Effects of Different Feeding Frequencies on Growth, Body Composition, and Fillet Composition of Juvenile Sunshine Bass, *Morone chrysops* × *M. saxatilis*, Grown Indoors

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ABSTRACT. In an effort to feed sunshine bass (*Morone chrysops* × *M. saxatilis*) efficiently, promote optimal growth, and reduce labor costs associated with feeding, sunshine bass were fed one of four feeding schedules: once per day, twice per day, once every other day, and twice every other day for 10 weeks. Ten fish were stocked into each of sixteen 110-L aquaria with four replications per treatment. At the conclusion of the feeding trial, percentage weight gain of sunshine bass fed twice/day were significantly ($P < 0.05$) higher (342%) compared to fish fed all other feeding frequencies. Specific growth rate (SGR) of fish fed twice/day was significantly higher (1.85%/day) compared to fish fed once every other day (0.69%/day) and twice every other day (1.18%/day) but not different ($P > 0.05$) from fish fed once/day (1.51%/day). The amount of diet consumed by fish fed twice/day was significantly higher (119 g diet/fish) compared to fish fed all other feeding frequencies. Feed conversion ratio (FCR) of fish fed twice/day were significantly higher (1.50) compared to fish fed once/day (1.28) and once every other day (1.15) but not different ($P > 0.05$) from fish fed twice every

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other day (1.35). Percentage fillet weight of fish fed once/day and twice/day were significantly higher (20.3% and 21.2%, respectively) compared to fish fed once every other day (15.7%) but not different from fish fed twice every other day (18.8%). Percentage lipid in fillet was not significantly different among all other treatments and averaged 9.7%. Percentage protein in fillet of fish fed once every other day and twice every other day was significantly ($P > 0.05$) higher (90% and 82.1%, respectively) compared to fish fed once/day and twice/day (81.1% and 81.5%, respectively). Based upon data from the present study, it appears that producers growing small juvenile sunshine bass indoors should feed fish twice daily. This feeding regimen allows for higher growth rates, without adverse effects on body or fillet compositions. *[Article copies available for a fee from The Haworth Document Delivery Service: 1-800-342-9678. E-mail address: <getinfo@haworthpressinc.com> Website: <http://www.HaworthPress.com>]*

KEYWORDS. Sunshine bass, feeding frequency, growth, body composition

INTRODUCTION

Hybrid striped bass is a popular aquaculture fish in the United States. There are two crosses of hybrid striped bass produced. The first, known as the palmetto bass (original cross), is produced by crossing female striped bass, *Morone saxatilis*, with the male white bass, *M. chrysops*. The second cross is known as the sunshine bass (reciprocal cross) where the female white bass is crossed with the male striped bass. In recent years, hybrid striped bass producers have increased their production from 636,000 kg in 1990 to 3.8 million kg in 1997, and reports indicate that commercial production could reach 5.9 million kg in 1999. With this rapidly growing industry, much attention has been focused on formulating nutritious, economical diets.

Information on numerous aspects of the nutritional requirements of juvenile hybrid striped bass have been described. Dietary protein requirement has been reported to be between 36% (Brown et al. 1993a) and 40% (Webster et al. 1995; Keembiyehetty and Wilson 1998); dietary energy-to-ratio has been stated to be between 8 kcal/g of protein (Nematipour et al. 1992) to 9 kcal/g of protein (Keembiyehetty and Wilson 1998) or a protein-to-energy ratio of 99 mg protein/kcal (Webster et al. 1995); dietary lysine requirement has been reported as 1.4% of the dry diet (4.0% of dietary protein) (Griffin et al. 1992; Keembiyehetty and Gatlin 1992); dietary arginine requirement has been estimated as 1.5% of the dry diet (4.4% of dietary protein) (Griffin et al. 1994a); total sulfur amino acid requirement has been reported to range from 0.73%

(Griffin et al. 1994b) to 1.0% of the diet (Keembiyehetty and Gatlin 1993); dietary threonine has been estimated as 0.9% of the diet (2.6% of dietary protein) (Keembiyehetty and Gatlin 1997); dietary choline requirement was 500 mg/kg of diet (Griffin et al. 1994c); dietary phosphorous was estimated at 0.5% of the diet (Brown et al. 1993b); and some practical diet formulations have been evaluated (Webster et al. 1995; Webster et al. 1997; Webster et al. 1999).

