Northeast Aquatic Research

Inventory of Grass Carp Stockings to Control Aquatic Invasive Species in the Lower Hudson PRISM

Prepared for the Lower Hudson PRISM
New York State Department of Environmental Conservation

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Study Goal and Objectives

The goal of this study was to examine grass carp stockings patterns across Region 3 (Dutchess, Putnam, Rockland, Sullivan, Ulster and Westchester Counties) of the New York State Department of Environmental Conservation (NYSDEC). Our objective is to compile all of the grass carp stocking records from 1991 to 2020 to provide insight into the stocking history, practices, distribution and types of vegetation controlled. We also aim to provide recommendations to improve stocking practices and permit evaluation for the Region 3 fisheries biologists. There has been no comprehensive accounting of grass carp stockings within both Region 3 and the rest of New York despite its widespread practice. Region 3 is an appropriate area to conduct this kind of work, as it boasts many natural and man-made waterbodies of diverse sizes and depths.

We would like to thank the Lower Hudson Partnership for Invasive Species Management and the NYSDEC for funding this work. Region 3 fisheries unit provided us with the stocking records spreadsheets and supplemental consulting reports/notes on vegetation.

Introduction

Native aquatic plants provide various key benefits to the aquatic ecosystems in which they reside. Plants provide structure, habitat, and food for young-of-the-year fish, macroinvertebrates, and waterfowl, along with stabilization of sediments and shorelines that prevent re-suspension and erosion of soil. Invasive aquatic plants, which are not native to the region and are highly aggressive, can rapidly take over a waterbody, degrading the ecosystem and reducing recreational value.

There are limited techniques to control aquatic invasive plants. These techniques can be divided into three categories: physical, chemical, and biological. Physical management involves the removal of plant biomass from the lake system, using a variety of methods such as diver assisted suction harvesting or mechanical harvesting. Chemical management involves the use of EPA-registered herbicides, which can be either selective to certain plant species or non-selective based on chemical type and application strategy. Biological control involves the introduction of organisms to a waterbody to consume nuisance aquatic plants. Similar to terrestrial pest management, there are several identified aquatic insects which graze on aquatic plants. The alligator-flea beetle (*Agasicles hygrophila*) is an aquatic insect that targets alligator weed (*Alternanthera philoxeroides*) and milfoil weevil (*Euhrychiopsis lecontei*) targets Eurasian watermilfoil (*Myriophyllum spicatum*). However, the most widely used biological control for aquatic plants in the United States is a fish, the Grass Carp (*Ctenopharyngodon idella*).

Grass carp have been used in the United States for biological control for more than 40 years. Originally introduced into the United States in 1963 in Arkansas via the US Fish and Wildlife Service Fish Farming Experimental Station (Mitchell and Kelly 2006), grass carp quickly became recognized as a potentially viable control strategy for aquatic plants. At the time, many state and federal agencies focused on research and development of non-chemical means of weed control, hence the push for biological controls. This was especially true after the development of sterile grass carp in 1983 via the induction of triploidy in the hatchery. Inducing triploidy involves a temperature of other stressful shock in the hatchery to the eggs which produces an extra set of chromosomes, which makes them unable to reproduce. Reproductive sterilization of grass carp meant that the fish can be stocked with minimal risk for natural reproduction which made states more comfortable with grass carp as an aquatic plant management technique. Since 1985, millions of grass carp have been shipped throughout the states (Mitchell and Kelly 2006). Most states now allow grass carp stockings. Of those states, most only allow the triploid grass carp variety. New York State permits triploid grass carp.

Grass carp have long lifespans, upwards of 30 years in some cases, which allows for the potential of long-term aquatic plant control. Fish are also relatively inexpensive (~$21 per fish with bulk discounts often available). Grass carp are often considered an attractive technique because plant control can be achieved for a fraction of the cost of chemical or mechanical control. Grass carp also have the advantage of positive community perception, as much of the public regard them as a “natural solution”, despite their non-native status and documented impacts on native species.

Unfortunately, some of the most attractive features of grass carp are also some of the most damaging to aquatic ecosystems. Grass carp are selective generalists, meaning that they will eat almost any kind of aquatic vegetation but have preferences linked to increasing palatability (Fischer 1968; Sun et al. 2017). Their non-selective nature means that a single species cannot be targeted for control. Rather, all palatable plants are susceptible to consumption regardless of their nuisance level or native status. It is well known that native plants can be consumed well before the target invasive species is consumed. This is especially true in waterbodies with Eurasian watermilfoil, which is often not the most preferred plant (Pine and Anderson 1991). Selective feeding can lead to an increase in non-palatable plants (June-Wells et al. 2017).

Overstocking of carp can lead to the complete de-vegetation of waterbodies within a season or two. Loss of all aquatic vegetation can have cascading effects to the entire ecosystem, including increases in turbidity, increases in nutrients (Kirkagac and Demir 2004), and declines in fish abundance and growth (Bettoli et al. 1993). Out of all the management techniques available for aquatic plants, grass carp stockings are among the most indiscriminate and detrimental to the ecosystem, especially if conducted improperly. Most New England states (Massachusetts, Vermont, New Hampshire, Maine and Rhode Island) have banned the use of grass carp, in part because of the risk to non-target impacts.

State of New York allows the stocking of grass carp limiting the stocking rate to a maximum of 15 fish per surface acre. Waterbodies under 5 acres have a relatively simple permit process, while waterbodies over 5 acres occasionally need an environmental impact study, with a site visit from DEC biologists. Waterbodies that have a permanent outlet need to construct a barrier to keep fish from escaping downstream. Stocking permits are issued via the NYSDEC Bureau of Fisheries, with regional biologists handling individual stocking requests.

Such a widely used and potentially detrimental technique needs closer evaluation to ensure that non-target impacts are quantified, and steps are taken to mitigate risks that directly oppose goals of other NYSDEC conservation initiatives. To date, there has not been a comprehensive evaluation of grass carp stocking data in any region of the DEC.

Data Treatment

NEAR received stocking records via two excel spreadsheets from the NYSDEC region 3 fisheries unit. The first sheet detailed complete stocking records for waterbodies over 5 acres. The second spreadsheet detailed the number of permits issued, permits used (permits where carp were actually stocked), and number of carp reported stocked for all waterbodies under 5 acres. Data from waterbodies under 5 acres were determined to be too vast to be compiled in a timely manner for this project. Therefore, outside of the number of permits issued per county and carp stocked, data discussed in this report is limited to waterbodies over 5 acres.

The spreadsheet containing records of waterbodies over 5 acres is organized by permit number, meaning that each row is a separate permit. A row can be a new permit (i.e. a waterbody which has never received triploid grass carp) or a reissued stocking. The spreadsheet contains multiple data columns including waterbody names, year of application, number of fish requested, number of fish stocked, waterbody size etc. There is also a detailed notes section that describes additional characteristics of the permits including if the fish were stocked, mortality events that precipitated new stockings, and general information on permit conditions. There is also a vegetation column, which details the types of plants that are present in each waterbody that is applying for a permit. For most ponds, this information is contained either directly in the spreadsheet or in a reference to an additional document. NEAR has had consistent communication with DEC regional fisheries staff in order to clarify any discrepancies within the dataset.

The Region 3 fisheries office also provided NEAR with supplemental reports and letters detailing vegetation status prior to and after carp stocking. These reports are used by regional fisheries staff to help shed light on the vegetation conditions and aid in the final determination of stocking rates. These reports/letters can also contain other information such as fisheries survey data, water quality information, and historical management.

NEAR analyzed the spreadsheet to elucidate patterns of stockings across the region. NEAR used both Microsoft Excel and R Statistical Software to analyze data. Specifically, the packages dplyr, ggmap, and ggplot were used within R to organize data and generate graphics.

Results

Region-Wide Trends in Permits

Number of Permits Issued

Since 1991, Region 3 fisheries staff have issued 7,885 triploid grass carp permits to landowners, associations, municipalities and other organizations. The majority, 94% or 7,437 of these permits were issued to waterbodies under 5 acres. These permits represent a combination of re-issued, renewal permits and new permits to waterbodies that have never submitted a permit for triploid grass carp. Across the counties, Dutchess had the most grass carp permits issued for waterbodies under 5 acres, with 2,980 since 1991. Ulster County and Westchester County had the second and third most permits issued (1,509 and 1,267 respectively). Rockland and Putnam Counties had the lowest number of permits issued (101 and 222 respectively). Approximately 75% issued permits were used (carp purchased and stocked).

A total of 448 permits were filed for waterbodies over 5 acres since 1991. Just about half were filed in Dutchess and Westchester counties, followed by about 20 % in Putnam County (Figure 1). Ulster and Rockland had the lowest number of permits filed, probably due to their smaller size and fewer waterbodies over 5 acres.

