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TRIPLOID GRASS CARP

A REVIEW OF SELECTED LITERATURE AND AN ASSESSMENT OF INTRODUCING GRASS CARP AS A BIOLOGICAL CONTROL AGENT IN MONTANA

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EXECUTIVE SUMMARY

Grass carp have been introduced into most of the United States as a biological control agent. Montana is one of several northern states that has not permitted the introduction of grass carp due to concerns about potential adverse effects the fish may have on existing fish populations and other aquatic resources. In recent years the development and commercial availability of sterile, triploid grass carp has stimulated a renewed interest in using the grass carp to control nuisance aquatic vegetation.

This literature review and evaluation of the potential for grass carp use in Montana was conducted to assist the Montana Department of Fish, Wildlife and Parks in making decisions regarding grass carp introductions in Montana.

There are extensive data and scientific literature on the use of grass carp for vegetation control. Much of the early work focused on diploid and hybrid grass carp (grass carp X bighead carp) which were mostly introduced into southern regions of this country. In the past five to eight years, triploid grass carp have been introduced into many new regions, including several of the northern and western states. The expanded interest in grass carp has come about because the triploid fish is considered to be functionally sterile.

Certified triploid grass carp are available from commercial producers located primarily in the southcentral and southeastern United States. The certification procedure, which is used to determine the ploidy of a sample of fish from a designated load, is considered to be at least 97% accurate. Triploid fish are considered functionally sterile and the probability of triploid grass carp successfully producing viable young is considered to be very low.

The possibility that a shipment of fish might include diploid fish is a concern. Human error in the certification procedure is a problem due in part to the long tedious procedure required to examine a large number of fish. The U.S. Fish and Wildlife Service conducts certification inspections as a service to the states and some states require additional testing of imported fish to verify the ploidy and to inspect for diseases. Obviously the greater the number of fish introduced into an area the greater the possibility that diploid fish may be introduced.

Despite efforts to screen imported fish for disease and parasites, grass carp have been a source of both. The Asian tapeworm Bothriocephalus acheilognathi(gowkongensis) is a major parasite of grass carp that was introduced to Europe and North America from the Far East. Some states require fish to be imported only from a certified disease-free source. This restriction significantly reduces the availability of fish, but it provides an added safeguard against an inadvertent introduction of disease or parasites.

Most research has shown the grass carp to be an effective biological control agent. Triploid grass carp are essentially equal to diploid grass carp in their ability to consume and control aquatic vegetation. When stocked at appropriate densities in a suitable environment, the triploid grass carp will eradicate most species of submergent aquatic plants including filamentous algae.

Water temperature is probably the most important environmental factor affecting the success of vegetation control by grass carp. Although feeding activity begins as low as 10 C, active feeding and vegetation control is not expected at temperatures much below 15 C. Higher stocking densities are required to control vegetation at lower water temperatures. If vegetation is rapidly established in the early spring and summer water temperatures are marginal(less than 18 C), vegetation control may not be accomplished by grass carp, even at higher stocking densities.

Some introductions of grass carp have failed because the density of carp was not sufficient to control the nuisance plants. Preferred plant species are eaten first and if fish densities are too low, the least preferred plants may flourish and grow in even greater quantities. Research on stocking densities is continuing although some researchers feel it is impossible to predict stocking densities that will allow partial control.

Grass carp have been reported to be effective for controlling vegetation in flowing waters although less information is available for the northern, colder climates. When placed in flowing water systems the fish have shown a tendency to move downstream, especially in response to changing water temperatures. Effective vegetation control in flowing water probably would require fish-proof barriers placed at intervals to prevent fish from moving out of the upper vegetated areas.

Grass carp do not compete with or prey upon endemic fish populations, but they have the capability fo utilize animal foods throughout their life cycle. In some instances they have indirectly caused negative impacts on water quality due to complete eradication of aquatic vegetation. The complete removal of vegetation has also caused adverse impacts on fish habitat and fish populations.

Some states have found the regulation of grass carp to be very time consuming,costly and ineffective. The unrestricted distribution of diploid grass carp in the Mississippi and lower Missouri rivers has seriously compromised efforts to restrict their distribution. Some states have found diploid grass carp are imported despite regulations prohibiting their use.

The grass carp is capable of surviving and growing in Montana The Yellowstone, Missouri and Clark Fork river basins appear to have most of the attributes necessary to sustain a reproducing grass carp population.

It is recommended that grass carp should not be introduced in Montana, unless a very significant need and benefit for the state can be demonstrated. Any proposed introduction should be supported by an Environmental Impact Statement and a very thorough evaluation according to the protocol for the introduction of exotic species as adopted by the American Fisheries Society.

INTRODUCTION

The grass carp was introduced into the United States from Malaysia and Taiwan in 1963 for aquatic plant control research. In the more than 25 years since its introduction to this country it has been distributed to at least 35 states. There are many confirmed reports of successful reproduction of grass carp in the lower Mississippi River. Although most states initially banned the importation of grass carp, many now allow the use of a sterile triploid form of the fish for aquatic plant control and/or research. Some states consider regulation of the species futile, because of its widespread distribution and they now allow importation of either diploid or triploid grass carp. Except for local problems, no significant, negative environmental impacts have been reported due to its widespread use. There continues to be considerable concern however about the potential long-term effects of this fish in natural rivers and lakes of North America.

There has been extensive research and field testing to evaluate the effectiveness of the grass carp in controlling aquatic plants and to evaluate their potential effect on other organisms. A significant research effort has also been devoted to the development of sterile grass carp to reduce the potential for establishing naturalized populations.

This report reviews some of the current literature on grass carp, especially as it pertains to Montana's environment, and it summarizes the recent experiences of other northern states where triploid grass carp have been used in research or management.

The report begins with a brief summary of biological and ecological information about grass carp followed by a section describing various attempts to develop sterile grass carp including a brief discussion of the methods used to produce and verify polyploidy in fish. This section also describes the basic procedures used by the U.S. Fish and Wildlife Service to certify that fish are triploid before they are transported to a purchaser. This is followed by a description of the grass carp's food habits and its effect on other fish populations and the aquatic environment.

The status of grass carp in other northern states and one Canadian province is described in the following section including a review of regulatory policies and the design or results of research on the use of grass carp.

The final sections of the report are focused on the potential for using grass carp to control aquatic vegetation in Montana, with special attention given to an evaluation of a proposal to use grass carp to control vegetation in a sewage lagoon at a location in the Big Horn river drainage.

Biology and Life History Information

Taxonomy - The grass carp *Ctenopharyngodon idella* is the sole member of the genus. It is a member of the family Cyprinidae and therefore closely related to a number of other large-sized minnows including the bighead carp, *Hypopthalmichthys nobilis*, silver carp, *Hypopthalmichthys motrix* and the common carp,, *Cyprinus carpio*. The most frequently used common names are white amur, grass carp and amur.

Distribution Grass carp are native to low-gradient rivers, lakes and ponds below 1000 meters on the Pacific coasts of the USSR and China from latitudes 50N to 23N. A monsoon climate characterizes the area with average annual rainfall ranging from 200 cm in the south to 51 cm in the north. Average annual temperature extremes range between 5 C in January and 30 C in July in the south to -4 C and 22 C during corresponding months in the north (Shireman and Smith, 1983).

The grass carp has been introduced into many countries throughout the world. Although it has been released into many waterways established populations outside its native range are known to occur only in Japan, USSR and Mexico (Stanley 1976). Recent information suggests populations are probably established in the lower Mississippi River basin in the U.S.(Conner et al., 1980).

Environmental Limitations The successful introduction of grass carp into many parts of the world is evidence of its adaptability and tolerance of a wide range of environmental conditions. Strict spawning requirements, however, are responsible for its relatively restricted native range and its failure to form self-reproducing populations in most countries (Shireman and Smith 1983). The grass carp is very tolerant of extreme environmental conditions. Ice cover occurs from October to March in areas of its northern range (Hsieh, 1973, cited by Shireman and Smith, 1983). Spawning usually occurs in highly turbid rivers and in the remainder of the year they occupy stillwater feeding grounds in heavily vegetated areas. The grass carp must encounter a wide range of dissolved oxygen, and pH and associated parameters in its natural environment.

The optimum temperature for normal development of eggs is 21-25 C with poor survival at temperatures lower than 18 C. Fry, fingerling and adult fish are known to survive water temperature down to 0.0 C; upper mean lethal maximum temperature of 40 C has been reported by Opusynzynski (1967). Several workers have reported grass carp tolerate dissolved oxygen concentrations as low as 1.0 part per million (ppm); Opuszynski,(1967) reported the mean lethal minima dissolved oxygen for acclimated fry and yearlings were 0.41 and 0.22 ppm respectively.

Reproduction - Sexual maturity occurs at ages 1 to 11 years and at standard lengths of 58 to 67 cm for females. Male fish mature an average of one year earlier at lengths of 51 to 60 cm (Shireman & Smith, 1983). Maturity occurs at an earlier age and at a smaller size in tropical climates. There is evidence that maturation of females is tied to temperature, physical environment, and photoperiod. Spawning can be induced under laboratory conditions in December and January by artificially increasing water temperature and photoperiod (Sutton, Miley and Stanley, 1977,cited by Shireman and Smith, 1983). The spawning season is well-defined in temperate climates, but occurs over a longer season and is less distinct in tropical areas. Shireman and Smith (1983), have summarized literature reports on the time of sexual maturation for grass carp in many parts of the world;most occurrences in temperate climates were in May through August.

