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Growth and Feed Utilization of Captive Wild Black Sea Bass *Centropristis striata* at Four Different Densities in a Recirculating Tank System

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Abstract

A study to determine the effects of four stocking densities on growth and feed utilization of wild-caught black sea bass *Centropristis striata* was conducted in a pilot-scale recirculating tank system. The outdoor system consisted of 12 insulated fiberglass tanks (dia. = 1.85 m; vol. = 2.17 m³) supported by biological filters, UV sterilizers, and heat pumps. Subadults (*N* = 525; *x* ± SD = 249 ± 16.8 g) were stocked at densities of 4.6 fish/m³ (1.18 kg/m³), 16 fish/m³ (3.91 kg/m³), 25.3 fish/m³ (6.83 kg/m³), and 36 fish/m³ (7.95 kg/m³), with three replicate tanks per treatment. Fish were grown under 35 ppt salinity, 21–25 C, and under ambient photoperiod conditions. A commercial flounder diet containing 50% protein and 12% lipid was hand-fed twice daily to satiation for 201 d.

Mean (range) total ammonia-nitrogen, 0.61 (0–2.1) mg/L, nitrite-nitrogen, 0.77 (0.04–3.6) mg/L, and nitrate-nitrogen 40.1 (0–306) mg/L were significantly higher ($P < 0.0001$) in the 25.3 and 36 fish/m³ treatments than in the 4.6 and 16 fish/m³ treatments [0.19 (0.05–0.5), 0.1 (0.24–0.63), and 11.9 (1.3–82.2) mg/L, respectively]. However, there were no significant differences ($P > 0.05$) in growth (RGR = 196.8–243.1%; DWG = 2.55–2.83 g/d; and SGR = 0.55–0.61%/d), coefficient of variation of body weight (CV_{wt} = 0.24–0.25), condition factor (K = 2.2–2.4), feed consumption (FC = 1.45–1.65%/d), and feed conversion ratio (FCR = 1.45–1.52) among stocking densities. Final biomass densities on day 201 reached 3.48, 12.0, 21.1, and 27.2 kg/m³ at stocking densities of 4.6, 16, 25.3, and 36 fish/m³, respectively. Survival (83.8–99.1%) did not differ among treatments. Apparent net protein retention (ANPR) was significantly higher ($P < 0.005$) for fish stocked at the lower densities of 4.6 and 16 fish/m³ (22.5–23.7%) than for those stocked at 25.3 and 36 fish/m³ (21–20.1%). There were no significant differences ($P > 0.05$) in apparent net energy retention (ANER = 55.9–59.1%) among stocking densities. Final whole body protein (15.3–16.3%) and lipid (23.1–26.4%) levels did not differ significantly ($P > 0.05$) among treatments.

The results demonstrated that growth, survival, and feed utilization were not impaired under stocking densities ranging from 4.6–36 fish/m³ (3.48–27.2 kg/m3), despite a slight reduction in water quality at the higher densities. In addition, growth variation and final whole body protein and lipid levels were not influenced by these densities. The results suggest that black sea bass are tolerant of crowding and moderate variations in water quality during intensive culture in recirculating tank systems and that higher stocking densities are possible.

Market demand for black sea bass *Centropristis striata* has shown rapid growth in recent years, due to its high quality flesh and versatility for cooking techniques ranging from sashimi to deep frying. Commercial and recreational landings have shown a declining trend for several decades. Total commercial U.S. landings decreased from 10,000 metric tons (mt) in 1952 to 1,700 mt in 1968. Since this time, landings peaked in 1977 at 2,700 mt and were reported at 1,500 mt in 2000 valued at $5.7 million ex-vessel (personal communication, NMFS, Fisheries Statistics and Economics Division). With pressure remaining high on wild stocks and fishing regulations becoming more restrictive, there is growing interest in development of commercial aquaculture of black sea bass (Berlinsky et al. 2000; Copeland et al. 2002).