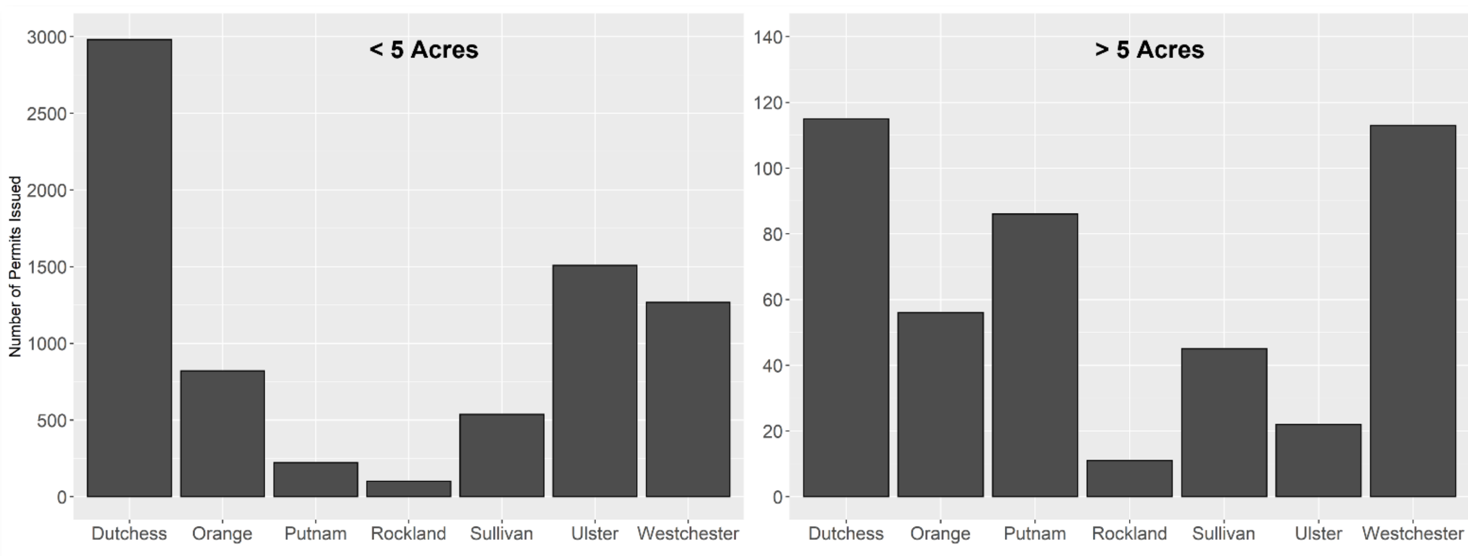

Figure 1. Number of grass carp permits issued per county within Region 3 of DEC. Top graph shows number of permits for waterbodies <u>under</u> 5 acres and bottom graph shows number of permits <u>over</u> 5 acres. Note difference in Y-axis scale.

The number of grass carp permits issued for small waterbodies, <5 acres, has consistently been over 100/year since the program started in 1991 (Figure 2). There were 350 permits issued during the years 2002 and 2003, highest on record. The numbers of permits issued has steadily declined since then with the fewest, 155, issued in 2019.

Far fewer permits have been issued for large waterbodies (>5 acres), generally between 10-25/year (Figure 2). In the last 10 years, between 9 and 14 permits have been issued each year.

Permits by county shows Duchess, and Winchester Counties have highest number of permits on file with consistently high number of filings each year. Rockland County on the other hand has only a few permits on file, with many years when no permits were issued.

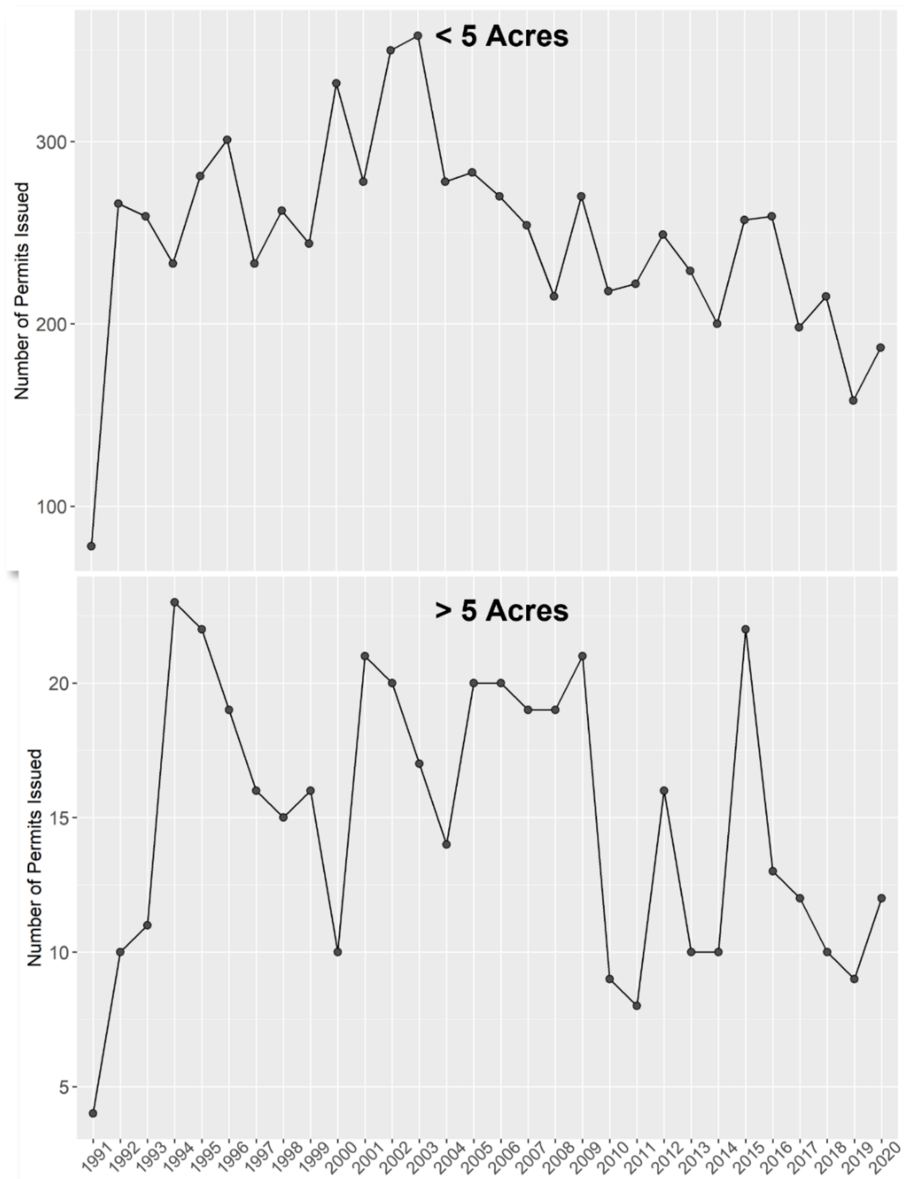

Figure 2. Grass carp permits issued across the years for Region 3 for waterbodies under 5 acres (top) and over 5 acres (bottom). Top graph shows number of permits for waterbodies under 5 acres and bottom graph shows number of permits over 5 acres. Note difference in Y-axis. scale.

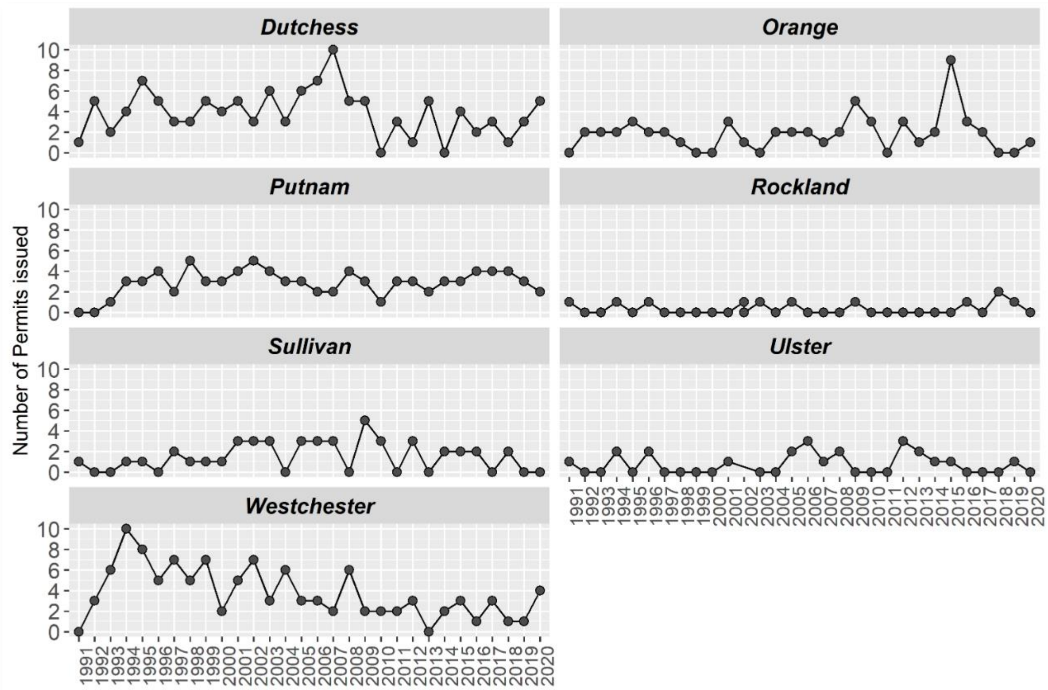

Figure 3. Grass carp permits issued in each county in waterbodies over 5 acres.

