66-07

AN EVALUATION OF THE ADVISABILITY OF THE RELEASE OF THE GRASS CARP, *CTENOPHARYNGODON IDELLA*, INTO THE NATURAL WATERS OF THE UNITED STATES

DAVID W. GREENFIELD
Department of Biological Sciences,
Northern Illinois University,
DeKalb, Illinois 60115

ABSTRACT.—A review of the literature concerning the biology of the grass carp, *Ctenopharyngodon idella*, is presented, including information on the usefulness of this species as an agent to control aquatic vegetation. Feeding habits, digestion, reproduction, age and growth, physiological requirements, and interactions with other species are described. The advantages and disadvantages of the release of the grass carp are presented and recommendations concerning future control of this species are made.

The grass carp, *Ctenopharyngolon idella* Valenciennes, has recently received considerable attention from various state and federal agencies as a potential means of controlling noxious aquatic plants. This heightened interest necessitates a thorough evaluation of the probable impact of new introductions of this species on the native fish fauna of the United States.

The grass carp, *Ctenopharyngodon* white amur or Waan Ue, is native to the rivers, lakes and ponds of Siberia (Amur Region), Manchuria and China, southward to the Chu River, South China. It has been introduced for pond culture into Formosa, Malaysia, Japan, Viet Nam, Thailand, Hong Kong, Ceylon, and India as well as into the U.S.A., Great Britain, Israel, eastern Europe, Germany and Holland (Cross, 1969; Kuronuma, pers. comm.; Lin, 1935; and Steven son, 1965).

In the United States the grass carp was first introduced by the Bureau of Sport Fisheries and Wildlife to the Fish Farming Experimental Station, Stuttgart, Arkansas in November, 1963. The grass carp has been introduced into five state-owned fishing lakes in Alabama, cultured at the Marion Fish Hatchery, Alabama, maintained at Auburn University, Alabama, planted into an irrigation pond at Tucson, Arizona, kept in artificial ponds in Arkansas, and at Oregon State University. Three grass carp, weighing about 20 pounds each (4 years old), have already been taken in the Mississippi River, two from as far north as southern Illinois. (St. Louis Post Dispatch, Feb. 9, 1971). There is no evidence that these introductions have resulted in any established wild populations in the United States.

CONTROL OF AQUATIC VEGETATION

Nair (1968) cites numerous references attesting to the ability of the grass carp to control the growth of aquatic plants. Cross (1969) presents a table listing the various plants eaten by the grass carp, in the approximate order of their preference. Avault (1965) presented data on its herbivorous habit in ten experimental pools, which had each been planted with 12 species of aquatic plants. Each pool was stocked with a single grass carp, 12 to 16 inches long, equalling 685/acre. Within two to three weeks complete control was obtained. Stevenson (1965) reports that six fish averaging 908 grams were placed in a 0.25 acre pond (24/acre) containing *Chara, Najas, Eleocharis,* and *Polygonum*. In two months the aquatic plants were reduced but not eliminat-

ed, but the fish were also supplied with commercial feed. In a second pond (0.1 acre) containing *Chara, Najas,* and *Anacharis,* three fish, approximately 1,270 grams each, were introduced. Two months later the *Chara* and *Najas* had been removed but the Anacharis remained and an abundant growth of *Spirogyra* was present. Commercial feed was also supplied to this pond. McConnell (pers. comm.) reported that forty 2-inch fingerlings were introduced in a two-acre pond on a Tucson, Arizona, golf course and that "after the first year they were very effective in keeping the pond free of undeisirable weed growth". McConnell also reported that a single grass carp was transferred to a ½-acre pond which was weed-choked, Although it did not completely control the weeds, its grazing caused a noticeable reduction in weed density.

