TOPIC AREA:
INDIGENOUS SPECIES DEVELOPMENT

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DEVELOPMENT OF SUSTAINABLE FEEDS, IMPROVED STOCKING DENSITIES, AND SALINITY MANAGEMENT IN CLOSED RECIRCULATING SYSTEMS FOR GAR (*ATRACTOSTEUS* SPP.) CULTURE

Indigenous Species Development/Experiment/09IND11UM

FINAL INVESTIGATION REPORT

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ABSTRACT

The purpose of this study was to determine success of closed and recirculating filtration systems on water quality and growth of tropical and Cuban gars, and to determine the effect of salinity on growth (treatments 0, 10, and 15 ppt salinity). Fish were divided into treatment groups. For the system experiment, treatments were a control in a recirculating system, and closed systems for a second treatment with aquarium filtration systems. For the salinity experiments, treatments were 0-15 ppt salinity. Fish length and weight were measured at beginning and end of experiments (tropical gars also measured every 15 days), and were fed *ad libitum* with trout feed (tropical gars) or commercial pellet feed (Cuban gars). In all experiments, ammonia, nitrite, nitrate, and pH were measured weekly, and temperature daily. The various salinity treatments and recirculating or filtered systems resulted in no significant differences in growth for any treatment. Water quality was generally similar among all treatments as well. Overall, this experiment indicates that tropical and Cuban gars are tolerant of a range of conditions and could be reared using a variety of systems without any loss of yield. Since the various systems have different costs of maintenance and operation, this wide-ranging tolerance of rearing conditions allows gar to be reared more efficiently in systems to suit local conditions.

INTRODUCTION

Gars are a group of ancient air-breathing fishes that make up the family Lepisosteidae. The family consists of two genera, *Atractosteus* and *Lepisosteus*, and seven extant species. The genus *Lepisosteus* consists of the longnose gar (*L. osseus*), shortnose gar (*L. platostomus*), spotted gar (*L. oculatus*), and Florida gar (*L. platyrhincus*); *Atractosteus* consists of the tropical gar (*A. tropicus*), Cuban gar (*A.*

tristoechus), and alligator gar (*A. spatula*). Although the fossil record for gars exhibits a Pangeaic distribution, extant species are relegated to North and Central America and Cuba, and range from southern Canada (longnose gar) to Costa Rica (tropical gar) (Suttkus, 1963; Wiley, 1976).

Gars are top-level predators in their native ecosystems and are characterized by their elongate jaws, cylindrical bodies, and diamond-shaped ganoid scales. Their maximum size and age varies with species, from approximately 80 cm and 10 years (shortnose gar) to 300 cm and over 70 years (alligator gar). Gars are generally polyandrous in reproductive strategy, with multiple male individuals spawning with 1-2 females. Gars spawn during late spring and early summer in temperate regions and during the rainy season in tropical regions. Growth is extremely rapid, with all species capable of reaching 30 cm or more in their first growing season (young–of-the-year alligator gar can reach over 30 cm, 250 g in 3 months).

Gars are excellent candidates for aquaculture as they exhibit rapid growth to large sizes, are highly resistant to disease, can be maintained at high densities, readily adapt to artificial feed at early life stages, and are tolerant of low water quality conditions due to their air-breathing abilities (Alfaro et al., 2008). Their tolerance of low water quality via aerial respiration also allows for a less complicated technological system for aquaculture, as opposed to other fishes, which may require considerable aeration and water turnover. Gars are therefore well suited for culture in developing regions.

Much progress has already been made in the aquaculture of *Atractosteus* gars (tropical, Cuban, alligator), primarily in regions of Mexico, Cuba, and the southern United States. Broodstock for all three species have been established and are currently maintained in their native regions, and juveniles have been released to help restock diminishing wild populations. Further efforts are being made in the southern US to protect alligator gar populations and manage them as a viable sport fishery, as well as increase its potential as a food fish. Gars are already a popular food fish in various regions of Mexico and Cuba.

Due to their unique appearance and predatory nature, gars are becoming increasingly popular in the ornamental fish trade. Gars have been sought-after aquarium fish in Southeast Asia for many years and are growing in popularity in the United States and other countries. The Florida gar, native to only a small portion of the southeastern US, is the most popular aquarium species of gar in the US (usually wild-caught) and most readily available abroad. Prices in the US range from $15-40 USD for 20-35-cm individuals. Other gar species at similar sizes command a much higher price, largely due to their rarity in the aquarium trade, such as $200 USD for an individual tropical gar and over $300 USD for a Cuban gar (in the United States). Tropical and Cuban gars are also highly valued overseas; in Singapore 15-cm tropical gar average $150 USD, and Cuban gar $400 USD. Ironically, tropical and Cuban gars are among the most commonly cultured gar species. Specimens exhibiting genetic mutations in pattern or coloration (i.e., melanistic, xanthochroic, leucistic) command an even higher price, ranging from $1000 to over $5000 USD. Hybrid gars, although rare in the trade, are also much sought after.

