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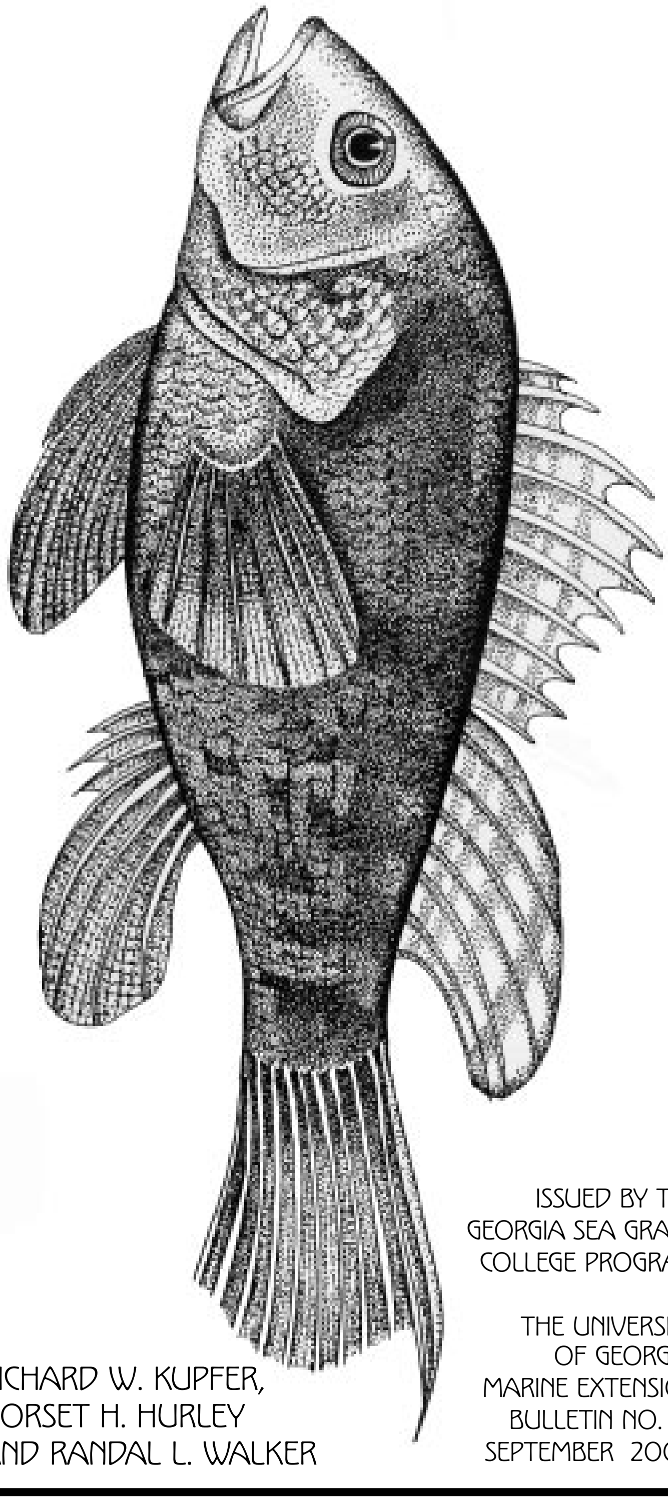

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ABSTRACT

Two studies of juvenile black sea bass, *Centropristis striata*, were conducted to address questions concerning the biological feasibility of aquaculture of *C. striata*. Juvenile *C. striata* and rock sea bass, *C. philadelphica*, were trapped inshore, while sub-adult *C. striata* were trapped in nearshore waters of coastal Georgia, south of Savannah.

Catch composition of inshore trapping was dominated by *Centropristis philadelphica* (80%). Few *C. striata* were caught. A comparative growth study of juvenile *C. philadelphica* and *C. striata* fed a 3% daily ration (gram dry weight feed/gram wet weight of fish) was performed over 27 days. Overall juvenile *C. striata* mean increase in growth was 42% ± 5.3% (SE), with 10% mortality; whereas, *C. philadelphica* mean growth was 14% ± 4.7%, with 65% mortality.

