6.

Recapture/Removal Techniques

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Triploid grass carp have not been routinely stocked in large lakes because they are difficult to remove if they begin to damage desirable vegetation. Because of the limited "tools" available to manage aquatic vegetation, grass carp are being considered more often especially in large systems. As a result, more attention has been given to the possibility of removing grass carp to more precisely control their impacts.

Capture techniques were evaluated in various grass carp research lakes in central Florida. The size and morphometry of the study lakes varied and ranged from 0.8 to 168 hectares. Original stocking rates ranged from 40 to 374 triploid grass carp per hectare. Density of submersed aquatic plants at the time of the recapture studies was extremely low and, in most cases vegetation had been completely eliminated by the grass carp. Various capture techniques were evaluated to determine the feasibility of their use for mark-recapture population estimates, for efficiency, and for large scale removal of grass carp so macrophytes can reestablish. Sampling effort and number of fish caught were recorded to determine overall success rates (catch per unit effort - CPUE) for the various sampling techniques.

PASSIVE CAPTURE TECHNIQUES

Passive capture techniques are defined as entanglement or entrapment devices that are not actively moved by man or machine (Lagler 1978). Techniques were categorized into entanglement and entrapment devices following Hubert (1983).

Table 1. Net description, set methods and capture results for passive capture techniques involving nets.

Net type	Dimension (feet)	Type of bait	Mesh size (inches)	Set description	Set type	Set duration	Grass carp density at stocking	Replication	Overall CPUE fish/hour
Gill	150L x 6D	Unbaited	4-6	Floating	Half circle[a]	12-19 hours	150/acre	5	<.05
	300L x 6D	"	6	"	L-shaped	"	"	5	<.05
	300L x 6D	"	"	"	Cross	"	"	5	<.05
Trammel	150L x 8D	"	3.5 (inner) 12.0 (outer)	"	Shoreline	"	"	5	<.05
	300L x 8D	"	4.0 (inner) 12.0 (outer)	"	Vegetation	"	"	5	<.05
	300L x 8D	"	3.0 (inner) 14.0 (outer)	"	Shoreline	"	"	5	<.05
Hoop	3 to 5	Soybean cakes	2	6-8ft depth	"	48 hours	"	14	0
	3 to 5	Unbaited	"	"	"	"	"	14	0
Fyke with wings	4H x 50	Hydrilla	1	4-5ft depth	Perpendicular to shore	"	"	20	0
	5H x 50	"	"	"	Parallel to shore	"	"	20	0
	4H X 50	Unbaited	"	"	Perpendicular to shore	"	"	20	0
	5H x 50	"	"	"	"	"	"	20	0
Indiana Trap	4	Hydrilla	"	3 1/2ft depth	"		"	4	0
	4	Unbaited	"	"	"	"	"	4	0
	4	Hydrilla	"	"	"	"	"	8	0
	4	Unbaited	"	"	"	"	"	4	0
Onieda Trap	4	Hydrilla	"	4ft depth	Perpendicular to vegetation	"	"	15	0
	4	Unbaited	"	"	"	"	"	15	<.05
	6	Hydrilla	"	6ft depth	"	"	"	20	0
	6	Unbaited	1	6ft depth	"	"	150/acre	15	0
	8	Hydrilla	"	8ft depth	"	"	"	8	0
	8	Unbaited	"	"	"	"	"	8	0
Pound Net	5	Soybean Cake	"	5ft depth	Perpendicular to shore	"	35/acre	30	0
Wire Catfish	4 x 2.6 x 1.3	"	"	0-6ft depth	Shoreline	24 hours	20/acre	24	<.05

[a] Refer to text for further description.

Passive entangling devices such as gill nets and trammel nets (Table 1) resulted in very low CPUEs ranging from 0.0 to 0.05 fish/hr overall. The gill nets were fished for 960.2 hours during the study with only 27 triploid grass carp caught. Trammel nets were fished a total of 80 hours with one triploid grass carp caught. With these low catch rates it became apparent that entanglement devices would not be adequate for large scale removal projects.

A total of 37 net days were sampled with unbaited hoop, fyke, or Indiana trap nets and a total of 32 net days were sampled with baited nets. Since this net type failed to catch fish, they would be useless for mark-recapture studies or large scale removal of grass carp (Table 1).

Oneida trap nets, similar to Crowe's (1950) small trap net, were set in water depths corresponding to the size of the net. Three different size nets were used to sample different areas of the study lakes. A 4 foot deep net with 30 foot long wings, and a 100 foot long lead all of which had 1 inch mesh was used to sample areas approximately 1.2 meters deep. The 6 and 8 foot nets had the same wing and lead length as the 4 foot deep net, but had 2 inch mesh. Crowe (1950) described the setting of these nets. Baited and unbaited nets were used. Sets were made perpendicular to shore, parallel to shore, angled around a point, and set in open water. Most sets were checked every 48 hours.

Evaluation of Oneida trap nets indicated higher catch rates for all modified 6 and 8 foot versions. However a 4 foot unmodified net had the highest catch rates. One modified version consisted of nets with the 100 foot lead removed from the center and placed on a wing. In another modified version, a gill net (4 inch mesh, 150 feet long) was used to extend the opposite wing. The relatively high catch rate of the 4 foot net was due to a high first day catch of seven fish followed by three net days of one fish per day. Overall 70.7 net days were sampled with the unmodified versions and 17.9 net days were sampled with the modified Oneida trap net. A baited modified Oneida net (no lead) was set for two net days without catching any triploid grass carp. The Oneida net was further modified by installing a wire swinging door on the "pot ring" (to prevent any escapement if they entered the pot), and four net days were sampled without catching a triploid grass carp. Oneida trap nets proved unsuitable for sampling triploid grass carp.

A modified pound net was constructed and used. Modifications to the pound net consisted of replacing the conventional pound net with a 5 inch diameter hoop net. The heart of the net was enlarged to accommodate a floating automatic feeder and the front ring of the hoop net was replaced with a square frame to effectively enclose the heart.

Grass carp began to feed around the pound net within nine days. The grass carp congregated along the outer edge of the pound net and waited for the feed to drift outside of the heart. Feeding activity of other fish species increased inside the heart; however, there was no evidence of grass carp feeding inside the heart. After four months the modified pound net was removed without having captured any grass carp.

Wire catfish traps with 1 inch square mesh of plastic coated wire were set in groups of three in 4 to 6 feet of water. These traps had wire, free swinging doors and were 4-feet long, 2.6 feet wide and 1.3 feet in height. Wire catfish traps were baited (soybean) and fished 23.8 trap days with one triploid grass carp captured. This is a 0.04 fish per trap day catch rate and therefore insufficient for capturing grass carp.

Trotlines were investigated for their efficacy of capturing grass carp because commercial catches in Missouri reported grass carp as a rare by-catch (Pflieger 1978). A trot line, 820 feet long with 0.6 foot nylon droppers (18 foot separation) was used. Brazilian elodea (*Egeria densa*) was used as bait and was attached to treble or single hooks with a rubber band. Several hook sizes were evaluated (size 2, 4 and 8 treble hooks and 2/0 Mustad Limerick). Mid-water and bottom sets were evaluated. Set time was approximately 24 hours. Although the fish removed some of the Brazilian elodea, no fish were caught and there was no sign that any triploid grass carp had been hooked. A total of 72.4 hours were sampled using this technique. Trotlines were not suitable for either study objective, although we only evaluated with elodea as bait due to concerns with sportfish by-catch with other baits.

ACTIVE CAPTURE TECHNIQUES

Active capture techniques are defined as methods that capture fish due to direct mechanical or man controlled effort.

Table 2. Electrofishing variables evaluated to determine efficacy of capture and physical damage to triploid grass carp.