The grass carp is a pelagophilic spawner in relatively large rivers. Breeding migrations begin when water temperature reaches 15-17 C and spawning can occur at temperatures of 18-19 C. In its native range reproduction occurs during the monsoon seasons when water levels rise quickly and temperatures range between 20 and 30 C and current velocities range between 0.7 and 1.8 m/sec. Spawning has been observed to occur in open flowing water near the surface. Absolute fecundity ranges from tens of thousands to 2 million eggs with an average of 500,000 eggs for 5 to 7 kg brood stock-based on reports from many locations in the Soviet Union, China and India, cited by Shireman and Smith, (1983).

Growth "Compared to fish of similar size, the grass carp under optimal conditions, exhibits an intrinsic growth rate perhaps greater than any other species.",(Shireman and Smith, 1983). It is reported to regularly grow to 1.0 kg in first year and 2-3 kg/yr thereafter in temperate climates. Growth rates of 10 to 22 g/day during the growing season have been reported (Mitzner, 1978, Colle and Maceina, 1980). Shireman and Smith (1983) have summarized growth rates for grass carp at different ages and from several different locations showing a wide range depending upon the environmental conditions.

Low temperature affects growth through reduced food consumption and by slowing the metabolic rate. Edwards (1974) found grass carp fingerling grew very little at temperatures of 14 C or less but at temperatures of 20-23 C, fingerling increased from 20 g to 500 gram in a single summer. The summer growth rates were appproximately 4 gram/day. Colle, Shireman and Rottman (1978) recorded growths 0.59 g/day and 1.29 mm/day until water temperatures fell below 14 C after which growth rates dropped to 0.17 g/day and 0.17 mm/day.

TRIPLOID GRASS CARP

Aquatic resource managers have expressed concern about the potential impact of introduced grass carp on the environment. Most states initially banned or restricted the use of grass carp to prevent unwanted introductions. In recent years, however, progress has been made in producing functionally sterile fish.

Monosex and Hybrid Fish Initial efforts were focused on creating monosex populations through gynogenesis (Stanley, 1976) and later by hormonal implants and sex reversal. Although these efforts were successful, monosex populations remain fertile and the accidental introduction of a male into an all-female population could lead to reproduction. Surgical gonadectomies were also attempted but failed due to the rapid regeneration of the gonads (Underwood et al., 1986).

Considerable effort has been devoted to evaluating the intergeneric cross between the grass carp (female) and the bighead carp (male, *Hypopthalmichthys nobilis*). Initial reports indicated the F1 hybrid were 100% triploid (Marian and Krasznai, 1978 as cited by Allen and Wattendorf, 1987). Later tests by others, however, indicated hybrid larvae were only about 67% triploid and the remainder were subvital diploids. Although the production of hybrids stimulated a new interest in grass carp, comparison of the hybrid with diploid and triploid fish has shown the hybrid to be distinctly inferior in its ability to control aquatic vegetation (Harberg and Modde, 1985;Wiley and Wike, 1986) and others.

Triploid Induction New technology has led to the induction of polyploidy in grass carp through thermal and pressure shocks of the fertilized egg. Triploidy is induced by inhibiting the second maturation division of meiosis. If applied at the proper stage of development, the shock causes retention of an extra set of chromosomes in the second polar body of the egg. This genetic alteration ultimately causes production of non-functional eggs and sperm when the fish reach sexual maturity. The success of different methods used for inducing polyploidy has varied. Cassani and Caton 1985, obtained 50-100 % triploidy with less than 20% survival using a cold shock treatment. Thompson et al.(1987) used heat shock which yielded 87% triploidy and up to 50% survival. Cassanni and Caton (1986) have reported consistent production of nearly 100% triploid fish and 30% mortality by applying hydrostatic pressure to the fertilized egg. Commercial producer's methods are proprietary but they probably use methods similar to those reported in the literature.

Because polyploid induction is not 100%, researchers have worked to develop techniques to identify triploid fish and separate them from diploids. Certain meristic and morphological characteristics differ between the diploid and triploid fish but the differences are not sufficient to reliably separate the two genetic forms (Bonar et al., 1984). The most important difference between diploid and triploid grass carp is in the quantity of genetic material contained in the cell nucleus. Triploid grass carp have three haploid sets of chromosomes resulting in a larger nuclear and cellular size. This difference can be readily measured in the fish erythrocyte using manual techniques with a microscope or electronically using a Coulter Counter (Wattendorf,1986). The technique is essentially 100% effective.

<u>Sources of Certified Triploid Fish.</u> Triploid grass carp are available from commercial producers located primarily in the south central states. Many of the states purchasing grass carp require certification of triploidy. The U.S. Fish and Wildlife Service provides an inspection service for state government agencies to verify the procedures and certification process. The USFWS

monitors the verification procedure which is conducted by the producer. The inspection usually requires a sample of 120 fish from a load of 1000 or more. At times the sample may serve to verify a load of fish which is then subdivided among several purchasers.

Ploidy Verification Procedure A blood sample from each individual fish is passed through the Coulter Counter to measure its cellular or nuclear size in comparison with diploid fish. If a diploid fish is found, the inspection is stopped and a new lot of fish is selected. If all 120 fish are shown to be triploid, the inspection is completed and the verification information is provided to the state official both by telephone and by mail.

The fish are usually transported by a dealer who is hired by either the producer or the recipient. Some states require additional verification of the transported fish by a state laboratory before they are accepted for introduction.

All producers occasionally find diploid fish during the inspection procedure. The procedure is expected to identify triploid fish with 97% accuracy. The occurrence of three diploid fish in a lot of 1000 is not unexpected, but the occurrence of 10 diploids in a lot of 1000 is unacceptable and is evidence of a problem with a particular lot of fish (Andrew Mitchell, Fish Farm Experimental Station, Stuttgart, Arkansas, personal communication 1989). The verification procedure is considered to be very good but it is not foolproof due to potential human error.

The U.S. Fish and Wildlife Service also conducts tests to examine and treat fish for the occurrence of Asian tapeworm (Bothriocephalus gowkogensis). The procedure requires holding the fish for 72 hours in a antihelminthic solution and then holding them in clean water for 72 hours to allow the fish to purge the chemical. A sample of fish is then sacrificed for inspection to verify the elimination of the tapeworms. The states of California, Oregon, and Washington require examination of thirty fish out of each load to give 95% confidence the fish are free of tapeworms. The cost of the chemical is about $62/gram. The cost of treating 4000 to 5000 fish is approximately $2000 (Andrew Mitchell, Fish Farm Experiment Station, Stuttgart, Arkansas, personal communication, 7/14/89).

Potential for Reproduction Triploid fish are capable of producing gametes. Ovaries are rudimentary with egg production almost non-existent while triploid males often produce functional testes and some triploid fish species have produced spermatazoa (Lincoln, 1981). Allen and Wattendorf (1987) cite California researchers as having induced spermiation in a triploid grass carp with subsequent fertilization of eggs from a normal diploid female. Some larvae survived, but all had died within a month. Allen (1986) has shown the mean DNA content of triploid sperm is 1.5N (aneuploid); only 60 cells in every billion in a triploid will be a euploid (i.e. haploid or diploid) gamete. Because of the small likelihood of triploid gametes uniting, and the offspring producing sufficient young to establish reproducing populations, the triploid grass carp is described as functionally sterile (Allen and Wattendorf 1987).

FEEDING AND FOOD PREFERENCES

Food selection and fish size. There is relatively little information on food habits of grass carp in their natural environment. Shireman and Smith (1983) have summarized information from the Russian and Chinese literature to give a general description of feeding activity during the early life stages.

Grass carp larvae begin feeding when they are about four-days old and a total length of 4 to 6 mm. Algae and some small zooplankton are selected during the first 4-5 days. Protozoans, rotifers and nauplii occurred in the diet of fry that were 7 to 9 mm total length, and larger zooplankton such as cladocerans, copepods and some insect larvae were found in the diet of 10 to 18 mm TL fry. Opuszynski (1979) found Chironomid larvae to be important in the diet of fry 17-18 mm and longer.

Grass carp shift to a diet of macrophytes when they are about 20 mm but apparently they are capable of utilizing animal foods throughout their life. Some researchers have found grass carp fingerling readily utilized insect larvae, larvae of common carp, snails, oligochaetes and zooplankton, especially in the absence of plant material (Cross 1969; Edwards 1973; Willey, Doskosil, and Lembi (1974). Larger grass carp inadvertently ingest epiphytic organisms associated with food plants (Colle, Shireman, and Rottman, 1978; Mitzner 1978), but in areas lacking vegetation they may rely on animal foods (Forester and Avault 1978; Lewis 1978).

In laboratory feeding tests, grass carp readily consumed invertebrates in an open aquarium but they did not pursue the invertebrates when stones were placed in the tank for cover (Edwards 1973). The fry ignore food particles unless they are suspended in the water column (Stevenson 1965). Edwards (1973) suggests grass carp are physiologically adapted for a variety of foods but lack the ecological adaptations to utilize these foods.

Macrophytes in the diet of young grass carp gradually increased in importance until fingerling of 45 to 52 mm TL were feeding exclusively on aquatic plants.(Sobolev, 1970, as cited in Shireman and Smith, 1983). Fingerling grass carp select soft, tender plants or plant parts, especially filamentous algae, duckweeds and new shoots of pond weeds (Bailey, 1978). This preference for small tender plant parts apparently continues until fish are 3 lbs. or more when they gradually diversify their diet to include larger, more fibrous plant species. The expansion of their diet occurs as the lips, mouth parts, and branchial teeth develop and strengthen to allow grazing and mastication of the larger more fibrous plant part(Edwards 1973;1974).

In the temperate zones of its native range the grass carp shows distinct seasonality in the feeding pattern. Adult fish winter in deep river channels without eating; in the spring, the adults feed on macrophytes available in primary waterways and after spawning the adults and fry move into the flooded, highly vegetated flood plains and feed intensively until the water levels drop in August or September (Nikolsky, 1963).