Sub-adult *C. striata* (164 g mean weight ± 1.74) were subjected to six ration treatments for 18 weeks. Three replicate 500-L tanks were used per treatment, and each tank was stocked with 15 fish. Ration treatments consisted of a high-protein trout feed, a lower-protein trout feed, and an equal mixture of both delivered daily in rations of 2% and 3% dry weight feed/wet weight fish. All rations were adjusted biweekly based upon mean fish wet weight per treatment. At week 16, ANOVA revealed no significant differences (p=0.4096) in mean fish weight among treatments with a pooled treatment mean fish weight increase of 48%. Based on cost effectiveness, the lower-protein 2% ration was judged the optimum choice among the diets tested. This study reinforces the biological feasibility of rearing trapped *C. striata* on a commercial diet of 2% dry weight feed/wet weight fish.

INTRODUCTION

The black sea bass, *Centropristis striata*, is considered one of the most important reef fishes in the southeastern U.S. coastal waters from recreational, ecological (Steimle and Figley 1996; Gregg 1995) and economical (O'Bannon 1995) perspectives. In 1994, 2,072 metric tons of *C. striata* were landed by U.S. commercial fishermen at a market value of 6.3 million dollars (O'Bannon 1995). The market for *C. striata* has seen an increase in value and demand over the past two decades, which has resulted in increased fishing pressure upon isolated Atlantic stocks (Gregg 1995; Low 1981). Increases in the market value for *C. striata* have been precipitated partly by the live sushi market. *C. striata* shipped live to New York, New Jersey, and Canada for sushi typically bring a wholesale price of $4.00 - $8.00 per pound, as compared to $1.50 per pound for iced fillets (G. Kinard, personal communications).

C. striata frequent coastal waters from Cape Cod, Massachusetts to Cape Canaveral, Florida (Mercer 1978; Able et al. 1995) and sometimes range as far south as the Florida Keys. Typically, *C. striata* are found at depths ranging from 20-60 meters (Mercer 1989) and temperatures ranging from 6˚-29˚ C (Link 1980). Southern stocks, unlike those found north of Cape Hatteras, North Carolina, tend to be non-migratory (Mercer 1989; Ansley and Harris 1981; Shepherd 1991). Northern stocks move inshore during summer months for the annual spawning event, in contrast to southern stocks which spawn in both spring and fall (Mercer 1989; Waltz et al. 1979).

C. striata are protogynous hermaphrodites and are sexually dimorphic based on size (Lavenda 1949). Sexually mature males have been found in all age groups, while sexually mature females are found predominately between age classes one and three (Wenner et al. 1986; Mercer 1978). While *C. striata* under age class four and less than 220 mm standard length, SL (measured from anterior-most point to caudal peduncle), are predominately females, the majority of males are both older and larger (Waltz et al. 1979). Females outnumber males 1.5:1.0 (Hood et al. 1994).

Juvenile *C. striata* have been found associated with both man-made and natural structures in estuaries with an inverse relationship between age class and proximity to inshore waters (Kendall 1977). Adult and sub-adult fish from offshore areas inhabit hard-bottom and coral regions. *C. striata* are described as an opportunistic omnivore with a prey diversity relationship to specific habitats (Steimle and Figley 1996; Hood et al. 1994; Link 1980).

Rearing studies have shown *C. striata* to be an outstanding candidate for aquaculture (Costa and Provenza 1993; Harpster et al. 1977; Roberts et al. 1976; Hoff 1970). It grows at a much faster rate under farmed conditions (4x -5x) than it does in its natural habitats (Kim 1987). General observations have shown that *C. striata* adapt quickly to both commercial feeds and confinement and exhibit behavior conducive to their culture (Kim 1987; Hoff 1970). Under experimental conditions, *C. striata* have been observed to have a gross growth rate efficiency between 29 and 37 percent (Kim 1987). Growth efficiency rates decline as the fish grow older (Hood et al. 1994). *C. striata* larvae less than 24-days old have been shown to have a gross growth rate efficiency of approximately 13 percent (Roberts et al. 1976; Tucker 1988). The objectives of this study were: 1) to compare the growth of juvenile rock sea bass, *C. philadelphica* and *C. striata* fed trout chow; and 2) to evaluate the growth of trapped, sub-adult *C. striata* fed different rations of two commercial trout feeds.