Voltage	Mode (pps)[1]	Pulse width	Amps	Number caught	Number dead	Physical damage
168 DC	60	4.5 - 7.0	2.0	0		
336 DC	60	3.0	3.0	1	0	Not determined
480 DC	60	5.0	4.5	0		
504 DC	60-20	2.25 - 5.0	4.2	5	0	Broken back, compressed vertebrae
672 DC	60	2.5	3.0	3	1	Broken back, compressed vertebrae
840 DC	60-120	2.5 - 7.0	3.0	4	0	Broken back, compressed vertebrae
1008 DC	60-120	2.0 - 6.0	3.0 - 6.0	7	4	Broken back, compressed vertebrae
240 AC		3.0	3.0	0		
480 AC		5.2	5.2	1	1	Not determined
600 AC		6.2	6.2	2	2	Bled at gills
720 AC		6.8	6.8	0		

[1] pps - pulses per second.

Electrofishing was investigated for its potential use in mark-recapture population studies and for large scale removal of triploid grass carp. Because the type of current, voltage, and amperage can be varied this technique can be used in a number of ways. Various voltages and amperages were tested to determine the amount of physical damage to the fish, which could affect mark-recapture. Also, methods were evaluated for large scale removal with the intention of killing the fish. Lakes were generally electrofished using DC current with 660 volts and 4.5 amps (average 1.1 hours shocking time per sample). A lake stocked at 125 fish/hectare was also sampled using DC current 500 to 550 volts and 6.5 to 7.0 amps (average 1 hour shocking time per sample). Another lake stocked at 110 fish/hectare was sampled using 672 volt and 4.0 amps (average 1.2 hours per sample). In all cases, a single pass was made along the shoreline.

Mortality due to the sampling technique must be kept to a minimum to reduce loss of marked fish. Various voltage and amperage values were evaluated for their physical damage to fish (Table 2). Only those settings that induced rheotaxis could be used. Voltage ranging from 504 to 1,008 (DC) and corresponding amperages ranging from 3 to 6 were successful in facilitating capture, but were found to break backs and/or compress vertebrae. As a sampling method for mark-recapture studies, electrofishing does not appear to be a suitable methodology.

Hill (1986) achieved somewhat better results while conducting Peterson mark-recapture population estimates of diploid grass carp in Iowa. Electrofishing was conducted during the fall using 240 volts AC and 3 amps when water temperatures ranged from 7 to 10°C. Summer sampling, when water temperatures are near 21°C, was considered too warm for effective capture of diploid grass carp with electrofishing (K.R. Hill, Iowa Department of Natural Resources, personal communication). During the tests, the water temperature was above 22°C, and the results of electrofishing at 240 volts of AC current and 3 amps was ineffectual. In addition, water conductivity may have varied between studies, thereby affecting capture efficiency.

Although electrofishing catch rates are reasonably high (average CPUE 8.9 fish/hr at best voltage 500 volts DC and 5-6 amp.) large scale removal of fish would involve considerable effort. For example, an 800 hectare lake stocked with 1800 triploid grass carp would require removal of 1400 fish to bring the stocking rate down to 0.5 fish per hectare (a plausible no-impact density assuming macrophytes have already been eliminated). Using a catch rate value of 10 fish per hour (assuming a constant catch rate) would require 140 hours of electrofishing. Based on a three man crew, 420 man hours (52.5 man days) of shocking time would be required to remove those fish. In addition, the catch rate would most likely be reduced with continued electrofishing due to a diminishing population and gear avoidance.

In this study, electrofishing data were collected by a single pass along the shoreline for each sampling trip. Past experience by all investigators has been that the initial CPUE

Table 3. Results of commercial haul seining operations in lakes stocked at 40 fish per hectare. Number of triploid grass carp (TGC) collected and estimated CPUE (fish/hour) based on 6 hours of effort expended per haul.

Date	Number of TGC removed	CPUE (fish /hour)
05/14/87	63	10.5
05/18/87	65	10.8
05/26/87	19	3.2
06/02/87	12	2.0
06/10/87	57	9.5
06/17/87	42	7.0
06/02/88	262	43.7
06/07/88	204	34.0
06/14/88	10	1.7
06/21/88	65	10.8

could not be sustained when multiple passes were conducted; therefore, shocking for extended periods of time in the same area would not yield a sustained CPUE. In the previous example, the 140 electrofishing hours would not be enough to obtain the desired number of fish and effort would need to be increased substantially. Other factors associated with electrofishing that require consideration are various lake characteristics. Spatial distribution of grass carp may be affected by aquatic vegetation, density and distribution or some other factor inherent to the lake. Under optimal conditions, triploid grass carp may be removed at relatively high rates, but electrofishing for grass carp is inconsistent.

Commercial haul seiners were contracted to determine the efficacy of this method. The haul seine was 2,641 feet long with 6 inch mesh in the mid-section and decreased to 4 inch meshing on the ends. The bag had 4 inch mesh and was 10 feet long by 7 feet wide and 15 feet in height. This net can effectively fish water up to 3.5 meters deep. The net was deployed for a shallow water "take up". Four boats, (a net boat, a pull boat, a catch boat and a net minder boat) were used to deploy and conduct the operation. Five personnel were used for this typically 5 to 6 hour operation.

Commercial haul seine operations were monitored on 10 separate occasions to determine their catch of triploid grass carp (Table 3). CPUE was based on the total time expended in two lakes stocked at 40 fish/hectare, to determine their catch of triploid grass carp (Table 3). CPUE based on the total time expended (deploying and retrieving the net) was relatively high and ranged from 1.7 to 43.7 fish per hour. Although these catch rates were high, removing enough fish to obtain a minimum impact density level, perhaps 0.5 fish/hectare, is still costly and impractical for many situations.

Water flow was investigated as a possible attractant for triploid grass carp. Grass carp have been observed to have a positive rheotaxis to water flow

(Schramm and Jirka 1986) and it was evaluated as a possible attractant to triploid grass carp. A Crisafulli pump with a power take off drive was used to create a recirculating flow of approximately 19,000 liters per minute (11 CFS at pump discharge) in a 6 hectare lake averaging 4 meters in depth and stocked at 90 fish/hectare. The pump was run for 22 continuous hours. Prior to pump operation, detonating cord was placed in an area near the pump discharge to sample approximately 0.16 hectares. The detonating cord was placed 2.1 meters deep which ensured concussion sampling throughout the water column (4.3 meters total depth) in that area. The cord was suspended in mid-water by using floats and anchors and detonated after 22 hours of pump operation as described by Metzger and Shafland (1986).

The pump and cord were monitored for safety purposes during the hours preceding detonation. Fish were collected immediately following detonation and project personnel checked for floating fish the following nine days. An estimated 20.3 acre-feet of water was pumped during that 22 hour period. The lake had an estimated 180 acre-ft of water, thus approximately 11 percent of the lake volume was pumped during the 22 hour period. Water temperature at the time of pumping was 14°C and night time air temperatures dropped to below freezing. Two boats were used to pick up the fish immediately following detonation. Initial fish recoveries did not result in any grass carp being collected. Only one grass carp was recovered during the nine day post-pumping period and this one was recovered by a lakeside resident. Schramm and Jirka (1986) reported similar results using a smaller capacity pump for shorter duration.

Lift nets were evaluated at a single 50 hectare lake stocked with 15,000 triploid grass carp (300 per hectare). Nets were made using 3.5 and 6.0 inch stretch mesh, and 40 ft sides (1600 ft^2). Grass carp were baited (floating catfish feed) into the vicinity of the lift net by personnel at location. A trial pull was made five days after construction using the 3.5 inch net to ensure proper functioning of the lift net. The trial pull netted eight grass carp, and the net was reset. Baiting of the grass carp continued for three weeks until the number of grass carp feeding in the area stablized. The first lift effort netted 40 grass carp. Another 7-10 grass carp were counted jumping out of the net as it was elevated.