In a previous study, growth and feed utilization of captive wild subadult black sea bass were compared in a recirculating tank system on four practical diets with protein and lipid levels ranging from 45–55% and 11–15%, respectively (Copeland et al. 2002). In this initial study, fish were stocked at a relatively low density (4.6 fish/m^3), and relatively good growth (2.54–3.28 g/d) and feed conversion (1.49–1.62) were obtained on all diets. However a diet with a 50% protein, 12% lipid content produced optimum growth from an average of 316 to 970 g in 221d (3.28 g/d) with a feed conversion ratio of 1.52.

The objective of this study was to evaluate the effects of stocking density on growth rates and feed utilization of wild-caught subadult black sea bass in a recirculating tank system.

Materials and Methods

This study was conducted at the University of North Carolina at Wilmington, Center for Marine Science (UNCW-CMS) Aquaculture Facility at Wrightsville Beach, North Carolina, from March through October 2001. Wild-caught subadult black sea bass (N = 525; $x \pm$ SD = 249 ± 6.14 g) were collected using commercial traps set at approximately 14-m depth off Carolina Beach, North Carolina. Some specimens were smaller than the minimum legal size limit (10" TL), requiring a scientific collecting permit from the North Carolina Division of Marine Fisheries. Fish were transported to a shoreside holding facility and were maintained in rectangular raceways (10 m × 1 m × 0.3 m) supplied with flow through seawater (35 ppt) for up to 24 h before transfer to the aquaculture facility. Upon arrival, fish were held in 1.8-m-diameter tanks supplied with recirculated seawater (35 ppt) pumped from the Atlantic Intracoastal Waterway adjacent to the laboratory. Fish were weaned onto a floating commercial (Melick Aquafeed, Catawissa, Pennsylvania, USA) flounder diet (7 mm) containing 50% protein, 12% lipid within 2–3 d.

The experimental system consisted of two independent recirculating systems, each comprising six 1.8-m diameter (vol. = 2,660 L, depth = 0.91 m) insulated fiberglass tanks. One system (system 1) consisted of a high rate sand filter, fluidized bed biofilter (Aquatic Ecosystems Inc., Apopka, Florida, USA), foam fractionator, and UV sterilizer. The second system (system 2) consisted of a bubble wash bead filter (Aquaculture Systems Technology, LLC, New Orleans, Louisiana, USA), cyclobiofilter (Marine Biotech, Inc., Beverly, Massachusetts, USA) foam fractionator and UV sterilizer. Temperature in each system was controlled using a heat pump, and aeration was supplemented using pure oxygen supplied through diffusers. Average daily water exchange for each system averaged 17%.

To determine the effects of stocking density on growth performance, fish were stocked at densities (fish/tank) of 4.6 fish/m^3 (1.18 kg/m^3), 16 fish/m^3 (3.91 kg/m^3), 25.3 fish/m^3 (6.83 kg/m^3), and 36 fish/m^3 (7.95 kg/m^3), with three replicate tanks per treatment. Fish under treatment densities of 4.6 and 16 fish/m^3 were stocked into system 1, while those under treatment densities of 25.3 and 36 fish/m^3 were stocked into system 2. Mean initial weights (249 ± 17 g) and total lengths (242 ± 3.6 mm) did not differ significantly ($P > 0.05$) among treatments (Table 1). Coefficients of variation (CV = SD/x) for initial weights (CVwt) and lengths (CVlt) averaged 0.26 ± 0.23 and 0.07 ± 0.01, with the 25.3 fish/m^3 treatment having a significantly lower ($P < 0.05$) CVwt than the 36 fish/m^3 treatment (Table 1). Initial condition factor ($K = W/L^3 \times 100$) averaged 1.8 ± 0.06, with no signifi-

TABLE 1. *Mean initial and final weights, biomass densities, total lengths (TL), coefficients of variation (CV) of weights and lengths, condition factor (K), and survival of wild-caught, subadult black sea bass reared in a recirculating tank system for 201 d at four different stocking densities. Fish were fed a commercially prepared diet containing 50% protein and 12% lipid. Values are x ± SD (N = 3). Means in the same row without a letter in common are significantly different (P < 0.05).*

