Utilization Of Hydrilla By The White Amur[1]

DAVID L. SUTTON

Assistant Professor (Assistant Agronomist)
University of Florida, Agricultural Research Center
3205 S.W. 70th Avenue
Fort Lauderdale, Florida 33314

ABSTRACT

Utilization of hydrilla (*Hydrilla verticillata* Royle) by white amur (*Ctenopharyngodon idella* Val.) held in concrete tanks and plastic pools was studied. Growth of the white amur was correlated with an increase in consumption of hydrilla, but the efficiency of conversion of this aquatic plant to fish flesh decreased with increased consumption. Small white amur of approximately 100 g were more efficient converting hydrilla to fish flesh than were larger fish of approximately 1 kg. An increase in water temperature in the range of 23 to 29 C was correlated to growth of the small white amur but not with the larger ones.

INTRODUCTION

The white amur is one of the most promising biological

[1]Cooperative investigations of the University of Florida Agr. Exp. Sta.; Agr. Res. Serv., Southern Region, Florida Area, U.S. Dep. of Agr.; the U.S. Army Corps of Engineers; and the Central and Southern Florida Flood Control District. Financial support for this research was also provided by the Rockefeller Foundation (Contract Number GA NES 7113) and the Florida Department of Natural Resources, Aquatic Plant Research Control. Published as Journal Series No. 4901 of the Florida Agr. Exp. Sta.

control agents for submersed aquatic vegetation problems (4, 7, 14). The conversion of excessive plant growth into marketable fish is one feature of the white amur which is particularly appealing.

White amur feed on many different aquatic plants (4, 6, 7, 9), but quantitative measurements of the amount of aquatic vegetation consumed in relation to growth has not been adequately studied. Stott and Orr (13) estimated that 2,800 g fresh weight of lettuce (*Lactua* sp.) (133 g dry weight) was required to increase the live weight of the white amur by 10 g. Hickling (6) found that white amur converted 21.81 kg of napier grass (*Pennisetum purpureum* Schum.) into 0.45 kg of fish flesh. Hydrilla was a superior diet to napier grass or tapioca leaves (*Manihot utilissimus* Pohl.), but the amount of vegetation converted to fish flesh was not determined (16).

Hydrilla is the principal submersed aquatic plant problem in Florida. The efficient utilization of hydrilla by the white amur would certainly enhance the usefulness of this herbivorous fish as a biological agent in helping to control this and other unwanted aquatic macrophytes which interfere with the many uses placed on present water supplies. A study was therefore conducted to evaluate the conversion of hydrilla to fish flesh by the white amur.

METHODS AND MATERIALS

1. Experiments In Static Water In Concrete Tanks

White amur of an average initial weight of 176 g were placed one each in seven concrete tanks 0.76 m wide by 0.60 m high by 2.18 m long filled with pond water. Hydrilla collected from canals in the Fort Lauderdale area was fed to the fish three times a week. Prior to feeding, fresh weights of the plants were determined after excess water was allowed to drain from the surface of the leaves and stems. Hydrilla was fed in sufficient amounts so that the fish had consumed the vegetation by the time of the next feeding. If all the hydrilla had been consumed within 24 hr, then the amount added was increased at the next feeding; but if vegetation was present at the end of a feeding period, then the amount fed was reduced. Hydrilla not consumed by the end of a feeding was removed and weighed as previously mentioned. Plant samples were taken periodically for dry weight determinations. Water temperature was taken at the time of feeding. Every 4 weeks the fish were removed from the tanks and weighed. The fish were placed in water containing $C_6H_4N{:}C(CH_3)CH{:}CH$ (quinaldine)[2], at a concentration of 10 to 15 mg/l to reduce injury to the fish while they were being handled. The tanks were cleaned every 4 weeks and refilled with fresh pond water. This study was initiated 18 September 1970 and concluded 16 August 1971. Water temperature measurements were started on 14 December 1970 and continued for the remainder of the study.

[2]Eastman Kodak Co., Rochester, New York 14650. Mention of a trademark or proprietary product does not constitute a guarantee or warranty of the product by the University of Florida or U.S. Department of Agriculture and does not imply its approval to the exclusion of other products that may also be suitable.