Because gars are air-breathers, they should perform well in completely closed recirculating systems, potentially using less water for culture. Gars may also be cultured in systems with reduced or no additional aeration, further reducing energy consumption. Our experiments on recirculating and filtered systems will begin to address the potential of reducing water and energy use in the culture of gars. Several gar species have been shown to have moderate-to-high salinity tolerances (compared to other teleost and non-teleost freshwater fishes) and, in some cases, showed improved growth under saline conditions (Suchy, 2009). Furthermore, gar from different latitudes may exhibit different growth rates (latitudinal variation); therefore, specific populations may be better candidates for culture than others. By comparing our growth models with those from other regions (specifically with the wide-ranging tropical gar), we may determine the populations with the highest capacity for growth and therefore production in culture. This could be incorporated into existing operations to potentially increase efficiency, sustainability, and production, as well as making the technology for gar culture more accessible to developing regions.

OBJECTIVES

1. Determine success of closed and recirculating filtration systems on water quality and growth of gars (closed versus recirculating systems).

2. Determine the effect of salinity on growth of gars (treatments salinity 0 ppt, 5, and 10 ppt and 0, 10, and 15 ppt).

3. Evaluate the growth of gars using feed with lower fishmeal content.

METHODS AND MATERIALS

Experiment 1a. Differential growth of tropical gar in closed and recirculating filtration systems, and variation in water quality – tropical gars were divided into four treatment groups: one (control) in a recirculating system, and three in closed systems with aquarium filtration. Fish were placed in 12 plastic tanks of 170 L (triplicated). Treatments were set as follows: a) control group, 7 fish/tank in a recirculating system; b) 3 fish/tank (treatment 2); c) 5 fish/tank (treatment 3); and d) 7 fish/tank (treatment 4). The last three treatments were in closed systems. Tanks in closed system treatments used a small sponge filter to maintain water quality. Recirculating system treatment used a large central biofilter and reservoir to maintain water quality.

Experiment 1b. Differential growth of Cuban gar in closed and recirculating filtration systems, and variation in water quality – Cuban gars were randomly divided into 2 treatment groups: recirculating filtration and non-recirculating filtration. Each treatment consisted of 3 replicates (6 fish/replicate). Individuals were maintained in 170 L fiberglass tanks (1 replicate group per tank); the recirculating filtration treatment tanks were connected via stand pipe to a large recirculating system with a central biofilter (1,000 gallons) and the non-recirculating filtration treatment tanks utilized a small air-driven sponge filter. All replicates were fed commercial floating pellet feed (New Life Spectrum pellet) every other day at approximately 5-10% mean body weight of all 6 fish comprising the replicate. At the end of each week, water quality was measured (pH, NH_4, NO_2, NO_3) for each replicate, and non-recirculating tanks were backwashed for 10 minutes to help prevent excessive deterioration of water quality. Water temperature was maintained at approximately 27°C using heaters in each tank for the duration of the experiment. Experimental duration was 30 days; fish length and weight were measured at the beginning and end of the experiment to determine growth and growth rates. Descriptive statistics and ANOVA were used to analyze growth data (JMP/SAS Software).

Experiment 2a. Effects of salinity on growth of tropical gar – A random complete design was used with three salinity treatments: 0 (freshwater), 5, and 10 ppt. Each treatment was performed in triplicate. Fish were maintained in 1-m^3 tanks at a density of 25 fish per tank. Fish length and weight were measured every 15 days to determine growth over the course of the experiments. Additionally, we performed another trial using 0, 10, and 15 ppt of salinity (treatment 1, 2, and 3, respectively) with the same conditions.

Experiment 2b. Effects of salinity on growth of Cuban gar – Cuban gars were randomly divided into 2 salinity treatments: 0 ppt (freshwater) and 10 ppt. Each treatment consisted of 2 replicates (9 fish/replicate). Individuals were maintained in 132 L plastic injection-molded tanks (1 replicate group per tank). Each tank contained an internal underwater filter to maintain water quality. Salinity was attained using Instant Ocean commercial sea salt mix and measured weekly using a hydrometer. All replicates were fed commercial floating pellet feed (New Life Spectrum pellet) every other day at approximately 5-10% mean body weight of all 9 fish comprising the replicate. At the end of each week, water quality was measured (pH, NH_4, NO_2, NO_3) for each replicate. Water temperature was maintained at approximately

27°C using heaters in each tank for the duration of the experiment. Experimental duration was 30 days; fish length and weight were measured at the beginning and end of the experiment to determine growth and growth rates. Descriptive statistics and ANOVA were used to analyze growth data (JMP/SAS Software).

