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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

Prepared for: Montana Department of Fish, Wildlife and Parks

Prepared by
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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.
lower water temperatures. If vegetation is rapidly established, higher stocking densities are required to control vegetation at temperatures much below 10°C. Although feeding activity begins at 9°C, active feeding and factor affecting the success of vegetation control by grass carp. Water temperature is probably the most important environmental factor. Specifics of submerged aquatic plants including interments and suitable environment, the trophic grass carp will reach most aquatic vegetation. When stocked at appropriate densities and controlled to the desired grass crop, in their ability to consume and control vegetation control is an effective method research has shown the grass carp to be an effective parameter. added safeguard against an inadvertent introduction of disease or soybean cyst nematodes reduce the importance of that source, thus reducing the risk of grass carp that was introduced to Europe and North America from the Far East. Some states require local to be imported grass carp, which have been a source of both, the Asian parasite, grass carp have been a source of both, the Asian

Despite efforts to screen imported fish for disease and that diploid grass may be introduced, the number of fish introduced into an area is greater than the number of fish introduced. Clearly, the greater the size of the fish, the greater the risk of introducing a large number of fish. The U.S. Fish and Wildlife Service to verify the possibility that a strain of fish might include diploid grass carp. The possibility that a strain of fish might include diploid grass carp.
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 to 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.
adapted by the American Fisheries Society. According to the protocol for the introduction of exotic species as advocated by an Environmental Impact Statement and a very thorough evaluation can be demonstrated. Any proposed introduction should be supported and recommended unless a very significant need and benefit for the state is anticipated. It is recommended that grass carp should not be introduced in Montana. Grass carp have most of the attributes necessary to sustain a reproducing population. Grass carp is capable of surviving and growing in Montana.
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.
Big Horn River drainage.

carp to control vegetation in a sewage lagoon at a location in the
special attention given to an evaluation of a proposal to use grass
for using grass carp to control aquatic vegetation in Montana, with

The initial sections of the report are focused on the potential

research on the use of grass carp.

review of regulatory policies and the design or results of
Canadian provinces described in the following section including a

The status of grass carp in other northern states and one

environment

and the effect on other fish populations and the aquatic

While it is followed by a description of the grass carp's food habits
that fish are transported before they are transported to a purchaser.

Procedures used by the U.S. Fish and Wildlife Service to certify

section follows the basic

This section also describes the basic

The report begins with a brief summary of background and

describing various attempts to develop sterile grass carp including

descriptive information about grass carp followed by a section
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, *Hypophthalmichthys nobilis*, silver carp, *Hypophthalmichthys molitrix* 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
clusters were in May through August.

Grasses can in many parts of the world most occurrences in temperature
summarized literature reports on the time of sexual maturation for

different in tropical areas, Shierman and Smith, 1983), have

occurs over a longer season to less

in temperature clusters, but occurs over a longer period of time, which was

by Shierman and Smith, 1983). The growing season in wet-deciduous

temperature and photoperiod (Hessen, 1973) cited by Shierman and Smith, 1983.

temperature conditions in December and January by activity increase solar

water and photoperiod. Spawning can be induced under laboratory

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that

a year, size in tropical clusters. There is evidence that

(Schierman & Smith, 1983). Maturation of clusters at an earlier age and at

weture an average of one year earlier at lengths of 60 to 60 cm

and at standard lengths of 60 to 60 cm for females. More fish

Reproduction - Sexual maturation occurs at ages 1 to 2 years.

were 0.41 and 0.22 ppm respectively.

Lethal minimum dissolved oxygen for accounted 11 ppm and 14 ppm

reported the mean (ppm) (Oppuzynski, 1967). Several workers have

reported various dissolved oxygen concentrations as low as 1.0 ppm.

C. upper mean lethal maximum temperature of 41 C has

been reported by Oppuzynski (1967).

The optimal temperature for normal development of 49 to 51

The optimal temperature for normal development of 49 to 51

3C with poor survival at temperatures lower than 18 C. FiV.

the natural environment,

range of dissolved oxygen and pH and associated parameters in this

These grass carp must encounter a wide

beaver vegetated areas. The grass carp must encounter a wide

Shierman and Smith, 1983.

northern range (Hessen, 1973) cited by Shierman and Smith, 1983).

condition. Ice cover occurs from October to March in areas of this

condition.
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 (Nitzner, 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 approximately 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.
Tetraploid induction

New technology has led to the induction of

Barlowy and Rocke, 1986; Attew and Weke, 1986; and others.