MATERIAL AND METHODS

Trapping

Juvenile *C. striata* were trapped using 22-mm mesh galvanized steel minnow traps 0.6 m in length (Fig. 1). The traps were equipped with retrieval lanyards and weighted lead strips to ensure benthic placement. They were baited with frozen, cut fish, crab, shrimp and styrofoam chips. Twelve traps were baited in the morning and again in the evening, and were checked four times daily. A total of 12 traps was deployed at locations associated with natural and man-made structures in the Skidaway and Wilmington Rivers. At capture, juvenile *C. striata* were placed into a 2000-L tank for acclimation to experimental conditions, identification, and subsequent removal of unhealthy fish. Fish were fed Zeigler Brother's Trout Grower during the acclimation period.

Offshore trapping was conducted utilizing six modified crab traps (0.06 m^3 of 44-mm mesh; Fig. 2) with 12.7-cm entrances. The traps were baited with cut fish, crabs, and shrimp and deployed in approximately 19.8 meters of water near J-Reef west of Savannah, Georgia, at LORAN coordinate 454945. Each trap was allowed a soak time of 20 to 30 minutes per deployment. Offshore trapping was conducted on October 16 and October 22, 1996.

Fish were returned to the laboratory and placed into a 2000-L tank for an initial acclimation period of 36 to 48 hours (to allow the fish to adjust to the new water and containment conditions). All captured fish were fed a ration of Zeigler Brother's Trout Grower to condition them to a diet of commercial pellets.

Juvenile Growth Trial

C. striata and *C. philadelphica* captured inshore were separated into two groups per species and placed into four, flow-through 500-L fiberglass cylindrical tanks with 88.9-cm overflow pipes and tops made of household window screening to prohibit escape. Ten *C. striata* (5 fish per tank) and 20 *C. philadelphica* (10 fish per tank) juveniles were placed in duplicate tanks to gain an understanding of species-related growth and morphological development