Experiment 3a. Fishmeal replacement in tropical gar feeds – A complete randomized design was used with five treatments in which fishmeal was substituted at different rates (0, 25, 50, 75 and 100% substitution). The experiment was started using fish that averaged 14.4 g in weight and 15.8 cm in length. Every treatment had three replicates. The gar were placed in a recirculation system (every tank stocked with 10 fish). Fish length and weight was measured every 15 days to determine growth over the course of the experiment. Every diet had a final content of 40% animal protein and 7% fat. The software Nutrition 5.0™ was used to estimate the ingredients needed to accomplish the target composition. Diets were made according to Álvarez et al. (2001).

Experiment 3b. Fishmeal replacement in Cuban gar feeds – Cuban gars were randomly sorted into 3 treatment groups with 2 replicates per group (6 fish per replicate). Individuals were maintained in 170 L fiberglass tanks (1 replicate group per tank) which were connected to a closed recirculating filtration system with a central biofilter. Each treatment group was given a different fishmeal substitution diet (0, 50, and 100% substitution) manufactured by colleagues at UJAT. Cuban gars were trained onto a commercial pelletized feed (New Life Spectrum pellets) for 2 months preceding experiment 3b in order to encourage consumption of experimental feed. Each replicate was fed once daily at approximately 5-10% mean body weight of all 6 fish comprising the replicate. Excess feed was removed after 30 minutes. Water temperature was maintained at approximately 27 °C using heaters in each tank for the duration of the experiment (30 days). Length and weight were measured at beginning and end of experiment to determine growth and growth rates. Descriptive statistics and ANOVA were used to analyze growth data.

Feeding – Fish for experiments 1 and 2 were fed *ad libitum* with trout feed (Pedregal®). This diet has 45% protein and 32% fat. Fish were fed 2 times a day (9:00 and 15:00 hours). For experiment 3a, fish were fed 3 times a day (9:00, 12:00, and 15:00 hours) with the targeted diet. Excess feed was removed after 30 minutes of feeding, the systems were cleaned by siphoning daily, and all filters were washed using tap water.

Water Quality – In all experiments, water quality measurements (ammonia, nitrite, and nitrate) were taken weekly, and pH and temperature daily. Water temperature was not controlled in the systems, but temperatures were recorded throughout the experiment to allow for comparison of the two culture systems. Nitrite, nitrate, and ammonium were measured using a spectrophotometer (Hanna®), pH with a Hanna® pH-meter, and temperature with an electronic thermometer (YSI®).

Growth performance – Length and weight was measured on each fish during experimental days 0, 15, and 30. Survival was calculated based on number of fish obtained at the end of the experiment.

Statistical Analysis – ANOVA tests were used to determine statistically significant differences in growth indicators and water quality parameters between treatments. The statistical analysis was performed using the STATGRAPHICS® Centurión package, and graphs were made using Sigma Plot®.

RESULTS

Experiment 1a – Differential growth of tropical gars in closed versus recirculating filtration systems. This experiment was conducted using tropical gar with an average weight and length 88.7-99.2 g and 26.5-27.5 cm. After 30 days, no significant differences were observed between treatments for mean

weight or length (ANOVA; P>0.05). The lowest growth was observed in treatment 4, with 83.1 ± 26.4 g and 27.2 ± 2.4 cm, and the highest growth in treatment 1 (control) with 104.0 ± 8.3 g in weight and 28.7 ± 0.5 cm in length (Figure 1). Temperature ranged between 26.1 and 28.0 °C; pH between 8.2 and 8.8 IU; ammonia between 0.1 and 0.9 mg/L; nitrate between 9.7 and 86.6 mg/L; and nitrite between 0.1 and 1.4 mg/L (Table 1). Survival was 100% for treatments 1 and 2; 66% for treatment 3, and 52% for treatment 4.

