AN INTENSIVE CULTURE SYSTEM FOR CHANNEL CATFISH FINGERLINGS

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Abstract: Channel catfish (*Ictalurus punctatus*) were stocked at rates of 250, 500, 1,000 and 2,000 fry/208 l drum, and reared to fingerling size. No significant differences occurred in rate of gain from days 0-33, but gains ranged from 0.22 g/day at the 250 stocking rate to 0.08 g/day at the 2,000 stocking rate from days 0-70. The highest average total biomass of 10,095 g was reached at the 2,000 stocking rate. Flow rate was maintained at a constant 0.32 l/sec in all drums. Food conversion from days 17-70 ranged from 1.42 at the 250 stocking rate to 2.67 at the 2,000 stocking rate. Water quality was monitored to evaluate the effect on growth. Oxygen concentration became a critical limiting factor as total biomass increased. Growth rates were best at the lower stocking rates in which the oxygen concentrations were higher.

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Specialized catfish culture systems have received much publicity in recent years and several high density methods are currently under investigation. These include the use of cages, earthen, metal or concrete raceways and various tank systems Meyer et al. 1973). Channel catfish have been reared successfully in cages (Lewis 1969, Schmittou et al. 1969).

An accepted method to rear channel catfish to fingerling size of 8 to 15 cm, is to raise channel catfish in ponds. These fish are hatched in either spawning containers and remain in ponds or may be incubated in hatching troughs. The same fry can then be placed in trough containers and held for a period of 3 to 10 days to begin feeding (Meyer et al. 1973). The swim-up fry are then counted and stocked in ponds at rates from 12,000 to 60,000/ha. Culture success with these methods has been variable depending on the percentage of fry which began feeding in the ponds, predation by insects and loss because of disease or water quality.

To improve the percentage of fry that begin feeding, the fish are often held in a restricted area (e.g., screen cages) until they reach a larger size. Trough culture is mentioned by Martin (1967) as a culture method for fingerling catfish, but he suggests that these fish be transferred to a pond at the advanced fry stage.

Although most research has been directed toward culture of food size catfish, Stickney et al. (1972) have shown that it is possible to rear advanced fry to fingerlings (15 g) in tanks in 8 wks. However, attemps to rear smaller fry (1 g) in fiberglass tanks resulted in high mortalities. Most commercial attempts to produce fingerlings in tanks have been unsuccessful because of nutritional problems or nitrogen embolism (Lock 1973). Johnson (1970) investigated the possibility of rearing channel catfish fingerlings in small, wire-mesh cages and encountered problems with feed quality, feeding methods, parasites, predaceous insects and algal growth clogging the mesh.

Newton (1974) attempted to rear fry of channel catfish in flow-through troughs and reported that survival of fingerlings in raceways was low each season with only isolated cases of a commercially acceptable survival being attained. Channel catfish fry can be cultured very successfully in large raceways as reported by Hawkinson (1971).

An innovation was proposed by Buss (1968) to utilize 208 l drums to rear swim-up trout fry to fingerlings. The purpose of this study was to evaluate this procedure to culture channel catfish fry to a total length of 5 cm.

MATERIALS AND METHODS

Design of Culture System

Sixteen 208 l drums were modified to facilitate the introduction of water and the screening of the discharge to prevent fry escapement. Water from a 4 ha reservoir was picked up by pump and discharged on the bottom of the drum (Fig. 1). Water flowed out through a screen baffle. The water flow rate was held constant at 0.32 l/sec with gate valves on each drum. Plywood covers were installed to prevent most light entry and provide support for self-feeders.