Feeding Habits

All of the above mentioned studies have been conducted with adult or subadult individuals, in artificial ponds or lakes. Lin (1935) in a study conducted at the West River in the interior of Kwangsi Province, China, reports "Its omnivorous feeding habits are well known. The Waan Ue eats grass, leaves of trees, and water plants as well as small fish, earthworms, silkworm pupae, beef, insects and even decayed cloth and shoes". Hora and Pillay (1962) reported that the fish is an omnivore eating chopped fish, flesh of freshwater mussels, and silkworm pupae along with aquatic vegetation. Stevenson (1965) reports that fingerlings fed heavily on *Daphnia,* and chopped earthworms were eaten in large quantities. Chironomid larvae were also highly preferred. Stevenson (1965) further states that in one pond the fish fed on zooplankton to the exclusion of algae and commercial feed. Cross (1969) reported that in his laboratory, grass carp about nine inches in length ate *Daphnia,* tubifex worms and *Asellus* as well as vegetation. Nikolskii (1954 and 1956) reports that the young of the grass carp feed on crustaceans, rotifers, and chironomid larvae. It has been suggested by Stevenson (1965) that in pond situations the grass carp may be forced to feed exclusively on aquatic vegetation and thus any preference for other foods would not be seen.

Recent studies at Auburn University by R. H. Kilgen and R. O. Smitherman (pers. comm. and 1971) have dealt with the feeding habits of the grass carp in pond situations where other species of game fish were present. A comparison of the stomach contents of the grass carp indicated that 84% of its food consisted of macrophytes, 9% insects, mostly chironomid larvae, and 7% Purina Trout Chow. The largemouth bass, spotted bass, redeye bass, Israeli carp and channel catfish in the pond fed mainly on insects. The presence of high percentages of insects in the stomachs of the species other than the grass carp indicates that animal food was available but that the grass carp fed mainly on plant material. Tang (1970) has indicated that in the absence of competition or when the supply of macrophytes is low the grass carp will switch to food items other than aquatic plants.

Digestion

Hickling (1966) reported that the digestive tract of the grass carp is extremely short for a herbivorous fish and that at a temperature of 28° to 30° C, the food passes completely through the fish in less than 8 hours. Digestion is incomplete, with about ½ of the food material passing through undigested. Hickling (1966) states that this undigested food can support, directly or indirectly, a large biomass of other species of fish. Stroganov (1963) reported that the

feces of the grass carp promotes vigorous growth of plankton. Due to the incomplete digestion, the grass carp must consume large quantities of food and this, of course, is the reason for its usefulness in controlling aquatic vegetation.

Reproduction

Lin (1935) and Kuronuma (pers. comm.) reported that spawning takes place in the center of large rivers with currents of 3.3 to 5.5 feet/second usually just below extensive rapids. Nikolskii (1956) states that a current flow of between two and five feet per second is required. The temperature required for spawning is 26-30° C according to Lin (1935) and above 20° C, Nikolskii (1956). In addition to these requirements, spawning takes place after a sudden rise in the river, usually after heavy rains. Lin (1935) stated that a rise in excess of 4 feet within a 12-hour period is necessary for spawning to occur. Presumably, spawning during periods of high turbidity reduces predation on the semi-pelagic eggs. This species undergoes a spawning migration, usually in large shoals, with spawning occurring from April to mid-August. Most of the spawning in the West River, China, occurs from the end of May to mid-June.

Lin (1935) reported that a 16-pound female contained 100,000 eggs, but felt that all of the eggs were not spawned at one time. The eggs are semi-pelagic, floating downstream in the mid-layers of the water (Kuronuma, pers. comm.). Lin (1935) reported that hatching takes place 34 hours after fertilization, while Tang, Hwang and Lin (1963) gave a figure of 24 to 30 hours at 25° C. Within a short time the larvae are swimming actively and begin feeding on ooplankton and to a lesser extent phytoplankton.

Generally, grass carp have not reproduced in pond situations outside their natural habitat. However, this species has been reported to have spawned in Japan (Anon., 1961) and in Taiwan (Tang, 1960). Spawning has been induced in pond situations by injections of fish pituitary extracts (Tang *et al.*, 1963 and Alikunhi, Sukumaran and Parameswaran, 1963).

Age and Growth

Lin (1935) found that most of the grass carp in the West River, China, were about four years old and that none of the mature fish were less than three. Females were larger than males, reaching a length of about three feet. Cross (1969) reported that the fish takes between five and nine years to become sexually mature. Stevenson (1965) presented data showing a weight of 4 grams and a length of 8 cm at 6 months, 372 gm and 28 cm at 12 months and 1.816 gm and 50 cm at 18 months. He also indicated the following age at first maturity for various areas.