Table 1. *Average values (± SD) for water quality indicators.*

Treatment	Temperature (°C)	pH (IU)	Ammonia (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)
1	27.97 (± 0.65)	8.79 (± 4.27)	0.26 (±0.21)	12.82 (± 5.71)	0.57 (± 0.62)
2	26.18 (± 0.99)	8.21 (± 0.30)	0.43 (± 0.66)	66.01 (± 59.18)	0.80 (± 0.59)
3	26.16 (±1.01)	8.26 (±0.32)	0.85 (± 1.54)	86.61 (± 68.16)	1.37 (± 1.79)
4	26.13 (± 1.00)	8.20 (± 0.30)	0.87 (± 1.44)	84.75 (± 67.02)	0.85 (± 0.54)

Experiment 1b – Differential growth of Cuban gars in closed versus recirculating filtration systems. This experiment was conducted using Cuban gars with an initial average weight and length of 73.9 g and 26.4 cm, and ending with a final mean weight and length of 84.3 g and 26.8 cm, respectively. After 30 days, no significant differences were observed between treatments for mean weight or length (ANOVA, P>0.05; Figure 5). Water chemistry parameters did not vary significantly for the duration of the experiment in either treatment. Survival was 100% for all treatments.

Experiment 2a – Effects of salinity on growth of tropical gar. Fish used in this experiment had an initial weight of 142.6 g (±1.7), 135.8 g (±4.3) and 138.2 g (±1.6) for 0, 5, and 10 ppt, respectively; and 30.6 cm (±0.1), 30.17 cm (± 0.2) and 30.1 (±0.1) cm for initial length. After 30 days, ANOVA indicated no statistically significant differences in weight or length among treatments (P>0.05). Fish achieved average weight of 165.0 g (±9.5) for 0 ppt, 150.1 g (±8.4) for 5 ppt, and 145.0 g (±16.3) for 10 ppt of salinity (Figure 2). The results in length were 32.1 cm (±0.3), 31.3 cm (±0.5), and 31.3 cm (±0.9) for 0, 5, and 10 ppt, respectively.

Water quality parameters remained relatively stable (Table 2); but a significant rise in ammonia, nitrate, and nitrite was observed for treatment 3 (10 ppt). Survival for this experiment was 100% for treatment 3, 98.7% for treatment 2, and 93.3% for treatment 1.

Table 2*. Average values (± SD) for water quality indicators.*

Treatment	Temperature (°C)	pH (IU)	Ammonia (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)
1	27.59 (±0.75)	7.83 (±0.55)	2.06 (±1.56)	10.30 (±15.41)	0.63 (±0.72)
2	27.65 (±0.61)	7.70 (±0.29)	1.53 (±1.85)	16.50 (±17.63)	1.06 (±1.37)
3	27.56 (±0.63)	7.46 (±0.34)	2.59 (±2.18)	35.02 (±51.19)	1.70 (±0.62)

For the second trial, there were also no statistically significant differences among treatments for length or weight gain. Fish reached an average of 189. g (±18.7) in 0 ppt, 166.0 g (±20.5) in 10 ppt, and 159. g (±9.) in 15 ppt of salinity. The average final length results were 33.1 cm (±0.7), 31.9 cm (±0.7), and 31.7 cm (±0.3) for 0, 10, and 15 ppt, respectively (Figure 3).

Water quality parameters again remained relatively stable in this trial (Table 3); but a significant rise in ammonia, nitrate, and nitrite was observed for treatment 3 (15 ppt). Survival for this experiment was 100% for treatments 2 and 3, and 97.3% for treatment 1.

Table 3. *Average values (± SD) for water quality indicators.*

Treatment	Temperature (°C)	pH (IU)	Ammonia (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)
1	27.63 (±0.57)	8.30 (±0.20)	2.58 (±0.72)	0.81 (±1.34)	0.53 (±0.59)
2	27.81 (±0.60)	7.55 (±0.34)	1.12 (±0.38)	0.50 (±1.86)	0.14 (±0.65)
3	27.73 (±0.62)	7.33 (±0.47)	5.08 (±5.67)	9.15 (±10.99)	0.73 (±0.62)

Experiment 2b – Effects of salinity on growth of Cuban gar. Fish used in this experiment had an initial mean weight of 84.6 g and 27.4 cm for initial mean length. Final mean weight and length was 91.9 g and 27.8 cm, respectively. After 30 days, ANOVA indicated no statistically significant differences in weight or length among treatments ($P>0.05$; Figure 6). Water quality parameters did not vary significantly among replicates or treatments for the duration of the experiment, and survival was 100% overall.