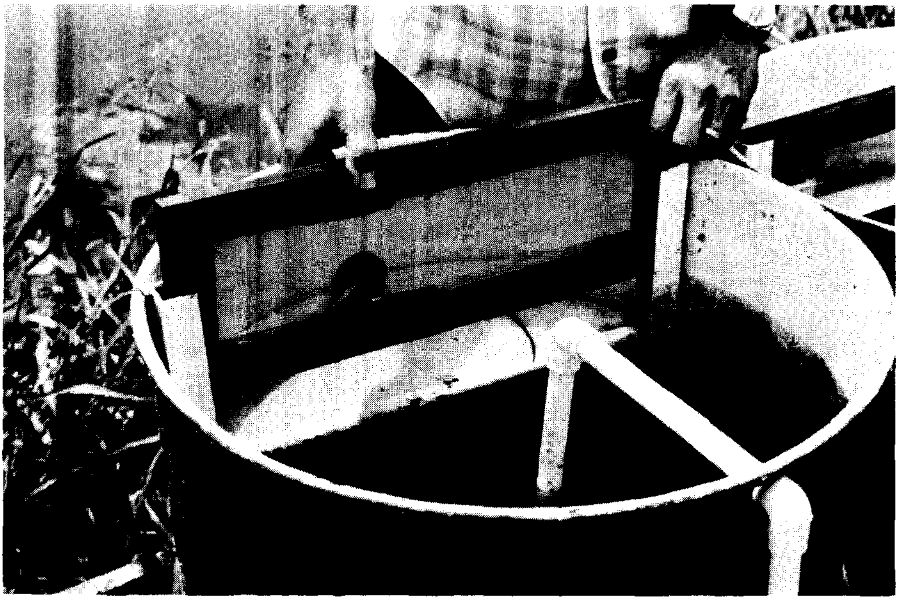

Fig. 1. Drum (208 l) used to culture fry. The water capacity was 167 l with an exchange rate of 20 l/min.

Stocking Procedure

The number of fry stocked was estimated by weight. The 5-7 day old fry were provided by the Texas A&M Fish Culture Facility. Sixteen drums were stocked; 4 each with 250, 500, 1,000 and 2,000 fry on 8 June 1976. Fry were weighed after 33 days and the stocking rates of all drums adjusted to beginning stocking rates except for 2 drums of 2,000 fish which were terminated to provide fish for other drums.

Feeding Methods

The fry were fed not less than 60 percent of body weight per day in the initial phase of the study by automatic feeders divided into 6 equal feedings. Feed was introduced in excess to insure each fish having the opportunity to feed. All fish were fed the same ration (Master Mix, F-45, 970 Fish Starter), #0 powder in the initial phase progressing to No. 1, No. 2, No. 3 and No. 4 size granules as the fry grew. Fish above 1 g in weight were hand fed twice daily in feedings of 5 percent each for the continuation. Fish weights were determined at 2 wk intervals or when feeding rates did not appear adequate.

Drum Maintenance—Disease and Parasite Control

The screens required cleaning to prevent clogging. Feed and feces accumulated on the bottom of the drums and required cleaning for the first 3 wks. Both siphoning and stirring of the bottom accumulations for removal were attempted. After 2 wks, the 2.1 mm mesh size screen was removed and replaced by 3.2 mm mesh size. The smallest fish weighed 0.3 g when the screen was changed.

Formalin treatments of 50 and 150 ppm were tested for parasite control on 3 July 1976. A treatment of 150 ppm of formalin was administered to all drums on 7 July 1976. Terramycin and Furacin were used for control of an *Aeromonas* sp. infection. The antibiotics were incorporated in the feed with vegetable oil at the rate of 1 g active antibiotic per 3,000 g feed.

Growth and Survival

The growth and survival of the fry were considered essential to evaluating the success of the culture system. Thirty fish were captured with a dip net and weighed on days 12, 17, 26 and 50. On day 33, all fish were counted and weighed. The study was terminated on day 70 and all fish were again counted and weighed.

Water Quality

Ammonia and carbon dioxide were measured periodically with a Hach kit. Temperature and oxygen were measured with a YSI oxygen and temperature meter. When levels appeared detrimental, e.g., when oxygen levels dropped below 2 ppm, intensive monitoring of that parameter was conducted. Regular measurements of the oxygen level in the culture drums and the water supply reservoir were conducted.

