Estimating Abundance of Grass Carp in Devils Lake and A Plan for Continued Stocking of Fish

A Report to the
Devils Lake Water Improvement District
Lincoln City, Oregon

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INTRODUCTION

Grass carp (*Ctenopharyngodon idella*) is a large herbivorous member of the carp family introduced throughout the United States as a method for controlling aquatic plants in lakes. The Devils Lake Water Improvement District (DLWID) applied for and received permission from the Oregon Department of Fish & Wildlife to introduce grass carp into Devils Lake as an experimental program to reduce the extensive growths of aquatic plants, much of which were comprised of invasive taxa. The DLWID introduced 10,000 fish in 1986, 17,050 in 1987 and an additional 5,000 fish in 1993. By 1994, the lake was virtually free of submerged aquatic macrophytes and has remained relatively macrophyte-free since then.

The DLWID has developed a broad strategy for reducing the input of nutrients to Devils Lake with activities that include encouraging the use of more natural vegetated shorelines, implementation of best management practices to reduce urban runoff and development of plans for local sewer districts to reduce inputs from septic systems. However, the District would still like to have the option to continue stocking grass carp as one of its management tools for the lake. This report provides an assessment of the current status of grass carp in Devils Lake and offers a suggested plan for additional stocking should the District receive permission to continue with the experimental stocking program.

ESTIMATION OF GRASS CARP ABUNDANCE IN DEVILS LAKE

A total of 32,050 grass carp have been stocked in Devils Lake, however it is unknown how many grass carp are currently present in Devils Lake. Attempts to quantify the number present when they were abundant were unsuccessful (CH2M-Hill 1992). A project was conducted by the DLWID in 2006, with the aid of local volunteers, to position individuals throughout the lake and make observations of fish presence. The results suggested that the population had declined to between 300 to 1000 grass carp (Paul Robertson, personal communication, April, 2013), although this estimate was considered semi-quantitative at best. Life history information indicate that grass carp have a life span of 10 to 20 years, although this is subject to uncertainty because most of the life history data are derived from studies of the fish in warmer climates. Grass carp have been present in Devils Lake for over 20 years.

I attempted to provide an independent estimate of the abundance of grass carp in Devils Lake using assumptions regarding mortality rates and life history information. Sources of mortality for grass carp in Devils Lake include mortality upon stocking, predation, disease, and escape to the ocean through the D River. The triploid grass carp were trucked to Devils Lake from a fish farm and released into the lake. Some fish were observed in distress during stocking, although it is unknown how many fish expired during this transition. Many fish are susceptible to predation, especially from piscivorous fish such as bald eagles, cormorant, pelicans, herons and mergansers. Some predation from bald eagles was observed at Devils Lake, but again it was unquantified and likely to have been relatively low. Fish are susceptible to a wide array of diseases and parasites. However, few dead grass carp have been observed in the lake throughout the years. Grass carp are native to rivers and some grass carp have exited the lake through the outlet. However, these fish are intolerant to saltwater and quickly perish in saline environments (Cross 1970). Some dead grass carp have been observed on the beach near the D River, but again it is unclear if these represent just a few individuals or a larger number of grass carp that have exited the lake.

The major difficulty in estimating the current population of grass carp in Devils Lake, besides not having any interim data on abundance, is the lack of information specific to grass carp mortality rates for lakes in the Pacific Northwest. Most of the information generated on mortality rates of grass carp are based on data from southern states. For example, Morrow et al. (1997) and Kirk and Socha (2003) report annual mortality rates in South Carolina of 22 to 39 percent which results in a population survival on the order of a decade. This contrasts sharply with annual mortality rates of 2.0 to 7.7 percent for two lakes in Iowa (Hill 1986). Shireman and Smith (1983) report a maximum age of 21+ years. I selected an annual mortality rate of 10 percent for Devils Lake carp which reflects an intermediate rate of annual mortality as appears to be the case for colder climates.