Russia	
8-10 years	2.7- 3.8 kilograms
S. China	
4	6.0
Israel	
5-8	8.0-10.0
Malaysia	
10-14 months	2.0- 5.0

Kuronuma (pers. comm.) indicated that the rate of growth of the grass carp is two to three times that of the common carp, *Cyprinus carpio*, under similar environmental conditions. The grass carp attains the size of 1.5 meters in length in river waters within five or six years. Hooper (pers. comm.) stated that in Alabama lakes grass carp stocked as two year olds grew up to 6 pounds the first year.

Physiological Requirements

Cross (1969) summarized the physiological requirements of the grass

carp as follows: "It is able to withstand a wide range of water temperatures from 0 to 35° C (Stevenson, 1965), can tolerate salinities as high as 10,000 p.p.m. (Doroshev, 1963) and can withstand oxygen concentrations as low as 0.5 p.p.m. (Yeh, 1959)." Stevenson (1965) noted that in one of his experimental ponds, in which the temperature fell to 0° C and a heavy ice cover formed which lasted five weeks, the grass carp showed no ill effects.

Interactions With Other Species

Kuronuma's (pers. comm.) studies have shown that the production of *Carassius auratus* and small shrimp was not affected by the existence of grass carp in farm ponds in Japan. McConnell (pers. comm.) found that grass carp did not noticeably interfere with a November to April put and take fishery in Arizona. The trout grew well despite the presence of an estimated 300 lbs./acre of grass carp. He has also stated that "During every spring in which grass carp were present in the pond we introduced brood stock of *Tilapia zillii*. Extremely dense populations of *T. zillii* were always produced by the following winter. Apparently there was no significant negative interaction between these species". Nakamura *et al.* (1954) found that in Japan the addition of the grass carp to ponds did not interfere with production of other fish species.

Kilgen and Smitherman (1971) in analyzing the food habits of grass carp in combination with largemouth bass, spotted bass, redeye bass, Israeli carp and channel catfish found that the overlap in food items was relatively little. Kilgen and Smitherman (pers. comm.) evaluated the growth rates of channel catfish and striped bass when stocked with grass carp at rates of 40 to 80 per acre and found no detrimental effects when compared with control ponds. Smitherman (pers. comm.) has evaluated the effects of grass carp (20 or 40/acre) on largemouth bass-bluegill, largemouth bass-bluegill-shad and fathead minnow-walleye-bluegill populations. The survival of walleye, threadfin shad and fathead minnows was erratic in the experimental ponds. The presence of grass carp at either 20 or 40 fish per acre did not greatly affect survival of fingerling bluegill or largemouth bass. Considering growth rates, comparing ponds with no grass carp with those containing grass carp at a rate of 40/acre, Smitherman found that the bass-bluegill in the control averaged 159.73 lb./acre, while in the ponds with the grass carp the weight was 119.15 lb./acre. This could be interpreted as a competitive effect on the growth or reproduction of the bass and bluegill, but Smitherman feels this is the result of greater survival of young bluegill in the ponds where the vegetative cover had not been removed by the grass carp.

Advantages of the Release of the Grass Carp

The grass carp, when stocked at high enough densities, may serve as an effective biological method for the control of noxious aquatic plants. The presence of an effective biological control would eliminate the necessity of utilizing chemical controls and reduce the potential of environmental contamination. The Alabama State Conservation Department Hatchery at Sartaboga, Alabama, has experienced an increased fingerling bluegill production when using grass carp versus chemicals for weed control (Hooper, pers. comm.). In terms of economics ,the use of a biological control should be less costly than the use of chemical or mechanical clearing. However, if hatchery rearing and pituitary injections are necessary to maintain the species, the cost would be increased.

Cross (1969) reported that in the commercial fish farms of eastern Europe, grass carp are reared primarily as a food and only secondarily as a weed clearing agent. He also reported that he found the flesh to be very pleasant. Hooper (pers comm.) has indicated that the fishermen in Alabama have found the grass carp to be an excellent sport fish and to have outstanding eating qualities. Smitherman (pers. comm.) has indicated that the flesh of the grass carp is bony but excellent in flavor.