The following formula was used to determine oxygen consumption rates:

Oxygen consumption = mg O_2/g fish/min
r = total O_2 consumed/drum
I = incoming oxygen (mg/l)
C = outgoing oxygen (mg/l)
Q = flow rate

$$\text{Oxygen consumption} = \frac{r}{\text{Total weight fish per drum}}$$

The gain per fish per day and gain of total biomass per drum per day were compared to the drum volume (167 l) and flow rate (.32 l/sec). These comparisons were then used to derive W and W' with the following formula:

$$W = \frac{\text{gain per fish per day) (vol)}}{\text{Flow rate}}$$

$$W' = \frac{\text{(gain in biomass per drum per day) (vol)}}{\text{Flow rate}}$$

Data Analysis

The growth and gain data for individual fish and the total population in each drum were examined for differences by analysis of variance. Differences between stocking densities were then tested with Student—Newman Keul's Multiple Range Test. Variations in oxygen consumption of fish were analyzed by step-wise multiple regression analysis and a correlation matrix plotted to examine the relationship between oxygen consumption and individual fish weight, total fish weight, incoming dissolved oxygen, temperature, oxygen consumed per g fish, oxygen consumed per drum and stocking rate. Duncan's New Multiple Range Test was used to test differences in food conversion and survival. All statistical analyses were performed at the .05 level of significance (Steel and Torrie 1960).

RESULTS AND DISCUSSION

Operation of Culture System

The drums required very little maintenance. Water was introduced at a high exchange rate (19.2 l/min) with minimum water turbulence. The water's high flow rate, coupled with action of the fish, kept the drums free of excess feed and feces as the study progressed.

Introduction of very small sizes of feed presented some problems with the feed clogging the screens and larger amounts of feed had to be introduced to insure availability to the fry. As number 2 and 3 sizes of feed were used, this ceased to be a problem.

Diseases and Parasites

External parasites were controlled with treatment of 150 ppm of formalin for 1 hr. Fish were checked on 14 June 1976, and had very light infestations of *Cleicodiscus* sp., *Henneguya* sp. and *Trichodina* sp. on the gills; *Trichodina* and *Ambiphyra* sp. on the skin and *Corallobothrium* sp. in the gut. No mortalities were observed to this time. On 3 July 1976, dead fish were observed in a 500 stocked drum. The fish were then treated with 50 ppm formalin for 1 hr. No success in removal of parasites was attained. On 4 July, 3 drums were treated with 150 ppm formalin. All parasites were removed with treatment and all remaining drums were treated on 7 July 1976.

On 6 July 1976, 2 fish were observed with what appeared to be a *Columnaris* sp. bacterial infection. A treatment of 10 g oxytetracycline per 3,000 g feed was offered to the 2 drums with 2,000 fish. No further mortalities were observed from the *Columnaris* sp. infection. However, the stress induced by counting and weighing the fish on day 33 (10 July 1976) was detrimental to the fish as reflected by decrease in total gain per day. The bacterial infection of *Aeromonas* sp. which occurred after day 33 was influential on survival. There was no significant difference in survival due to stocking rate. The *Aeromonas* sp. infection was contained with the use of Furacin as a flush and food additive.

Growth and Survival

Lower stocking rates produced progressively larger fingerlings. The higher stocking rates produced the greatest number of fish (Table 1). Significant differences in individual

Table 1. Stocking and harvest data for the channel catfish fry in the 1976 culture experiment.