The lift net was removed for repairs, and another lift net with a large mesh (6" stretch mesh) was installed to compare performance. Baiting was continued for six days as feeding activity had appeared to stabilize at a similar density to the first pull. During the second pull, the lift net temporarily contained a large number of grass carp. However, the mesh size was too large and allowed grass carp (500-600 mm total length) to pass through the webbing, resulting in the capture of only one grass carp. The original lift net was reinstalled and a third pull was attempted. The third pull netted 42 grass carp, the most collected in a single pull.

The lift net showed potential as an effective grass carp removal technique. However, lift net operation is labor intensive, requiring constant maintenance and cleaning as well as a minimum of three individuals to operate. In addition, someone has to be on-site daily to bait the fish.

Angling (hook-and-line) has been a suggested removal technique by various investigators (Terrel and Fox 1974, Sutton et al. 1977, Wilson and Cottrell 1979), and grass carp have entered the creel in several areas (Sutton et al. 1977, Pflieger 1978).

Angling efficiency was evaluated using Florida Game and Fresh Water Fish Commission personnel to determine CPUE (Table 4). Catch rates of 0.33 to 1.56 triploid grass carp per hour were achieved using bread as bait. Catch rate is dependent on angler proficiency which varied among the test anglers as it would vary in the general angling population.

Table 4. Results of angling (hook and line) for triploid grass carp from two lakes.

Date	Lake	Grass carp stocking rate no/hectare	Number of anglers	Total hours fished	Total number of fish	CPUE (fish/hour)	Bait
10-08-86	A	300	5	24.0	25	1.04	bread
10-09-86	A	300	3	10.5	5	0.48	bread
10-28-86	A	300	4	25.0	39	1.56	bread
04-07-87	B	120	2	3.0	1	0.33	egeria
04-16-87	B	120	4	12.0	1	0.08	egeria

Anglers in Georgia removed 61% of the grass carp with a variety of techniques in eight days of fishing a lake of 3.6 hectares (Terrell and Fox 1974). Catch rates for those eight days ranged from less than 0.05 to slightly greater than 0.15 fish per hour. Wilson and Cottrell (1979) reported CPUE for diploid grass carp as 0.009 per hour. This lower CPUE may be the result of using a broader range of attractants (spinner and minnow lures, vegetation and earthworms); they determined earthworms were the only successful bait. Unfortunately, they based their results on total angling time using all four types of bait, including time spent with less effective bait types. Vegetation included terrestrial and aquatic plants, but the plant names were not mentioned so it is impossible to tell if they used palatable plants. They did not evaluate bread which precludes any comparison with our results. Also, basic fishing techniques can vary considerably as well as angler proficiency, both of which may have been contributing factors to the poor success achieved by Wilson and Cottrell (1979).

Grass carp removal by public angling was attempted and homeowners meetings were organized to inform interested individuals of the goals of the public angling project and method in which it could be conducted. Homeowners were encouraged to participate by selecting automatic feeder sites and feeding periods. Automatic feeders were floated at pre-determined locations and put into operation. Reports of grass carp feeding activity were confirmed within 7 days and the feeders were monitored weekly for the first month to ensure proper functioning (Trent et al. 1992).

During 16 months of angler participation, 12 permitted anglers reported the removal of 242 triploid grass carp from Lake Mills (Mallison et al. 1994a). This represents 13 percent of the 1800 (19/hectare) that were stocked 4 years before the study. Three individuals were responsible for 70 percent (170 fish) of the total number reported and 52 percent (126 fish) of the grass carp were captured during the first 2 months of the program. Popular baits used for angling were dough balls and live worms.

Archery or fishing with bow and arrow has been a means of limited removal. Personnel with the Army Corps of Engineers have used this method on several lakes to collect grass carp for age and growth studies. This technique was used to aid in grass carp removal in several central Florida lakes under a limited number of permits. Success rates vary as with angling. One individual has been successful and averages about 2 grass carp per hour. The other individuals averaged less than one per hour throughout the year. Success appears to depend on the archers ability, cool water (less than 18 °C), and populations not being heavily hunted. Grass carp get extremely wary when hunted and the CPUE dropped drastically from February to July.

Bonar et al. (1993) found herding to be the most successful method they tested for removing grass carp. The fish were moved starting at one end of the lake using noisemakers such as boat motors, boat paddles, plungers, or human movement through the water. After a certain point was reached a gill net reaching from the surface to the sediment was stretched across the lake and the process started again.

Table 5. Number and weight of, A) sport fish, B) rough fish, and C) forage fish removed during Lake Monterey renovation on November 9, 1993. These results represent the remaining fish population in this lake where FMB was previously used to remove 69% of the grass carp, 30 threadfin shad and seven bluegill, demonstrating the selectivity of FMB.

	Number	Weight (kg)	Harvestable* number	Harvestable* weight (kg)
A) Sport fish				
Largemouth bass	113	18.3	16	10.2
Black crappie	3	0.6	3	0.6
Redear sunfish	488	36.8	266	33.6
Bluegill	772	23.6	147	14.1
Warmouth	207	2.3	7	0.9
Channel catfish	4	3.8	4	3.8
Brown bullhead	24	9.6	21	9.5
Total sport fish	1611	95.0	464	72.7
B) Rough fish				
Grass carp	15	45.2		
Tilapia	3	4.5		
Lake chubsucker	4	2.4		
Goldfish	1	3.2		
Total rough fish	23	55.2		
C) Forage fish				
Golden shiner	6	<0.1		
Madtom	1	<0.1		
Mosquito fish	2	<0.1		
Swamp darter	2	<0.1		
Threadfin shad	387	5.4		
Total forage fish	398	5.4		
Grand total	2032	155.7	464	72.7

* Harvestable lengths were defined as follows: largemouth bass 300 mm; black crappie 180 mm; redear sunfish, bluegill, and warmouth 160 mm; and channel catfish and brown bullhead 200 mm.

When the fish were in a small enough area, they were removed by a combination of seining and gill net. Herding was most successful in warmer temperatures (greater than 20 C) and in small lakes (less than one hectare), where ten percent of the stocked number was removed in one trial.

ROTENONE

Due to the difficulty in removing grass carp with active and passive capture techniques, fish toxicants, specifically rotenone, may be used. Selective removal of grass carp using low concentrations of rotenone may be practical in some cases. Henderson (1974) and Marking (1972) documented that grass carp are very sensitive to rotenone. Colle et al. (1978) successfully used this technique on an 80 hectare lake in Florida with minimal impact to the sport fish population. They used 0.1 mg/liter rotenone for the treatment. The Florida Game and Fresh Water Fish Commission recently conducted a non-selective grass carp removal using rotenone on a 135 hectare lake in central Florida. Rotenone was applied at 0.25 mg/liter which removed 98% of the estimated number of grass carp and many non-target fish (53,180 kilograms). With non-selective removal, heavy equipment and additional personnel may be needed to remove dead fish, especially in urban areas (Moxley et al. 1993).

In an effort to reduce rotenone impact on non-target fish, personnel with the Florida Game and Fresh Water Fish Commission began development in 1988 of a rotenone-laced food pellet intended for selective removal of grass carp. This project evolved into a cooperative effort with Jim Fajt at Auburn University, where extensive testing led to the development of a palatable rotenone-laced pellet. Further evaluation of the alfalfa-based pellet indicated favorable results and the product is now known as Fish Management Bait (FMB).

In tests on hatchery ponds, FMB removed up to 79% of the grass carp populations. However, once grass carp had been exposed to FMB, successive trials were ineffective in removing those fish that survived previous tests. To evaluate the selectivity of FMB, a 0.5 hectare pond that had been used to test FMB for two years was treated with rotenone at 2 mg/liter. During these trials 60% of the triploid grass carp were removed while only 30 threadfin shad and seven bluegill were removed (Mallison et al. 1994b). Table 5 is a summary of the fish remaining, demonstrating the selectivity of FMB. This preliminary work has resulted in Prentis Incorporated applying for and receiving an Experimental Use Permit from the United States EPA.

