CULTURE OF YELLOW PERCH IN RECIRCULATING SYSTEMS

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ABSTRACT

Fifty-five yellow perch (Perca flavescens) that average 7.5 grams each were stocked into each of twelve recirculating systems (380 L each). Fish were fed a 30% protein (4% lipid),or a 50% protein (15% lipid) diet, either continuously or twice daily for 23 weeks. Yellow perch grew significantly ($p<0.05$) larger and exhibited better feed conversion (3.2:1) on the 50% protein, 15% lipid, ration. At harvest, they averaged 45.6 grams weight and exhibited an average 98% survival. Fish fed a 30% protein, 4% lipid ration averaged 25.7 grams at harvest, exhibited a 96.5% survival, and had an average feed conversion of 4.4:1. Fish maintained on the 30% protein, 4% lipid diet presented continuously had significantly ($p<0.05$) more mortalities and lower feed conversion. Their mortality rate was 6% vs. the 1% of fish fed twice/day and the 3% of all fish maintained on the 50% protein, 15% lipid diet fed continuously. Fish fed the 30% protein regimen also had a feed conversion of 5.1:1 vs. the 3.8:1 exhibited by the group fed the 30% protein, 4% lipid diet twice/day. Yellow perch survived and grew reasonably well when cultured under controlled laboratory conditions that simulated a commercial operation.

INTRODUCTION

There exists a growing desire to develop effective methods for the commercial cultivation of yellow perch (Perca flavescens). These pericids range throughout lentic and lotic freshwaters in temperate and subarctic regions of the Northern Hemisphere, which illustrates their great adaptability to different habitat conditions (Stickney 1993). The major source of yellow perch, popular among consumers in the North Central United States, traditionally has been the wild catch from the Great Lakes, especially Lakes Erie and Michigan (Smith 1975; Kraft 1982; Hushak et al. 1988). Because of increased pollution, overfishing, and regulatory restraints the availability of perch harvested from nature has decreased (Brown and Giatzek 1980; Kraft 1982; Henderson and Nepszy 1990). Concurrently, consumer demand for yellow perch and other fish has increased (Pique 1986); the harvest of wild perch no longer meets the demand of local markets (Stickney 1993). Recent determination of the positive effects that Omega-3 fatty acids (in fish oil) have on human health; such as decreased risk of cardiovascular disease and decreases in blood pressure, triglycerides and total cholesterol, has further increased consumer demands (Herold and Kinsella 1986; Radack et al. 1990; Green et al. 1990; Flaten et al. 1990; Oh et al. 1991; Bhathena et al. 1991).

In the Great Lakes region, particularly Wisconsin, northern

Illinois and Ohio, and southern Ontario, yellow perch have long been considered a premium food fish, a low calorie alternative to red meat that is also easy to prepare (Spira 1975). They are lean (<1% fat) and have a delicate flavor that is seldom, if ever, fishy. The flesh is tolerant of freezing and thawing during processing and storage (Stickney 1986). Under optimal conditions, when food and temperature are not limiting, yellow perch can reach a marketable size in 9 to 11 months (Stickney 1993). The fish are typically marketed as 2-3 oz (~4" or 12 cm) fillets at $6-$9/lb (Salesman for Chicago Fish House, Chicago, IL, and Dr. David Stuiber, University of Wisconsin, Madison, WI, personal communication).

Because the yellow perch is an important recreational and food fish, they have been considered for aquaculture (Stickney 1986; Vilstrup 1975; Kayes et al. 1991).

Natural populations of yellow perch may become stunted if their abundance exceeds the available food supply (Werner 1980). It is uncertain whether stunting is due specifically to lack of food and/or other reasons. When stunted fish are relocated to a less crowded habitat and amply fed, they have made remarkable weight gains in short periods of time (Craig 1987).

With the possible exception of their intolerance of temperatures > 35°C (Appendix A), the biology of the yellow perch suggests that the species is a strong candidate for commercial aquaculture in temperate latitudes. Major impediments to their commercial cultivation are their intolerance to high water temperature, the difficulty associated with training hatchlings (< 35-40 mm TL) to accept prepared feeds, the limited availability of trained fish, and lack of practical information on their cultivation. Under culture conditions, trained yellow perch fingerlings (40-50 mm TL) readily ingest pelleted feed (Kayes et al. 1991), but conditions can be difficult as natural food organisms for fry (e.g., rotifers and napulii) are hard to supply in sufficient quantity (Dr. D. Stuiber, University of Wisconsin, Madison, WI, personal communication).

The objectives of this study were: 1) to correlate survival, growth and feed conversion of yellow perch with protein and lipid content of the feed and frequency of feeding; 2) to determine the amount of feed and time required to raise yellow perch fingerlings to marketable size; and 3) to determine survival and growth of yellow perch when cultured under controlled conditions in recirculating systems.

MATERIALS AND METHODS

Laboratory Setup

A closed recirculating system was used to cultivate yellow perch as the systems facilitated environmental control. Twelve systems in the Wet Laboratory at SUNY College at Brockport, NY, were used to culture fish. Each system consisted of a 0.45 m^3 stainless steel fish holding unit that contained approximately 400 L of water and a trickle down biological filter with 28 L of crushed limestone gravel (2.5-7.5 cm in size). A 1/40 hp submersible pump returned water from the biological filter to culture tank at 3.0 to 6.0 L/min. PVC pipe (0.5 inch diameter) was used to transfer water; pipes were periodically cleaned to remove organic buildup and to facilitate water flow. A fine nylon mesh placed at the end of the discharge from fish holding unit to biological filter served as a particulate filter. Mesh filters were cleaned daily. Without mesh, biofilters required frequent flushing (at least every other day), which interfered with their function and greatly increased maintenance effort.

Village of Brockport water from Lake Ontario (Ph 7.5-8.0, alkalinity 90-100 mg $CaCO_3$/L, and hardness 120-150 mg/L; Brockport Treatment Plant, personal communication) was dechlorinated by activated charcoal before addition to systems. Throughout the culture period, environmental conditions were maintained at levels considered acceptable for yellow perch (except for 4-5 March 1991). Water temperature was maintained at 21 - 25° C, except during a county-wide power outage on 4-5 March 1991. During the outage, tanks were switched to flow-through with unheated water for approximately 28 h. Water temperature dropped to 9° C. Fish stopped feeding, but no other adverse effects were observed, which is consistent with the thermal tolerance described by Craig (1987). Within 72 h (8 March 1991) the recirculating systems were back to "control" conditions (21 - 25°C) and fish again fed.

Photoperiod was maintained at 16 h light: 8 h dark except during the previously noted power outage. Change was abrupt; however, the light was kept low to mimic dawn/dusk light levels (no lux values were obtained). Lighting was primarily by incandescent bulbs, but fluorescent lights were also used ~ 1h / day during tank maintenance.

Additional aeration was continuously provided in all tanks to maintain DO (dissolved oxygen) above 4.0 mg/L and to ensure that fish experienced no oxygen related stress.

<u>Fish Source and Conditioning</u>

On 27 July 1990, approximately 950 young-of-the-year (YOY) pond-reared yellow perch fingerlings (25-35 mm TL) were obtained from a commercial supplier (Empire Fisheries, Warsaw, NY) and stocked into three 400 L flow-through systems. On 14 August 1990, approximately 250 additional YOY yellow perch were obtained from the original supplier and placed into two

additional tanks. These fish were similar in size to the now larger (30-45 mm TL), previously stocked fish.

During the conditioning period (27 July - 5 November) fish were fed a mixed ration of Biokiowa #3 Salmon Starter (crushed) and Purina Trout Chow #2, several times daily. Some fish (about 20%) accepted the feed immediately; most did not. To facilitate acceptance of pelleted feed, fish were concurrently fed frozen adult brine shrimp and pelleted ration. Feeding response was good, although most fish initially ate only the shrimp. Larger fish were isolated and weaned from the shrimp diet, to enhance overall fish condition and to help reduce mortality from starvation and cannibalism. The amount of shrimp offered was decreased as dry food was increased for six weeks or until approximately 75% of fingerlings accepted the pelleted feed. Fish that accepted the pelleted training ration were fed to satiation daily until the formal study initiated.

On 5 November 1990, 660 trained fish (60-110 mm TL) were selected and randomly distributed among 12 recirculating systems at 0.14 fish/L (1.0 g/L). Stocking density was intentionally low so fish would grow under conditions with little or no stress. On 12 November, fish in each of the 12 recirculating systems were randomly assigned to a specific test regimen. The fish were then acclimated to their new environment, feeds, and feeding schedules. Fish were fed lightly (1-2% of body weight/day) with their assigned ration for a three week conditioning period to activate biological filters. On 29 November 1990, the 163 day yellow perch study formally began.

Experimental Design

During the formal study, fish in six tanks were fed Purina Catfish Chow (Table 1a and 1b), a 30% protein, 4% lipid sinking ration used for omnivorous fish (catfish). Fish in the other six tanks received BioKiowa #3 Salmon Starter (Table 1a and 1b), a 50% protein, 15% lipid sinking ration formulated for more carnivorous species (trout). Within each group of six tanks, three tanks were fed twice a day, once two hours after the onset of the light period and once toward the end of that period (a 12 hour feeding interval). The other three tanks of each group received the same quantity of food with the appropriate protein and lipid content, but presented continually throughout the sixteen hour light period. Food was dispensed with automatic feeders; feeders were checked and refilled daily.

Fish were fed initially at the rate of 5% of their body weight per day. This rate proved excessive as considerable amounts of uneaten feed accumulated in tanks and had to be siphoned out each day. Although recognized as excessive, the rate remained at 5% until after December 15 in an attempt to ensure that all fish would obtain ample feed (Table 2). The amount of feed offered was adjusted every 10 days after 15 December for estimated weight gain and observed mortalities

(Table 3). Every 30 days the estimated weight gains were checked by weighing all fish, in groups of 25 - 30.

Water was added daily to replace that lost to siphoning or evaporation, normally 20 - 40 L/tank (4-9% system volume). More was removed and replaced if conditions warranted (e.g., high particulate matter, high total-ammonia nitrogen) to a maximum of 115 L (20% system volume) (Spotte 1979).

At harvest (11 May) all fish were removed, enumerated, weighed (g), measured (TL), and feed conversion computed as the average harvest weight of fish from each treatment divided by the average amount of food fed.