Number fish stocked (estimated)		250	500	1000	2000
Average g fish per drum stocked June 8		10.5	21.0	42.0	84
Average g per fish stocked		0.04	0.04	0.04	0.04
Average weight per fish harvested August 16 (g)		15.40	11.90	8.30	5.60
Number harvested	—Day 0-33[a]	216	462.30	855.30	1845.50
	Day 33-70	194.80	425.00	885.60	1790.50
Percent survival	—Day 0-33[a]	86%	93%	86%	92%
	Day 33-70	78%	85%	89%	90%
Total weight harvested per barrel (g)		2961.30	4625.00	7467.50	10095.00
Gain per fish	—Day 0-33	2.4	2.3	2.3	2.2
	Day 0-70	15.4	11.9	8.3	5.6
Gain per day	—Day 0-33	0.073	0.070	0.070	0.067
	Day 0-70	0.22	0.17	0.12	0.08
Total average weight gain per barrel		2950.70	4604.00	7425.50	10011.0
Average g of feed per drum	—Day 0-70[b]	31452	41052	68796	55316
	Day 17-70[b]	15860	25460	53204	45720
Conversion	—Day 0-70[b]	2.66	2.23	2.32	2.76
	Day 17-70[b]	1.42	1.49	1.95	2.67
Harvest load (g/m^3)		17731.7	27760.5	43718.6	60449.1
g/l/min		147.6	231.1	364.0	503.2

[a]Survival due to error in estimation at stocking and not due to mortality.

[b]This time period includes the 17 days when the fish were fed with automatic feeders and the amount fed to the fish stocked at lower densities was in excess of amount required.

weight did not occur until day 50 when the biomass in the drums reached levels of 1,184.83 g/250 drum to 6,441.56 g/2,000 drum. At this time, size differential among individual fish became obvious with the fish ranging in average size from 4.80 g in the 250 drums to 3.24 g in the 2,000 drums. Allen (1972) reported that the growth rate decreased with increases in density. On day 50, all stocking rates had significant weight differences, except those stocked with 250 and 500 fish. All weights of individual fish were significantly different on day 70, except the drums stocked with 1,000 and 2,000 fish.

There were no significant differences in net gain of individual fish from days 0-33 in any drum. As the total biomass increased in relationship to stocking density, the rate of gain decreased in the higher stocking rates. The individual gain of fish during days 33-50 was significantly different in all drums, except between drums stocked with 250 and 500 fish and 1,000 and 2,000 fish. Gain per fish during the final period, days 50-70, was significantly different between all drums, except those stocked with 500 and 1,000 and 1,000 and 2,000 fish.

Higher stocking rate had significant influence over size of individual fish, total weight and gains. There was a signficant difference in total weight on all days, except at the

250 and 500 stocking rate on day 17. The total weight of 60.5 kg/m^3 with a 7 min exchange rate compares favorably with Hawkinson (1971) who cultured fry up to 36.2 kg/m^3 with a 90 min exchange.

After day 26, the total gain per day was significantly different between all groups of fish until the final period, days 50-70. During this period, the 1,000 stocked group averaged 195.9 g/day which surpassed the 2,000 stocked group at 182.69 g/day. The influence of biomass caused the total rate of gain of the 1,000 stocked fish to surpass the 2,000 stocked fish during the period, days 50-70, though surpassed, it was not significant. There was a marked decrease in gain per day at the 2 higher stocking rates from the period, days 33-50. This decrease in gain per day followed the handling of all fish for weight determination.

There was no significant difference in survival from days 33-70 due to stocking rate. The difference in survival from days 0-33 was due to error in estimation of fry numbers at stocking. There were no significant differences in the survival of fry because of stocking rate. Diseases seem to affect fish in all drums regardless of stocking rate.

As reported by Allen (1972) food conversion efficiency does decrease with increased biomass. The food conversion efficiency in this study decreased significantly as stocking rates increased.

Water Quality

During the study, the values of oxygen were the most variable water quality feature monitored. The highest values recorded for carbon dioxide were 0.8 ppm and 0.45 ppm for ammonia. The temperature ranged from a low of 27.75 C on day 28 to a high of 28 C on day 60.