II. Experiments In Flowing Water In Plastic Pools

This part of the study was conducted in 5,170-liter containers (0.9 m high by 3.6 m in diameter) supplied with flowing pond water at approximately 6,300 liters every 24 hr. Sufficient hydrilla was placed in the containers so that vegetation was available at all times for the fish. White amur of an average initial weight of 153 g (small fish) and 753 g (large fish) were placed three each in the containers. A total of three containers was used for the small fish, and three containers for the large fish which gave a total of 18 fish in the experiment. The fish were weighed every 2 weeks, and at this time the containers cleaned and refilled with pond water. Water temperature was determined by measurements taken three times a day (morning, noon, late afternoon) for 5 days of each week. This experiment was composed of two parts of which the first part was initiated in April 1972 and continued for seven 2-week periods. A second part was conducted in a manner similar to the first, beginning 31 July 1972 with other small fish of an average initial weight of 99 g and large fish of 1020 g.

Samples of hydrilla used in this experiment were analyzed for crude protein by the improved Kjeldahl method using $HgO\text{-}K_2SO_4$ as a catalyst (1). Caloric content of the hydrilla was determined with an oxygen bomb calorimeter.

RESULTS AND DISCUSSION

The regression equation for the relationship between the quantity of hydrilla consumed (x) to growth of the white amur (Y) held in static water in concrete tanks was $Y=8.8447+0.01376x$ (Figure 1). The correlation between these two factors was estimated to be 0.6264, based on 77 observations. Although the correlation was significant at the 1% level, this relationship of using the amount of plants eaten as the independent variable explained only 39.2% of the observed variation in growth.

During these eleven 4-week periods, the fish consumed a total of 285,025 g fresh weight of hydrilla and grew 4,604 g live weight for an average daily gain of 2.13 g. Samples taken for dry weight determinations indicated that the hydrilla contained 91.8% moisture; in other words, 23,201

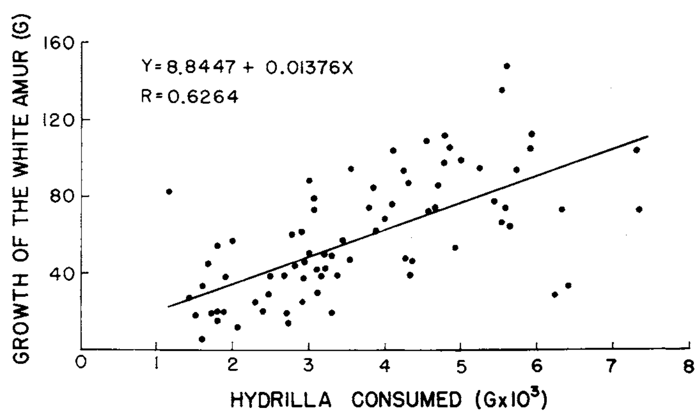

Figure 1. Growth of white amur in relation to consumption of hydrilla by these fish during an 11-month period beginning in September, 1970.

g of dry hydrilla produced 4,604 g of fish weight. The conversion relationship showing the amount of hydrilla consumed divided by fish growth, indicated that 5.04 g of dry hydrilla were required for each 1.0 g increase in growth of these fish.

Additional statistical analyses were conducted to evaluate the relationship between the quantity of hydrilla consumed to growth of these white amur for each of the feeding periods. Correlation between these two factors was estimated to be 0.9250, 0.7997, and 0.8010 for the feeding periods in November and December of 1970, and April, 1971, respectively, with values lower than these for the other feeding periods. The correlation in November was significant at the 1% and at the 5% level for December and April. Regression equations of $Y=26.4302 + 0.0229x$. $Y=2.7318 + 0.0137x$, and $Y=85.3759 + 0.0508x$ were calculated for the feeding periods in November, December, and April, respectively where x is the quantity of hydrilla consumed and Y is growth of the fish. The amount of hydrilla required for a 1.0 g increase in weight of the white amur was 4.61, 6.14, and 2.41 g dry weight for November, December, and April, respectively. These data indicate that certain periods of the year may be more favorable than at other times for efficient utilization of hydrilla by white amur contained in static water.

