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To the Graduate Council:

I am submitting herewith a thesis written by Kirby Darrell Cottrell entitled "An Evaluation of the White Amur (Ctenopharyngodon idella Valenciennes) as a Sport Fish in East Tennessee Ponds." I recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Wildlife and Fisheries Science.

J. Larry Wilson, Major Professor

We have read this thesis
and recommend its acceptance:

Accepted for the Council

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AN EVALUATION OF THE WHITE AMUR (CTENOPHARYNGODON IDELLA VALENCIENNES) AS A SPORT FISH IN EAST TENNESSEE PONDS

A Thesis

Presented for the

Master of Science

Degree

The University of Tennessee, Knoxville

Kirby Darrell Cottrell

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ABSTRACT

A study was conducted to determine the potential of the white amur (Ctenopharyngodon idella Valenciennes) as a sport fish based on catchability, organoleptic properties, and effects on existing fish populations as evidenced by stomach analysis. Catchability on four baits and lures proved to be low (.0046) but was complicated by high mortality (62%) for study ponds. Organoleptic evaluation was performed by a 28 member taste panel; when white amur was compared to largemouth bass and bluegill, no significant difference in taste was found at the .05 level. Channel catfish was significantly different from white amur, bluegill, and largemouth bass. Stomach analysis revealed high consumption of animal matter (Chironomidae, Chaoborus, Pelecypoda (Sphaeriidae), and Trichoptera) in three study ponds. Reduction in plant densities was noted but turbid conditions in study ponds was thought to be a major factor. It was concluded that the white amur has marginal potential as a sport fish.

CP-WES FOREST

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CHAPTER I

INTRODUCTION

In recent years, research to discover means of controlling undesirable aquatic vegetation has taken a new direction. The scientific community has become aware that effective biological controls are more desirable than many existing chemical control methods which are potentially hazardous to the ecological balance of a pond, lake, or river, as well as to man himself (after Gangstad, 1973). Investigations using biological control include insects, mites, snails, pathogenic microorganisms, fish, ducks, geese, manatees, parasitic higher plants, and competitive plants (Blackburn, Sutton, and Taylor, 1971).

Various species of herbivorous fish have been investigated (Avault, Smitherman, and Shell, 1966; Blackburn, et al., 1971; Gangstad, 1973; Lawrence, 1966; and Sills, 1970). One of the most promising species being evaluated is the white amur or grass carp, Ctenopharyngodon idella Valenciennes. The white amur is native to the rivers, lakes, and ponds of Siberia (Amur Region), Manchuria, and China southward to the Chu River (Greenfield, 1973). It has been introduced for pond culture into Formosa, Malaysia, Japan, Viet Nam, Thailand, Hong Kong, Ceylon, and India as well as the United States, Great Britian, New Zealand, Israel, Eastern Europe, Germany, and Holland (Cross, 1969; Lin, 1935; Greenfield, 1973). As a result of its wide introduction, the grass carp has exhibited qualities that elicit

optimism as to its ability to control certain types of aquatic vegetation in habitats occupied by other fish populations.

Since the introduction of the white amur into the United States at the Fish Farming Experimental Station in Stuttgart, Arkansas, it has been the subject of extensive research. Specific research such as determination of stocking rates necessary for complete or partial control of aquatic vegetation and the determination of types of vegetation as preferred food items has been carried out by numerous authors (Avault, 1965; Bailey and Boyd, 1971; Blackburn, et al., 1971; Blackburn and Sutton, 1971; Prowse, 1971; Sills, 1970; Stevenson, 1970; Sutton, 1974; and Terrell and Fox, 1974). Other studies (Nakamura, et al., 1954; Kilgen and Smitherman, 1971; Crowder and Snow, 1969; Stott, et al., 1971; and Nikoliski and Verigin, 1969) have shown the effects of the grass carp in combination with other species such as largemouth bass (Micropterus salmoides Lacépède), bluegill (Lepomis macrochirus Rafinesque), channel catfish (Ictalurus punctatus (Rafinesque)), and common bream (Abramis brama Linnaeus).

Much controversy has arisen due to the fact that the white amur is an exotic species and therefore must be considered potentially dangerous as an introduction to new environments. Recognized as a member of the family Cyprinidae and closely related to the common carp (Cyprinus carpio Linnaeus), the white amur will be subject to much suspicion and scrutiny until major questions about its biology are answered. The abundance of research already completed has led some researchers to wholeheartedly endorse it as the solution to controlling aquatic

vegetation problems in the United States. To the contrary, other researchers caution the widespread introduction until an unbiased evaluation of the white amur's impact on aquatic ecosystems can be obtained. Questions that arise are the white amur's effect upon waterfowl habitat, its contribution to sport and commercial fisheries, its impact on native non-game species, and its contribution to eutrophication.

One should note that it may already be too late to obtain answers to some questions before the grass carp becomes widespread because it is being advertised and sold by commercial fish farmers. In addition, accidental releases have occurred in Arkansas and Alabama. Two 20 pound white amur have been taken from the Mississippi River in southern Illinois; Louisiana and Missouri also report catches from the Mississippi River and its tributaries (Burkhalter, 1975). The Kaskaskia River in Illinois has yielded grass carp to commercial fisherman (Horner, personal communication, 1976) and catches from Reelfoot Lake in Tennessee have been reported (Burkhalter, 1975).

With this information in mind it is imperative that research be designed to determine the lesser known aspects of the white amur's biology. Two aspects which have had little study concern the value of the white amur as a sport fish and its acceptability as a food fish; this is the purpose of this investigation. The white amur will be evaluated according to the following criteria:

1) catchability - number of fish caught per angler hour on selected lures and bait materials.

2) organoleptic properties - acceptability to those who would eat their catch.

3) its effect upon established sport fish populations and pond habitat - by direct observation and thorough examination of digestive tract contents of the white amur.

CRANES CREST

CHAPTER II

LITERATURE REVIEW

Differing opinions appear in the literature when the sport fish qualities of the grass carp are discussed. Sneed (1971) states, "we can note that they have been caught on spinners, spoons, streamer flies, dry flies, dead and live minnows, liver, worms, algae, and even grass at the Fish Farming Experimental Station (Stuttgart, Arkansas). They are extremely wary and are strong swimmers but will jump only occasionally after being hooked. If they do jump they are in a class with the tarpon. Usually the fish jump when being seined but seldom jump at the end of a line." Kilgen and Smitherman (1971) reported that the white amur could be caught on worms and thus considered them to be a game fish. Zawisza and Backiel (1972) recaptured few white amur due to poaching by anglers. Bailey (1972) reiterates some of Sneed's observations and reports that the white amur has been taken on a variety of baits and presents quite a challenge to the fisherman.

