Water Quality of Small Enclosures Stocked With White Amur[a]

JANE E. MICHEWICZ, D. L. SUTTON, and R. D. BLACKBURN

Laboratory Technologist, Assistant Professor, and Botanist
Agricultural Research Center,
Fort Lauderdale, Fla. 33314

INTRODUCTION

The awareness of the public and its concern over water pollution must lead to ever increasing efforts to control the growth of aquatic weeds. One of the most recently explored media of biological weed control is the white amur (*Ctenopharyngodon idella* Val.). This fish, with its insatiable appetite for aquatic vegetation may develop into one of the most effective biological control agents (10).

While the white amur's food consumption undoubtedly will help to alleviate the growth of aquatic weeds it must be recognized that the white amur cannot be introduced into alien waters without a thorough evaluation of its effect upon the aquatic environment. A study was initiated therefore to observe the effect of the white amur on the quality of water in small enclosures.

METHODS AND MATERIALS

White amur of an average initial weight of 888 g were stocked during July and August 1970 in outdoor plastic pools which contained 9,500 L of pond water. These pools were planted previously with hydrilla (*Hydrilla verticillata* (L.F.) Casp.). After a dense growth of vegetation became established, one fish was introduced into each of three pools while two pools without fish served as controls. Water quality determinations were made at 0, 3, 5, 10, 14, 19, and 24 days. The fish were removed following the 24-day sampling period.

Outdoor concrete tanks which contained 900 L of water were stocked with white amur during October 1970 through May 1971. Fish of an average initial weight of 364 g were stocked one each in five tanks. Duckweed (*Lemna minor* L.) was cultured in other tanks and fed to the fish three times a week. Fresh weight of the plants was determined prior to placing this vegetation in the tanks. Uneaten duckweed was removed from the tanks and weighed prior to each feeding. The weight of the duckweed was determined after allowing excess water to drain from the plant's surface. Every 4 weeks the fish were weighed, samples of water taken for water quality measurements, and the tanks cleaned and refilled with fresh pond water.

Indoor tests were conducted in eight aquaria containing 20 L of pond water. Each aquarium was stocked with one white amur of an average initial weight of 224 g. These aquaria were aerated with compressed air in a controlled environment room having a temperature of 22 ± 2 C and a photoperiod of 14 hr of light and 10 hr of darkness. The fish were also fed three times a week with a measured amount of duckweed taken from the concrete tanks. Samples for water quality measurements were taken every 2 weeks. The fish were removed and weighed at the end of each 4-week period, and the aquaria cleaned and filled with pond water. This test was initiated in December 1970 and continued for 5 months.

In all experiments, water quality measurements for total phosphorus, nitrate-nitrogen, turbidity, sulfate and tannins and lignins were made using the Hach Field Kit.[b] The Hach manometric method was used to measure biochemical oxygen demand (BOD). The Weinkler method was used for dissolved oxygen determinations. Total hardness (calcium and magnesium carbonate), pH, and alkalinity were measured by methods described in Standard Methods (1).

RESULTS AND DISCUSSION

White amur stocked at the rate of one fish/pool is equivalent to 950 fish/ha; one fish/tank equals 5,747 fish/ha; and one fish/aquarium equals 50,325 fish/ha of water. The stocking rate of these fish in the aquaria and tanks are higher than the normal stocking rate for bass (*Micropterus* spp.) and bluegill (*Lepomus macrochirus* R.) which is a ratio of 74 to 247 bass with 988 to 3,705 bluegill/ha of water (3).

The plastic pools containing white amur were devoid of vegetation after 24 days. The average final weight of these fish was 1041 g which represents an average daily gain of 7.3 g.

Pools containing one fish exhibited a rapid drop in the dissolved oxygen content while the controls remained basically the same (Figure 1). The major cause for the decline in oxygen content may be due to the oxygen utilized by the white amur in respiration, and the removal of the weeds which produced the oxygen.

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[b] Mention of a trademark name or a proprietary product does not constitute a guarantee or warranty of the product by the University of Florida or the USDA, and does not imply its approval to the exclusion of other products that may also be suitable.