Two central Florida lakes were selected to continue testing FMB (Mallison et al. 1994c). Live Oak Lake (152 hectares) was stocked with 1900 triploid grass carp from 1987 to 1990 and Lake Whippoorwill (132 hectares) was stocked with 4070 triploid grass carp between 1985 and 1990. All submersed plants and most emergents were eliminated by grass carp in both lakes. Initial applications of FMB removed 251 triploid grass carp (average 9/trial at Live Oak Lake and 110 (average 5/trial) at Lake Whippoorwill. Secondary applications of FMB were much less effective and removed 24 triploid grass carp (average 2/trial) at Live Oak Lake and 14 (average 1/trial) at Lake Whippoorwill. Effects on non-target fish were minimal, removing on average 1 fish/5 trials. There were no observed effects on wildlife. The recapture results of using FMB in Lakes Live Oak and Whippoorwill were substantially less than what was achieved in relatively small hatchery ponds assuming at least 50% survival. Their preliminary finding may indicate that FMB has limited potential in larger systems.

CONCLUSIONS AND RECOMMENDATIONS

Effective management of triploid grass carp for aquatic plant management is dependent on a knowledge of the population (grass carp mortality factors, escapement) and the practicality of removal techniques. For most situations, the sampling techniques evaluated in this study would not be practical in a mark-recapture population study. Each technique was primarily limited due to the very low CPUE obtained and effort needed to obtain sufficient sample sizes. Electrofishing, haul seining, angling and rotenone are the only methods that have relatively high catch rates, but all these techniques have limitations for practical application and must be evaluated within the context of each.

Public fishing (commercial and/or sport) for triploid grass carp does create problems that must be addressed in some states because possession of live grass carp could lead to unwanted introductions. Public fishing would also require lake-by-lake management, that is, each lake must be managed uniquely. For example, if a lake was overstocked, that particular lake would need to be opened to fishing until the lake's vegetation started to regrow. At that point, the lake would be closed to triploid grass carp fishing. Monitoring plant regrowth would probably be the best indicator of triploid grass carp densities. Conducting intensive creel surveys on each system stocked to determine grass carp harvest would probably not be economically feasible as a management practice. Removal of triploid grass carp by public fishing has two implications for law enforcement. First, a protocol must be available for the opening and closing of lakes to triploid grass carp removal. Second, because of the high density distribution of lakes in many urban areas, it is possible that two lakes in close proximity would have different management strategies. Opening and closing adjacent lakes to taking of triploid grass carp would create additional law enforcement problems.

Rotenone, which has restrictions that vary by state, could be considered in cases where its use is legal and most of the grass carp need to be removed from a water body immediately. This is very costly and could result in negative public relations or even litigation from various lake user groups if conflicting interests cannot be resolved. Fish Management Bait (FMB) is still experimental, however it appears promising. FMB appears most effective in lakes under 400 hectares and/or where aquatic macrophytes have been removed. It may be possible to remove over 75% of the grass carp in this type of water body. The removal of this many grass carp combined with natural mortality should enable greater manipulation of macrophytes with grass carp.

Triploid grass carp mortality rates are highly variable and not very predictable with our current state of knowledge. Further studies using rotenone or other piscicides should be conducted to determine mortality rates. If high mortality rates are common for triploid grass carp, then the total number that would have to be removed would be greatly reduced. Even if mortality rates are determined to be high, caution should be used when considering stocking triploid grass carp due to the extreme difficulty of removing them. Once the aquatic macrophytes have been eliminated, they are very difficult to reestablish even under minimal grazing pressure from grass carp.

7.

Administration Of A State Permitting Program

Robert J. Wattendorf and Clayton Phillippy

Aquatic plants are an important habitat component of most freshwater ecosystems and, therefore, are of special concern to state fish and game agencies. These systems evolved a delicate balance of producers, grazers and predators to take advantage of local biochemical and climatic conditions.

Human activity impacts this relatively stable situation and causes continual changes in aquatic ecosystems. Consequently, management agencies are in a dilemma of trying to mitigate human impacts. In most states there is a game and fish agency responsible for ensuring welfare of fish and wildlife resources. Although many of these agencies originally focused on providing for sustainable harvest for consumptive sport and commercial users, most now have a broader conservation goal that includes protecting threatened and endangered species and managing non-game wildlife, but they may not have direct control over habitat issues such as water quality or quantity and aquatic plants. In other states, the responsibility for game and fish is addressed within an even larger agency that deals with all natural resource issues, including aquatic plants. Consequently, administration of a state program dealing with grass carp will be different in individual states.

With regard to aquatic vegetation, man has introduced through runoff from farms, residential areas, and mines (e.g., phosphate pits) vast amounts of fertilizers, which accelerate growth of aquatic plants beyond what the natural trophic state of the water body would produce. These plants eventually die and decompose, contributing to the rate at which organic sediments accumulate in lakes.

To make matters worse, we impound rivers and streams to store water for drinking, irrigating crops, power generation, navigation, recreation or aesthetics, and also channelize areas to drain wetlands and prevent floods. Lack of natural water level fluctuations including periodic extreme droughts or floods, exacerbates aquatic plant problems. Fixed water levels prevent flocculent sediments from periodically drying and consolidating during droughts, which would otherwise provide firm substrate for plants and stimulate germination of seeds in the soils. During rainy periods, fixed water levels prevent inundation of flood plains that would provide critical spawning habitat and food for fish.

Non-native aquatic plants are imported for the aquarium industry or aquatic landscaping. Several (e.g., curly-leaf pondweed, Eurasian watermilfoil, hydrilla, water hyacinth) compete very effectively with endemic plants due to aggressive growth habits and absence of natural pathogens and parasites that keep them in check in their native ranges. These non-native nuisance aquatic plants frequently require artificial control.

There are a number of methods to eliminate aquatic plants. However, each of them have drawbacks. Herbicides can kill plants too quickly, resulting in rapid decomposition of organic material by aerobic bacteria that deplete the water's dissolved oxygen content and may indirectly kill fish and other animals. Many chemicals, if misused, can be directly harmful to invertebrates, fish, wildlife and people. Some herbicides cannot be used in potable waters, or have periods during which swimming or plant irrigation is unsafe. Other chemicals and adjuvants, for instance copper, remain in aquatic systems for long periods. In addition, chemicals generally need to be applied at least yearly and often as frequently as four times per year in areas with extended growing seasons. Costs for chemical control are expensive and are reported to average $418-1,339/ hectare/year in 1985 dollars, in Florida (Shireman et al. 1985).

Mechanical harvesters are generally more desirable, since plant nutrients are physically removed from the system. However, harvesters can accelerate spread of plants by fragmenting them. They also remove significant quantities of small fish and invertebrates (Wile 1978). Costs for mechanical control in 1985 averaged $1,000/hectare/year, in Florida (Shireman et al. 1985).

Use of host-specific biological control agents, especially for non-native species, is supported by an intrinsic logic. If plants are growing out of control because of lack of natural predation by grazers, pathogens and parasites, then importing such natural antagonists could solve the problem. The obvious counter point is that you do not want to create a bigger problem trying to correct the first mistake. Therefore, such control agents must be carefully screened for a multitude of possibly disastrous effects that their establishment could cause. Several insects and viruses have been successfully imported to help control non-native plants (e.g., alligatorweed flea beetle; Cofrancesco 1991). However, those that have been cleared for use on hydrilla (e.g., hydrilla fly; Center et al. 1991) have so far proven ineffective on a large scale.

Grass carp and their genetically altered offspring, triploid grass carp, are known to be very effective in grazing on a wide variety of aquatic plants over a broad range of environmental conditions (Stott and Robson 1970; Shireman and Maceina 1981; Wiley and Gorden 1984a, Beaty et al. 1986, Allen and Wattendorf 1987, Leslie et al. 1987, Sanders et al. 1991). Functionally sterile triploid grass carp will not reproduce, thus removing concerns that they might develop expanding naturalized populations. They can, however, eliminate aquatic plants when they are overstocked or concentrated in small areas rather than dispersing. Since these fish can live for 10 to 15 years, reach weights of over 45 kg, and are difficult to recapture or selectively kill (see Chapter 6), it is important that they not be overstocked (Leslie et al. 1987). Projected cost for up to seven years of control in 1985 was estimated to be $158-247/hectare/year using triploid grass carp, in Florida (Shireman et al.