Parameter	Stocking density (number/m³)			
	4.6	16	25.3	36
Initial (day 0)				
Wt. (g)	255 ± 2.50a	242 ± 32.3a	269 ± 4.00a	230 ± 12.0a
$CV_{wt.}$	0.23 ± 0.05ab	0.29 ± 0.05ab	0.19 ± 0.02a	0.32 ± 0.06b
Biomass density				
(kg/m³)	1.18 ± 0.01a	3.91 ± 0.52a	6.83 ± 0.1a	7.95 ± 0.42a
(lb/gal)	0.01a	0.03a	0.06a	0.07a
TL (mm)	243 ± 1.8a	241 ± 7.5a	247 ± 2.7a	238 ± 5.6a
CV_{TL}	0.07 ± 0.02a	0.07 ± 0.02a	0.06 ± 0.01a	0.08 ± 0.02a
K	1.8a	1.8 ± 0.1a	1.7 ± 0.06a	1.7 ± 0.06a
Final (day 221)				
Survival (%)	90 ± 10.0a	83.8 ± 28.1a	98.8 ± 2.08a	99.1 ± 0.75a
Wt. (g)	766 ± 74a	756 ± 116a	838 ± 98a	788 ± 30a
$CV^{wt.}$	0.24 ± 0.06a	0.24 ± 0.03a	0.24 ± 0.04a	0.25 ± 0.02a
Biomass density				
(kg/m³)	3.48 ± 0.37a	12.0 ± 2.17a	21.1 ± 2.63a	27.2 ± 1.05a
(lb/gal)	0.03a	0.09a	0.18a	0.23a
TL (mm)	326 ± 5.4a	318 ± 11.3a	325 ± 7.3a	323 ± 1.6a
CV_{TL}	0.07 ± 0.02a	0.07 ± 0.01a	0.07 ± 0.02a	0.07 ± 0.01a
K	2.2 ± 0.15a	2.3 ± 0.12a	2.4 ± 0.15a	2.3 ± 0.06a

cant differences ($P > 0.05$) among treatments (Table 1).

Fish were fed twice daily (0900 and 1600 h) to satiation a floating commercial flounder diet (7 mm) containing 50% protein, 12% lipid. At each feeding, fish in each tank were scored according to feeding response from 0 (no response) to 5 (strong response). The scores were averaged at the end of the day to determine the next day's ration which was adjusted by 0–0.25%.

Fish were individually weighed and measured for standard (SL) and total length (TL) at the beginning of the experiment and every 6 wk with the aid of an anesthetic (100 ppm tricaine methane sulfonate; MS-222). Temperature (C), dissolved oxygen (mg/L), salinity (ppt), and pH were monitored daily in each system. Ammonia, nitrite, and nitrate (mg nitrogen/L) were monitored on a weekly basis (HACH Company, Loveland, Colorado, USA).

When the study was terminated on day 201, a sample of four fish and three filets from each treatment were collected for analysis of proximate composition. These specimens were analyzed by standard methods (AOAC 1984) at a commercial laboratory (New Jersey Feed Lab, Trenton, New Jersey, USA). Dietary gross energy content of each diet and carcass was calculated from those results by using published physiological fuel values of 5.64 (23.6 kJ), 9.44 (39.5 kJ), and 4.11 (17.2 kJ) kcal/g for protein, lipid, and carbohydrate, respectively (NRC 1993).

Relative growth rate (% increase in weight) was calculated as:

$$RGR = 100[(\text{wet final weight} - \text{wet initial weight}) \div (\text{wet initial weight})]$$

Specific growth rate (% increase in weight/d) was calculated as:

$$SGR = 100\{\log_e(\text{wet final weight}) - \log_e[(\text{wet initial weight}) \div (\text{time in days})]\}.$$

Condition factor (K) was calculated as:

$$K = 100\ (W/L^3)$$

in which W = weight in g and L = total length in cm.