Experiment 3a. – Fishmeal replacement in tropical gar feeds. After 105 days, no significant differences were found for weight or length among gar grown under each experimental diet (ANOVA $P>0.05$; Figure 4). Growth indicators are shown in Table 4. A significant increase in weight (262.2-323.9% gain) and length (45.8-54.16% gain) was obtained in this experiment. Daily growth varied between 0.40 and 0.48 g. Food Conversion Rate (FCR) was very similar in all treatments ranging from 1.18 to 1.30. The highest FCR was observed for the fish fed with no fishmeal substitution and the lowest for the fish with 50% substitution. Table 5 shows growth indicators, FCRs, and final biomass obtained.

Survival was very high in all treatments. No significant differences were found between treatments (Chi square, $P > 0.05$). In diets with 25 and 75% substitution, we obtained 100% survival; 97% for diets with 50 and 100% substitution, and 90% for the control diet. Water quality was good along the experiment. Water temperature averaged 28.4°C. Dissolved oxygen remained relatively high (6.1±0.1 mg/l) and pH was slightly basic (7.6).

Table 4. *Average Weight and length (±SD) and growth indicators after 105 days of experimentation.*

Variable	***Treatment***				
	Control (0% substitution)	***Diet 1 (25% substitution)***	***Diet 2 (50% substitution)***	***Diet 3 (75% substitution)***	***Diet 4 (100% substitution)***
Initial Length (cm)	15.8±7.4	15.9±7.3	15.7±7.6	15.9±7.7	15.7±7.1
Final Length (cm)	23.5±20.2	23.2±17.0	24.1±17.4	24.0±18.4	24.1±16.1
Initial Weight (g)	14.4±1.83	14.5±2.0	14.2±2.1	14.1±2.4	14.0±2.8
Final Weight (g)	56.1±13.5	52.4±12.1	58.9±13.0	56.3±14.5	59.3±13.5
AG (cm)	7.75±0.49	7.28±0.22	8.52±0.21	8.17±0.65	8.41±0.41
AGR (cm/d^{-1})	0.08±0.01	0.08±0.00	0.09±0.00	0.09±0.01	0.09±0.00
AG (g)	41.68±3.09	37.9±1.81	44.78±1.31	42.21±3.41	45.31±3.42
AGR (g/d^{-1})	0.44±0.03	0.40±0.02	0.47±0.01	0.44±0.04	0.48±0.04
RG Length (%)	49.15±2.89	45.80±2.32	54.16±1.48	51.49±4.61	53.53±2.8
RGR Length ($\%/d^{-1}$)	0.52±0.03	0.48±0.02	0.57±0.02	0.54±0.05	0.56±0.03
RG Weigh (%)	288.86±17.32	262.23±21.48	315.61±15.71	300.26±23.52	323.95±23.23
RGR Weight ($\%/d^{-1}$)	3.04±0.18	3.76±0.23	3.32±0.17	3.16±0.25	3.41±0.24

AG: Absolute Growth; AGR: Absolute Growth Rate; RG Relative Growth; RGR Relative Growth Rate.

Table 5. *Average values (±SD) of growth indicators, FCR and Biomass.*

Variable	***Treatment***				
	Control (0% substitution)	***Diet 1 (25% substitution)***	***Diet 2 (50% substitution)***	***Diet 3 (75% substitution)***	***Diet 4 (100% substitution)***
SGR ($\%/d^{-1}$)	1.43±0.0	1.35±0.1	1.50±0.0	1.46±0.1	1.52±0.1
FCR	1.30±0.1	1.30±0.1	1.18±0.1	1.21±0.1	1.27±0.1
CF	0.43±0.0	0.42±0.0	0.41±0.0	0.40±0.0	0.42±0.0
FB (g)	1,082±27.5	1,137±18.1	1,283±22.2	1,266±34.1	1,299±48.8

SGR: Specific Growth Rate; FCR: Food Conversion Rate; CF: Condition Factor; FB: Final Biomass.

Experiment 3b. – Fishmeal replacement in Cuban gar feeds. After 30 days, significant increase in weight occurred over all treatments, however, no significant differences were found for weight or length among Cuban gars grown under each experimental diet (ANOVA, $P>0.05$; Figure 7). Initial mean weight was 61.9 g and length 25.5 cm, with final mean weight 73.9 g and length 26.5 cm. Survival was 100% for the duration of the experiment, and water quality parameters did not vary significantly among treatments.