A number of factors affect the intake and utilization of food for maintenance and growth of fish. Water temperature was one of these factors which affected both growth and feeding activity of the white amur in the concrete tanks. Correlation between the average water temperature (Figure 2) for the feeding periods from December to July and the average growth of the fish for these periods was estimated to be 0.8588 based on nine observations, and was significant at the 1% level. This relationship of using water temperature as the independent variable explained 73.7% of the observed variation in average growth of these white amur.

The correlation between the amount of hydrilla consumed by the white amur (Y) and water temperature (x)

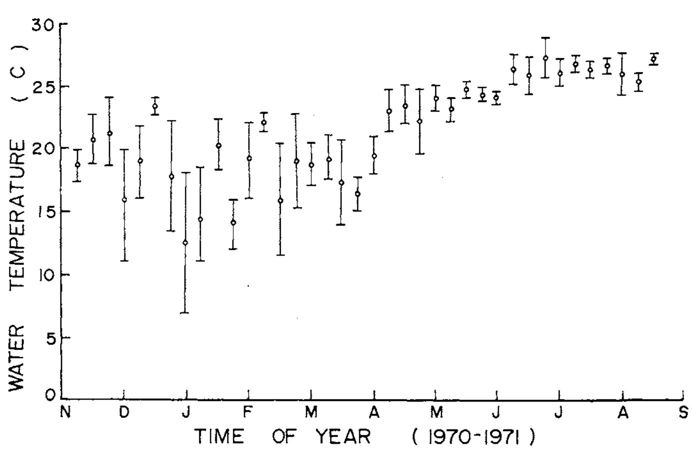

Figure 2. Water temperature of the concrete tanks containing white amur fed hydrilla. Values presented are the means of three determinations of seven replications made during 1-week intervals. The standard deviation of each value is indicated by the bar on each line.

in the concrete tanks was estimated to be 0.7916 based on 112 observations and is significant at the 1% level. Water temperatures used in this correlation were the averages of six determinations of the seven tanks made during 2-week intervals. In this relationship values for hydrilla consumed were the amounts of vegetation consumed during 2-week feeding periods for each of the seven fish. The regression equation $Y=2089.81 + 187.303$ (x) explains 62% of the observed variation in the amount of hydrilla consumed and appears to be a fairly good predictor of hydrilla consumption by these white amur.

Growth of the large grass carp in Experiment II fluctuated considerably for the 2-week feeding periods even though the amount of hydrilla consumed remained relatively constant (Table 1). This fluctuation is less evident for the small fish in the first part of this experiment where a correlation of 0.8823 which is significant at the 1% level was estimated between the amount of hydrilla consumed by the grass carp (x) and growth of these fish (Y). A linear regression equation of $Y=24.0997 + 0.0031x$ was established for this relationship. Correlation values between hydrilla consumed and growth were not significant for the large fish or the small fish in the second part of this experiment.

The crude protein content of hydrilla fed to the fish in the first part of Experiment II (14 plant samples) averaged $11.82\% \pm 2.41$ ranging from 8.76 to 17.23. Plants in the second part of this experiment contained an average of $11.71\% \pm 2.45$ with a low of 8.21 and a high of 13.74. These means are not significantly different as determined by the t-distribution analysis described by Ostle (10). This crude protein content of hydrilla may be adequate for good growth of the white amur, since Bardach et al. (2) reports that 10 to 15% protein in the diet is considered sufficient for carp (*Cyprinus carpio* L.) in general. However, the protein requirements of the white amur are not known. Other nutrients such as carbohydrates, fats, amino acids, etc., although their concentrations were not determined for the hydrilla, may have had more of an influence than the protein content of this plant on the growth of these white amur.