Food Preference The interest in grass carp for vegetation control has stimulated numerous investigations into the grass carp's preference for different plant species. Shireman and Smith 1983, Provine 1975, and others have summarized information from the early literature regarding food preference studies. Studies conducted in the laboratory and the field show grass carp are highly selective for certain plant species and they will usually eradicate a preferred plant before shifting to one of lesser preference. In the presence of abundant food, some plant species are avoided, but where food is limited the grass carp may consume all species until all plants are eradicated. Table 1. provides a listing of aquatic plants according to preference ranking determined by several investigators working in northern latitudes.

The research has clearly shown that preference can be very site specific and dependent on other environmental conditions. A low preference plant in one location may be readily consumed at another location.

Wiley, et al.(1986) examined the relation between feeding rate and plant preference in the grass carp and a hybrid (female grass carp x male bighead carp, Hypopthalmicthys nobilis Rich.). The tests were conducted in a controlled laboratory environment with water temperatures ranging between 23 and 24 C. Food preferences of the grass carp and hybrid were similar but hybrids consumed less food per day than grass carp. The food preferences were clearly established with the most preferred plant species often chosen exclusively. At the low end of the scale, the order of preference was less distinct but the least preferred species was consistently selected last. In food consumption studies the same general pattern held with the highest rate of consumption associated with the most preferred species. The study showed the preferred species were those that could be consumed most rapidly. The analysis further indicated that neither preference nor consumption rate were correlated with caloric content, percent water or percent nitrogen (index of protein) of the various plants. The authors hypothesized that plants are probably selected on the basis of handling time; i.e., those plants most easily grasped and chewed. It is suggested that herbivorous fish optimize their energy gains with foods they can consume most

Table 1.—Plant species preferred by grass carp as determined by studies in northern states.

High	Medium	Low
Najas guadalupensis Chara sp.	Potamogeton pectinatus	Myriophyllum spicatum Ceratophyllum demersum
Harberg and Modde, 1985. SOUTH DAKOTA		
Ceratophyllum demersum Chara sp. Elodea canadensis Lemna sp. Najas guadalupensis Nitella sp. Potamogeton pusillus	Eleocharis sp. Potamogeton sp. Potamogeton pectinatus Potamogeton richardsonii Ruppia maritima Zanichellia palustris	Claodophora sp, Spirogyra sp. Myriophyllum exalbescens Nuphar luteum Polygonum amphibium Potamogeton crispus Potamogeton praelongus Ranunculus sp. Utricularia sp.
Swanson and Bergerson, 1988. COLORADO		
Potamogeton crispus Potamogeton pectinatus Potamogeton zosteriformes Elodea canadensis Vallisneria sp.	Myriophyllum spicatum Ceratophyllum demersum Utricularia vulgaris Polygonium amphibium	Potamogeton natans Brasenia schreberi Elodea densa
Bowers, Pauley and Thomas, 1987. WASHINGTON		
Najas flexilis Najas minor Chara sp. Nitella sp. Najas guadalupensis	Potamogeton crispus Potamogeton pectinatus Potamogeton foliosus Elodea canadensis Zanichellia palustris	Brasenia schreberi Myriophyllum spp. Ceratophyllum demersum Ranunculus sp. Polygonum fluitans
Wiley, Tazik, and Sobaski, 1987. ILLINOIS		

rapidly. Pine, et al.(1989) also suggested that accessibility and ease of mastication were more important in determining preference by grass carp than nutritional quality of the plants.

Fish size also influences the species of plants consumed by grass carp. Edwards (1974) reported that fish weighing 14 g would not feed on several plant species offered during feeding trials but these same fish at 500 g weight ate considerable quantities of these plants.

Temperature is also an important factor influencing the selection of plants for food. Edwards (1974) found grass carp were much more selective in their feeding at colder temperatures. At a mean water temperature of 9°C or less, the fish ate only a few highly preferred plant species. As water temperatures increased during the summer, the grass carp utilized a greater variety of aquatic plants but the order of preference did not change.

<u>Food Consumption and Growth</u> The grass carp is a voracious feeder; given optimum food and environmental conditions a mature fish may consume up to 100% of its bodyweight per day (Hickling 1966). The rate that grass carp consume plant material is an important consideration in their role as a biological control agent. The number of fish or stocking rates required to achieve plant control in a given body of water is dependent on the quantity of plant material each fish will consume during a growing season. The primary factors known to directly affect food consumption are ploidy, food type, body size and temperature.

<u>Ploidy</u> Wiley and Wike (1986) conducted a detailed study comparing the bioenergetics of diploid, triploid and hybrid grass carp. Their investigation provided empirical relationships for consumption rate, metabolic rate and assimilation efficiency as

functions of temperature and size. The energy balance for each type of fish showed diploid and triploid grass carp are similar but hybrids were distinctly inferior (Table 2.).

Table 2.—Standardized energy balances for grass carp and genetic derivatives showing fate of energy as a percentage of energy consumed. (From Wiley and Wike, 1986).

Genetic type	Metabolism	Excreted	Growth
Diploid and Triploid	12-13 %	74%	13-14%
Hybrid	16%	81%	3%

Triploid grass carp consumption rates were 10% less than for diploid fish of similar size and feeding on identical foods at the same temperatures. Hybrids had a 66% higher metabolic rate than diploid fish which resulted in a slower growth rate. The study results suggest grass carp can maintain a high growth rate by a "low efficiency-high volume" energy strategy as long as food supplies permit.

Swanson and Bergerson (1988) recommend higher stocking rates for triploid grass carp to account for their slightly lower food consumption rate.

Body size Most grass carp are stocked as 20 to 25 cm fingerling. This size fish readily utilizes most aquatic vegetation and it is less susceptible to predation than smaller fish. Food consumption rates (percentage of body weight eaten per day) change with fish size. Fish under 2.7 kg consume up to 100% of their body weight per day;2.7-5.9 kg fish,75% and more than 5.9 kg, 25% (Clugston and Shireman 1987).

Temperature Mitchell (1980) reported grass carp feeding rates are temperature dependent with fish selecting the warmest and probably the best oxygenated feeding sites where plants were available. Active selection of the most palatable plants within the feeding sites occurred first and plants in deeper cooler water were not utilized until after palatable plants in shallow waters were eliminated.

STOCKING RATES

It is generally recognized that grass carp are an effective and efficient means of eradicating aquatic vegetation. Eradication of aquatic plants may be desirable in some systems, for example in irrigation and drainage canals, in ponds on golf courses and for aesthetic purposes in other small ponds or lakes. There is evidence, however, that total eradication of vegetation may cause detrimental impacts in some water bodies, especially if it occurs during a short time period. In other waters, aquatic plants may be important as fish habitat and as food for fish, aquatic invertebrates and waterfowl. In these instances, partial vegetation control may be more desirable than eradication.

Grass carp stocking rates have been proposed by various workers based on results from experimental introductions. In most instances very little prestocking data were available and the proposed stocking rates were estimates based on surface area of the water body. For example, English workers have proposed stocking densities of 125 Kg/ha to achieve 50% reduction in vegetation

(Stott et al., 1971) and 125 to 200 Kg/ha to reduce and maintain plant growth at 20-25% of its growth potential (Stott and Buckly, 1978). To the contrary, however, Mugridge et al.,(1982), found a stocking rate of 177 Kg/ha did not significantly reduce the standing crop of Elodea ernestae over a four-year period in an English drainage canal. Low water temperature was considered the single most important factor limiting vegetation control. The average water temperature over a four-year period was 14.1 C, with a maximum of 20 C. Such low temperatures would restrict feeding rates and fish growth and greatly reduce the grass carp's effectiveness.

Field studies indicate many environmental factors influence feeding activity such as temperature, water depth, seasonal growth patterns of plants, climatic changes and other environmental variables. The complex interaction of these factors limits our ability to predict appropriate stocking rates to obtain the desired level of control. Considerable research is currently focused on determining appropriate stocking rates for grass carp to achieve a specific level of vegetation control.

The State of Illinois has conducted an intensive evaluation o: grass carp focused on the feasibility and impact of its use as a biological control agent. Using research on the bioenergetics and feeding characteristics of grass carp, the Illinois Herbivorous Fish Stocking Simulation System (IHFSS) was developed to provide guidelines for stocking grass carp in Illinois (Wiley and Gorden, 1984). The model is based on Illinois conditions and plant types but it also provides a basic framework for estimating stocking rates in other locations.

The stocking recommendations for Illinois are designed for a target plant coverage of 40% of the littoral surface area. Their research indicates that less than 40% plant coverage in the littoral zone will cause harm to sport fishery. (Wiley, et al. 1984). Various other workers have also reported that moderate amounts of vegetation are beneficial for fish production and the stabilization of water quality and phytoplankton populations.

The Illinois stocking model is adjusted according to climatic zones (temperature) of the state, specific plant species (palatability), and the area of the pond covered by vegetation. The model recommends a 10 year stocking schedule with a second stocking after 5 to 7 years depending on the vegetation type and the climatic region. Highest stocking rates are recommended for the northern climatic region and for ponds with the least palatable plant species.

Swanson and Bergerson (1988) have developed a simple stocking model for grass carp in cold water lakes and ponds. The model is based on the results of experimental grass carp introductions into six lakes of 0.8-15 ha at elevations of 1884 to 2542 meters above sea level in Colorado. The model considers 8 attributes as key factors influencing stocking densities and the likelihood of successful control of vegetation. Measures or estimates of water temperature (based on lake elevation), density distribution of aquatic plants, particular plant species and the degree of human activity or disturbance are factors used to establish a base stocking rate. The base rate is then adjusted as needed according to the lake management objectives, the size of fish to be stocked and the ploidy of the fish.