In the absence of data, a structured approach was taken to estimate the number of grass carp in Devils Lake. Simple models were generated assuming various parameters for annual mortality and death upon stocking. The first model assumed a constant 10 percent annual mortality rate and no mortality on stocking (Figure 1). This model yields the highest estimate for the current population. Two additional models were added that also included a 10 percent annual mortality rate, but also included additional mortality upon stocking. Both of these models yield slightly lower current population estimates for the grass carp. A fourth model was developed that included a high mortality on stocking, increased survivability through years 2 through age 10 and increased mortality rate with increasing age. According to this model, the grass carp would have expired by year 2013, which apparently is not the case. Of course, the assumptions regarding mortality rates shown in Figure 1 could over-emphasize the early decline in the population. In which case, the actual trajectory for the population might be better represented by a relatively stable population followed by a rapid decline as fish approach their maximum lifespan in this environment (Figure 2).

These models for estimating the number of grass carp in the lake suggest that the current population is on the order of 1,000 fish, which is in general agreement with the DLWID observations in 2006. Given the uncertainty in the models, the estimate number of fish could easily be well under 1,000. It's unlikely that the number of fish would be much greater than 1,000 because of the extreme age of the fish.

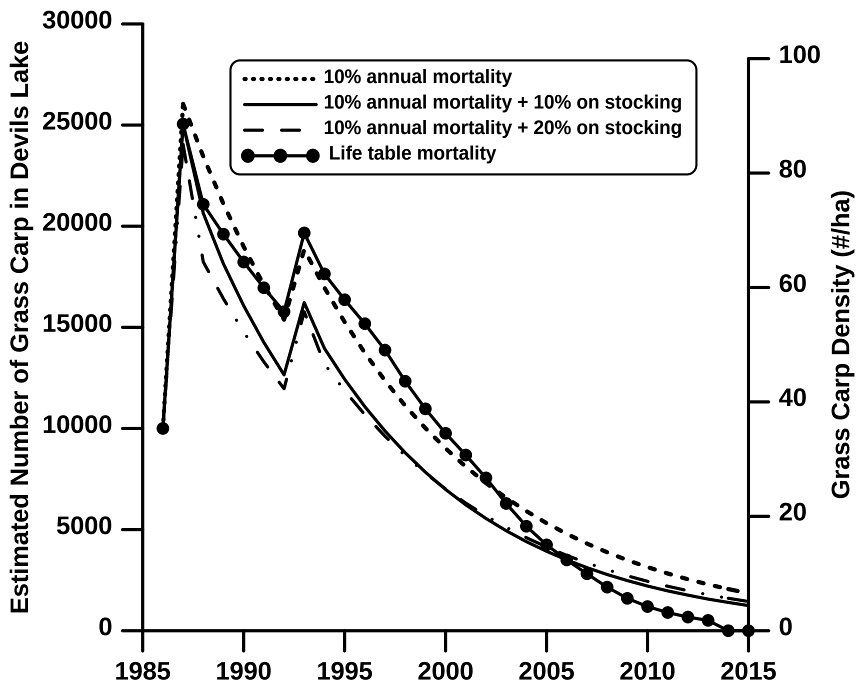

Figure 1. Estimated population of grass carp in Devils Lake under four ranges of assumptions regarding stocking mortality and annual mortality.