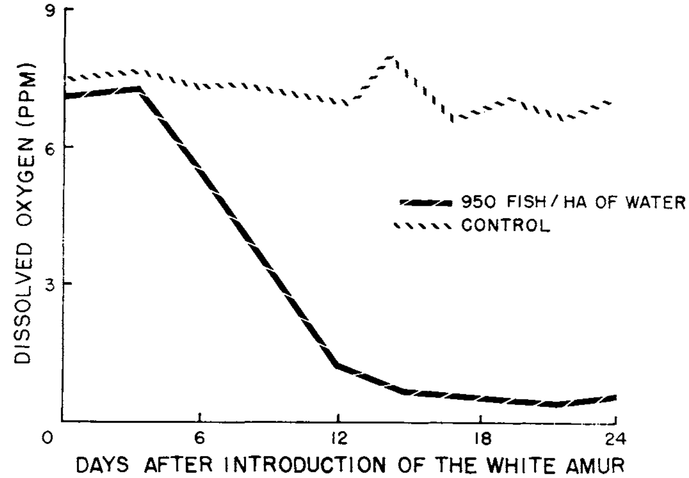

Figure 1. Dissolved oxygen in 9,500 L plastic pools containing white amur feeding on hydrilla.

The pH dropped in those pools stocked with fish (Table 1). This change was caused primarily by the increase in carbon dioxide produced by fish respiration as well as the oxidation of organic substances by bacteria. This oxidation can raise the levels of carbonates and nitrates which would result in a shift toward an acid condition (9).

Total hardness of water increased in those pools containing fish (Table 1). The calcium carbonate component of the total hardness at the beginning of the feeding period was 47 ppmw and had risen to 123 ppmw by the end of the experiment. Total hardness did not change in the control pools. Calcium from decaying organic material may be the principal cause for the increase because of the large amount of fecal material produced by the white amur, as well as the normal decaying of organic matter.

In a closer look at the process in which calcium and magnesium carbonates are formed in the water, a correlation between fish and total hardness can be drawn. Both white amur and bacteria produce carbon dioxide, which in turn combines with water to form a bicarbonate (8). At the same time, the fish consumes plant material and produces organic waste (2). The bicarbonate splits and becomes attached to Ca^{++} and Mg^{++} ions which are released from the decaying plant material to form calcium carbonate and magnesium carbonate (8).

TABLE 1.—MEASUREMENTS OF WATER FOR pH AND TOTAL HARDNESS IN 9,500 L PLASTIC POOLS CONTAINING WHITE AMUR FEEDING ON HYDRILLA.

Time (Days)	pH[a]		Total hardness (ppmw)[a]	
	Control	One fish /pool	Control	One fish /pool
0	9.5 c	10.0 c	66 a	70 a
3	9.9 c	9.9 c	68 a	62 a
5	9.7 c	9.6 c	60 a	62 a
10	9.8 c	8.2 b	64 a	76 a
14	9.5 c	7.6 a	74 a	110 b
19	9.6 c	7.6 a	59 a	138 c
24	9.6 c	7.4 a	70 a	158 d

[a] Means followed by the same letter are not significantly different at the 5% level as determined by Duncan's Multiple Range Test. Each value is the mean of two pools.

Changes in the aquatic fauna and flora populations are associated with water hardness. For example, in very soft water (less than 20 ppmw of calcium) stoneflies (*Plecoptera* spp.) and mayflies (*Ephemeroptera* spp.) are generally dominant as the calcium content increases chironomids (Chioptera), shrimp and snails (Gastropoda) become more prevalent (6). Furthermore, hard water is more stable chemically than soft water. Toxicity by lead and other heavy metals is reduced by hard water because of the precipitation of these metals by calcium ions (4, 7). Thus, a rise in total hardness in areas where very soft water occurs could be advantageous.

Turbidity in the pools was not affected by the fish (Figure 2). A drop or rise in turbidity in the pools containing fish was accompanied by a corresponding drop or rise in the controls. The white amur's effect on turbidity may be evaluated adequately by using more fish in larger enclosures.

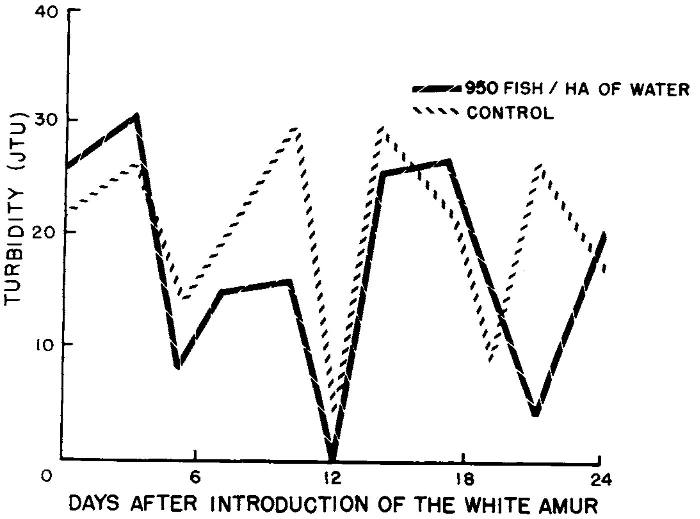

Figure 2. Turbidity of water in 9,500 L plastic pools containing white amur feeding on hydrilla.