Water Quality

Alkalinity, hardness, total ammonia-nitrogen (TAN), nitrate-nitrogen (NO_3-N), and nitrite-nitrogen (NO_2-N) were monitored by a Hach Kit or by Standard Methods (APHA 1985). A meter was used to measure pH, a thermistor to measure temperature and the Winkler method to monitor dissolved oxygen (DO). Known standards obtained from the Water Quality Laboratory at SUNY College at Brockport were used to examine accuracy for alkalinity, pH, and total ammonia-nitrogen (TAN). Measured values were within 5% of standards.

Water chemistry remained within ranges considered acceptable for yellow perch in all recirculating systems with no significant differences between treatments (Stickney 1986, Hokanson 1977a) (Table 4).

Statistical Analyses

Data from the four test conditions were analyzed using MINITAB on an IBM compatible computer by two-way analysis of variance (ANOVA) and Tukey's pairwise comparision (Tukey's HSD). Data from the three replicates within each feeding regime were combined and analyzed as one unit. Replicates of water quality values within a treatment group were also grouped together and analyzed to ensure that there were no significant differences in culture conditions. The null hypotheses were that protein and lipid content of feed and frequency of feeding had no effect on survival, growth (weight gain), and feed conversion of yellow perch raised in recirculating systems.

RESULTS

Water Quality

No significant differences ($p>0.05$) in water quality among the test regimens (Table 4 and Figures 1-6) and culture conditions in each of the 12 study tanks were judged the same. Hardness and pH values remained relatively constant in all units throughout the study, while alkalinity fluctuated in all tanks as the study progressed (Figures 1, 2, and 3). Alkalinity was maintained between 60-100 mg/L through periodic addition of $NaHCO_3$ (approximately 35-40 g per application). Nitrification activity in the biological filter and culture tanks caused the decline in alkalinity.

Total-ammonia nitrogen (TAN), nitrite (NO_2^-), and nitrate (NO_3^-) concentrations were not statistically significantly different for the 23 week period. In tanks provided with the 50% protein and 15% lipid feed, total-ammonia nitrogen concentrations were significantly higher ($p<0.05$) in weeks 11-17 and week 21. Concentrations of nitrite (NO_2^-) in these tanks were significantly ($p<0.05$) higher in weeks 4, 6, 7, 15, 19, and 20, while nitrate (NO_3^-) concentrations became significantly ($p<0.05$) higher only in weeks 19 and 20. These differences were probably an effect of ammonia excretion by fish supplied the 50% protein diet and/or the higher biomass in these tanks due to the more rapid growth of fish.

Fish Survival

There were no significant differences ($p>0.05$) in survival of fish fed either the 50% protein, 15% lipid diet continuously or twice/day and the 30% protein, 4% lipid diet fed twice/day (Table 5). Survival was significantly lower ($p<0.05$) for the group fed the 30% protein, 4% lipid ration continuously than those fed the same ration twice/day and those fed the 50% protein, 15% lipid ration both twice/day and continuously (Figure 7, Appendix B).

In the first week of the study, 29 fish in one tank assigned the high protein, high lipid diet fed continuously were lost due to equipment malfunction. Most sickness and mortalities occurred midway in the study (weeks 8-15) and were due to an apparent fungal or bacterial infection (Table 3). A few fish mortalities were apparently due to starvation, as they were emaciated and a few jumped out of their tanks.

<u>Fish Growth</u>

Growth of yellow perch was significantly different ($p<0.05$) with ration fed, but not with feeding frequency ($p>0.05$) (Figures 8 and Appendix C). Perch fed the 30% protein, 4% lipid ration did not grow as rapidly or as large as did perch fed the 50% protein, 15% lipid ration (Figures 9-12). Differences in weight of fish maintained on the two rations became apparent and were significant ($p<0.05$) after only 2 weeks into the study and became more dramatic as the fish approached harvest (Table 6 and Figure 8).

<u>Feed Conversion</u>

There was a significant difference ($p<0.05$) in feed conversion between the fish fed the 30% protein, 4% lipid diet and those fed the 50% protein, 15% lipid diet (Table 5 and Appendix D), with those being fed the higher protein, higher lipid diet having the better feed conversion. There was no significant difference ($p>0.05$) in feed conversion between the fish fed the 50% protein, 15% lipid diet continuously or twice daily. There was, however, a significant difference ($p<0.05$) in feed conversion between the fish fed the 30% protein, 4% lipid diet continuously and fish fed the same diet twice daily (Table 5). The fish fed the 30% protein, 4% lipid diet twice daily exhibited better feed conversion than fish fed the 30% protein, 4% lipid diet continuously (Table 5). No benefit was apparent for feeding fish continuously versus twice daily for the 50% protein, 15% lipid diet.

DISCUSSION

The study was terminated after 5 1/2 months, before most fish reached marketable size (7-8" TL, 150 grams live weight). Initial information suggested erroneously a marketable size of six inches TL. Yellow perch were grown in recirculating systems at stocking densities of up to 17 grams live weight/L (density at harvest), a lower density than used in other operations. The North Central Regional Aquaculture Center's project on the advancement of yellow perch aquaculture determined that perch could be reared to a density of 85 g/L without a significant decrease in growth or performance (Garling 1991). The low density was employed in this study to ensure optimum culture conditions for fish.

Perch used in this study (25-35 mm TL) quickly learned to ingest commercial rations (when Brine shrimp were used in training) and tolerated disturbances caused by humans, which is necessary for commercial production. They tolerated temperature changes, low DO, and handling for monthly weighing and examination. Yellow perch found on the lab floor often survived when returned to water.

Harvest at 5 1/2 months resulted in an average weight of harvested fish of 1.5 oz. (46 g), which would produce butterfly fillets of only 0.7 oz. (21 g), assuming a dress-out yield of 45% (Calbert and Huh 1976). This is less than a quarter the desired weight of fillets. Fillets of 2 1/2 - 3 1/2 oz. are the preferred size for restaurants (Dr. David Stuiber, University of Wisconsin, Madison, WI, personal communication). A reasonable market size would be 150 g live weight (4.5-5.0 oz.; 7-8" TL) (Garling 1991). Extrapolation from linear equations derived from data collected in this study (Figure 8), determined it would require over 21 months for fish stocked at 6-8 g (0.2-0.3 oz, 60-110 mm TL) and fed a 50% protein, 15% lipid ration to attain marketable size. A correspondingly longer time would be needed for those fed on the 30% protein, 4% lipid ration. Calbert and Huh (1976) believed that perch stocked at the weight of only 1.0 to 1.5 g would reach market size in 9-11 months when cultured at 21^{0}C, 16 hours light, and fed 3-4% of body weight daily with a ration containing as low as 27% protein. Stickney (1993) later hypothesized it would take 7.5-9.0 months for yellow perch to reach market size in recirculating systems where temperature and light are controlled, although size at stocking and feeding regimens were not defined. Since previous studies indicated that yellow perch from different geographic areas respond differently under controlled laboratory conditions, differences in growth under "optimal conditions" can be partially explained by differences in fish stock. In order for commercial culture of yellow perch to become a reality, strains of broodstock with good growth potential must be maintained, culled, and spawned. Culture data obtained from other areas and with different strains must be used with caution.

Yellow perch survival was good when cultured in the recirculating systems. Stocked fish had an average survival of > 97%. Previous researchers also experienced few mortalities with yellow perch when fish previously trained to ingest commercial feed were cultivated and cannibalism was prevented (Stickney, 1993).

Fish fed the 50% protein, 15% lipid ration required a total of 34.0 kg of feed to gain 10.5 kg in total weight and reach an average size > 6" TL (15 cm). Fish fed the 30% protein, 4% lipid ration were presented 21.0 kg of feed, and exhibited a total weight gain of only 4.0 kg or 38% of the gain exhibited by fish fed 50% protein during the same time period. Average feed conversion for fish on the 30% protein ration was ~ 4.4:1. High mortality (6%) of fish fed the 30% protein ration continuously affected their feed conversion. This group's poor health also affected their growth. A possible explanation would be that high levels of particulate matter present in these tanks increased fish stress and caused more susceptibility to disease and reduced growth. A conversion ratio of 1.5:1 has been observed in the past for yellow perch fed a 27 to 50% protein feed (Stickney 1993). That fish maintained on either 50% (15% lipid) or 30% protein (4% lipid) never approached this ratio is partly explained by feeding rates. The 1.5:1 conversion efficiency was realized feeding at 3 to 4% of body weight daily (Stickney 1993) whereas my feeding rate was at 4.5 and 5% of body weight until well into the study (10 February) when fish averaged > 16g. My feeding rate was initially kept high to insure that all fish had a chance to feed and there was considerable uneaten feed continuously present. Feeding rate was decreased to 4.5% on 16 January and then to 3.3% on 10 February with the final decrease to 2.5% on 14 April. From 10 February little if any uneaten food remained in tanks. Differences in efficiency of feed conversion are also partially explained by the 10 day adjustment interval. Over estimates of weight gain at the start of the study diminished and became more accurate as fish grew. Therefore, my feed conversion estimates must be viewed as liberal estimates and actual efficiency when corrected for poor health and excessive feed would be better. With reduced feeding at the start, more accurate estimation of weight gain, and a development of a semi-domesticated stock, it is anticipated that feed conversion will improve.

Additionally, both rations used in the study had been developed for fish species other than yellow perch. Previous studies used Spearfish W-3 and W-7, Trout Grower Diet (Zeigler Bros., Inc., Gardner, Pa.), and #3 crumbles (Stickney, 1993) which were also not formulated for perch. A ration specifically formulated for yellow perch should be developed concurrently with the commercialization of yellow perch, as it would enhance feed conversion. However, recent research suggests that perch from different stocks may require different diet formulations for optimum growth (Garling 1991).

The Biokiowa Salmon Starter (50% protein, 15% lipid) improved palatability, acceptance, feed conversion, and reduced waste and promoted better survival, growth, and conversion rates in yellow perch than did the diet formulated with 30% protein, 4% lipid (Purina Catfish Chow). The better performance of the Biokiowa Salmon Starter may be due to higher caloric value and palatability (due to higher fat content) as much as to its higher protein content.

It is apparent that a low protein ration such as formulated for omnivorous fishes increases the time required for yellow perch to reach market size. Low protein feed was also lower in fat (4% vs. 15%) and was not as readily accepted as the higher protein (and fat) ration. Yellow perch were observed to eagerly and quickly consume the higher protein and fat ration, whereas the fish fed the lower protein and fat ration exhibited no such eagerness and took longer to consume their ration. Whether reduced acceptance was due to physical appearance, size, and/or taste is not known (Table 1b). However, the ration containing 50% protein resulted in levels of ammonia in culture tanks which were significantly higher in weeks 11-17 and 21. Elevated ammonia levels suggest that excess protein was presented and metabolized for energy rather than used in growth (Figure 4) in tanks maintained on the 50%

protein ration, resulting in increased production costs and reduced water quality (Table 4).