A study by Terrell and Fox (1974) evaluated the catchability of grass carp in ponds with no aquatic vegetation. They operated on the premise that vulnerability to angling would be high in the absence of aquatic vegetation. Their results were that fisherman harvested 61% of the grass carp in eight days of fishing.

From a personal communication with Hooper, Greenfield (1973) reports that fisherman in Alabama have found the white amur to be an

excellent sport fish. According to Sills (1970), grass carp have been caught on several types of natural bait as well as artificial lures. Kilgen (1973) collected grass carp by hook and line in his experimental ponds.

Other researchers have found the white amur is not a good sport fish. Courtenay and Robins (1973) state, "the potential of the species as a sport fish seems nil."

Thus some disagreement does exist as to whether the white amur has potential as a sport fish; specific research emphasizing this aspect of the white amur's biology has not been pursued. Terrell and Fox (1974) and Bailey (1972) voice the need for investigations into the grass carp's sporting qualities.

Most sport fish are prized not only for their fighting and jumping abilities but also for their value as a food fish. The desirability of the grass carp is very high in Asia, the Orient, and parts of Europe where it is cultured (Pentelow and Stott, 1965). One significant test performed in Poland by Okoniewska (1968) compared the white amur to the highly valued mirror strain of the common carp. Flesh of the white amur prepared as fillets or as a jelly was judged superior to carp. Bailey (1972) reports that he is yet to hear anyone express a dislike for white amur after an unplanned, unrehearsed meal of white amur.

Walker (in Bailey, 1972) surprised the personnel at the Southeastern Fish Control Lab in Warm Springs, Georgia, with an impromptu "taste test" and the white amur rated 8.0 on a scale of 10 against such delectables as red snapper (8.9) and channel catfish (6.5).

Kilgen and Smitherman (1971), Cross (1969), Sneed (1971), and Stevenson (1965) all report the white amur has an excellent flavor.

At Auburn University, Dr. Ron Phelps (personal communication) reports the white amur may be canned like tuna and that he personally likes it better. He also added that if you are dealing with a large fish, the fillets can be chopped into steaks, thus effectively getting rid of the troublesome intramuscular bones that are a nuisance in smaller fish.

A dissenting vote is cast by Martin (personal communication) who thinks the commercial fisherman who are catching an occasional grass carp would be selling them for more money if its eating quality was very good.

Another important criteria that faces an exotic species is its effect (either positively or negatively) on the existing ecosystem after it is introduced. It is probable that Asian freshwaters may be somewhat different from those in the United States; thus, one cannot predict the effects the grass carp will have on native fish populations. Greenfield (1973) states, "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." Many researchers have studied this very problem and at times disagree as to what impact the white amur does have.

Kilgen and Smitherman (1971) found little overlap in food items between white amur and other species.

Bailey (1972) provided evidence of general improvement in intra-specific population dynamics from work at Lake Greenlee, Arkansas.

Stocking of white amur was in accordance with a winter drawdown and fertilization program. While these factors are major contributors to the improved populations, the results seemingly indicate that the introduction of the white amur did not reverse or adversely affect the desired results of these methods.

Other workers have observed the same results and in some cases, the introduction of the grass carp has caused an increase in production of other fish species. Stott, et al. (1971) introduced common bream (Abramis brama Linnaeus) in grass carp experimental ponds and their results showed that bream sharing ponds with grass carp had a better growth rate than those in control ponds. Crowder and Snow (1969) and Nikoliski and Verigin (1968) also found that the white amur increased growth and/or production in experimental ponds over that of control ponds.

McConnell (personal communication, Greenfield, 1973) relates that grass carp did not affect a put-and-take trout fishery in Arizona. The trout showed good growth while in the presence of an estimated 300 pounds per acre of grass carp. Avault (1965) states that the white amur does not interfere with other species either as a competitor for food items or as a deterrent to production. Prowse (1965) reports, "in Asia grass carp are usually reared in mixed culture and so far we have never found them aggressive toward any other species of fish."

Direct competition with other fish is evident in the fry stage. The young white amur act as other fry and are dependent for a short while on zooplankton (Michewicz, Sutton, and Blackburn, 1972). However, at 30 millimeters total length the grass carp is classified

wholly vegetarian (Nikolski, 1956; Cagni, Sutton, and Blackburn, 1971; Bailey, 1972; Kilgen and Smitherman, 1971; and Hickling, 1966).

Some workers prefer to classify the grass carp as omnivorous due to the occasional presence of animal matter in the gut and to the relatively short gut length for a herbivore. Lin (1935) reported that grass carp consumed small fish, worms, insects, and even decayed cloth and shoes. Hora and Pillay (1962) note the grass carp would eat chopped fish, flesh of freshwater mussels, and silkworm pupae. Chopped earthworms sustained white amur reared by Stevenson (1965). Cross (1969) found that grass carp would eat Daphnia, tubifex worms, and Asellus. Whitley (in Purkett, 1972) reports that fingerling grass carp prefer amphipods and grew faster when amphipods were offered over a strictly aquatic vegetation diet. Edwards (1973) in New Zealand has noted that 0-group (young-of-the-year) grass carp would eat mayfly nymphs, stonefly nymphs, aquatic oligochaetes, chironomid larvae, snails, caddis fly larvae, amphipods, Dobson fly larvae, and rainbow trout fry.

Another aspect of the white amur's impact on the native fish fauna is what effect it will have upon the habitat occupied by the native fish. Bailey (1975) noted that lakes favoring redear sunfish (Lepomis microlophus (Günther)) and chain pickerel (Esox niger LeSueur) have changed to favor largemouth bass (M. salmoides Lacépède), bluegill (L. macrochirus Rafinesque), and primary consumers and forage species such as gizzard shad (Dorosoma cepedianum (LeSueur)).

Pelzman (1971) fears that turbidity may result when the white amur pulls plants up by the roots or digs into the lake bottom to secure roots or parts of plants.

Another fear voiced by Hickling (1966) is an increase in productivity leading to eutrophic conditions caused by undigested fecal material. Bailey (1972) noted this effect in lakes where the resulting algal blooms were not utilized by other fish.

CRANE CREEK

CHAPTER III

METHODS AND MATERIALS

Two hundred and twenty white amur were obtained from the Arkansas Game and Fish Commission's Joe Hogan State Fish Hatchery, Lonoke, Arkansas, on May 14, 1975. These fish, averaging 90.9 grams and 200.7 millimeters total length (Figure 1), were transported from Lonoke to Knoxville, Tennessee, in a 275 gallon fiberglass tank which was aerated by 110 volt agitators. Water temperature on departure from Lonoke was 21°C and upon arrival in Knoxville was 24°C. Water in the transport tank was treated with acriflavin at approximately one part per million to lessen chance of bacterial disease due to stress during transportation and handling. The fish were acclimated and stocked immediately on arrival at the research ponds.