Waterbody Size

Most waterbodies in the larger group (>5ac) were between 5-10 acres in size (Figure 4). Only 13 waterbodies are larger than 100 acres, the largest is Lake Mahopac at 583 acres. Other large waterbodies include Orange Lake (Orange County; 410 acres), Lake Oscawana (Putnam County; 386 acres), Peach Lake (Westchester County; 244 acres) and Putnam Lake (Putnam County; 226 acres).

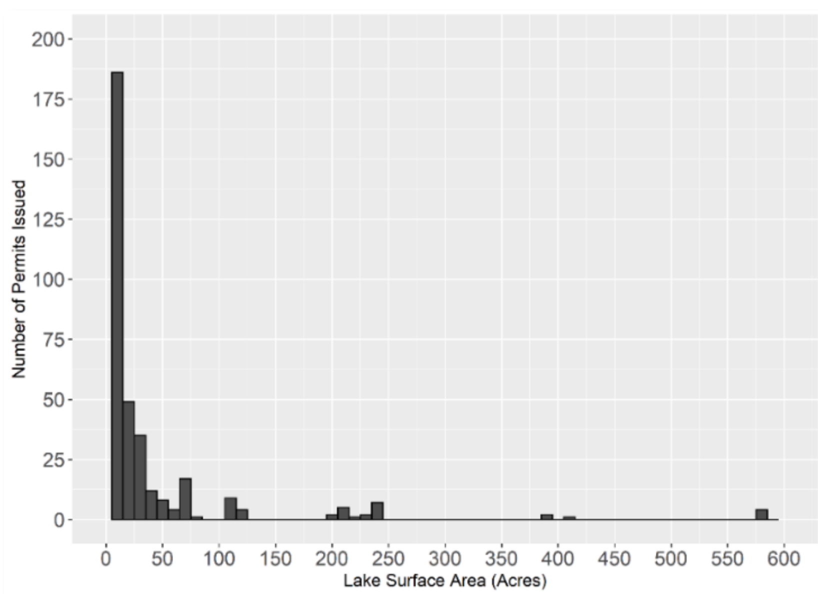

Figure 4. Distribution of waterbody sizes stocked with grass carp.

Number of Grass Carp Stocked

Since 1991, a total of 129,656 grass carp have been stocked in Region 3. There is a near equal split between waterbodies over 5 acres (63,517; 49%) and under 5 acres (66,139; 51%) (Figure 5). For waterbodies under 5 acres, Dutchess County had the most carp stocked (25,125), followed by Westchester County and Ulster County (16,537 and 10,341 respectively). Rockland and Putnam Counties had the fewest number of carp stocked (1,163 and 2,889, respectively). For waterbodies over 5 acres, Putnam County had the most carp stocked (22,336) followed by Dutchess County, and Orange County (11,150, and 10,882 respectively). Rockland and Ulster Counties had the fewest number of carp stocked in waterbodies over 5 acres.

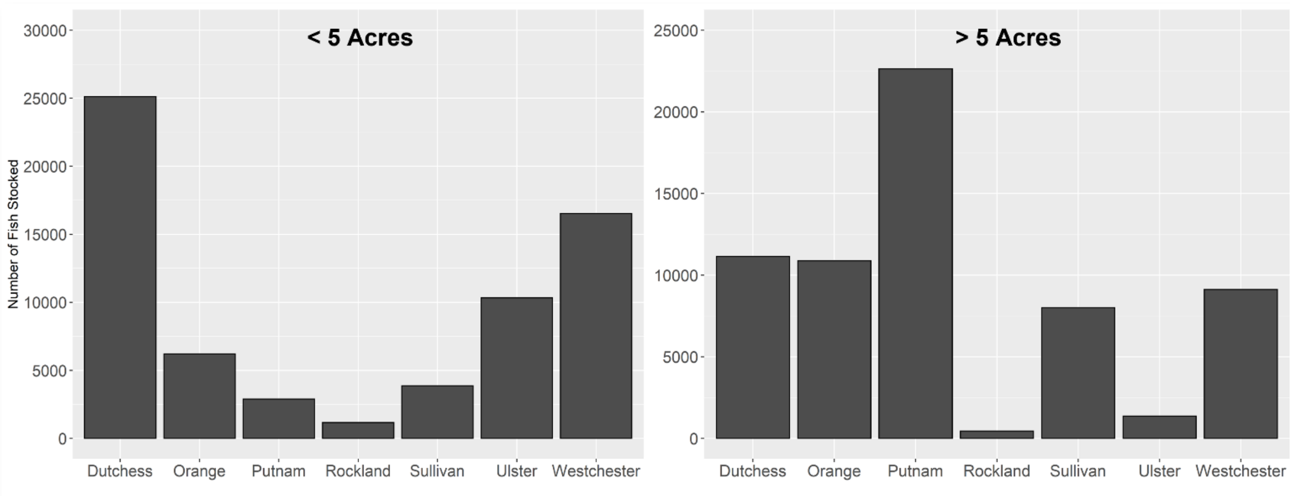

Figure 5. Number of grass carp stocked per county for waterbodies under 5 acres (left) and over 5 acres (right) Note difference in Y-axis scale.

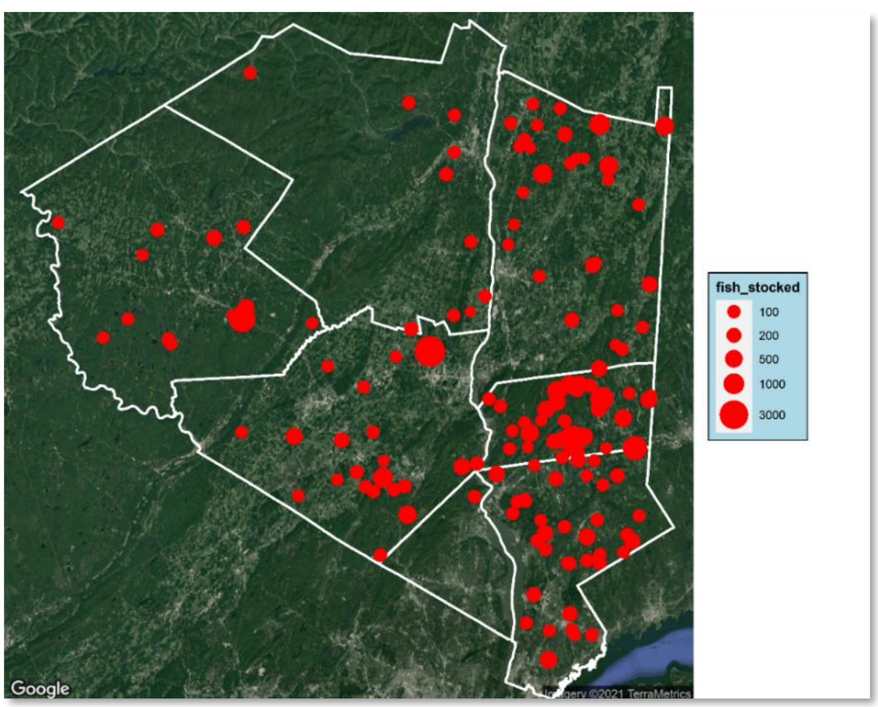

Figure 6. Locations and number of fish stocked per stocking event in waterbodies over 5 acres.

Stocking Rates

Stocking rates varied from a low of 0.2 to a high of 18.5 fish per acre, with 15 fish/acre used in 80% of the permits (Figure 7). Stocking rates of between 4 and 10 are generally used in lakes over 50 acres (Figure 8).

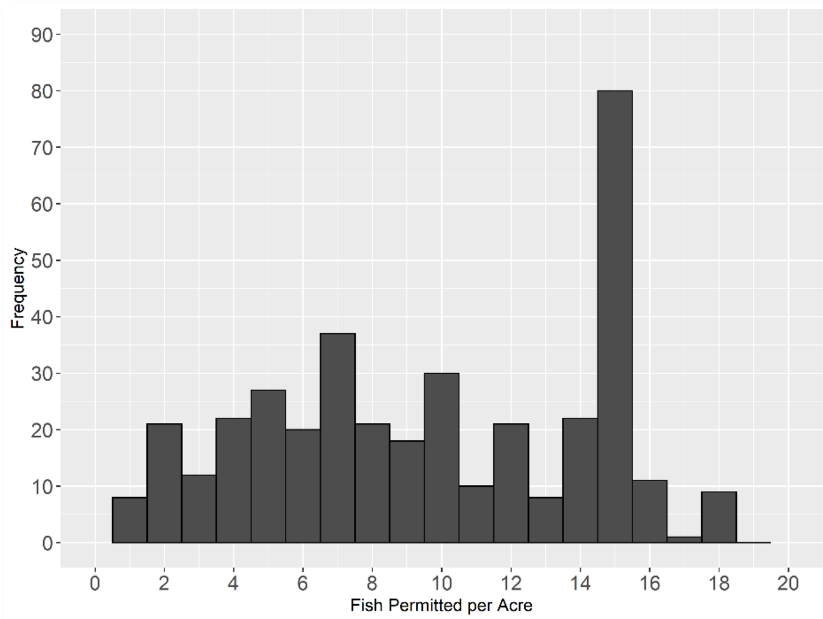

Figure 7. Permitted grass carp stocking rates across Region 3.