The oxygen concentration in the water supply reservoir (measured at approximately 8 a.m. on sample days) ranged from 6.5 ppm to 11.0 ppm. The average values of ppm oxygen in the drums and standard deviation of the 4 stocking rates 250, 500, 1,000 and 2,000 were 6.07 (.75), 5.33 (.84), 4.37 (1.00) and 3.40 (.83), respectively.

Perhaps the overriding condition causing decreases in growth rate was the lack of oxygen, as the result of increases in total biomass. There was a very close relationship of the oxygen readings in the culture drums and the reservoir oxygen. The oxygen values were always lower at the higher stocking rates. As the total biomass increased, the dissolved oxygen readings in the drums decreased (Fig. 2 and 3).

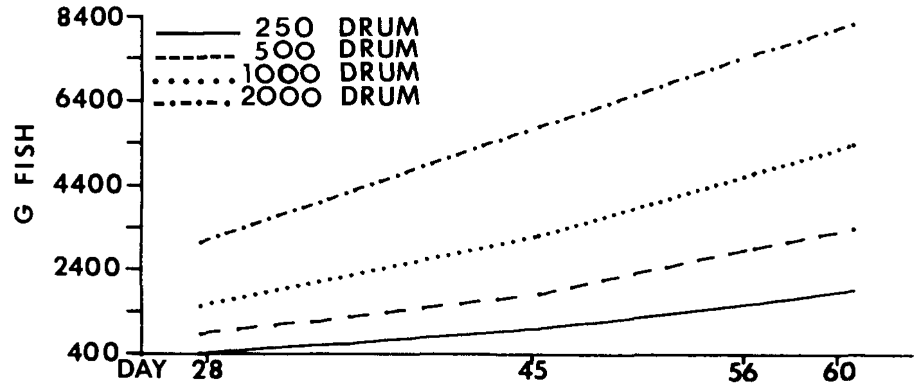

Fig. 2. Average total weight of fish per drum in each of the 4 stocking rates.

Respiratory dependence for 200 g channel catfish was reported by Andrews and Matsuda (1975) at 7 ppm or higher. The relationship of smaller fish having higher oxygen consumption rates than larger fish was also demonstrated by Andrews and Matsuda (1975).

Both of these variables affected oxygen consumption rates in the study. On day 28 (Fig. 4) the smaller fish in the 1,000 stocking rate were consuming more oxygen (.0188 mg O_2/g fish/min) than the 250 stocked fish (.0114 mg O_2/g fish/min).

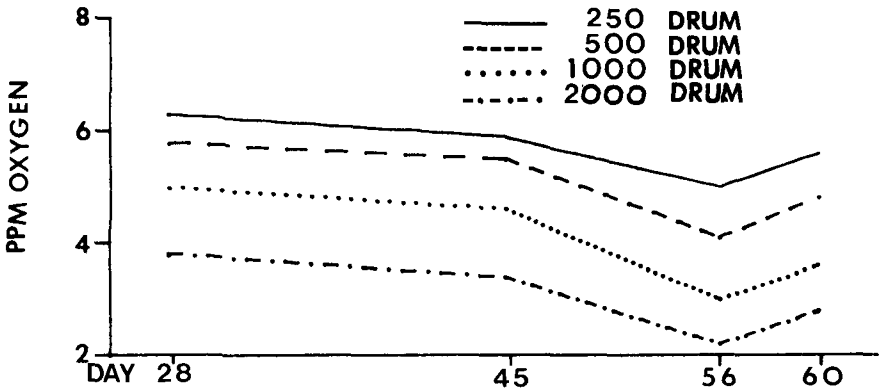

Fig. 3. The ppm of oxygen in each drum of the 4 stocking rates.

