 1.—Locations of the 184 lakes or ponds in Washington State where confirmed grass carp were stocked between April 1990 and June 1995. We examined 98 of these sites.

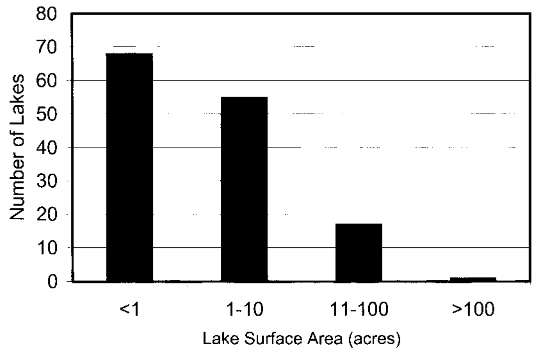

FIGURE 2.—Size distribution of the 184 Washington State lakes and ponds stocked with grass carp between April 1990 and June 1995.

had little prestocking data other than the landowner-drawn surface coverage maps, we used these with some qualitative data to separate lakes into three groups. Eradication lakes had less than 5% of the lake volume occupied by submersed vegetation at the time we conducted our survey, and both the initial map and the waterfront property owner suggested that substantial declines (i.e. 50% or more) in the submersed plants had occurred following grass carp stocking. Intermediate-control lakes were those where the landowner noticed, or comparisons with prestocking surface coverage maps indicated, a substantial decline in submersed vegetation and 5–40% of the lake's volume was occupied by submersed vegetation at the time of our survey. We chose 40% as the upper limit because this was the mean volume of macrophytes in 13 lakes that the public considered overgrown that had either not been stocked with grass carp or had been stocked within the last 6 months. No-control lakes were those where landowners did not report substantial reductions in submersed vegetation coverage or more than 40% of the lake's volume was occupied by submersed vegetation at the time of our survey. If the grass carp were seen cutting holes in the lake's macrophyte cover or removing small sections of macrophytes, we did not consider this a substantial reduction. Lakes excluded from our analysis were those treated with herbicides or drained at any time, those where no macrophyte information was available before grass carp were stocked, or those that did not contain macrophytes before grass carp stocking. For analysis of stocking rate, we considered only lakes stocked before October 1993 so grass carp would have had time to have an effect.

We measured chlorophyll *a,* total turbidity, secchi depth, alkalinity, and water color to assess water quality. Chlorophyll *a* was measured to assess the degree that phytoplankton contributed to total turbidity. Alkalinity was measured to determine if it was sufficient (>20 ppm) for a healthy phytoplankton population. Water samples were composites of the top 3.25 ft of the water column and were collected using a PVC tube. We used a syringe attached to a membrane filter to filter 1.7 oz of water for chlorophyll samples. Filters were stored in acetone and transported in the dark and on ice to a laboratory for analysis, according to the procedures in Jefferey and Humphrey (1975) and Strickland and Parsons (1972). Total turbidity was measured on a nephelometric turbidity meter. Because we were using three different meters, all readings were calibrated to each other using regression techniques. Water color on the Fore–Ule scale and alkalinity were determined using Lamonte[2] portable water kits. One-way analysis of variance (ANOVA) was used to test for differences in mean turbidity or chlorophyll *a* among the control levels of submersed macrophytes ($\alpha = 0.05$). The Student–Newman–Keuls' test was used to estimate where differences in means were located.

Results

The WDFW approved applications to stock triploid grass carp in 184 lakes and ponds (5 of these were pond complexes where the total number of ponds was unknown) in Washington between April 1990 and June 1995 (Figure 1). Most stocking was in the Puget Sound region and in lakes of less than 10 surface acres (Figure 2).

[2] Mention of a vendor does not constitute endorsement of a product.