Nitrate-nitrogen levels in the pools containing fish were higher than the controls at the 24-day sampling period, but the total phosphorus levels were not affected (Table 2). This increase in nitrate-nitrogen was due principally to the ammonium nitrogen produced by the fish (8), as well as nitrogen produced from the decaying plant material. The organic fecal waste material contains ammonia (NH_4) (8). Nitrogen fixing bacteria such as *Nitrobacter* sp. decompose the waste products and convert the ammonia into nitrate-nitrogen (NO_3) as a by-product (9). High concen-

TABLE 2. NITRATE-NITROGEN AND TOTAL PHOSPHORUS LEVELS IN 9,500 L PLASTIC POOLS CONTAINING WHITE AMUR FEEDING ON HYDRILLA.

Days	Nitrate-nitrogen (ppmw)[a]		Total phosphorus (ppmw)[a]	
	Control	One fish/ pool	Control	One fish/ pool
3	0.67 a	0.85 bcd	1.45 a	1.43 a
10	0.73 ab	0.79 abcd	1.04 a	1.04 a
17	0.90 bcd	0.94 d	0.25 a	0.65 a
24	0.76 abc	0.93 cd	0.70 a	1.12 a

[a] Means for nitrate-nitrogen and total phosphorus followed by the same letter are not significantly different at the 5% level as determined by Duncan's Multiple Range Test. Each value is the mean of two replications.

trations of nitrogen compounds are likely to occur when extremely high stocking rates of white amur are used to control aquatic weeds.

Fluctuations were noted in the growth of white amur feeding on duckweed in the concrete tanks (Table 3). No appreciable effect on water quality was observed during the 4-week feeding periods (Table 4). However, water quality changes occurred in the aquaria containing fish feeding on duckweed. For example, the initial total hardness of 178 ppmw rose to 200 ppmw in 2 weeks and to 246 ppmw after 4 weeks. The total phosphorus levels increased from 1.3 ppmw to 9.8 ppmw in 2 weeks, and to 13.0 ppmw in 4 weeks. Nitrate-nitrogen showed the greatest rise, increasing from 0.57 ppmw to 15.0 ppmw in 2 weeks, and to 17.9 ppmw in 4 weeks. Those changes that were only minutely noticeable in the plastic pools and concrete tanks were quite evident in the aquaria. The stocking rates in the aquaria were exceptionally high and would probably never occur in a natural situation; therefore, these extreme water quality changes should not be experienced.

Growth and food consumption of the white amur feeding on duckweed in the aquaria was highest during the second 4-week growth period (Table 5). The correlation of duckweed consumed to growth of the fish is presented in Figure 3. This low correlation is probably due to the stress placed on the fish by the high stocking rates. Abnormal water quality factors could inhibit the normal feeding activity. Fluctuations in nutrient content of the duckweed might also affect growth. The correlation was somewhat higher for fish feeding out-of-doors in the concrete tanks. Since temperature affects the feeding habits of the white amur (5), this environmental factor, in addition to other factors, probably influenced the conversion of duckweed to fish flesh.

TABLE 3. GROWTH OF THE WHITE AMUR FEEDING ON DUCKWEED FOR 4-WEEK PERIODS IN 900 L OUTDOOR CONCRETE TANKS.

Time of year 1970 to 1971	Amount of[a] duckweed consumed (g *fresh* wt)	Growth of[a] the white amur (g)
Oct.-Nov.	4080 d	160.4 c
Nov.-Dec.	2400 c	73.9 bc
Dec.-Jan.	1950 bc	71.7 bc
Jan.-Feb.	1280 a	46.6 a
Feb.-March	1064 a	87.8 bc
March-April	1507 ab	46.1 b
April-May	1681 ab	33.9 ab

[a] Values followed by the same letter are not significantly different at the 5% level as determined by Duncan's Multiple Range Test. Each value is the mean for five fish.

TABLE 5. GROWTH OF THE WHITE AMUR FEEDING ON DUCKWEED DURING 4-WEEK PERIODS IN 20 L AQUARIA IN AN ENVIRONMENT CONTROLLED ROOM.

Growth periods	Amount of duckweed consumed[a] (g fresh wt)	Growth of the white amur[a] (g)
1	1026 a	48.5 ab
2	3364 c	72.2 b
3	1555 b	32.2 a
4	1508 ab	20.3 a
5	1665 b	25.3 a
6	1774 b	22.0 a
7	1959 b	35.0 a

[a] Values in a column followed by the same letter are not significantly different at the 5% level as determined by Duncan's Multiple Range Test. Each value is the mean for eight fish.