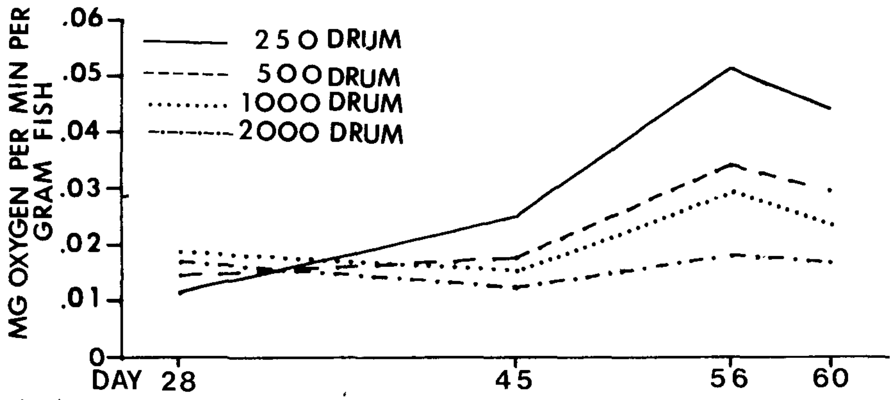

Fig. 4. Oxygen consumed per g fish per min at each of the 4 stocking rates.

This relationship began reversing itself on approximately days 34-36, at which time respiratory dependence began dominating the size effect of the higher metabolic rate of smaller fish. This relationship was reported by Fry (1957).

Increasing high values of incoming oxygen (Fig. 5) enabled the fish to continue to

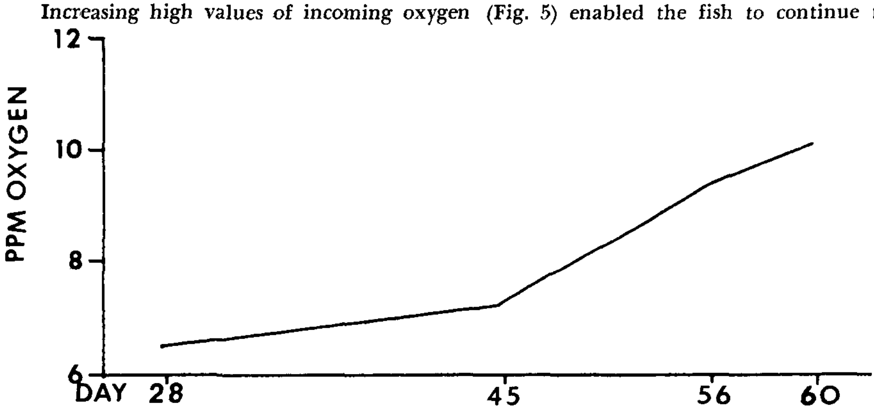

Fig. 5. The ppm of oxygen of the incoming water.

gain weight, though at a lesser rate as the total biomass increased. The greater demand for oxygen (Fig. 6) of the higher biomasses resulted in very low oxygen concentrations

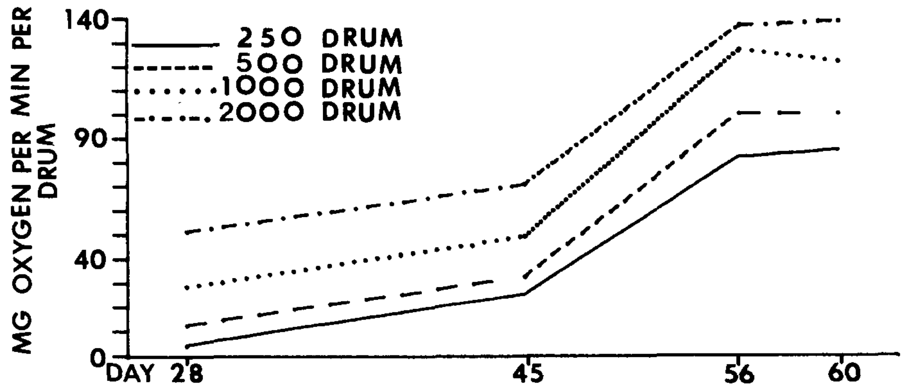

Fig. 6. The total oxygen consumed per drum.

in these drums (3 ppm). Raible (1975) reported mortalities at 2.5 ppm oxygen and decreased growth rates at lower oxygen concentrations (10% decrease in growth rate per 1 ppm oxygen) while holding oxygen concentrations constant (range 3-6.8 ppm). The degree of respiratory dependence is of importance because of the effect of values of incoming oxygen concentrations and the total oxygen consumption (Fig. 5 and 6). Growth can be attained by a respiratory dependent fish if it can maintain body functions and assimilate food (Fig. 7).