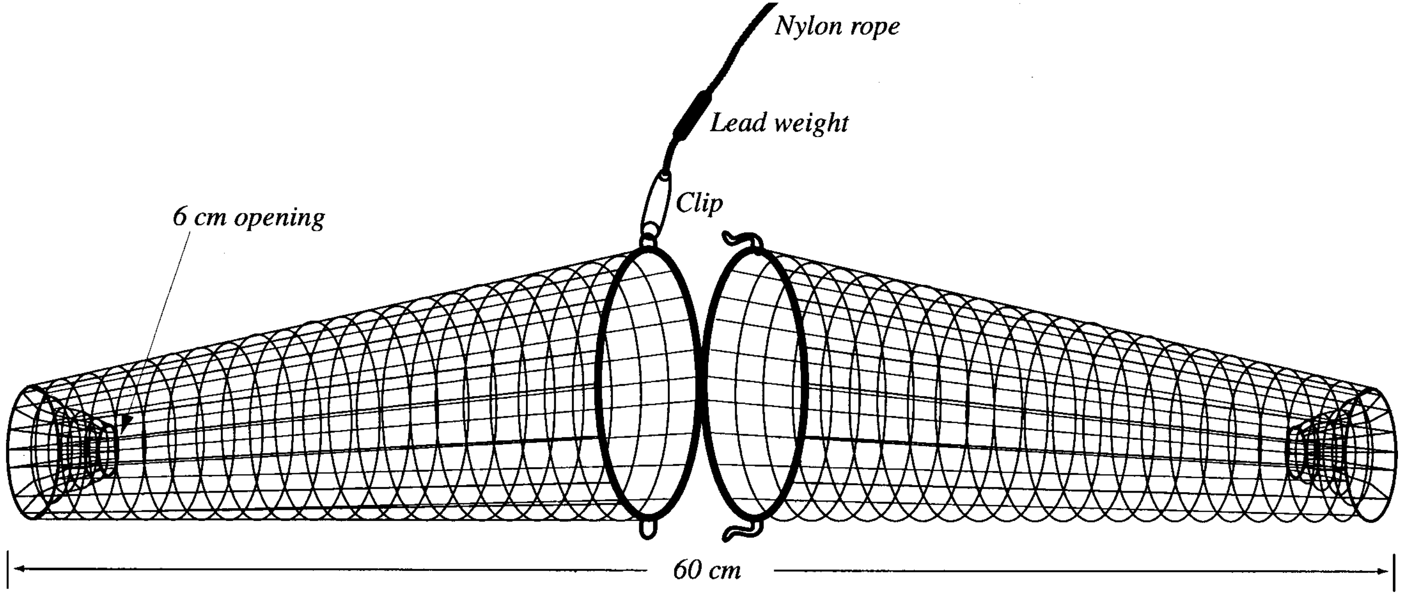

Figure 1. Steel galvanized minnow trap used for inshore collection of juvenile *Centropristis striata*.

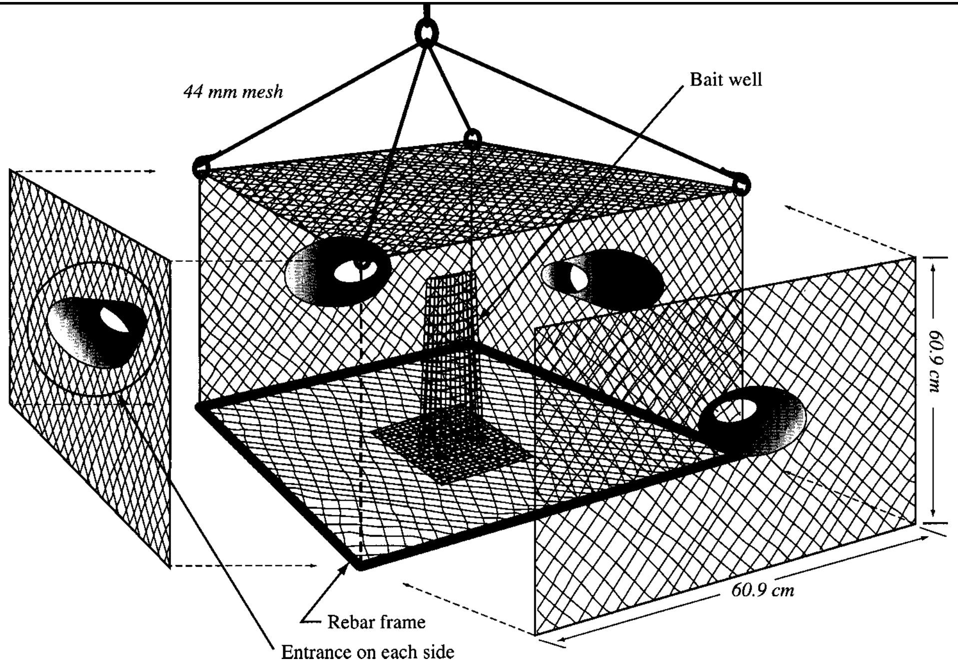

Figure 2. Modified crab trap with shackle harness used for offshore collection of sub-adult and adult *Centropristis striata*.

under culturing conditions. Tanks were supplied gravel- and sand-filtered, ambient seawater from the Skidaway River at a rate of 10L/tank/minute on a flow-through design. Aeration was provided to each tank. All fish were fed a 3% daily ration (dry weight feed/wet weight fish) of Zeigler Brother's Trout Grower. Ration adjustments were made biweekly based upon pooled mean fish wet weight per treatment.