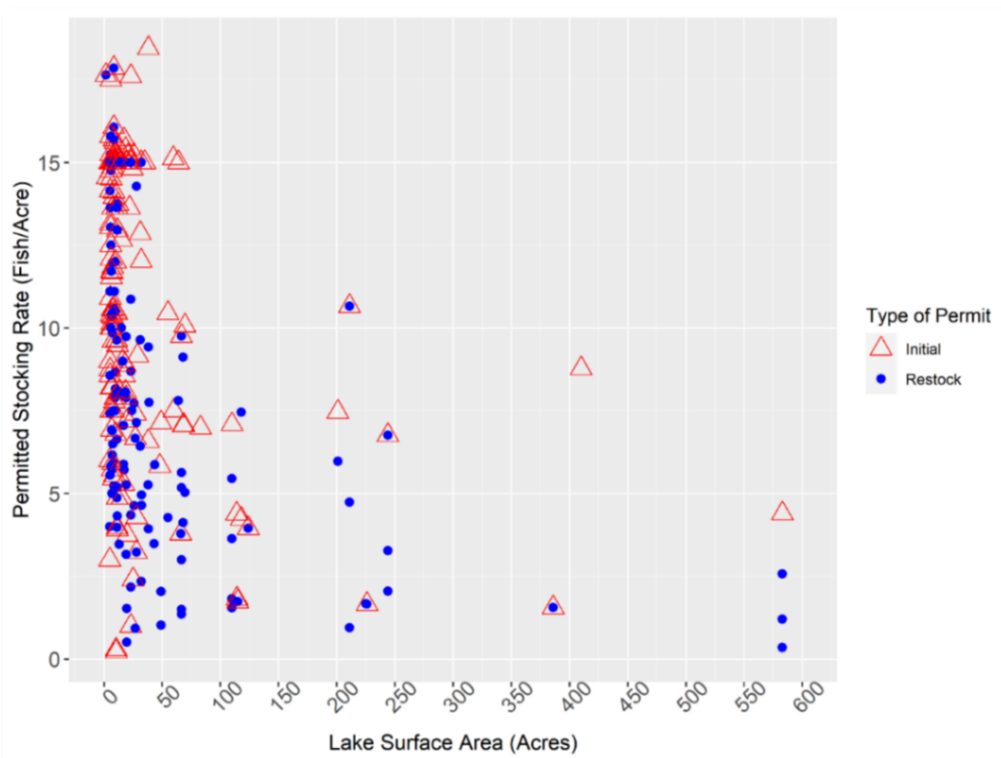

Figure 8. Comparison of permitted stocking rates across waterbody surface area.

Invasive Plants

There were 238 permits that listed one or more of nine invasive aquatic plant species (Table 1). Most common species was Eurasian milfoil (*Myriophyllum spicatum)* listed on 126 permits followed by curly-leaf pondweed (*Potamogeton crispus*) and water chestnut (*Trapa natans*) (62 and 20 permit applications, respectively). It is important to note that the permits often do not signify the target plants, but rather just include description of the plant problem and the percentage of each species present in the waterbody. Because of this, an invasive plant listed in the permit does not necessarily mean that the documented AIS was the management focus.

Table 1. Aquatic invasive species mentioned in permits

Common name	Scientific name	Number of Permits	Percentage of total
Brazilian Elodea	*Egeria densa*	1	0.2
Brittle Naiad	*Najas minor*	3	0.7
Curly Leaf Pondweed	*Potamogeton crispus*	62	13.8
Eurasian Watermilfoil	*Myriophyllum spicatum*	126	28.1
Fanwort	*Cabomba caroliniana*	15	3.3
Hydrilla	*Hydrilla verticillata*	6	1.3
Parrot Feather	*Myriophyllum aquaticum*	1	0.2
Variable Leaf Milfoil	*Myriophyllum heterophyllum*	4	0.9
Water Chestnut	*Trapa natans*	20	4.5

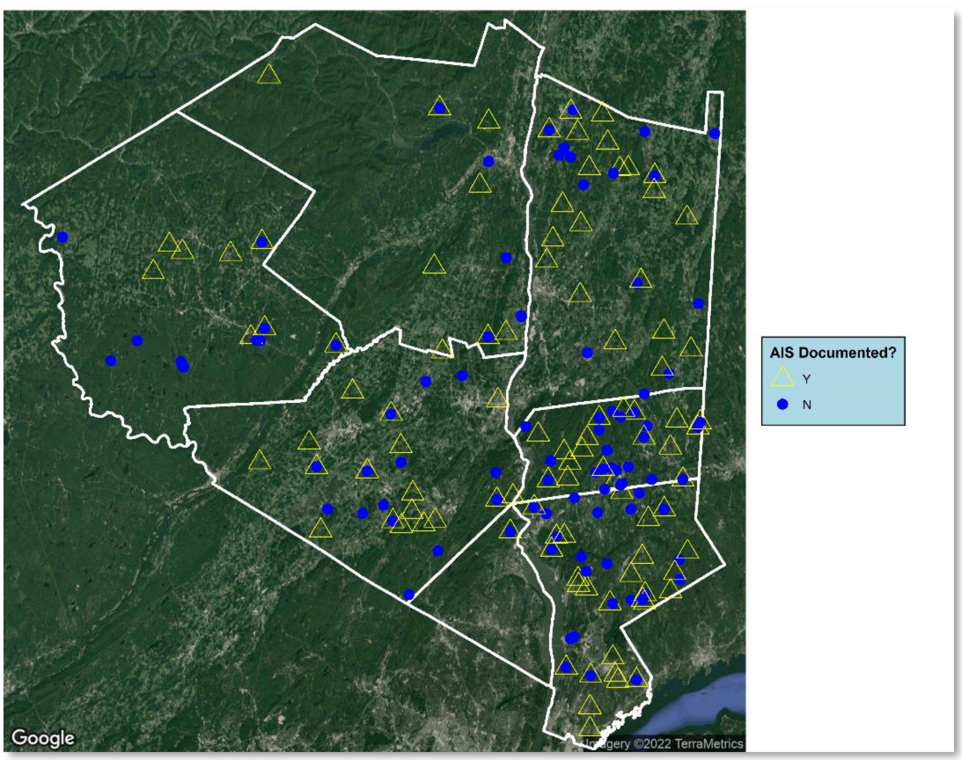

Figure 9. Stocking permits that contained invasive species throughout Region 3 DEC. Points that overlap indicate single waterbodies with multiple applications that had different species listed.

When they did, permits contained vague language regarding target plants. Typically the plants were listed as "milfoil". Although, most likely eurasian watermilfoil was indeed the target plant, two other invasive milfoils look similar; varable-leaf milfoil (*Myriophyllum heterophyllum*) and parrot feather milfoil (*Myriophyllum aquaticum*), as well as 4 native species two which are state protected species in the region. The same issue arises for native plants, which are often named by the genus or common name which could refer to multiple species (ie. "pondweed" or "duckweed").

Impacts of Grass Carp on Vegetation

Identifying grass carp impacts to vegetation is difficult without consistent vegetation measurement. Out of the 177 lakes that have received grass carp stocking permits, only 23 waterbodies (13%) provided the DEC fisheries unit with supplemental maps and/or consulting reports available for review in this study. Of these 23 waterbodies, most had notes on post vegetation condition for at least one stocking event, linked most often to restocking permit applications and letters of support. The timing of the post monitoring is not always consistent. Since the decision to re-stock a lake does not take place at a set time post initial stocking, reports are not available on a consistent basis. Lake Mahopac is the only lake that has consistent plant data available throughout the entirety of all stocking applications. Lake Sagamore (Putnam County) had grass carp stocked in 2005, 2009, 2011 and 2012, but the dataset only contains a survey from 2001 and a letter from 2015. Lake Celeste (Putnam County) noted that the initial stocking in 1993 was "effective for 5 years" but without any context on what that meant. A general lack of pre and post vegetation data is common among lakes within the dataset.