While there are increasing reports on the nutritional requirements and use of practical diets, there are limited data in the literature on feeding schedules for hybrid striped bass. Increased feeding frequency has been shown to improve the growth of several species. Wang et al. (1998) reported that when age-0 hybrid sunfish (female green sunfish, *Lepomis cyanellus* × male bluegill, *L. macrochirus*) were fed to satiation at one of four frequencies (one, two, three or four meals per day) for 30 days, fish fed three times per day showed the greatest food consumption and growth rates. However, overfeeding is wasteful financially and could degrade water quality. Diet cost represents 40%-70% of the total operating cost of an aquaculture enterprise. Determination of the appropriate feeding frequency required to give optimal growth and feed efficiency could reduce the amount of diet fed and thereby increase profits. Further, proper feeding does not adversely affect water quality in the pond and allows for good growth and health of fish. As the industry expands, there is a need to know what feeding frequency is optimal, both financially and in terms of production, for hybrid striped bass.

Approximately 50% of the hybrid striped bass produced in the United States are grown indoors using recirculating culture systems. These systems are not subject to the natural conditions that exist outdoors (e.g., day/night cycle, water temperature fluctuations). Production costs using a recirculating system are generally higher than those for fish grown in ponds. Thus, it is imperative that the most cost-effective and efficient method of feeding is utilized when fish are grown indoors. The objective of this study was to evaluate growth and body composition of juvenile sunshine bass that were fed using different feeding frequencies and were grown indoors.

MATERIALS AND METHODS

Juvenile sunshine bass were fed a commercial floating diet (EXT 400; Rangen, Inc., Buhl, Idaho[1]) containing 40% protein and 11.5% lipid for 10 weeks. All fish were fed one of four feeding schedules: (1) once/day at 0800; (2) twice/day at 0800 and 1530; (3) once every other day at 0800; (4) and twice every other day at 0800 and 1530.

1. Use of trade or manufacturer's name does not imply endorsement.

The experiment was conducted in sixteen, 110-L glass aquaria at the Aquaculture Research Center, Kentucky State University. Water was recirculated through biological and mechanical filters. The recirculating system consisted of a 500-L vertical screen filter system comprising high-density polyester screens (Red Ewald, Inc., Karnes City, Texas) and a propeller-washed bead filter (Aquaculture Systems, New Orleans, Louisiana). This filter system removed particulate material and provided substrate for *Nitrosomonas* and *Nitrobacter* bacteria. Continual aeration was provided by a blower and airstones. Water replacement rate for the system was approximately 5% of total volume per day. Each aquarium was cleaned daily to remove uneaten diet and feces. All aquaria sides and back were painted black to minimize disturbances when personnel were present in the laboratory. Continual illumination was supplied by fluorescent ceiling lights. Water temperature and dissolved oxygen were measured every other day using a YSI Model 58 oxygen meter (YSI Industries, Yellow Springs, Ohio). Total ammonia nitrogen and nitrite were measured three times weekly, using a DREL 2000 spectrophotometer (Hach Co., Loveland, Colorado). Total alkalinity and chloride were monitored three times weekly, using the titration method of the DREL 2000; pH was monitored three times weekly using an electronic pH meter (pH pen; Fisher Scientific, Cincinnati, Ohio).