A total of nine ponds were used for the study. The seven experimental and two holding ponds ranged in size from .13-2.5 acres (.02-1.00 hectares) (Table 1). Eight of the ponds were located on the Energy Research and Development Administration's (ERDA) Oak Ridge, Tennessee, Reservation; the other pond was privately owned and located in North Knox County, Tennessee. All ponds were utilized by livestock at some time during the course of the study.

Experimental ponds were stocked at two densities, 25 and 40 per acre, and the two holding ponds were stocked at 100 per acre. A total of 193 fish were stocked (Table 1). Nomenclature of the ponds appears in Table 1 and will be used to identify individual ponds throughout this paper.

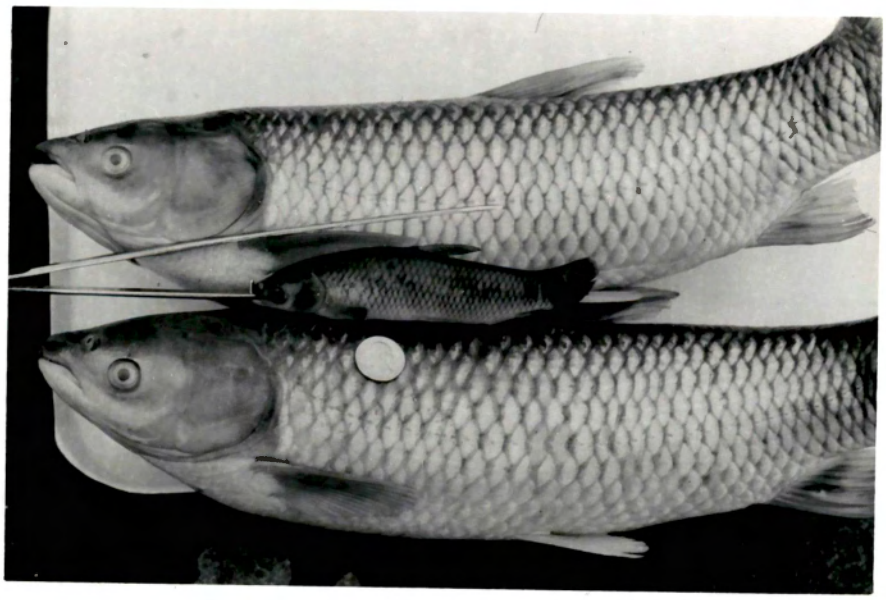


Figure 1. Photograph of white amur showing the size stocked and size recovered.

TABLE 1

LISTING OF PONDS BY CODE INCLUDING THE SIZE, STOCKING RATE, AND NUMBER OF WHITE AMUR STOCKED PER POND

Pond Code	Size (Acre)	Stocking Rate Per Acre*	Number of Fish Stocked
BV1	.42	25	15
BV2	.10	100	10
BV3	.33	25	13
BV4	.13	25	9
BV5	.05	100	5
QP1	.49	40	26
GB2	.44	40	22
CR1	.40	40	26
SP1	1.00	25	67

*Actual stocking rates were increased by 10% to allow for natural mortality and fish removed for stomach analyses.

Five of the experimental ponds contained established fish populations and two ponds had no fish. The species present in each pond are given in Table 2 and were determined by random seine hauls in each pond. Pond BV3 was treated with rotenone at one part per million as a check and no fish were found.

Most of the ponds contained much vegetation; representative samples from each pond are presented in Table 3.

One-by four-inch welded wire enclosures mounted on steel fence posts and encompassing a 10 meter square area were placed in ponds CR1, BV1, SP1, and GB2. The enclosures were set over patches of thick vegetation and visual observations were made during the course of the study as to the amount of vegetation inside as compared to the outside. Ponds CR1, BV1, and GB2 contained two enclosures each; five enclosures were placed in SP1. An effort was made to include representative plants from each pond within the area of each enclosure. This was done in order that observations might be made on the selectivity and preference for certain plants by the white amur and also as a measure of the degree of control, if any, the white amur was having on vegetation in the individual ponds.

At random times during the course of the study white amur were taken from each pond and sacrificed for stomach analysis. One particular attempt was made to take white amur from ponds CR1, BV1, and QP1 when the nests of other fish were observed. The white amur obtained for stomach analysis were collected by seine hauls. In addition a trap net (1-inch mesh) was set in SP1 after thick vegetation prevented successful seining. Stomachs were taken immediately and placed in 10%

TABLE 2

SPECIES OF FISH PRESENT IN THE STUDY PONDS

Pond	Species of Fish
BV1	Bluegill, Green Sunfish, Largemouth Bass Bluegill♀ x Green Sunfish♂ Hybrids
BV3	No fish
BV4	Bluegill, Green Sunfish Bluegill♀ x Green Sunfish♂ Hybrids
QP1	Largemouth Bass, Bluegill, Green Sunfish
CR1	Green Sunfish, White Crappie, Largemouth Bass, Bluegill
GB2	No fish
SP1	Largemouth Bass, Bluegill, Redear Sunfish, Channel Catfish

TABLE 3

REPRESENTATIVE VEGETATION AND PERCENT COMPOSITION IN STUDY PONDS

Pond	Vegetation	Percent Composition (Approximate)
BV1	Typha sp.	15
	Chara sp.	65
	Salix sp.	10
	Eleocharis sp.	5
	Spirogyra sp.	5
BV3	Typha sp.	15
	Juncus sp.	20
	Salix sp.	10
	Chara sp.	50
	Spirogyra sp.	5
BV4	Typha sp.	80
	Potemogeton spp.	15
	Spirogyra sp.	5
SP1	Typha sp.	5
	Potemogeton spp.	35
	Nymphaea odorata	55
	Spirogyra sp.	5
GB2	Juncus sp.	40
	Polygonum sp.	40
	Elodea sp.	15
	Spirogyra sp.	5
QP1	Spirogyra sp.	50
	Panicum spp.	50
CR1	Salix sp.	10
	Spirogyra sp.	50
	Panicum spp.	40

formalin for later evaluation (Terrell and Fox, 1974). The entire gut (pharynx to anus) was considered to be the stomach.

Stomach content analysis was performed by opening the gut from the anus to the pharynx and rinsing the contents into a white porcelain pan and examining macroscopically. Contents of the porcelain pan were then poured through a series of #20, #40, and #100 sieves and allowed to drain for 15 minutes. After this period, a wet weight was taken for the contents of each sieve and combined to give a total wet weight of stomach contents. Each stomach was examined by diluting 0.5 gram (wet weight) samples with 25 milliliters of water and placing them in gridded petri dishes. Each petri dish was then searched with a dissecting microscope. Contents from 12 stomachs were examined completely using this method. Ten stomachs were sub-sampled by weighing out one 0.5 gram (wet weight) portion per sieve and searching with the dissecting microscope. Stomach contents were classified as plant matter, animal matter, and unidentified. When possible all identified material was classified to the specific level but the degree of mastication usually permitted identification only to genus or in some cases family. Volumetric determinations were not made due to the difficulty encountered when trying to separate semi-digested material.

