Homing Behavior of Tagged and Displaced Carp, *Cyprinus carpio,* in Pymatuning Lake, Pennsylvania/Ohio[1]

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ABSTRACT. Pymatuning Lake, located on the Pennsylvania/Ohio border, is noted for the large numbers of bread-eating carp that frequent the Linesville Causeway "carp bowl" from May to November. Carp were trapped in 1952 and 1984 at the carp bowl, tagged, and relocated varying distances away from the bowl in Sanctuary, Middle, and Lower lakes. Carp traversed the return distances of up to 9 km in less than 4 or 5 days. Return movements often necessitated swimming around Tuttle Point and across the length of Middle Lake. One carp did migrate northward in 1984, but not 1952, from Lower Lake through the east-west Andover-Espyville Causeway into Middle Lake. Another carp released near the bowl in Middle Lake in 1984 migrated west and south through the Andover-Espyville Causeway and was caught 23 km to the west and south near the Lower Lake dam at Jamestown, Pennsylvania. Larger and older carp frequented Sanctuary and Middle lakes. Carp sizes decreased progressively with distance from the bowl. Visual cues, currents, sounds, sun orientation, "follow-the-leader", and schooling behavior did not explain the carp aggregations in the carp bowl or the homing behavior by carp. Odors from feeding carp or other sources may be the causal basis for the homing behavior.

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INTRODUCTION

Many freshwater fishes exhibit homing or specific migratory behaviors (McCleave et al. 1982). Examples include salmon which travel great distances from freshwater to the sea and return to their native stream to breed (Hasler and Scholz 1983) and the carp, *Cyprinus carpio*. Johnson and Hasler (1977) used ultrasonic tracking gear to document winter aggregations of carp in Lake Mendota, Wisconsin. Similar techniques were used by Otis and Weber (1982) and Priegel (1982) to record carp movements in Lake Winnebago and several other Wisconsin lakes. Osipova (1979) described specific movements of wild carp in the Cheremshansk pool of the Keybyshev Reservoir in Russia. Vostradovska (1975) and Vostradovsky (1974) noted the movements of carp in Lipno Reservoir, Czechoslovakia. Yet, with the natural and worldwide occurrence and introduction of carp, its ability to home or aggregate has been overlooked.

Since the creation of Pymatuning Lake, myriads of carp congregate annually at its Linesville Causeway "carp bowl" to feed on bread tossed to them from May to November by tourists. This study, which was done during the summers of 1952 and 1984, was designed to address the following questions. (1) Why do carp congregate at the Linesville Causeway carp bowl? (2) Is their behavior innate or a learned response? (3) Are they drawn to the carp bowl by the abundance and availability of food? (4) If displaced to other parts of the lake do they return to the bowl? (5) At what speed, and by what avenues do they return, and is the aggregating behavior the same over time?

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Study Area. Pymatuning Lake is a 24-km-long, L-shaped impoundment on the Pennsylvania-Ohio state line, that is divided into three parts by two causeways. Construction of the lake began on 5 December 1933; the dam at Jamestown, Pennsylvania was closed on 1 January 1937.

Sanctuary Lake (Fig. 1), the east-west part of Pymatuning Lake, is formed by the north-south Linesville Causeway located at its western edge. Overflow water from Sanctuary Lake passes into the "carp bowl" and Middle Lake. Middle Lake extends from the Linesville Causeway northwest and then southward 9.6 km to the east-west Andover, Ohio-Espyville, Pennsylvania Causeway. Two small openings in this causeway connect Middle Lake waters with those in the longer Lower Lake, which is dammed at Jamestown, Pennsylvania, located 14 km to the south. The maximum width of Pymatuning Lake is 3.5 km, with most widths averaging 2.5 km. The average depths of Sanctuary, Middle, and Lower lakes are 2.4, 3.0, and 4.0 m, respectively. Water depth near the carp bowl is about 5.3 m. Maximum depths of 11.4 m are known in the Lower Lake near Jamestown, Pennsylvania. Water levels in Sanctuary Lake are governed by the height of the concrete Linesville Causeway. Excesses simply spill over into Middle Lake. Water levels in Middle and Lower lakes may fluctuate 2 m throughout the year, depending on discharges into Shenango River at Jamestown, Pennsylvania.

Stations And Habitat Descriptions. The carp bowl (CB) is a semicircular, concrete-lined area about midway along the Linesville Causeway. A water level differential of 1 m usually exists between Sanctuary Lake to the east and Middle Lake to the west. Water passing from Sanctuary Lake flows over a spillway into Middle Lake. Carp congregate in Sanctuary Lake along the causeway and spillway.