Feed consumption (% body weight/d) was determined for every sampling interval and calculated as:

$$FC = 100\{(\text{weight feed consumed}) \div [(\text{final weight} + \text{initial weight})/2]\}.$$

Consumption for the duration of the experiment was taken as the average over all sampling intervals. Feed conversion ratio was calculated as:

$$FCR = (\text{weight of feed fed})/(\text{wet weight gain})$$

Apparent net protein retention (%) was calculated as:

$$ANPR = 100\{[(\text{final wet weight}) \times (\text{final body protein }\%)] - [(\text{initial wet weight}) \times (\text{initial body protein, }\%)] \div (\text{protein fed})\}$$

Apparent net energy retention (%) was calculated as:

$$ANER = 100\{[(\text{final wet weight} \times \text{final kJ/g bw}) - (\text{initial wet weight} \times \text{initial kJ/g bw})] \div (\text{kJ energy fed})\}$$

Treatment means were compared by one-way ANOVA (Sokal and Rohlf 1995). Differences between means were analyzed for significance ($P < 0.05$) with Tukey-Kramer HSD. All data were analyzed using JMP-IN version 3.2.6 software (SAS Institute, Inc., Cary, North Carolina, USA).

Results

Mean (range) water quality parameters for both systems were as follows: temperature, 22.9 (7.6–27.9) C, pH, 7.7 (7.2–8.4); dissolved oxygen, 6.92 (4.33–10.24) mg/L; salinity, 35 (30–40) ppt. Temperature, 23.1 (17.6–27.9) C; total ammonia-nitrogen, 0.61 (0–2.1) mg/L; nitrite-nitrogen, 0.77 (0.04–3.6) mg/L; and nitrate-nitrogen 40.1 (0–306) mg/L in system 2 (25.3 and 36 fish/m^3) were significantly higher ($P <$ 0.0001) than in system 1 (4.6 and 16 fish/m^3) [22.3 (18.5–27.1) C; 0.19 (0.05–0.5) mg/L; 0.1 (0.24–0.63) mg/L; and 11.9 (1.3–82.2) mg/L, respectively].

Survival to day 201 remained high in all treatments, ranging from 83.8–99.1%, with no significant differences ($P > 0.05$) (Table 1). Final weights and total lengths averaged 787 (756–838) g and 323 (318–326) mm, respectively, with no significant differences ($P > 0.05$) among treatments (Table 1). Final CV_{wt} and CV_{tl} averaged 0.24 and 0.07, respectively, and did not differ significantly ($P > 0.05$) among treatments or from initial values. Final condition factors ranged from 2.2–2.4 among treatments and were significantly increased ($P < 0.0001$) compared to initial values (range = 1.7–1.8) (Table 1). There were no significant differences ($P >$ 0.05) in final condition factor among treatments. Final biomass densities on day 201 reached 3.48, 12.0, 21.1, and 27.2 kg/m^3 (0.03, 0.09, 0.18, and 0.23 lb/gal) for treatment densities of 4.6, 16, 25.3, and 36 fish/m^3, respectively (Table 1).

Growth rates, including DWG (2.55–2.83 g/d), RGR (197–243%), and SGR (0.55–0.61%/d), showed no significant differences ($P > 0.05$) among treatments (Table 2). FC (1.45–1.65 %/d) and FCR (1.45–1.52) showed no significant differences (P > 0.05) among treatments (Table 3). ANPR was significantly lower ($P < 0.05$) in the

TABLE 2. *Daily weight gain (DWG), relative growth rate (RGR), and specific growth rate (SGR) of wild-caught, subadult black sea bass reared in a recirculating tank system for 201 d at four different stocking densities. Fish were fed a commercially prepared diet containing 50% protein and 12% lipid. Values are* x *± SD* (N *= 3). There were no significant differences among treatment means for any parameters.*

	Stocking density (number/m^3)			
Parameter	4.6	16	25.3	36
DWG (g/d)	2.55 ± 0.37a	2.55 ± 0.60a	2.83 ± 0.47a	2.78 ± 0.20a
RGR (%)	197 ± 32a	211 ± 74.5a	210 ± 36.9a	243 ± 30.8a
SGR (%/d)	0.55 ± 0.05a	0.56 ± 0.10a	0.56 ± 0.06a	0.61 ± 0.04a

36 fish/m^3 treatment (20.1%) than in the 16 fish/m^3 treatment (23.7%) (Table 3). ANER ranged from 56.6–59.1% (Table 3) with no significant differences among treatments ($P > 0.05$).

