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USE OF THE WHITE AMUR FOR AQUATIC PLANT MANAGEMENT

by

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20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*

This manual is a practical guide for operations use in managing problem submersed aquatic plants with the white amur fish. The instructions reported herein are based on the Large-Scale Operations Management Test conducted in Lake Conway near Orlando, Fla. Detailed data and analyses of this very extensive study may be obtained in a series of reports on the project published by the U.S. Army Engineer Waterways Experiment Station through its Aquatic Plant Control Research Program.

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PREFACE

This manual was written as a practical guide for the operational use of the white amur as a biological control tool for managing submersed aquatic vegetation in situations where it is possible and practical. The guide is based on extensive evaluation of the white amur in the Large-Scale Operations Management Test (LSOMT) in Lake Conway, near Orlando, Fla. The LSOMT was sponsored by the Office, Chief of Engineers (OCE), and the U.S. Army Engineer District, Jacksonville, and conducted through the Aquatic Plant Control Research Program (APCRP) at the U.S. Army Engineer Waterways Experiment Station (WES) with the major portions of the field work performed under contract with agencies of the State of Florida and Orange County. Preparation and publication of this manual was sponsored by OCE. Technical monitor at OCE for the APCRP is Mr. E. Carl Brown.

Although massive amounts of data and subsequent analyses are available in other publications on the LSOMT, the information in this guide is a summary of pertinent results considered appropriate for a user manual. This manual was prepared by Dr. Andrew C. Miller and Mr. J. Lewis Decell of the Environmental Laboratory (EL) at WES. Dr. John Harrison was Chief, EL, and Mr. Decell was Manager, APCRP.

Commander and Director at WES during the preparation of this manual was COL Tilford C. Creel, CE. Technical Director was Mr. F. R. Brown.

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CONTENTS

CONVERSION FACTORS, U.S. CUSTOMARY TO METRIC (SI) UNITS OF MEASUREMENT

U.S. customary units of measurement used in this report can be converted to metric (SI) units as follows:

Multiply	*By*	*To Obtain*
acres	4046.873	square metres
Fahrenheit degrees	5/9	Celsius degrees or Kelvins*
feet	0.3048	metres
inches	25.4	millimetres
pounds (mass)	0.4535924	kilograms
pounds (mass) per acre	0.000112	kilograms per square metre
tons (mass) per hectare	0.09072	kilograms per square metre

* To obtain Celsius (C) temperature readings from Fahrenheit (F) readings, use the following formula: C = (5/9) (F - 32). To obtain Kelvin (K) readings, use K = (5/9) (F - 32) + 273.15.

USE OF THE WHITE AMUR FOR AQUATIC PLANT MANAGEMENT

PART I: INTRODUCTION

Background

The Aquatic Plant Control Research Program (APCRP) of the U. S. Army Corps of Engineers was authorized by Section 302 of the River and Harbor Act of 1965, Public Law 89-298. This research program is tasked with the responsibility of developing effective and economic macrophyte control techniques for implementation in navigable waterways, tributary streams, and other allied waters for the purposes of flood control, navigation, recreation, agriculture, fish and wildlife, and public health. As part of the APCRP, and in response to the Jacksonville District (SAJ), the Large-Scale Operations Management Test (LSOMT) at Lake Conway, Florida, was initiated. The LSOMT was specifically designed to test the use of the white amur (*Ctenopharyngodon idella*) for control of aquatic macrophytes on a large scale. In addition, it was the intent of this research to investigate the effects of the white amur stocking on native fish, waterfowl, reptiles, amphibians, zooplankton, phytoplankton, aquatic macrophytes, and water and sediment chemistry in a large lake system. Scientists working on this project collected data on the fate of the fish through time—how their numbers, size, biomass, and dietary habits changed during the course of the study. All aspects of working with the fish were investigated: the possible need for restocking, movements within the water body, growth rates, and feeding preferences. A computer-accessed model was developed and revised several times that can be used to select stocking rates based on the predicted effect of the white amur on existing and projected growth of submersed vegetation.

Data for the LSOMT at Lake Conway were collected for a minimum of 1 year prior to introduction, and up to 4 years following introduction of the fish. A major emphasis of this work was to base stocking rates and study objectives on the knowledge of initial conditions as well as projected future conditions. The purpose was to integrate the methodology into the existing ecosystem, to manage, and not eradicate, plant communities. It was intended that results of this study could be extrapolated to other large-scale operational uses of the white amur.

Purpose and Scope

The purpose of this manual is to present practical guidelines for the use of the white amur to manage aquatic vegetation in lakes and ponds. This document will introduce the reader to the white amur as a biological control agent for submersed aquatic plants, and present information necessary for successful use of the fish.

Included are methods for calculating the number of fish required to effect a desired level of plant control, as well as information on obtaining, shipping, and releasing white amur. Data on feeding, growth rates, food preferences, reproduction, and tolerances to various aquatic conditions are also presented. Case studies on the use of the fish are discussed to illustrate possible impacts of white amur on water chemistry and native biota. While the majority of the information for this report originated with the LSOMT in Lake Conway, Florida, the fish is a viable control agent in other parts of the country. This manual should have utility in all parts of the United States in providing background data on the white amur and concise information on the proper use of fish to control submersed aquatic plants.

PART II: THE WHITE AMUR

History of Usage

The Chinese have raised white amur as a source of protein since the tenth century.* In 1956, when techniques for mass transport became available, the Soviets began large-scale importation of these fish for food. During the 1960's, the white amur was brought into Western Europe for plant control and into Eastern Europe for food. To date, the white amur has been introduced into over 50 countries worldwide as a protein source and plant control agent. They have been used in enriched waters from sewage treatment plants, in fallow rice fields, in the cooling reservoirs of power-generating stations, and in canals, ponds, lakes, large rivers, and reservoirs.

In 1962, representatives from the U. S. Fish and Wildlife Service, Auburn University, United Nations Food and Agriculture Organization, and the Arkansas Fish and Game Commission brought the white amur into the United States for study. The following year, the fish was stocked at Auburn University and the Fish and Farming Experiment Station in Stuttgart, Ark. In 1966, the imported fish reached maturity and were spawned with limited success. The fish were then successfully spawned in 1970 and 1971. Beginning in 1970, the Arkansas Game and Fish Commission began an extensive stocking program and introduced this fish into 115 lakes and ponds in Arkansas.

Range in the United States

Since its introduction in 1963, the white amur has achieved a wide distribution in the United States (Table 1 and Figure 1). While most records have been from Florida and waters near Arkansas, it has been recorded in the north (Michigan and Wisconsin), the northeast (Vermont), and the west and southwest (California and Nevada). It has been estimated that 35 to 40 states have stocked the white amur for

* To enhance readability, the majority of the literature citations have been omitted from the text. See Appendix A for scientific literature used to compile this manual.

Table 1

White Amur Distribution in the United States, 1963 to 1977*

State	*I*	*II*	*III*
Alabama	X	X	X
Arizona	X	X	
Arkansas		X	X
California	X	X	
Colorado	X	X	
Connecticut	X		
Florida	X	X	X
Georgia	X	X	X
Illinois	X	X	X
Indiana	X	X	
Iowa	X	X	X
Kentucky	X		X
Louisiana	X	X	X
Maryland	X		
Michigan	X	X	
Mississippi	X	X	X
Missouri	X	X	X
Nebraska	X		X
Nevada	X		
New Hampshire	X		
New Jersey	X		
New Mexico	X		
New York	X		
North Carolina	X		
North Dakota	X	X	
Ohio	X	X	
Oklahoma	X	X	
Oregon		X	
Pennsylvania	X	X	
Puerto Rico	X	X	
South Carolina	X		
South Dakota	X	X	
Tennessee	X	X	X
Texas	X		
Virginia	X		
West Virginia	X		
Wisconsin	X	X	
Total	31	20	12

* After Guillory and Gasaway (1978). Column I gives instances of importation from private hatcheries; II gives research efforts; III gives collection records of wild fish.

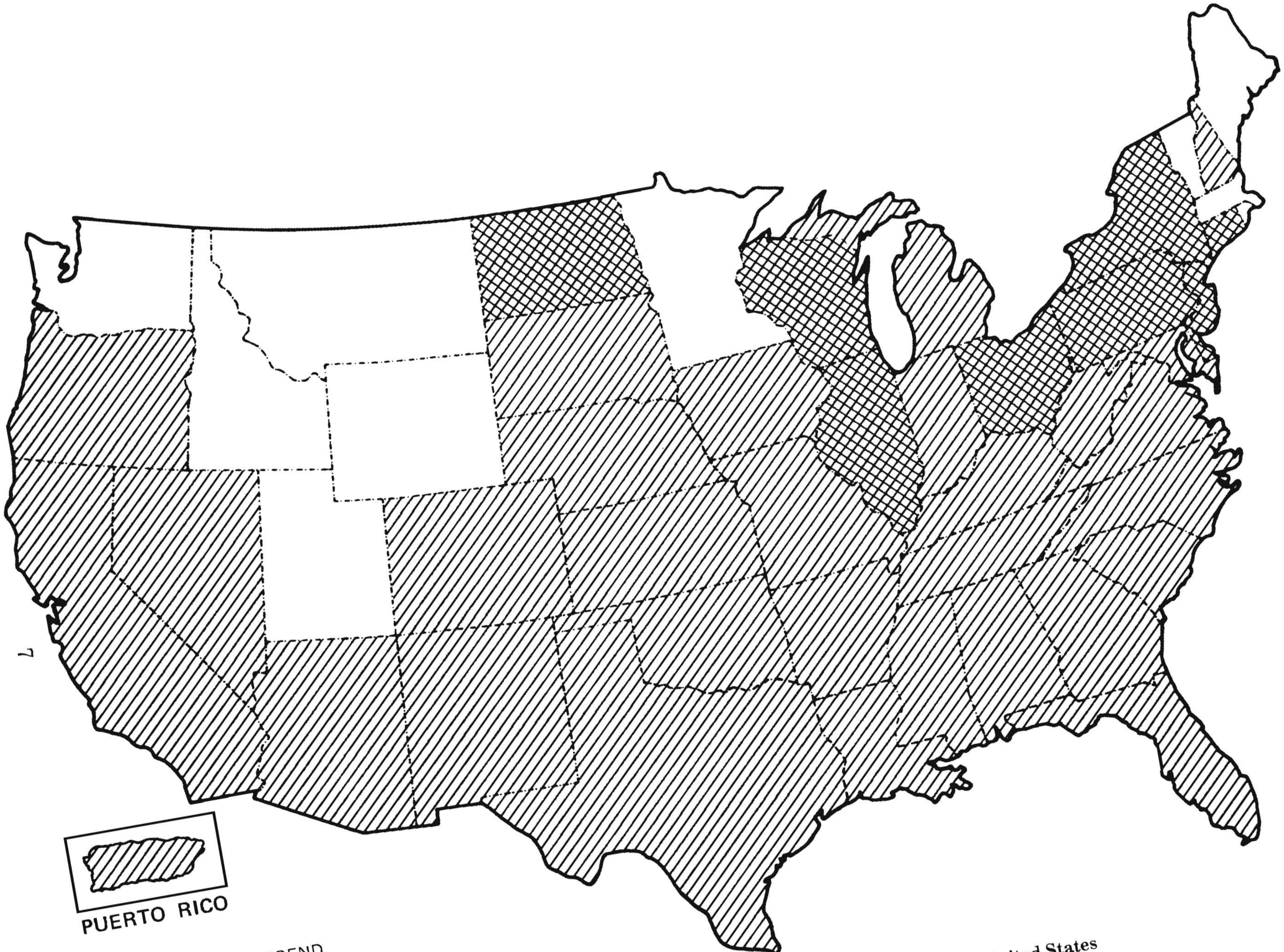

Figure 1. Reported distribution of the white amur in the United States

experimental or weed control purposes at one time or another. This fish is common in rivers in the Mississippi Valley, especially the Missouri, middle Mississippi, and the Ouachita Rivers. White amur have also been collected in the Altamaha and Chattahoochie Rivers in Georgia; the Coosa and Black Warrior Rivers in Alabama; and the North Bay and Econfina Creek in Florida. Private companies have imported white amur into Louisiana, Oklahoma, Texas, Maryland, Arkansas, Michigan, Ohio, and Indiana.