1985).

Total elimination of aquatic plants may be acceptable in some limited situations such as irrigation ditches, or golf course, hatchery or reflecting ponds, but it is unacceptable in many states in natural waters. In natural waters, aquatic plants are extremely important to sport fisheries. An average freshwater angler spends $37.40/day, which provides substantial local economic value as a result of every fishing trip (Fish and Wildlife Service 1991). Typical lakes provide 60 to 250 hours/hectare/year of angling enjoyment, and some intensely managed areas can reach 5,000 hours/hectare/year.

From ecological, recreational and economic viewpoints, it is unacceptable to jeopardize sport fisheries to eradicate nuisance plants. Killgore et al. (1993), in the introductory section of their manuscript entitled: "Relationships Between Fish and Aquatic Plants: A Plan of Study," state "aquatic plants are not only a vital habitat component of aquatic systems but also a source of revenue and recreation for many people."

In Florida, Division of Fisheries staff believe 10 to 50% of a lake's bottom that is used as a public fishery should be vegetated at all times, with a dynamic fluctuation between these levels being desirable. As a rule of thumb, an average of 20 to 30% of the lake should have aquatic plants, especially submergent vegetation. These estimates evolved from review of a number of studies involving interactions between fish and aquatic plants (Chew 1974, Colle and Shireman 1980, Estes et al. 1990, Porak et al. 1990, Canfield and Hoyer 1992). Greater amounts of vegetation can adversely impact use of the fisheries, boating, skiing, riparian property values and flood control. It can also result in some stunting of fish populations, consequently, some management is needed to keep plant coverage within the desirable range.

Canfield and Hoyer (1992) suggest, based on examination of 60 lakes in

Florida, that macrophyte coverage of 15% or more would be beneficial to most Florida lakes and seems to preclude the probability of any adverse fisheries problems. Young-of-the-year bass abundance improves drastically as plants go from 0% to 15% percent volume invested (PVI) and continues to exhibit some improvement up to about 50%. They also point out that significant changes in whole-lake algal biomass and water clarity only occur when macrophyte coverage exceeds 30% to 50% with a PVI of 40% or more. Moreover, reducing macrophyte coverage by more than 40% will "insure a significant change in water quality as measured by chlorophyll *a* and water clarity." Canfield and Hoyer (1992) also point out that aquatic macrophyte coverages of 30% to 50% or more are often viewed as an "aquatic weed" problem by lake users. Finally, they indicate that PVIs of less than 20% or more than 75% tend to reduce the harvestable fish biomass (as adjusted for chlorophyll *a*).

Aquatic plants are in many cases very important to fish population. Aquatic macrophytes provide a buffer against winds and currents that is important to successful spawning of many species of fish (e.g., centrarchids and exocids; Porak et al. undated). Without such protection, eggs are often buried and die (Kramer and Smith 1962). Young fry and fingerlings need aquatic vegetation in which to hide from predators (Wegener and Williams 1974). Aquatic plants also provide substrate for invertebrates (Moxley and Langford 1982; 30 to 50 times as much as bare bottom per Engel 1990) that in turn are major food items for most species of sport fish as they convert from feeding on zooplankton to larger food items to sustain their rapid growth.

More generally, aquatic and wetland plants provide filters to reduce particulate runoff that could otherwise increase turbidity in open areas of lakes. Plants further protect shorelines from waves and currents thus reducing erosion. In the absence of macrophytes, nutrients are taken up and utilized by phytoplankton, potentially leading to major blooms, especially of blue-green algae (Wetzel 1975). Such blooms color the water and shade the bottom making it difficult for rooted plants to reestablish. During prolonged periods of cloudy weather, when they cannot photosynthesize, algae can utilize too much oxygen from the water and thus result in fish kills (Herman and Meyer 1990). Similarly, such blooms can reach a critical mass and spontaneously die back, creating situations similar to a major herbicide kill that ultimately kill fish. Individual states must determine the value of aquatic plants to their unique ecosystems, balance ecological and economic merits of using triploid grass carp and decide whether or not to allow use of the fish. Other aspects of decision making will involve impacts on adjoining states or countries and the presence of exotic grass carp in open waterways.

A HISTORY OF GRASS CARP IN FLORIDA

At the time that grass carp were introduced into Florida, little was known regarding their effect on aquatic plant species, aquatic habitat, sport fishing and migratory waterfowl populations.

As an example of the controversy that followed and to help describe the history of grass carp use and development of a certification program for triploid grass carp, we will summarize the Florida experience. Grass carp were first imported into Florida in 1970 by the United States Department of Agriculture for research at the Ft. Lauderdale Agricultural Research Center (Blackburn and Sutton 1971). At the time, the Florida Game and Fresh Water Fish Commission (GFC) was the lead agency in Florida for aquatic plant control (Hyacinth Control Act; Chapter 372.931 F.S.). However, during 1979 the Florida Aquatic Weed Control Act (Chapter 372.925 F.S.) was passed, which gave the Department of Natural Resources (DNR) the lead role in controlling aquatic plants.

From September 1972 to August 1975, the GFC and DNR studied four ponds (Pasco, Suwannee, Madison and Broward ponds) to determine the aquatic weed control potential and environmental impact of stocking grass carp in Florida lakes (Beach et al. 1976, Gasaway and Drda 1976, Ware and Gasaway 1976, Hestand and Carter 1978, Miley et al. 1979, Osborne et al. 1982, Leslie et al. 1983, Richard et al. 1984, Van Dyke et al. 1984). While the four-lake study was being conducted a controversy arose in which the GFC wanted to severely restrict use of diploid grass carp to protect natural fishery resources, and the DNR wanted the fish used to prevent the spread of exotic aquatic plants.

As a result of the controversy and various lobbying pressures, the 1974 Florida Legislature rewrote the Florida Aquatic Weed Control Act, which was renamed the Florida Nonindigenous Aquatic Plant Control Act (Chapter 372.925 F.S.). This new legislation directed the DNR to use biological control agents to control nonindigenous aquatic plants.

This legislation and the four-lake study led to other research projects and six additional lakes (lakes Bell, Clear, Holden, Deer Point, Conway and Wales) were stocked with diploid grass carp to help answer basic biological questions concerning changes in water quality, effects on the food chain, reproduction of forage species, shifts in aquatic habitat and sport fishing success (Shireman 1976, Nall and Schardt 1978, Miley et al. 1979, Leslie et al. 1987, Van Dyke et al. 1984, also note Chapter 2). These investigations and other on-going laboratory and literature studies showed significant impacts when plant communities were depleted following stocking of this herbivorous fish (Hestand and Carter 1978, Osborne et al. 1982, Richard et al. 1984). Consequently, the GFC continued to oppose allowing widespread use of diploid grass carp, especially in public waters.

In 1977, the DNR promulgated a limited use rule for diploid grass carp, which was adopted by the Governor and Cabinet in February 1978. DNR Rule 16C-21 permitted use of grass carp in secured private ponds, 10 hectares (25 acres) or smaller, for control of submersed nonindigenous aquatic plants. The GFC continued to oppose use of diploid grass carp believing they could spawn in several major river systems based on their reproductive needs (Stanley et al. 1978, Leslie et al. 1982). If grass carp established expanding naturalized populations they would severely impact native aquatic habitats as well as sport and commercial fisheries. Therefore, the GFC took the DNR to court and won the initial trial. Subsequently, the DNR appealed to the Florida Supreme Court, and there was a reversal.