Juvenile sunshine bass were obtained from a commercial supplier (Keo Fish Farm, Keo, Arkansas) and had an average weight of 19.0 ± 2.0 g. Ten fish were randomly stocked into one of sixteen aquaria with four replications per treatment. At the conclusion of the study, three fish were randomly sampled from each aquarium. Fish were killed by lowering the body temperature in a freezer. Whole-body weight was measured to the nearest 0.01 g; abdominal fat was gently detached from the connective tissue and weighed; the liver was removed and weighed; and the skinned fillets were removed from the backbone and weighed. Fillets were stored in polyethylene bags and frozen for proximate analysis (moisture, protein, and lipid). Protein was determined by the macro-Kjeldahl method; lipid was determined by ether extraction; and moisture was determined by placing a 10-g sample in an oven (100°C) and dried until constant weight (AOAC 1990).

Growth performance, feed conversion, and body analysis were measured in terms of percentage weight gain, percentage survival, specific growth rate (SGR, %/day), feed conversion ratio (FCR), percentage abdominal fat, percentage fillet weight, and hepatosomatic index (HSI). Growth parameters were calculated as follows:

SGR (%/day) = 100[(ln Wt − 1n Wi)/T)], where Wt is the weight of fish at time t, Wi is the weight of fish at time 0, and T is the culture period in days;

FCR = total dry diet fed (g)/total wet weight gain (g);

HSI = 100[wet weight of the liver (g)/wet weight of the fish (g)].

Differences were assessed by analysis of variance (ANOVA), using the Statistix Version 4.1 (Analytical Software 1994) for significant differences among treatment means. Least significant difference (LSD) test was used to compare differences among individual means. All percentage and ratio data were transformed to arc sin values prior to analysis (Zar 1984). Significance was tested at the $P = 0.05$ level.

RESULTS AND DISCUSSION

Over the duration of the study, water quality parameter averages ($\pm$SD): water temperature, 27.6 ± 0.97°C; dissolved oxygen, 7.0 ± 0.54 mg/L; total ammonia nitrogen, 0.41 ± 0.19 mg/L; nitrite, 0.142 ± 0.113 mg/L; alkalinity, 107 ± 27 mg/L; chlorides, 117 ± 38 mg/L; pH, 8.2 ± 0.2. During the study, these averages were within acceptable limits for fish growth and health (Boyd 1979; Mazik et al. 1991).

Percentage weight gain of sunshine bass fed twice/day were significantly ($P < 0.05$) higher (342%) compared to fish fed once/day (235%), once every other day (70%), and twice every other day (166%) (Table 1). Final mean weight of fish fed twice/day was significantly higher (78.6 g) compared to

TABLE 1. Means ($\pm$SE) of final individual weight, percentage weight gain, specific growth rate (SGR), feed conversion ratio (FCR), and percentage survival of sunshine bass fed one of four feeding regimes. Values are means of four replications. Means in the same row with different letters are significantly different ($P < 0.05$).

	Feeding Frequency			
	Once/day	Twice/day	Once every other day	Twice every other day
Final wt. (g)	60.3 ± 5.2b	78.6 ± 3.7a	32.9 ± 4.0c	50.0 ± 6.3b
Weight gain (%)	235 ± 17b	342 ± 29a	70 ± 26c	166 ± 42b
SGR (%/day)	1.51 ± 0.06ab	1.85 ± 0.08a	0.69 ± 0.15c	1.18 ± 0.19b
Diet fed (g/fish)	76.1 ± 4.2b	118.8 ± 2.5a	36.9 ± 2.1c	66.8 ± 4.4b
FCR	1.28 ± 0.05b	1.50 ± 0.08a	1.15 ± 0.09b	1.35 ± 0.06ab
Survival (%)	97.5 ± 2.5a	97.5 ± 2.5a	100 ± 0.0a	97.5 ± 2.5a

fish fed all other treatments. SGR of fish fed twice/day was significantly higher (1.85%/day) compared to fish fed once every other day (0.69%/day) and twice every other day (1.18%/day) but not different ($P > 0.05$) from fish fed once/day (1.51%/day). Percentage survival was not significantly ($P > 0.05$) different among all treatments and averaged 98%. The average amount of diet fed per fish for twice/day was significantly higher (119 g/fish) compared to all other treatments. FCR of fish fed twice/day were significantly higher (1.50) compared to fish fed once/day (1.28) and once every other day (1.15) but not different ($P > 0.05$) from fish fed twice every other day (1.35).