Tetraploid barley with diploid and triploid F1 hybrid has shown the hybrid to be

of interest in grass carp. Although the production of

however, induced hybrid larvae were only about 62% triploid and

called by Alston and Westendorf, 1987), later tests by others.

Intera-specific crosses between the grass carp (female) and the triploid

Conducting this effort has been devoted to evaluating the

Underwood et al., 1966.

attempted but failed due to the rapid regeneration of the gonads

could lead to reproduction. Surplus gonadectomized were also

ectodermal introduction of a male into an all-female population

although these

creating monosexual populations through gynogenesis (Sternay, 1976)

Monosexual and hybrid flash. Initial efforts were focused on

has been made in producing functionally sterile fish.

progress

potential impact of introduced grass carp on the environment. Most

Aquatic resource managers have expressed concern about the

Tetraploid grass carp
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.

Sources of Certified Triploid Fish. 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
The U.S. fish and wildlife service also conducts tests to examine and treat fish for the occurrence of rotenone. The procedure requires holding

the fish in clean water for 72 hours to allow the fish to purge the

rinch for 72 hours in a nutrient-rich solution and then holding

the rotenone concentration of arotrope prior to the

examination and treat fish for the occurrence of rotenone. The

procedure is conducted by the

producer. The procedure usually requires a sample of 120 fish

from a lead of 1000 or more. At times the sample may serve to

purchase a lead of fish which is then subjected among several

procedures. The vermiculite procedure is considered to be very good

experimental station, suitably. Arizes personal communication

problem with a particular lot of fish (another Mitchell, Fisch, Farm

duction in a lot of 1000 is unacceptable and to evidence of a
diploid in a lot of 1000 is not unexpected, but the occurrence of 10
fish in a lot of 1000 is not unexpected, but the occurrence of these diploid

diploids with 79% accuracy. The occurrence of these diploid

diploid is expected to identify

All producers occasionally find diploid fish during the

laboratory before they are accepted for introduction.

Additional vermiculite of the transported fish by a state

either the producer or the recipient. Some states require

the fish are usually transported by a dealer who is hired by

the state officials both by telephone and by mail.

The inspection is completed and the vermiculite information is

whose diploid is shown to be triploid, the

diploid fish is found, the inspection is stopped and a new lot of

to the cellular or nuclear size in comparison with diploid fish. If a

Vermiculite is passed through the counter counter to measure

each sample from each

purchase.

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to the cellular or nuclear size in comparison with diploid fish. If a

Vermiculite is passed through the counter counter to measure

each sample from each

purchase.
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 spermatozoa (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).
...
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
optimize their energy gains with foods they can consume most easily gathered and chewed. It is suggested that hermit crabs
selected on the basis of handling time; t.e., those plants most
preferred. The authors hypothesized that plants are probably
not correlated with carboxyl content, percent
water or percent nitrogen (index of protein) of the various
plants. The results further indicated that neither preference
showed the preferred species were those that could be consumed most
associated with the most preferred species. The study
showed that general pattern held with the highest rate of consumption
some general pattern held with the highest rate of the scale, the order
often chosen exclusively. At the low end of the scale, the order
consumed less food per day than grass carp. The food preference
preferences of the grass carp and hybrid were similar but hybrids
Food with water temperatures ranging between 23 and 24 C.
Food

The least were conducted in a controlled laboratory environment
grass carp x male bighead carp, Hypophthalmichys nobilis, Rich.
rate and plant preference in the grass carp and a hybrid (female
Miley et al. (1986) examined the relation between feeding

another location.

low preference plant in one location may be readily consumed at
site specificity and dependent on other environmental conditions. A
The research has clearly shown that preference can be very
determined by several investigators working in northern California.

It is seen that aquatic plants according to preference ranking
all species with all plants are ranked. Table 2 provides a
are avoided, but where food is limited the grass carp may consume
Table 1. Plant species preferred by grass carp as determined by studies in northern states.