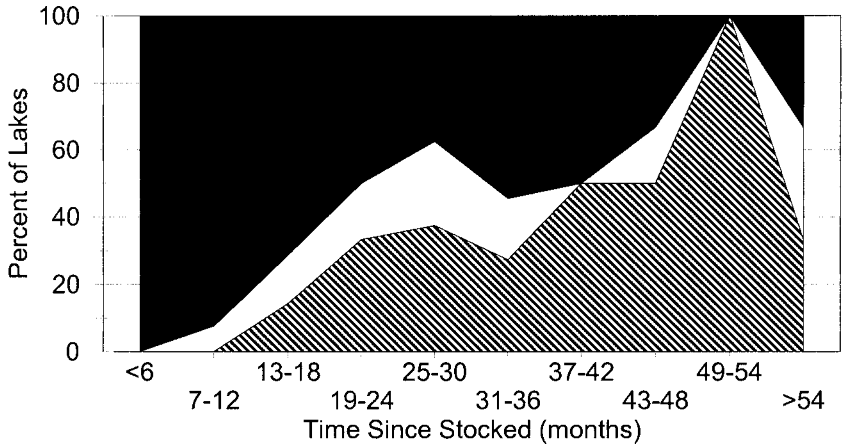

FIGURE 3.—Percentage of the 98 Washington State lakes and ponds we examined in which submersed macrophytes were eradicated (hatched area), controlled (white area) or not controlled (black area) by stocked grass carp versus number of months after stocking.

Stocking Rates and Effects on Macrophytes

A wide range of stocking rates (5–174 fish per vegetated acre) were used in Washington for the control of submersed macrophytes. Of the lakes we examined, 68 had sufficient plant community information to use in a stocking rate analysis. Generally, more than 19 months elapsed before substantial effects were observed from grass carp stocking. Thirty lakes stocked for less than this period showed little or no impact from grazing regardless of the stocking rate (Figure 3). In 31 lakes stocked for more than 19 months, grass carp either eradicated submersed macrophytes (15 lakes) or few effects were noticed (16 lakes). The general goal of intermediate macrophyte control was achieved in only seven lakes stocked for more than 19 months.

Average stocking rates were extremely high because of outliers, and not representative of the group. Therefore, we report median stocking rates instead of means. Median stocking rate for the seven lakes where intermediate control occurred was 24 fish per vegetated acre (Figure 4). Stocking rates producing intermediate control, no control, and eradication varied widely; that is, stocking rates as low as 8 fish per vegetated acre produced eradication, whereas rates as high as 74 fish per vegetated acre produced no control.

In the sites where submersed macrophytes were not controlled 19 months following grass carp stocking, predominant species mentioned were broad-leafed (22% of the sites) and thin-leafed (17%) pondweeds *Potamogeton* spp., water milfoil *Myriophyllum* spp. (17%), coontail *Ceratophyllum demersum* (13%), bladderwort *Utricularia* spp. (9%), duckweed *Lemna* spp. (9%), macroalgae (*Chara* sp. and *Nitella* sp.; 9%), and water-weed *Elodea canadensis* (4%). In the seven sites where macrophytes were controlled but not completely eradicated, *Myriophyllum* spp. were dominant in four (57%) and broad-leafed *Potamogeton* spp., thin-leafed *Potamogeton* spp. and macroalgae were each dominant in one.

Water Quality Effects

Turbidity was higher ($P < 0.001$) in lakes where all submersed macrophytes were eradicated than in lakes with intermediate or no vegetation control. There was no difference ($P > 0.50$) in turbidity between intermediate-control and no-control sites. Average turbidity was 11 nephelometric turbidity units (NTU) in eradication sites, 5 NTU in no-control sites, and 4 NTU in intermediate-control sites. Chlorophyll *a* was not different ($P > 0.80$) between the three types of sites. Modal water color for intermediate-control and eradication sites was 21 on the Forel–Ule scale, which corresponds to browns and tannins. For sites where no control occurred, the modal Forel–Ule measurement was 14, a green color. We could not find a significant relationship ($P > 0.07$) between chlorophyll *a* and turbidity in lakes where grass carp effects were pronounced (intermediate control and eradication). Alkalinity was sufficient (>20 ppm; Boyd 1990) for a healthy phytoplankton population in 97% of the sites. Because most lakes we surveyed were shallow, secchi depth was often greater than the