Catchability was determined by angling with four different types of lures and bait materials. Angling was done at various times of the day and pond selection was at random. An attempt was made to fish each pond approximately the same number of angler-hours per bait or lure. Angling began on July 14, 1975, and ended October 24, 1975, with most being done by the author.

Lures and bait materials were as follows: 1) artificial floating minnow types, 2) spinner, 3) live earthworms, and 4) vegetation (aquatic and terrestrial). Lures were cast and retrieved at various speeds and with different actions. Bait materials were either fished on the bottom or suspended by means of a bobber. Lures and bait materials were usually fished for one-half hour or one hour time periods. All fish caught were recorded as to species, number per angler hour, and number per bait or lure, and returned to the pond. White amur caught were weighed and measured and also returned. When white amur were seen swimming near the shore or surface, lures and bait materials were cast directly to them in order to observe their reaction.

Organoleptic properties of the grass carp were evaluated by a 28 member taste panel. Grass carp were collected from experimental ponds by weining, as were the other fish used in the organoleptic evaluation. Three other species of fish were used in the taste comparison: largemouth bass, bluegill, and channel catfish. Following the methods of Wilson, Hord, and McCarty (1973), all fish were skinned and filleted; fillets were frozen into 8-inch square blocks. Uniform portions of fish (1-inch x 1/2-inch) were cut from the blocks and prepared for the taste panel. The portions were battered and breaded[1] and deep-fried at 400°F until done. Portions were held at 200°F until served. Samples were given a three-digit code and served on paper plates appropriately marked. The samples were scored on a six-point hedonic rating scale

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[1]Batter #70-65, Breader #48-01, Golden Dipt Company, Millstadt, Illinois 62260.

with the following range of responses: 1 = like very much; 2 = like moderately; 3 = like slightly; 4 = dislike slightly; 5 = dislike moderately; and 6 = dislike very much. A sample scoring sheet is presented in the Appendix. Rating scores were tabulated and analyzed statistically to determine any significant differences in taste preference.

At the end of the study, ponds BV1, BV2, BV3, BV4, and BV5 were treated with one part per million rotenone to eradicate all fish. White amur were removed from QP1 by drawdown and seining and from GB2 by seining. Pond CR1 was electrofished. White amur were not removed from SP1 but were left as a continuing project.

Coefficients of condition (K) were calculated by the formula

$$K = \frac{100\ W}{L^3}$$

where K is the calculated coefficient of condition, W is the weight of the particular fish in grams, and L is the length of the same fish in centimeters.

CHAPTER IV

RESULTS

Grass carp were collected from all study ponds (except SP1) at the end of the study using one or a combination of methods: chemical renovation using rotenone, drawdown and/or seining, electrofishing, and a trap net. The recovery of white amur and the technique employed is shown in Table 4. Ponds BV1, BV2, BV3, BV4, and BV5 were treated with rotenone at one part per million to eradicate all fish. Unexpected results were obtained from this procedure in that very few white amur were recovered. A total of 52 grass carp were stocked in these ponds and only 16 were eventually recovered, either by previous seining for stomach analysis or by the application of rotenone.

Pond QP1 was drawn down and seined to recover white amur and of 26 fish stocked, a total of 8 were recovered either by this procedure or by seining for stomach analysis. Seining to recover white amur from pond GB2 yielded 6 of 22 fish stocked. Electrofishing in pond CR1 on March 15, 1976, produced no fish but 9 fish had previously been recovered by seining for stomach analysis and organoleptic evaluation. Pond CR1 had been stocked with 26 white amur.

All experimental methods employed in the study were based on the original numbers of white amur stocked. The realization that unexpected mortality had occurred led to reevaluation of the data. Only 34 of 91 (37%) fish stocked in ERDA study ponds were recovered. White amur were left as a continuing project in SP1; no estimate has been made as to their survival.

TABLE 4

RECOVERY OF GRASS CARP FROM STUDY PONDS

Pond	Number Stocked	Number Recovered	Method*	Percent Recovery
BV1	15	3	R,D	20
BV2	10	4	R	40
BV3	13	2	R,D	15
BV4	9	6	R,D	67
BV5	5	1	R	20
CR1	26	9	S,E	38
QP1	26	8	D,S	30
GB2	22	6	S	27
SP1	67	2**	S,T	--
Totals	193	41	Average	32

*R = rotenone, D = drawdown, S = seining, E = electrofishing, and T = trap net.

**White amur were not recovered from SP1 but left for future study.

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A. CATCHABILITY

The seven experimental ponds were fished a total of 426.25 angler-hours. The number of hours fished in each pond along with the number of hours each bait or lure was fished in the respective pond is given in Table 5. Although seven other white amur were hooked, only two were actually landed during the catchability experiments. This computes to a catch rate for all ponds of .0046. Both white amur caught and the others that were hooked fell prey to earthworms as bait. The method of fishing the earthworms was not significant for strikes were noted with each method. Of the two fish that were caught, one in QP1 was caught when the earthworms were fished on the bottom and the other white amur was caught in pond BV4 with the earthworms suspended in the water column. No white amur were caught or hooked on any of the other baits or lures. Grass carp were, however, attracted to the spinner or the minnow lure when it was cast to them, as evidenced by them actively following the lure. On one occasion in pond CR1, a single fish did strike at the minnow lure as it was slowly fished along the surface. Repeated casts to this fish and the use of this same retrieve on other days failed to produce another strike. On several occasions, anglers fishing in pond SP1 reported grass carp "nudging or playing with" a minnow lure fished on the surface. It should be noted though that none of the anglers believed the white amur was trying to devour the lure.

As mentioned before, several other strikes and hookings of white amur were observed. On four separate days white amur were hooked in ponds GB2, BV3, and BV4, and in all cases the fishing line was broken.

TABLE 5

ANGLER-HOURS FISHED IN EXPERIMENTAL PONDS

Bait	POND						
	BV1	BV3	BV4	QP1	CR1	GB2	SP1
Earthworms	14.5	27.5	15.0	13.5	13.0	35.5	18
Vegetation	15.5	16.0	18.0	13.5	17.5	17.0	18
Spinner	11.5	14.5	10.5	11.0	11.75	11.5	11
Minnow Lure	10.0	14.0	11.0	14.5	11.0	17.0	15.5
Total	51.5	72.0	54.5	52.5	53.25	81	62.5

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It was also noted that the fishing line was extremely frayed a few centimeters above the break.