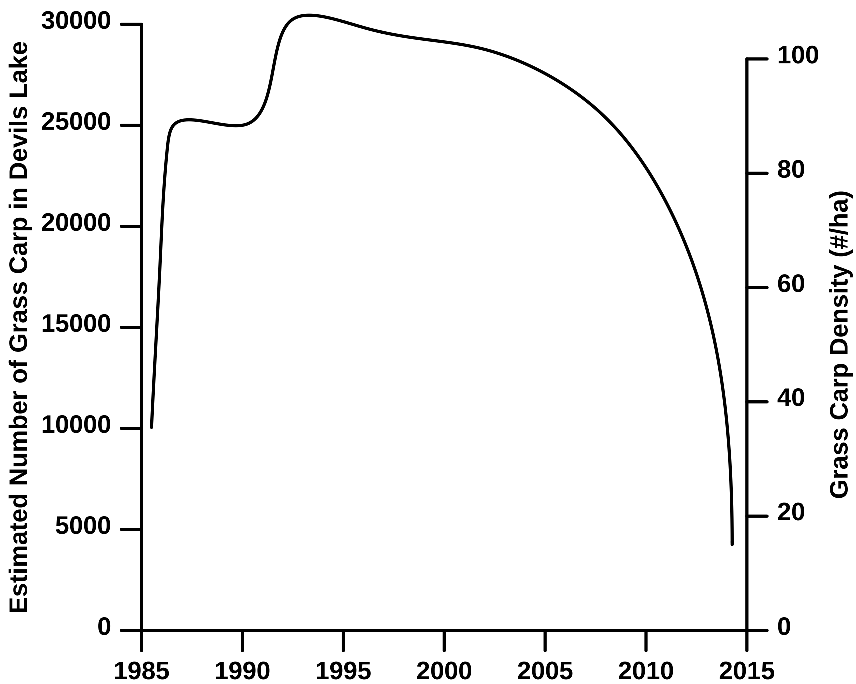

Figure 2. Estimated population of grass carp in Devils Lake assuming low rates of stocking mortality and low annual mortality rates until advanced age of fish.

FACTORS AFFECTING STOCKING RATES OF GRASS CARP

Determining the appropriate stocking density of grass carp has been a challenge for lake managers. Common outcomes are to stock at a density resulting in either complete eradication of submerged macrophytes, such as what was initially done in Devils Lake, or too low to achieve control of the plants. Researchers now recognize that the consumption of aquatic plants by grass carp is a function of a number of factors including feeding preferences for aquatic plant taxa, water temperature, age of fish, bathymetry of lake, and lake-specific mortality factors (cf. Stewart and Boyd 1999). A more recent approach is to use grass carp to suppress macrophyte populations, but not eliminate the plants (Cassani et al. 1996; Hoyer and Canfield 1997). This approach requires that the stocking be done incrementally and that it be done concurrently with a program to monitor the biomass of aquatic macrophytes. This allows the current plant conditions in the lake to inform decisions regarding future stocking practices. A cautious and incremental approach to grass carp stocking is required because of the considerable number of uncertainties with regard to the feeding rate of the grass carp and the longevity of the fish.

The multiple stockings of grass carp from 1986 to 1993 could have resulted in a population exceeding 30,000 fish and a density of over 100 fish/ha. Most stocking regimes are now based on available macrophytes, either as percent lake coverage or percent biovolume of edible plants. Note that emergent macrophytes such as *Typha* (cattails) or floating taxa such as *Nuphar* (spatterdock) are not consumed by grass carp (cf. Stewart and Boyd 1999). If we assume that the historical coverage of edible macrophytes in Devils Lake was about 60 percent of the lake surface area, then the effective stocking density was over 200 fish/ha of macrophytes. This is an extraordinarily high stocking density based on current recommended rates of stocking. As noted, recommended stocking rates are dependent on a number of factors, including the taxa of macrophytes present in the lake, the annual water temperature, desirability to maintain complex aquatic habitats, age of grass carp, ploidy of grass carp and local recreational preferences.

Food preferences by grass carp vary widely as summarized by Bowers et al (1987), although they reported high preferences for *Potamogeton crispus*, *P. pectinatus*, *P. zosteriformes*, *Elodea canadensis* and *Vallisneria* among 12 Pacific Northwest macrophyte species examined. For macrophytes from Devils Lake, they reported the highest degree of preference for *P. zosteriformes* based on short-term, controlled studies (Table 1). However, preferences only indicate the order in which plants are consumed and all of these species were eventually consumed in Devils Lake. Preferences based on longer-term studies found very different rankings for preference of macrophyte consumption than those reported by Bowers et al. (Stewart and Boyd 1999; Swanson and Bergersen 1988).

Table 1. Grass carp preferences for aquatic macrophytes from Devils Lake, Oregon (from Bowers et al. 1987).