The model uses daily temperature units,(DTU) - the cumulativ mean daily temperatures above 12.8 C, as one measure to determine stocking rates. Their study indicates grass carp effectively consumed aquatic plants in lakes at elevations of 2530 meters and DTUs as low as 900. They suggest that lakes above 2896 meters elevation and DTU fewer than 400 probably preclude the use of grass carp to control vegetation. The authors suggest the model is appropriate for lakes above the 37° N latitude.

Swanson and Bergerson (1988) recommend estimating plant density and distribution because actual measures of standing crop is labor intensive and expensive. They recommend visual estimates of plant densities and areal coverage to be made during peak periods of vegetation biomass. The vegetation and water temperature (DTU) have the greatest influence on the stocking rate calculations. Baseline stocking rates range from 20-25 fish/ha for low elevation lakes with low, plant biomass to 90-100 fish/ha for high elevation lakes with high, vegetation biomass.

The order of plant preference is important in the model because grass carp may efficiently control a preferred species while a less palatable species may persist or increase. Plants are assigned to high, moderate, or low preference categories and the baseline stocking rate is adjusted accordingly.

Swanson and Bergerson (1988) studies have shown grass carp ar sensitive to disturbances on the water or near the shoreline. They noted grass carp feeding activity was noticeably depressed where high levels of human activity occurred, such as a well-traveled road near a shoreline. The disturbance factor is especially important in lakes where temperatures are marginal. The activity near shore may force fish out to deeper, colder water where metabolic activity is reduced and feeding rates decline.

The final stocking rate is based on a desired level of contro and the intended use of the water body. If fingerling trout are to be stocked for growth, a 20-25% vegetation cover is recommended, for recreational lakes managed as a put and take fishery, only 10-15% vegetation is suggested; and for lakes used for water storage or aesthetics, 0-10% vegetation is recommended.

The model is designed to use 20-28 cm fish which is the size most available from producers. The larger fish are desired because they eat a greater diversity of aquatic plant species, have higher food conversion rates and they are less susceptible to disease and predation. The time required to achieve vegetation control is dependent on the size of carp stocked as well as the stocking rate. Larger carp, 36-51 cm, may reduce control time by 1 year and fish larger than 51 cm by 2 years. The model is designed to result in vegetation control by the third season. Control longevity is unknown, but restocking is recommended after 5 to 6 years.

Several researchers have shown triploid grass carp consume only about 90% as much vegetation as diploid fish. Because the coldwater lakes model was developed for diploid fish, a 10% higher stocking rate is recommended for triploid fish to compensate for their lower rate of food consumption.

Swanson and Bergerson (1988) recognize the limitations of their model and the need to carefully monitor and adjust stocking rates as needed. They suggest supplemental chemical or mechanical control may be required to achieve control in some locations. In other instances it may be desirable to reduce grass carp numbers to maintain desirable plant levels. The recommended stocking levels are conservative to avoid the need for grass carp removal. Grass carp are not recommended if the vegetation density is at or below the suggested level for lake management objectives.

A comparison of the attributes of the Illinois and the Coldwater Lakes stocking models is given in Table 3.

In the Pacific northwest, the Washington Cooperative Fisheries Unit is conducting a series of studies to define the potential for using grass carp in that region (Pauley et al.,1985). An important goal of their research is to develop a stocking model designed specifically for plant assemblages and temperature regimes typical of Washington and Oregon. Their initial studies suggest that neither the Colorado cold lakes model nor the Illinois (INHSS) model are satisfactory for conditions in the state of Washington. They have concluded that Pacific northwest plant communities and temperature regimes more closely approximate those of northern Europe.

The Washington Cooperative Fishery Unit has worked with a water improvement district to determine a stocking rate for Devil's Lake, Oregon (Pauley et al., 1987). The lake is a large (680 acre), shallow, water body with dense growths of Eurasian milfoil (Myriophyllum spicatum) Brazilian water weed (Elodea densa), and coontail (Ceratophyllum demersum). A 1986 decision to stock triploid grass carp in Devil's Lake, Oregon required an estimation of an appropriate stocking rate that would partially reduce vegetation but not result in eradication. Twenty-four case histories of grass carp introductions from locations around the world were analyzed to find a basis for estimating a stocking rate. Seven case histories were identified where measurements of plant densities had been used to estimate stocking rates as a ratio of fish to plant weight. Three of the seven studies showed effective control, three resulted in eradication and, one had been a failure resulting in a shift to dominance by unpalatable plants. The average stocking rate of the three introductions that had achieved control was 1.41 kg grass carp per metric ton of vegetation. Using this stocking rate as a base, the authors calculated a stocking rate of + or - 15% to allow for the 15% confidence limits on vegetation density calculations. The authors estimated a maximum of 36,340 fish, a mid-value of 31,860 and a low-value of 27,090 fish to stock this 245 ha lake. As a comparison, the Illinois stocking model estimated 56,250 fish would be required to achieve vegetation control. The lowest stocking rate was used due to the uncertainty of the estimation procedure and their desire to avoid vegetation eradication (Bonar et al.,1987).

The results of this experimental stocking after two years, indicate the stocking rate was probably low (Pauley et al.,1988). The macrophyte density actually increased with a shift in relative percentage of different species. The changes appeared to be a result of preferential feeding by grass carp and possibly natural seasonal fluctuations in plant densities.

Table 3. _ Attributes of models used to estimate stocking rates for grass carp.

Coldwater Lakes Model (Swanson and Bergerson 1988)	Attributes	Illinois Natural History Survey Model. (Wiley and Gordon, 1984)
Based on elevation and daily temperature units (DTU)	Temperature	Based on the states climatic regions
Ranked as High, Moderate, Low Categories	Vegetation Preference	Five categories grouped by species.
Vegetation biomass and distribution estimated as Sparse, intermediate or high.	Vegetation Quantity	Percentage distribution and percentage of lake less than 8 foot deep.
Four levels of control : 0-10%, 10-15%, 15-25% and 20-25% plant cover.	Management Objectives	Designed for target level of 40% plant cover.
Based on 20-28 cm fish with with adjustments for larger or smaller sizes.	Fish Size	Based on 25.4 cm fish.
Adjustments for site specific disturbances.	Site Specific Variables	Adjustments recommended for site specific variables.
Supplemental stocking may be required after 5-6 years to compensate for mortality.	Stocking strategy	Stocking recommended at 5 7 year interval. Frequency and numbers of fish depend on climatic region.

Effects of Grass Carp on the Aquatic Environment

Grass carp have the potential to modify their environment through the selective removal or total eradication of aquatic macrophytes and by indirect effects on water quality. Rooted aquatic plants and filamentous algae are important as buffers for exogenous nutrients and they can restrict phytoplankton growth by limiting nutrients and by the release of repressive substances (Boyd 1971).

Effects on Water Quality Studies of grass carp feeding and digestion efficiency indicate they retain only about 50% of the nutrients they ingest. The release of the plant nutrients from their feces and from damaged plant parts should continuously enrich the water column during times of the year that grass carp actively feed. Some early studies conducted in small tanks or pools with high stocking densities reported dramatic changes in water quality due to the feeding activity of the grass carp. Stanley (1974) reported concentrations of ammonium and orthophosphate increased by five-fold in the test tank water and he suggested that additional organically bound nitrogen and phosphorus in the feces would be released gradually through decomposition. Stanley (1974) and Prowse (1971) suggested that consumption of aquatic plants and the decomposition of fecal matter may enhance the production of phytoplankton. However, Lembi et al.(1978) believed that water quality changes in small test vessels were not representative of conditions expected under field conditions where microorganisms, plankton, and macroinvertebrates would modify and sequester materials released by grass carp feeding activity.

Many field studies of grass carp have shown only moderate or temporary increases in nutrient concentrations in the water column and either no changes, or decreases in chlorophyll-a (Lembi et al. 1978, Rottman and Anderson 1978, Mitzner 1978). Leslie et al. 1983) suggested that nutrients are released slowly during grass carp feeding which may allow their incorporation into the sediments, making them unavailable to phytoplankton.

Leslie et al.(1983) monitored water quality for 48 months in four Florida lakes following grass carp introductions. Turbidity increased in all lakes but chlorophyl decreased or remained the same. The least developed (human habitation) lake experienced short-term increases in nutrients, but concentrations returned to baseline within a few years. Long term increases in Kjeldahl nitrogen, orthophosphorus and total phosphorus occurred in three lakes. The authors proposed the degree of enrichment was probably related to external nutrient loading, water depth and the reduction of the nutrient filtering capacity of the submerged and marginal plant communities. As submerged plants decline, nutrients from runoff may enrich the water column because of the decreasing foliar uptake. This is especially true if the marginal flora is also removed by terrestrial development. They found no evidence that a reduction of macrophytes stimulated production of phytoplankton.

Changes in the water chemistry of Illinois ponds stocked at low densities were attributed to reductions in primary productivity (Wiley and Gorden 1984). The daytime pH decreased, but alkalinity, carbon dioxide, nutrients and total dissolved solids increased. In the same study, ponds stocked with grass carp at high densities had similar but more dramatic changes. Some increase in planktonic algae occurred at both stocking densities. Sedimentation rates increased in ponds with grass carp due to the high rate of fecal production and the continuous resuspension of bottom materials as

the grass carp searched for vestigial plant materials. In ponds with high stocking density, sedimentation increased up to 22 times over the controls. A catastrophic decline in invertebrates in these ponds was probably related to the loss of habitat as well as the high rate of sedimentation. They suggest the complete removal of vegetation by grass carp could have serious impact if there is a loss of filtering capacity of plants for allochothonus sources of nutrients or a loss of fish habitat.