Tanks maintained on 50% protein ration developed a yellowish color which the particulate filters did not abate, although they did collect uneaten feed and feces. The discoloration did not appear to hurt the fish nor reduce their appetite. The color appeared to leach out of the food as feeding rates intensified or when excess food was left in the tanks. Water changes were the only way discoloration was reduced.

Frequency of feeding appeared to have little effect on yellow perch except for survival of fish fed the 30% protein, 4% lipid diet continuously. These findings suggest that feeding schedules can be reduced and based on the convenience of the aquaculturist in most cases.

CONCLUSIONS

1. Fish fed the 50% protein, 15% lipid diets exhibited better survival, growth, and feed conversion than fish fed on the 30% protein, 4% lipid diet.
2. There was no significant difference ($p > 0.05$) in survival, growth, or feed conversion in fish fed the 50% protein, 15% lipid diet, continuously or twice daily.
3. Fish fed the 30% protein, 4% lipid diet had better rates of survival, growth, and feed conversion when fed twice daily vs. continuously.

4. Fish cultured under conditions used in this study (16 h light: 8 h dark photoperiod, water temperature 21-25°C, good water quality, and 50% protein, 15% lipid ration) would require almost two years to reach market size.

5. Yellow perch survive and grow well in recirculating systems under properly controlled conditions that emulate a commercial facility, but economics and technical details need clarification.

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TABLE 1a: Proximate analyses of feeds used to maintain yellow perch. Analyses were performed by the Fish and Wildlife, Tunnison Laboratories of Fish Nutrition, Cortland, NY. Analyses were duplicated until 1% agreement was obtained.

RATION	% DM *	% PROTEIN	% WATER	% FAT	% ASH	** F.F.P.
Purina Catfish Chow	88.57	30.83	11.43	4.35	8.67	32.23
Biokiowa #3 Salmon Starter	89.48	51.04	10.52	15.31	9.33	60.26

* Dry Matter
** Fat Free Protein

TABLE 1b: Physical characteristics of feeds used to maintain yellow perch.

PHYSICAL CHARACTERISTICS	Purina Catfish Chow	Biokiowa #3 Salmon Starter
Calories/gram from fat	39	138
Color	light, yellowish tan	dark brown
Size	large 1/4" pellets before grinding *	small 1/16" granules
Consistency	obvious grain particles	uniform granules, no noticeable unmixed ingredients

* Feed was ground and sifted to make particle size uniform.

TABLE 2: Feed adjustments for yellow perch maintained on four different feeding regimens. The amount of feed offered was based on body weight. The rate was reduced if excess food was consistently present.

DATE	AVERAGE WEIGHT (g) OF ALL FISH IN ALL RATIONS	% OF BODY WEIGHT FED
NOV 29	7.5	5
DEC 15	9.5	3.2**
JAN 16	13	4.5
FEB 10	16.4	3.3
MAR 16	22	3.3
APR 14	29.9	2.5

**Fish were being fed at a theoretical rate of 5% body weight/day. Upon weighing the fish on Dec. 15, weight gain had occurred and they were, in reality, being fed at 3.2 % body weight/day. At this rate, fish ingested all of the ration presented. The rate was returned to 5% and subsequently was dropped to 4.5 % on Jan. 16 due to the continuous presence of uneaten food.

TABLE 3: Mortalities by week of yellow perch maintained on four different feeding regimens.

Week	30% protein fed continuous	50% protein fed continuous	30% protein fed twice/day	50% protein fed twice/day
1	0	29 *	0	3
2	0	0	0	1
3	0	0	0	0
4	0	0	0	0
5	0	0	0	0
6	1	0	1	0
7	0	0	0	0
8	3	0	3	0
9	2	0	0	1
10	6	0	1	0
11	15	0	0	1
12	11	0	4	0
13	3	0	1	0
14	2	0	0	0
15	3	0	0	1
16	0	0	0	0
17	1	0	0	0
18	1	0	0	0
19	0	0	1	0
20	0	0	0	0
21	1	0	0	0
22	3	0	1	1
23	0	0	0	0
Total mortalities found	52 (4 fish not found)	29	12	8 (1 fish not found)

* A system malfunction caused these mortalities.

TABLE 4: Water quality in culture tanks used to maintain yellow perch on four different feeding regimens.

		30% protein fed continuously	50% protein fed continuously	30% protein fed twice/day	50% protein fed twice/day
Oxygen (mg/L)	Mean Range SD	7.4 5.7-8.7 0.6	7.2 4.1-9.4 0.8	7.5 5.6-9.2 0.8	7.1 4.6-9.0 0.8
Temperature (C^{o})	Mean Range SD	22.6 15-25.5 1.5	22.7 14-26 1.5	22.5 18-25.5 1.5	22.7 9-26 1.5
TAN mg/L	Mean Range SD	0.2 0.0-0.6 0.1	0.4 0.0-1.1 0.2	0.2 0.0-0.8 0.1	0.5 0.1-1.2 0.2
Nitrite mg/L	Mean Range SD	0.06 0.01-0.68 0.09	0.12 0.0-0.39 0.1	0.05 0.0-0.18 0.03	0.15 0.01-0.35 0.08
Nitrate mg/L	Mean Range SD	6.5 0.1-14.0 2.9	9.8 1.4-30.0 5.8	6.2 0.6-14.0 2.9	8.9 0.5-20.0 3.9
pH	Mean Range SD	7.6 6.7-8.1 0.2	7.4 7.0-7.9 0.2	7.6 7.1-8.0 0.2	7.4 7.1-7.8 0.2
Alkalinity ($CaCO_3$ mg/L)	Mean Range SD	79.3 54-104 11.4	67.8 28-98 16.4	78.1 52-108 11.0	68.1 42-93 12.7
Hardness ($CaCO^3$ mg/L)	Mean Range SD	147.7 130-166 6.5	148.6 132-170 7.6	146.0 138-162 4.7	148.9 134-170 6.4

TABLE 5: Pertinent weights for fish, food, and % surviving of yellow perch maintained for 163 days on four different feeding regimens.

	30% protein fed continuously	50% protein fed continuously	30% protein fed 2xday	50% protein fed 2xday
Mean start weight (g)	8.4	8.2	6.2	7.1
Mean harvest weight (g)	26.5	46.0	25.0	43.3
SD	14.0	19.3	13.5	20.8
Mean weight gain (g)	18.1	37.8	18.8	36.2
Total wt gain (g)	1451.8	4927.0	2568.0	5570.3
# of fish at harvest	109	136	153	156
% surviving to harvest	94	97	99	99
Total Amt of feed fed (kilograms)	10.1	17.9	10.9	16.1
Amt food fed/fish (g)	93	132	71	103
Feed conversion /fish	5.1:1	3.5:1	3.8:1	2.8:1

TABLE 6: Size distribution of yellow perch when harvested, maintained on four different feeding regimens for 163 days.

	30% protein fed continuously	50% protein fed continuously	30% protein fed twice/day	50% protein fed twice/day
Number of fish > 7"	0	28	1	25
Number of fish 6-6.9"	27	81	31	85
Number of fish < 6"	82	27	121	46

TABLE 7: Weight (g) of yellow perch at start, harvest, and periodically, maintained for 163 days on four different feeding regimens.

		30% protein fed continuously	50% protein fed continuously	30% protein fed twice/day	50% protein fed twice/day
Nov 29	Mean SD	8.4 0.8	8.2 0.6	6.2 2.4	7.1 0.5
Dec 16	Mean SD	8.8 0.9	11.3 1.4	8.0 0.4	9.8 1.5
Jan 16	Mean SD	10.9 1.5	15.5 3.1	10.4 1.0	15.2 2.0
Feb 10	Mean SD	12.7 1.6	21.0 3.1	12.1 1.4	19.8 3.6
Mar 16	Mean SD	16.6 2.0	30.0 3.1	15.5 2.5	26.2 1.9
Apr 14	Mean SD	21.3 1.2	38.6 4.7	21.1 3.6	38.5 3.7
May 11	Mean SD	26.5 1.5	46.0 3.4	25.0 3.6	43.3 6.1

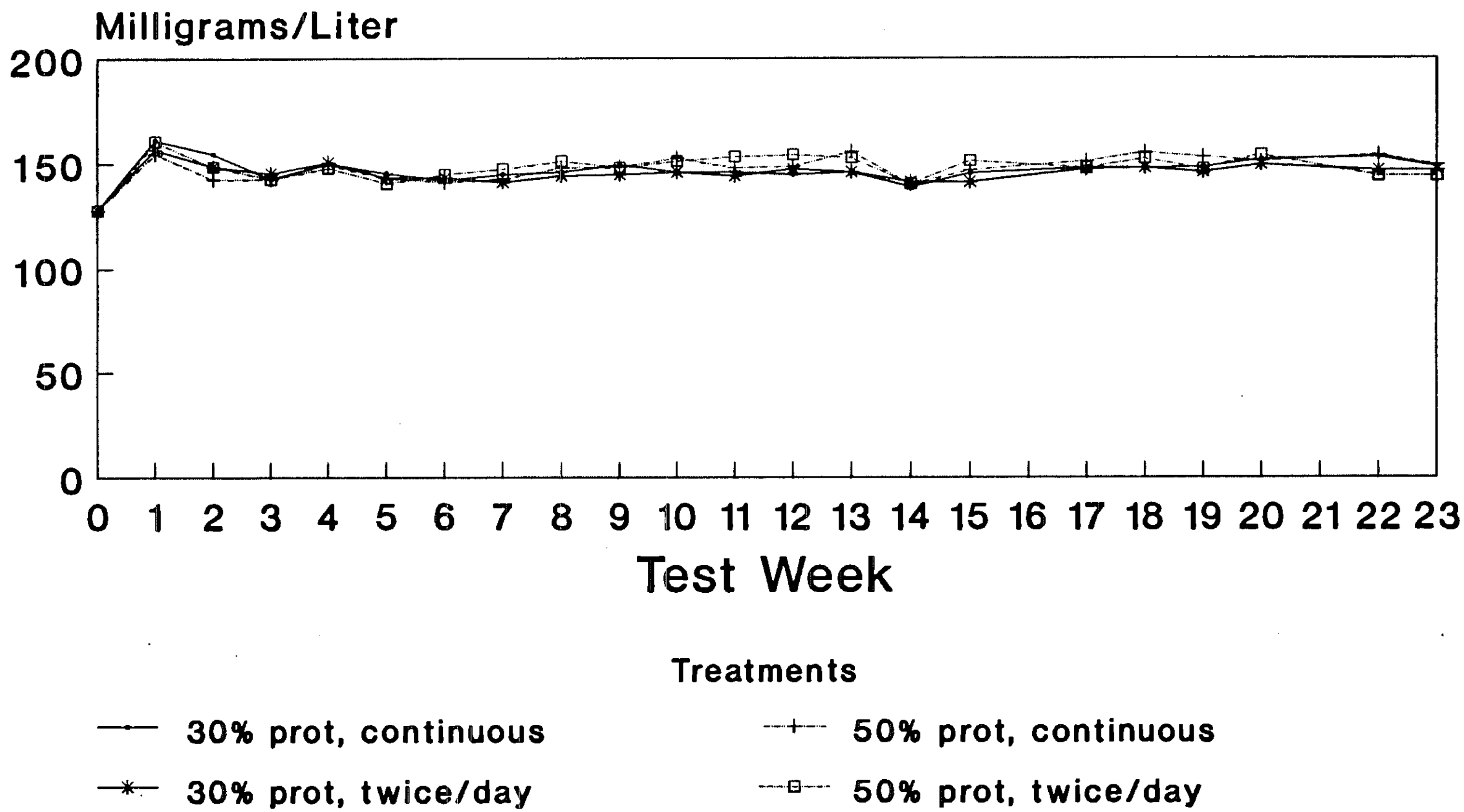


FIGURE 1: Water hardness by week for four regimens used to culture yellow perch.