Species	Mean consumption (g)		
	15 °C	20 °C	25 °C
P. zosteriformes	63.2	95.1	104.1
E. canadensis	46.9	66.3	37.1
V. americana	16.7	17.6	29.6
M. spicatum	0	6.3	0.9
C. demersum	0	1.4	0
E. densa	0	0	0

Water temperature is believed to affect the rate at which plants are consumed and the growth rates of grass carp. Secondarily, it may affect the longevity of grass carp. Temperature is a predominant factor in the model AMUR/STOCK developed for estimating the desired stocking rate of grass carp (Stewart and Boyd 1999). The model incorporates temperature as a factor strongly affecting the growth of macrophytes an in the bioenergetics of the fish whereby higher temperatures promote higher rates of plant growth and higher rates of plant consumption. The authors emphasize that key characteristics of plant growth should be considered in establishing stocking rates of grass carp: (1) overwintering level, (2) onset of regrowth, (3) rate of regrowth, and (4) peak biomass in addition to lake temperature regime. Other investigators report on the effects of temperature and in short-term studies the effects of feeding rates were not significant (Bowers et al. 1987). However, Swanson and Bergersen (1988) found that incorporation of daily temperature units (DTU) was necessary to account for variations in consumption of macrophytes by grass carp in coldwater lakes. Most studies indicate that cooler temperatures will slow the growth of macrophytes and slow the consumption of macrophytes by grass carp, although the degree to which this effect is exerted is complex. Some authors indicate that a minimum temperature threshold results in no further consumption of plants by grass carp (Stewart and Boyd [11 °C]; Colle et al. 1978: 14 °C).

STOCKING RATES THROUGHOUT THE UNITED STATES

State fish and game agencies and affiliated university extension services often provide guidance on recommended stocking rates for grass carp, particularly in the southern United States (Table 2). The rates are typically based on stocking triploid fish of 200-300 mm length. Oregon is the only state listed that requires fish also be implanted with PIT tags. Many of the southern states base stocking rates on the need to control hydrilla, an invasive macrophyte. Note that several states recommend use of techniques other than stocking grass carp, such as mechanical harvest or herbicides, when plant coverage is less than 20 percent.

Hanlon et al. (2000) found in a study of 38 Florida lakes that the minimum number of grass carp that can be stocked to yield partial control over macrophyte growth was a stocking density of 10 to 15 fish per acre of lake. Others have found that densities of 4 to 7.5 grass carp per hectare can yield partial control (10 – 40% plant coverage) based on a study of four impoundments in Texas (Blackwell and Murphy 1996). No studies were found that described what is proposed in Devils Lake – namely where macrophytes had been totally eliminated by grass carp and a managed regrowth of macrophytes with modest subsequent restocking of grass carp was implemented (cf. Chilton and Muoneke 1992).

Table 2. Recommended grass carp stocking rates for selected states. Low rates generally correspond to plant coverage of 20-40 percent, moderate of 40-60 percent and high of greater than 60 percent.

State	Recommended Stocking Rate (fish/ha)				Note	Source
	General	Low	Medium	High		
Alabama		8	25-38	38-50	For ponds with bass	Auburn Univ.-Ext
Florida	13	3-8				UF-Ext
Georgia	13-25					GDNR
Kentucky		5-13	13-25	25-50	Don’t stock w/ plant cover < 20%	KDF&W
Mississippi		8-13	13-25	30-50		MSU-Ext
Missouri		5-13	13-25	25-50	Don’t stock w/ plant cover < 20%	MDoC
New Mexico		8	13	18	Don’t stock w/ plant cover < 20%. Low elevation lakes	NMDF&G
Ohio		10-15	15-20	20-25	5-8 for coverage < 20%	OSU-Ext
Oklahoma	13-23				For partial control	OSU
Oregon	55				Maximum density allowed	ODFW
South Carolina	25-100				Preferred rates should be based on plant biomass	SCDNR
Tennessee		< 13	13-25	38-50		TWRA
Texas		13		25	Criteria is 50% plant coverage	TPWD
Virginia		5	13	25		VDGIF
Washington	23-63				Per vegetated acre	WDOE
Southern Regional Aquatic Center		25-30	30-38	>50	8/ha for vegetation cover < 10 %	USDA-SRAC