Water in the bowl flows along a concrete-lined and walled discharge tailrace into Middle Lake. Pennsylvania Route 285 and an abandoned Pennsylvania Central railroad bridge also cross over the outlet of the 20-m-wide tailrace. An abandoned railroad breakwater, 60 m to the west of the carp bowl tailrace outlet, with central channel piers, protects the bowl area from violent wave actions, although extreme westerly storms do cause occasional water surges within the bowl. Middle Lake water levels at the bowl are affected by lake drawdown as well as prevailing summer winds from the west or southwest. Water depth in the carp bowl is about 5.3 m; flows vary according to seasonal overflow from Sanctuary Lake.

MS2 (Fig. 1) is a channel station located between the largest island (Soldier?) situated on the south shore of Middle Lake about 1 km east of Tuttle Point (T). Water depth at this station is 1 m. Mud and sand substrates prevail. Enormous stands of *Myriophyllum* and *Lotus* flourish during the summer months. In June, both MS1 and MS2 are used as one of the prime Middle Lake carp spawning areas. The area is protected from all but northerly winds.

All other stations (Fig. 1), MS, MN, LEO, and SS, have a water depth of 1 to 2 m, mud-sand substrates, and gradual shore slopes, and are subject to wave action from prevailing winds. Stations MS1, MS3, MN3, and MN6 are also subject to heavy *Myriophyllum* growths from May through August. Site MN2 has many stumps, logs, and fallen trees; rocks, stones, and pebbles line the substrate of MN4 and are found along the shore of MS3. Sanctuary stations (SS1 and SS2) are subject to dense summer blooms of *Microcystis* (in 1952) or *Anabaena* in July and August (in 1984).

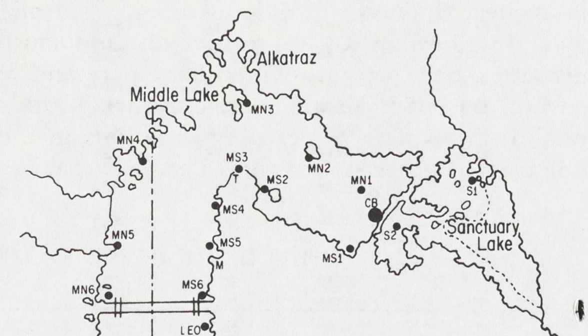

Figure 1. Map of Pymatuning Lake denoting carp bowl (CB), location of the three lake partitions and two causeways, and relocation sites for releases of tagged carp in 1952 and 1984. Note that fish relocated to MS4, MS5, and MS6 stations had to swim north for 4.8 km before swimming eastward to the bowl.

MATERIALS AND METHODS

The carp bowl was sampled daily during the summers (July-August) of the 1950's by the Pennsylvania Fish Commission (PFC). Carp were captured at the bowl by lifting an unbaited metal frame (20 m^2) fitted with webbing. These fish were stocked throughout the state and were also used in the 1952 studies.

Two methods were used to capture carp in 1984. A seine (21 × 1.5 m; 15 mm bar mesh) was used at all relocation stations where water depths were less than 1.5 m. Varying shoreline distances (30-150 m) were sampled at each site, depending on absence of snags or vegetation. The number of sweeps of the seine in each habitat was determined by the size of catch. A bag (1.2 × 1.2 m) was fitted into the seine in July to prevent carp from escaping the net by digging under the lead line. Seining was not attempted in August, when carp were scattered widely throughout the lakes.

Morton Big "M" traps were set at the carp bowl breakwater as well as most relocation stations. The Big "M" is a metal-framed trap (1.2 × 1.2 × 0.6 m) covered with knotless netting (38 mm bar mesh). Additional netting buoyed with floats permit its extension to a height of 1.5 m. A vertical slit on each side of the vertical webbing permits entry to the trap. Entry to a conical bait box in the center of the trap is through a flap in the bottom mesh (Schwartz 1986). Baits were either pressed soybean or cottonseed cake that had been soaked in molasses. Traps were fished for 24 h and were checked daily, usually at 0700 and 1500 h. Sampling periods in 1984 were 6-10 May, 3-9 June, 13-16 July, and 14-19 August. Standard lengths (mm, SL) were recorded for all carp captured or relocated during the 1952 and 1984 studies. Air and water temperatures (°C), wind conditions, water clarity, spawning activity, and behavior of carp were also recorded in both years.

United States Department of the Interior
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December 12, 1978

IN REPLY REFER TO: 122

Dr. Robert J. Behnke
Cooperative Fisheries Unit
Colorado State University
Ft. Collins, CO 80521

Dear Bob:

Somewhere at some meeting you once handed me a seven-page draft paper of yours entitled "Efficacy of the Grass Carp for Vegetation Control and the Potential Environmental Impact of their Introduction."

Did you subsequently publish this? Are your views now different? And, where is the Dez Canal?

Will appreciate a note from you on this.

Best wishes.

Sincerely,

"Woody"

E. A. Seaman
Senior Scientist

Enclosure: Copy of paper referred to.