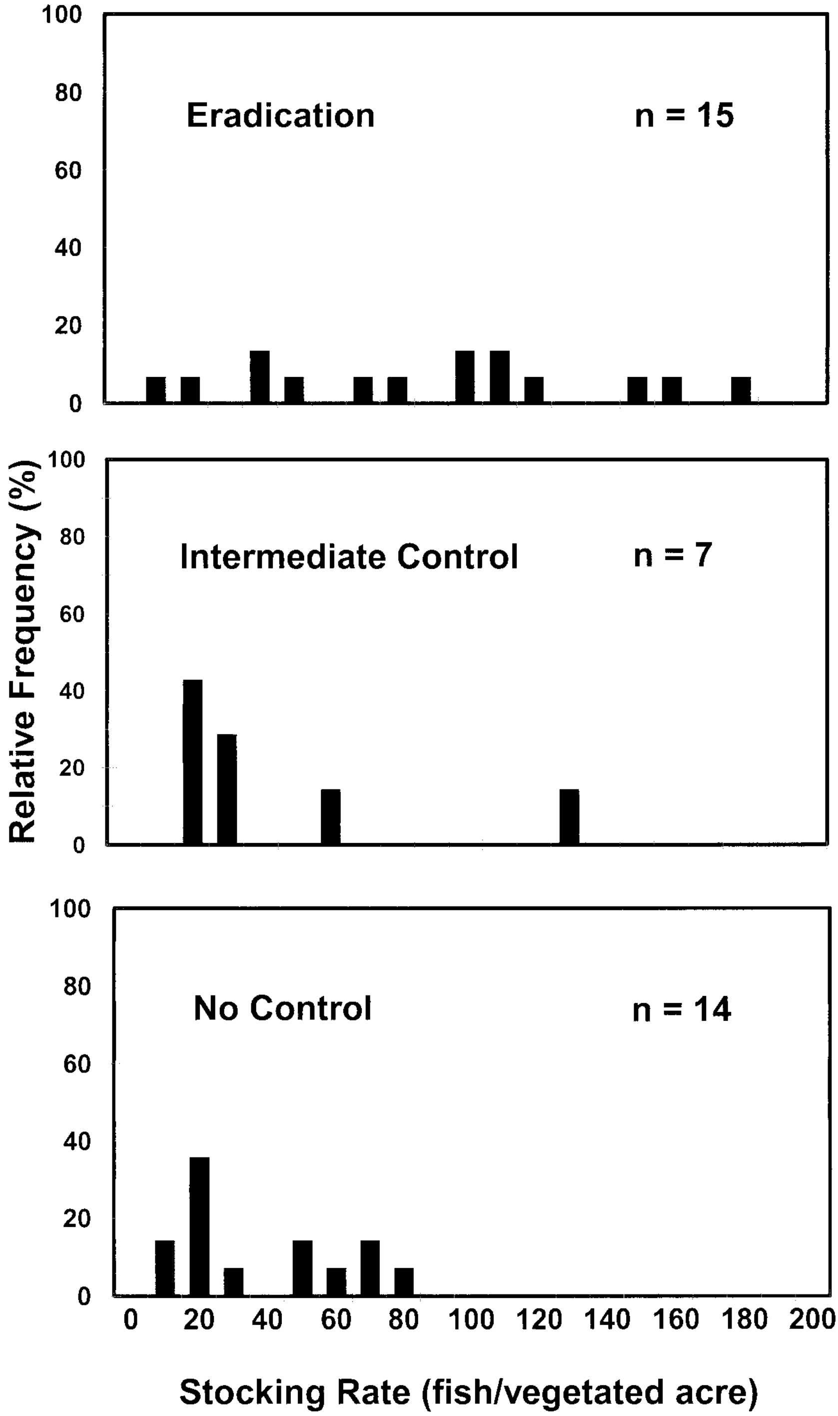

FIGURE 4.—Relative frequency of grass carp stocking rates versus level of aquatic macrophyte control in the 98 Washington State lakes and ponds we examined.