Early Studies

In the United States, the majority of work with the fish has been conducted in Florida, Arkansas, and Alabama. The most intensively studied and controversial investigation involved four ponds located in the central part of the state of Florida. The fish controlled vegetation to a varying extent in all of the ponds; substantial negative effects were observed on sport fish in only two ponds. However, it has been stated that prestocking sampling methods rather than white amur caused these effects (Beach et al. 1976). In Arkansas, work started in 1963 with research on the selective acceptance of different foods (Stevenson 1965). Weed control was attained in Lake Greenlee in 1964 and by 1975 they were controlling aquatic macrophytes in over 100 large lakes (Bailey 1972a, 1972b, 1975, 1978). In 1963, Alabama imported the white amur and numerous tests were conducted on its food selectivity and its weed control potential in ponds. Since that time, it has been tested on filamentous algae (*Pithophora*, *Hydrodictyon*, and Lyngbya) as well as on waterhyacinth. Much of that work was done by the Alabama Department of Conservation.*

* Organizations that have conducted research on the white amur in the United States are listed in Table 2.

Table 2
Organizations Which Have Conducted Research on White Amur in the United States

State Agencies	Universities (Continued)
Alabama Department of Natural Resources	San Francisco State University
Arizona Game and Fish Department	Southern Illinois University
Arkansas Game and Fish Commission	University of Arizona
Florida Department of Natural Resources	University of California at Davis
Florida Game and Fresh Water Fish Commission	University of Florida
Georgia Department of Natural Resources	University of Georgia
Indiana Department of Natural Resources	University of Michigan
Iowa Conservation Commission	University of Missouri
Louisiana Wildlife and Fisheries Commission	University of Oklahoma
Missouri Department of Conservation	University of South Dakota
North Dakota Game and Fish Department	University of Southwestern Louisiana
Ohio Department of Natural Resources	University of South Florida
Puerto Rico Department of Natural Resources	University of Tennessee
Tennessee Wildlife Resources Agency	University of Wisconsin
Universities	Wayne State University
Auburn University	**Federal Laboratories**
Colorado State University	Fish Farming Experimental Station at Stuttgart
Florida Atlantic University	Southeastern Fish Control Laboratory at Warm Springs
Florida Technological University	U.S. Department of Agriculture at Fort Lauderdale
Illinois Natural History Survey	U.S. Fish Hatchery at Marion
Indiana State University	U.S. Forest Service at Davis
Louisiana State University	U.S. Army Engineer Waterways Experiment Station
Nichols State University	
Northwestern Louisiana University	

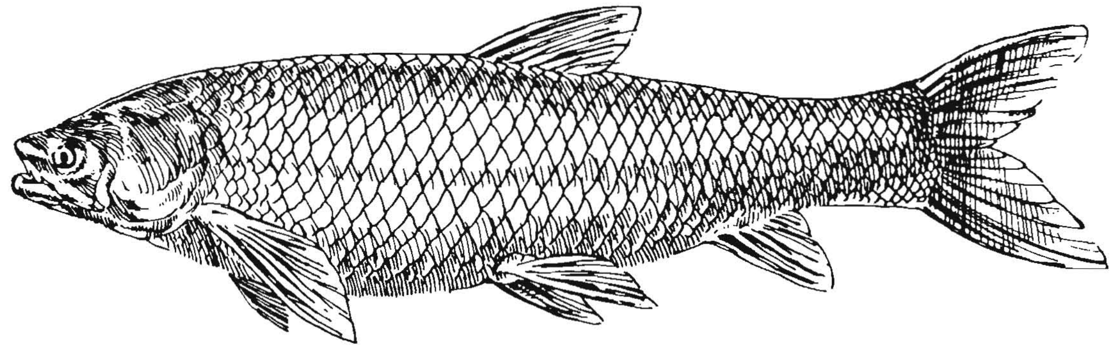

Figure 2. The white amur

Physical Description

The white amur is the largest member of the minnow family (Cyprinidae); in their native range they can grow to as large as 50 kg. The head is broad with a short snout and the upper jaw slightly overhangs the lower jaw (Figure 2). The body is elongate (length-to-breadth ratio is 3.8:4.8). The color is gray to brown on the upper surface and silvery on the underside. The scales are large and average 42 in number along the lateral line. Unlike the common carp, the white amur have no barbels around the mouth. The white amur has no true stomach; food passes directly from the esophagus to the large intestine. Here, only the ruptured cells are digested. There are no cellulitic enzymes to break down undamaged cells. The intestine is only twice the total body length which is very short when compared with other herbivorous minnows which typically have intestines that range from 6 to 16 times total body length. Passage of food through the intestine takes about 8 hr at 27°C. More time is required at a lower temperature. Only about half of the plant material taken in by the white amur is digested.

Feeding Behavior

White amur have a horny pad on the roof of their mouth but no true teeth. They have pharyngeal teeth which consist of a double row of finely serrated structures: this feature distinguishes them from other minnows. The fish feeds by grasping plants between the horny pad and pharyngeal teeth and shaking violently from side to side to break the material loose. Unlike the common carp which muddies the water as it pulls up vegetation, the white amur actually cuts or breaks loose vegetation as it feeds. Plants are macerated by the action of the pharyngeal teeth against each other and horny parts. While young, the fish seem to prefer soft succulent material. However, as the fish grows, the pharyngeal teeth increase in size and grow further apart allowing mature individuals to successfully feed on more fibrous aquatic plants. Appendix B lists plants eaten by the white amur.

White amur have been described as "grazers." They feed on submersed vegetation by working from one end to the other. Mature fish are able to eat cattail by cutting it at the base, then consuming the entire plant from base to tip.

Feeding and Consumption Rates

The rate at which white amur feed is dependent on water temperatures. They reportedly do not feed at all below 14°C. Between 14° and 16°C they are very sluggish and feed selectively. Above 20°C, they become voracious and will feed on "nonpreferred" plants. Feeding rates remain constant from 23°C to about 36°C where they decline. In northern latitudes, this fish will not effectively control vegetation when water temperatures are much below 20°C. In Lake Conway, Florida, where the white amur was used successfully, water temperatures were at or above 20°C for about 8 months of the year, from March through October.

Daily consumption rates for the white amur range from 80 percent of body weight to two to three times the body weight under optimal conditions. This high rate is the result of the quick passage of food through the short intestine and incomplete digestion. Consumption rates can be slowed by increased salinity, decreased oxygen content, abrupt drops in temperature, and disturbance caused by wind.

Development and Growth

Under optimal conditions, the white amur can grow faster than other fish of comparable sizes. In their native habitat, these fish increase in length from 9 to 10 cm annually in the first 4 or 5 years and from 6 to 7 cm in the sixth and seventh years. After 8 years, the increase is about 2.5 cm/year. For intermediate to adult sizes, weight increases of 10 to 22 g/day are typical. In tropical countries, culture specimens have obtained 7 to 8.5 kg in 1 year with rates of increase averaging 1 kg/month in the last 6 months.

In the temperate Amur Basin of the Soviet Union, the greatest growth rate of wild fish amounts to 2.7 kg/year and occurs in fish older than 6 years. Growth rate is dependent upon factors such as stocking density, dissolved oxygen, and salinity. The white amur ceases feeding at about 2.5 mg/ℓ dissolved oxygen content. At salinities greater than 30 percent seawater, mortalities occur, while growth slows appreciably at lower salinities. When stocked at high densities (0.1- to 0.9-kg fish at 49 to 3800 fish per hectare), reduced growth rates have been reported by some workers.

PART III: RATIONALE

In using the white amur as a biocontrol agent, many considerations must be given to the time-dependent nature of both the fish and the target plant species. The approach used should have the objective of achieving an acceptable level of control in some future time frame, as opposed to achieving a quick, short-term level of control.

It should be remembered that proper management technique recognizes that stocking rate is related to vegetated area, not simply total area of a system. During the actual stocking, it is good management practice to place the fish in the system, in proper proportion to the problem distribution, and within the targeted areas. This is especially true for the larger systems.

Understocking

When lakes or ponds are understocked, the most significant initial effect is lack of desired control of the problem plant. Consumption rate is simply too low to overcome growth rate of the plant. Once this is realized, and the problem has increased, there is a danger of overreacting with a supplemental stocking, resulting in an overstocked condition.

Overstocking

When the stocking rate is too high, the fish will quickly consume all plants, usually within less than one growing season. Following removal of these plants, the amur have been observed to feed on terrestrial plants along the land-water interface, and root in the muck or sand in the bottom. They do not, however, feed on other fish or fish eggs when they have no vegetation. Benthic invertebrates found in the stomachs of starving white amur were determined to be the result of random feeding on mud and sand once vegetation had been eliminated (Terrell and Fox 1975). Removal of all vegetation due to overstocking will also eliminate habitat and negatively impact native fish. Once it has been determined that too many fish have been stocked in a water body, it is very difficult to correct the situation. While these fish can be removed by seines, rotenone, and other methods, it is usually a very tedious process and is often expensive.

PART IV: CALCULATING THE STOCKING RATES

Initial Considerations

In ponds less than 0.5 acres* in size, the fish appear easily disturbed and nervous most of the time. In ponds larger than 0.5 acres, white amur appear more tolerant of outside disturbances. If the lake or pond has large inflowing or outflowing streams which connect to other water bodies, white amur should not be used unless some type of fish barrier can be erected. The fish should not be stocked in rivers since it is virtually impossible to restrict the white amur from escaping to other areas.

Overview of the White Amur Stocking Rate Model

Determination of the stocking rate can best be accomplished with the assistance of a computer-accessed stocking rate model. This model is written in Fortran IV and stored on the U. S. Army Engineer Waterways Experiment Station (WES) computer. It can be accessed easily by way of telephone hookup from anywhere in the United States. The purpose of the model is to predict the growth of the problem aquatic plants, with time, as a result of stocking selected number(s) and size(s) of white amur. Should the growth of the plant respond in a manner unacceptable to the user, the selected stocking rate can be adjusted (either size and/or numbers of fish) and the model rerun. Through this process, the user can select a stocking rate based on predicted system responses that most nearly meets his requirements.

In most cases, no model can nor should attempt to account for all variables that might be considered in an ecosystem. No model should be expected, therefore, to totally duplicate the natural environment. Most simulation models are best employed as an exploratory device that is used to play "what if" games and arrive at a decision based on predicted responses to realistically described situations. The user can thus examine a wide array of options very quickly and with modest expense, without subjecting the actual environment to trial-and-error sequences. The White Amur Stocking Rate Model (Figure 3) was formulated to provide just such a capability as a planning/decisionmaking tool.

* A table of factors for converting U.S. customary units of measurement to metric (SI) is presented on page 4.

Relationships Used in the Model

The second-generation stocking rate model uses several basic relationships to depict the growth rate of hydrilla and the consumption rate of the white amur, both as a function of time. The interaction of the growth rate of hydrilla and the consumption rate of the fish determines the resulting infestation level on a monthly basis over a chosen time interval.

Determining the growth rate of hydrilla. The monthly growth rate of hydrilla (G) is determined by considering the combined effects of season G_s, water temperature G_t, photoperiod G_p, lake density G_d, and cropping G_c. The monthly growth rate factor is determined by the following equation:

$$G = (G_s + G_t)(G_p)(G_d)(G_c)$$

Season—The model considers the effect of seasonal changes to be independent of water temperature and photoperiod influences. The seasonal influences used in the model are shown in Figure 4. This curve reflects positive growth during the prime spring/summer growing months and negative growth (dieback) during the winter months.