DISCUSSION

In this study, closed or recirculating filtration systems or different salinity conditions did not affect growth indicators and survival for tropical and Cuban gars. In the recirculating system growth was slightly better for tropical gars. This could be due to better water quality conditions, since ammonia, nitrate, and nitrite were lower than in the tanks with aquarium filters. Another factor that differed in experiment 1a was the temperature (by 1.5 degrees), which could have enhanced growth. This was reflected in food intake since fish had better appetites in the recirculating system and showed more swimming activity. Survival was better in the recirculating system and tanks with the lowest density (3 gar/tank); but this difference was small. Since water quality conditions deteriorated as the trial advanced, it is possible that mortality in higher densities and aquarium filtration would be worse after a longer

period of time. Gar can tolerate high levels of nitrogen in the water, but at a certain point, nitrogen levels could damage gills and kidneys (Boudreaux et al., 2007). Several authors have demonstrated that fish have better health and growth indicators under recirculating conditions; the freshwater eel is an example of having survival rates up to 91% (Suzukia et al., 2003). In another experiment, De la Mora et al. (2003) obtained 99% survival for tilapia (*Oreochromis niloticus)* and rainbow trout (*Oncorhynchus mykiss)* in recirculating systems with different biomass (13 and 98 kg/tank). In these experiments, the fish were kept in systems for 120 days, water quality was always optimal, and growth estimates were acceptable. Jiménez-Martínez et al. (2009) evaluated different densities of *Petenia splendida* and *Cichlasoma urophthalmus* larvae in recirculating systems for 45 days. The lowest densities (0.5 and 1 larvae/L) presented the highest growth for both species. The disadvantage of lower densities was that a lower amount of fish was obtained per tank.

The confinement of fish under brackish water conditions (5-15 ppt) did not affect weight, length, or survival of the tropical or Cuban gar juveniles; but in experiment 2a, the fish kept under freshwater conditions showed a slight increase in weight. This was valid for both trials performed on tropical gars and the highest salinities evaluated (10 and 15 ppt). Despite the short experimental period, tropical gars in freshwater grew 15-22 g more than the other fish. This is the first time in which tropical and Cuban gars have been evaluated under brackish water conditions. While anecdotal information from anglers indicates that tropical gars do not venture into brackish water, they have been seen in coastal lagoons with these conditions. A possible explanation for this is that gars are frequently parasitized by freshwater sea lice (*Argulus spp.*) and may enter brackish water to eliminate them from the skin. In several freshwater species, confinement in brackish water does not affect growth. Tilapia is a good example of this, since they maintain growth even at sea water conditions (Mena-Herrera et al., 2002). In some cases, salinity acting together with temperature may cause lesions to the fish; this has been reported in tilapia juveniles (Linkongwe et al., 1996). We did not observe lesions in the body or gills of the gar in our study, but a prolonged confinement may cause such problems. We have used salt in the water as prophylactic treatments to eliminate sea lice in gars; the results obtained in our experiments indicate that even long treatments can be used for this species causing no harm to the fish.

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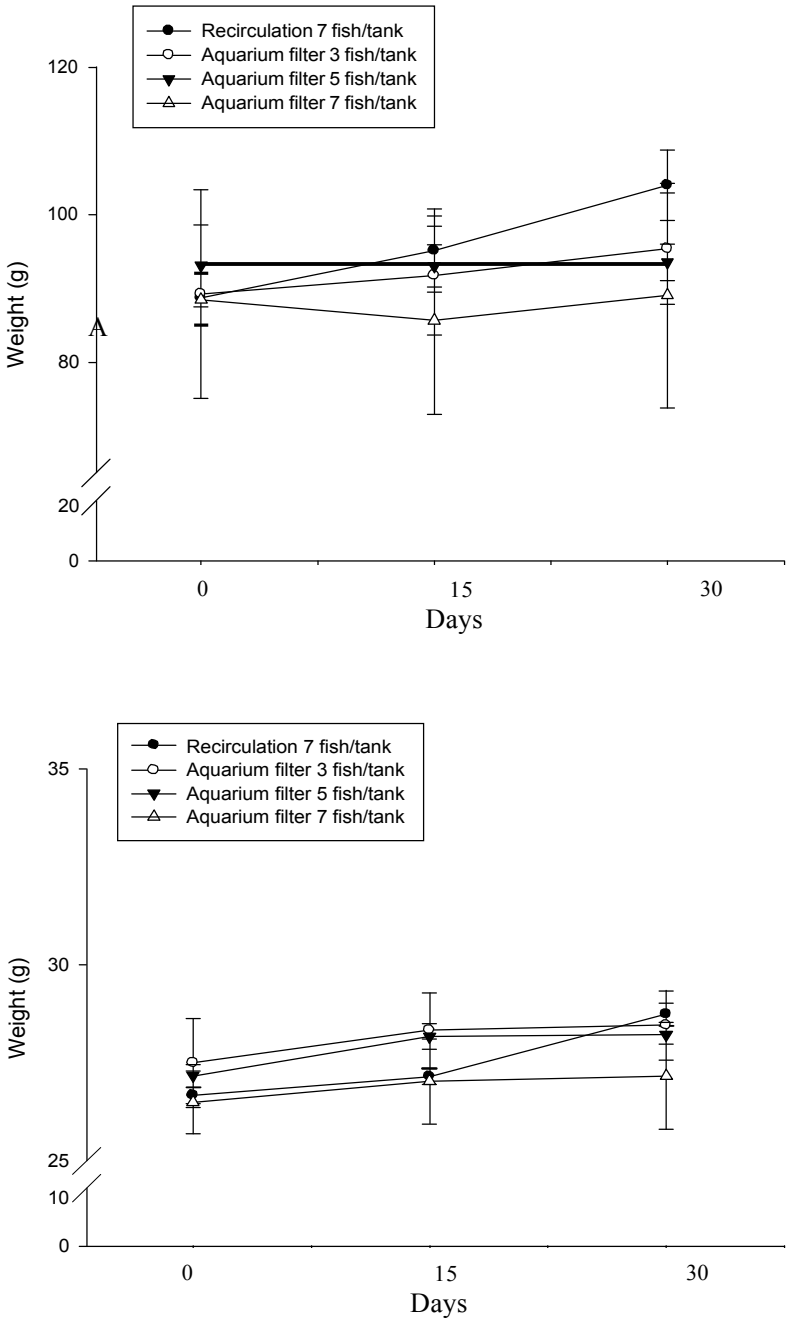