Mitzner(1978) reported an overriding trend toward improved water quality in Red Haw Lake, Iowa and no evidence of accelerated eutrophication. The biological control of aquatic vegetation by grass carp has shown no detrimental effects on water quality or phytoplankton production more than ten years after grass carp were introduced (Mitzner, 1989- personal communication).

Lembi et al.(1978) found an increase in turbidity but no significant increase in phytoplankton. The low release of nutrients into the water column indicated a rapid flow of nutrients into other components of the ecosystem A large increase in potassium concentration in the water column was excreted by grass carp feeding on aquatic macrophyte. They suggest the complete removal of vegetation by grass carp could have serious impact if there is a loss of filtering capacity of plants for allochothonus sources of nutrients or a loss of fish habitat.

Mitchell et al.(1984) reported on limnological changes in a small New Zealand lake where grass carp had eliminated heavy infestations of aquatic weeds. They found no significant effect on dissolved oxygen and only minor increases in organic phosphorus and a temporary increase in particulate phosphorus. Oxidized nitrogen levels did not fluctuate. There was some decrease in transparency but no overall increase in chlorophyll-a. Zooplankton increased in both numbers and biomass. Negative side effects were due to the in the low-density ponds and decreased in the high density ponds. The highest production of piscivorous bass was in ponds with intermediate levels of plant control. The young-of-the-year bass production was highest in the high density ponds although none varied by more than 20%. Increased condition factors were found in fish from the high stocking density ponds. The author suggests the improved condition may have been a temporary response to a higher vulnerability of prey. The young-of-the-year recruitment of centrarchids declined in ponds stocked with grass carp probably due to increased predation with the reduction of plant cover. The authors of this report acknowledged that long-term impacts were unknown from these studies but the use of their model (Wiley et al.1984) suggested a major suppression of aquatic macrophytes over several growing seasons will result in major reductions in centrarchids. They suggest, however, that situations where pelagic forage fish are available as substitute forage, the bass may be insulated against the effects of macrophyte loss.

The nearly complete removal of submergent vegetation by grass carp in Red Haw Lake in southcentral Iowa improved fishing opportunities for shore fisherman although it did not affect angler catch rates (Mitzner 1978). In contrast to the predictions by Wiley and Gorden (1984), bluegill and largemouth bass production in the lake continues to be excellent more than ten years after the introduction of grass carp.

Heavy predation on grass carp fingerlings by largemouth bass and northern pike has been identified as a factor that may limit the success of grass carp in some instances (Bauer, 1988; Shireman, 1978).

Rowe(1984) concluded that vegetation removal by grass carp in a small eutrophic lake in New Zealand indirectly affected rainbow trout production. As the weeds declined there was an increase in lack of filtering capacity for sediments and nutrients that had previously been provided by shoreline weed beds.

Some researchers have reported increased dissolved oxygen in lakes and ponds as aquatic plants were removed (Rottman and Anderson 1978, Lembi et al. 1978). They attributed this change to increased water circulation and mixing of surface waters after plant removal.

Effects on other Fish Populations The potential effect of grass carp on game fish populations has been a major concern of fishery managers. Most research in this country has indicated grass carp do not compete for food or prey on native fishes (Kilgen and Smitherman, 1971;Terrel and Fox 1974; Forester and Lawrence 1978; Lewis 1978) but they may indirectly affect existing fish populations by removal of submergent vegetation.

Various workers have demonstrated the importance of aquatic vegetation as hiding cover, spawning substrate for some fish species, and as a mechanism controlling the distribution and abundance of fish food organisms. Wiley et al., (1984) used results of Illinois pond studies to model the influence of vegetation cover on centrarchid populations. Their data indicate a 40% vegetation cover is necessary to maintain a balanced population of bluegill and largemouth bass. In another study vegetation cover greater than 30% surface area was correlated with poor condition factors in largemouth bass >250 mm total length but smaller largemouth bass were not affected until vegetation coverage exceeded 50%. Condition factors decreased in bluegill, redear sunfish and largemouth bass as vegetation density increased (Shireman and Maceina, 1981).

The effects of grass carp introductions on existing fish populations have been inconsistent and difficult to interpret. Bailey (1978), reviewed the fish population data for 31 Arkansas lakes where grass carp had been introduced for vegetation control. He found the introduction of grass carp was beneficial to native fish populations in some instances and under other circumstances it was detrimental. Factors other than the grass carp were believed to have played a role in the changes observed in some fish populations.

Baur, Buck and Rose (1979) found grass carp stocked in 0.4 ha ponds did not adversely affect the survival of age 0 bass and bluegill except where vegetation was severely depleted. The fall standing crop of smallmouth bass increased by 1.4 to 25 times over that of the controls and almost nine times greater than in largemouth bass-bluegill ponds. Kilgen (1978) reported improved growth and production of channel catfish and striped bass after grass carp had reduced the standing crop of water hyacinth. He attributed the improvements to greater feeding efficiency of the game fish after the vegetation had been reduced. Similar results were reported by Maceina and Shireman (1982) and Rottman and Anderson (1977). In an English study, common bream stocked with grass carp had greater growth rates than when stocked alone (Stott et al. 1971).

Wiley and Gorden (1984) compared the effects of high and low stocking densities of grass carp in a series of Illinois ponds containing various species of game fish. Bluegill production declined dramatically in high stocking density ponds, but channel catfish production increased significantly. The response of largemouth bass population was more complicated, but it was consistent with the trophic model developed by Wiley et al.,(1984). The fingerling and breeder bass production increased significantly

in the low-density ponds and decreased in the high density ponds. The highest production of piscivorous bass was in ponds with intermediate levels of plant control. The young-of-the-year bass production was highest in the high density ponds although none varied by more than 20%. Increased condition factors were found in fish from the high stocking density ponds. The author suggests the improved condition may have been a temporary response to a higher vulnerability of prey. The young-of-the-year recruitment of centrarchids declined in ponds stocked with grass carp probably due to increased predation with the reduction of plant cover. The authors of this report acknowledged that long-term impacts were unknown from these studies but the use of their model (Wiley et al.1984) suggested a major suppression of aquatic macrophytes over several growing seasons will result in major reductions in centrarchids. They suggest, however, that situations where pelagic forage fish are available as substitute forage, the bass may be insulated against the effects of macrophyte loss.

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Rowe(1984) concluded that vegetation removal by grass carp in a small eutrophic lake in New Zealand indirectly affected rainbow trout production. As the weeds declined there was an increase in

piscivorous birds which contributed to trout mortality. At the same time the rudd (Scardinius erythropthalmus) which had previously been entirely herbivorous shifted to feeding on animal foods and thus became competitors with trout. The forage fish population declined as trout increased predation on smelt and the tench population was reduced by piscivorous birds. In addition the removal of aquatic plants indirectly led to low oxygen conditions in the hypolimnion and further reduction in the trout population . The author concluded that aquatic plant communities are an important structural component of lake ecosystem which help to stabilize the interrelationships between biological populations.

Forester and Lawrence (1978) reported a lower production of bluegills in non-vegetated ponds heavily stocked with grass carp. They suggested that schooling behavior of the grass carp may have disrupted the spawning activity of bluegill. Ware and Gasaway (1977) recorded negative changes in fish populations in ponds receiving high stocking rates of grass carp. The elimination of aquatic vegetation was followed by decreased production of largemouth bass and overcrowding by bluegill. The drastic decline of endemic game fish was followed by an increase in coarse fish.

SURVEY OF GRASS CARP USE IN OTHER LOCATIONS

An important objective of this report was to assess the results of grass carp introductions in other states, especially those located at northern latitudes. In July and August, 1989, fisheries officials and researchers in selected states were contacted by telephone to request information about their state's policy regarding grass carp and the results of any introductions of grass carp in their state. The following is a summary of information obtained from 12 states and one Canadian province. The individual(s) contacted, their organization and the date of contact is given for each state and province.

Colorado

Robin Knox
Colorado Division of Wildlife
Denver, Colorado
7/29/89

Policy Initally the state required individuals to obtain a permit for the introduction of grass carp. After 5 years, the state determined the process was too time consuming and expensive. Individuals are now allowed to purchase the grass carp but they are required to file a post-stocking notification with the state. The state does limit stocking to specific types of waters.

The state allows diploid grass carp east of the continental divide but only triploids are permitted on the west side. They recognize the fish are being imported regardless of the regulations.

Dealers are required to have an import permit.

Research/results The state has used the grass carp in Denver in some urban fishing ponds and in some fish culture rearing ponds.

The U.S. Bureau of Reclamation has conducted research on the use of grass carp to remove vegetation in irrigation canals in northeastern Colorado. Thullen and Nibling (1986) conducted a study to determine the potential of diploid grass carp to control aquatic vegetation in cold-water irrigation canals typically found in many of the western states.

A two-year study in the South Platte Supply Canal in northern Colorado demonstrated that grass carp were effective in controlling aquatic weeds in cold, flowing water. The maximum biomass controlled by the fish was 257 grams of dry weight macrophytes per square meter in a two-month period. Their study showed grass carp tend to remain in fixed territories during steady flow conditions, but they moved downstream with abrupt changes in the canal's water flow. The fish moved downstream over drops up to 1.8 meters in height. The researchers recommended additional research to design barriers that are effective in confining fish to areas of the canals where vegetation control is needed.

Although the canal's water temperature regime was not described, the report did indicate the maximum water temperature was 20 C. The report suggests active feeding occurred between 10 C and 20 C, but the fish overwintered in the canal in 0 C water under ice cover. Ninety-seven percent of the fish were recovered after the winter period and restocked in the canals for a second summer control period.