Water temperature—The effect of water temperature on the growth rate of hydrilla is shown in Figure 5. This value is predicted from the mean monthly water temperature for the body of water in question.

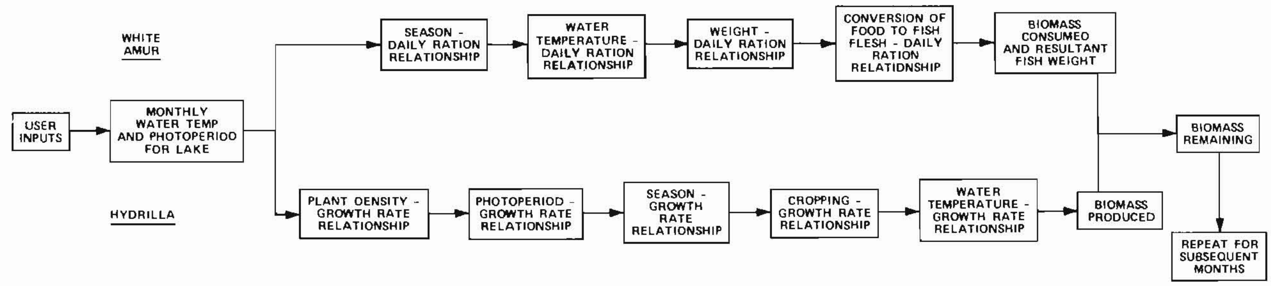

Figure 3. White Amur Stocking Rate Model

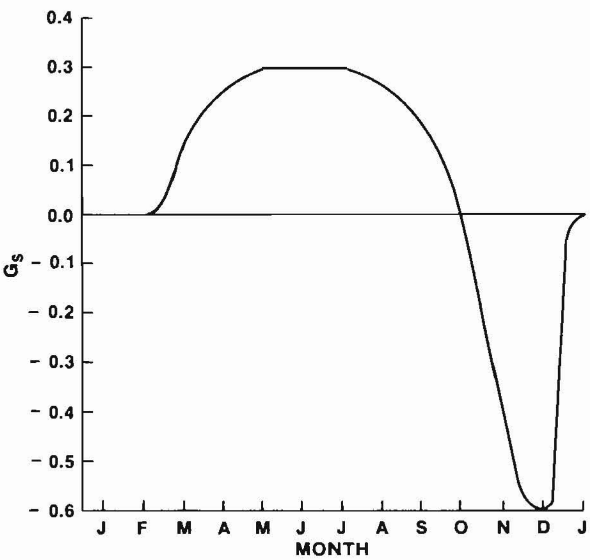

Figure 4. Growth rate factor — season relationship

Photoperiod—In the model, day length (Figure 6) is assumed to modify growth and provides a latitudinal adjustment for the annual growth cycle.

Lake density—Density of hydrilla is assumed to modify the growth rate with growth rates of 1.0 being attained until the lake becomes 60 percent full (Figure 7). Then growth rate declines rapidly. Density in the model is the ratio of hydrilla biomass to lake capacity.

Cropping—The effect of cropping on the growth of hydrilla is expressed in Figure 8. This factor expresses the stimulatory effect low cropping rates have on growth and the inhibitory effect higher cropping rates have on growth from stem cutting by the fish due to lack of preferred growth.

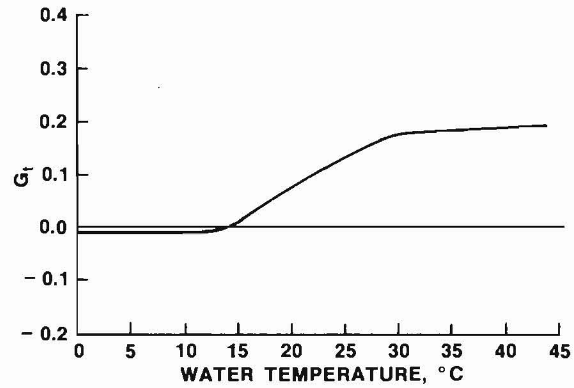

Figure 5. Growth rate factor — water temperature relationship

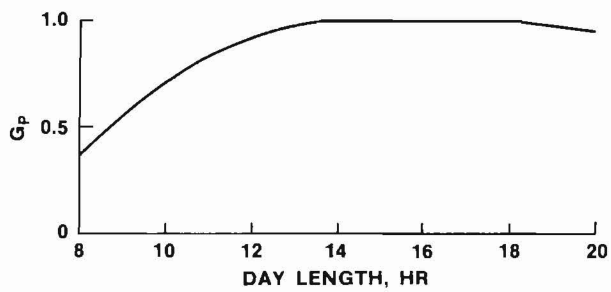

Figure 6. Growth rate factor — photoperiod relationship

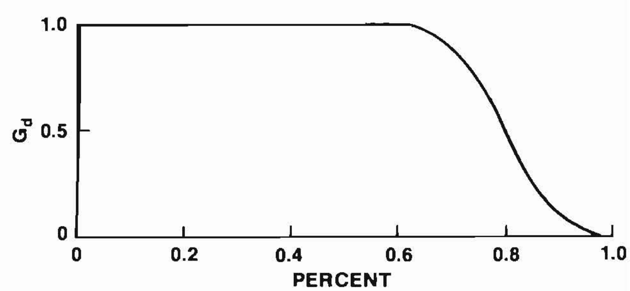

Figure 7. Growth rate factor — percent lake volume infested relationship

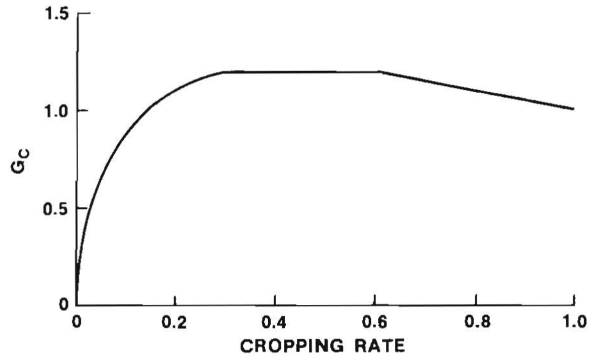

Figure 8. Growth rate factor — cropping rate relationship

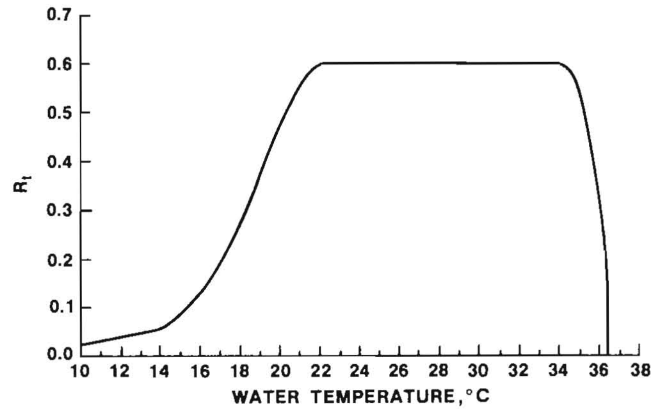

Figure 9. Daily ration — water temperature relationship

Determining the consumption rate of the white amur. The model predicts the biomass of hydrilla consumed monthly CB by the fish using the following equation:

$$CB = R\ W\ N\ T$$

where

R = daily ration of each fish, lb
W = mean weight of each fish, lb
N = number of surviving fish
T = time, days

The model predicts the daily ration R from three independent factors:

$$R = R_t\ R_w\ R_s$$

where:

R_t = effect of water temperature on R
R_w = effect of weight of the white amur on R
R_s = seasonal changes in R

The model also includes calculation of the number of surviving fish (i.e., number left after natural mortality and predation).

Water temperature—The food consumption of the white amur as a function of water temperature is shown in Figure 9. Consumption increases with increased water temperature to a maximum consumption level and decreases rapidly at lethal temperatures. The shape of this curve was estimated from compilation and interpretation of data in available literature.

Fish weight—The daily ration as a function of weight is believed to decrease with the size of the white amur (i. e., a smaller fish consumes a larger percentage of its body weight daily than a larger fish). This relationship is shown in Figure 10. The values reflected by this curve are based on studies in Lake Wales, Florida.

Season—Daily consumption as a function of season is shown in Figure 11, although the effect of season independent of temperature has not been completely evaluated at this time.

Conversion of biomass consumed by the fish to fish weight—The percentage of the plant biomass consumed that is converted to fish weight is shown in Figure 12. It is assumed that the fish are not food limited, energy for metabolism increases with water temperature, and egestion and energy requirements for digestion increase with the increase in daily ration.

Survivability—The model considers the effect of stocking mortality and predation in determining survivability. This model uses 0.9967 as the monthly survival rate.

Interaction of hydrilla growth, fish consumption, and fish growth. The general logic of the model is shown in Figure 3. The amount of biomass produced monthly minus the consumption of the fish produces the amount of biomass remaining or present at the beginning of the next month and a resultant number of fish of a

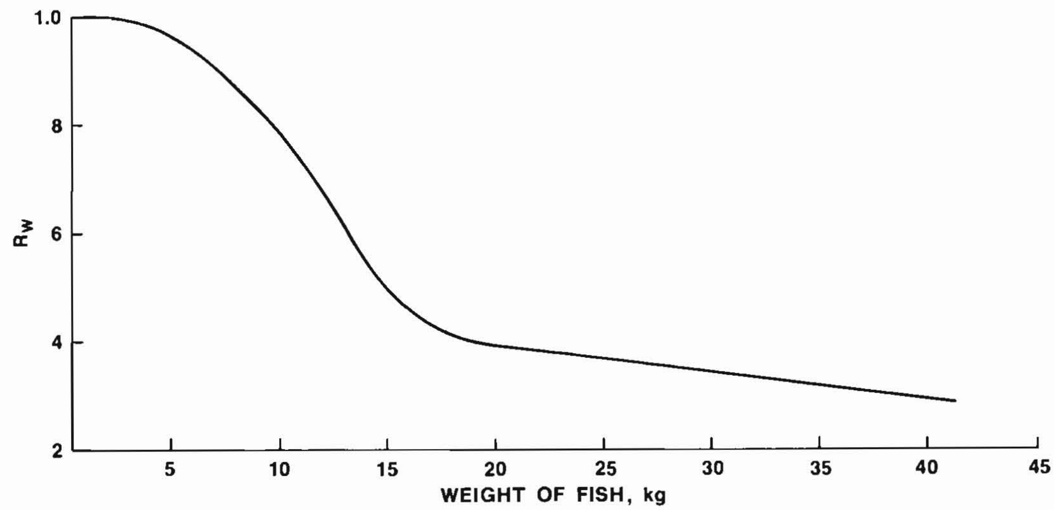

Figure 10. Daily ration - weight relationship

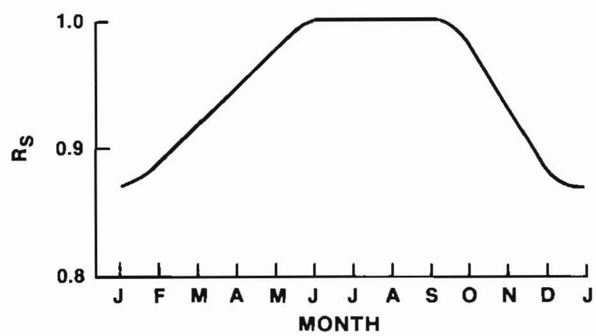

Figure 11. Daily ration - season relationship

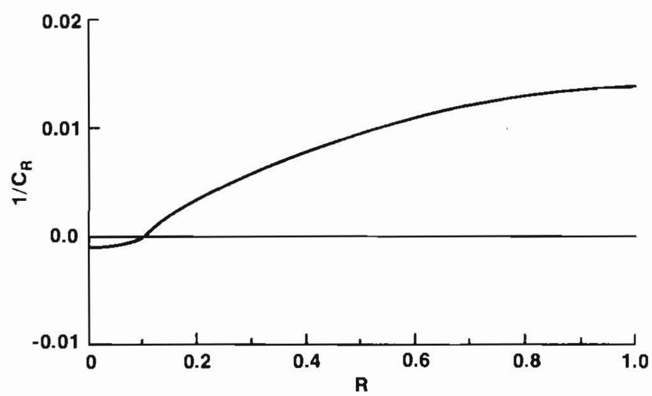

Figure 12. Daily ration - conversion to fish weight $1/C_r$ relationship

mean weight. This iteration is continued for the period desired. The model may be rerun until a stocking rate is determined that meets the user's criteria, based on the resulting growth of the plant with time.