TABLE 1.—Landowner satisfaction with grass carp treatments in Washington State, combined and subdivided by degree of control of submersed macrophytes.

Control level	Number of lakes (*N*)	Landowner response: Highly satisfied (%)	Moderately satisfied (%)	Not satisfied (%)
Combined	49	69	14	16
Eradication	16	88	13	0
Intermediate	7	86	14	0
No control	13	38	15	46

lake depth, so we excluded this variable from our water-clarity comparisons.

Public Satisfaction Associated With Grass Carp Treatments

Stocking grass carp was a popular method for controlling aquatic vegetation with permit holders. Satisfaction data were available for 49 lakes stocked with grass carp before October 1993. Property owners were highly or moderately satisfied with the results obtained in 83% of these sites (Table 1). When subdividing satisfaction by the amount of plant control obtained, all landowners of sites where intermediate control or eradication was achieved were highly or moderately satisfied. Even in 13 lakes where grass carp had little or no effect, landowners were highly or moderately satisfied with 54% of the introductions.

Grass carp grazing appeared to have little effect on perceived angling quality in lakes (Table 2). Landowners fished in 27 of the lakes, and 71% reported that angling quality had not changed. Few changes in angling quality were reported for each of the three levels of plant control. Nineteen respondents reported that they swam, skied, or boated at these lakes. Overall, 63% of the landowners reported that quality of these activities increased following grass carp stocking (Table 2), and for the eradication sites, all respondents reported that quality of these activities increased. For intermediate-control sites 60% reported an increase in quality, and 40% reported that quality declined or remained the same. All respondents indicated that swimming, skiing, or boating quality had not changed in no-control sites.

Most landowners (90%) reported that they watched bird and wildlife populations at these lakes. Most reported no change, even when lakes were subdivided by level of control (Table 2).

Landowners were generally pleased with the esthetic value of their lakes after the stocking of grass carp (Table 2). Overall, 83% thought that lake esthetics had increased following grass carp stocking, 14% thought esthetics had remained the same, and 2% (one landowner) thought esthetics had declined. All landowners with lakes where vegetation was eradicated thought that esthetics had increased, whereas for intermediate-control sites, 66% thought esthetics had increased. For no-control sites, 45% thought that esthetics remained the same and 55% thought esthetics had increased.

TABLE 2.—Changes perceived by landowers in various lake attributes following stocking of grass carp in Washington State lakes and ponds.

Degree of macrophyte control	Number of lakes (*N*)	Landowner indicating (%): No change	Increase	Decrease
Angling quality				
Combined	24	71	13	17
Eradication	7	71	14	14
Intermediate control	5	60	20	20
No control	7	100	0	0
Swimming, skiing, and boating quality				
Combined	19	32	63	5
Eradication	6	0	100	0
Intermediate control	5	20	60	20
No control	4	100	0	0
Bird and other wildlife abundance				
Combined	37	81	14	5
Eradication	12	67	17	17
Intermediate control	4	75	25	0
No control	10	90	10	0
Aesthetics				
Combined	42	14	83	2
Eradication	14	0	100	0
Intermediate control	6	17	67	17
No control	11	45	55	0

Mortality of grass carp was reported in 47 of 92 lakes where landowners responded. The most common sources of mortality reported were unknown causes (32%), stress associated with stocking (30%), and bird predation (19%). Other sources of mortality included otter predation (9%), winter kill (6%), collision with ski boats (2%), and lake draining (2%).

Discussion

Effects of Grass Carp on Macrophytes

We found that most submersed macrophyte species in Washington were effectively grazed by grass carp, even though grass carp preference affected the order in which they were eaten. Pondweeds, water milfoil, and coontail were predominant macrophytes in lakes where vegetation was not controlled. However, because these plants were effectively grazed in many other lakes, lack of control was probably not the result of grass carp being unable to effectively graze these species.