IDAHO

Bill Horton
Idaho Department of Fish and Game
Coeur d'Alene, Idaho
7/18/89

Policy In 1988, the Idaho Fish and Game Commision approved a policy to allow (1) the importation of triploid grass carp which have been certified sterile by the U. S. Fish and Wildlife Service, and (2) their release in waters having no outlet or outlets which are screened to prevent the escape of fish. Such importation and release would be allowed only with written permission of the Director (of the Department) pursuant to authority under Idaho Code.

They have approved at least two introductions where they are certain the fish do not have access to open water. Applicants are required to notify the agency when the fish arrive at their destination.

Research/Results Idaho is not conducting research with grass carp but they have authorized the use of grass carp for vegetation control in sewage lagoons located at Kuna, Idaho, southwest of Boise and Sagle, a small community south of Sandpoint. Leo Ray, a fish dealer located at Buhl, Idaho will probably obtain and transport the fish. The purpose of the planned introductions is to control filamentous algae.

ILLINOIS

Jim Mick and Greg Ticacheck
Department of Fisheries, Illinois Department of Conservation
7/26/89

Policy It is the policy of the Illinois Department of Conservation to not permit the stocking of triploid grass carp into any natural body of water including glacial lakes, slough potholes, bottomland lakes, streams, or rivers; waters known to harbor rare, threatened or endangered animals or plants on the official National or State listing; any State inventory natural area; any State Nature Preserve; or any wetland.

Beginning in 1986, triploid grass carp became legal for stocking in Illinois waters. A pond owner may purchase fish from a licensed Illinois fish dealer or they must obtain a permit to import the fish. Diploid fish are illegal. The state requires a subsample of each load of fish entering Illinois to be checked for ploidy and disease at their Animal Disease Control Laboratory. The center tests over 65 fish/load (95% confidence level) at a cost of $2/fish. In recent times approximately 56,000 grass carp have been imported/year or a total of about 50 loads. Despite these efforts however, diploid grass carp are being found in Illinois waters.

Illinois also imports other fish species (eg. channel catfish bullhead) to stock urban fishing ponds in Chicago. The state requires certification that the source of fish is disease free and the fish are free of toxic substances.

Research /Results Illinois has spent more than $750,000 in a six-year contract with the Illinois Natural History Survey (INHS) to evaluate the use of grass carp. INHS developed an elaborate model to predict stocking rates for a given water body, but it has not been useful for management due to its complexity. The model requires too much information to make it practical for private use.

Illinois is continuing to conduct studies as part of a multistate effort to evaluate the impact of grass carp in the aquatic environment. The study is in the fourth year with completion expected in two more years. The studies are considering stocking rates, changes in vegetation, fish species composition, zooplankton, water quality, and recreational fishing. The results are incomplete but their general impressions at this time are:

1. Vegetation control is an all or nothing proposition. A threshold is reached at a certain stocking rate and the change or eradication is rapid. There does not appear to be an intermediate stage.

2. Grass carp demonstrate definite food preferences. Plant types have a major influence on the feeding activity and effectiveness of the grass carp.

3. The type of pond has a major influence on the effectiveness of grass carp. The stocking rate that is effective in one pond may have poor results in another pond.

4. It may be impossible to predict the outcome for a specifi water body.

Their department is not yet convinced that grass carp are appropriate for the State. They have not initiated any state efforts to stock grass carp into state waters. The grass carp have been allowed in a limited number of private ponds where there is good control over the fish.

IOWA

Don Bonneau
Iowa Department of Natural Resources
Des Moines, Iowa
7-28-89

Policy Initially the state required a permit to stock grass carp in private waters. The private pond owner was required to submit an application to the department for evaluation and approval. The state found this to be a very time consuming activity and they found regulatory action to be very difficult. They also found it was not practical to limit introductions to triploid fish. Iowa now allows the importation of both diploid and triploid grass carp.

Research/Results Iowa has major weed problems. Herbicides have been used extensively, but chemical control is usually temporary and not very effective. The Iowa Department of Natural Resources has evaluated the effect of grass carp introductions on water quality and on existing fish populations.

Their studies indicate grass carp are effective in controlling shore line vegetation in some lakes without adverse impacts on the aquatic environment. Sport fishing has increased by as much as three-fold in some lakes where vegetation has been controlled.

Their biologists have introduced grass carp into various types of lakes. The results indicate the grass carp will probably not be successful in hypereutrophic lakes with poor fish habitat. In one very shallow waterbody, the grass carp removed rooted macrophytes but stimulated phytoplankton growth. Iowa has stocked their lakes at a rate of 10 fish/acre with 8 inch or larger fish; smaller fish are subject to predation. At this stocking rate, the vegetation is usually controlled within two years. If the lake is overstocked, the vegetation is eliminated, the fish starve and the vegetation returns.

Larry Mitzner
Iowa Conservation Commission
Des Moines, Iowa
7-31-89

Grass carp were an effective control agent for aquatic vegetation in a south central Iowa Lake (Mitzner 1978),. The 29 ha lake was stocked with grass carp in three successive years 1973, 1974 and 1976. Within two years, the grass carp had reduced the total vegetation biomass in sample plots from 2438 g/m in 1973 to 211 g/m in 1976; a 91% decrease in vegetation by weight. Nearly all plant material consumed was macrophytes with only traces of filamentous algae. Potamogeton, Najas, Ceratophyllum and Elodea were dominant plant groups. Grass carp showed preferences for each plant groups at least some of the time. All plant groups were controlled and they have not experienced any nuisances algae blooms following plant removal. The annual mortality rate of grass carp was estimated to be 33%. The study suggested supplemental stocking is necessary ever fifth year to maintain vegetation control. It has been more than 12 years since Red Haw Lake was stocked with grass carp and the lake continues to be void of vegetation today (Larry Mitzner,1989, personal communication). The successful reduction of shoreline vegetation resulted in a 241% increase in shoreline fishing (Mitzner, 1978).

Mitzner feels it is very difficult or impossible to provide site specific stocking rates for partial vegetation control. His experience indicates vegetation control with grass carp is an all or nothing proposition. In locations where the capture of grass carp is feasible, the partial removal of the introduced fish may allow for vegetation control without eradication.

Kentucky

Mr. "Doc" Williams

Policy Dealers must be registered with the state and are required to have a permit. Only triploid grass carp are permitted and dealers must have a certificate of ploidy. The dealers are being certified by the U.S. Fish and Wildlife Service. The dealers must maintain records of all sales.

The state initially required a permit for individuals to import and stock private waters. The permit required that a state biologist survey the pond to determine the size, vegetation type, and to estimate the stocking rate. The process was very time consuming and costly; the state now allows the pond owner to determine this information. Some problems occur when the pond owner does not properly identify the type of weeds or miscalculates the pond size.

The state initially recommended a stocking rate of 12 fish/acre, but they are now recommending 15/acre.

Research/results Kentucky biologists have introduced grass carp into state lakes using stocking rate of 24 fish/acre. The fish eradicated all vegetation and then starved. They have also found grass carp to be very sensitive to chlorine toxicity. Dealers have often experienced serious fish mortalities because they have failed to feed them adequately. Unlike many carnivorous species the herbivorous grass carp must eat frequently at temperatures above about 10-15 C.

MINNESOTA

Floyd Hennagir
Minnesota Department of Natural Resources
Minneapolis, Minnesota
8/4/89

Policy The state does not allow the use of grass carp for any purpose. They are adamant about keeping the fish out of the state. They have eradicated grass carp in ponds where they have been illegally introduced. Grass carp have been found in Minnesota in the Mississippi River.

He indicated a skepticism about the ability to verify the ploidy of large numbers of grass carp.

MICHIGAN

Gary Whelan,
Department of Natural Resources. Fisheries Division
East Lansing, Michigan
8/4/89

Policy Michigan does not allow the importation of grass carp. They have and will continue to eradicate any grass carp introduced into the state. The largest number of illegal introductions has been in ponds on golf courses.

New York

Ed Woltmann
Bureau of Fisheries, Department of Environmental Conservation
Albany, New York
7/17/89

Policy The state banned the diploid grass carp in 1969 and has allowed the use of triploid grass carp under an experimental use permit only. The state required the Bureau of Fisheries to prepare an environmental impact statement before they were allowed to introduce grass carp for research purposes (Woltmann E.F.,1986).

The state is developing a policy for using grass carp in private ponds. He predicts the state may be liberal with using grass carp in small closed pond and lake systems, but they will probably continue with a conservative experimental approach to the larger lake systems. Lakes of 80 to 100 acres might be permitted for experimental stocking but the state will probably require a lake association to monitor the results under an approved plan.

They have a concern about the triploid certification process. The state may require certification by their own personnel or by a contract laboratory.

Research/Results A four-year study of grass carp in experimental ponds on Long Island, New York was completed in 1988-89 (Woltmann and Goetke, (1989). Triploid grass carp (8-10 inches) were stocked in three kettle ponds at densities of 15, 25, and 40 fish/acre. Submergent vegetation was eliminated in all ponds, but most rapidly in the higher stocking density ponds. Floating vegetation (white water lily, Nymphaea odorata and water shield, Brasenia schreberi) was not controlled. They suggested that cool temperatures may have reduced the feeding activity; there was definitely a higher feeding rate in August when water temperatures were higher. Phytoplankton increased in the test ponds with the greatest increases evident in the pond with the highest stocking rate. The grass carp increased in size to 7 pounds in two growing seasons.

Woltmann questions the value of existing stocking models. He will recommend the use of incremental stocking to achieve partial vegetation control rather than attempting to predict a stocking rate.