Sub-Adult Diet Study

Evaluations of six diets consisting of Zeigler Brother's High-Performance Trout Grower (45% protein, 12% fat and 1.0% fiber), Zeigler Brother's Trout Grower (38% protein, 8% fat and 4% fiber) and an equal mixture (by weight) of both, in two ration concentrations (2% and 3% gram dry weight feed/gram wet weight of fish). Replicates were composed of flow-through water systems in each of 18 500-L cylindrical fiberglass tanks with 88.9-cm overflow stand pipes. Vinyl-coated, 16-gauge wire screens of 22-mm mesh were fitted over the top of all replicates to prevent fish from jumping out of tanks or mixing with other treatments. Each replicate received ambient filtered seawater at a rate of 10 L/tank/minute. Aeration was supplied to each replicate tank via water jets and forced air diffusers (Fig. 3). Treatments consisted of three randomly assigned 500-L tanks according to diet (Fig. 3). Treatments were fed to the fish for a period of 123 days, from February 23 to June 26, 1997. All trapped *C. striata* were weighed (g), measured for total length (from most anterior to most posterior point) in mm, and divided into equal size and biomass groups to ensure equal replicate tank fish density and biomass. At the beginning of the study, replicate tanks were stocked with 15 fish per tank with a mean fish weight of 164 g $\pm$ 1.74 SE and a mean size of 210 mm (TL) $\pm$ 3.26 SE, respectively. Fish were allowed to acclimatize in all replicate tanks for a period of 11 days prior to initiation of the study. Total lengths (TL) of individual fish per sample period were taken via a fish-measuring board (Fig. 4). Fish were administered food rations once daily at mid-day, except for the period 24 hours prior to the biweekly biomass sampling. They were not fed at that time to prevent ingested feed from significantly altering individual fish weights. Individual fish weights recorded biweekly were obtained with an Ohaus 1200-S CT Electronic Balance. Food rations were adjusted according to the mean increase of fish weight per treatment. Individual fish length measurements

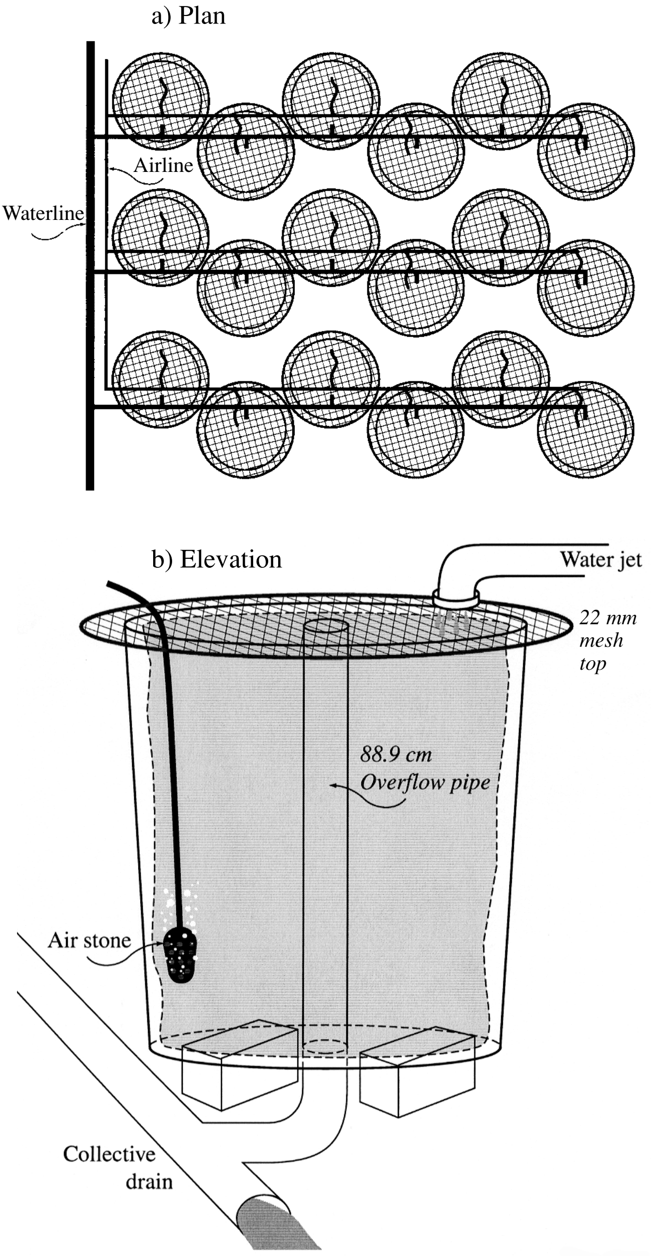

Figure 3. (a) Schematic of randomized 500-L replicate tank arrangement (b) Profile cutaway of a 500-L treatment replicate tank.