Figure 1. *Average weight (a) and total length of tropical gar juveniles confined in closed and recirculating systems (experiment 1).*

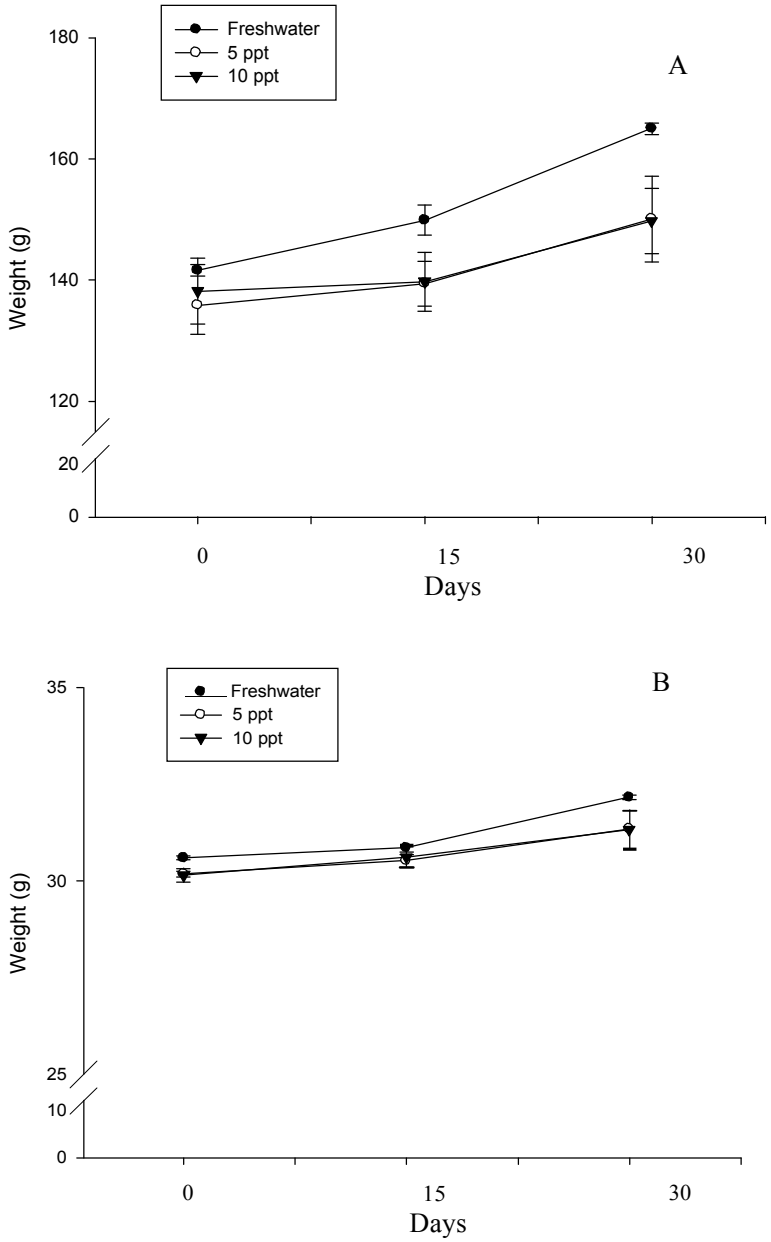

Figure 2. *Average weight (a) and total length of tropical gar juveniles kept under different salinity conditions (experiment 2; trial 1).*