The grass carp were hardy, surviving ice cover and very poor winter conditions which resulted from unusually low water levels in the experimental ponds

The final report concludes that sterile grass carp can be an extremely effective control of submergent aquatic vegetation and therefore, deserve consideration as a tool for aquatic plant management in New York ponds. The report suggests that negative impacts can occur if nonpreferred plant species increase due to selective feeding by grass carp and if grass carp quickly eradicate all vegetation.

OHIO

David Ross
Ohio Department of Natural Resources
Columbus, Ohio
7/28/89

<u>Policy</u> Approximately 10-12 years ago the introduction of grass carp in Ohio waters was illegal. About 1987, the state legalized the use of triploid grass carp. They had determined

there was considerable illegal traffic of diploid fish with much of it through air commerce. Their hope has been that legalization of triploids might displace the illegal diploid traffic, but they recognize that some diploids probably will continue to enter the state.

The restriction to triploid grass carp is probably not effective unless federal legislation is enacted. The Ohio fisheries department does not feel we know enough about the fish to decide that diploids should be banned. One factor influencing the state is the growing market for commerce of Asiatic carp as a food fish. The ethnic market has a high demand for grass carp, but only the diploid would be economical. Ohio does not have evidence that the diploid market should be shut down.

There is evidence that grass carp are established in southern rivers and some young-of-the-year grass carp have been found in the Ohio River. Ross feels it would be helpful to have discussions between adjoining states with consideration given to developing common regulations.

<u>Research/Results</u> The state has found the grass carp is very effective in removing rooted aquatic plants and green algae which are major problems in the state. There has been concern expressed about the potential effects of grass carp on waterfowl habitat. The state has considered this and determined it is not a likely problem because most Ohio waterfowl are on controlled management areas . It would be possible to counter the problem but it is highly unlikely that sufficient fish could accidentally enter one of these areas to cause an impact.

One area of special concern are the glacial potholes of Ohio in which there are endangered or threatened fish and plants. There is a high degree of concern to prevent the entry of grass carp into these water.

UTAH

Bill Bradwisch
Utah Department of Natural Resources
Salt Lake, Utah.
7/31/89

<u>Policy</u> The state had banned the importation/use of grass carp until 1988. They now recognize there is a use for the fish in private waters and possibly in public waters. However they have very strict requirements to prevent the introduction of diseases or parasites. They require that fish come from a certified disease free source and that grass carp are certified by the U.S. Fish and Wildlife Service to be triploids. The state has not found a certified disease free source and therefore grass carp have not been legally imported to Utah.

Dr. Tim Modde
Utah Cooperative Fish and Wildlife Research Unit
Utah State University
Logan, Utah
7/31/89

The state has removed some illegal introductions of grass car] from ponds on golf courses.

His previous experience in South Dakota indicated the grass carp may be very effective in one location and not in another. The larger water bodies are less predictable. He believes the grass

carp is less consistent in northern climates. The fish respond more slowly due to lower water temperatures and the vegetation growth in the spring is very rapid.

Washington

Paul Mongillo
Washington Department of Wildlife
Olympia, Washington
7-17-89

Policy The Department of Wildlife expects to complete a policy statement in early 1990 regarding the use of grass carp in private waters. Grass carp are presently illegal for use in Washington except for approved research projects. The state has eradicated fish in ponds illegally stocked with grass carp.

Research/results The state initiated studies of grass carp in 1983. The Washington Cooperative Fishery Unit working under contract with the Department of Wildlife has conducted a 5-year study to assess the effectiveness and the environmental impacts of using triploid grass carp to control nuisance aquatic vegetation in lakes and ponds. The goal of this research is to determine how to control, but not eliminate aquatic macrophytes in lakes in the Pacific Northwest (Pauley et al.,1985).

The university has completed 5-years research with most work in the laboratory and in small ponds (20 acre). The studies have addressed questions concerned with techniques for identification of triploid and diploid fish (Bonar et al. 1985), verification of triploid sterility (Pauley et al., 1985), feeding preferences (Bowers et al. 1987), efficacy of plant control by triploid grass carp (Pauley et al., 1988) and the effects of triploid grass carp on aquatic invertebrates, existing fish populations and waterfowl (Pauley et al., 1985). They have recently initiated field studies in small lakes located in both eastern and western Washington. In addition, they are testing the use of grass carp in Devil's Lake, a large coastal lake in western Oregon. The study will consider effects of grass carp on limnetic conditions, fish populations and waterfowl production.

Pauley (1989, personal communication) reports all results t the present time have been positive, but they have not yet developed an appropriate stocking rate to provide partial elimination of aquatic vegetation. They have not found negative impacts on the environment, but their results after only one season indicated the grass carp had failed to control nuisance vegetation in Devil's Lake, Oregon and in Keevies Lake, Washington (Pauley et al., 1988). In each instance the lakes were stocked at low densities to avoid plant eradication;the low stocking rates have allowed the grass carp to eradicate their preferred forage species with a subsequent expansion of other less palatable plant species.

Mongillio suggested that temperature may be a problem for using grass carp in Montana. Their results show grass carp feeding was reduced or ceased at 50-55° F. He also indicated the fish are very expensive, with costs at about $6.00/fish. The costs include extra funds used for ploidy verification and prophylatic treatment of parasites. Washington has imported grass carp in the 8-10 inch size.

Wyoming

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Policy The State Fish and Game Commission in July, 1989, adopted a proposal to permit the use of triploid grass carp in Wyoming. The fish were previously prohibited in the state. Wyoming has participated in an agreement with other states to prevent the introduction of grass carp to the Colorado River. Triploid grass carp may now be imported but only by special authorization from the Chief of the Fish Division.

Research/results Triploid grass carp have been introduced by the state into two different water bodies to evaluate their effectiveness in removing aquatic vegetation.

Renner Reservoir, a 72 acre water body is located at 4000 foo elevation near Lander, Wyoming. The reservoir has a heavy growth of aquatic plants consisting of 80% *Myriophyllum spicatum* and *Potamogeton pectinatus* and 20% Chara spp. and filamentous green algae. The goal of the research effort is to remove 75% of the vegetation cover to improve sport fishing and to improve the production of largemouth bass. The reservoir was stocked in July, 1987 with 1600 triploid grass carp. A sample of 81 fish measured at the time of stocking ranged from 9.2 to 11.9 inches in length. The stocking rate, 21 fish/acre, was based on the Colorado model developed by Swanson and Bergerson, 1988. Transects across the reservoir are being sampled on a periodic basis to measure changes in plant biomass and three exclosures have been placed into the reservoir to aid in evaluating the effectiveness of vegetation control. Although grass carp have been observed since they were stocked, there was no evidence that plants had been reduced by mid-July in 1988. Attempts to collect grass carp with trap nets, gill nets and electrofishing were unsuccessful except for a single specimen collected by electrofishing in June 1988. The fish had grown to 17.6 inches and approximately 3 pounds. Based on observations in mid-July 1989, the fish were approximately 7 pounds. (Contact- Donald Pedlar, Wyoming Game and Fish Department, Lander, Wyoming).

The second introduction of grass carp was in a lake near Laramie, Wyoming. No information on this introduction was obtained.

Alberta, Canada

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<u>Policy</u> Grass carp have not been introduced to Alberta except as allowed under a very carefully structured evaluation study initiated in 1988 by the Irrigation Council of Alberta. The study plan involves a 5-tiered review and decision model for evaluating proposed exotic fish introductions (Lloyd, 1988b). A Committee on Biological Control of Aquatic Vegetation has developed a 5-year study plan to evaluate the grass carp before making recommendations for its use in the province (Lloyd D.,1988a).

<u>Research/results</u> The study is a multi-agency effort involving the Department of Agriculture, Fish and Wildlife, Department of Environment, Irrigation District and Canada Agriculture. The study is intended to determine the efficacy and the potential impacts of introducing grass carp to Alberta.

In 1988, 5000 four-day old fry were imported and quarantined in a hatchery. A sample of ten fish are tested each month for disease including viruses and parasites and for ploidy. Tests are also being conducted to evaluate the influence of different diets and temperature regimes on growth (Lloyd, 1989).

In 1989 the fish(estimated to be 250 mm length)were stocked in shallow "dugouts" for further evaluation and growth. The fish will be moved to deeper ponds for the winter. Exclosures placed in the ponds have shown dramatic effects of vegetation removal (Lloyd 1989).

They plan to stock the fish in the Raymond Irrigation Project in southern Alberta, which is a closed system with no opportunity for the fish to escape to other waters. A prestocking evaluation of the irrigation system has been conducted to measure vegetation densities and to determine the presence of other fish species. The fish will be stocked in the irrigation canals in 1990 (Lloyd D., 1988b).

The Alberta plan appears to be the most carefully structured pre-introduction study of grass carp of any conducted in North America. The estimated cost of the entire project is $310,000 (Lloyd D., 1988a).

EVALUATION OF A PROPOSAL TO INTRODUCE GRASS CARP IN MONTANA

In January 1989, the U.S. Bureau of Reclamation proposed using grass carp to control aquatic vegetation in two sewage stabilization ponds located adjacent to the Big Horn River at Fort Smith Government Community in Big Horn County, Montana. The agency has requested the Montana Department of Fish, Wildlife and Parks to identify issues and concerns regarding this conceptual proposal.

Description of the site and the proposal The sewage stabilization ponds consist of one permanent pond designed for a population of 100 and a second, temporary pond designed for a population of 400. The design liquid depth of the ponds is 5 feet maximum and together the ponds have a surface area of approximately 4 acres.