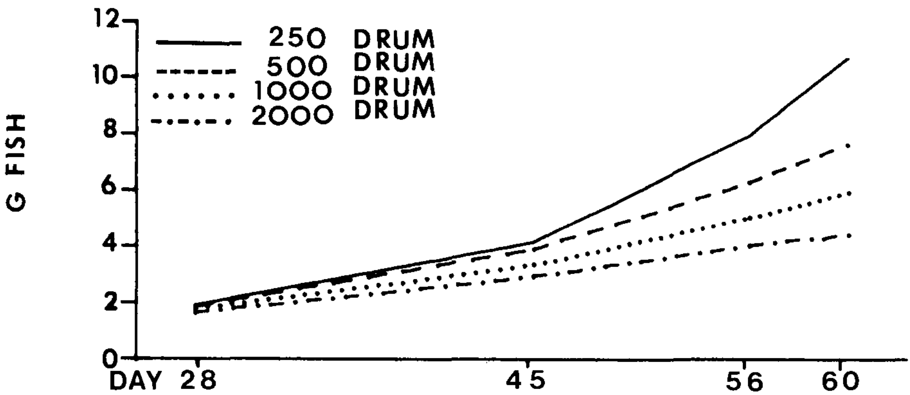

Fig. 7. Average individual weight of fish in each of the 4 stocking rates.

From days 28-60, there is a significant positive correlation between the individual size of fish and oxygen consumption. If adequate oxygen were available, one would expect a negative correlation between size of individual fish and oxygen consumption. Step-wise multiple regression selected individual size of fish as the most significant independent variable with oxygen consumption being dependent. The total weight of fish per drum was not significant at the .05 level, but is near a significant correlation with oxygen consumption per fish.

The higher stocking rates which produced higher total biomass did not directly affect the growth of the individual fish. If high oxygen levels could be maintained to prevent the incipient limiting level (e.g., where the active metabolic rate becomes restricted) then, the growth should not be suppressed at these stocking levels.

Several factors, acting independently or interacting, enhance or limit production. The beneficial effect of higher oxygen has been demonstrated. The oxygen values were directly affected by the flow rate and total biomass which resulted in varying oxygen consumption rates. In order to examine these various factors simultaneously, ratios of the gain per fish per day and the gain of total biomass per drum per day were each compared to the volume of water in the drum (167 l) and the flow rate (.32 l/sec).

By comparing these values at each of the 4 stocking rates, one can examine the limitations of high stocking rates versus low stocking rates and predict a point of least effect of limiting factors. This stocking rate would be approximately 950 as shown in Fig. 8.