The percentage of whole-body weight comprised of abdominal fat in sunshine bass fed once/day and twice/day were significantly ($P < 0.05$) higher compared to fish fed once every other day (3.0%), but not significantly ($P > 0.05$) different from fish fed twice every other day (3.9%) (Table 2). Percentage fillet of sunshine bass fed once/day and twice/day were significantly higher (20.3% and 21.2%, respectively) compared to fish fed once every other day (15.7%), but not different from fish fed twice every other day (18.8%) (Table 2). HSI of sunshine bass fed twice/day was significantly higher (4.05%) compared to all other treatments.

TABLE 2. Means (±SE) of percentage abdominal fat, hepatosomatic index (HSI), percentage fillet, and proximate composition of fillet (moisture, protein, and lipid) of sunshine bass fed one of four feeding regimes. Values are means of four replications. Means in the same row with different letters are significantly different ($P < 0.05$).

	Feeding Frequency			
	Once/day	Twice/day	Once every other day	Twice every other day
Ab. fat (%)	4.35 ± 0.26a	4.98 ± 0.53a	3.03 ± 0.46b	3.88 ± 0.38ab
HSI (%)	3.30 ± 0.17b	4.05 ± 0.18a	3.43 ± 0.14b	3.40 ± 0.20b
Fillet (%)	20.3 ± 0.78a	21.2 ± 1.13a	15.7 ± 1.76b	18.8 ± 0.74ab
Fillet Analysis (dry-matter basis)				
Moisture (%)	24.6 ± 0.7a	24.4 ± 0.4a	22.0 ± 0.3b	24.0 ± 0.4a
Protein (%)	81.1 ± 1.8b	81.5 ± 3.8b	90 ± 2.4a	82.1 ± 2.2ab
Fat (%)	9.5 ± 1.2a	11.0 ± 1.6a	8.4 ± 0.7a	10.0 ± 1.7a
Fillet Analysis (wet-weight basis)				
Protein (%)	20.0 ± 0.7a	19.8 ± 0.7a	19.8 ± 0.4a	19.7 ± 0.3a
Fat (%)	2.50 ± 0.3a	2.7 ± 0.4a	1.8 ± 0.2a	2.4 ± 0.4a

Percentage lipid in fillets of sunshine bass was not significantly ($P > 0.05$) different among all treatments (either on a dry-matter basis or a wet-weight basis) and averaged 9.7% (dry-matter basis). Percentage moisture in fillets of fish fed once every other day was significantly lower (22%) compared to fish fed the other three feeding frequencies (Table 2), while percentage of protein in fillets of fish fed once every other day and twice every other day was significantly higher (90% and 82.1%, respectively) compared to fish fed once/day and twice/day (81.1% and 81.5%, respectively) when analyzed on a dry-matter basis, but no significant differences were found when data were reported on a wet-weight basis.

Based upon data from the present study, it appears that producers growing small (10-20 g) juvenile sunshine bass indoors should feed fish twice daily. There were substantial decreases in average final weight, percentage weight gain, and SGR when fish were fed less than twice daily. Teshima et al. (1984) reported that milkfish, *Chanus chanus*, fingerlings fed twice/day grew larger than fish fed once/day, while Chiu et al. (1987) stated that milkfish fed eight times per day grew larger from when fed four times per day. Chua and Teng (1978) reported that feeding estuarine grouper, *Epinephelus tauvina*, once every other day resulted in optimum growth, while weight gains were reduced in fish fed every 3, 4, or 5 days. In hybrid sunfish, fish fed once/day were smaller than fish fed 2, 3, or 4 times per day; however, there were no differences among the latter three feeding frequencies. These results are in contrast to reports that feeding channel catfish, *Ictalurus punctatus*, once/day produced similar growth (percentage weight gain and SGR) compared to fish fed twice/day when grown in cages (Webster et al. 1992a) or in ponds (Webster et al. 1992b). Data on Atlantic salmon, *Salmo salar*, has shown that feeding regimen has little influence on growth provided that the fish are fed to satiation (Juell et al. 1994; Sveier and Lied 1998).