Disadvantages of the Release of the Grass Carp

The major question concerning the further release of the grass carp into the natural waters of the United States is its impact on the native fish fauna. Concerning the adult grass carp, direct competition with native fish does not seem to be a major problem, for it does not appear to have an ecological counterpart among the native fishes. Also, it does coexist with a natural fish community in Asian freshwaters. However, the ecosystem of Asian freshwaters may differ basically from that in the United States and the effects on the native fauna cannot be entirely predicted.

Indirect competition resulting from the removal of aquatic vegetation may, however, presen ta problem. Aquatic vegetation provides shelter and spawning areas for many native freshwater species and while the removal of aquatic vegetation from choked ponds may be desirable, the removal of such vegetation from rivers might reduce suitable spawning areas. The removal of aquatic plants by the grass carp in areas where food plants for water fowl have been established would pose a serious threat to water fowl management programs. Another consequence of the removal of aquatic vegetation concerns the fact that many species of fish utilize invertebrates which in turn are found on or around aquatic vegetation. In this respect competition could be direct. Smitherman (pers. comm.) in evaluating the grass carp for weed control stated, "All ponds except F-22 to -24 were entirely free of weeds, with bottoms nearly as clean as those in newly constructed ponds.... The bottoms of F-25 and F-27 were even cleaner than ponds with the lower stocking rate of grass carp; evidently the fish dug into the soil to obtain roots of the midget sedge and other plants".

The young grass carp, as mentioned previously, would be in direct competition with the young of other species of native fish, since they feed mainly on invertebrates.

One other problem relates to the studies which have been conducted on digestive rates. Both Hickling (1966) and Stroganov (1963) have discussed the fact that the undigested food is returned to the water and can be utilized by other organisms. With this release of nutrients into the water, one could predict an increase in productivity perhaps leading to eutrophic conditions in some cases.

If reproduction were to occur in our larger rivers, it is possible that the grass carp might multiply uncontrollably. One need only to look at the common carp, *Cyprinus carpio*, for a graphic example. It is probable that once established it might be extremely difficult to control.

Recommendations

Several workers have already urged extreme caution in introducing the grass carp into our native waters: Stevenson (1965) "Although it would appear that the grass carp is an ideal fish to serve as a biological control for aquatic weeds, great care should be exercised and extensive studies made before the fish is released in natural waters"; Ling (1960), "But the possibility of having it become another major problem fish like the

common carp is so great that unless the fish can become acceptable to the Americans its introduction should not be done hastily"; Cross (1969), ". . . but tests will have to be performed here before any decision on the use of this fish can be taken"; Kuronuma (pres. comm.), "It may be recommended that careful evaluation be made to weigh the effective uses of the species as a biological weed controller in fish ponds against the probable impact to the lives of native freshwater species in the United States".

I will add my voice to those who urge caution concerning further introductions. Perhaps in light of the recent captures in the Mississippi River, this caution is already too late. Smitherman (pers. comm.) reported that he and his colleagues at Auburn University are investigating the possibility of developing a monosex population which could be utilized for stocking in areas where the fish might escape to open waters. Investigations of the relationship between the addition of large amounts of undigested feces and eutrophication should also be made.

Studies at Auburn University have dealt extensively with the interactions between the grass carp and various game species, however, the majority of the fish fauna of the Mississippi drainage is not composed of these larger game species but rather the suckers, minnows, darters, and other species which in the past have been considered as "trash species". With the welcomed new-found interest in environmental quality has come the realization that the native non-game fish species are a valuable resource which must be preserved. Studies involving competition of the young grass carp with the young of native non-game species should be performed as well as studies on the direct effects of the adults on non-game species. All of the studies involving interactions of the grass carp with other species have been conducted in ponds and reservoirs, however, the potential danger to native species lies in the grass carp becoming naturalized in streams.

It is my opinion that until these studies have been made, the risks are too great to allow importation and release of the grass carp.

Acknowledgments

I wish to thank the following persons for furnishing information concerning their personal experiences with the grass carp: Mr. Archie D. Hooper, Chief, Fisheries Section, Alabama Department of Conservation; Dr. Katsuzo Kuronuma, Ex-President, Tokyo University of Fisheries; Mr. William J. McConnell, Unit Leader, Colorado State University; and Dr. R. Oneal Smitherman and Ronald H. Kilgen, Auburn University. Dr. William L. Pflieger, Missouri Department of Conservation, kindly provided a preliminary evaluation of the grass carp which was prepared for the Missouri Department of Conservation. Dr. C. K. Mathers reviewed the manuscript and offered valuable suggestions.