In 1979, an American Assembly Conference (a standardized forum for obtaining agency, public, political and scientific input) recommended the GFC assume full responsibility for use of freshwater fish as biological control agents for noxious aquatic plants (Anonymous 1979). The Conference transferred herbicide permitting responsibilities and aquatic plant management to DNR. Among the rationale given was the same agency should not apply herbicides and permit the action, as the GFC had been doing until that time. GFC Rule 39-8 provided guidelines under which herbivorous fishes could only be used for research purposes and prohibited use of diploid grass carp for weed control in Florida.

In late 1980, fisheries scientists determined grass carp had been reproducing in the Mississippi River system since 1975 (Conner et al. 1980). This discovery, along with staff findings on potential impacts, helped justify the Commission's continuing prohibition against use of diploid grass carp. However, there remained a strong lobby for finding a long-term, cost-effective aquatic plant control agent.

Marian and Krasznai's (1978) report that F_1 hybrids from female grass carp and male bighead carp resulted in sterile triploid fish stimulated renewed interest in grass carp and their derivatives. The GFC initiated a research program utilizing triploid hybrid grass carp in 1979. Progeny somewhat resembled grass carp, but it was soon discovered that potentially fertile diploid hybrids were also produced (Beck et al. 1980).

Unfortunately, the hybrid was only about one - two-thirds as effective a plant control agent as regular grass carp (Sutton et al. 1981, Cassani et al. 1982, Osborne 1982, Wattendorf and Shafland 1983; Wiley and Gorden 1984). The GFC initiated a permit system for limited use of triploid hybrid grass carp by the private sector to control submersed aquatic vegetation. The program was established to provide relief to owners of waterfront property on small lakes troubled with dense stands of undesirable aquatic plants in areas where hunting and fishing were not a prime concern and as an alternative to widespread use of aquatic herbicides in Florida.

The GFC issued permits that allowed individuals to purchase, transport and stock triploid hybrid grass carp for aquatic vegetation control from September 1980 through February 1984. During that period, triploid hybrid grass carp were stocked in 171 private areas ranging in size from 0.04 hectare to 50 hectares. Stocking rates ranged from 50 to 150 fish per hectare for hydrilla control. Under the best circumstances, triploid hybrid grass carp controlled target plants for up to two years. They were not as effective or hardy as diploid grass carp, and there was a lingering concern that a black market in diploid grass carp was developing.

Meanwhile Jim Malone and Sons enterprises, the first commercial producers of triploid hybrid grass carp, developed a genetically pure triploid grass carp (i.e., both parents were grass carp; Malone 1984). Although the exact technique they used was proprietary, triploids are created by shocking eggs after fertilization in a manner that will cause retention of the second polar body. Subsequently, Cassani and Caton (1986b) developed an efficient method of producing triploid grass carp using hydrostatic pressure that is now the standard method among state agencies and many commercial producers. Other techniques utilizing temperature shocks have not proven as effective (Thompson et al. 1987).

Regardless of the method used, the zygote develops with two sets of maternal chromosomes and one set of paternal chromosomes. The resultant three sets of chromosomes in gametic cells cannot be divided equally during meiosis into the prerequisite haploid gametes rendering the fish functionally sterile (Allen and Wattendorf 1987). Females can be distinguished, but egg production is virtually non-existent (Thorgaard 1983, Doroshov 1986). Males, on the other hand, can produce some seminal fluid; however, their milt is only about one-tenth as dense as normal and only 0.00002% of the sperm will be euploid. Therefore, they are functionally sterile. The only chance of a male triploid grass carp reproducing would be if they came in contact with a fertile diploid female in an area of suitable habitat (i.e., a large swift flowing river), and the one sperm out of 5 million that was euploid was the one to inseminate the egg and subsequently survive, which itself is a one in ten thousand proposition. Due to this infinitesimally small probability, it has been proposed that deliberately stocking triploid grass carp in rivers such as the Mississippi or Missouri with naturally spawning diploid grass carp populations could disrupt spawning and help control the grass carp population.

Although triploid fish are functionally sterile, hatchery efforts to produce triploid grass carp also create diploid fish that are indistinguishable to the eye (Bonar et al. 1988). Those diploids are naturally fertile.

The GFC decided that only 100% triploid populations of genetically pure grass carp would be allowed for operational weed control in Florida. Such a restriction necessitated a certification program, which in turn required a quick cost-effective and accurate method of evaluating the ploidy of each individual fish. In 1982 GFC personnel created a new use for the Coulter Counter System by developing a rapid certification program centered around this electronic particle size analyzer (Wattendorf 1986). Since this equipment allowed a three-person team to analyze approximately 2,000 fish per day, at a cost of only a few cents per analysis, it was possible to require producers to evaluate every fish for ploidy prior to shipment to Florida.

Triploid grass carp were determined to be generally as effective as the original diploid grass carp (Wattendorf and Anderson 1984, Cassani and Caton 1986a). In spite of adequate assurances that they would not reproduce, there still existed a substantial concern about not overstocking these fish, which may eventually live to be around 20 years old and reach weights exceeding 45 kg like diploid grass carp (Leslie et al. 1987).

FLORIDA'S CURRENT PERMITTING SYSTEM — AN EXAMPLE THAT WORKS

GFC Rule 39-23.088 (Appendix 1) permits use of triploid grass carp for aquatic vegetation control and aquatic plant research. The rule also contains guidelines for producing triploid grass carp, and holding diploid grass carp brood fish. The public can obtain an application (Appendix 2) for a permit to stock triploid grass carp for aquatic plant control purposes from any of the Commission's five regional offices or the Tallahassee headquarters. Applications are mailed to a GFC office in Tallahassee, Lakeland, or Eustis where the request is processed, placed on a master log, assigned a file number according to region, county, year and sequential order and forwarded to an appropriate field biologist. A biologist or technician then conducts an on-site inspection of any area over 5 acres to determine if the area meets the rule criteria including determining if fish barriers are necessary to prevent movement of triploid grass carp from the targeted area. In addition, the triploid grass carp program is explained to the permit requestor; information (Appendix 3) on any necessary fish barrier(s) is provided and recommendations for the number of fish and/or auxiliary plant control methods required to control the target species are made.

A copy of the field inspection (Appendix 4) is forwarded to Tallahassee, Lakeland, or Eustis where a permit to import, possess and stock a specific maximum number of triploid grass carp for each site is issued, or the permit denied. If a barrier is required, the applicant is given a form with which to notify the GFC when the barrier is ready for inspection (Appendix 5). After the barrier is inspected, the notice is signed by a Commission employee, and is sent to Tallahassee to complete the application. Permits are issued by the Executive Director and signed by an aquatic plant management biological administrator (Appendix 6).

The permit holder is required to purchase triploid grass carp from a vendor listed by the Commission as approved (Appendix 7). For a vendor to be approved, he/she must demonstrate the ability to supply healthy 100% triploid populations of grass carp. In addition, an arrangement must be made with a local United States Fish and Wildlife Service office or GFC, whereby a subsample of each load of triploid fish is verified for ploidy and examined for diseases before shipment (Appendix 8). The signature of the inspector (Appendix 9) accompanies the Commission permit when the fish are shipped into Florida, and the inspector notifies the Commission that a shipment is on the way. This certification process is a double check of the ploidy of a significantly acceptable number of fish, since the producer individually checks each fish prior to placing them in the proposed shipment. For shipments of less than 120 fish all fish are sampled for ploidy; for larger shipments 120 fish are sampled, since this provides 99% confidence for an infinite size population. Once the fish are received and stocked in the permitted water body, the applicant submits a stocking report to us for our records (Appendix 10). This is important, since many permitted sites are never actually stocked, or are stocked well below the authorized level.