OPTIONS FOR GRASS CARP STOCKING RATES IN DEVILS LAKE

The choice of an initial stocking density is dependent on whether Devils Lake still has a viable population of grass carp present. If the decision to renew the experimental stocking density is postponed until the current population expires, then macrophytes will begin to regrow. The extent of subsequent macrophyte regrowth would alter the strategy for grass carp stocking considerably. However, the current conditions are that grass carp are present and still exerting macrophyte suppression. The proposed stocking plan is based on current conditions.

I suggest an initial stocking density of approximately 1 grass carp per hectare of lake surface area, which for Devils Lake would result in introduction of 270 fish. This would be roughly equivalent to a stocking rate of 2 fish/ha of potentially available macrophyte habitat. This rate is two orders of magnitude less than the original stocking density of 98 fish/ha used in 1986/87 and supplemented with another 18.3 fish/ha in 1993 for a total of 116 fish/ha. This proposed stocking density is predicated on starting the stocking in 2016. As the number of grass carp currently in the lake die off, control over the macrophyte growth is expected to decline rapidly. Thus, if grass carp stocking can be initiated while macrophyte biomass is low, it greatly reduces the need for a high stocking rate to suppress a plant population that is in a rapid growth phase. The population of grass carp would be slowly raised by continued stocking at the rate of 270 fish every other year. This would continue while monitoring of the extent and density of the macrophytes is conducted to provide information regarding the effectiveness of the carp to suppress, but not eliminate macrophytes. This would result in population increases, whereby the grass carp stocking would eventually be curbed to balance the desire for relatively stable macrophyte extent (Figure 3). One such scenario could involve achieving a modest density of grass carp and then gradually decreasing that level to further experiment with optimal densities of grass carp and macrophytes in Devils Lake (Figure 3, dotted line). Devils Lake Water Improvement District has a relatively stable level of revenue and is financially able to commit to this level of macrophyte monitoring.

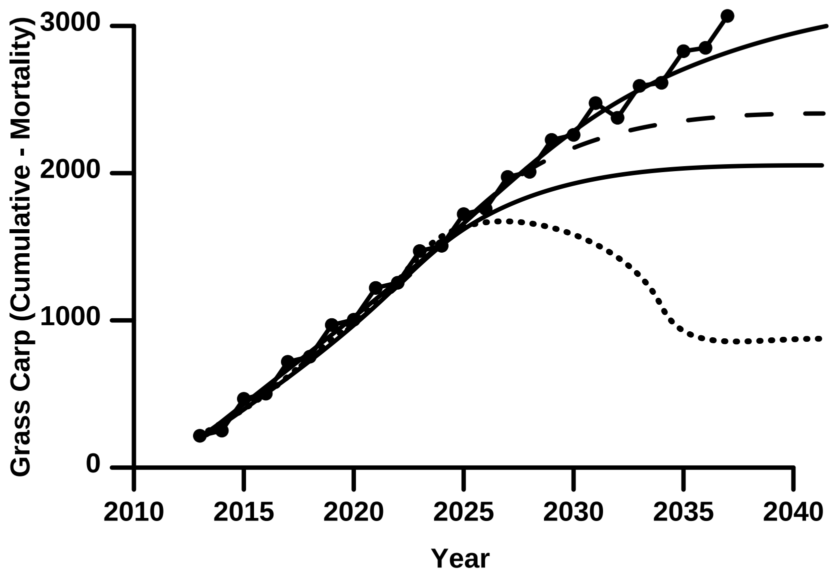

Figure 3. Proposed increase in grass carp in Devils Lake under a stocking rate of 1 fish/ha every other year coupled with a life-stage model for estimated annual fish mortality (solid line with circles). The four curves deviating from this line show possible scenarios for stabilizing the grass carp population in equilibrium with a modest macrophyte density.

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