FIGURE 2: Water pH by week for four regimens used to culture yellow perch.

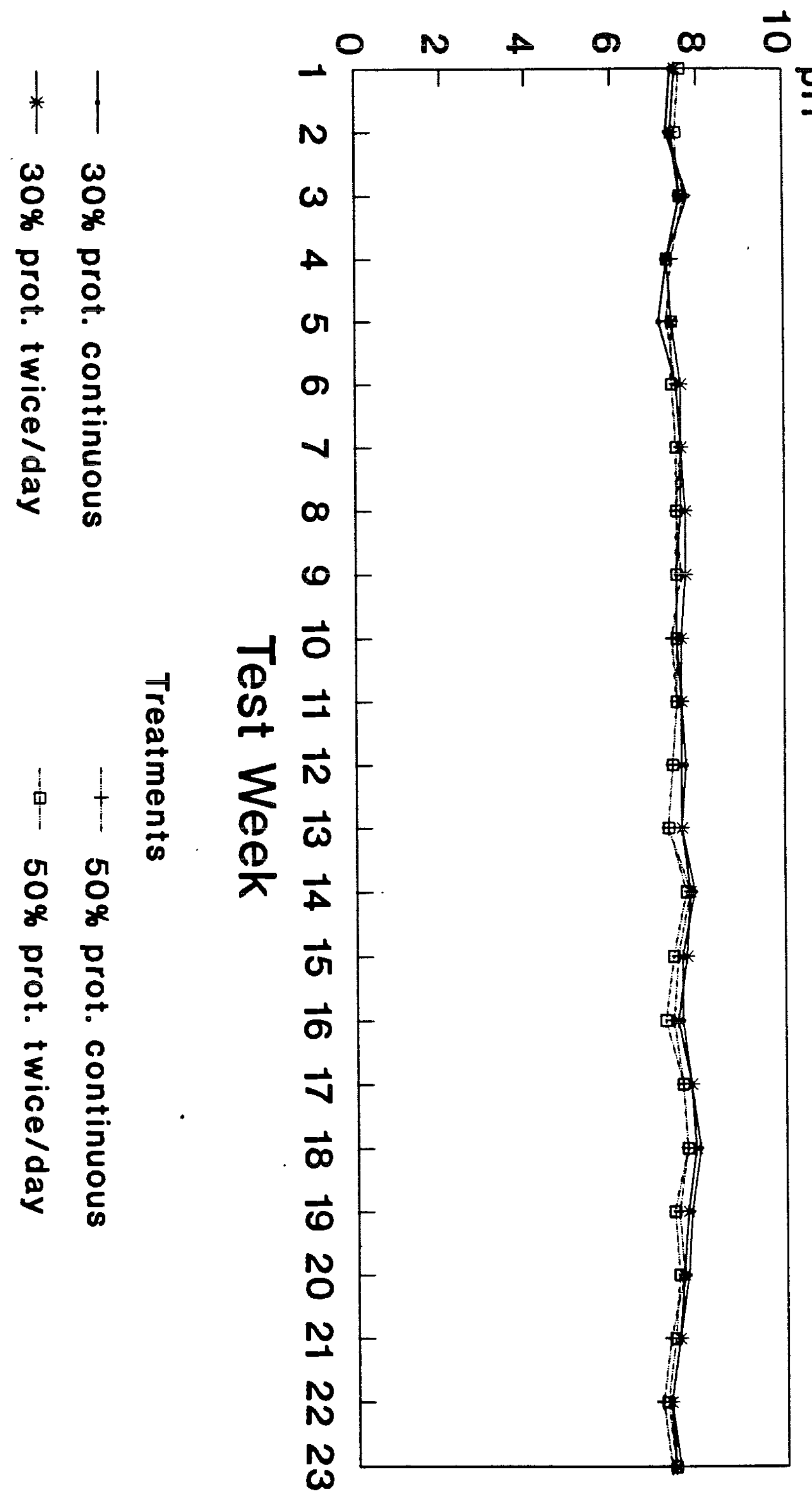
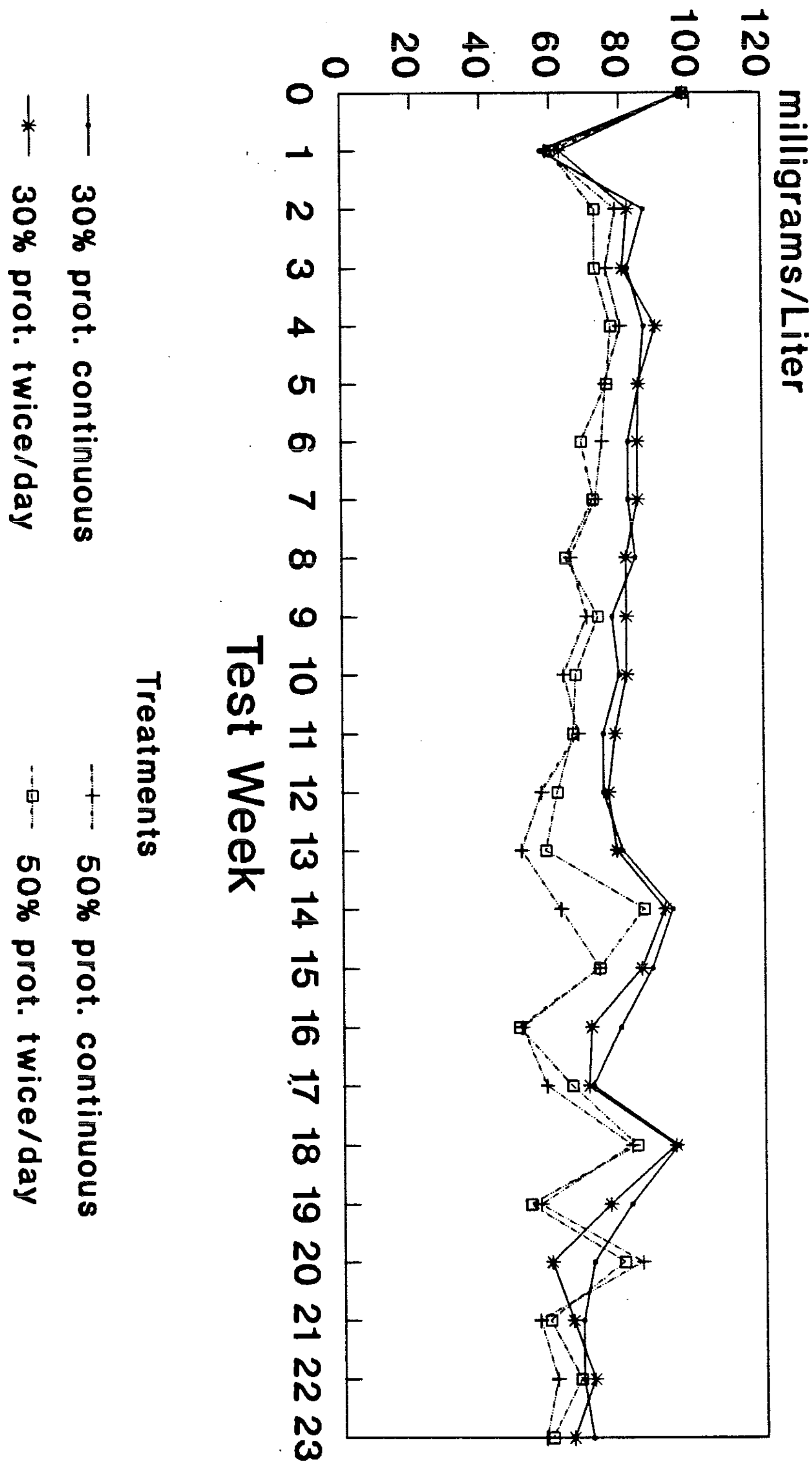


FIGURE 3: Alkalinity by week for four regimens used to culture yellow perch.