The quality and consistency of the data submitted to the DEC is questionable as well. Most lakes have a combination of actual studies and notes from associations/consultants commenting on status of vegetation. For example, Beaver Lake in Thompson, Sullivan County, only had hand drawn maps of vegetation coverage, with no indication that a qualified professional surveyed the lake for every permit application. Hunns Lake (Dutchess County) is similar, with hand drawn maps for all but one permit application. The 2007 and 2013 maps and narrative are identical to each other, and the two presented coverage estimates do not match up. Once again, it is unknown if this was done by a homeowner or a professional.

Table 2. Notes on select waterbodies over 5 acres which provided the DEC with supplemental information. Citations are included at the end of the report.

Lake	Stocking Year- Number of Fish Stocked)	Impact on Vegetation
Lake Carmel	1999 – 1500	2002 – reduction of biomass in northern end from 250.07 g/ft2 to 17.5g/ft2 2002 – reduction of biomass in southern end from 344.2 g/ft2 to 43 g/ft2.
Lake Louise Marie	1994 - 2250 1997 - 1000 2001 - 800 2009 - 100 2010 - 200	1997 – no change noted in milfoil since initial stocking, no report to justify, only narrative. 2000 – note from consultant that 1997 stocking helped clear plants from surface, notes on reduced growth, but no hard data. 2001 - Buttercup and bladderwort increases

		2010 – notes fanwort as dominant plant, only pondweed and white water lily as other species.
Lake Mahopac	1994 - 2565 2015 – 200 2017 -1500 2019 – 700	2/3 reduction from 1994 to 1995, 99% biomass reduction in 1997. Vegetation did not recover until 2013.
Lake Sagamore	2003 – 780 2005 – 200 2009 - 600 2011 - 400 2012 - 170	Effects of 2001 stocking unknown, 2015 survey showed 10% vegetation coverage, 2015 permit to restock denied.
Long Pond	1992 - 700 2003 - 350 2006 - 75 2013 - 75	By 1995, reductions in all plant species, white water lily increased, milfoil frequency increased, but biomass decreased. Robbin's pondweed completely eliminated. 2002- Allied biological report, fanwort documented, no comparison to previous stockings
Lost Lake	1998-385 2000-75 2001-150 2003-150 2005-150 2008-160	1998 – coontail and small amounts of elodea 2001 – loss of a lot of fish to hurricane Hugo, undetermined 2003 – curly leaf pondweed across entirety of lake 2005 and 2008 – just a letter with descriptions of plants, no survey. Plants not controlled.
Palmer Lake	1996 - 285 2001 – 285 2004-185 2018-185 2020-60	1996 – roughly 85% coverage of *Potamogeton natans* (30%); *Elodea* (80%); *Cabomba* spp (25%); *Najas* spp (60%); *Chara* spp (45%) 2004 – mostly coontail and duckweed, no updated veg coverage 2018 – 11 acres of plants ~85% coverage, milfoil and coontail dominant plants 2020 – 4.1 acres of plants
Peach Lake	1996- 1650 1999-300 2001-500 2002-500 2007-800	1998 – most high preference submersed plants eaten, feeding on milfoil and coontail but most ripped and floating. 2000 – coontail and milfoil dominant species, coontail growing in deeper water. Most other plants declined from 1994 survey. 2007 – no survey, but letter from homeowners indicating coontail is dominant plant.
Twin Island Lake	1991-960 2007 - 500	2005 report 1992 to 1997 no submersed vegetation present, 1997, some submersed vegetation came back.
Beaver Lake	1997 - 405 2000 - 50 2002 - 200 2012 - 202 2018 - 250	No consulting report, just hand drawn vegetation maps. 1996 indicates significant native plant community that was not documented in subsequent maps. No indication that professional services were used to map lake post 1996.

Howlands Lake	1994 - 390 1998 - 120 2002 - 120 2009 - 100	1993 – Maps indicate significant coverage of elodea and pondweed. 1998 – Report indicates shift to naiad (species unknown), large reduction in elodea and pondweed. Total vegetation coverage seemed to decline as open area documented in maps. Note to chemical management of plant beds in between 1993 and 1998. No further updates after.
Hunns Lake	1997 - 650 2007 - 375 2013 - 345 2015 - 200 2017 - 100 2019 – 90	No vegetation reports after 1993, maps indicate ranges of white water lily and milfoil coverage. Milfoil was not noted in original 1993 survey. 2007 permit map and 2013 permit map are identical. Potential eradication of elodea and coontail, with significant reduction in pondweed.
Kirk Lake	2011-490 201-365	Report from 1999, but no permit filed until 2011. 49 acres of vegetation, milfoil dominated in 2011. Shift in vegetation from milfoil and curly leaf to coontail and naiad via 2014 allied biological report. 365 carp stocked in 2018, but DEC was not notified. The lake also undergoes a significant drawdown annually. There is also an inlet that leads to a large wetland complex, not identified in either
Lake Celeste	1993 - 83 2002 - 85 2008 - 70	1993 – report details water lily and pondweed coverage totaling 5.5 acres of 7.1 acre lake. 2002 – Note detailing that 1993 stocking was "effective for 5 years" no data or maps to verify. *Rannunculus* and water lilies dominant plants. No pre-post stocking monitoring or vegetation maps for 2008 stocking.
Lake Dutchess	2016 – 350 2017 – 50 2019 – 100 2020 - 100	Original application said high coverage of elodea and pondweed. Only consulting report provided was an excerpt from a 2016 monitoring report. Unclear what the justification was for stocking fish in subsequent years.
Treasure Lake	1999-200 2001-200 2010- 150	No information from original application, 2010 letter noted 40-50% fanwort, 50% white water lily and 15-20% duckweed. No actual consulting survey.
Lake Stahahe	2012 - 580	Stocking to control Brazilian elodea infestation. Fanwort has recently invaded and is current focus of management.
Macgregor Lake	2007 - 90 2015 - 90 2020 - 90	Original report by NEAR in 2005, reported 7 acres of plant coverage mostly of curly leaf pondweed and elodea. No follow up.
Marx Pond	2007	Most recent report in 2003, entire lake covered in vegetation, mostly coontail and water lillies
North Lake	2008 - 144 2017 - 30	2008 – application details 60% *Ceratophyllum* and 60% *Elodea canadensis.* Note in 2008 application that in 2010, all weeds were gone and there was an algae bloom. Applicator confirmed carp were removed from lake at some point after 2010.

		2017 – *Najas minor* was dominant plant, followed by *Chara* sp. and *Elodea/Nitella*. 2020- Najas minor dominant plant
Orange Lake	2008-3600	2007 – letter from Scott Kishbaugh – no vegetation data, just noting that milfoil has taken over entire lake. No follow up survey.
Putnam Lake	2018-306	2014 survey from allied biological-71% of sites vegetated, curly leaf pondweed was dominant plant. No follow up survey. 306 fish stocked, but not noted by DEC
Seven Hills Lake	2000 - 575 2006 - 235 2010 - 235	1999 – map only showing beds of *Chara*, milfoil, curly leaf pondweed, naiad. 95% of lake covered in vegetation. 2002 – reduction of *Chara*, naiad and curly leaf pondweed. Milfoil was dominant 2005 – reduction of milfoil, replaced by curly leaf pondweed. Only 18% of lake was densely covered. 2010 – Management plan showing that 2009 assemblage still is curly leaf pondweed dominant. Also notes history of multiple management techniques used on lake since late 80's.
Silver Lake	2008 - 256	April 2007 survey from Princeton hydro showing Elodea and *Potamogeton pusillus*. No maps present. Coverage estimated by April secchi disk reading.
Walton Lake	1987 – 400 1989 – Unknown	No initial reduction in 1987 Stocking in 1989 reduced vegetation by 30%, milfoil became monoculture. Additional stocking removed remaining milfoil

Due to the infrequency of post treatment monitoring, understanding what impacts these carp stockings had on native and invasive plants is difficult. Based on the stocking spreadsheet, at least four lakes have lost all vegetation after grass carp stockings: North Lake (Westchester County), Lake Mahopac (Putnam County), Twin Island Lake (Dutchess County) and Walton Lake (Orange County). With only 13% of all lakes providing any supplemental reports and a small percentage of those lakes reporting timely post-monitoring results, the number of lakes that have completely lost vegetation is likely far larger than reported here.

Many lakes have seen drastic reductions in plants and shifts in plant community structure. Lake Carmel (Putnam County, NY) saw a 93% and 88% reduction of biomass in the north and south end of the lake respectively three years post stocking (1999 to 2002; Mininger 2007). Palmer Lake (Putnam County) saw total vegetation acreage decrease from 11.4 to 4.1 in two years (2018 to 2020; Perrone et al. 2020), which was mostly milfoil and coontail. Long Pond (Dutchess County) saw a reduction in the biomass of eurasian watermilfoil, but an increase in frequency post stocking (Grim 1992b). Peach Lake (Westchester County) showed reduction in all plants, but floating milfoil and coontail were still present (Grim 2000b).

In a few lakes, native plants have been significantly altered by grass carp introductions. Long Pond (Dutchess County), which was previously mentioned, experienced a complete eradication of robbins pondweed (*Potamogeton robbinsii*) three years post stocking. Reductions were also seen in large-leaf pondweed (*Potamogeton amplifolius*), coontail and stonewort (*Nitella sp*.). Similar declines of native plants were noted in Peach Lake (Grim 2000b), Beaver Lake (Beaver lake 2012, and Oscawana Lake (NEAR 2020).