Efficacy of the Grass Carp for Vegetation Control
and the Potential Environmental Impact of Their Introduction

By: Robert J. Behnke
May 1975

The grass carp, Ctenopharyngodon idella, a primary herbivorous fish native to the Far East, has been introduced throughout much of the world as a biological control agent for undesired vegetation and as a food fish utilizing a resource not consumed by native fishes.

The early literature on this species is confusing and often contradictory. The grass carp was credited with many attributes--good, bad and indifferent. More detailed data from controlled studies have appeared in the literature during the past few years and a more realistic and balanced view of the grass carp's potential can be made along with predictive assumptions concerning environmental impact.

It must be recognized that environmental conditions vary greatly from one geographical area to another and even between neighboring waters, so that the results of one study can not be expected to be precisely duplicated in another situation. Sufficient information, however, is now available to interpret repeatable patterns and factual answers to the following questions. What types of vegetation will the grass carp control? What types won't it control? What density is necessary to effect control? Is control feasible in north temperate regions where maximum summer water temperatures do not exceed 20-25°C (67-75°F)?

What is the environmental impact of grass carp introduction--on the native fish fauna, as a predator and competitor--on habitat and water quality?

Will the grass carp reproduce and become a pest species, following the course of the common carp in North America?

Much of the confusion re. the grass carp's diet, preferred food and impact on vegetation is due to the fact that diet preferences change during ontogeny and is age and size related. Fry and young fingerlings feed on animal life such as rotifers and minute crustaceans. Vegetation becomes dominant in the diet during the first year, but typically some animal foods are found in the intestine in small quantities at all ages (probably much of this is taken incidentally as invertebrates attached to plants).

Food conversion ratios are variable (weight of food consumed/weight gained), ranging from 40-50:1 to more than 300:1. This variation is largely due to the per cent water content and the nutritive qualities of the vegetation. The nutritive value of vegetation varies between species and perhaps seasonally in a single species. Vegetation deficient in certain amino acids will yield higher conversion ratios (poorer growth). A general conversion figure commonly used to estimate vegetation consumption from the biomass increase of a grass carp population is 100:1, which assumes that for every kg of biomass increase of the grass carp population 100 kg. of vegetation has been consumed. The actual impact of the grass carp on the vegetation in reference to control may be much greater than implied from actual consumption figures. This is due to selective feeding on the soft vegetation, which are usually the problem species and to the wasteful feeding habits of the grass carp. The destruction of vegetation by biting leaves and stems and clipping off branches of the vegetation is particularly apparent in flowing waters such as the canals of the Dez Irrigation Project (large amounts of vegetation were removed daily from the screens of the test sections containing grass carp). Where?

Wasteful feeding of grass carp seems the only plausible explanation of the grass carp effectively controlling vegetation in the test sections of the Dez canals in the light of the data concerning vegetation production and biomass increase of the fish.

There is considerable room for error in the limited sampling in 1974, but it appears that effective control was exerted by the grass carp while consuming not more than 5% of the total vegetation production of the test sections.

Most quantitative production estimates for most types of aquatic macrophytes in temperate regions during a 100-120 day growing season is generally about 15-20 metric tons per hectare (production=total biomass increase during a season). The annual production of vegetation in the Dez Canals must certainly be several fold greater than 15-20 tons/ ha. due to the continual supply of nutrient rich water and a tropical climate with intense sunlight. Based on the wet weight of all vegetation within 1/4m^2 sampling plots in September 1974, I calculated standing crop estimates of 40-120 tons/ha. The fact that this vegetation is cut by chaining the canal sections from 6-10 times per season, indicates extremely high production of vegetation in the Dez canals. I note in Saadati's report that he estimates the annual vegetation production at 250 tons/ha., which may be a realistic figure. ?

The efficacy of the grass carp for vegetation control in the Dez canals is evaluated by a most practical method: When growth of vegetation attains a stage interferring with water delivery, the vegetation is removed by chaining, and, as mentioned avove, the sections without grass carp were chained from 6-10 times during the season, but the two test sections stocked in May with grass carp (100 fish, averaging 100 gm/ha.) required no chaining.

This season, more quantitative data on both vegetation and grass carp production should be obtained (and an estimate on vegetation destroyed but not consumed), to arrive at some relatively confident estimated re. stocking rates necessary to effect various levels of vegetation control and to relate that fraction of vegetation production actually consumed by the grass carp to these control levels.

The fact that grass carp select different foods at different sizes and densities allows for the manipulation of the population to control virtually any form of vegetation, except perhaps, unrooted, floating plants such as water hyacinths. Underyearling and yearling fish eat large quantities of filiamentous algae but older fish do not. Large specimens (1 kg. +) have been reported to attack and tear down fibrous emergent plants such as Typha and Phragmites after consuming the available soft vegetation.