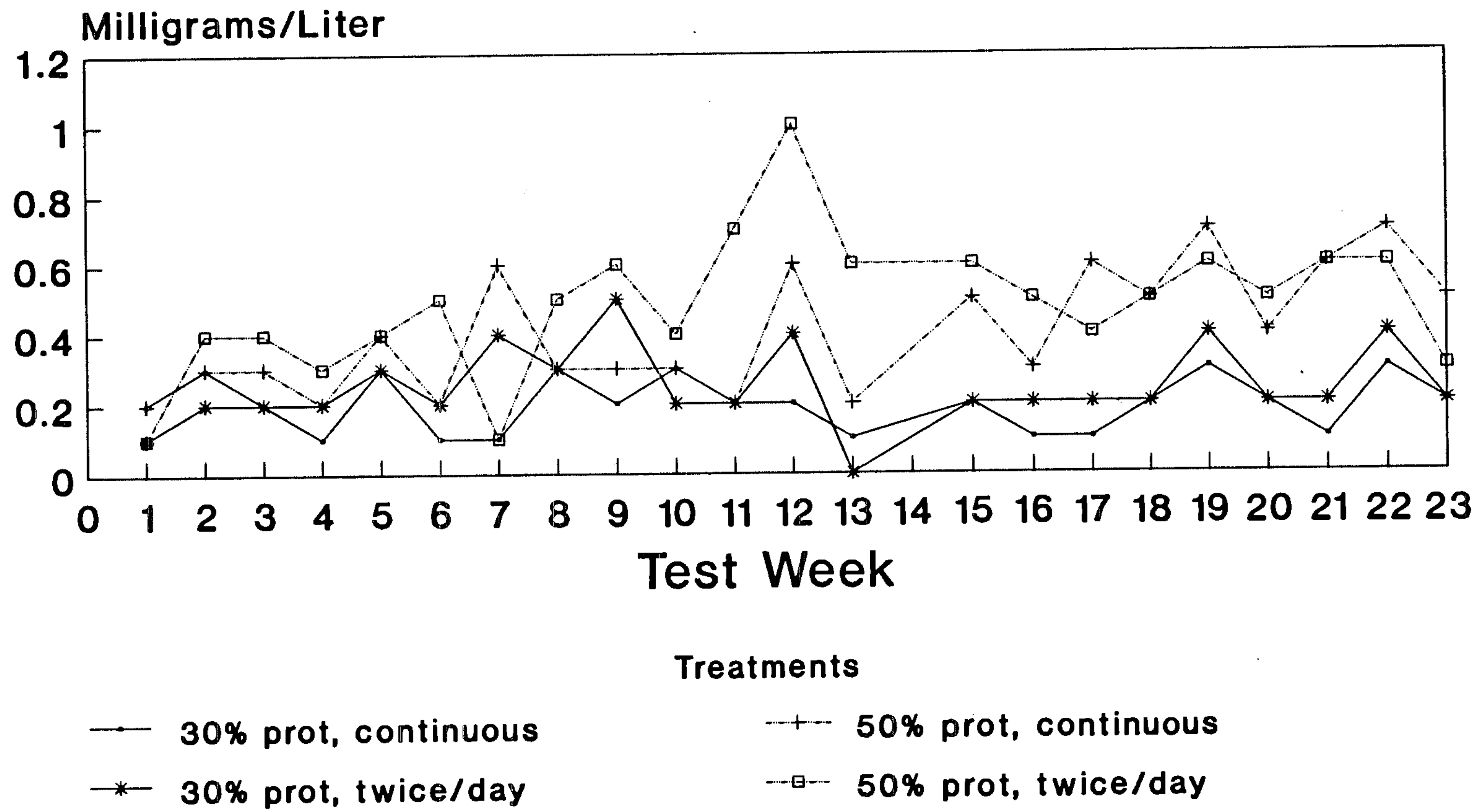


FIGURE 4: Total Ammonia Nitrogen (TAN) by week for four regimens used to culture yellow perch.

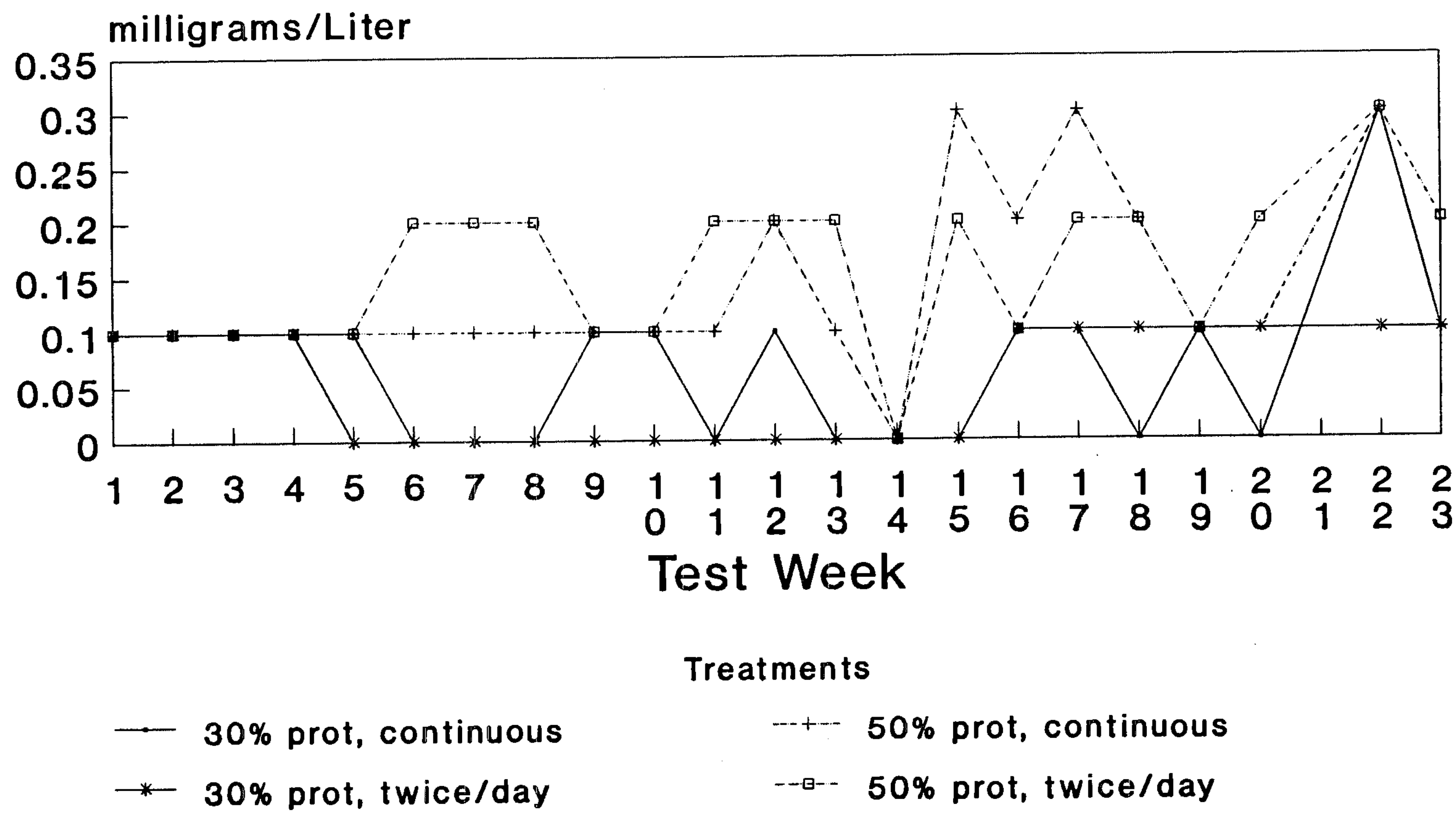


FIGURE 5: Nitrites by week for four regimens used to culture yellow perch.

FIGURE 6: Nitrates by week for four regimens used to culture yellow perch.