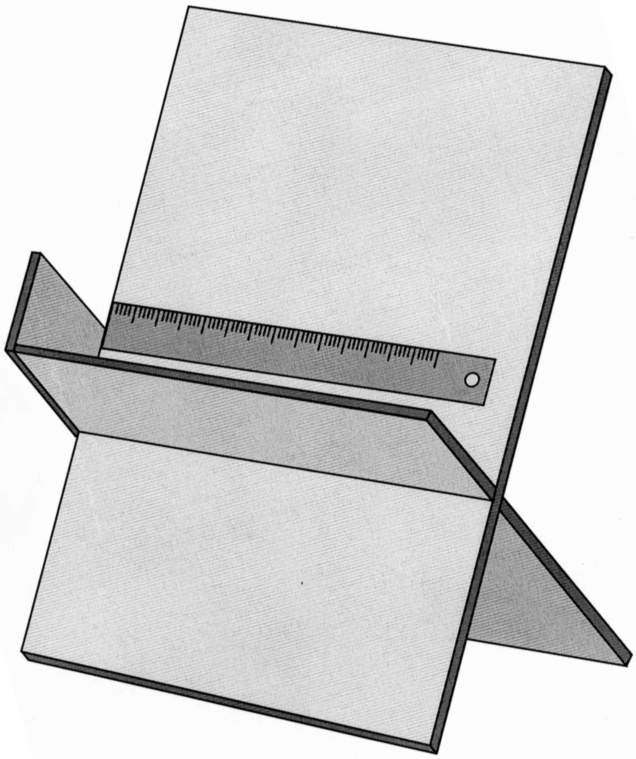

Figure 4. Schematic of self-standing, collapsible, fish measuring board.

were recorded on alternate biomass sampling dates (monthly). Temperature and salinity data were recorded daily per replicate tank. Weekly dissolved oxygen readings were taken per replicate tank via a YSI Dissolved Oxygen Meter. Weekly measurements of ammonia, nitrite and iodide concentrations per replicate were taken via HACH standardized methods. Biowaste material (fecal and excess ration deposits) was removed daily per replicate tank via a 15-20% (100 liter) purging of water from the tank bottom.

RESULTS

Trapping

Inshore trapping yielded a total catch of 52 juvenile fish belonging to the genus *Centropristis*. Ten of these fish were identified as *C. striata* and the remaining 42 were identified as *C. philadelphica*. Trapping success decreased to 11 fish taken in 25 days when Hurricane Bertha passed on July 12, 1996.

Day one of offshore trapping yielded 80 sub-adult *C. striata* (with an average trap soak time of 30-40 minutes per deployment). Day two yielded a catch of 111 sub-adult fish (with an average trap soak time of 15-20 minutes per deployment).

Juvenile Growth Trial

Juvenile *C. striata* mean growth was 42% ± 5.29 SE, with 10% mortality; whereas, *C. philadelphica* mean growth was 14% ± 4.74 SE with 65% mortality over 27 days (Table 1).

Sub-Adult Diet Study

After 10 weeks, ANOVA on the mean weight of sub-adult *C. striata* fed six different diet treatments of commercial feed demonstrated no significant differences among the diets ($p= 0.4096$) (Fig. 5). Likewise, after 12 and 14 weeks, no significant differences ($p=0.1589$ and 0.0918, respectively) in mean fish weight existed among treatments. Overall, pooled treatment mean fish weight and total length increased from a mean 164.5 g ± 1.74 SE to 314.0 g ± 5.34 SE and from 210 mm ± 3.26 SE to 257.6 mm ± 1.55 SE in 123 days. During this time, salinity, water temperature, NH_4, and pH measurements remained within acceptable levels. Salinity ranged from 18-27 ppt; NH_4 ranged from 0.12 - 0.38 ppm; dissolved oxygen ranged from 6.0 - 8.6 mg O_2/liter; pH ranged from 7.1-8.1; and water temperature ranged from 15-28° C. Technical difficulties associated with an electrical power failure resulted in fish mortality and elimination of three diets (3.0 % Trout Growers, 3.0% combined feed of 1.5% High Performance and 1.5% Trout Growers, and 2.0% combined feed of 1.0% High-Performance Trout Growers and 1.0% Trout Growers) on day 70.