In those ponds (CR1, QP1, BV1, BV4, and SP1) containing other fish (Table 2, page 15) as well as white amur, numerous other species were caught. Those caught most often were largemouth bass and hybrid sunfish. Largemouth bass were caught mainly on the floating minnow lure and spinner while hybrid sunfish, bluegill, and green sunfish preferred earthworms or the spinner. No fish were caught or strikes observed on vegetation as a bait.

B. ORGANOLEPTIC EVALUATION

Rating scores of the 28 taste panel members for the organoleptic evaluation of the flesh of white amur, largemouth bass, bluegill, and channel catfish are presented in Table 6. Analysis of the data and comparison of the means by Duncan's New Multiple Range Test revealed a significant difference at the .05 level in the taste preference of the four species (Table 7). A definite preference was shown for channel catfish over that of largemouth bass, white amur, and bluegill. Channel catfish was rated 1 (like very much) by 50% (14) of the panelists. Of 28 taste panel members, five gave the white amur a score of 1 and seven scored it as 2 (like moderately). In all, 64% (18 of 28) of panelists gave scores indicating they enjoyed the taste of white amur. From those panelists indicating a dislike, seven were scores of 4 which rated slightly less than neither like nor dislike.

During the taste panel it became evident that some panel members were aware that grass carp was one of the species being evaluated. To

TABLE 6

RATING SCORES OF 28-MEMBER TASTE PANEL FOR WHITE AMUR, LARGEMOUTH BASS, BLUEGILL, AND CHANNEL CATFISH*

	Number Panelists Rating Each Sample			
Rating	White Amur	Largemouth Bass	Bluegill	Channel Catfish
1	5	2	10	14
2	7	15	9	8
3	6	7	5	5
4	7	3	3	0
5	3	0	1	0
6	0	1	0	1
Mean Score**	2.15	2.08	1.92	1.81

*Rating Score: 1 = like very much, 2 = like moderately, 3 = like slightly, 4 = dislike slightly, 5 = dislike moderately, 6 = dislike very much.

**Data was transformed by $\sqrt{x}$ + .5.

TABLE 7

SIGNIFICANCE BETWEEN MEAN SCORES OF WHITE AMUR, LARGEMOUTH BASS, BLUEGILL, AND CHANNEL CATFISH AS SHOWN BY DUNCAN'S NEW MULTIPLE RANGE TEST*

White Amur	Largemouth Bass	Bluegill	Channel Catfish
2.15	2.08	1.92	1.81

*Data was transformed by $\sqrt{x}$ + .5.

check for any bias due to knowledgeable versus naive panel members, the scores of those considered knowledgeable or naive were analyzed separately and their variances compared. The summary of each analysis of variance for the knowledgeable and naive panel members is presented in Table 8. The comparison of the MS values for the two groups showed no large difference, thus allaying the fear of any bias.

Grass carp was also served to 40 persons at the annual Wild Game Supper hosted by The University of Tennessee Student Chapter of the Wildlife Society. The four rating categories were very good, good, fair, and poor. Percentages of tasters scoring in these categories were 35, 43, 18, and 5, respectively. This was an unplanned evaluation by persons totally naive to grass carp and the results were that 78% (very good plus good) of tasters rated it as acceptable table fare.

C. STOMACH ANALYSIS

Great difficulty was encountered when searching the contents of the stomachs in the porcelain pan because of the large amount of material contained in most stomachs. Few specific items were identified in this manner because it was often not possible to see the bottom of the pan. Separation of stomach contents into "workable units" was achieved when the contents of the pan were poured through the sieves. Animal matter, mostly insects, insect parts, or mussels, were found in all stomachs examined. Although most stomachs contained only a few individual items such as chironomid larvae or insect parts, the contents of some stomachs were almost totally animal matter. Specifically, the stomachs of fish from pond CR1 contained very little

TABLE 8

ANALYSIS OF VARIANCE FOR COMPARISON OF MS-VALUES OF 28-MEMBER TASTE PANEL, KNOWLEDGEABLE AND NAIVE PANELISTS†

Source	df	MS	F
	28-Member Taste Panel		
Samples	3	5.727	4.33*
Pooled**	108	1.323	
Total	111		
	Knowledgeable Panelists		
Samples	3	5.72	3.60*
Pooled**	16	1.589	
Total	19		
	Naive Panelists		
Samples	3	10.77	7.50*
Pooled**	88	1.436	
Total	91		

†Transformation of data by $\sqrt{x}$ + .5 also revealed no bias.

*Significant at the .05 level.

**Error plus panelists.

vegetation but great quantities of chironomid larvae, mussels (Sphaeriidae), and caddis fly larvae (Table 9). Fish stomachs from pond GB2 contained large numbers of Chaoborus spp. larvae and pupae. Crustaceans (Cladocera, Ostracoda, and Copepoda) and chironomid larvae occurred rarely in the stomach contents of white amur from ponds BV1, BV3, BV4, and SP1. The stomach contents of fish from these ponds were large amounts of highly masticated plant matter. Stomach contents from QP1 fish taken early in the study contained numerous crustaceans and chironomid larvae but those stomachs taken near the end or at the conclusion of the study revealed large quantities of vegetation and little animal matter.

It was evident during examination of stomach contents that those stomachs containing appreciable amounts of animal matter also contained large quantities of mud and sand. Two stomachs taken from fish on September 30, 1975, from pond CR1 contained essentially mud and sand. When sieved the mud and sand washed through the sieves and only a small portion of the two stomachs' original content remained and was mainly detritus and chironomid larvae.

Identification of plant material contained in stomachs examined was all but impossible due to its highly masticated condition. However, it was possible to identify Spirogyra sp. and Chara sp. because filaments of Spirogyra sp. remained intact and were found in conjugation with mature zygospores. Chara sp. was identified by the presence of the oogonia, a gamete structure indigenous to Chara sp. Few seeds or other gamete structures that could lead to identification of other plants were found.

TABLE 9

PERCENT COMPOSITION OF MATERIAL FROM STOMACH ANALYSIS OF WHITE AMUR

Pond	Sample Date	Percent Animal	Percent Plant	Percent Unidentified
QP1	5/27	90	5	5
	9/30	10	85	5
	9/30*	10	85	5
	9/30*	10	85	5
CR1	6/6	95	1	4
	6/19	90	1	9
	9/30	15	-	85
	9/30*	15	-	85
SP1	6/13	1	99	-
	6/13*	1	99	-
GB2	5/27	60	35	5
	6/19	70	25	5
	6/19*	70	25	5
BV4	5/27	1	99	-
	9/30	1	99	-
	11/11	5	95	-
	11/11*	5	95	-
BV2	11/11*	1	99	-
	11/11*	1	99	-
BV1	6/6	1	99	-
	11/11*	1	99	-
	11/11*	1	99	-

*Sub-sampled.