Discussion

Fisheries Department Role in Grass Carp Stockings

Examining grass carp stocking permit data since 1990 has revealed many different aspects of the program. First, the number of new permit requests each year is large. Since 1990, on average, the DEC Region 3 staff have issued 262 permits annually, or slightly more than 1 per business day, every day of the year. This is in addition to managing sportfish populations and angling opportunities across the region. This may lead to minimal attention for each permit when the volume of permits is high. This increases the chances that the final number of grass carp stocked is scientifically inappropriate, or a detail is missed with regards to outlet barrier construction, vegetation coverage/type, etc.

Future policies for grass carp permit submissions and evaluations should aim to prioritize gathering of quality information from the waterbody in question. Ideally, each permit for waterbodies over 5 acres should have the following information: vegetation survey(s), list of past management activities with comments on success, and stated goals of vegetation management.

Vegetation surveys

Vegetation surveys by qualified professionals should be a prerequisite before the department even considers a stocking application for a waterbody over 5 acres. This survey should be done in the year immediately preceding the application year. This is to ensure that the plant information the state is reviewing is the most up to date. The vegetation surveys should encompass the entirety of the waterbody using a survey design that can track long term changes and map acreage of palatable vegetation. Tracking changes over time allows the state to discern if the carp stockings have had the intended effect and if there are any non-target impacts. Accurate estimates on the vegetated acreage are important to determining the number of carp needed to control vegetation.

Vegetation included in the survey should be identified to the lowest possible taxon. Identifying plants only to the genus level or with generic descriptors does not allow for proper evaluation of the aquatic plant community. For example, many permits listed just “pondweed” as a species with a particular percent cover. This is problematic because there are 27 species within the *Potamogeton* genus, five species on the rare plant active inventory list, and one invasive species. This is not including any other species of aquatic plants that look like pondweeds but are not in the same genus, such as *Stuckenia pectinata* and *Zosterella dubia*. There are multiple genera of aquatic plants that contain both invasive and rare species, such as “milfoil”, “naiad”, “duckweed” etc. This is especially problematic for rare species, as they are already at a low abundance statewide. Failing to identify plants to the species level can lead to stocking a waterbody that contains a rare plant, which could extirpate the population.

Vegetation surveys conducted by professionals can also aid in informing state programs and inventories. Groups such as the DEC Invasive Species Unit, NY Floral Atlas, Natural Heritage Program and IMAP Invasives program greatly benefit from data on plant distributions. The grass carp stocking permits represent a vast, untapped resource for species distributions that can aid the state. Currently, the manner in which vegetation data is collected an reported may not be adequate for use in state purposes, mostly because the state does not require vegetation data to be collected by a professional. Requiring professional vegetation surveys would help the state make more informed decisions about invasive species management on a regional scale.

Fanwort (*Cabomba caroliniana*) is one example of a plant that could be better managed with an improved understanding of its distribution. Currently, this tier 2 species (LHPRISM 2021) is located in 14 waterbodies throughout the region according to IMAP invasives. Looking through the grass carp permits, fanwort was documented in 9 waterbodies throughout the region. All 9 waterbodies where fanwort was documented in the region are different from the 14 known locations. While it is unknown whether all nine of these waterbodies actually have fanwort (due to the data uncertainty mentioned in the previous paragraphs), this represents a situation where one office in DEC knows about an invasion well before another branch does. We recommend that any time a permit comes in with an invasive species, that the Lower Hudson PRISM staff, DEC Invasive Species Unit and IMAP invasives be notified.

Table 3. Comparison of invasive species documented occurrences between IMAP invasives and grass carp permits.

Invasive Species	IMAP Waterbodies	Waterbodies with Grass Carp	Number In Common
Fanwort	13	9	0
Eurasian Watermilfoil	92	68	12
Curly Leaf Pondweed	22	39	3
Water Chestnut	64	9	1
Variable Leaf Milfoil	13	3	0
Brittle Naiad	21	3	1
Hydrilla	3	3	1
Brazilian Elodea	0	1	0

Recommendations for Vegetation Surveys:

1) Surveys should be required for all waterbodies over 5 acres seeking permits.
2) Surveys should be conducted by a professional trained in aquatic plant ID and survey techniques.
3) Vegetation should be identified to the lowest possible taxonomic classification.
4) DEC Staff should notify Invasive Species Unit and Lower Hudson PRISM when an application lists an invasive species.

Competing Management Activities

The use of multiple techniques to combat invasive species has been a staple of management for many years. Often, it is advantageous for groups to use more than one technique to achieve stated goals, as no one technique can handle every invasive species and every situation. Common examples in aquatic plant management include using mechanical harvesting to clear boating lanes, while herbicides handle larger areas, or using select harvesting to manage summer growth after a drawdown in areas that were not adequately exposed to freezing/drying conditions. Grass carp are commonly used in integrated management, with some waterbodies opting to manage with herbicides first, then allowing grass carp to clean up any remaining plants as they re-emerge.

While the integration of management techniques is not an issue itself, problems arise when managers do not have a complete account of other techniques happening concurrently. Numerous factors must be considered when determining the number grass carp to stock in a waterbody. The assumption is that the amount of grass carp stocked will be enough to reduce the current level of vegetation to a pre-determined amount. When additional management techniques are implemented during the season, the ratio between the number of carp and vegetation changes. For example, if a waterbody that is 10 acres and completely covered in vegetation received 50 fish, the stocking rate would be 5 fish per vegetated acre. If, then, the waterbody was treated with an herbicide, the number of fish per vegetated acre would be much larger. The treatment effectively increases the stocking rate and increases the amount of vegetation controlled. This can push waterbodies closer to complete de-vegetation, which is an undesirable result in most cases.

The current DEC triploid grass carp stocking application does not ask for information regarding past management strategies or management strategies to be employed in the following year. Going forward, it would be prudent to require every landowner to disclose all plant management permits and management actions that take place on the waterbody. Intradepartmental communication is key in this as well, especially with the pesticide permits division and wetlands division. Ideally, any time an application for triploid grass carp is submitted for a waterbody over 5 acres, the application should be cross referenced with other permit applications to make sure there are not two overlapping management techniques that will drive a waterbody towards de-vegetation. This cross-referencing should also happen from the pesticides division for future permits. Grass carp are not a one-year management technique as other strategies are. Pesticide permits should consider history of grass carp stockings to evaluate the potential of removing too much vegetation from a waterbody

This strategy will apply to some management techniques but may miss poorly un-regulated activities such as drawdown and mechanical harvesting. These two techniques can often remove a significant amount of vegetation from a waterbody on an annual basis. Oscawana Lake (Putnam County) has been using a mechanical harvester for years, harvesting around 20 acres of vegetation per year. This information was only available to the DEC regional staff because the Town’s consultant decided to include it in a supplemental letter of support (NEAR 2020). Drawdown can significantly affect the plant distribution and coverage, especially if the winter was extremely cold and dry. Plants functionally have a late start growing in the affected areas and often are absent if drawdowns happen consistently. Since the timing and duration of drawdown changes each year based on weather and precipitation, it is hard to predict what the plant acreage will be when grass carp are stocked. This adds an additional layer of complexity.

Recommendations for Competing Management Strategies

1) Suggest that every applicant disclose all plant management activities undertaken on the waterbody.
2) Applications should be cross referenced with the division of pesticides and invasive species to complete full picture of management.

Stocking Rates

Stocking rates vary widely across the region and across lake size. Determining how many fish are needed to control aquatic vegetation is the crux of grass carp management and arguably the most complicated aspect of the process. Completely eliminating vegetation is quite easy to achieve with grass carp, as one can stock well above recommended rates and reach vegetation elimination in a matter of months. The complicated aspect associated with grass carp stockings is controlling vegetation to a certain point without de-vegetating the entire system. De-vegetation of waterbodies is most often undesirable for most waterbody uses, as fishing, swimming and general aesthetics can be directly or indirectly affected.

Stocking rates should vary depending on factors such as plant palatability, water temperature, dissolved oxygen, plant location, the age of fish, and proximity to humans. Because plant production is controlled by factors such as spring water temperatures, nutrient input, light availability, presence of other herbivores, and additional management techniques, the final determination of fish / acre should include consideration of these variables.

An additional complication is the time scale of grass carp stockings. The effects of stocking grass carp last for multiple years after the initial introduction of the fish. If grass carp reduce a significant portion of vegetation within a year, then the consumption of plants was higher than the plant production. If only 30% of those plants grow back in year 2, then the balance tips further to the side of carp consumption, as grass carp mortality rates are usually not higher than 30% unless vegetation is severely reduced (Kirk and Socha 2003). The fish per vegetated acre number increases in year 2, meaning that the scale keeps tipping toward more carp consumption than plant production. If no other stockings happen, the balance will eventually tip back towards plant production, with the time it takes depending on how many fish were initially stocked and mortality rates.