All permitting work is accomplished out of three offices by 12.5 full-time positions. Personnel from these three offices also evaluate public sites for stocking with triploid grass carp, and review herbicide permit applications for the DEP to ensure fish and wildlife populations are not harmed. During 1993 and 1994, they annually processed about 1,250 permit requests to stock triploid grass carp in private waters. Of those, about 890 sites are actually stocked each year. A typical site averaged 4 hectares and received 50 triploid grass carp. Permitting triploid grass carp in private ponds took about four and a half employee-years of effort and about $175,000 (salary, per diem, overhead, expenses and equipment). Thus all inclusively, it cost nearly $140 to process each application, or about $4.00 per fish stocked.

Based on the above figures, approximately 2.0 private pond-pond permit reviews for triploid grass carp permits were conducted out of each office per work day. Typically the initial inspection and recommendation is completed within 15 working days of receiving the application. The GFC receives Aquatic Plant Trust Fund monies transferred from the DEP to run this program. Those monies come from a motor boat registration fee and percentage of the gas tax associated with boats, thus we do not charge for permits. Other states, however, may want to follow the Texas example, where a $15 permit fee, with a $2 per fish surcharge, was recently implemented.

STOCKING CONSIDERATIONS

The Commission's recommendations for stocking triploid grass carp for control of aquatic vegetation range from 10 to 200 fish per hectare depending on the following general considerations:

I. Sociological

  A. Primary use of the water body

    1. Fishing—stocking rates are minimal, with herbicides often used to reduce plant biomass thus allowing lower stocking rates to prevent eliminating desirable native plants.

    2. Aesthetics—stocking rates are moderate, herbicides occasionally used first, a major concern is preventing algal blooms or removal of plants used in aquatic landscaping.

    3. Boating, Skiing, Navigation, Swimming—stocking rates can be somewhat heavy, if there is no connection to waters used for fishing or barriers are installed.

    4. Irrigation, Industrial Use, Flood Control, Potable Water (no fishing) — stocking rates are heavy, complete elimination of plants is not a major concern and cost-effective, maintenance-free plant control is the intent.

  B. Ownership

    1. Private Single Owner Water Bodies--These are the simplest to deal with. The water body is considered private if it is man-made, entirely within the property lines of one owner (individual or corporate) and not connected to waters of the state. Under such circumstances, we provide best management recommendations but will accede to personal preferences of the land owner. However, only a reasonable maximum number of fish is permitted for the area to ensure they are not being used elsewhere.

    2. Private Multiple Owner Water Bodies—Developments and home owners associations frequently have water bodies that

were constructed for retention or soil-borrow purposes. There are frequent disputes by such riparian owners as to whether the fish are desirable or not. We place the burden of getting community consent on the developer or home owners association representative by requiring them to develop a consensus, or indicate that they have authority to speak for the group, prior to our issuing permits (see Appendix 2).

3. Public Waters—The Division of Fisheries makes the appropriate determination in conjunction with the Division of Wildlife and Department of Environmental Protection (DEP; which includes the old Department of Natural Resources). The primary considerations are ecological, sociological and economical. We are very conservative in recommending stocking for water bodies larger than 200 hectares, due to the difficulty in removing fish if over control occurs and containing them on site. In addition, the triploid grass carp can move to smaller contiguous water bodies in large enough numbers to cause significant damage to the plant community.

II. Morphometric and Edaphic Considerations

A. Size of the water body—Generally the larger the water body the more fish are needed.

B. Area of the lake in which plants can grow—If only a small fraction of the water body is shallow and has suitable substrate for plants, then less fish should be stocked. If the area is too shallow, triploid grass carp will generally avoid the area and be ineffective.

C. Trophic level—The more eutrophic the system, the more fish that are needed. This is a key factor that can be determined quantitatively based on historic nutrient concentrations and clarity, or empirically by knowing the history of plant infestations that are not controlled.

III. Aquatic Plant Community Considerations

  A. Species Present—Target plants should be high on the food preference list for triploid grass carp (Edwards 1974, Vinogradov and Zolotova 1974, Fowler and Robson 1978, Van Dyke et al. 1984, Clugston and Shireman 1987, Leslie et al. 1987, Sanders et al. 1991) see also Chapter 1. If target plants are not highly preferred, then usually high stocking rates will be required and total elimination of plants should be expected. Plants generally will be removed in the order of triploid grass carp's feeding preferences. Selective browsing can lead to expansion of non-preferred plant species, which can be positive (e.g., eel-grass) or negative (e.g., water hyacinth).

  B. Biomass Present—If large quantities of plants are present at stocking and rapid control is needed, it is generally best to use an integrated approach of applying herbicides first and then stocking fish to prevent regrowth (Sutton 1977, Shireman and Maceina 1981, Richard et al. 1984, Leslie et al. 1987).

  C. Plant Distribution—Although grass carp may roam, they tend to stay near an area with preferred food and eliminate it, unless overly disturbed by man's activities or poor water quality (Clapp et al. 1994).

  D. Growing Season—If the plant growth season is long, potentially more triploid grass carp are needed.

IV. Faunal Community

A. Predators—Systems with relatively high predator populations will require proportionately more triploid grass carp at stocking (Shireman et al. 1978, Osborne and Sassic 1981). Predators include fish (e.g., bass, pike), birds (e.g., ospreys, cormorants), reptiles (e.g., alligators, water snakes), amphibians (e.g., frogs) and mammals (e.g., otters). Generally, 20-30 cm triploid grass carp grow rapidly and avoid most smaller predators (e.g., snakes, frogs and most fish less than 40 cm). In predator-rich environments, it is sometimes worth the extra cost to stock 30-35 cm triploid grass carp.

B. Triploid grass carp—Size and health of the fish stocked is the primary consideration. Mortality rates immediately after stocking ranged from 5-27% in winter to 16-52% in summer in hatchery pond tests (Hestand et al. 1990), with larger fish having better survival rates in both seasons. Size not only affects survival due to predators, but also is important in calculating how much they will eat. Up to about 60 cm (less than 4 kg and generally less than 2 years old), triploid grass carp commonly consume approximately 100% of their body weight daily (Wattendorf and Shafland 1983). Over 60 cm (4-11 kg, typically 2-3 years old) they begin consuming less, averaging about 50% to 75% of their weight. When they get older and larger than that their feeding declines to less than 10% of their body weight (Rue Hestand, Florida GFC, Personal Communication).

V. Season—Triploid grass carp should generally be stocked in early spring. This allows the fish to be handled in cool weather and improves survival rates. In addition, this timing allows lower numbers of triploid grass carp to be stocked by taking advantage of the winter die back in aquatic plants and allowing the fish to begin feeding on succulent new growth. Finally, it coincides well with when aquaculturists have appropriately sized triploid grass carp available and allows the farmer to clear his/her ponds to make room for the new crop.

PURCHASING TRIPLOID GRASS CARP FOR PUBLIC WATERS

Prior to stocking any public water bodies the above criteria are thoroughly considered by the Triploid Grass Carp Committee. The Committee includes fishery biologists, wildlife biologists and a representative from the DEP. If the site is considered appropriate, competitive bids are requested following state purchasing guidelines from all vendors on the approved list. The bid request (Appendix 11) contains specifications for certification, handling, transporting and tempering. These specifications are important to ensure that healthy fish are delivered and that if a significant mortality occurs the vendor will replace them.

Funding for stocking triploid grass carp in Florida comes from the Aquatic Plant Trust Fund. These funds are administered by the DEP and come from a small portion of money motor boat users contribute to the Gas Tax Collection Fund and part of the Florida boat registration fees. Federal Aid in Sport Fish Restoration funds are also eligible to be used for this purpose due to the "Biological Opinion" on triploid grass carp issued by the United States Fish and Wildlife Service on 2 December 1985 (Clugston and Shireman 1987). Finally, money for aquatic plant management is also channeled to DEP from the Corps of Engineers for maintaining navigation.