Using the Model

Input. The WES stocking rate model requires the following input:

- Size of the lake in acres.
- Average depth of the lake in feet.
- Total acres of the lake infested with hydrilla.
- The month of the year when stocking will take place.
- Total number of white amur to be stocked.
- Average individual weight of fish to be stocked.
- Number of months into the future to be considered.

Output. Once the inputs have been specified, the model will respond with tabular data on a monthly basis for the following information:

- Number of fish remaining in the lake.
- Mean weight of an average size fish.
- Total weight of fish (as a population) remaining.
- Weight of plant material consumed.
- Number of vegetated acres remaining.

Demonstration. The model was run using the inputs shown in Figure 13. Figure

SAMPLE RUN

- LAKE = 120 ACRES
- AVERAGE LAKE DEPTH = 2.5 FT
- NUMBER OF INFESTED ACRES = 60
- MONTH OF STOCKING = JAN.
- NUMBER OF FISH STOCKED = 600 (10/INFESTED ACRE), 1200 (20/INFESTED ACRE), 1800 (30/INFESTED ACRE), 2400 (40/INFESTED ACRE), 3000 (50/INFESTED ACRE)
- STOCKING WEIGHT = 1.0 LB
- NUMBER OF MONTHS FOR WHICH CALCULATIONS ARE DESIRED = 48

Figure 13. Inputs for model demonstration

14 shows the differences in the effect of stocking 1.0-lb fish at rates of 10, 20, 30, 40, and 50 fish/acre in a 120-acre lake that was initially 50-percent infested (60 acres). The plot shows that there is a significant difference in the time required to eradicate the infestation when stocking rates of 10 and 20 fish/acre are used compared to the higher rates. However, stocking rates of 30, 40, and 50 fish/acre give control in about the same length of time; therefore, significant savings can be realized by stocking 30 fish/acre instead of 50. Other combinations of larger fish and different stocking rates could be run to determine other choices more acceptable to the user's needs.

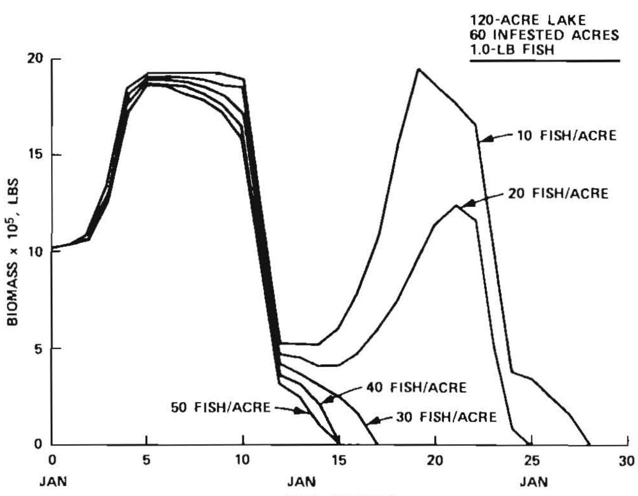

Figure 14. Effect of stocking rate on biomass of aquatic plants over time

Estimating Without the Simulation Model

By referring to Tables 3-5, it is possible to manually estimate the total number of fish required to effect a certain level of control. These data for growth of hydrilla and growth and consumption rates for white amur were produced from the WES stocking rate model.

Estimated consumption rates for four size classes of white amur are presented in Table 3. Daily consumption rates are maximal in late summer or early fall and minimal in January. The model predicts that consumption rates of approximately 50 percent of the total weight of fish are possible. These data are conservative since values as high as 100 percent of the body weight have been reported. Growth rates, as predicted by the model for a 48-month period, are presented in Table 4. Based on these data a 0.10-kg fish should achieve 0.49 kg within 12 months and 14.78 kg after 48 months. Percentage increases or decreases in hydrilla biomass, as predicted from the model, are presented in Table 5. These data assume no vegetative control and no inhibitory effects caused by crowding of the plants. Increases vary from +3.0 in January to +47.9 percent in July. Negative rates, or losses caused by physiological changes caused by senescence, are -39.9 percent and -63.0 percent, which occur in November and December, respectively.

A technique for estimating numbers of fish needed to bring about a certain level of control is presented in Table 6. In this example 100 0.1-kg fish are stocked in June in a water body containing 1000 kg of hydrilla. By using this technique, 100 fish will consume all but 1466 kg by November, and all but 366 kg by December. To compare the results of this estimate with the output of the stocking rate model, see Appendix C. Appendix D lists some actual rates used and their effectiveness in various studies.

Table 3

Daily Hydrilla Consumption Rates (Percent Body Weight) of Four Size Classes of White Amur as Predicted by the WES Stocking Rate Model

Month	*Avg Water Temperature °C*	*Consumption Rate for Indicated Fish Weights, kg*			
		0.10	*0.50*	*1.0*	*5.0*
Jan	10.0	0.018	0.083	0.164	0.813
Feb	11.0	0.042	0.189	0.373	1.843
Mar	12.0	0.058	0.238	0.464	2.267
Apr	13.0	0.070	0.250	0.476	2.278
May	14.0	0.0597	0.248	0.484	2.369
Jun	15.0	0.0738	0.259	0.491	2.346
Jul	15.0	0.053	0.249	0.494	2.453
Aug	14.0	0.061	0.253	0.493	2.413
Sep	13.0	0.074	0.260	0.492	2.353
Oct	12.0	0.106	0.270	0.475	2.113
Nov	11.0	0.0378	0.160	0.314	1.541
Dec	10.0	0.0293	0.116	0.224	1.090

Table 4

Growth Rate of White Amur as Predicted by the WES Stocking Rate Model for Florida Lakes

Month	*Avg Water Temperature °C*	*Year 1 Growth kg*	*Percent Increase*	*Year 2 Growth kg*	*Percent Increase*	*Year 3 Growth kg*	*Percent Increase*	*Year 4 Growth kg*	*Percent Increase*
Jan	10.0	0.13	10.0	0.47	4.2	1.84	16.3	6.98	17.8
Feb	11.0	0.11	18.2	0.49	0.0	2.14	7.0	7.15	16.5
Mar	12.0	0.13	15.4	0.49	10.2	2.29	3.0	8.33	12.2
Apr	13.0	0.15	20.0	0.54	16.7	2.36	0.8	9.35	4.4
May	14.0	0.18	22.2	0.63	19.0	2.38	10.0	9.76	1.8
Jun	15.0	0.22	18.2	0.75	18.6	2.62	16.8	9.94	0.5
Jul	15.0	0.26	23.1	0.89	20.2	3.06	18.3	9.99	6.3
Aug	14.0	0.32	18.7	1.07	18.7	3.62	18.8	10.62	10.2
Sep	13.0	0.38	15.8	1.28	20.3	4.30	19.1	11.70	9.2
Oct	12.0	0.44	6.8	1.54	19.5	5.12	18.5	12.78	8.0
Nov	11.0	0.47	4.2	1.84	16.3	6.07	7.4	13.81	7.0
Dec	10.0	0.49	4.2	2.14	16.3	6.52	7.0	14.78	

Table 5

Percentage Increase in Hydrilla Biomass as Predicted by the WES Stocking Rate Model*

Month	*Avg Water Temperature °C*	*Percent Change*
Jan	10.0	+ 3.0
Feb	11.0	+ 5.8
Mar	12.0	+ 23.8
Apr	13.0	+ 38.5
May	14.0	+ 63.7
Jun	15.0	+ 47.6
Jul	15.0	+ 47.9
Aug	14.0	+ 29.3
Sep	13.0	+ 22.9
Oct	12.0	+ 7.0
Nov	11.0	- 39.9
Dec	10.0	- 63.0

* This simulation assumed no vegetation control and no decrease in growth rates attributed to approaching carrying capacity.

Table 6

A Technique for Estimating Hydrilla Biomass Consumed by 100 0.1-kg Fish

	Hydrilla		*Initial Fish*	*Final Fish*	*Plant Consumption*		*Consumption for 30 days*	*Final Plant Biomass (Hydrilla Growth — 30-Day Consumption*
Month	*Biomass*	*Growth**	*Weight*	*Weight***	*1 Fish*†	*100 Fish*	*(100 Fish)*	*Rate for 100 Fish)*
Jun	1000	1476	0.10	0.1182	0.08	8.0	240	1476 - 240 = 1236
Jul	1236	1828	0.1182	0.1455	0.07	7.0	210	1828 - 210 = 1618
Aug	1618	2092	0.1445	0.1717	0.08	8.0	240	2092 - 240 = 1852
Sep	1852	2276	0.1717	0.1988	0.14	14.0	420	2276 - 420 = 1856
Oct	1856	1985	0.1988	0.2025	0.212	21.2	636	1985 - 636 = 1349
Nov	1349	811	0.2025	0.2110	0.0756	7.56	227	811 - 227 = 584
Dec	584	217	0.2110	0.2199	0.0586	5.86	176	217 - 176 = 41

* Estimated from Table 5.
** Estimated from Table 4.
† Estimated from Table 3.
†† Taken from final plant biomass from previous month.

PART V: OBTAINING, TRANSPORTING, AND STOCKING THE WHITE AMUR

Obtaining the White Amur

Types of white amur available. A bisexual population of white amur contains males and females capable of reproduction. Although the reproductive requirements of this species are quite specific, immature white amur have been found frequently in large rivers of the United States, presumably the results of natural reproduction. Whenever males and females of a species coexist, the production of viable offspring should not be discounted. To date, there have been no reports of large numbers of white amur establishing themselves naturally in the United States. The bisexual white amur available from many fish hatcheries (Table 7) could be used if the potential for natural reproduction is deemed minimal or nonexistent. Such a situation can exist in a lake or pond with no outlet or with easily controlled areas where fish barriers can be constructed. The cost per fish in a bisexual population depends on size purchased (Table 8).

Monosex (all female) white amur population would have to be generated and reared using a specific procedure. In this procedure, female fish are produced through artificial gynogenesis, which is a process where sperms are irradated to destroy their capacity to produce males. These females are fed sex reversal hormones prior to formation of sex organs. This process produces sex reversed females (males) carrying chromosomes capable of producing only females. These "males" are then paired with normal females and the offspring are all females. If there is concern over natural reproduction, such a monosex population should be used. Natural reproduction can, of course, take place if a male finds his way into the areas where the mature females have been stocked, and proper conditions exist.

Table 7

Commercial Sources of White Amur

Source	*Fish Types**
Arkansas Aquatics, Inc. 109 Sunflower Lonoke, AR 72086	B
Leon Hill 605 Park St. Lonoke, AR 72021	B
J. M. Malone & Son Enterprise P.O. Box 158 Hwy 31-S Lonoke, AR 72086	B, E
Schroder Fish Farm Box 598 Carlisle, AR 72024	B
Sea Ranch Route 1 Box 103 Sheridan, AR 72105	B

* B = Bisexual population; E = Experimental hybrid.