With the complicated nature of stocking rates and anticipating impacts, the decision on when to allow a restocking can be difficult. Some landowners want to be proactive in stockings, so vegetation coverage does not return to nuisance levels. On the other hand, restocking proactively can push the waterbody towards de-vegetation, as the carp that are already within the waterbody are still grazing. Adding more fish on top of the existing population can be dangerous. We believe that using a more reactive approach is appropriate for grass carp stockings. Applications for restocking should show that within the time between the initial stocking and the restock, vegetation has either stayed the same or increased in coverage. The detailed, professional vegetation survey discussed earlier will be used any permit that does not show this should be denied a restocking event. If there is a decline of vegetation, but not to the level satisfactory for the goals of the waterbody, alternative techniques should be encouraged to manage plants. The advantage of techniques such as herbicides, hand harvesting, benthic mats and mechanical harvesting is that the landowner can control how much vegetation is removed. This controlled management can help a landowner achieve the 20-30% desired vegetation coverage while minimizing the chance of de-vegetation.

Recommendations for Stocking Rates/Restocking

1) Applications for restocking should show that within the time between the initial stocking and the restock, vegetation has either stayed the same or increased in coverage.
2) Encourage applicant to explore alternative techniques for plant control when there is a decline in vegetation, but it is not sufficient for waterbody goals.

Recommendations

Examining grass carp stocking permits throughout the region revealed many shortcomings of the program. While, in recent years, stocking practices seem to have become more conservative as biologists have become more aware of the negative impacts of overstocking carp, there is still room for improvement. Below is a list of recommendations that we believe will improve the stocking evaluation process and ensure that the most relevant data will be available for biologists to review. These recommendations should be restricted to waterbodies over 5 acres, as the sheer numbers of permits from waterbodies under 5 acres may end up being too onerous on DEC staff.

Submitted with new permit application:

Full-waterbody vegetation survey – performed by consultant or group trained in aquatic plant identification/surveying. Survey should be performed the summer immediately before fish enter the waterbody.

Needs to Include:

- Estimation of total vegetation coverage
- List of all plant species found in waterbody
    - Plants need to be identified to species level unless there is a suitable reason (no reproductive structures present etc.)
- Percent coverage estimates for each species at point intercept locations

List of currently employed management strategies

List should include:

- Permitted and non-permitted management strategies
- Acreage of vegetation managed by listed techniques

Restocking Permits (same requirements as new permit application including:

Follow up survey repeating the methodology of the initial stocking survey

- If survey shows a decrease in total vegetation coverage after stocking , permit will be denied.

When permits get filed with DEC Fisheries Staff:

- Cross reference with other DEC permit offices to check on concurrent management techniques.

These requirements can be included in a fact sheet linked to the DEC Triploid Grass Carp application webpage. A factsheet will provide applications with a clear understanding of the permit requirements to facilitate efficient processing.

Future Work

The work done during the 2021 season is an important start to completely understanding the scope of grass carp stockings and associated impacts. There are many avenues to follow up with future work; We wanted to highlight a few here:

Water Quality Impacts

The de-vegetation of lakes can lead to increased turbidity and nutrients, potentially creating conditions that are favorable for harmful algae blooms. Examining the effects of grass carp stockings on water quality would improve our understanding of how to mitigate impacts, along with identifying which lakes may be most susceptible to negative water quality impacts following de-vegetation. Impacts can be analyzed using data from the Citizens Statewide Lakes Assessment Program and The Lakes Classification Inventory, along with consultant reports. In recent years, the HABs notification system has been gathering data on reported harmful algae blooms on a multitude of lakes. The HAB's archive can be cross referenced with grass carp stockings.

Fisheries Impacts

Fisheries can be negatively impacted by grass carp stockings, as vegetation coverage is important for young-of-the-year refuge and macroinvertebrate production. Investigating impacts to fisheries is a more involved process, due to the lack of fisheries data from many private lakes within Region 3. A few select lakes that have received grass carp in recent years could be followed over time to determine whether any fisheries impacts have occurred. Angler surveys could play a role as well, especially on private waterbodies where survey data would be sparse.

Determining Proper Stocking Rate

Any detrimental impacts to plants, water quality, and fisheries are inherently linked to and exacerbated by the rate of de-vegetation. Determining the stocking rate that will cause de-vegetation in specific scenarios will help prevent this from happening in the future. Based on the stocking records, the lakes which lost vegetation entirely were stocked at rates well below the maximum of 15 fish per acre. Understanding what caused these lakes to lose all vegetation, while other lakes with the same stocking rate did not is important for future stockings.

Literature Cited

Bettoli, P. W., M. J. Maceina, R. L. Noble and R. K. Betsill. 1993. Response of a reservoir fish community to aquatic vegetation removal. N. Am. J. Fish. Manage. 13:110-124.

Dibble, E.D. and Kovalenko, K., 2009. Ecological impact of grass carp: a review of the available data. *Journal of Aquatic Plant Management*, *47*(1), pp.1-15.

Fischer, Z., 1968. Food selection in grass carp (*Ctenopharyngodon idella* Val.) under experimental conditions. *Pol. Arch. Hydrobiol*, *15*(1), pp.1-8.

June-Wells, M., Simpkins, T., Coleman, A.M., Henley, W., Jacobs, R., Aarrestad, P., Buck, G., Stevens, C. and Benson, G., 2017. Seventeen years of grass carp: an examination of vegetation management and collateral impacts in Ball Pond, New Fairfield, Connecticut. *Lake and reservoir management*, *33*(1), pp.84-100.

Kirk, J.P. and Socha, R.C., 2003. Longevity and persistence of triploid grass carp stocked into the Santee Cooper reservoirs of South Carolina. *Journal of Aquatic Plant Management*, *41*, pp.90-92.

Lower Hudson Partnership for Invasive Species Management (LHPRISM) 2021. Species Categorization. https://www.lhprism.org/system/files/documents/Species%20Categorization%20LHPRISM.pdf

Mitchell, A.J. and Kelly, A.M., 2006. The public sector role in the establishment of grass carp in the United States. *Fisheries*, *31*(3), pp.113-121

Northeast Aquatic Research (NEAR) 2020. Grass Carp Stocking Life Table and Recommendation 2021. Submitted to the New York Department of Environmental Conservation, Region 3 Fisheries Division. 3pp.

Pine, R.T. and Anderson, L.W.J., 1991. Plant preferences of triploid grass carp. *Journal of Aquatic Plant Management*, *29*(2), pp.80-82.

Sun, J., Wang, L., Ma, L., Min, F., Huang, T., Zhang, Y., Wu, Z. and He, F., 2017. Factors affecting palatability of four submerged macrophytes for grass carp *Ctenopharyngodon idella*. *Environmental Science and Pollution Research*, *24*(36), pp.28046-28054.

Supplemental Reports

2002. Letter to Michael J. Flaherty, NYSDEC. Lake Celeste, Putnam County, New York.

2016. Email correspondence between Michael P. Hartshorne, Princeton Hydro, LLC and Michael J. Flaherty, NYSDEC. Re: Lake Sagamore-Carp Permit Status.

Allied Biological, Inc. 2002. Triploid Grass Carp Pre-Stocking Report. Long Pond, Dutchess County, NY. Allied Biological, Inc. Hackettstown, NY.

Allied Biological. 2016. Aquatic Biota. Lake Dutchess. Allied Biological.

Aquatic Control Technology, Inc. 2003. Baseline Biological Survey Report for Marx Pond- Highland, NY. Aquatic Control Technology, Inc. Sutton, MA.

Aquatic Ecosystem Consulting. 2020. Lake Mahopac Biomass Study (Preliminary Report). Aquatic Ecosystem Consulting. Mahopac, NY.

Belskie, D. 2009. Letter to Michael Flaherty, NYSDEC. Emerald Green Property Owners Association, Inc. Rock Hill, NY.

Bruen, D. M. 2007. Letter to Michael Flaherty, NYSDEC Division of Fisheries. Peach Lake Environmental Committee. Brewster, NY.

Clark, J.W. 1998. Howland’s Lake Aquatic Vegetation Survey. Northeastern Aquatics.

Clean Lakes Incorporated. 1994. Draft Environmental Act Statement for Proposed Biocontrol of Aquatic Weeds in Lake Louise Marie. Rock Hill, New York.

Fernwood Limne, Inc. 1999. Aquatic Macrophyte Map of Seven Hills Lake. Fernwood Limne, Inc. Gansevoort, NY.

Fernwood Limne, Inc. 2005. Seven Hills Lake Report. Prepared for Seven Hills Lake Property Owner’s Association. Fernwood Limne, Inc. Gansevoort, NY.

Field, T.C. 2010. NYS DEC Aquatic Plant Management Plan Seven Hills Lake. Prepared for Seven Hills Lake Property Owner’s Association. Fernwood Limne, Inc. Gansevoort, NY.

Beaver Lake 2012. Floating and Submersed Aquatic Plant Map with Key.