HATCHERY PERMITS TO USE DIPLOID GRASS CARP

Rule 39-23.008 (Appendix 1) allows properly equipped hatcheries to possess diploid grass carp for the sole purpose of producing triploids. With the exception of being allowed to produce a limited supply of diploid grass carp to replace their broodstock, all other diploid grass carp must be destroyed. Hatchery requirements to ensure containment of eggs, fry and adult fish even during flood conditions are detailed in the rule. In addition, there are security requirements to prevent poaching or illegal removal of grass carp from hatchery facilities. Reporting requirements are designed to ensure that all triploids sold for stocking purposes are properly certified and permitted. GFC inspectors have the authority to enter hatchery grounds unannounced to inspect fish, facilities and records.

PERMITS FOR REMOVAL

To help prevent grass carp being moved into unpermitted waters and to protect the public/private investment in triploid grass carp as aquatic plant control agents, it is illegal to harvest triploid grass carp using sport fishing or other methods without a permit. When angler harvest of grass carp may be a problem, we typically post signs at sites stocked with triploid grass carp that help identify the fish and its purpose and ask anyone catching them to immediately release them unharmed.

However, when a site is overstocked with triploid grass carp, as illustrated by near total elimination of submerged vegetation, we occasionally issue harvest permits for triploid grass carp. These permits are specific to the water body (Appendix 12), and the permittee is not allowed to transport the fish alive to any other location. On small private ponds, especially with active home owners associations, this can sometimes be a viable way of reducing the triploid grass carp population and allowing some recovery of aquatic plants.

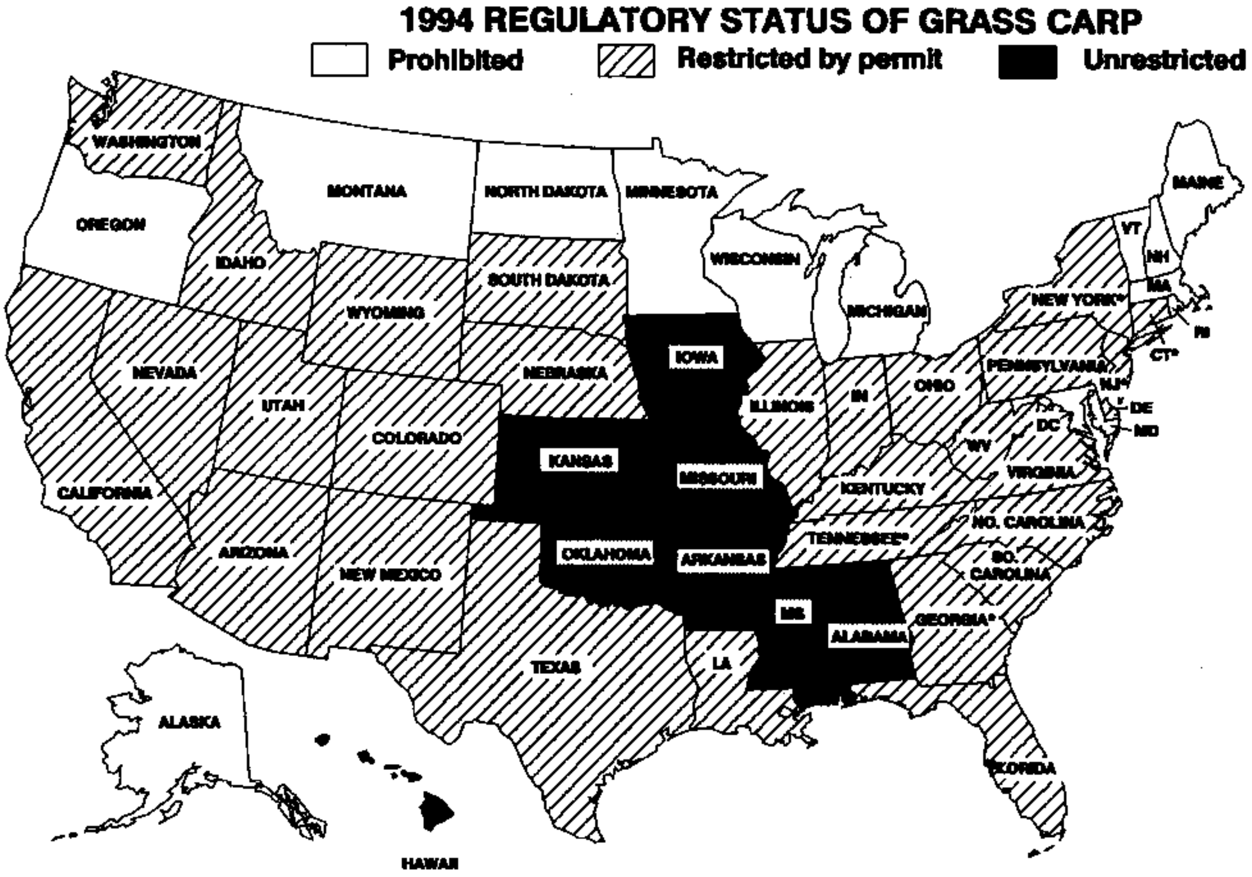

Figure 1. 1994 regulatory status of grass carp. Prohibited means that both diploid and triploid grass carp are illegal, the only exception being for research at enclosed locations. Restricted means that triploid grass carp are used by the state to manage some public waters (Note: New Jersey and Connecticut do not use the fish in public waters) and private citizens may also use the fish by permit (Note: Georgia and Tennessee do not issue permits but do allow triploids; New York does not allow private use). Unrestricted means that both diploid and triploid grass carp can be used without permit.

OTHER STATE'S CURRENT RULES AND PERMITTING TRENDS

In 1987, Allen and Wattendorf (1987) reported there were four general regulation concepts used by state agencies to deal with grass carp. First, 12 states allowed unrestricted grass carp use. Second, 15 states allowed only certified triploid grass carp. Third, four states allowed triploid grass carp use, but only for research. Fourth, 19 states prohibited all grass carp, including triploids, but were considering changes.

Since that time several changes have taken place, as would be expected. In general, seven states became more restrictive and 13 states became more liberal during the years between 1987 and 1994 (Figure 1). There are now 13 states that prohibit both diploid and triploid grass carp, 29 states that allow only triploid grass carp for vegetation control, and 8 states that do not restrict the use of diploid grass carp.

It is notable that the northern-most states with the least aquatic plant problems and borders contiguous with Canada are most likely to prohibit all grass carp. Problem aquatic plant species in these states, such as curlyleaf pondweed and Eurasian watermilfoil, may not be as high on the grass carp feeding preference list as desirable natives (Bill McClay, Michigan DNR, Personal Communication). Further the cold weather helps control the magnitude of the plant problem and the active feeding season of the grass carp. Therefore, the benefits of using the fish may not be as distinct as they are in more southern areas and do not offset the risks of establishment of grass carp or over control of aquatic vegetation.

Those states contiguous with the Mississippi or Missouri drainage basins in which diploid grass carp are spawning tend to be the most liberal with unrestricted use of the fish. The remaining states tend to take an intermediate approach by using the sterile triploid grass carp.

CONCLUSION

Aquatic plants are vitally important to inland fisheries in most states. However, based on each state's past history with grass carp, the feasibility of effectively prohibiting grass carp introduction, and the need for cost-effective aquatic plant control, each state needs to continually evaluate their position on triploid grass carp.

Experiences in Florida and several other states have demonstrated that establishing permit programs allowing only certified triploid grass carp can work. Moreover, legal availability of triploid grass carp may discourage a black market for diploid grass carp. Stocking triploids in areas with reproducing diploids may reduce natural reproduction.

If stocking rates to consistently eliminate target plants and leave adequate natural vegetation become available and if methods to selectively remove grass carp are developed, it is likely that more states will go to a permit system for triploid grass carp. Furthermore, the permit systems may become less intensive, especially for small isolated water bodies, thus helping control administrative costs. Meanwhile, a sound permit system for triploid grass carp, with occasional checks and legal action , is the best approach for those states authorizing use of herbivorous fish for plant control.