The caloric content of 14 hydrilla samples in the first part of Experiment II averaged 2.38 kcal$\pm$0.25 per gram dry weight of plant material and 2.66 kcal$\pm$0.25 for the second part. Values for kcal ranged from a low of 2.01 to a high of 2.69 for hydrilla used to feed white amur in the first part of the experiment and 2.10 to 3.04 for samples of plants used in the second part. A significant difference at the 1% level as determined by the t-distribution was found for plants used in the first and second part of the experiment. However, since the growth rates of the fish were similar for the two parts of this experiment, difference in caloric content appeared to have little influence on the growth of white amur in this part of the study.

The small white amur were more efficient in converting hydrilla to fish weight than were the large fish in Experiment II (Table 2). As determined by the t-distribution at the 5% level using the means of each 2-week feeding period, consumption of hydrilla by the large fish in the second part

TABLE 1. GROWTH OF WHITE AMUR AND HYDRILLA CONSUMED BY THESE FISH HELD IN PLASTIC POOLS WITH FLOWING POND WATER DURING 2-WEEK FEEDING PERIODS.

Number of 2-week feeding periods	Hydrilla consumed (g fresh wt) [a]		Increase in fish weight (g)[a]	
	Small fish	Large fish	Small fish	Large fish
Part 1				
1	6,122 a	18,666 bc	47.7 ab	105.0 cde
2	10,865 ab	31,828 de	54.2 ab	79.6 abc
3	16,365 bc	30,370 d	87.4 bcd	115.6 cde
4	21,883 c	36,336 de	81.1 abc	40.9 a
5	18,288 bc	35,056 de	74.9 abc	127.2 de
6	31,666 de	37,483 de	133.6 e	52.9 ab
7	32,630 de	39,726 e	120.3 cde	103.4 cde
Part 2				
1	11,566 a	42,500 de	63.9 ab	138.0 d
2	16,533 ab	42,000 de	55.6 ab	129.6 cd
3	20,633 bc	50,000 e	80.4 bc	95.2 bcd
4	23,366 bc	36,600 d	21.5 a	61.4 ab
5	24,500 bc	38,500 d	99.7 bcd	124.3 cd
6	17,076 ab	40,000 d	77.1 bc	48.3 ab
7	26,712 c	42,333 de	78.9 bc	67.5 ab

[a]Values within an experiment for hydrilla consumed or increase in fish weight followed by the same letter are not significantly different at the 5% level as determined by Duncan's Multiple Range Test (5). Each value for hydrilla consumed is the mean of the total amount of hydrilla consumed for each 2-week period in three pools. Each value for increase in fish weight is the mean of nine fish with three in each pool. Part 1 of this experiment was initiated in April, 1972, and Part 2 began July, 1972 with other white amur.

was higher than in the first part of this experiment. No differences were determined for intake of hydrilla by the small fish or for growth of the white amur in these two parts of the study. In general the large fish consumed approximately 50% more hydrilla than the small fish, but growth rates for these two sizes of fish were essentially the same.

Factors relating to the consumption and utilization of hydrilla by white amur in this study are presumed to have occurred in the following manner. Water temperature accounted for a large portion in the variability of both hydrilla consumption and growth of fish in the concrete tanks and for the small fish part of Experiment II. Stroganov (15) notes that the feeding rate may drop when a sudden decrease in a few degrees at temperatures of 22 C or more occurs. The small fish in the first part of Experiment II may have responded in this manner, but apparently, the large fish were not affected by temperatures ranging from 23.3 to 28.9 C.

TABLE 2. CONVERSION OF HYDRILLA TO FISH FLESH BY WHITE AMUR HELD IN PLASTIC POOLS WITH FLOWING POND WATER.

Initial white amur size	Hydrilla consumed (g fresh wt/day)	Fish growth (g live wt/day)	Conversion factor[a]
Part 1			
Small fish	1,406	6.11	21.20
Large fish	2,341	4.86	33.73
Part 2			
Small fish	1,432	6.37	26.36
Large fish	2,978	6.77	39.37

[a]Dry weight of hydrilla/live weight of white amur as determined by using a moisture content of 90.9% for hydrilla. Each value is the mean of three pools containing three fish. Part 1 of this experiment was initiated in April, 1972 and Part 2 began 2 July 1972 with other white amur.