<table>
<thead>
<tr>
<th></th>
<th>High</th>
<th>Medium</th>
<th>Low</th>
</tr>
</thead>
<tbody>
<tr>
<td>Najas guadalupensis</td>
<td></td>
<td>Potamogeton pectinatus</td>
<td>Myriophyllum spicatum</td>
</tr>
<tr>
<td>Chara sp.</td>
<td></td>
<td></td>
<td>Ceratophyllum demersum</td>
</tr>
</tbody>
</table>

Harberg and Modde, 1985. SOUTH DAKOTA

| Ceratophyllum demersum          | Eleocharis sp.          | Claodophora sp., Spirogyra sp.                  |
| Chara sp.                      | Potamogeton sp.         | Myriophyllum exalbescens                       |
| Elodea canadensis              | Potamogeton pectinatus  | Nuphar luteum                                  |
| Lemna sp.                      | Potamogeton richardsonii| Polygonum amphibium                           |
| Najas guadalupensis            | Ruppia maritima         | Potamogeton crispus                            |
| Nitella sp.                    | Zanichellia palustris   | Potamogeton praelongus                         |
| Potamogeton pusillus           |                       | Ranunculus sp.                                 |
|                               |                       | Utricularia sp.                                |

Swanson and Bergerson, 1988. COLORADO

| Potamogeton crispus             | Myriophyllum spicatum  | Potamogeton natans                            |
| Potamogeton pectinatus          | Ceratophyllum demersum | Brasenia schreberi                            |
| Potamogeton zosteriformes       | Utricularia vulgaris   | Elodea densa                                  |
| Elodea canadensis              |                       |                                                 |
| Vallisneria sp.                |                       |                                                 |

Bowers, Pauley and Thomas, 1987. WASHINGTON

| Najas flexilis                 | Potamogeton crispus    | Brasenia schreberi                            |
| Najas minor                   | Potamogeton pectinatus | Myriophyllum spp.                             |
| Chara sp.                     | Potamogeton foliosus   | Ceratophyllum demersum                        |
| Nitella sp.                   | Elodea canadensis      | Ranunculus sp.                                |
| Najas guadalupensis           | Zanichellia palustris  | Polygonum fluitans                            |

Wiley, Tazik, and Sobaski, 1987. ILLINOIS
consumption rate, metabolic rate and assimilation efficiency as

The primary factors known to directly affect food consumption are

Food, body size and temperature. Food, body size and temperature are

important consideration in their role as a photosynthetic control

that grass carp consume plant material in an

Troy P.C. Whybark (1966) conducted a detailed study

Food Consumption and Growth. The grass carp is a voracious

aquatic plants but the order of preference did not change.

During the summer, the grass carp utilized a greater variety of

highly preferred plant species. As water temperature increased

mean water temperature of 90°C or less, the fish ate only a few

much more selective in their feeding at colder temperatures. At a

selection of plants for food. Edwards (1974) found grass carp were

Temperature is also an important factor influencing the

these plants.

these same fish at 50°C weight at considerable quantities of

not feed on several plant species offered during feeding trials but

grass carp. Edwards (1974) reported that fish weighing 1 g would

size also influence the species of plants consumed by the

by grass carp than nutrient content quantity of the plants.
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 rate of energy as a percentage of energy consumed. (From Wiley and Wike, 1986).

<table>
<thead>
<tr>
<th>Genetic type</th>
<th>Metabolism</th>
<th>Excreted</th>
<th>Growth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diploid and Triploid</td>
<td>12-13%</td>
<td>74%</td>
<td>13-14%</td>
</tr>
<tr>
<td>Hybrid</td>
<td>16%</td>
<td>81%</td>
<td>3%</td>
</tr>
</tbody>
</table>

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
denitrification of 125 kg/ha to achieve 50% reduction in vegetation
water body. For example, English workers have proposed stocking
proposed stocking rates were estimates based on surface area of the
instances very little predating data were available and the
workers based on results from experimental introductions. In most
carp stocking rates have been proposed by various
vegetation control may be more desirable than eradication.
Invertebrates and waterfowl. In these instances, partial
treatment was less hazardous and a good food for fish, aquatic
during a short time period. In other waters, aquatic plants may be
destroyed in some water bodies, especially if it occurs
evidence, however, that total eradication of aquatic plants can
aesthetic purposes in other small ponds or lakes. There is
irrigation and drainage canals, in ponds on golf courses and for
of aquatic plants may be desirable in some systems. For example in
and efficient means of eradicating aquatic vegetation. Predation
It is generally recognized that grass carp are an effective