Table 8

Comparative Costs of Bisexual White Amur and Triploid White Amur (Costs as of 21 December 1981)

Size Range in.	*Number*	*Cost/Fish*
Bisexual White Amur		
Larvae	50,000	$0.03
Fingerling	1,000	0.50
Fingerling	1,000	0.30
4 - 7	1,000	1.75
4 - 7	1,000	1.25
8 - 11	1,000	3.00
8 - 11	1,000	2.00
Triploid Hybrid White Amur		
1-1/2 - 3	1,000	$0.75
1-1/2 - 3	1,000	0.50
8 - 11	1,000	4.00
8 - 11	1,000	3.00

Hybrid white amur can be produced using either male white amur and female carp (*Cyprinus carpio*) or female white amur and male bighead carp (*Aristichthys nobilis*). Resulting offspring from such crosses are sterile. Such individuals could be produced naturally from stocked (bisexual or monosexual) white amur. Recently, considerable interest has developed over the use of the hybrid as a macrophyte control agent (see Appendix A for references). Earlier reports suggested that the hybrid did not consume as much vegetation as the white amur and techniques for its production were difficult. However, recently (1981) Mr. Jim Malone, Lonoke, Ark., has produced a "man-made" triploid hybrid which has traits very similar to the white amur (Table 8).

Diseases. In the United States and within its native range the white amur is subjected to numerous parasites (Table 9). The eggs, larvae, and fry are susceptible to external fungal and bacterial infections. Adverse incubation conditions can cause dropsy, which results from hydration of body cavities. Curvature of the spine can result from imbalanced diets in some areas. Infection with *Rhabdovirus* sp. can cause "spring viremia" or acute dropsy. Bacterial gill rot and bacterial enteritis have also been reported. The most dangerous parasite of this fish is the nonspecific cestode (*Bothriocephalu acheilognathi* = *gowkongnsis*), which was introduced into the United States along with the white amur. This worm has caused losses in European fish cultures. *Clonorchis* (= *Opisthoreis*) *sinensis*, which can parasitize man and other animals, uses the white amur as an intermediate host.

There have been no reported outbreaks of disease in native fish populations as a result of stocking white amur. Part of the reason for this is that disease prevention is a concern of the reputable supplier. If deemed necessary, a qualified fish pathologist can examine white amur and certify that they are disease-free prior to shipment.

Transporting the White Amur

Trucking. For large numbers of fish, transportation is most efficiently done using large tank trucks. The white amur can tolerate 1 to 2 days of transportation with no adverse effects. The truck should be backed up to the edge of the water so the tanks can be emptied into the lake or pond. If the tank water is not similar to the receiving water in terms of temperature and pH, the natural waters should be gradually mixed with the tank water. When the lake and tank water conditions are about equal the fish should be released directly to the water body. If direct access to the water body is not possible using a truck, the fish can be transferred to smaller, more portable tubs. The supplier should take the responsibility for providing healthy fish. Payment should be based on the number of healthy fish that are delivered to the site.

Regulations. Regulations pertaining to transportation and stocking white amur are presented in Appendix E. The only Federal law which can regulate transportation is the Black Bass Act (16 U.S.C. 856-856). This law, which supports state legislation, makes it unlawful to transport black bass (or any fish) between states when local laws prohibit this transportation. Additional information on the introduction of white amur with reference to state laws can be found in Lachner, Robins, and Courtenay (1970); Henderson (1979); and Rosenthal (1980).

Stocking the White Amur

Preparing the site. Generally no site preparation is necessary for stocking the white amur. There is usually sufficient access to the water's edge to accommodate the trucks. This access is not always in close proximity to the weed-infested areas, but this proximity is critical only in large systems. In these cases, the fish should be transported by boat to the heavily infested areas to be stocked, or temporary access to the water's edge should be prepared.

Table 9
Parasites of White Amur*

Parasite	*Reference*
Viruses	
Rhabdovirus spp.	Ahne (1974); Bisseru (1979)
R. carpio	Bisseru (1979)
Bacteria	
Archromabacter spp.	Szakolczai and Molnar (1966)
Aeromonas spp.	Szakolczai and Molnar (1966)
A. punctata	
A. salmonicida var. *achromogenes*	Bisseru (1979)
Flexibacter columnaris	Astakhova and Stepanova (1972)
Myxoccus piscicola	
Pseudomonas	Laboratory of Fish Diseases (date unknown)
Fungi	
Branchiomyces sanguinis	Bisseru (1979)
Saproglenia spp.	Doroshev (1963); Edwards and Hine (1974); Huisman (1978); Prabhavathy and Sreenivasan (1972)
Protozoa	
Apiosoma cylindriformis	Ivasik, Kulakovskaya, and Vorona (1969); Musselius (1969); Bykovskaya-Pavlovskaya et al. (1962) as cited in Riley (1978); Chen (1955) as cited in Riley (1978); Molnar (1971) as cited in Riley (1978)
A. magna	Stepanova (1971) as cited in Riley (1978)
Eimeria mylopharyngodoni	Ivasik, Kulakovskaya, and Vorona (1969)
E. sinensis	Ivasik, Kulakovskaya, and Vorona (1969)
Entamoeba Ctenopharyngodonti	Bykovskaya-Pavlovskaya et al. (1962) as cited in Riley (1978); Chen (1955) as cited in Riley (1978)
Epistylis spp.	Stepanova (1971) as cited in Riley (1978)
E. lwoffi	Kashkovskii (1964) as cited in Riley (1978)
Euglenosoma caudata	Chen (1955) as cited in Riley (1978)
Glaucoma pyriformis	Chen (1955) as cited in Riley (1978)
Hemiophrys macrostoma	Bykovskaya-Pavlovskaya et al. (1962) as cited in Riley (1978); Chen (1955) as cited in Riley (1978)
Hexamita spp.	Chen (1955) as cited in Riley (1978); Sullivan and Rogers, pers. comm. as cited in Riley (1978)
Icthyophthyrius spp.	Bisseru (1979)
I. multifiliis	Cross (1969); Dah-Shu (1957); Edwards and Hine (1974); Ivasik, Kulakovskaya, and Vorona (1969); Konradt and Faktorovich (1966); Laboratory of Fish Diseases (date unknown); Musselius (1969); Chen (1955) as cited in Riley (1978); Kashkovskii (1964) as cited in Riley (1978); Molnar (1971) as cited in Riley (1978); Stevenson (1965)
Myxidium spp.	Molnar (1971) as cited in Riley (1978)
M. ctenopharyngodonis	Bykovskaya-Pavlovskaya et al. (1962) as cited in Riley (1978)
Myxobolus dispar	Musselius (1969); Molnar (1971) as cited in Riley (1978)
M. ellipsoides	Bykovskaya-Pavlovskaya et al. (1962) as cited in Riley (1978)
Sphaerospora carassii	Molnar (1971) as cited in Riley (1978); Stepanova (1971) as cited in Riley (1978)
Spironucleus spp.	Ivanova (1966) as cited in Riley (1978)
Tetrahymena pyriformis	Bykovskaya-Pavlovskaya et al. (1962) as cited in Riley (1978)

(Continued)

* Modified from Shireman and Smith (1981).

Table 9 (Continued)

Parasite	*Reference*
Protozoa (Continued)	
Thelohanellus oculi-leucisci	Yukhimenko (1972)
A. minimicro nucleata	Stepanova (1971) as cited in Riley (1978)
A. piscicola	Ivasik, Kulakovskaya, and Vorona (1969) as cited in Riley (1978); Musselius (1969); Stepanova (1971) as cited in Riley (1978)
Balantidium ctenopharyngododontis	Astakhova and Stepanova (1972); Bauer (1968); Musselius (1969); Prabhavathy and Sreenivasan (1972); Bykovskaya-Pavlovskaya et al. (1962) as cited in Riley (1978); Chen (1955) as cited in Riley (1978); Molnar (1971) as cited in Riley (1978)
Chilodonella spp.	Bisseru (1979); Vanyatinskii (1978)
C. cyprini	Dah-Shu (1957); Ivasik, Kulakovskaya, and Vorona (1969); Konradt and Faktorovich (1966); Musselius (1969); Musselius and Strelkov (1968); Prabhavathy and Sreenivasan (1972); Kashkovskii (1964) as cited in Riley (1978); Molnar (1971) as cited in Riley (1978)
Chloromyzum spp.	Konradt and Faktorovich (1966)
C. cyprini	Musselius (1969); Bykovskaya-Pavlovskaya et al. (1962) as cited in Riley (1978); Molnar (1971) as cited in Riley (1978)
C. nanum	Musselius (1969); Bykovskaya-Pavlovskaya et al. (1962) as cited in Riley (1978); Molnar (1971) as cited in Riley (1978)
Costia necatrix	Dah-Shu (1957); Chen (1955) as cited in Riley (1978)
Cryptobia spp.	Bisseru (1979)
C. branchialis	Bykovskaya-Pavlovskaya et al. (1962) as cited in Riley (1978); Chen (1955) as cited in Riley (1978); Molnar (1971) as cited in Riley (1978)
C. cyprini	Anon. (1972); Musselius (1969)
Eimeria carpelli	Stepanova (1971) as cited in Riley (1978)
Trichodina spp.	Dah-Shu (1957); Musselius and Strelkov (1968); Sullivan and Rogers, pers. comm. as cited in Riley (1978)
T. bulbosa	Chen (1955) as cited in Riley (1978); Kashkovskii (1964) as cited in Riley (1978)
T. carasii	Kashkovskii (1964) as cited in Riley (1978)
T. domerguei	Musselius (1969); Ivanova (1966) as cited in Riley (1978); Kashkovskii (1964) as cited in Riley (1978)
T. meridionalis	Musselius (1969); Kashkovskii (1964) as cited in Riley (1978)
T. nigra	Musselius (1969); Kashkovskii (1964) as cited in Riley (1978); Stepanova (1971) as cited in Riley (1978)
T. nobilis	Kashkovskii (1964) as cited in Riley (1978); Wu (1971); Yukhimenko (1972)
T. ovaliformis	Musselius (1969); Bykovskaya-Pavlovskaya et al. (1962) as cited in Riley (1978); Chen (1955) as cited in Riley (1978)
T. pediculus	Musselius (1969); Bykovskaya-Pavlovskaya et al. (1962) as cited in Riley (1978); Chen (1955) as cited in Riley (1978); Ivanova (1966) as cited in Riley (1978); Stepanova (1971)
T. reticulata	Ivasik, Kulakovskaya, and Vorona (1969); Stepanova (1971) as cited in Riley (1978)
Trichodinella epiotica	Musselius (1969); Ivanova (1966) as cited in Riley (1978); Molnar (1971) as cited in Riley (1978)

Special handling. When introducing the amur into a new area, care must be taken to ensure that mortalities do not occur as a result of thermal shock. The carrying water should be within 1° to 2° of the receiving waters. If this is not the case, time must be allotted to allow the white amur and the transporting water to achieve ambient conditions. Typically, changes in water temperature should be no more than 1° per hour, otherwise fish mortalities can result.

Season. The best time of year to stock white amur is early spring. Summer water temperatures may be higher than the fish have been exposed to and mortality could result in warm climates. Stocking fish in the fall is usually not recommended since predation by larger fish will decrease white amur numbers before they get a chance to feed on vegetation and grow.

Stocking locations. As previously stated, the desired results are better achieved when the white amur are stocked in close proximity to the weed-infested areas. As the water body increases in total size, in proportion to the percent infested with plants, the stocking location becomes even more important. In addition to stocking in close proximity to the plant problem areas, the number of fish should be stocked in proportion to the distribution of the problem plant acreages. Thus, in large systems where the total plant population is widely distributed, the total population of white amur might be stocked proportionately in four or five accessible areas of the system. In smaller systems, of less than 100 acres, one or two release points will probably be sufficient.

Poststocking considerations. After white amur have been introduced into a lake or pond, some effort should be made to determine how successfully they are controlling the vegetation.

Decreases in aquatic macrophytes should be noticeable within 1 to 3 years after stocking. Any changes to water chemistry, phytoplankton, certain native fish, or other components of the system should become noticeable at about the same time. The white amur user should be prepared to conduct selected samplings for plants, water quality, or other variables depending on the interests of the local community.