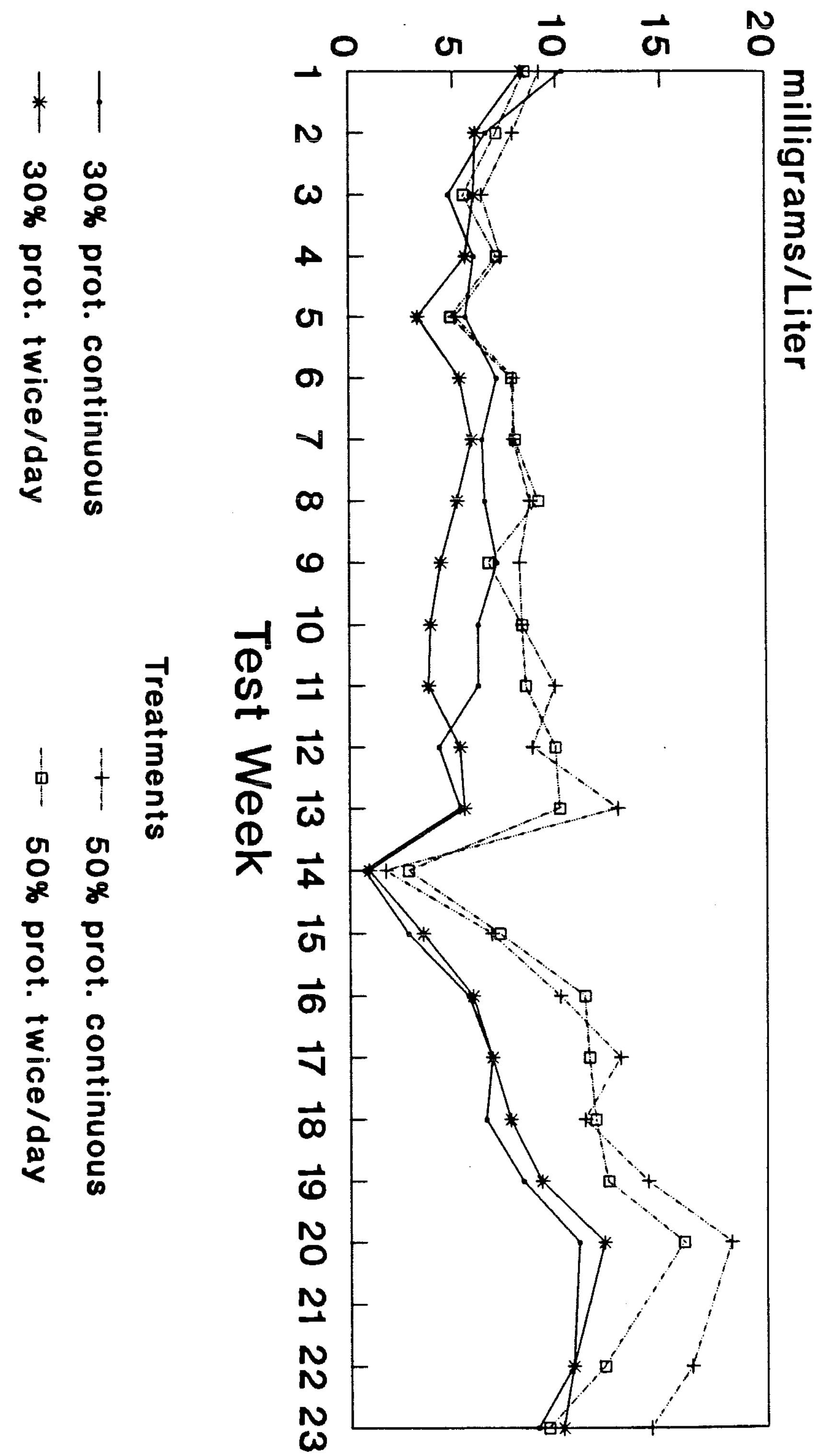
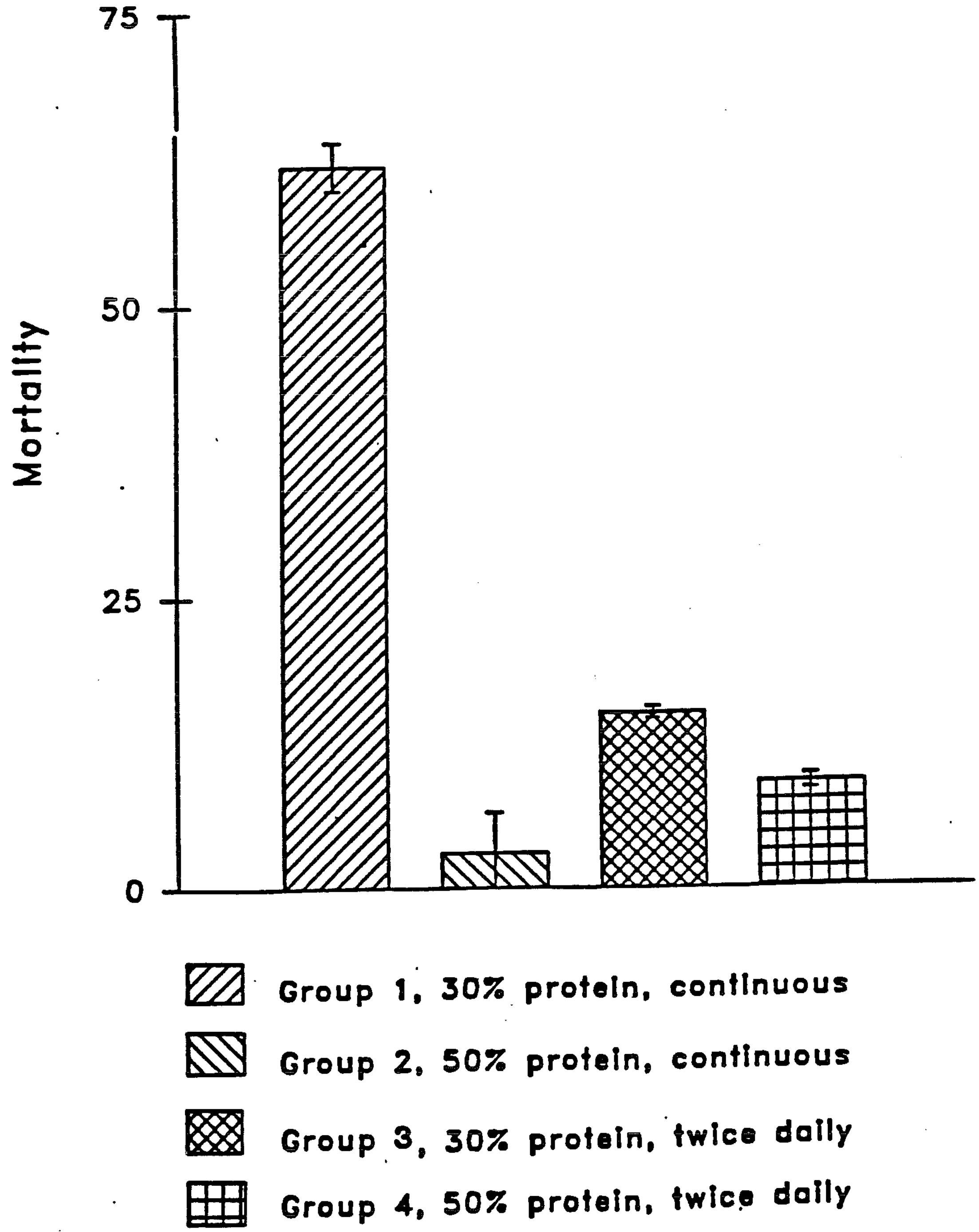


FIGURE 7: Mortalities at harvest of the 163 day study period for fish maintained on four different regimens. All units contained the same number of fish at start, N = 55. Standard error is indicated for each treatment.



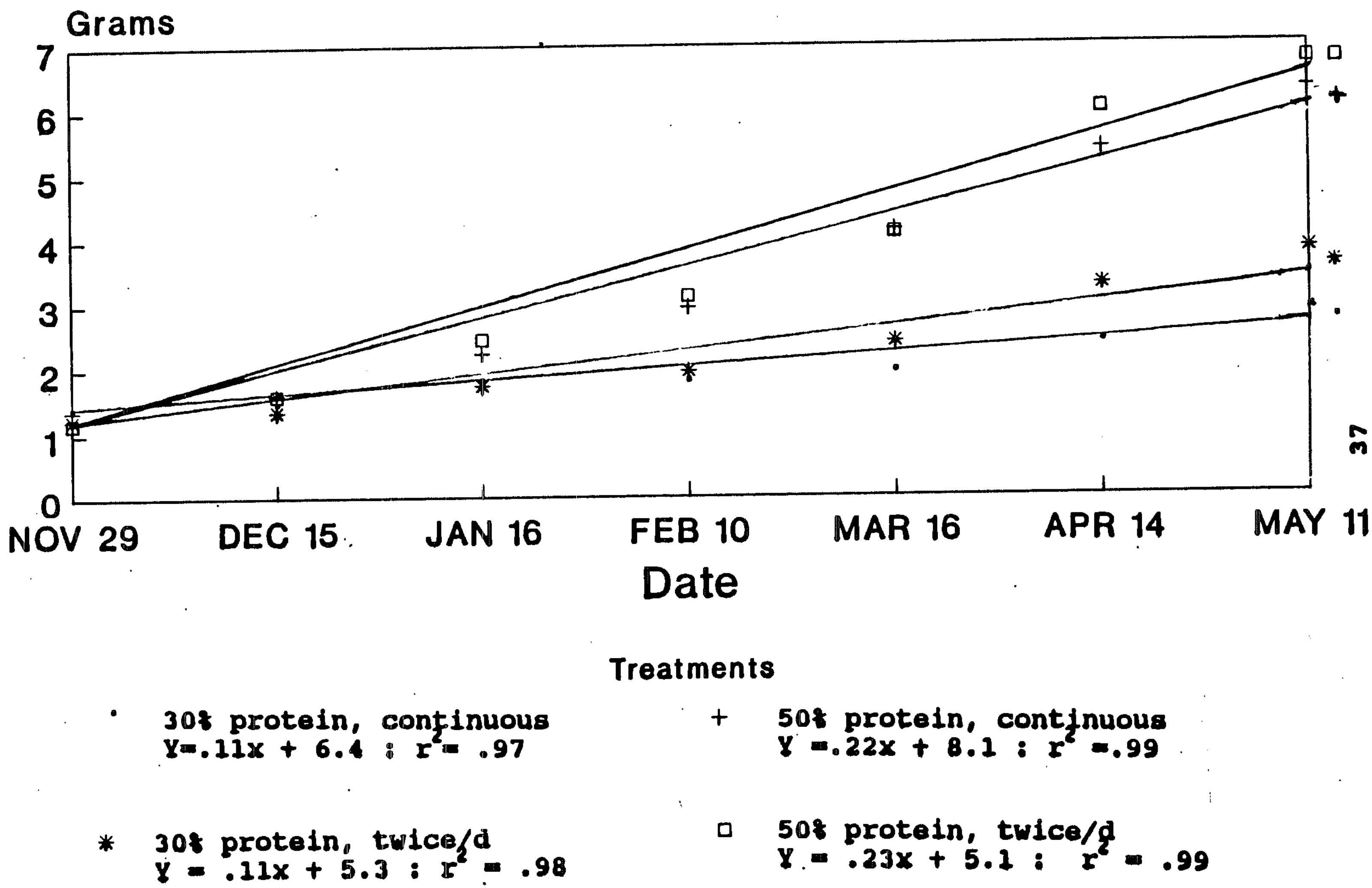


FIGURE 8: Weight of yellow perch cultured under four different regimens, from stock to harvest.

FIGURE 9: Fish size at harvest of yellow perch maintained for 163 days on a 30% protein, 4% lipid ration fed continuously.