Final whole body moisture content (55.5–58.8%) was significantly higher ($P < 0.05$) in the 16 fish/m^3 treatment (58.8%) than in the 36 fish/m^3 treatment (55.5%) and all final values were significantly lower ($P < 0.0001$) than the initial value (69.2%) (Table 4). Final protein content (15.3–16.3%), showed no significant differences ($P > 0.05$) among treatments (Table 4), but was significantly lower ($P < 0.003$) in the 25.3 and 36 fish/m^3 treatments than the initial level of 17.2%. Final crude lipid (23.1–26.4%) did not differ significantly ($P > 0.05$) among treatments and was significantly increased ($P < 0.0001$) in all treatments compared to the initial level of 4.84%. Final muscle gross energy content (12.9–14.1 kJ/g) was not significantly different among treatments, but was significantly increased ($P < 0.0001$) compared to the initial level of 5.95 kJ/g.

Final muscle moisture (59.2–63.4%) and protein (15.4–18.3%) were significantly ($P < 0.0001$) lower in all treatments compared with initial values of 78.6% and 21.3%, respectively (Table 5). Muscle crude lipid content (18.8–23.2%) was significantly elevated ($P < 0.0001$) in all treatments compared with an initial value of 0.31%. Final gross energy (11.8–13 kJ/g) was not significantly different among treatments, but was significantly increased ($P < 0.0001$) compared to the initial level of 5.14 kJ/g.

Discussion

Growth

The results demonstrated that growth and feed utilization of captive wild black sea bass fed a practical diet in a recirculating tank system were not impaired and that growth variation was not influenced at stocking densities as high as 27.2 kg/m^3. This suggests that higher stocking densities are possible. In a number of species, including rainbow trout *Oncorhynchus mykiss* (Zoccarato et al. 1994), red tilapia (Suresh

TABLE 3. *Feed consumption (FC), feed conversion ratio (FCR), apparent net protein retention (ANPR), and apparent net energy retention (ANER) of wild-caught, subadult black sea bass reared in a recirculating tank system for 201 d at four different stocking densities. Fish were fed a commercially prepared diet containing 50% protein and 12% lipid. Values are* x *± SD* (N *= 3). Means in the same row without a letter in common are significantly different* (P *< 0.05).*

	Stocking density (number/m^3)			
Parameter	4.6	16	25.3	36
FC (%/d)	1.45 ± 0.04a	1.45 ± 0.14a	1.53 ± 0.06a	1.65 ± 0.03a
FCR	1.47 ± 0.07a	1.45 ± 0.14a	1.51 ± 0.08a	1.52 ± 0.10a
ANPR (%)	22.5 ± 0.99ab	23.7 ± 1.04ac	21.0 ± 1.67b	20.1 ± 0.73b
ANER (%)	56.6 ± 5.3a	59.1 ± 2.4a	55.9 ± 1.9a	57.5 ± 2.8a

TABLE 4. *Initial and final whole body proximate composition (% wet weight), nitrogen free extract and gross energy of wild-caught, subadult black sea bass reared in a recirculating tank system for 201 d at four different stocking densities. Fish were fed a commercially prepared diet containing 50% protein and 12% lipid. Values are x ± SD (N = 3). For final values, means in the same row without a letter in common are significantly different (P < 0.05). Asterisk (*) denotes significant differences from initial values.*