The ponds are located northeast of the Fort Smith Government Community and upstream from Yellowtail Afterbay Dam on the right bank of the afterbay. An overflow pipe connects the stabilization ponds with the afterbay. The operation permit granted by the

Environmental Protection Agency requires the ponds to be operated with the overflow gate closed. Normally the ponds are drawn down once annually in October. A slidegate in the overflow pipe is closed and locked at all times to prevent backflows from the afterbay into the stabilization ponds. The ponds are enclosed within a locked, chain link fence to discourage human entry.

Each year the ponds develop dense growths of aquatic vegetation including coontail, _Ceratophyllum spp._, duckweed, _Lemna spp_ and _Wolffia spp._ and several species of filamentous algae. The ponds are treated with Diquat and Cutrine Plus, four to six times per season to control this problem vegetation. During the period from 1981 to 1983 the average annual cost of herbicide treatment has been $1879 (H.E. Hergenrider, personal communication 1989).

The dense growths of aquatic plants reduce the efficiency of the stabilization ponds. Odor problems also occur on an annual basis, but the facility has routinely met its wastewater discharge permit requirements with only minor exceptions.

The U.S. Bureau of Reclamation proposes to stock triploid grass carp in the sewage stabilization ponds to control the aquatic vegetation. Although the agency has not proposed any specific methods, this site would probably require 25 to 50 ten-inch fish per acre or a total of 100 to 200 fish to accomplish vegetation control. The agency proposes to construct screening devices to prevent the movement of fish out of the pond facility--especially when the pond is drained in the fall. The fish would be overwintered in the ponds if water quality conditions are suitable.

Evaluation of the proposal The proposed use of grass carp at the Fort Smith sewage stabilization ponds has several obvious potential advantages

1. The successful control of vegetation with grass carp woul

eliminate the need to apply toxic herbicides to an aquatic environment that eventually is discharged to the Bighorn River.

2. The proposed program provides an opportunity to obtain data on the efficacy of aquatic vegetation control by grass carp under Montana's climatic conditions.

3. The long-term costs of using grass carp may be much less than the costs associated with multiple, annual treatments with herbicides.

Despite these apparent advantages there are several factors that could affect the use of grass carp in this situation. First, the proposal assumes that water quality conditions in the sewage ponds are suitable for year around survival of the fish and for their active consumption of vegetation. It is possible, however, that dissolved oxygen concentrations in the ponds may occasionally drop to lethal levels especially during periods of prolonged ice cover. If such winter conditions required the annual removal and overwintering of grass carp in another facility, the economic benefits may be reduced or nonexistent. Second, we must assume the screen structures used to prevent loss of grass carp to the afterbay would guarantee that fish could not escape. Although screen devices are routinely used to hold fish in confined areas they are seldom, if ever, foolproof.

The Bighorn River is one of the most famous sport fisheries in Montana and the nation. The fishery attracts large numbers of fishermen who in turn contribute to the local economy. Any activity that has potential to damage this sport fishery is a major concern to fishery managers, sportsmen, and local businesses. The obvious concerns associated with introducing grass carp to the Fort Smith sewage ponds are:

1. Aquatic vegetation in the Bighorn River is critically important as habitat for fish and aquatic invertebrates. The

predominant plant species present in the river include Potomageton spp., Elodea sp., Chara sp., and filamentous green algae; these are plant species readily consumed by grass carp. If sufficient numbers of grass carp escaped from the sewage stabilization ponds into the river there is concern they could adversely impact the sport fishery by reducing the vegetation in parts of the river.

2. The Yellowstone and Missouri rivers in Montana appear to have habitat suitable for successful reproduction by grass carp. If diploid grass carp were accidentally introduced to the Bighorn River, it is possible a naturalized population could be established. A more detailed analysis of the available habitat would be required to verify this potential.

3. There is a potential to introduce a new disease or parasite with the introduction of an exotic fish. The introduction of a new disease in the Bighorn River could have devastating effects on the endemic fish fauna.

Each of these incidents are possible, but the probability of their occurrence is remote. First, the numbers of fish that would be required for use in the sewage ponds would not likely have a detectable impact on aquatic vegetation in the river environment. As the escaped fish consumed the preferred plant species they would most likely move to adjacent areas without having a noticeable impact on the vegetation standing crop. It is even more likely that the escaped fish would move downstream to seek warmer temperatures. Second, some diploid fish can be expected to occur in any lot of certified triploid grass carp due to sampling error and human error. The likelihood that diploid fish would be lost to the river and successfully reproduce in sufficient number to establish a naturalized population is very remote. However, if grass carp were eventually introduced into multiple locations in the Yellowstone-Missouri River drainage, the potential for introductions of diploid fish would be greatly increased. Finally, the disease factor can be addressed by requiring that fish are obtained from a certified disease free producer with subsequent careful testing and prophylactic treatment before they are imported. Although this would increase the costs of the fish it would greatly diminish the potential for introduction of a disease or parasite. It should be recognized however that disease and parasite introductions can occur regardless of precautions.

In conclusion, the introduction of grass carp into the sewage stabilization ponds at Fort Smith would probably not pose a significant hazard to the sport fishery or other aquatic resources of the Bighorn basin provided that adequate safeguards were provided. However, the proposal has implications far beyond this specific site. If allowed, it would set a precedent as the first official introduction of grass carp in Montana. The decision to permit the introduction of an exotic species into Montana waters must be based on a very careful evaluation of the need, the potential risks, and the potential benefits for the entire state.

Recommendation The proposal to introduce grass carp in sewage lagoons at Fort Smith, Montana should be postponed indefinitely. Although there appears to be a legitimate need for vegetation control at the Fort Smith sewage ponds, the need is clearly not sufficient to justify the introduction of an exotic fish into a new environment.

A comprehensive statewide environmental impact statement should be prepared to determine if there is a justification for the introduction of grass carp in the state. The decision to permit the introduction of grass carp in Montana waters should be based on a clearly demonstrated need in a significant part of the state.

DISCUSSION AND RECOMMENDATIONS

The use of grass carp to control aquatic vegetation has several potential advantages over the use of aquatic herbicides. In situations that have routinely required large amounts of herbicides, water resource managers have demonstrated that grass carp are less costly than herbicides for vegetation control. Under ideal conditions grass carp may survive and control vegetation for five to seven years before restocking is necessary. The eradication of rooted aquatic vegetation with herbicides frequently results in heavy growths of phytoplankton due to the sudden release of nutrients contained in the decomposing plants; eradication of rooted aquatic plants by grass carp releases the nutrients more slowly with less likelihood for nuisance algae to occur. Finally the use of grass carp in place of herbicides reduces the potential for damage by toxic chemicals in the aquatic environment.

Aquatic vegetation is not a major problem in Montana, but excessive aquatic weed growth does cause problems in some irrigation systems and in some shallow lakes.The most important potential use of grass carp in Montana would probably be for control of aquatic vegetation in irrigation canals. Although some research has shown grass carp can be effective for vegetation control in canals, other results were negative. Canals present special problems, including the problem of the fish moving downstream and failing to control vetetation in upper reaches. Special barriers and drop structures would probably be necessary to restrict the fish to the areas requiring vegetation control. The fish would also require suitable areas for overwintering. Finally, the use of grass carp in flowing waters greatly increases the potential for escape and distribution within the drainage. Some western states do not allow the use of grass carp except where it can be demonstrated that the fish cannot enter natural waterways due to natural or manmade barriers.

The large river basins of Montana, including the Yellowstone, Missouri, and Clark Fork rivers have conditions that appear to be suitable for the successful reproduction of grass carp. It is not known however, if conditions are suitable for growth and sexual maturation which is dependent in part on adequate food supplies. Montana is clearly at the margin of suitable climatic conditions for grass carp. Although it appears the grass carp could live and reproduce in Montana waters, seasonal water temperatures would probably limit their growth and effectiveness in many locations.

A decision to permit the use of triploid grass carp in Montana would result in new costs to the state to provide for regulation and disease control. The state would need to acquire the capability to determine the ploidy of fish either directly by purchase of the necessary instrumentation or indirectly through contractual arrangements. Other states have found such regulatory activity is costly, time consuming, and ineffective.

RECOMMENDATIONS

1. The grass carp should not be introduced into Montana unless the following conditions are met:
   - A. There is a clearly defined need that is justified on the basis of both significant environmental improvement and reduced costs.
   - B. There is convincing evidence that grass carp would be an effective vegetation control agent for selected sites.
   - C. The fish is imported from a certified disease-free source and absolutely guaranteed to be sterile.
   - D. The fish will be used only in waters that are not connected to an open water body. Screening will not prevent fish from escaping to open waters.

E. A thorough analysis of the proposed introduction indicate: the grass carp would not have adverse ecological effects i: Montana.

F. The fish must have potential benefits for a large portion of the state and not be limited to a small local area.

G. There is agreement by immediate downstream states that th introduction is not a potential threat to their resources

2. Montana should postpone consideration of any introduction of grass carp until the results of studies in other western locations are completed and evaluated. The studies currently underway in Alberta,and Washington and Wyoming should provide additional useful information for the Rocky Mountain and northern plains region.

3. Any exotic fish introduction in Montana should be evaluated according to the protocol suggested by Kohler and Stanley (1984) and discussed by Kohler and Courtenay, (1986). The apparent successful use of grass carp in other locations around the world is encouraging, but we do not yet have sufficient knowledge about the fish to be certain that its use will not have long-term detrimental effects. Therefore, the introduction of the triploid grass carp in Montana should not occur unless there is very significant need and a careful evaluation indicates a very low potential for harm to other aquatic resources..

4. Montana should urge the American Fisheries Society to develop and adopt a national policy on the use and distribution of grass carp in North America.

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