During analysis of the stomachs, a parallel between stomach contents and amount of adipose tissue around the gut was noticed. There appeared to be a direct relationship as to the amount of adipose tissue and what a particular grass carp had been utilizing as a food source. Those stomachs that contained large amounts of plant material had large quantities of adipose tissue around the gut; those containing large amounts of animal matter possessed small quantities of adipose tissue.

No fish or fish eggs were found in the 22 stomachs examined. Nests of largemouth bass, bluegill, and hybrid sunfish were observed in all experimental ponds containing these fish. Grass carp stomachs obtained on May 27, 1975, and June 6, 1975, were taken when the nests of the other species were present. Also, fry of bluegills, hybrid sunfish, and largemouth bass were observed in all ponds containing these species and were captured when seine hauls to remove grass carp for stomach analysis were made.

The coefficients of condition (K) calculated for all fish recovered are shown in Table 10. Since this data is intermittent, no definite conclusions can be drawn from it; however, the general trend shown is that coefficients of condition (K) improved during the course of the study. Those fish in ponds (SP1, GB2, BV1, BV2, BV3, and BV5) with large amounts of plant matter seem to show a better average coefficient of condition (K) than those in ponds (QP1, CR1, and BV4) that had little or no vegetation.

TABLE 10

COEFFICIENTS OF CONDITION (K) FOR RECOVERED WHITE AMUR

Pond	Date	Number White Amur	Range		Average		Average
			Weight (Grams)	Length (Millimeters)	Weight (Grams)	Length (Millimeters)	K
QP1	5/27	1	---	---	94	216	.93
	9/30	3	560-1085	358-445	815	402	1.22
	12/10	2	710-727	390-398	719	394	1.17
	2/4/76	2	509-767	368-412	638	390	1.06
CR1	6/6	1	---	---	159	260	.90
	6/19	1	---	---	195	267	1.02
	9/30	2	710-850	392-427	780	410	1.13
	12/10	5	492-751	348-408	655	386	1.12
SP1	6/13	2	335-345	279-298	340	289	1.42
GB2	5/27	1	---	---	78	203	.93
	6/19	2	300-336	279-318	318	299	1.21
	2/4/76	3	1379-1672	463-508	1541	489	1.31

TABLE 10 (continued)

Pond	Date	Number White Amur	Range		Average		Average
			Weight (Grams)	Length (Millimeters)	Weight (Grams)	Length (Millimeters)	K
BV4	5/27	1	---	---	110	229	.92
	9/30	1	---	---	655	379	1.20
	11/11	4	640-900	381-433	777	406	1.15
BV3	11/11	2	2299-2362	546-553	2330	550	1.40
BV2	11/11	4	1306-1730	470-499	1502	487	1.29
BV1	6/6	1	---	---	219	260	1.25
	11/11	2	1551-1821	492-532	1686	512	1.26
BV5	11/11	1	---	---	1000	446	1.12

D. HABITAT IMPACT

Evidence of some changes in plant densities was observed in the experimental ponds. Ponds showing the greatest reduction of plant growth were GB2, BV3, CR1, and BV1. In BV3, soft rushes (Juncus sp.) were cropped off just below or near the water line (Figure 2). Also, there was some evidence of grass carp utilizing cattails (Typha sp.) and Chara sp. in pond BV3. A definite "browse line" can be seen in the dense stands of cattails that were present in BV1 (Figure 3). Enclosures placed in BV1 were choked with vegetation such as Chara sp. (Figure 4) and Panicum spp. (Figure 5); little plant growth existed outside the enclosures. At the end of the study, the only plants found in CR1, except willows (Salix sp.), were inside the enclosures. The pond bottom in CR1 was void of plant growth. Dense stands of Polygonum sp. and soft rush (Juncus sp.) were observed inside enclosures in GB2 but not outside.

In SP1 no reduction was observed on the dense growth of fragrant water lily (Nymphaea odorata) and Potemogeton spp. However, on two occasions white amur were observed feeding on the leaves of the water lily. Grass carp were observed pulling on cattail leaves that were bent and extending into the water in BV4. No definite results in plant reduction could be observed in QP1. Spirogyra sp. was present in most grass carp stomachs examined and evidently was being heavily utilized but conclusions as to the extent of utilization could not be ascertained.

At the conclusion of the study, QP1, BV1, BV3, and BV4 were drained as part of pond renovation; when the pond bottoms were exposed, little or no plant growth was observed.



Figure 2. Photograph of soft rush (Juncus sp.) in study pond BV3 showing evidence of control by white amur.

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Figure 3. Photograph of cattails (Typha sp.) showing "browse line" in study pond BV1.

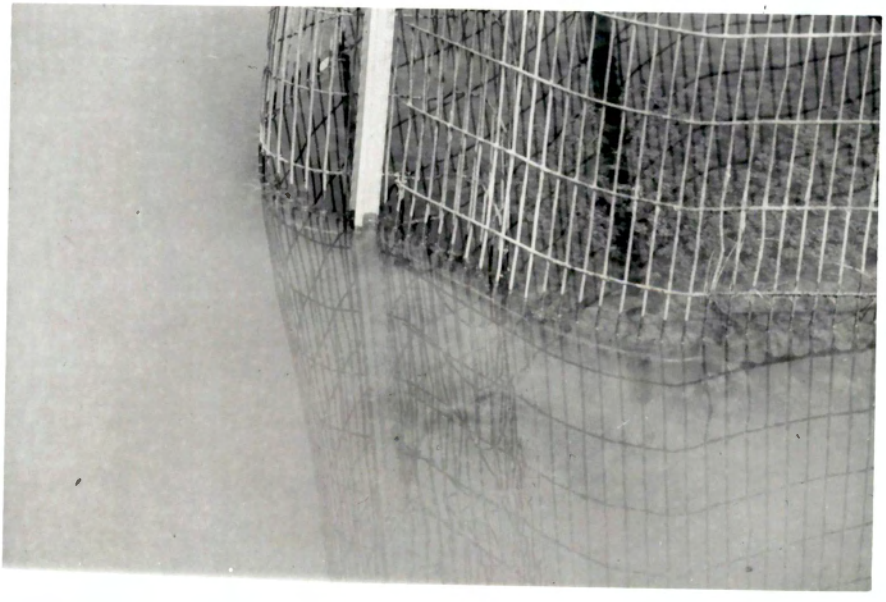


Figure 4. Photograph of Chara sp. showing dense growth inside enclosure but not outside.



Figure 5. Photograph of Panicum spp. showing growth inside enclosure as compared to outside.

CHAPTER V

DISCUSSION

A. CATCHABILITY

The results of the catchability experiments were greatly affected by the high mortality of white amur (62%). The assumption had to be made that the fish recovered at the end of the study constituted the total population during the study. The only ponds that lend themselves to a discussion of catchability are CR1 and BV4 because BV4 had the best percent survival (67%) and approximately 15 white amur were observed swimming in CR1 on the last day the pond was fished. In all other ponds the mortality was such that the data for catchability experiments were considered unreliable.