Parameter	Initial	Final for stocking density (number/m^3)			
		4.6	16	25.3	36
Moisture (M, %)	69.2 ± 1.68	58.3 ± 1.85bc*	58.8 ± 0.96b*	56.8 ± 0.99bc*	55.5 ± 1.06c*
Crude protein (CP, %)	17.2 ± 0.74	16.0 ± 0.47ab	16.3 ± 0.46ab	15.7 ± 0.81b*	15.3 ± 0.37b*
Crude lipid (CL, %)	4.84 ± 1.72	23.1 ± 2.76b*	23.7 ± 1.33b*	24.2 ± 1.33b*	26.4 ± 1.51b*
Crude ash (CA, %)	7.18 ± 3.46	3.03 ± 0.48b*	2.77 ± 0.08b*	3.00 ± 0.36b*	3.15 ± 0.04b*
Fiber (F, %)	0.41 ± 0.21	0.19 ± 0.04b*	0.16 ± 0.01b*	0.22 ± 0.03ab	0.17 ± 0.03b*
Nitrogen free extract (NFE, %)[a]	1.37 ± 1.64	0a	0a	0.25 ± 0.29a	0.09 ± 0.18a
Gross energy (kJ/g fish)[b]	5.95 ± 1.3	12.9 ± 1.01b*	13.2 ± 0.45b*	13.3 ± 0.37b*	14.1 ± 0.60b*

[a] NFE calculated by subtraction [100 − (Moisture + CP + CL + CA + F)].
[b] Gross energy determined by using physiological fuel values of 5.64 (23.6 kJ), 9.44 (39.5 kJ), and 4.11 (17.2 kJ) kcal/g for protein, lipid, and carbohydrate, respectively (NRC 1993).

and Lin 1992), Arctic charr *Salvelinus alpinus* (Metusalach et al. 1999), and turbot *Scophthalmus maximus* (Irwin et al. 1999), an inverse correlation between stocking density and growth rate has been reported. For example, in rainbow trout reared at stocking densities of 8, 16, 33, and 43 kg/m^3 (Zoccarato et al. 1994), final mean weight decreased significantly at the higher stocking densities (33–43 kg/m^3) due to social interactions caused by crowding and to reduced water quality. This is similar to what was reported for red tilapia in which growth and FCR were better at 50 fish/m^3 (vs. 100 and 200 fish/m^3), and final biomass densities reached 5.6, 10.4, and 19 kg/m^3, respectively (Suresh and Lin 1992). Likewise, Metusalach et al. (1999) found that FCR worsened and growth declined with increased stocking density in Arctic charr

TABLE 5. *Initial and final muscle proximate composition (% wet weight), nitrogen free extract and gross energy of wild-caught subadult black sea bass reared in a recirculating tank system for 201 d at four different stocking densities. Fish were fed a commercially prepared diet containing 50% protein and 12% lipid. Values are x ± SD (N = 3). Means in the same row without a letter in common are significantly different (P < 0.05). Asterisk (*) denotes significant differences from initial values.*

Parameter	Initial	Final for stocking density			
		4.6	16	25.3	36
Moisture (M, %)	78.6 ± 0.75	59.2 ± 1.57b*	63.4 ± 1.16b*	61.9 ± 1.16b*	59.4 ± 1.39b*
Crude protein (CP, %)	21.3 ± 1.05	15.4 ± 0.76b*	18.3 ± 0.76c*	15.8 ± 0.47b*	15.5 ± 0.50b*
Crude lipid (CL, %)	0.31 ± 0.42	23.2 ± 2.96b*	18.8 ± 3.34b*	20.8 ± 3.57b*	22.8 ± 1.68b*
Crude ash (CA, %)	1.29 ± 0.03	0.95 ± 0.06b*	1.04 ± 0.06b*	0.95 ± 0.07b*	0.93 ± 0.03b*
Fiber (F, %)	0.36 ± 0.03	0.26 ± 0.21a	0.20 ± 0.06a	0.21 ± 0.03a	0.20 ± 0.04a
Nitrogen free extract (NFE, %)[a]	0	1.07 ± 0.93a	0.1 ± 0.18a	0.40 ± 0.36a	1.19 ± 0.86a
Gross energy (kJ/g fish)[b]	5.14 ± 0.28	13.0 ± 0.89b*	11.8 ± 1.21b*	12.0 ± 1.36b*	12.9 ± 0.59b*