Although grass carp ate most types of submersed macrophytes, we did not see evidence of effective grazing of water-lilies, both *Nuphar* sp. and *Nymphaea* spp. *Nuphar* sp. was found in several lakes where eradication of submersed plant species occurred but did not appear to be grazed in any sites. *Nymphaea* spp. showed some evidence of grazing such as cuts in the leaves, but there was no evidence of this plant being controlled in any sites. In the lakes we examined, water-shield *Brasenia schreberi* was generally not controlled, which supported Bonar's (1990) findings. However, this plant was grazed heavily in Silver Lake, Washington, where the stocking rate was high, no submersed macrophytes were present, and grass carp were large (Scherer et al. 1995). Grazing damage was also noticed in Keevies Lake, Washington where grass carp had been present for 8 years.

Grass carp generally took at least 2 years to exert a significant effect. Information provided to landowners describing the amount of time required for macrophyte reduction would help them determine if grass carp were the best plant control option for their site and would thwart overstocking mistakenly effected when changes fail to become manifest in the first year.

Controlling aquatic vegetation to intermediate levels has been the objective of many fisheries managers when stocking grass carp. Whether submersed aquatic macrophytes are necessary in small lakes and ponds for optimal production of game fish is controversial, but most researchers believe that, when present in intermediate densities, submersed macorphytes do not harm and in many cases benefit some aspects of lake ecosystems (Durocher et al. 1984; Wiley et al. 1984). Unfortunately, the majority of grass carp introductions in Washington resulted in either eradication of submersed vegetation or no noticeable control, which reflects the findings of others who have reviewed large numbers of lake stockings (Bonar 1990; Kirk 1992; Haller 1994; Mitzner 1994). Therefore, the successful use of grass carp in Washington lakes to reduce submersed macrophytes to a predetermined intermediate level without eradicating them appears to be rare.

Several factors may be responsible for the variation in the degree of vegetation control obtained with a given stocking rate. Unpredictable shifts in annual temperature cycles can influence macrophyte growth, grass carp feeding, and grass carp growth, which in turn can affect the degree of control obtained. Because the limited resources of most agency budgets precludes on-site visits by trained biologists, landowner estimates of vegetation coverage or pond size, which can be in error and variable, are often the only data available to calculate a stocking rate. Another major factor causing variability in the amount of control achieved with a given stocking rate may be grass carp mortality. We found that many factors caused varying degrees of grass carp mortality in Washington lakes. Site characteristics and the size of fish stocked can influence their susceptibility to mortality factors (Shireman et al. 1978). Clapp et al. (1994) estimated that site-to-site mortality in Florida could range annually from 6% to 62%. Therefore, it is difficult to determine how many grass carp are present in a lake at any given time.

Although no control or eradication occurs most often, several researchers have reported macrophyte control to intermediate levels 2–5 years following stocking some lakes (Bonar 1990; Bonar et al. 1993; Henson and Sliger 1993; Cassani et al. 1995). Therefore, although intermediate control can be achieved, such results cannot be produced consistently or predictably at this time. Given this inconsistency, we recommend against using grass carp in Washington lakes where eradication of submersed vegetation cannot be tolerated.

Stocking Rates

The median stocking rate that resulted in control, 24 fish per vegetated acre, was considerably lower than stocking rates that were effective for Devils Lake, Oregon, (Bonar et al. 1993) and seven Washington lakes (Bonar 1990; Pauley and Bonar 1995) Temperature, plant species present, and grass carp growth were similar between studies. However, one factor that might have changed was grass carp mortality.

The shipments of grass carp in 1986–1990 were the first legal stockings in the Pacific Northwest. Fish for eight of the nine stockings were trucked across the country from Arkansas during late spring and early summer. After stocking, dead fish (300–600) were observed at some of the sites. Although stocking rates reported were adjusted to account for these mortalities, the actual number of fish left in the lakes may have been even lower than the reported rate.

Currently, sterile grass carp are regularly sent to the Pacific Northwest. Most are shipped by air, arriving much more quickly than the original truck shipments. Producers, because of the larger volume of fish they send to this region, are now well acquainted with procedures needed to ensure safe delivery of shipments. Initial stocking rates possibly compensated for high mortality, but now that transportation and stocking procedures have been refined, mortality has been reduced. This fact and results of our field study demonstrate that lower stocking rates are appropriate.