Possible explanations for the high mortality experienced in the study are: 1) turbidity caused by watering livestock and heavy rainfall may have shaded out vegetation and reduced the O_2 level in the ponds, 2) high temperatures coupled with the possible drop in O_2 level due to turbidity, 3) presence of fungus was noted on a few fish transported from the Joe Hogan State Fish Hatchery (although all fish were transported in one part per million acriflavin, the possibility exists that all fish may have been infected and only the hardiest individuals survived), 4) predation by largemouth bass in QP1 is a possibility since seine hauls revealed largemouth bass capable of preying on the small grass carp that were stocked, and 5) poaching may have been a problem but was not clearly evident.

Exactly why the survival rate for grass carp in BV4 was higher than any of the other ponds is not clearly understood. A possible explanation is that BV4 on at least three occasions during the study overflowed due to heavy rainfall. It is possible that a "flushing effect" enabled the grass carp to survive due to lower average water temperatures and increased dissolved oxygen levels. None of the other study ponds experienced overflow or a substantial rise in water level.

The most perplexing aspect of this high mortality is that no dead fish were ever observed during the study and none observed were acting in a stressed, diseased, or "unnatural manner." With such high mortality it is thought that at least some dead fish would be observed. It is possible that decomposition or scavengers quickly disposed of any dead white amur but this does not seem likely considering the number (56) of white amur that were not recovered. All experimental ponds were checked the day after stocking and grass carp were observed swimming leisurely in each pond. Visits to the ponds averaged two per week throughout the study and dead or sick fish would have been noticed. However, it is possible that turbidity may have obscured dead fish and they decomposed without ever being observed.

Compounding the mystery of why there was high mortality are the reports of other researchers (Stevenson, 1965; Bailey, 1972; and Cross, 1969) that the white amur is a highly adaptable and tolerant fish. Stevenson (1965) lists ranges of tolerance as water temperature, 0°-35.6°C, and oxygen concentrations as low as 0.5 parts per million. The fact that white amur disappeared but not a single observation of fish of another species is truly intriguing.

It is difficult to draw conclusions about the catchability of the white amur when only two fish were caught in 426.25 angler-hours of fishing. This indicates a catch rate of .0046 (number fish/angler-hour) and would not keep anglers interested for very long. In terms of hard evidence for catchability, it is possible to examine BV4 and CR1. In BV4, 67% (six of nine) white amur were recovered. Assuming these fish were the only ones present during the catchability experiment, it can be stated that 17% (one of six) of the population was caught in 54.5 angler-hours. The computed catch rate for BV4 would be .018 which is substantially higher than the .0046 catch rate for all ponds. Although white amur were visually observed and thus could be accounted for in CR1, no white amur were caught from this pond in 53.25 angler-hours. The only conclusion that can be drawn from the data on this pond is that grass carp were not catchable on any bait or lure.

The catch rate of .0046 could have been substantially higher had the fishing line not broken on several occasions due to a fraying of the line. A possible explanation for the fraying and breaking of the line is due to the grinding action of the pharyngeal teeth. Both white amur caught had completely swallowed the earthworms and were hooked deep in the gullet. If the other fish that were hooked also swallowed the bait, then the fishing line would be exposed to the grinding action of the pharyngeal teeth and could become frayed.

There is another factor that could have significant effects as to the sporting potential of the grass carp. Interpretation of results from this study seemingly indicate that if anglers fish for grass carp with earthworms then the probability they will catch bluegill, channel

catfish, largemouth bass, or some other species is far greater than the chance of catching grass carp. It is thought that this would also hold true for the other baits or lures used in this study since large numbers of other species were caught as compared to the number of white amur.

Another aspect of the catchability experiment is that no white amur were caught on vegetation as a bait. Since the amur is considered by many as a voracious herbivore, one would think they would be caught easily with vegetation as bait. Results from this study indicate this was not the case. Possible explanations are: 1) the vegetation used as bait was not presented in a "natural" manner or 2) the vegetation used as bait was not preferred by the white amur. It should be noted, though, that the types of plants that were fished were those occurring in the respective pond or along its shoreline and usually those on which the white amur had been feeding.

The fact that no white amur were caught on the minnow lure or the spinner is not surprising for a herbivore. Reports in the literature (Sneed, 1971; Bailey, 1972; and Prowse, 1971) that grass carp have been caught on these lures is not surprising either. This author tends to agree with Prowse (1971) who states the bait a fish will take is irrelevant. There are a number of factors that can affect what bait or lure a fish will take and all anglers will agree that fish are often caught on some very unusual baits. Many other fish were caught on the floating minnow lure, spinner, and earthworms and this suggests the baits were accessible when presented.

It was noted during the course of the study that grass carp were extremely shy and to observe them "behaving naturally" required a quiet and cautious approach to the pond. This may be a possible explanation to low or lowered catchability in that the presence of anglers on the shore moving about may have caused them to act accordingly and move away from lures and baits or to deeper water.

B. ORGANOLEPTIC EVALUATION

This study, as well as others by Bailey, 1972; Penetelow and Stott, 1965; Okoniewska, 1968; Walker, 1971; Cross, 1969; Sneed, 1971; and Kilgen and Smitherman, 1970, revealed that the white amur is of high quality as a food fish. The fact that 64% (18 of 28) of the taste panel members in this study liked the taste of white amur indicates its acceptability as compared with such favorites as channel catfish, bluegill, and largemouth bass. In the taste panel performed by Walker (in Bailey, 1972), grass carp rated second behind red snapper in taste. In other parts of the world the white amur is cultured primarily as a food fish and a study by Okoniewska (1968) proved white amur flesh to be superior to the highly prized mirror carp. Being the food rich country that it is, the United States has not had to search for supplemental sources of protein as some countries have had to do. However, the widespread acceptance of the white amur abroad will undoubtedly cause it to demand close attention as the population of the western world grows and additional protein sources are required.

As mentioned earlier, it was evident that some (5 of 28) panel members were aware that the grass carp was among those fish being

evaluated. It was revealed, however, that the variances of the knowledgeable versus the naive panel members were within a reasonable tolerance and no hidden bias or inflated variance was indicated.

The general acceptability of the white amur by those tasters participating in the Wildlife Game Supper is another plus for the white amur as a food fish. Of those tasting, 78% indicated they enjoyed the taste of white amur flesh. Since all the participants of the supper were totally naive, their scores are a good indicator that white amur should be highly valued as a food fish by anglers and possibly commercial enterprises.

Troublesome intramuscular bones present in the white amur's flesh was the frequent comment made by panelists. The fish used in the taste panel were small (492-751 grams) and one would expect bones to be more prominent in fish this size. The presence of bones also could have caused some panelists to score lower and thus affect the overall outcome of the taste panel. It is possible that the white amur could have scored somewhat better when this fact is considered. The answer to the problem of bones is relayed in the statement of Dr. Ron Phelps (reported earlier) in which his experience was that bones were no problem in large fish.