Table 1. Growth (g) and survival (%) of juvenile *C. striata* and *C. philadelphica* cultured in 500-L flow through tanks over a 27-day period.

	No. Fish	Initial Mean Weight g + SE	% Survival	Final Mean Weight g + SE
C. philadelphica				
Tank 1	10	15.8 + 9.7	70	18.6 + 10.2
Tank 2	10	14.8 + 5.7	0	---- + ----
C. striata				
Tank 1	5	31.4 + 12.8	80	36.5 + 13.2
Tank 2	5	28.6 + 11.8	100	40.8 + 9.9

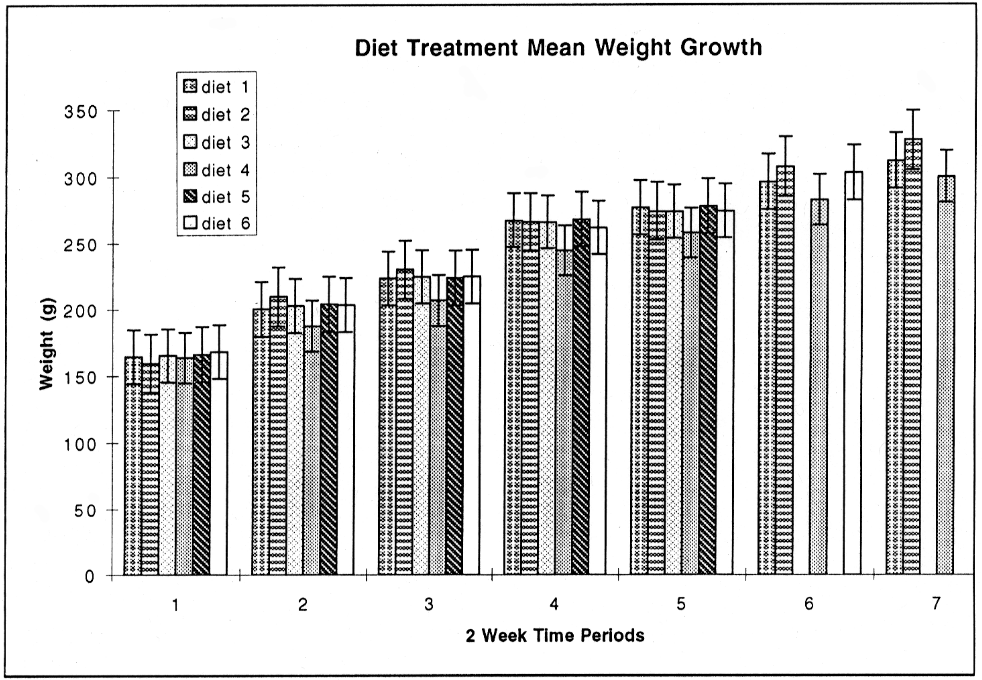

Figure 5.
Mean biweekly fish weight by treatment:
(diet 1) 3.0% High-Performance Trout Grower;
(diet 2) 2.0% High-Performance Trout Grower;
(diet 3) 3.0% Trout Grower;
(diet 4) 2.0% Trout Grower;
(diet 5) 3.0% combined feed of 1.5% High-Performance Trout Grower and 1.5% Trout Grower, and
(diet 6) 2.0% combined feed of 1.0% High-Performance Trout Grower and 1.0% Trout Grower. Fish weights were not significantly different during the course of the study.

DISCUSSION

Trapping

C. striata's attraction to a recently placed structure made inshore trapping relatively successful, regardless of bait type. Traps deployed using artificial bait (styrofoam chips) were equally successful in capture of *C. striata* compared to those deployed with bait composed of natural diet items. Identification of juvenile *C. striata*, however, proved difficult. Juvenile *C. striata* and *C. philadelphica* have very similar morphological characteristics, and it is difficult to ascribe positive identification to species of fish smaller than 70 mm (TL). Because of this, fish smaller than 100 mm (TL) were excluded from the juvenile diet study.