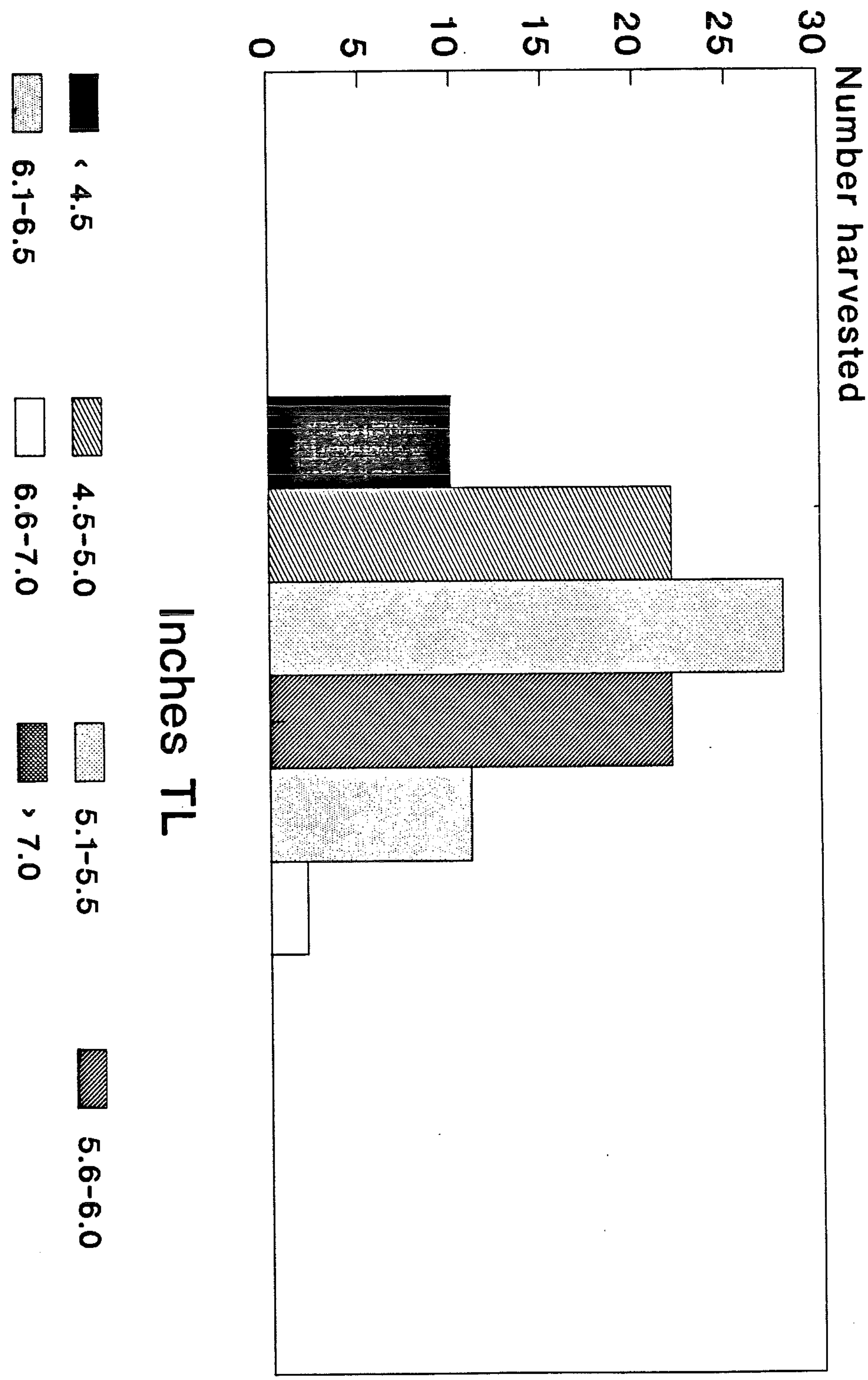


FIGURE 10: Fish size at harvest of yellow perch maintained for 163 days on a 50% protein, 15% lipid ration fed continuously.

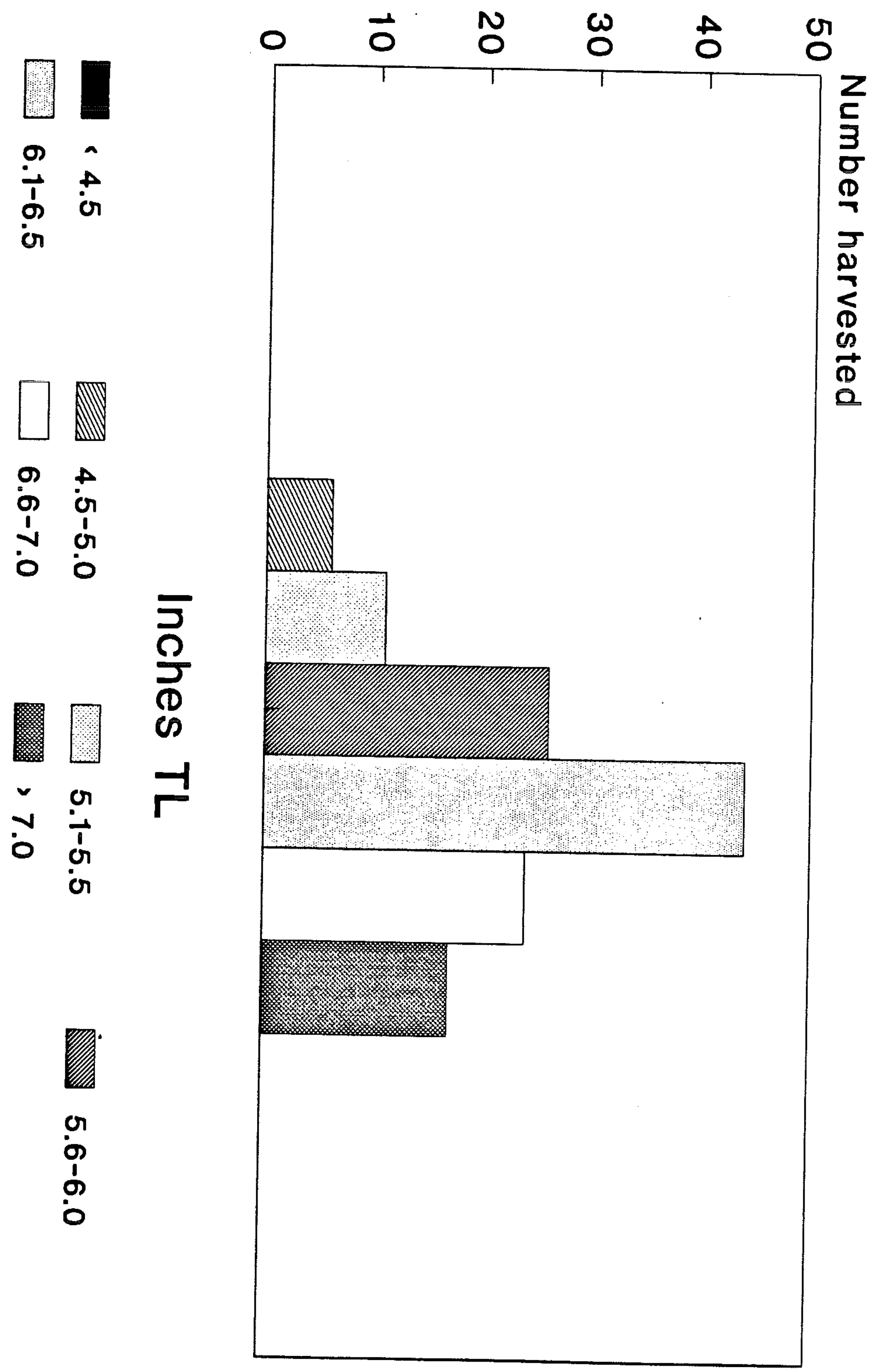


TABLE 11: Fish size at harvest of yellow perch maintained for 163 days on a 30% protein, 4% lipid ration fed twice a day.

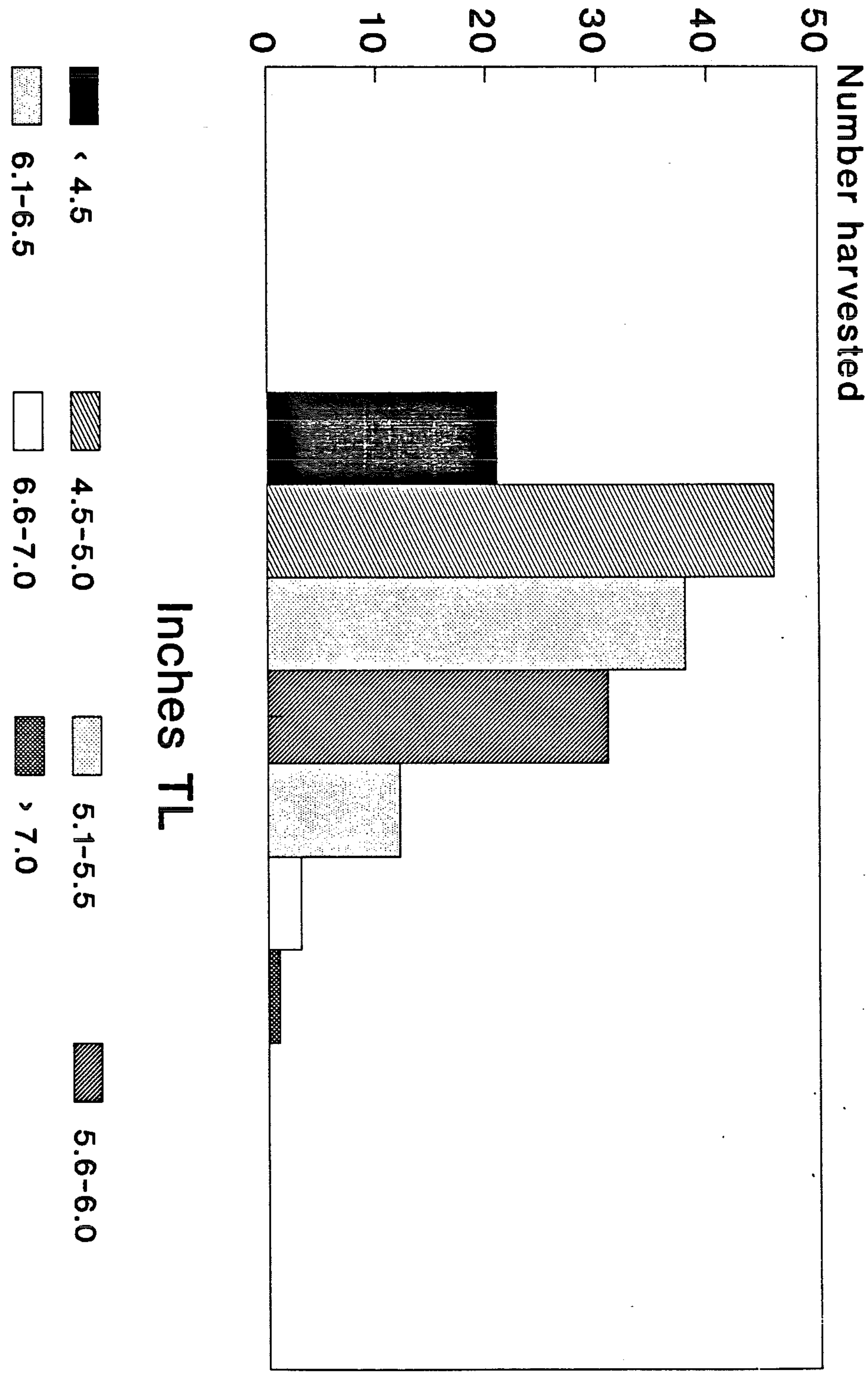
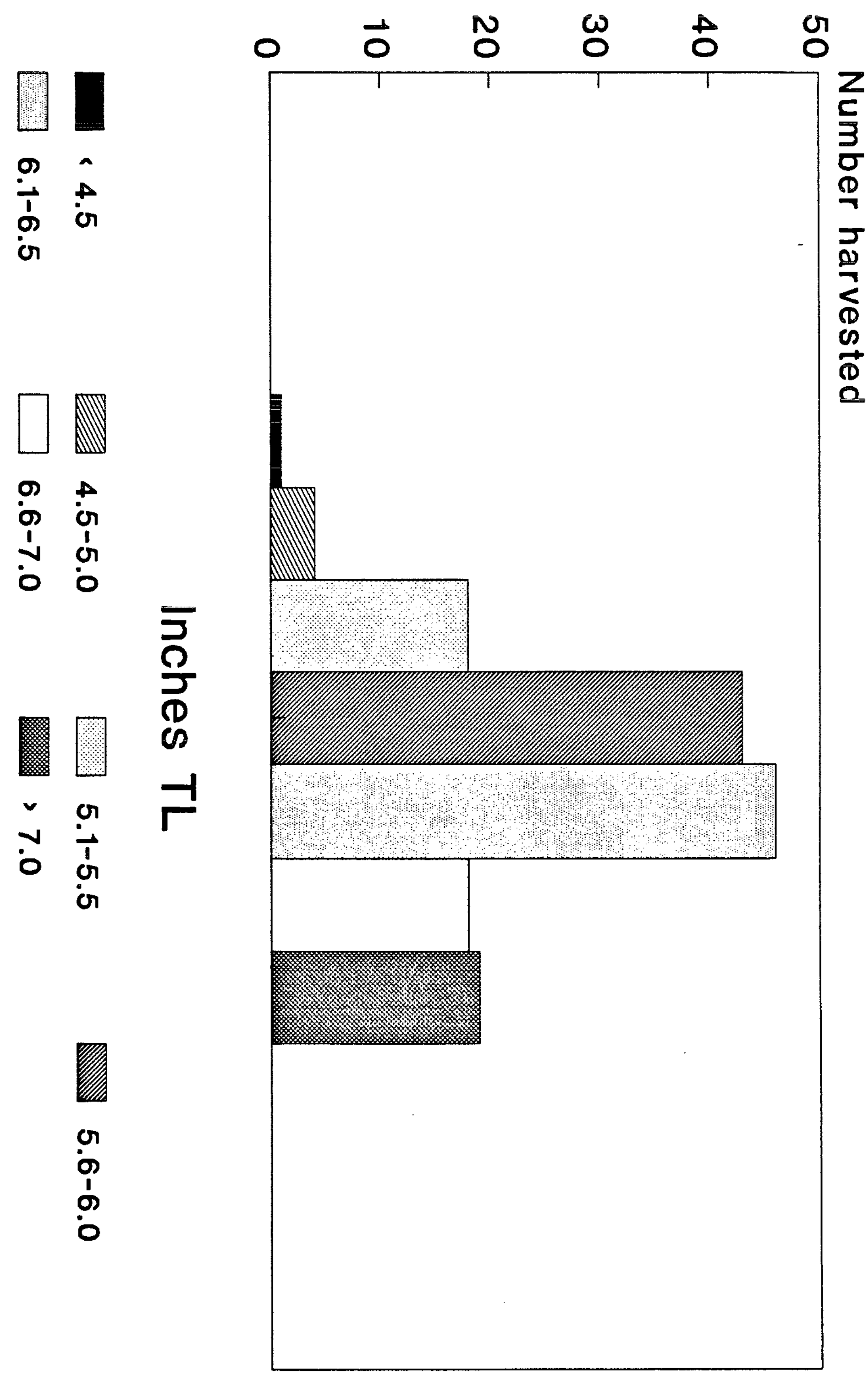