STOCKING RATES

were eliminated.
were not utilized until after palatable plants in shallow waters
the feeding sites occurred first and plants in deeper coider water
available. Active selection of the most palatable plants within
probably the best oxygenated feeding sites where plants were
are temperature dependent with rich selection the warmest and

Temperature Mitchell (1980) reported grass carp feeding rates

kg, 25% (Clugston and Strickland 1987).
9 kg of their body weight per day; 2.7-5.9 kg fish, 75% and more than 5.9
kg consume up to 100%
(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 of 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
evaporation and DWI lower than 400 probably preclude the use of grass
Dwlg to 204 C. They suggest that takes above 2996 meters
consumed aquatic plants in lakes at evaporation of 2500 meters and
stocking rates. Their study indicated grass carp effectively
mean daily temperatures above 22.4 C as one measure to determine

the model uses daily temperature units (DD) - the cumulative

and the density of the fish
to the lake management objectives, the size of the fish to be stocked
stocking rate. The base rate is then adjusted as needed according
activity or disturbance are factors used to establish a base
aquatic plants, peracteer plant species and the degree of human
aquatic plants, peracteer plant species and the degree of human
successful control of vegetation. Measures of estuaries of water
factors influencing stocking densities and the length of


Swanson and Berge (1986) have developed a simple stocking

perceptable plant species.
the northern climatic region and for ponds with the least
the climatic region. Highest stocking rates are recommended for
stocking after 5 to 7 years depending on the vegetation type and
the model recommends a 10 year stocking schedule with a second


The model recommends a 10 year stocking schedule with a second

climatic zones (temperature) of the state, specific plant species
the ITN data stocking model is adjusted according to

stocking at a rate of 8-15 ha at evaporation of 1849 to 2548 meters above
six takes of 0.8-15 ha at evaporation of 1849 to 2548 meters above


various other workers have also reported that moderate

As the water quality and phytoplankton population


1984). Various other workers have also reported that moderate

environmental zone will cause harm to sport fisheries (Miller, et al.
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 are 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 control 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
Coldwater lakes stocking models is given in Table 3.

A comparison of the attributes of the ITTO's and the

the suggested level for lake management objectives. The

carp are not recommended at the vegetation density is set or below

carp are conservative to avoid the need for grass carp removal. Grass

water table of plant levels. The recommended stocking levels

whether instances it may be desirable to reduce grass carp numbers to

control may be required to achieve control in some locations. In

the model and the need to carefully monitor and adjust stocking

asperation (1988) recognize the limitations of

their lower rate of food consumption.

The recommended rate is recommended for triploid trout to compensate for

stocking rates are developed for diploid trout, a 10% higher

cooler water takes model was developed because the

several researchers have shown triploid grass carp consume

unknown, but restocking is recommended after 5 to 6 years.

vegetation control by the third season. Control longevity is

larger than 51 cm by 2 years. The model is designed to result in

larger carp, 36-51 cm, may reduce control time by a year and thus

dependent on the size of carp stocked as well as the stocking rate.

the time required to achieve vegetation control is

vegetation control and they are less susceptible to disease and

the larger fish are harvested because

model is designed to use 20-28 cm fish which is the size

or aesthetically, 0-10% vegetation is recommended.
In the Pacific northwest, the Washington Cooperative Fisherie: 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
seasonal fluctuations in plant densities.

result of preferential feeding by grass carp and possibly natural
percentage of different species. The changes appeared to be a
the macrophyte density actually increased with a shift in relative
indicate the stocking rate was probably low (Beatty et al., 1988).