Schaeperclaus (12) found that the energy requirement of a 600-g carp was 16.5 kcal/kg of weight per 24 hr lower than for one weighing 12 g. Apparently, less loss of heat energy occurs due to the proportionally less body surface of the large fish. This factor is of importance in comparing the consumption of hydrilla by the small and large white amur. In this study fish approximately 10 times heavier than small fish consumed only about 50% more vegetation. However, the efficiency of the large fish was less than the smaller fish.

Gorging of food by carp in general, followed by poor digestion and inefficient conversion of food to fish flesh is well known. This may be one of the principal factors involved in the low efficiency exhibited by white amur in Experiment II where hydrilla was available at all times. Also, the hydrilla plants used in this study may have been limiting in a nutrient required for growth. Another factor to be considered is that some of the hydrilla dropped to the bottom of the pool, became mixed with feces from the fish, and decayed before it could be eaten by the white amur.

Growth rates of the white amur in this study were approximately one-fourth to one-half of the highest rates reported in other studies (3, 6, 8). The number of factors which affect the consumption and utilization of food by fish (11) make it difficult to determine the exact cause for this low to medium growth rate of the white amur in this study.

Conversion of unwanted hydrilla plants into a useful product is possible with the white amur. Although the white amur is not as efficient as catfish (*Ictalurus* spp.) in converting processed feeds to fish flesh, the white amur provides one method for converting a troublesome aquatic plant to much needed protein.

LITERATURE CITED

1. Association of Official Agricultural Chemists. 1965. Official Methods of Analysis. Washington, D.C. 957 p.
2. Bardach, J. E., J. H. Ryther, and W. O. McLarney. 1972. Aquaculture. New York: Wiley—Interscience. 868 p.
3. Blackburn, R. D. and D. L. Sutton. 1971. Growth of the white amur (*Ctenopharyngodon idella* Val.) on selected species of aquatic plants. Proc. Eur. Weed Res. Coun. 3rd Int. Symp. Aquatic Weeds. pp. 87-93.
4. Cross, D. G. 1969. Aquatic weed control using grass carp. J. Fish Biol. 1:27-30.
5. Duncan, D. B. 1955. Multiple range and multiple F tests. Biometrics 11:1-42.
6. Hickling, C. F. 1960. Observations of the growth of the Chinese grass carp, *Ctenopharyngodon idellus* (C and V). Malay. Agric. J. 43:49-53.
7. Hickling, C. F. 1965. Biological control of aquatic vegetation. Pestic. Abstr. 11:237-244.
8. Hickling, C. F. 1967. On the biology of a herbivorous fish, the white amur or grass carp, *Ctenopharyngodon idella* Val. Proc. R. Soc. Edinb. (B) 70:62-81.
9. Kilgen, R. H. and R. O. Smitherman. 1971. Food habits of the white amur stocked in ponds alone and in combination with other species. Progre. Fish-Cult. 33:123-127.
10. Ostle, B. 1958. Statistics in Research. Ames, Iowa: The Iowa State College Presses. 487 p.
11. Phillips, A. M., Jr. 1972. Calorie and energy requirement. Pages 1-28, *In* J. H. Halver, ed. Fish Nutrition. New York: Academic Press.
12. Schaeperclaus, W. 1933. Textbook of Pond Culture. U. S. Fish Wildlife Serv., Fishery Leaflet 311. 240 p.
13. Stott, B. and Lydia D. Orr. 1970. Estimating the amount of aquatic weed consumed by grass carp. Progre. Fish-Cult. 32:51-54.
14. Stott, B. and T. O. Robson. 1970. Efficiency of grass carp (*Ctenopharyngodon idella* Val.) in controlling submerged water weeds. Nature. Lond. 226:870.
15. Stroganov, N. S. 1963. The food selectivity of the amur fishes, pp. 181-191. *In*: Symp. Probl. Fish. Exploit. of Plant Eating Fishes in the Water Bodies of the U.S.S.R. Ashkhabad Acad. Sci. Turkmen, U.S.S.R. (In Russian).
16. Tan, Y. T. 1970. Composition and nutritive value of some grasses, plants and aquatic weeds tested as diets. J. Fish Biol. 2:253-257.