A higher level of BOD was found in the aquaria than the concrete tanks because of the higher concentrations of fecal material present per unit volume (Figure 4). Readings of 3 ppm indicate fairly clean water (6). In the concrete tanks, this value was not exceeded.

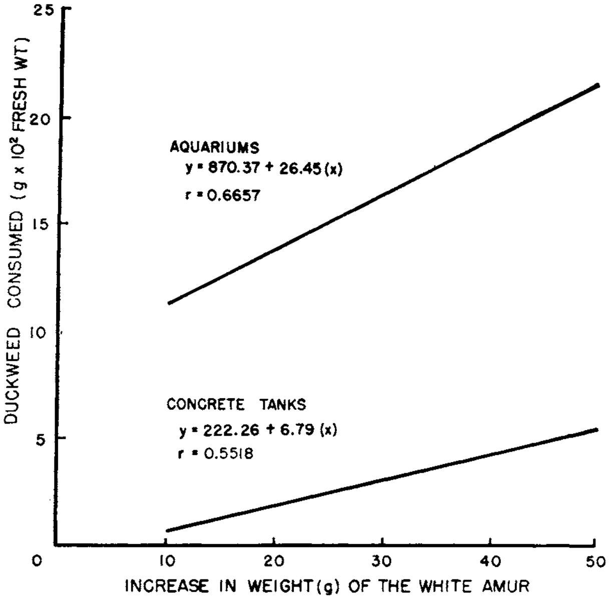

Figure 3. Correlation of duckweed consumption to growth of white amur.

TABLE 4. MEASUREMENTS FOR WATER QUALITY IN 900 L CONCRETE TANKS CONTAINING WHITE AMUR FEEDING ON DUCKWEED FOR 4-WEEK PERIODS.

Water quality measurement	Control (Pond water)	Time of year during 1971[a]			
		February	March	April	May
Total hardness (ppmw)	176.00 bc	171.00 bc	130.00 a	149.00 ab	193.00 c
Turbidity (JTU)[b]	30.00 bc	21.00 ab	35.00 bc	45.00 c	11.00 a
pH	7.80 a	8.50 b	8.10 a	7.80 a	8.60 b
Nitrate-nitrogen (ppmw)	0.78 a	0.76 a	0.85 a	1.01 a	0.69 c
Phosphorus (ppmw)	1.42 a	1.42 a	0.42 a	0.84 a	0.92 a

[a] Means followed by the same letter are not significantly different at the 5% level as determined by Duncan's Multiple Range Test. Values for the control are measurements of pond water prior to introduction of the fish. Each measurement is the mean of five replications.

[b] Jackson Turbidity Units.

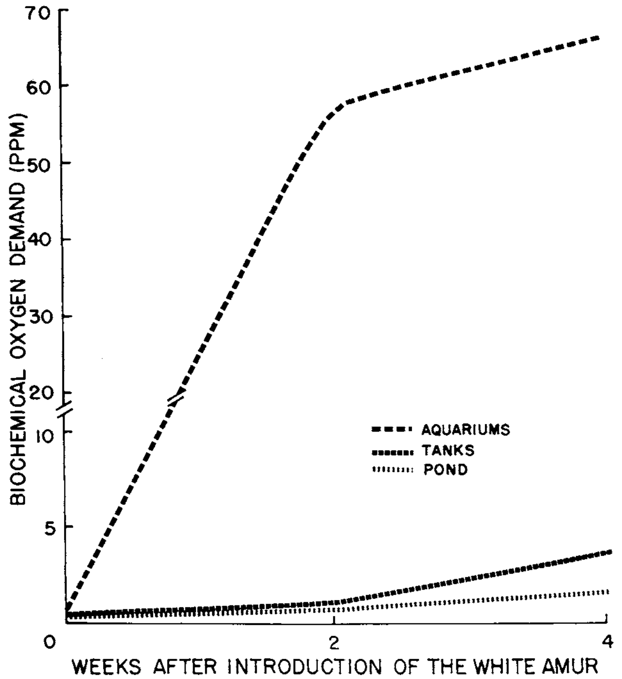

Figure 4. BOD of water from 20 L aquaria and 900 L concrete tanks containing white amur feeding on duckweed.

CONCLUSIONS

In comparing water quality from enclosures of three different sizes containing white amur feeding on aquatic plants, greater deviation from the normal condition was noted as container size decreased. While these tests are by no means conclusive, it appears that as the enclosure size increases there would be fewer changes in water quality where white amur are actively feeding on aquatic plants.

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