The results of this experimental stocking after two years,

vegetation eradication (Boatman et al., 1997).
uncertainty of the estimation procedure and their desire to avoid
the lowest stocking rate was used due to the
stocking model estimated 56.78 ha / 3000 ICHON would be required to achieve
fish to stock this 2.45 ha lake. As a comparison, the 1777
of 36.340 fish, a mid-value of 31.860 and a low-value of 27.900
Table 3. Attributes of models used to estimate stocking rates for grass carp.

<table>
<thead>
<tr>
<th>Coldwater Lakes Model (Swanson and Bergerson 1988)</th>
<th>Illinois Natural History Survey Model. (Wiley and Gordon, 1984)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Attributes</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Temperature</strong></td>
<td></td>
</tr>
<tr>
<td>Based on elevation and daily--Based on the states climatic</td>
<td>Based on the states climatic regions</td>
</tr>
<tr>
<td>temperature units (DTU)</td>
<td></td>
</tr>
<tr>
<td><strong>Vegetation Preference</strong></td>
<td></td>
</tr>
<tr>
<td>Ranked as High, Moderate, Low--Five categories grouped by</td>
<td>species.</td>
</tr>
<tr>
<td>Categories</td>
<td></td>
</tr>
<tr>
<td><strong>Vegetation Quantity</strong></td>
<td>Percentage distribution and percentage of lake less than 8 foot deep.</td>
</tr>
<tr>
<td><strong>Management Objectives</strong></td>
<td>Designed for target level of 40% plant cover.</td>
</tr>
<tr>
<td>Four levels of control:</td>
<td></td>
</tr>
<tr>
<td>0-10%, 10-15%, 15-25% and 20-25% plant cover.</td>
<td></td>
</tr>
<tr>
<td><strong>Fish Size</strong></td>
<td>Based on 25.4 cm fish.</td>
</tr>
<tr>
<td>Based on 20-28 cm fish with smaller sizes.</td>
<td></td>
</tr>
<tr>
<td>Adjustments for site specific disturbances.</td>
<td>Adjustments recommended for site specific variables.</td>
</tr>
<tr>
<td><strong>Site Specific Variables</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Stocking strategy</strong></td>
<td>Stocking recommended at 5 7 year interval. Frequency and numbers of fish depend on climatic region.</td>
</tr>
<tr>
<td>Supplemental stocking may be required after 5-6 years to compensate for mortality.</td>
<td></td>
</tr>
</tbody>
</table>
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 (Bord 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 Prouse (1971) suggested that consumption of aquatic plants and the decomposition of fecal matter may enhance the production of phytoplankton. However, Lebre et al. (1978) believed that water quality changes in small test vessels were not representative of conditions expected under field conditions where macroinvertebrates, macrophytes, and macroalgae 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 chlorophyll 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 allochthonous 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 allochthonous 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
trend production. As the weeds decimated there was an increase
in trout production. A small outbreak of lake in New Zealand indirectly affected rainbow

1978) concluded that vegetation removal by grass carp in

the success of grass carp in some instances (Beaver, 1968; Shriver, 1978) the

heavy predation on grass carp interacts with vegetation removal by grass

The nearly complete removal of submerged vegetation by grass

introduced agast the effects of macrophyte loss.

foreages typical are available as submersible forage, the bass may be

centered. They suggested, however, that situations where predation

several growing seasons will result in major reductions in

at 1968) suggested a major suppression of aquatic macrophytes over

unknown from these studies but the use of their model (Meffe et

authors of this report acknowledged that long-term impacts were

increased predation with the reduction of plant cover. The
centrations decreased in ponds stocked with grass carp probably due

to increased predation with the reduction of plant cover. The

values of the young-of-the-year recruitment of

improved condition may have been a temporary response to a higher

fish from the high stocking density ponds. The author suggested the

varied by more than 20X. Increased condition factors were found in

intermediate levels of plant cover. The young-of-the-year bass

the highest production of productive bass was in ponds with

in the low-density ponds and decreased in the high density ponds.

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.

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
piscivorous birds which contributed to trout mortality. At the same time the rudd (*Scardinius erythrophthalmus*) 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.
Peaters are required to have an import permit. Regulations recognize the fish are being imported regardless of the state. Only trout and carps are permitted on the west side. They are allowed to release the grass carp east of the continental divide but only for stocking note that the state does not allow for stocking by the state. The required to fill the post-stocking notification with the state. The directed to purchase the grass carp but they are required to fill the post-stocking notification with the state. The state determined the process was too time consuming and expensive. Permit for the introduction of grass carp. After 5 years, the state required introductions to obtain a permit.