Modified crab traps proved highly successful for offshore trapping of *C. striata*. Traps deployed for short soak periods of 15-20 minutes were often loaded to capacity with significant reductions in bycatch. Traps deployed for longer soak periods of 30-40 minutes had a reduction in *C. striata* and higher bycatch. Additionally, *C. striata* captured during longer soak periods were often too large to be utilized for this study. Traps deployed for shorter soak periods appeared to optimize the proportional catch of sub-adult *C. striata*. They also reduced the time allowance for fish escape (Low 1981), and reduced the proportional capture of non-targeted species.

Juvenile Growth Study

Behavorial differences in juvenile *C. striata* and *C. philadelphica* were established quickly as *C. striata* adapted rapidly to confinement and commercial feed in contrast to *C. philadelphica*. The ability of *C. striata* to adapt more rapidly than *C. philadelphica* may have played a significant role in the large growth differences observed between the two species (Table 1). Casual observations demonstrated *C. striata* to be highly visual feeders (Kendall 1977) who ingest rations aggressively near mid-day as opposed to morning or evening feedings. Feeding behavior in *C. striata* was also more voracious in fish fed only once daily.

Sub-Adult Diet Study

The results of this study showed that, in terms of fish growth rates, it made no difference whether the fish were fed 2% or 3% rations, nor did it matter whether they were given Trout Growers or the Hi-Performance Trout Grower's feed (Fig. 5). The overall good growth of fish and ease of adapting them to an artificial food reinforces observations by Kim (1984) that *C. striata* exhibit the ability to adapt to a variety of nutritional sources. This adaptation to a variety of food sources has also been observed in its natural diet (Hood et al. 1994; Link 1980; Cupka et al. 1973). Growth similarities observed among ration and diet treatments in the present study (Fig. 5) may also suggest that protein and lipid concentrations play no significant role in the growth of laboratory cultured *C. striata* within the parameters tested. Fish in all treatments appeared to feed to satiation without yielding significant differences in biomass or length increases as a result of ration concentration. A 2% (dry weight feed/wet weight fish) diet, however, resulted in cost and waste decreases with improvements in water quality.

This study confirms observations by Kim (1987) that *C. striata* grew rapidly under aquaculture conditions. They exhibited high adaptability to confinement and a high tolerance of extreme and flucuating environmental conditions, both of which make this fish an excellent candidate for aquaculture. The ecological impacts of sport and commercial fishing coupled with increasingly stringent fishing regulations make aquaculture a more attractive means of satisfying market demands. Kim (1987) reported that fish weighing 300 g after 190 days could reach a weight of 1000 g within one year of culture. In this study, fish of a minimum legal size were pot-trapped and placed into land-based tanks for culture. Under low stocking densities utilized in this study, *C. striata* grew from 164 g to 314 g in 123 days as opposed to the three years it would take for natural populations (Waltz et al. 1979) to reach a similar size. Thus, it appears possible for fish to be grown from a minimum legal size to a 900-g size in under 18 months. This study illustrates the biological feasibility of culturing *C. striata* as an aquaculture cash crop. Black sea bass can be cultured in tanks when fed a 2% ration of Trout Grower. Additional studies on nutritional requirements will likely result in lower maintenance costs, higher profits, increased efficiency and incentives for the aquaculture of *C. striata.*

In order for black sea bass culture to become successful nationwide, aquaculturists will have to be able to rear fish from egg to harvestable size for the sushi markets (900 grams). Heavy commercial fishing pressure has resulted in the NMFS's recent increase in the minimum legal size limit for this fish. This fish is also a popular recreational species. Additional fishing pressure applied by a growing aquaculture-based industry would probably only add to the existing threats to this species. In recognition of this, attempts are already underway to breed and rear juvenile black sea bass. Southland Fisheries, located on Yonges Island, South Carolina, has produced a stock of fingerling black sea bass for the Marine Extension Service. We are currently investigating the potential of rearing fingerlings to a marketable size. This research is being done at the request of industry. Given the high value of black sea bass in the American and Canadian sushi markets, it is believed that this species could become an important aquaculture species for the American fish farmer.

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