Monitoring aquatic plant levels should be conducted periodically and should use the same plant measuring technique employed during any prestocking measurements. The best time to measure vegetation levels would be early to midsummer, or whenever they are known to reach the highest infestation. As few sampling stations as possible should be selected to fully assess the situation. One or two deepwater sites and one or two shallow stations where plants are abundant is usually sufficient. It is good practice to monitor one or two sites where little or no vegetation is present. Each site should be checked for plants at least once a year.

The major items of concern are usually native fish and water quality. The former are very difficult to measure quantitatively. While subject to error, a creel survey, before, during, and after stocking, provides an acceptable way to monitor native fish.

Phytoplankton levels are most likely to increase temporarily following white amur introduction. Water samples should be collected from both deepwater and shallow-water stations at least two to three times during each year. Samples should be taken during low-water and warm-water conditions in the late spring or summer.

PART VI: SUMMARY CONCLUSIONS FROM THE LSOMT

The white amur or grass carp, the largest member of the minnow family, is an herbivorous fish native to the Amur River along the Sino-Soviet border in Eastern Europe. It was introduced into the United States in the early 1960s as a potential macrophyte control agent. Since that time it has spread or has been intentionally introduced to over 35 states. White amur are tolerant of a wide variety of environmental conditions, and survive well in lakes, ponds, canals, reservoirs, and rivers in all parts of the United States. Although there are reports of this fish reproducing naturally in the wild, its reproductive requirements are so specific that nuisance levels of white amur are unlikely to develop in the United States.

As an adult the white amur is a voracious plant feeder; it can sometimes consume at least its own weight each day in *Hydrilla*, *Nitella*, and *Chara* and will also feed upon tough plants such as *Vallisneria* and *Typha*. There are no known major detrimental environmental impacts associated with the proper use of the white amur as a macrophyte control agent. When stocked at rates commensurate with the problem level, and for long-term control, native fish, waterfowl, and reptile and amphibian populations will be unaffected. Water quality and benthic invertebrates are not affected, although in some cases blue-green algae populations increase following removal of the larger plants.

The white amur is a viable biological method for controlling macrophytes under most operational conditions. It should not be considered for use in rivers or lakes connected with other water bodies during periods of high water. It is most successfully used in lakes and ponds with few, or easily controlled, connecting waterways. White amur survive in cold waters, but feed most efficiently on plants in warmer climates.

A stocking rate model is available for the potential white amur user to gain insite into relationships between numbers of fish and amounts of vegetation consumed as a function of time. The user can make estimates of the number of white amur required to effect a certain level of plant control.

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APPENDIX A: SCIENTIFIC LITERATURE PERTAINING TO THE WHITE AMUR

The following is a brief review of some of the scientific literature pertaining to the white amur or grass carp. Many of the papers cited below were used to compile this manual. These technical papers were found by investigation of the scientific literature, examination of the various contractor's reports on the Large-Scale Operations Management Test (LSOMT) at Lake Conway, Florida, and from an excellent bibliography compiled by Smith and Shireman (1980). In addition to these citations, many scientific journals frequently publish papers on the white amur (Table A1). Publications which contain significant collections of papers are listed in Table A2.

Table A1
Journals Which Frequently Publish Papers on White Amur

Aquaculture
FAO Aquaculture Bulletin (*FAO Fish Culture Bulletin*), No Longer Published
Journal of Aquatic Plant Management (*Hyacinth Control Journal*)
Journal of Fish Biology
Journal of Ichthyology (English Translation of *Voprosy Ikhtiologii*)
Malaysian Aquaculture Journal
Proceedings of the Indo-Pacific Fisheries Council
Progressive Fish-Culturalist
Sport Fisheries Institute Bulletin
Transactions of the American Fishery Society

Table A2
Important Collections of Papers

Gangstad, E. O. ed. 1973. "Herbivorous Fish for Aquatic Plant Control" Technical Report 4, U.S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.
Florida Game and Freshwater Fish Commission. 1977. "The Grass Carp: A Special Research Report to the Governor and Cabinet," Florida Game and Freshwater Fish Commission, Tallahassee, Fla.
Transactions of the American Fishery Society. 1978. Vol 108, No. 1.
Shireman, J. V. ed. 1979. *Proceedings of the Grass Carp Conference*, Aquatic Weeds Research Center, University of Florida, Institute of Food and Aquacultural Sciences, Gainesville, Fla.
Environmental Laboratory. 1980. *Proceedings, 14th Annual Meeting, Aquatic Plant Control Research Planning and Operations Review*, U.S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.
Environmental Laboratory. 1981. *Proceedings, 15th Annual Meeting, Aquatic Plant Control Research Planning and Operations Review*, U.S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.

Applied Studies

Effects of using the white amur have been a subject of numerous studies. The U.S. Army Engineer Waterways Experiment Station (WES) has accumulated considerable information gathered during the LSOMT conducted from 1976 to 1982 in Lake Conway, Florida. An overview of the LSOMT can be found in:

- Environmental Laboratory (1975)
- Addor and Theriot (1977)
- Hamilton (1977)
- Theriot (1977)
- Theriot and Decell (1978)

Prestocking and poststocking information from Lake Conway has been published on water quality (Sawicki 1977, Kaleel 1980); aquatic macrophytes (Nall, Mahler, and Schardt 1977; Nall and Schardt 1978, 1980); reptiles and amphibians (Godley, McDiarmid, and Bancroft 1980); and fish, waterfowl, and mammals (Guillory, Land, and Gasaway 1977; Guillory 1979; Land 1980).

In addition to the Lake Conway LSOMT, various other workers monitored conditions in natural water bodies following white amur introduction. A study of four ponds in Florida was discussed in:

- Ware et al. (1975)
- Beach et al. (1976)
- Ware and Gasaway (1976)
- Beach, Lazor, and Burkhalter (1977)
- Drda (1977)
- Gasaway (1977a, 1977b)
- Gasaway and Drda (1978)

A study of Deer Point Lake, Florida, is reported by Kobylinski et al. (1980). The results of white amur in other Florida lakes were reported by:

- Montegut et al. (1976)
- Shireman (1976)
- Shireman, Colle, and Rottman (1977)
- Nixon and Miller (1978)
- Shireman, Colle, and Martin (1979)

Gasaway (1978) analyzed the use of the white amur in Lake Wales, Florida. A similar study in Lake Baldwin, Florida, was described in Shireman and Gasaway (1976), Gasaway (1977d), and Shireman and Maceina (1980).

The use of the white amur was reviewed in:

- Illinois — Baur, Buck, and Rose (1971)
Buck (1975)
Buck et al. (1975)
Lewis (1978)
- Missouri — Rottman (1976)
Rottman and Anderson (1976)
- Georgia — Terrell and Terrell (1975)
- Kansas — Stevens (1980)
- California — Dow (1975)

The use of the white amur in Lake Greenlee, Arkansas, was described by Bailey (1972a, 1972b, 1975), and Bailey and Boyd (1973). Alabama pond studies were reported by Avault (1965a, 1965b); Swingle et al. (1967); Avault, Smitherman, and Shel (1968); and Sills (1970). Mitzner (1975a, 1975b, 1978, 1979, 1980) provided data on Red Haw Lake in Iowa. Willey, Doskocil, and Lembi (1974) tested white amur with various aquatic plants in Indiana.

Forester and Avault (1978) studied the effects of white amur on crayfish; Fry and Osborne (1980) investigated zooplankton abundance and diversity in Florida ponds stocked with white amur. Lewis (1978) made observations on ponds containing white amur and fingerling channel catfish and hybrid sunfish.

Reproduction

Reproduction of the white amur is reviewed in Breder and Rosen (1966) and Gerking (1978). Stanley (1976b) discusses reproduction worldwide with emphasis on its potential in the United States. In a related paper, Stanley, Miley, and Sutton (1978) discuss the possibility of naturalization of escaped white amur in the United States.

Types of White Amur

The monosex procedure is discussed by Richardson (1974) and Stanley (1976a). The hybrid created by using female common carp are discussed by Theriot and Sanders (1975) and Stanley and Jones (1976). The cross using the male carp is described by Aliev (1967) and Avault and Merkowsky (1978). Kinnear (1974) briefly describes polyculture using different types of white amur.

Range

Information on the range and zoogeography of the white amur can be found in Guillory and Gasaway (1978). Pflieger (1978) discusses the status of the white amur in Missouri streams. Opuszynski (1972) describes thermal requirements of adult amur and relates this to range.

Feeding

An extensive literature review plus research data on feeding of the various life stages can be found in Bailey (1972a). Information on food habits of fingerlings can be found in Fischer (1968); Edwards (1973); Willey, Doskocil, and Lembi (1974) and Watkins et al. (1981). A report on the feeding habits of juveniles in devegetated ponds is discussed in Kilgen and Smitherman (1971, 1973) and Forester and Avault (1978). Data on animal material in gut contents of white amur is in Kilgen (1973), Mitzner (1975b, 1978), and Sutton, Miley, and Stanley (1977). Food preferences by white amur for various plants are presented by Nall and Schardt (1978). Hickling (1962, 1966) discusses morphology and the feeding process of white amur. Shireman, Colle, and Rottman (1978) discuss growth of white amur fed natural and prepared diets.

Data on plant consumption are found in Woynarovich (1968), Vietmeyer (1976), and Shireman and Maceina (1980). The effects of temperature on consumption are analyzed by Chapman and Coffey (1971), Edwards (1974), and Colle, Shireman, and Rottman (1978). The effect of size on consumption rate was examined by Chapman and Coffey (1971) and Shireman, Colle, and Rottman (1978). Data on digestion and feeding can be found in Hickling (1962, 1966) and Stroganov (1963). Additional information on consumption is in Sutton (1974, 1977).

Models

A stocking rate model to predict the number of white amur required for vegetation control was developed and reported by Schramm (1982) and is available for use. Dr. John Osborne developed a streamlined model for calculating numbers of white amur required to effect various levels of control.* Ewel and Fontaine (1977, 1980) developed a general ecosystem model for the Lake Conway study. Miller (1980) developed and described a method for modeling the growth of hydrilla based on results of laboratory studies conducted by Barko et al. (1980).

* Personal Communication, 1981, University of Florida, Gainesville, Fla.

Stocking Rates

Assistance in determing how many white amur are required can be obtained by examination of the previously referenced applied studies (see above). Schramm (1979, 1982) and Osborne* have stocking rate models which can be utilized for predictive purposes. The effects of temperature on stocking density were analyzed by Kilambi and Robinson (1979). Specific data on the numbers of white amur used under various condition can be found in Appendix D.

Popular Articles

The following popular articles present positive and negative aspects of the white amur as a weed control agent. Some may appear biased; none are scientific or technical in nature. This list was developed from Smith and Shireman (1981).

Anon. 1971. "Lake Erie Grass Carp?" *Sport Fisheries Institute Bulletin,* No. 223, pp 5-6.

Criticizes U.S. Fish and Wildlife Service's intention to study and possibly introduce grass carp into Lake Erie for weed control.

Anon. 1972. "Man's Best Friend?" *Time,* Jan 31.

An extremely distorted and inaccurate article on grass carp.

Anon. 1975. "Additional Experiments with White Amur," Illinois Natural History Survey Report 148.

Gives tentative results of experiments where grass carp successfully controlled weeds in ponds but negatively affected other fish species.

Anon. 1975. "Grass Carp Could Mean Trouble," Bass Research Foundation Report No. 2, p 4.

Reports on research in Alabama and Florida which indicates adverse impacts of grass carp on game fish.

Anon. 1976. "Lake Louise First for Grass Carp?" *Outdoor News*, Vol 9, No. 10.

Reports upcoming test introduction of grass carp in Minnesota Lake.

Anon. 1979. "Grass Carp Ban Ends," *The Marthasville (MO) Record*, Nov 23.

Restrictions on grass carp are lifted since surrounding states have stocked the fish so widely.

Anderson, A. 1979. "Grass Carp not the Answer," *The Dallas (Texas) Morning News*, Jan 30.

States that grass carp could not control weed problems in Texas waters but would cause detrimental ecosystem effects.