Effective, continuous control of a diversity of vegetation may require population manipulation to maintain a balance between size groups and avoid boom and bust situations. A significant problem concerning stocking density to effect control is the fact that most published studies cover a one year test period or a fraction of a year, which ignores the fact that the grass carp is a long lived species with a relatively great growth potential (potential life span of more than 10 years and maximum reported size of 60-70 lbs and more). For example, if effective control is attained by stocking 100 fish averaging 100 gm./ha. at the beginning of the season and these fish average 1 kg. at the end of the season, a 10 fold increase in biomass (if no mortality) has been achieved, but at the beginning of the next season there will not be sufficient vegetation to sustain such a population. Such consideration is particularly important where control and not complete elimination of vegetation is desired.

Grass carp feed in a temperature range of 15-35°C (59-95°F) but active feeding occurs between 20-33°C and peaks at 25-30°C. Grass carp have been effectively used in Sweden to control vegetation where 250 fish averaging 380 gm were stocked into 4.6 ha. Lake Osbijsjon (54 fish and 21 kg/ha). After 100 days the grass carp averaged 1030 gm and Myriophyllum was reduced from 16 tons/ha to 7 tons/ha (standing crop). Assuming 100:1 food conversion and no mortality, 3.5 tons/ha of vegetation was consumed by the grass carp during the 100 days of the test. Taking into account the production of vegetation during this period, the reduction of the standing crop of Myriophyllum was most likely achieved by the destruction of more vegetation than was actually consumed.

Potential Environmental Impact

With abundant examples of disasterous results from the introduction of non-native plants and animals throughout the world, caution, controls and thorough study must certainly be advised before grass carp introductions are undertaken.

Two factors make it highly unlikely that the grass carp will become a chronic pest or problem species, like the common carp. These factors relate to the specialized feeding habits of the grass carp and its highly restrictive requirements of reproduction.

The grass carp is a highly specialized herbivore and cannot successfully compete with native fishes for any food supply except macrophyte vegetation. Natural spawning of grass carp is similar to the striped bass in that the eggs are semi-bouyant and require a slow, steady current to keep them and the newly hatched fry suspended off the bottom. Suitable rivers for natural reproduction are rare and there are very few records of natural reproduction outside of their native range (a recent one concerns in lower Volga River in the USSR).

It is likely that the grass carp has spawned in the Mississippi drainage where they have been free for several years, but this has not been verified and with the diverse native fish fauna of the Mississippi, the grass carp could only be locally successful where dense areas of macrophytes exists--there is no other open niche for them.

For virtually every situation where the grass carp may be used for vegetation control, the populations must be maintained by introductions. A potential danger for sport fishing lakes is the complete elimination of vegetation where grass carp are stocked at too high a density or where natural increase in biomass of this long-lived fish is not taken into consideration in subsequent years. In such situations removals of a part of the population can rectify the condition.

A common objection raised is that grass carp may speed up the rate of euthrophication of lakes, but it can more logically be theorized that the reverse is true.

Evaluation of research data reveals that grass carp create more rapid recycling of the nutrients bound up in plants from the natural annual cycle which depends on death and decomposition of the vegetation in the fall and winter. This recycling of nutrients in turn should increase the productivity of the other organisms in the ecosystem and potentially increase the production of other fishes. With ~~very~~ well managed harvest of grass carp and other fishes, a considerable quantity of nitrogen and phosphorous would be removed from the ecosystem, thus reducing the eutrophication process.

In irrigation systems the recycling of nutrients bound up in macrophytes would yield extra fertilizers to the irrigated crops.

In Lake Osbijsjon, Sweden, there was a temporary increase in phosphorous in the water, no change in the phytoplankton but the zoobenthos increased in the winter and changed to a clean water fauna as winter oxygen levels were higher.

Another possible benefit of vegetation control in areas where parasite diseases require a snail host, such as schistosomiasis, is the concomittant control of snail populations as their vegetative habitat is destroyed. The introduction of grass carp along with a specialized snail eating fish offers a most promising approach to snail control.

There is no debate on the eidibility of the grass carp--it is unanimously proclaimed as excellent eating. Surplus production and planned removals for population manipulation will find a ready market.

There is no doubt that the grass carp offers a great potential as a biological control for problem vegetation with many possible related benefits. Sufficient information is now available to justify more trials under natural conditions in actual problem situations, particularly long-term studies to obtain a predictive data base for the use of grass carp in a variety of environments.

In the final analysis the use of grass carp for vegetation control vs. manual control or chemical control will be decided on a cost-benefit ratio. The utilization of an animal in an ecosystem to consume vegetation and recycle the nutrients should have a much more positive impact (probably an ameliorating effect) on that ecosystem than control by manual or chemical destruction of vegetation--particularly the latter alternative.

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