Policy

July 29, 1989
Denver, Colorado
Division of Wildlife
Robin Knox

Colorado

is given for each state and province. (2) contacted, their organization and the date of contact, national organization from other states and one Canadian province. The information obtained from 12 states and one Canadian province. The following is a summary of their state. The results of any introductions of grass carp are required to report information about their state’s contact. (3) contacted by telephone to request information. An important objective of this report was to assess the

SURVEY OF GRASS CARP USE IN OTHER LOCATIONS
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.
control of two contiguous agee.
transport the trash. The purpose of the planned introduction is to
teach deer located at Duck, Idaho with atypical objection and
a small community south of Sandpoint. Leo Ray, a
carp but they have authorized the use of grass carp for vegetation
Research/Results Idaho do not conducting research with grass
deratation.
certain the trash do not have access to open water. Approaches are
they have approved at least two introductions where they are

Code
Director (of the Department) pursuant to authority under Idaho
released would be allowed only with written permission of the
are screened to prevent the escape of trash, such introduction and
(2) their release in waters having no outlet or outlets which
have been certified sterile by the U. S. Fish and Wildlife Service.
Policy to allow (1) the introduction of triffical grass carp which
Policy. In 1966, the Idaho Fish and Game Commission approved a

7/18/69
COUNTY: Kootenai, Idaho,
Idaho Department of Fish and Game
BRIAN HORTON
IDaho
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
good control over the fish.

been approved in a limited number of private ponds where there is

efforts to stock grass carp into state waters. The grass carp have

appropriate for the State. They have not interacted any state

Their department is not yet convinced that grass carp are

water body.

1. It may be impossible to predict the outcome for a specific

in one pond may have poor results in another pond.

effectiveness of grass carp. The stocking rate that is effective

3. The type of pond has a major influence on the

effectiveness of the grass carp.

Types have a major influence on the feeding activity and

2. Grass carp demonstrate definite food preferences. Plant

stages

egradation is rapid. These do not appear to be an intermediate

threshold is reached at a certain stocking rate and the change or

vegetation control is an all or nothing proposition. A

vegetation is general impression at this time are:

suppression, water quality, and recreational fishing. The results

stocking rates, changes in vegetation, fish species composition,

competition expected in two more years. The studies are considering

agricultural environment. The study is in the fourth year with

make efforts to evaluate the impact of grass carp in the

Trends are continuing to conduct studies as part of a

requires too much information to make it practical for private use.

not been used for management due to its complexity. The model

model to predict stocking rates for a given water body, but it has
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 type 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
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.
Introduction has been to ponds on golf courses. The number of illegal carp introduced into the state. The target number of illegal carp they have been continuing to eradicate any grass carp. They have and will continue to eradicate any grass carp. Michigan does not allow the importation of grass carp. Michigan does not allow the importation of grass carp.

6/4/89
East Lansing, Michigan
Department of Natural Resources. Floyd Hemmart

MICHIGAN

Gerry Wheilen.

MICHIGAN

The state does not allow the use of grass carp for any purpose. They are detrimental to keeping the fish out of the state. Invertebrate. Floyd Hemmart.

MINNESOTA

Minnesota, Department of Natural Resources.

Floyd Hemmart.
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.
Leggized the use of triploid grass carp. They had determined
grass carp in Ohio waters was Leggized. About 1987, the state

672/89
Column 3, Ohio
Ohio Department of Natural Resources
David Ross

OHIO

IMO

vegetation.

selective feeding by grass carp and it grass carp quickly eradicate
impacts can occur at unprotected plant species increase due to
management in New York ponds. The report suggests that negative
therefore, degree consideration as a tool for aquatic plant
extremely effective control of submergent aquatic vegetation and
the laboratory report concludes that sterile grass carp can be an
experimetal ponds

where conditions which resulted from unusually low water levels in
The grass carp were hardy, establishing the cover and very poor
rate.

vegetation control rather than attempting to predict a stockage
vegetation control will recommend the use of incremental stockage to achieve partial
Wollman questions the value of existing stockage modes. He
pounds in two growing seasons.

highest stockage rate, the grass carp increased in size to
pounds with the greatest increases evident in the pond with the
temperature were higher. Phytoplankton increased in the test
was determined a higher feeding rate in August when water
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.