Ball, J. 1977. "Weed-Chomping Fish Experiment a Flop," *Orlando (Fla.) Sentinal Star*, Oct 18.

Documents failure of grass carp to control weeds in Florida lake because of inadequate stocking.

Bosley, R. W. 1975. "White Amur — The Wonder Fish — Solves Water Source Problems," *American Nurseryman*, Vol 141, No. 9, p 983.

Discusses weed control ability, taste quality, and regulations of grass carp.

Hacker, D. W. 1975. "Superfish! No Bird or Plane, It's a White Amur," *The National Observer*, Jan 1.

A figurative account of the grass carp which describes a controversy over its use for weed control in the United States.

Harris, C. 1978. "Grass Carp: Bane or Blessing?" *Florida Sportsman*, Nov, pp 20-22, 25-26, 80.

Reviews controversy surrounding use of grass carp for weed control, with the emphasis on Florida.

Hawker, J. L. date unknown. "Whither The Grass Carp?" *St. Joseph (MO) Gazette*.

Evaluates grass carp for weed control in the United States, particularly Missouri, and suggests that adverse impacts outweigh benefits.

Parker, Jr., W. D. 1969. "The White Amur," *Alabama Conservation*, Vol 39, No. 2, pp 11-12.

Describes attributes of grass carp for weed control, but cites need for further investigation of potential impacts.

Prewitt, R. 1972. "Rambling Along," *American Fish Farmer*, Aug pp 18-21.

Describes advisory committee dealing with importation of exotic fish, including grass carp.

Reiger, G. 1976. "The White Amur Caper," *Audubon*, Sep, pp 108-111.

Suggests that introduction of the undesirable grass carp into the United States is mostly a result of political infighting and competition of fishery biologists for research funding.

Rose, S. 1972. "What About the White Amur? A Sportfish Or A Super Curse?" *Florida Naturalist* Oct, pp 156-157.

Describes positive and negative characteristics of grass carp for weed control in the United States.

Sneed, K. E. 1971. "A Controversial Biological Control," *American Fish Farmer*, (2, 6), pp 6-9.

Describes advantages of grass carp over other methods of weed control and reviews research and controversy surrounding its use in the United States.

Sutton, D. L. 1975. "Controlling Aquatic Vegetation Herbicides," *Fish. Grounds Maintenance*, Vol 9, pp 18-22.

Describes weed control research using grass carp in combination with herbicides in Florida.

Vance, J. M. 1975. "Amur is a Four-Letter Word," *Field and Stream*, March 13-20.

Emphasizes adverse effects of grass carp introduction.

Vance, J. M. 1975. "Grass Carp Moving On," *All Outdoors* (Missouri Department of Conservation), Mar 17.

Cites reports of grass carp spread in Mississippi drainage and potential for carnivory.

Availability of Information

To obtain the following information, contact, in writing, Program Manager/ Aquatic Plant Control Research Program (APCRP) U.S. Army Engineer Waterways Experiment Station, P.O. Box 631, Vicksburg, Miss. 39180:

- Copies of any of the APCRP reports dealing with the Lake Conway study.
- Use of the Stocking Rate Model (Schramm 1982).
- Information on other methods (mechanical, chemical, other biological) which can be used in place of or in many cases in conjunction with the white amur.

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APPENDIX B: PLANT PREFERENCES AND CONSUMPTION RATES OF WHITE AMUR

Table B1

White Amur Plant Preferences*

White amur seems to greatly prefer:

- *Nitella* and *Chara* spp.
- *Hydrilla verticillata*
- *Najas* spp.
- *Potamogeton* spp.
- Duckweeds (*Lemna, Spirodella, Wolffia, Wolffiella, Azolla*)
- *Ceratophyllum demersum*
- *Eleocharis acicularis*
- *Elodea canadensis*
- *Pithophora* sp.

White amur will control but does not seem to prefer:

- *Myriophyllum* spp.
- *Bacopa* spp.
- *Egeria densa*
- *Nymphaea* spp.
- *Spirogyra* sp.

(Continued)

- *Utricularia* spp.
- *Cabomba* spp.
- *Fuirena scirpoides*
- *Brasenia schreberi*
- *Hydrocotyle* spp.

White amur will not control effectively:

- *Vallisneria* spp.
- *Typha* spp.
- *Myriophyllum brasiliense*
- *Phragmites* spp.
- *Carex* spp.
- *Scirpus* spp.
- *Eichhornia crassipes*
- *Alternanthera philoxeroides*
- *Pistia stratiotes*
- *Nymphoides* spp.
- *Nuphar macrophyllum*

* From Nall and Schardt (1978).

Table B2
Plants Consumed by White Amur*

Plants Readily Consumed	Poor Consumption
Aquatic Plants:	Amphibious Plants:
Fennel pondweed (*Potamogeton pectinatus*)	Marsh woundwort (*Stachys palustris*)
Hornwort (*Ceratophyllum demersum*)	Red vartsia (*Odontites rubra*)
Water thyme (*Elodea canadensis*)	Thread rush (*Juncus filiformis*)
Ivy-leaved duck weed (*Lemna triscula*)	Cyperuslike sedge (*Carex pseudocyperus*)
Frogbit (*Hydrocharis morsus-ranae*)	Terrestrial Plants:
Amphibious Plants:	Corn sowthistle (*Sonchus arvensis*)
Swamp meadowgrass (*Poa palustris*)	Tansy (*Tanacetum vulgare*)
Great reedmace (*Typha latifolia*)	Rose bay (*Chamaenerion angustifolium*)
Common reed (*Phragmites communis*)	Yellow loosestrife (*Lysimachia vulgaris*)
Terrestrial Plants:	Autumn hawkbit (*Leontodon autumnalis*)
Red clover (*Trifolium pratense*)	Dandelion (*Taracoxum officinale*)
Zigzag clover (*T. medium*)	Narrow-leaved cress (*Lepidium ruderale* L.)
White clover (*T. repens*)	Shepherd's purse (*Capsella bursa-pastoris*)
Couch (*Agropyron repens*)	Birds-foot trefoil (*Lotus corniculatus*)
Average Consumption	Hedge mustard (*Sisymbrium officinale*)
Aquatic Plants:	Hare's foot clover (*Trefolium arvense*)
Spiral wide celery (*Vallisneria spiralis*)	Canadian fleabane (*Erigeron canadensis*)
Milfoil (*Myriophyllum* sp.)	"White" bent (*Agrostris alba*)
Amphibious Plants:	Large-flowered hemp nettle (*Calaeopsis speciosa*)
Bog arum (*Calla pallustris*)	Yellow toadflax (*Linaria vulgaris* Miller)
Willow grass (*Polygonum amphibium*)	Bush grass (*Calamagrostis epigeios*)
Common rush (*Juncus effusus*)	Marsh horsetail (*Equisetum palustrus*)
Three-lobed bur marigold (*Bidens tripartita*)	Krantz' cinquefoil (*Potentilla crantzii*)
Flowering rush (*Butomus umbellatus*)	Bush vetch (*Vicia sepium*)
Wood scirpus (*Scirpus sybraticus*)	Corn mint (*Mentha arvensis*)
"Black" sedge (*Carex nigra*)	Bracken (*Pteridium aquilinum*)
Terrestrial Plants:	Ground ivy (*Nepta glechoma*)
Greater celandine (*Chelidonium majus*)	White campion (*Lychnis alba*)
Knotweed (*Polygonum aviculare*)	Wild chamomile (*Matricaria chamomilla*)
Milfoil, yarrow (*Achillea millefolium*)	Coltsfoot (*Tuesilago farfara*)
Silverweed (*Potentillaanserina*)	

* Data obtained experimentally using 1-year-old fish (170-260 g) in water 30-34°C. Information from Veit and Dong (1963) as presented in Bailey (1972a).

Table B3

Daily Consumption of Selected Aquatic Plants by White Amur*

Plant	*Consumption g/day/ fish*	*Initial Avg Size g*	*Final Avg Size g*	*Period of Observation*
Hydrilla verticillata	903	955	1070	Apr 22 - May 4, 1966
Najas indica	210	94	470	Jul 7 - Aug 17, 1965
Najas indica	269	94	474	Jul 7 - Aug 17, 1965
Najas indica	813	789	989	Oct 28 - Nov 11, 1965
Hydrilla verticillata + Najas indica	80	62	113	Apr 23 - May 11, 1965
Ceratophyllum demersum	680	616	623	Sep 17 - 27, 1965
Ceratophyllum demersum	757	830	892	Oct 12 - 19, 1965
Ceratophyllum demersum	757	623	748	Oct 12 - 19, 1965
Spirodela polyrhiza	260	474	616	Aug 17 - Sep 7, 1965
Lemna trisulca	155	124	145	Apr 6 - 17, 1965
Lemna trisulca	200	100	169	Sep 15 - 24, 1965
Lemna trisulca + Wolffia arrhiza	187	87	150	Sep 10 - 22, 1965
Wolffia arrhiza + Utricularia stellaris	479	948	975	May 23 - Jun 16, 1966
Salvinia cucullata	155	958	1000	May 30 - Jun 16, 1966

* Based upon Singh et al. (1969) as presented in Bailey (1972a).

Table B4

Consumption Rates of White Amur*

Plant	*Amount Consumed/Fish g wt/day*	*Size of Fish g*	*Increase in Weight g/day*
Hydrilla	1406	153	6.11
Hydrilla	2341	753	4.86
Duckweed	436.5 - 700.5	35.2	ND**

* Information in Sutton (1974, 1977).

** No data.

APPENDIX C: THE STOCKING RATE MODEL

Three examples of the Stocking Rate Model are presented herein. See Part IV of main text for explanatory information on input parameters and logic used in the model.

```
COEWES HIS TIMESHARING ON  12/13/83 AT  8.752  CHANNEL 2342 TS1

USER ID --R0F766
PASSWORD--
[redacted]
#USERS=031 TSS=150K %MEM-USED=55 SYS=0107K #PRO=2 000-WAIT-000K

*OLD AMUR1
*FRN



GREETINGS

THIS IS THE WES WHITE AMUR STOCKING-RATE MODEL.
IT WAS DESIGNED TO PREDICT THE NUMBER OF WHITE AMUR REQUIRED
TO REMOVE A SPECIFIC AMOUNT OF THE AQUATIC PLANT HYDRILLA
FROM A LAKE OR POND. IF YOU HAVE PROBLEMS WITH THIS MODEL, OR
WOULD LIKE ADDITIONAL INFORMATION ON METHODS FOR CONTROLLING
AQUATIC PLANTS, PLEASE CONTACT:

   PROGRAM MANAGER
   AQUATIC PLANT CONTROL PROGRAM
   WATERWAYS EXPERIMENT STATION
   VICKSBURG, MISSISSIPPI      39180
     (601) 636-3111 (EXT. 3494)
       (FTS 542-3494)

TO USE THIS MODEL, ANSWER THE FOLLOWING QUESTIONS
AFTER THE  =  SIGN APPEARS:
(BE SURE TO HIT THE 'RETURN' KEY AFTER ENTERING DATA)


ENTER THE SIZE OF THE LAKE IN ACRES.

=120

ENTER THE AVERAGE DEPTH OF THE LAKE IN FEET.

=2.5

ENTER TOTAL ACRES INFESTED WITH HYDRILLA.

=60

ENTER THE MONTH OF THE YEAR (JAN, FEB, ETC.) WHEN STOCKING
WILL TAKE PLACE.

=APR
```

FIRST ENTER THE TOTAL NUMBER OF WHITE AMUR TO BE STOCKED,
THEN ENTER THE AVERAGE WEIGHT (IN POUNDS) OF A SINGLE FISH.
USE A COMMA TO SEPARATE THE TWO VALUES.

=1800,1.0

HOW MANY MONTHS INTO THE FUTURE DO YOU WISH TO PREDICT?

=24

THERE WILL BE A DELAY OF SEVERAL MINUTES WHILE RESULTS
ARE BEING CALCULATED.