[a] NFE calculated by subtraction [100 − (Moisture + CP + CL + CA + F)].
[b] Gross energy determined by using physiological fuel values of 5.64 (23.6 kJ), 9.44 (39.5 kJ), and 4.11 (17.2 kJ) kcal/g for protein, lipid, and carbohydrate, respectively (NRC 1993).

reared at 40, 50, and 75 kg/m^3. Irwin et al. (1999) found that turbot reared at highest densities within the range 0.7 to 1.8 kg/m^2 showed decreased growth and greater variation in body weight over time. They suggested that this was due solely to social interactions (e.g., formation of hierarchies) resulting in a disproportionate acquisition of food by dominant fish. In this study, mean temperature differences between systems 1 and 2, while significant, were small in magnitude (0.8 C). Although total ammonia-nitrogen was significantly higher in system 2 (which supported higher densities of fish), DO and un-ionized ammonia in both systems were within ranges recommended for warmwater recirculating aquaculture systems (DO > 5 mg/L, un-ionized ammonia-nitrogen < 0.02 mg/L) (Masser et al. 1999). The results suggest that growth of black sea bass was unaffected by physical crowding or moderate increases in ammonia under stocking densities as high as 27 kg/m^3.

Feed Utilization

In this study, FCR averaged 1.52 and was not significantly influenced by stocking density within the ranges of 3.48 to 27.2 kg/m^3. These FCRs are comparable to or better than what has been reported for other finfish species grown in recirculating tank systems. For example, hybrid tilapia *Oreochromis niloticus* × *O. aureus* reared in a static system on a 34% protein feed under comparable densities of 1, 5, 10, and 15 kg/m^3 showed FCRs of 2.0–2.2 (Siddiqui and Al-Harbi 1999). Likewise, FCR in red tilapia fed a 23% protein commercial diet ranged from 2.57 to 2.61 for fish reared at densities of 3.8 to 15 kg/m^3 (Suresh and Lin 1992). FCR in Arctic charr fed a 45.3% protein, 22.6% lipid diet increased from 1.05 to 2.05 with increasing stocking densities of 40, 50, and 75 kg/m^3 (Metusalach et al. 1999).

In this study, final carcass protein content of black sea bass (15.3–16.3%) was comparable to that reported for the Atlantic halibut *Hippoglossus hippoglossus* L. (16.4–16.6%), a marine flatfish species (Berge et al. 1999). Muscle protein content (15.4–18.3%) was also comparable with halibut muscle (17–18%) (Aksnes et al. 1996). Final crude lipid content (23.1–26.4%) was significantly elevated in all treatments and was higher than what was reported for halibut (14%) (Berge et al. 1999). Muscle lipid content 1 (8.8 to 23.2%) was also higher than what was reported for halibut muscle (6–13%) (Aksnes et al. 1996). High lipid content of black sea bass in this study suggests that dietary lipid levels may have been excessive and/or that fish were lacking exercise. Alternatively, excessive dietary choline may have impaired lipid metabolism (Halver 1989), causing increased body fat deposition, as has been reported in yellow perch (Twibell and Brown 2000). On the other hand, preliminary analyses have revealed that fish from the 4.6 and 16 fish/m^3 treatments contained high levels of omega-3 polyunsaturated fatty acids (C. Seo, personal communication), and marketing trials with tank grown product have suggested that higher muscle lipid content may be desirable for the sushi market. Additional studies are needed to determine optimal lipid levels for various consumer markets and if these can be manipulated through husbandry methods (e.g., diet and exercise).

To summarize, growth, survival, and feed utilization were not impaired in captive wild black sea bass fed a practical diet in recirculating tanks under stocking densities ranging from 3.48–27 kg/m^3 (0.03–0.23 lb/gal), despite a moderate reduction of water quality at the higher densities. Furthermore, growth variation, final whole body, and muscle protein and lipid compositions were not significantly different among these stocking densities. The results suggest that black sea bass are tolerant of crowding and variable water quality during intensive culture in recirculating tank systems, but further studies are needed to determine growth performance under higher densities of around ≥ 60 kg/m^3 to evaluate commercial feasibility (Losordo and Westerman 1994; Copeland et al. 2003).

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