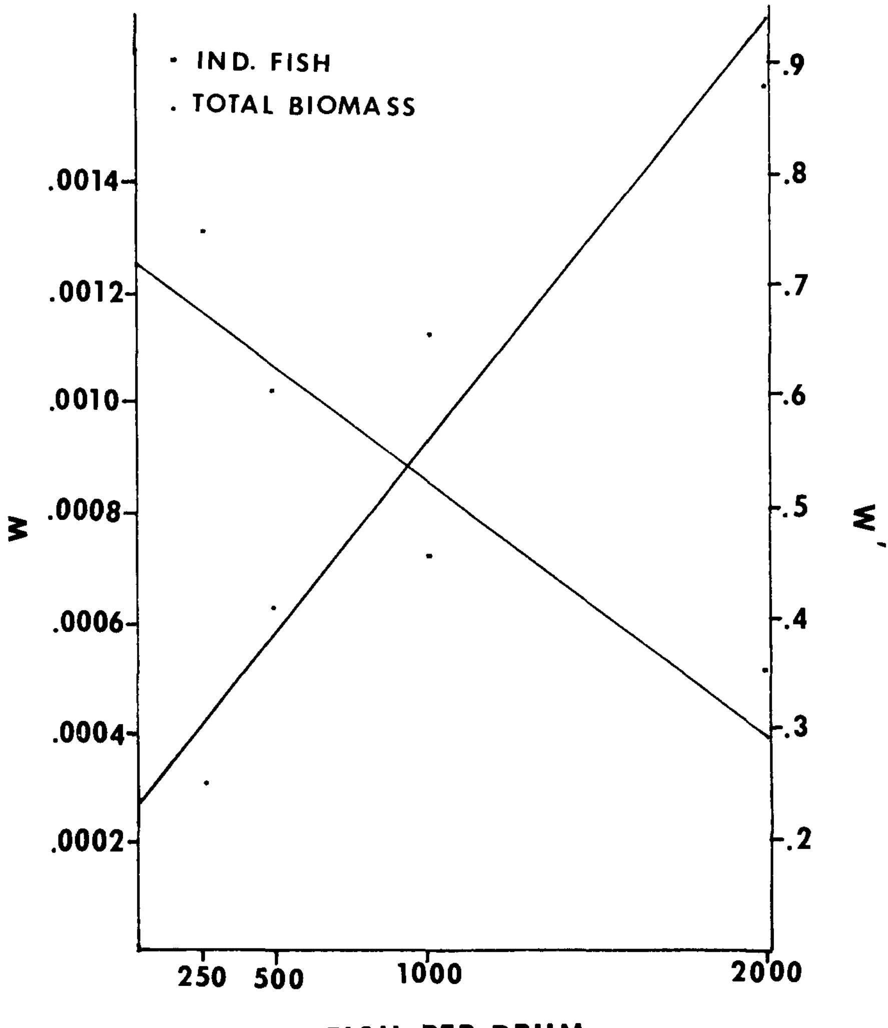

Fig. 8. Comparison of W (ration of individual gain per day x volume of water ÷ flow rate) and W' (total gain in biomass pe rday x volume of water ÷ flow rate). The point of intersection of these 2 lines predicts stocking rate which optimizes all limiting variables.

IMPLICATIONS OF STUDY

Channel catfish fry can be cultured at high densities in a flow-through system. densities of up to 60,464 g/m^3 can be cultured, but growth rate is suppressed. Lower densities have higher growth rates. The individual weight is correlated with incoming oxygen values, temperature and oxygen consumed per g fish. The total weight of fish is influenced by incoming oxygen values, oxygen consumed per drum and the stocking rate. These factors may act to limit production without mortalities. The limit in production will be reflected in increased food conversion and lower growth rate.

The drum culture system produced 4 distinct sizes of fish with respect to the 4 stocking rates. Most commercial fish culturists stock fingerlings of approximately 10 g. This system could produce this size fish stocked at 1,000 per drum which is the stocking rate at which limiting factors least affect growth and those enhancing growth are optimized (Fig. 8).

The use of this culture system would afford the culturist many advantages that the pond culture method would not offer. The introduction of prepared feeds in a confined intensive system should afford the culturist the same opportunities to make feed available as when fry are held in a restricted area in pond culture. The ability to monitor the death loss is possible in the confined system, thus allowing the culturist to predict crop size. Less space is required with intensive culture systems, thus reducing pond construction and land cost. The opportunity to monitor and possibly control water quality and disease are advantages of an intensive culture system. The present cost of energy requirements to pump water into this system may limit the capabilities due to the high oxygen requirements. These costs may be offset by incerased survival and food conversion.

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