C. STOMACH ANALYSIS

Greater amounts of animal matter than previously reported in the literature were found in grass carp stomachs analyzed from CR1, GB2, and QP1. Animal matter has been present in other studies conducting stomach content analyses but of a lower amount than found in this

study. Since animal matter is usually a very small amount of the total stomach content, most authors (Kilgen, 1973; Bailey, 1972; Terrell and Fox, 1974; and Kilgen and Smitherman, 1971) have felt that it is of accidental ingestion.

A possible explanation for the large amounts of animal matter present in stomachs examined from CR1 and QP1 is that virtually no vegetation was growing in these ponds and therefore grass carp resorted to utilizing insects as a food source. The exception to this is pond GB2 which contained large amounts of vegetation, yet great quantities of Chaoborus larvae and pupae were found in the stomach contents. It is also possible that grass carp were actively foraging for insects in GB2, CR1, and QP1 and that whether vegetation was or was not available did not affect their feeding habits. The data from stomachs analyzed from these ponds show large amounts of insects to support this explanation. A third explanation for high amounts of animal matter is that the grass carp were ingesting the bottom debris of ponds and thus would be collecting large amounts of insect larvae and mussels living in and on the substrate. This is supported by the fact that large amounts of mud, sand, and detritus were found in stomachs from QP1, DR1, and GB2. Benthic organisms such as chironomid larvae, Chaoborus larvae and pupae, Ostracoda, Pelecypoda, and Trichopteran larvae were those organisms found in large numbers. Since by their nature benthic organisms live on, in, or near the pond bottom, it is entirely possible that they would be picked up by grass carp feeding on the pond bottom. This explanation is also supported by evidence from Terrell and Fox (1974) who thought starving grass carp were ingesting the pond bottom

in their experiments. Kilgen and Smitherman (1971) report evidence that grass carp resort to eating insects only when absolutely necessary. In their experiment this occurred when vegetation amounts were very low.

Most stomachs analyzed contained only small amounts of animal matter and this was probably due to ingestion along with plant material as reported earlier. The fact that SP1, BV1, BV3, and BV4 contained appreciable amounts of vegetation indicate that grass carp, when given the choice, will choose vegetation but if necessary can subsist rather well on animal matter, particularly insects. This is supported by the general data on coefficients of condition (K) in that they improved for all white amur used in stomach analysis regardless of what food source (vegetation or animal) the fish was utilizing.

D. HABITAT IMPACT

Examination of stomach contents revealed grass carp were utilizing plants where they were readily available. Although some reduction in vegetation densities is attributed to the white amur, it is thought that "shading out" by turbidity was a major factor. Grass carp were evidently eating Juncus sp., Panicum spp., Potemgeton spp., Polygonum sp., Chara sp., and Typha sp. in the experimental ponds. Observations of grass carp feeding on the tougher macrophytes is noteworthy because these plants are among the hardest to control.

E. EVALUATION AS A SPORT FISH

It was indicated from this study that grass carp would not be catchable in significant numbers when stocked into waters containing

other species. Anglers would be more apt to catch another species even if fishing specifically for white amur. Since many opinions prevail as to the fighting aspects of every game fish, it is equally difficult to judge the grass carp. The grass carp was a strong fighter in that all fish hooked made powerful runs and thrashed wildly when attempts to beach them were made.

It was established that as a food fish the white amur would indeed be a choice table fare. Anglers that happen to catch the grass carp should not fear the stigma of "ole carp" but rather delight in its delectable qualities.

White amur could prove to be serious competitors with game fish if vegetation was not available for forage. The fact that in three ponds white amur utilized insects in large amounts in this study made them competitors with other fish in those ponds. Also, the evidence showing improved coefficients of condition (K) for those white amur utilizing insects indicates that they can show growth without vegetation as their main diet.

Reduction of plant densities in ponds by white amur could have a two-fold meaning. In ponds where the main management concern is to control vegetation thus reducing hiding areas for forage fish, the white amur could be stocked to eliminate vegetation thus making forage available. As a management principle this would be excellent in ponds with largemouth bass and bluegill populations since a major problem with this combination is overcrowding of bluegills. The second effect possible from reduced or elimination of plant growth would be loss of

critical habitat to those organisms endemic to marshes, wetlands, or the vegetated areas of lakes and ponds. Waterfowl and fish such as the grass pickerel could lose breeding and preferred habitat thus inflicting damage to their populations.

CHAPTER VI

SUMMARY

1. White amur or grass carp (Ctenopharyngodon idella Valenciennes) were stocked in seven study ponds and evaluated as a sport fish. Evaluation was accomplished by catchability, organoleptic properties, and impact on established fish populations by stomach analysis.

2. Catchability was not significant (catch rate of .0046) to keep anglers interested.

3. Organoleptic properties of the white amur were excellent and it was not significantly different in taste at the .05 level from bluegill or largemouth bass but was significantly different from channel catfish.

4. Stomach analysis revealed white amur utilizing animal matter (insect larvae and mussels) in three study ponds that were low in vegetation. Further analysis indicated white amur in heavily vegetated ponds consumed little animal matter but large quantities of vegetation.

5. Coefficients of condition (K) seemed to show general improvement regardless of what food source the grass carp was utilizing (animal or plant).

6. High mortality (62%) was experienced in study ponds. Turbid conditions were thought to be a major factor in low survival.

7. White amur possibly reduced some plant densities but turbid conditions also reduced plant growth due to "shading out."

8. Indications are the white amur has marginal potential as a sport fish.

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APPENDIX

ORGANOLEPTIC SCORE SHEET

NAME _____

Instructions: Evaluate these samples as to overall acceptability (taste, texture, color, oiliness, etc.) and determine how much you like or dislike each one. Use the appropriate scale to show your attitude by checking the point that best describes your feeling about that particular sample. Please give a reason for this attitude.

	Code 899	Code 456	Code 743	Code 576
Like very much	____	____	____	____
Like moderately	____	____	____	____
Like slightly	____	____	____	____
Dislike slightly	____	____	____	____
Dislike moderately	____	____	____	____
Dislike very much	____	____	____	____

Reason:	Reason:	Reason:	Reason:

VITA

Kirby Darrell Cottrell was born in Middlesboro, Kentucky, on September 5, 1951. He attended public schools there and was graduated in May, 1969. The following fall he entered The University of Tennessee, Knoxville, and was graduated with a Bachelor of Arts degree, major Zoology. In September, 1973, he began graduate studies at The University of Tennessee, Knoxville, and received the Master of Science degree with a major in Wildlife and Fisheries Science in June, 1976.

He is married to the former Margaret Gail Sanner of Decatur, Illinois.