Water Quality Effects

We found turbidity to be significantly higher in eradication lakes than intermediate-control or no-control lakes, but chlorophyll *a* was not significantly different among them. Also, in lakes where grass carp had an impact on the macrophyte community (intermediate-control and eradication lakes) we found no relationship between turbidity and chlorophyll *a*. Finally, modal water color of eradication lakes was 21, which was brown or humic-colored. These findings imply that the increased turbidity in eradication lakes primarily consisted of suspended sediments, not phytoplankton. We hypothesize that grass carp disturbing the sediment in their search for food or increased wind mixing of the sediments following the removal of the aquatic plant canopy could have contributed to this increased turbidity.

Increased turbidity following grass carp stocking has been documented frequently, but the source of this turbidity has differed. Turbidity increased in Lake Conroe from 2.4 to 3.9 NTU following grass carp stocking, but this turbidity was attributed to higher algal biomass and not increased abiotic turbidity (Maceina et al. 1992). Average turbidity also increased (from 6.7 to 9.9 NTU) following stocking of Indiana ponds but without change in phytoplankton populations (Lembi et al. 1978). In Washington, abiotic turbidity increased following macrophyte removal in Silver Lake (Scherer, Kramer, Chin and Mayo, Inc., personal communication), and conductivity increased (turbidity not measured) following stocking of Keevies Lake (Frodge et al. 1995).

Turbidity did not increase in lakes where submersed macrophytes were controlled to intermediate densities. In these lakes, grass carp still have submersed vegetation to graze and presumably do not disturb the sediment in their search for food. Also, some macrophytes were still present to protect the sediments from wind action. Therefore, removing intermediate amounts of macrophytes may be most beneficial, not only by leaving submersed macrophyte habitat and food for fish and wildlife, but by reducing the chances that water clarity will be reduced by grass carp foraging in the sediments or that wind action will stir up the sediments. Nevertheless, none of the turbidity levels found in our study were thought to be harmful to adult fish (Wallen 1951).

Although chlorophyll *a* was not significantly higher in eradication lakes, it was also not significantly lower. Therefore, we have no direct evidence that phytoplankton abundance has declined in these sites to date. However, managers should be aware that the potential for negative impacts exist with increased turbidity, and they should not permit grass carp stocking in lakes where increased abiotic turbidity would be of concern.

Public Satisfaction with the Results of Grass Carp Treatments

Grass carp were a highly popular macrophyte control option among the Washington landowners surveyed in this study. Where eradication of the aquatic plant community occurred, all landowners were satisfied with the results, and few reported any perceived changes in angling quality or wildlife populations at any sites. Presumably then, landowners believe that excess macrophyte growth is a greater detriment to the esthetic quality of their lakes and ponds than is higher turbidity associated with submersed macrophyte eradication. It is important to realize that although landowners reported few changes in fish and wildlife populations, the populations nevertheless may have changed.

Curiously, 54% of landowners with lakes showing no control were satisfied with the results. Many of these landowners considered their grass carp as pets or simply were satisfied to be trying alternative techniques to reduce nuisance aquatic plant growth in their ponds.

Conclusions

Sterile grass carp are effective and popular for removing submersed aquatic macrophytes from lakes and ponds in Washington. However, lake managers should consider that (1) the desired intermediate level of vegetation control is currently difficult to achieve using grass carp (i.e., most stockings either result in eradication or not enough control of aquatic plants); and (2) if submersed vegetation is eradicated from a lake, the potential exists for elevated abiotic turbidity.

Because potential negative effects are greater for grass carp in large lakes and the populations are much more difficult to manipulate, grass carp are probably best suited for plant control in small lakes and ponds. Exceptions may occur where complete eradication of a submersed plant is required in a large lake, such as an invasive exotic species, or when a lake can be treated with rotenone to eradicate the grass carp if too many plants are removed.

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