FIGURE 12: Fish size at harvest of yellow perch maintained for 163 days on a 50% protein, 15% lipid ration fed twice a day.



APPENDIX A

Biology of Yellow Perch (Perca flavescens)

Adult yellow perch have an oval, somewhat laterally compressed, body. They typically range from 0.1 kg to 1.0 kg, although most fish are on the lower end of this range (Stickney 1986; Craig 1987).

Yellow perch are extremely small at hatch (1-2 mm or 0.2 in TL) with a correspondingly small mouth gape (Kraft 1982; Schael et al. 1991). Hatchling yellow perch are limnetic; they tend to avoid littoral areas and heavily vegetated areas (Thorpe 1977; Whiteside et al. 1985). This avoidance is probably due to the presence of near-shore predators such as walleye (Stizostedion vitreum), northern pike (Esox lucius), and other fishes that feed on perch (Hasler and Villemonte 1953; Kraft 1982; Whiteside et al. 1985; Craig 1987; Szalai and Dick 1991). Fry $\geq$ 25 mm total length (TL) return to the littoral zone, where larger and more abundant prey are present (Whiteside et al. 1985).

Perch are predacious and often cannibalistic. As fry, they initially feed on rotifers and Protista; subsequently they ingest larger zooplankters (e.i. microcrustaceans). Fingerlings eat insects and small fish, while larger perch readily ingest fish and larger insects (Werner 1980; Craig 1987).

Yellow perch are diurnally active and often school, especially when feeding (Kraft 1982; Helfman 1979). Light strongly influences activity and feeding patterns (Orme 1975; Helfman

1979). Yellow perch are most active during the day with peak activity levels and feeding reported at dusk (Hergenrader and Hasler 1966). However, this activity peak may have been due to increased water temperature as well as light levels, as contradictory research indicates that yellow perch feed mostly at midmorning and mid-afternoon (Kraft 1982).

Yellow perch feed offshore in schools that vary in number of members, as individual fish enter and leave. As nightfall approaches, fish leave the feeding schools, enter the littoral zone and settle on the substratum for the night (Reynolds and Casterlin 1979; Kraft 1982).

Yellow perch prefer cooler waters, and can survive in ice covered lakes of the northern hemisphere (0-4° C). Adult perch prefer temperatures between 19.7° and 21.1° C, where they grow best and are most active (Ross and Siniff 1982). Recent research indicates that 22° C is the optimum temperature for growth of juvenile perch (Kayes 1991), although they have a tolerance range from at least 6.1° to 31.1° C (Hokanson 1977a). Additional studies have shown that the upper lethal temperature for both adults and juveniles is variable and can range from 29° C to 35° C, depending on other environmental factors such as oxygen levels, previous thermal history, and pH (Hokanson 1977b). Perch are tolerant of temperature increases to 8° C above their optimum, provided the increase is of short duration (< 16 hours) and does not exceed the lethal maximum (Thorpe 1977).

Yellow perch exhibit considerable tolerance to low levels of dissolved oxygen (DO). They apparently survive DO concentrations of < 0.25 mg/L at 2.5-4° C in ice covered lakes during winter months (Craig 1987). They continue to feed at DO levels of 3.8 mg/l and 25° C, they tolerate diel DO fluctuations found in typical farm ponds (Stickney 1986).

Yellow perch appear to be very hardy and conducive to culture in recirculating systems. In my study they tolerated a temperature change of 16°C in 2 hours and relatively low DO (< 4.1 mg/L). They also tolerated monthly handling to determine weight which involved keeping them in <4 gallons of water for up to 30 minutes and exposure to air for several minutes at a time.

APPENDIX B: Statistical Analyses for Mortalities Observed in Cultured Yellow Perch.

TABLE B-1: Analysis of variance (ANOVA) table for total mortalities of fish in four test conditions.

SOURCE	DF	SS	MS	F	P
TANK	11	163.82	14.89	2.59	0.009
ERROR	60	345.17	5.75		
TOTAL	71	508.99			

RESULTS:

There were statistically significant differences in mortality of yellow perch in the twelve tanks containing the study population; $p<0.05$.

APPENDIX C: Statistical Analyses for Weight Gained in Cultured Yellow Perch.

TABLE C-1: Two-way analysis of variance table (ANOVA) for weight of fish maintained on four feeding regimens at start (29 November 1991).

SOURCE	DF	SS	MS	F	P
TREATMENT	3	9.47	3.16	1.76	0.232
ERROR	8	14.33	1.79		
TOTAL	11	23.80			

RESULTS:

There were no statistically significant differences in weight between the fish in each treatment at stock (29 November 1991); $p>0.05$.

TABLE C-2: Two-way analysis of variance table (ANOVA) for the for weight of fish maintained on four feeding regimens at second weighing (16 December 1991).

SOURCE	DF	SS	MS	F	P
TREATMENT	3	18.80	6.27	4.73	0.035
ERROR	8	10.59	1.32		
TOTAL	11	29.40			

RESULTS:

There were statistically significant differences in weight between the fish fed two different protein levels at the second weighing (16 December 1991); $p<0.05$.

TABLE C-3: Two-way analysis of variance table (ANOVA) for weight of fish maintained on four feeding regimens on third weighing (16 January 1992).

SOURCE	DF	SS	MS	F	P
TREATMENT	3	67.76	22.59	5.42	0.025
ERROR	8	33.33	4.17		
TOTAL	11	101.08			

RESULTS:

There were statistically significant differences in weight between the fish fed two different protein levels at the third weighing (16 January 1992); $p<0.05$.

TABLE C-4: Two-way analysis of variance table (ANOVA) for weight of fish in the four feeding regimens on fourth weighing (10 February 1992).

SOURCE	DF	SS	MS	F	P
TREATMENTS	#	191.42	63.81	9.36	0.005
ERROR	8	54.54	6.82		
TOTAL	11	245.96			

RESULTS:

There were statistically significant differences in weight between the fish fed two different protein levels at the fourth weighing (10 February 1992); $p<0.05$.

TABLE C-5: Two-way analysis of variance table (ANOVA) for weight of fish maintained on four feeding regimens at fifth weighing (16 March 1992).

SOURCE	DF	SS	MS	F	P
TREATMENTS	3	444.75	148.25	25.07	0.000
ERROR	8	47.31	5.91		
TOTAL	11	492.05			

RESULTS:

There were statistically significant differences in weight between the fish fed two different protein levels at the fifth weighing (16 March 1992); $p<0.05$.

TABLE C-6: Two-way analysis of variance table (ANOVA) for weight of fish maintained on four feeding regimens at the sixth weighing (14 April 1992).

SOURCE	DF	SS	MS	F	P
TREATMENTS	3	902.1	300.7	24.05	0.000
ERROR	8	100.0	12.5		
TOTAL	11	1002.1			

RESULTS:

There were statistically significant differences in weight between the fish fed two different protein levels at the sixth weighing (14 April 1992); $p<0.05$.

TABLE C-7: Two-way analysis of variance table (ANOVA) for weight of fish maintained on four feeding regimens at harvest (11 May 1992).

SOURCE	DF	SS	MS	F	P
TREATMENTS	3	1091.2	363.7	22.50	0.000
ERROR	8	129.3	16.2		
TOTAL	11	1220.5			

RESULTS:

There were statistically significant differences in weight between the fish fed two different protein levels at harvest (11 May 1992); $p<0.05$.

APPENDIX D: Statistical Analyses for Feed Conversion in Cultured Yellow Perch.

TABLE D-1: Two-way analysis of variance table (ANOVA) for feed conversion in yellow perch maintained on four feeding regimens.

SOURCE	DF	SS	MS	F	P
REGIMENS	3	34.037	11.346	30.41	0.000
ERROR	8	2.985	0.373		
TOTAL	11	37.021			

RESULTS:

There were statistically significant differences between test regimens in feed conversions; $p<0.05$.