YR.	MONTH	NUMBER OF FISH REMAINING	MEAN WT. OF FISH (LB)	TOTAL WT. OF FISH (LB)	PLANT CONSUMED (LB)	VEGETATED ACRES
0	APR	1794	1.18	2120.7	30780.2	81.8
0	MAY	1788	1.41	2519.3	37410.9	114.9
0	JUN	1782	1.69	3008.0	45350.8	113.5
0	JUL	1776	2.02	3591.4	54150.9	112.2
0	AUG	1770	2.42	4288.0	64658.8	110.6
0	SEP	1764	2.90	5119.6	77205.6	108.4
0	OCT	1758	3.38	5934.6	82814.7	104.4
0	NOV	1753	3.61	6323.6	61118.6	65.2
0	DEC	1747	3.72	6493.0	45075.4	26.6
0	JAN	1741	3.76	6552.7	33050.5	25.3
0	FEB	1735	4.15	7191.8	82251.8	22.1
0	MAR	1729	4.85	8394.1	119145.3	21.3
1	APR	1724	5.73	9883.0	143040.9	22.8
1	MAY	1718	6.82	11712.6	172796.2	25.2
1	JUN	1712	8.15	13960.3	209573.6	27.2
1	JUL	1707	9.73	16613.0	247704.9	28.3
1	AUG	1701	11.59	19711.9	291911.3	25.2
1	SEP	1696	13.74	23307.3	341050.7	13.4
1	OCT	1690	15.74	26603.7	0.	0.
1	NOV	1684	16.61	27968.4	0.	0.
1	DEC	1679	16.98	28511.7	0.	0.
1	JAN	1673	17.13	28662.8	0.	0.
1	FEB	1668	18.48	30833.0	0.	0.
1	MAR	1662	20.84	34642.7	0.	0.

IF YOU WISH TO RUN THE MODEL AGAIN, ENTER YES
IF YOU WISH TO STOP, TYPE NO

=NO

END OF PROGRAM

◆

APPENDIX D: STOCKING RATES OF WHITE AMUR TO CONTROL AQUATIC VEGETATION

Table D1

Number, Weight, and Effectiveness of Control of White Amur Stocked in Little Lake Barton, Florida* and Red Haw Lake, Iowa**

Water Body	*Size acres*	*No. Fish*	*Size of Fish g*	*Stocking Rate fish/vegetated acre*	*Note*
Little Lake Barton	544	212	80	0.39	Within 1 year of stocking hydrilla decreased from 1700 g/m^3 to 0.923 g/m^3
Red Haw Lake	2900	780	380	0.27	*Potamogeton*, *Elodea*, *Ceratophyllum*, and *Najas*, were controlled

Mean weights of total vegetation in the lake were:

2438 g/m^3 (1973 the start of the study)
1142 g/m^3 (1974)
455 g/m^3 (1975)
211 g/m^3 (1976)

* Osborne and Sassic (1979).

** Mitzner (1978).

Table D2

Suggested Stocking Rates and Their Success in Particular Studies

Stocking Rate	*Notes*	*Reference*
50 lb/acre	Will completely eliminate heavy infestation of coontail (in Arkansas) in one summer	Bailey (1972a)
20-41 lb/acre (10- 16-in. fish)	Shows control of several plant species in 1 to 3 months	Bailey (1972a)
238 kg/ha	Reduced aquatic plants in England (water temperature = 47-70°F)	Stott and Robison (1970)
34.6 kg/ha	Completely removed submerged weeds in a canal in Russia	Aliev (1963)
35-220 lb/acre	Recommended for most stockings in Arkansas	Bailey (1972a)
300 kg/ha (2-year-old fish)	Reduced aquatic plants by 50% in 5 months (England)	Stott and Robison (1970)

Table D3
White Amur Stocking Rates and Success of Control for Various Species of Aquatic Plants*

Species	*Initial Avg Wt. of Fish, g*	*Stocking No./ha*	*Weed quantity tons/ha*	*Time to Clear, days*
Hydrilla verticillata	995	1210	11	10
Hydrilla + Najas indica	62	5200	7.4	18
Hydrilla + Najas indica	113	654	68.3	42
Najas indica	94	1250	10.8	41
Najas indica	94	1250	13.8	41
Najas indica	789	1667	19.0	14
Ceratophyllum demersum	2640	400	5.7	5
Ceratophyllum demersum	616	1250	8.5	10
Ceratophyllum demersum	830	1250	5.7	6
Ceratophyllum demersum	623	1250	5.7	6
Ceratophyllum demersum	974	250	37.2	49
Nechamandra alternifolia	1830	250	6.8	43
Nechamandra alternifolia	2000	400	3.8	18
Utricularia stellaris	948	725	3.1	9
Spirodela polyrhiza	474	1250	6.5	20
Lemna trisulca	124	1000	1.7	11
Lemna trisulca	100	2000	3.6	9
Lemna + Wolffia arrhiza	87	2500	5.6	12
Lemna + Wolffia arrhiza	150	2500	4.5	11
Salvinia cucullata	958	1190	3.1	17

* After Singh et al. (1967).

Table D4
Success of Various Stocking Rates in Arkansas*

Area Stocked	*No. Stocked No./acre*	*Size*	*Note*
Old River (oxbow lake)	20,000/200	10,000 were fingerlings; 10,000 were 10 to 20 cm	No noticeable change in a dense covering of duckweed until the end of the second year
Irrigation canal	100/2	1 lb	No noticeable change in alligatorweed during a 2-year period
Atkins Lake (watershed lake)	2,595/750	20 to 25 cm	Submersed vegetation eliminated in 3 years
Bois d' Arc Lake (isolated, small watershed)	3,540/700 12,070/700	Yearlings Fingerlings	Submersed vegetation eliminated although no effect on emergent vegetation (3 years)
Flag Lake	1,800/120	20 to 25 cm	Submersed vegetation eliminated although no effect on emergent vegetation (2 years)
Horshoe Lake (natural lake)	18,393/1,200	20 to 25 cm	Submersed vegetation greatly reduced although no effect on emergent vegetation (3 years)

* After Bailey (1975).

APPENDIX E: REGULATIONS CONCERNING USE OF THE WHITE AMUR

State	*Responsible Agency*	*Regulation*	*As of*
Alabama	Department of Conservation and Natural Resources Fisheries Division Montgomery 36130	None	Aug 1984
Alaska	Department of Fish and Game Division of Commercial Fisheries SubPort Building Juneau 99801	Permit required	Aug 1980
Arkansas	Game and Fish Commission Little Rock 72205	None	Mar 1984
Arizona	Game and Fish Department Fisheries Branch P.O. Box 9099 Phoenix 85068	Prohibited except by special permit	Aug 1984
California	Department of Fish and Game Sacramento 95814	Prohibited except for research (very restrictive)	Aug 1984
Colorado	Department of Natural Resources Division of Wildlife Denver 80216	Permit program for east of Rocky Mountains	Aug 1984
Connecticut	Department of Environmental Protection Hartford 06115	Prohibited	Aug 1980
Delaware	Department of Natural Resources and Environmental Control Division of Fish and Wildlife P.O. Box 1401 Dover 19901	Prohibited	Aug 1980
Florida	Game and Fresh Water Fish Commission Tallahassee 32301	Permit required	Aug 1984
Georgia	Department of Natural Resources Atlanta 30334	Permit required	Aug 1984
Guam	Department of Agriculture Division of Aquatic Resources Agana 96910	Permit required	Aug 1980
Hawaii	Department of Land and Natural Resources Division of Fish and Game Honolulu 96813	Permit required	Sep 1980
Idaho	Department of Fish and Game Boise 83707	None, presently against Department policy	Aug 1980
Illinois	Department of Conservation Springfield 62706	Prohibited	Aug 1980
Indiana	Department of Natural Resources Indianapolis 46204	Permit required	Aug 1980
Iowa	Conservation Commission Des Moines 50319	Permit required	Aug 1984

State	*Responsible Agency*	*Regulation*	*As of*
Kansas	Fish and Game Department Fisheries Management Section Pratt 67124	None	Aug 1984
Kentucky	Department of Fish and Wildlife Division of Fisheries Frankfort 40601	Prohibited except for research on new triploid. Permit required.	Aug 1984
Louisiana	Department of Wildlife and Fisheries New Orleans 70130	Permit required	Aug 1984
Maine	Department of Inland Fisheries and Wildlife Augusta 04333	Prohibited	Aug 1980
Maryland	Department of Natural Resources Annapolis 21401	Presently no permits issued	Apr 1981
Massachusetts	Division of Fisheries and Wildlife Westboro 01581	Prohibited	Apr 1981
Michigan	Department of Natural Resources Lansing 48909	Permit required	Aug 1980
Minnesota	Department of Natural Resources St. Paul 55155	Prohibited	Mar 1981
Mississippi	Mississippi Department of Wildlife Conservation P.O. Box 451 Jackson 39205	Permit required	Aug 1984
Missouri	Department of Conservation P.O. Box 180 Jefferson City 65102	None	Aug 1984
Montana	Department of Fish and Game Helena 59601	Prohibited	Aug 1980
Nebraska	Game and Parks Commission P.O. Box 30370 Lincoln 68503	Prohibited except for new triploid. Permit required	Aug 1984
Nevada	Department of Wildlife P.O. Box 10678 Reno 89520	Permit required	Aug 1984
New Hampshire	Department of Fish and Game Marine and Inland Fisheries Division Concord 03301	Permit required	May 1981
New Jersey	Department of Environmental Protection Division of Fish, Game and Shellfisheries P.O. Box 1809 Trenton 08625	Prohibited	Aug 1980
New Mexico	Department of Game and Fish Sante Fe 87503	Permit required	Aug 1980
New York	Department of Environmental Conservation Albany 12233	Prohibited	Mar 1981
North Carolina	Wildlife Resources Commission Raleigh 27611	Prohibited except for new triploid. Permit required	Aug 1984

State	*Responsible Agency*	*Regulation*	*As of*
North Dakota	Game and Fish Department Bismarck 58505	Prohibited	Aug 1980
Oklahoma	Department of Wildlife Conservation P.O. Box 53465 Oklahoma City 73152	Permit required	Aug 1984
Ohio	Department of Natural Resources Columbus 43224	Prohibited	Mar 1981
Oregon	Department of Fish and Wildlife P.O. Box 3503 Portland 97208	Prohibited except for research. Permit required	Aug 1981
Pennsylvania	Fish Commission P.O. Box 1673 Harrisburg 17120	Prohibited	Mar 1981
Rhode Island	Department of Environmental Management Division of Fish and Wildlife Wakefield 02879	None, but presently against Department policy	Mar 1981
South Carolina	Wildlife and Marine Resources Department P.O. Box 167 Columbia 29202	Permit required	Aug 1984
South Dakota	Game and Fish Department Fishing Staff Pierre 57501	Prohibited except for research. Permit required	Aug 1980
Tennessee	Wildlife Resources Commission P.O. Box 40747 Nashville 37204	Permit required	Aug 1984
Texas	Parks and Wildlife Austin 78744	Prohibited except in aquaria	May 1981
Utah	Division of Wildlife Resources Salt Lake City 84116	Prohibited	Aug 1980
Vermont	Agency of Environmental Conservation Department of Fish and Game Montpelier 05602	Prohibited	Aug 1980
Virginia	Commission of Game and Inland Fisheries P.O. Box 11104 Richmond 23230	Permit required	Aug 1984
Washington	Department of Fisheries Olympia 98504	Prohibited except for research. Permit required	Aug 1984
West Virginia	Department of Natural Resources Charleston 25305	Permit required	Aug 1980
Wisconsin	Fish and Game Commission Fishing Information Madison 53703	Prohibited	May 1981
Wyoming	Game and Fish Department Cheyenne 82002	Prohibited	Aug 1980
District of Columbia	Department of Environmental Services Environmental Health Administration Washington, D.C. 20004	None	Apr 1981