Beaver Lake 2016. Floating and Submersed Aquatic Plant Map with Key.

Beaver Lake 2018 Floating and Submersed Aquatic Plant Map with Key.

Grim, J.S. 1992. Purpose and Effects of Stocking Triploid Grass Carp in Lake Celeste. Lake Celeste Draft Environmental Impact Statement.

Grim, J.S. 1992. Purpose and Effects of Stocking Triploid Grass Carp in Long Pond, P375 Lower Hudson Watershed. Draft Environmental Impact Statement. Northeastern Biologists, LLC. Rhinebeck, NY.

Grim, J.S. 1992. Triploid Grass Carp Monitoring Report. Long Pond, Dutchess County, NY. Northeastern Biologists, LLC. Rhinebeck, NY.

Grim, J.S. 1993. Full Environmental Impact Statement. Howlands Lake.

Grim, J.S. 1993. Lake Mahopac Aquatic Weed Survey. Northeastern Biologists, LLC. Rhinebeck, NY.

Grim, J.S. 1994. Full Environmental Assessment Form. Peach Lake. Northeastern Biologists, Inc. Rhinebeck, NY.

Grim, J.S. 1995. Aquatic Weed Monitoring Report. Lake Mahopac. Northeastern Biologists, LLC. Rhinebeck, NY.

Grim, J.S. 1996. Aquatic Weed Monitoring Report. Lake Mahopac. Northeastern Biologists, LLC. Rhinebeck, NY.

Grim, J.S. 1996. Triploid Grass Carp Post-Stocking Report. Long Pond, Dutchess County, NY. Northeastern Biologists, Inc. Rhinebeck, NY.

Grim, J.S. 1997. Aquatic Weed Monitoring Report. Lake Mahopac. Northeastern Biologists, LLC. Rhinebeck, NY.

Grim, J.S. 1997. Supplementary Long Pond Triploid Grass Carp. Long Pond, Dutchess County, NY. Northeastern Biologists, Inc. Rhinebeck, NY.

Grim, J.S. 1998. Full Environmental Assessment Form. Lost Lake. Northeastern Biologists, Inc. Rhinebeck, NY.

Grim, J.S. 1998. Letter to David Bruen. Northeastern Biologists Inc. Rhinebeck, NY.

Grim, J.S. 1999. Addendum to Full Environmental Assessment Form.

Grim, J.S. 2000. Letter to Lorraine Janus, Peach Lake Environmental Committee. Northeastern Biologists, Inc. Rhinebeck, NY.

Grim, J.S. 2000. Peach Lake Aquatic Weed Survey. Northeastern Biologists, Inc. Rhinebeck, NY.

Hunns Lake Vegetation. 1994. Report for 1995-1997 Permits. Vegetation Maps.

Jaycox, J. 2011. Brazilian Elodea (Egeria densa) Control at Lake Stahahe. State Parks Natural Resource Project Proposal.

Kishbaugh, S. A., et al. 1998. Lake Celeste CSLAP Annual Report. 1997 Interpretive Summary. NYS Department of Environmental Conservation, Division of Water, Lake Services Section.

Kishbaugh, S.A. 2007. Email to Michael Flaherty, NYSDEC. Orange Lake. NYSDEC Division of Water.

Knoecklein, G.W. 2006. 2005 Annual Monitoring Report for Lake MacGregor. Northeast Aquatic Research. Mansfield Center, CT.

Mininger, G. Princeton Hydro, LLC. 2007. Document for re-issuance of sterile grass carp permit Lake Carmel. Letter to Michael J. Flaherty. Princeton Hydro, LLC.

Northeast Aquatic Research. 2021. Lake Oscawana 2020 Water Quality & Aquatic Plant Monitoring Report. Northeast Aquatic Research. Mansfield, CT.

NYSDEC Application for Stocking of Triploid Carp in Putnam Lake. Town of Patterson Supplemental Information.

NYSDEC 2002. Annual Report of Highlights and Accomplishments for State Fiscal Year 2001/2002. Division of Fish, Wildlife and Marine Resources

Palmer Lake. 2019. Aquatic Vegetation Survey. Grass Carp Stocking Permit- Application Form.

Perrone, A. A., et al. 2014. Water Quality Monitoring Report and Aquatic Vegetation Biomass Study for Lake Mahopac. Aquatic Ecosystem Consulting. Mahopac, NY.

Perrone, A., et al. 2001. Final Report Vegetation and Water Quality Study Lake Sagamore.

Perrone, A., et al. 2018. Aquatic Vegetation Survey. Palmer Lake. Kent, NY.

Perrone, A.A., et al. 1999. Water Quality Monitoring Report and Aquatic Vegetation Biomass Study for Lake Mahopac. Louis Calder Center. Armonk, NY.

Perrone, A.A., et al. 2001. Water Quality Monitoring Report and Aquatic Vegetation Biomass Study for Lake Mahopac. Louis Calder Center. Armonk, NY.

Perrone, A.A., et al. 2004. Water Quality Monitoring Report and Aquatic Vegetation Biomass Study for Lake Mahopac. Louis Calder Center. Armonk, NY.

Perrone, A.A., et al. 2008. Water Quality Monitoring Report and Aquatic Vegetation Biomass Study for Lake Mahopac. Louis Calder Center. Armonk, NY.

Perrone, A.A., et al. 2009. Water Quality Monitoring Report and Aquatic Vegetation Biomass Study for Lake Mahopac. Louis Calder Center. Armonk, NY.

Perrone, A.A., et al. 2011. Water Quality Monitoring Report and Aquatic Vegetation Biomass Study for Lake Mahopac. Louis Calder Center. Armonk, NY.

Perrone, A.A., et al. 2015. Water Quality Monitoring Report and Aquatic Vegetation Biomass Study for Lake Mahopac. Aquatic Ecosystem Consulting. Mahopac, NY.

Perrone, A.A., et al. 2016. Water Quality Monitoring Report and Aquatic Vegetation Biomass Study for Lake Mahopac. Aquatic Ecosystem Consulting. Mahopac, NY.

Perrone, A.A., et al. 2017. Water Quality Monitoring Report and Aquatic Vegetation Biomass Study for Lake Mahopac. Aquatic Ecosystem Consulting. Mahopac, NY.

Perrone, A.A., et al. 2018. Water Quality Monitoring Report and Aquatic Vegetation Biomass Study for Lake Mahopac. Aquatic Ecosystem Consulting. Mahopac, NY.

Perrone, A.A., et al. 2019. Water Quality Monitoring Report and Aquatic Vegetation Biomass Study for Lake Mahopac. Aquatic Ecosystem Consulting. Mahopac, NY.

Princeton Hydro, LLC. 1999. Permit Application Submission to Stock Triploid Grass Carp in Lake Carmel. The Town of Kent, Putnam County, New York. Princeton Hydro, LLC. Lambertville, New Jersey.

Princeton Hydro, LLC. 2007. Permit Application Submission to Stock Triploid Grass Carp in Silver Lake, The Town/Village of Harrison, Westchester County, New York. Princeton Hydro, LLC. Exton, PA.

Princeton Hydro, LLC. 2011. Lake Sagamore 2011 Water Quality and Macrophyte Survey. Princeton Hydro, LLC. Exton, PA.

Rowledge Pond Aquaculture, LLC. 2010. Triploid Grass Carp Application Package for Kirk Lake Putnam County, NY. Rowledge Pond Aquaculture LLC. Sandy Hook, CT.

Rowledge Pond Aquaculture, LLC. 2017. Triploid Grass Carp Application Package for Kirk Lake Putnam County, NY. Rowledge Pond Aquaculture LLC. Sandy Hook, CT.

Submersed Aquatic Plants. 1996. Beaver Lake. Maps. 1996 Application.

The Pond and Lake Connection. 2017. North Lake, Westchester County, New York. Maps. The Pond and Lake Connection.

The Pond and Lake Connection. 2019. North Lake, Westchester County, New York. Maps. The Pond and Lake Connection.

Withers, R. J. 2000. Letter to Wayne P. Elliot. Lake Louise Marie, Town of Thompson, Sullivan County. Triploid Grass Carp Stocking Program. Clean Lakes Incorporated.

Withers, R. J. 2001. Letter to Michael Flaherty. Emerald Green Property Owners Association, Inc. Lake Louise Marie Grass Carp Stocking Program. Clean Lakes Incorporated.

Withers, R. J. 2005. Letter to Michael Flaherty, New York State Department of Environmental Conservation. Re: Lost Lake Grass Carp Stocking Program. Clean Lakes Incorporated. Wallkill, NY.

Withers, R. J. 2008. Letter to Michael Flaherty, New York State Department of Environmental Conservation. Re: Lost Lake Grass Carp Stocking Program. Clean Lakes Incorporated. Wallkill, NY.

Withers, R.J. 2005. Letter to Michael Flaherty, NYSDEC. Re: Twin Island Lake Association- Grass Carp Stocking Program. Clean Lakes Incorporated. Wallkill, NY.