Research/Results 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
larger water bodies are less predictable. He believes the grass
carp may be very effective in one location and not in another. The
This previous experience in South Dakota indicated the grass
from ponds on golf courses.
The state has removed some illegal introductions of grass carp

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

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

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

Utah
The university has completed 5-year research with most work.

Results/Impacts

Research/Results: The state initiated studies of grass carp.

Research conducted trash in ponds to eliminate stocked with grass carp. The state has Washington except for approved research projects. Grass carp are presently utilized for use in private waters. Grass carp in early 1990 regarding the use of grass carp in policy statement. The Department of Wildlife expects to complete a

Policy: The Department of Wildlife expects to complete a

7-17-89

Draft, Washington Department of Wildlife

Paul Hoogfall

Washington
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 to 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.

Hongillio 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 prophylactic treatment of parasites. Washington has imported grass carp in the 8-10 inch size.
researchers to aid in evaluating the effectiveness of vegetation in plant stems and three exclosures have been placed into the reservoirs being sampled on a periodic basis to measure changes

developed by Swanson and Peterson, 1986. Transects across the stocking rate, 51/acre, was based on the Colorado model
at the time of stocking ranged from 9.2 to 11.9 inches in length. 1987 with 1600 tryploid grass carp. A sample of 61 fish measured
production of largemouth bass. The reservoir was stocked in July.

vegetation cover to improve sport fishing and to improve the aquatic plants consisting of 60% alternanthera and

the goal of the research effort is to remove 75% of the vegetation near Lander. Wyoming. The reservoir has a heavy growth
Remer Reservoir, a 72 acre water body is located at 4000 feet

vegetation in removin g aquatic vegetation.

the state into two different water bodies to evaluate their

Research/Results - Tryploid grass carp have been introduced by

authorization from the chair of the Fish Division.

Tryploid grass carp may now be imported but only by special

prevent the introduction of grass carp to the Colorado River.

Wyoming has participated in an agreement with other states to

Wyoming. The fish were previously prohibited in the state. adopted the proposal to permit the use of tryploid grass carp in


7/18/89

Cheyenne, Wyoming

Wyoming Game and Fish Department

Mike Stone
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.
Ponds have shown dramatic effects of vegetation removal (Lloyd, 1989). To move to deeper ponds for the winter, exclosures placed in the shallows developed for further evaluation and growth. The fish will die in 1989 the fish estimated to be 250 mm length were stocked in

and temperature regimes on growth on growth (Lloyd, 1989). The study also been conducted to evaluate the influence of different dates of disease including viruses and parasites and for product. Tests are done each month for in a hatchery. A sample of ten fish were tested each month for the potential impact of introducing grass carp to Alberta. The study is intended to determine the effectiveness and Department of Environment, Irrigation, District and Canada. Investigating the Department of Agriculture, Fish and Wildlife, the study is a multi-agency effort for the use in the province (Lloyd, 1988a).

The study plan to evaluate the grass carp before making recommendations proposed exotic fish introductions (Lloyd, 1986b). A committee on aquatic control of aquatic vegetation has developed a 5-year plan to introduce exotic fish into Alberta. The study was initiated in 1988 by the Irrigation Council of Alberta. The study is allowed under a very carefully structured evaluation study protocol. Grass carp have not been introduced to Alberta except

7/26/89

Lethbridge, Alberta

Agricultural Research Center

Duncan Lloyd

Alberta, Canada
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
The successful control of vegetation with grass carp would
potentially enhance the rate at which stormwater stabilization ponds have several advantages.

Evaluation of the Proposed

The proposed use of grass carp overwintered in the ponds is also desired, in the fall. The fish would be
prevented the movement of trash out of the pond as well as constituting some degree of
drainage. The agency proposed to construct screens to protect
beavers, but the facility has not been used, and the wastewater discharge
the dense growths of aquatic plants reduce the efficiency of

has been $187,975 (H. E. Hertzfelder, personal communication 1989).