This paper was prepared as a report from the American Fisheries Society Exotic Fishes Committee.

Literature Cited

Alikunhi, K. H., K. K. Sukumaran and S. Parameswaran. 1963. Induced spawning of the Chinese carps, *Ctenopharyngodon idellus* (C. & V.) and *Hypophthalmichthys molitrix* (C. & V.) in ponds at Cuttack, India. Curr. Sci. 32: 103-106.

Anonymous. 1961. Report of the subcommittee on fishes. Proc. 10th Pacific Sci. Cong. Honolulu: 277.

Avault, J. W., Jr. 1965. Preliminary studies with grass carp for aquatic weed control. Progr. Fish. Cult. 27: 207-209.

Cross, D. G. 1969. Aquatic weed control using grass carp. J. Fish. Biol. (1): 27-30.

Doroshev, S. I. 1963. The survival of the white amur and tolstobik fry in Sea of Azov and Aral Sea water of varying

salinity. In: Symp. Probl. Fish. Exploit. of Plant Eating Fishes in the Water Bodies of the U.S.S.R. Ashkhabad Acad. Sci. Turkmen U.S.S.R.

HICKLING, C. F. 1966. On the feeding process in the white amur (*Ctenopharyngodon Idella* Val.). J. Zool. (Lond.) 148: 408-419.

HORA, S. L. and T. V. R. PILLAY. 1962. Handbook on fish culture in the Indo-Pacific region. FAO Fish. Biol. tech. Pap. 14: 203 pp.

LIN, S. Y. 1935. Life history of Waan Ue, *Ctenopharyngodon idellus* (C. & V.). Lingnan Sci. J. 14(1): 129-135.

LING, S. W. 1960. Control of aquatic vegetation. In: Lectures presented at the Third International Inland Fisheries Training Centre conducted by the Government of Indonesia and the Food and Agriculture Organization of the United Nations with the cooperation of the Indo-Pacific Fisheries Council held at Bogor, Indonesia, 31 October - 10 December, 1955. Rome, FAO, 29 pp.

NAIR, K. K. 1968. A preliminary bibliography of the grass carp *Ctenopharyngodon idella* Valenciennes. PAO Fisheries Circular no. 302.

NAKAMURA, K., *et al.* 1954. Fish production in seven farm ponds in Shioda plain, Nagano Prefecture with reference to natural limnological environment and artificial treatment. Bull. Freshwat. Fish. Res. Lab., Tokyo. 3(1): 79 pp.

NIKOLSKII, G. V. 1954. Special ichthyology. Translation 1961, Smithsonian Inst.

_____. 1956. Ryby basseina Amura (Fishes of the Amur Basin). Itogi Amurskoi Ikhtiologicheskoi Ekspeditsii 1945-1949. Moscow, Akademia Nauk SSSR: 551 pp.

STEVENSON, J. H. 1965. Observations on grass carp in Arkansas. Progr. Fish Cult. 27: 203-206.

STROGANOV, N. S. 1963. The food selectivity of the Amur fishes. Problems of the fisheries exploitation of plant-eating fishes in the water bodies of USSR. Trudy Akad. Nauk Turkmen USSR: 181-191.

TANG, Y. A. 1960. Reproduction of the Chinese carps, *Ctenopharyngodon idellus* and *Hypophthalmichthys molitrix* in a reservoir in Taiwan. Jap. J. Ichthyol. 8: 1-2.

_____. 1970. Evaluation of balance between fishes and available fish foods in multispecies fish culture ponds in Taiwan. Trans. Amer. Fish. Soc. 99 (4): 708-718.

_____, Y. W. HWANG and C. K. LIU. 1963. Preliminary report of injection of pituitary hormone to induce spawning of Chinese carps. Occ. Pap. Indo-Pacific Fish. Coun. 63(14): 1-7.

YEH, Y. T. 1959. A preliminary report on the oxygen consumption, energy requirement, asphyxiation point and respiratory quotient of fish fry and young fish. Acta Zool. Sin. 11: 117-137.

Manuscript received April 7, 1972.

Contribution No. 402 from the Department of Biological Sciences, Northern Illinois University.