In the present study, sunshine bass fed twice/day had significantly higher FCR compared to fish fed less frequently. This might indicate that sunshine bass fed more frequently might utilize diet less efficiently than fish fed less frequently. However, Webster et al. (1992a) found that channel catfish fed once/day or twice/day had similar FCRs. Wang et al. (1998) reported that there was no difference in FCR among hybrid sunfish fed one, two, three, or four times per day. Hepher et al. (1988) stated that feeding frequency has little effect on FCR. This may indicate that diet consumption is the growth limiting factor. Sunshine bass fed more frequently and thus fed more diet had higher weight gain than fish fed less frequently. The amount of food in the stomach is a factor in controlling feeding response (appetite). When fish are fed to satiation, the gastric evacuation rate is dependent upon temperature and fish size (Fange and Grove 1979). Optimal water temperatures for growth

may result in a more rapid digestion process. Therefore, fish require more than one feeding per day.

While FCR and the amount of diet fed to fish were higher in fish fed twice daily, it is doubtful that any financial savings in the reduced amount of diet fed to fish would be economical in the long term when growing fish to market-size as quickly as possible is imperative for profitability. The cost of diet used in the present study was $0.75/kg of diet. Based upon this value, it cost $0.75 to produce one kilogram of sunshine bass fed twice/day; however, it cost $0.875 to produce one kilogram of fish fed once every other day. The amount of diet fed consumed by small (<50 g) juvenile fish is less than the amount consumed by larger (>100 g) juveniles, and a producer feeds most of the diet during the period from larger juvenile to market-size fish. Since these smaller fish do not consume a high percentage of the diet fed during grow-out, it does not save money for the producer and may actually cost more as was found in the present study.

This study suggests that body composition of juvenile sunshine bass is affected by the frequency of feeding. Sunshine bass fed once/day and once every other day had less abdominal fat than fish fed twice/day and twice every other day; however, the percentage of abdominal fat was similar to values reported in channel catfish when fed once or twice daily (Webster et al. 1992a, 1992b). The percentage of body weight in muscle (fillet) was lower in fish fed once/day and once every other day, probably due to the fact that they were smaller than sunshine bass fed twice/day and twice every other day; smaller fish have a higher percentage of body weight comprised as bone compared to larger fish. Noeske-Hallin et al. (1985) reported increased lipid levels in channel catfish fed twice daily compared to fish fed once daily; however, Webster et al. (1992a) reported that there were no significant differences in percentage moisture, protein, and lipid in fillet of channel catfish fed either once or twice daily. Sveier and Lied (1998) reported that body composition was not affected when Atlantic salmon were fed once/day. In the present study, there was no difference in percentage protein or lipid in the fillet of sunshine bass fed either once/day, twice/day, once every other day, or twice every other day when analyzed on a wet-weight basis. Shearer (1994) stated that proximate composition of fish should be reported on a wet-weight basis and that whole-body protein and ash percentages change as fish grow, so that fish size must be treated as a covariant. However, since only fillet composition was analyzed, it is appropriate to use ANOVA analysis.

Data from the present study indicate that juvenile sunshine bass should be fed twice per day when grown indoors. More frequent feeding frequencies were not evaluated in the present study so no determination can be made if more frequent daily feedings would increase growth rate in sunshine bass. In the present study, feeding twice/day produced higher growth rates in fish

while not adversely affecting body composition. It is imperative that as the hybrid striped bass industry grows and matures that the most cost-effective feeding methods are utilized to promote the fastest growth. Feeding fish twice/day may allow producers to be more profitable by optimizing growth rate.

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