From 1981 to 1983, the average annual cost of herbicide treatment
per season to control this problem vegetation increased from $75 to $90
ponds are treated with diquat and cutting these grows to a
species of Cyperus spp. and several species of Typha spp. The
vegetation introduced contains, Cyperophyllum spp., duckweed, Lemma
Each year the ponds develop dense growths of aquatic

within a locked, chain link fence to discourage human activity.

After the stabilization ponds, the ponds are enclosed
closed and locked at all times to prevent backflows from the

Environmental Protection Agency requires the ponds to be operated

The U.S. Bureau of Reclamation proposes to stock triploid
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
Finally, the disease factor can be addressed by requiring that introductions of diploid fish would be greatly increased. The yellowstone-historic River drainages, the potential for grass carp were eventually introduced into multiple locations in the Yellowstone River system, a naturalized population is very remote. However, it is essential that a naturalized population reproduce in sufficient number to sustain the river and successful reproduction in different number would be expected to occur. Any lot or certified, triploid grass carp due to sampling error and human error. The triploid fish that diploid fish would move downstream to seek warmer temperatures. Second, some diploid fish can be expected to not have detectable impact on the vegetation standing crop. It is even more likely that the triploid fish would not likely have a noticeable impact on the vegetation standing crop. First, the numbers of fish that would occur in any of these incidences are possible, but the probability of effects on the endemic fish fauna of a new disease in the Big Horn River could have devastating parasite with the introduction of an exotic fish, the introductress of a potential to introduce a new disease of the endemic fish fauna would be required to verify this potential.

A more detailed analysis of the available habitat establishment a more detailed analysis of the available habitat could be possible, a naturalized population could be established to the Big Horn River. It is possible that a naturalized population introduced to the Big Horn River faun would thus require species that would be suitable for successful reproduction by grass carp. The Yellowstone and Yellowstone River stonefishes in Montana appear to sport fishery by reducing the vegetation in the river. The diploid grass carp escaped from the sewage stabilization ponds significant plant species present in the river include Ptda, Hues sp., Chara sp., Chara sp., and the numerous green algae; these are predominant plant species present in the river include Ptda
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.
can be demonstrated that the fish cannot enter natural waterways
western states do not allow the use of grass carp except where it
potential for escape and distribution within the drainage. Some
the use of grass carp in flooding water greatly increases the
fish would also require suitable areas for overwintering. Finally,
restrict the fish to the areas requiring vegetation control. The
specific barriers and drop structures would probably be necessary to
downstream and limiting to control vegetation in upper reaches.

Specific problems, including the problem of the fish moving
control in canals, other results were negative. Canals present
research has shown grass carp can be effective for vegetation
control of aquatic vegetation in irrigation canals. Although some
potential use of grass carp in Montana would be for irrigation
projects and in some situations takes the most important
excessive aquatic weed growth does cause problems in some
aquatic vegetation is not a major problem in Montana, but

Discussion and Recommendations

The use of grass carp to control aquatic vegetation has
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.
c. Montana should urge the American Fisheries Society to develop a careful evaluation of the use and distribution of grass carp in Montana, and to work with other aquatic resources.

4. Montana should urge the American Fisheries Society to develop a careful evaluation of the use and distribution of grass carp in Montana, and to work with other aquatic resources.

Therefore, the introduction of the trichodont grass carp to Montana should not occur unless there is a very significant need and effect. Therefore, the introduction of the trichodont grass carp to Montana should not occur unless there is a very significant need and effect. Therefore, the introduction of the trichodont grass carp to Montana should not occur unless there is a very significant need and effect.

3. Any exotic fish introduction into Montana should be evaluated according to the protocol suggested by Kotler and Stanley (1984).

Information for the Rocky Mountain and northern plains region, Alberta, and Washington and Wyoming should provide additional useful data. The studies currently underway in these states are completed and evaluated. The studies currently underway in these states are completed and evaluated. The studies currently underway in these states are completed and evaluated.

Furthermore, the proposed introduction of any introduction of grass carp would not have adverse ecological effects in Montana, and the grass carp would not displace native species. A thorough analysis of the proposed introduction indicates that the grass carp would not a potential threat to their resources.
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