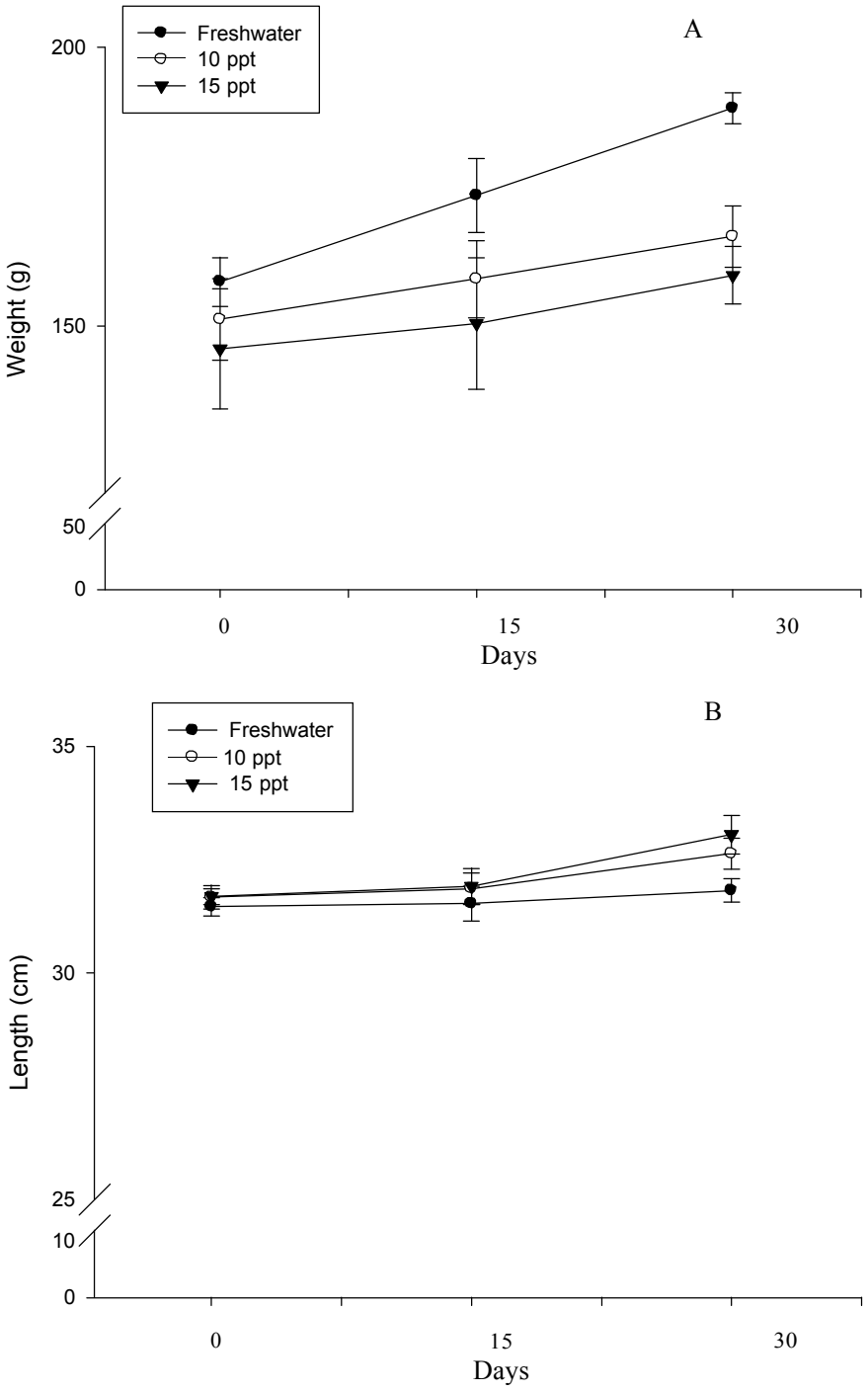

Figure 3. *Average weight (a) and total length of tropical gar juveniles kept under different salinity conditions (experiment 2; trial 2).*

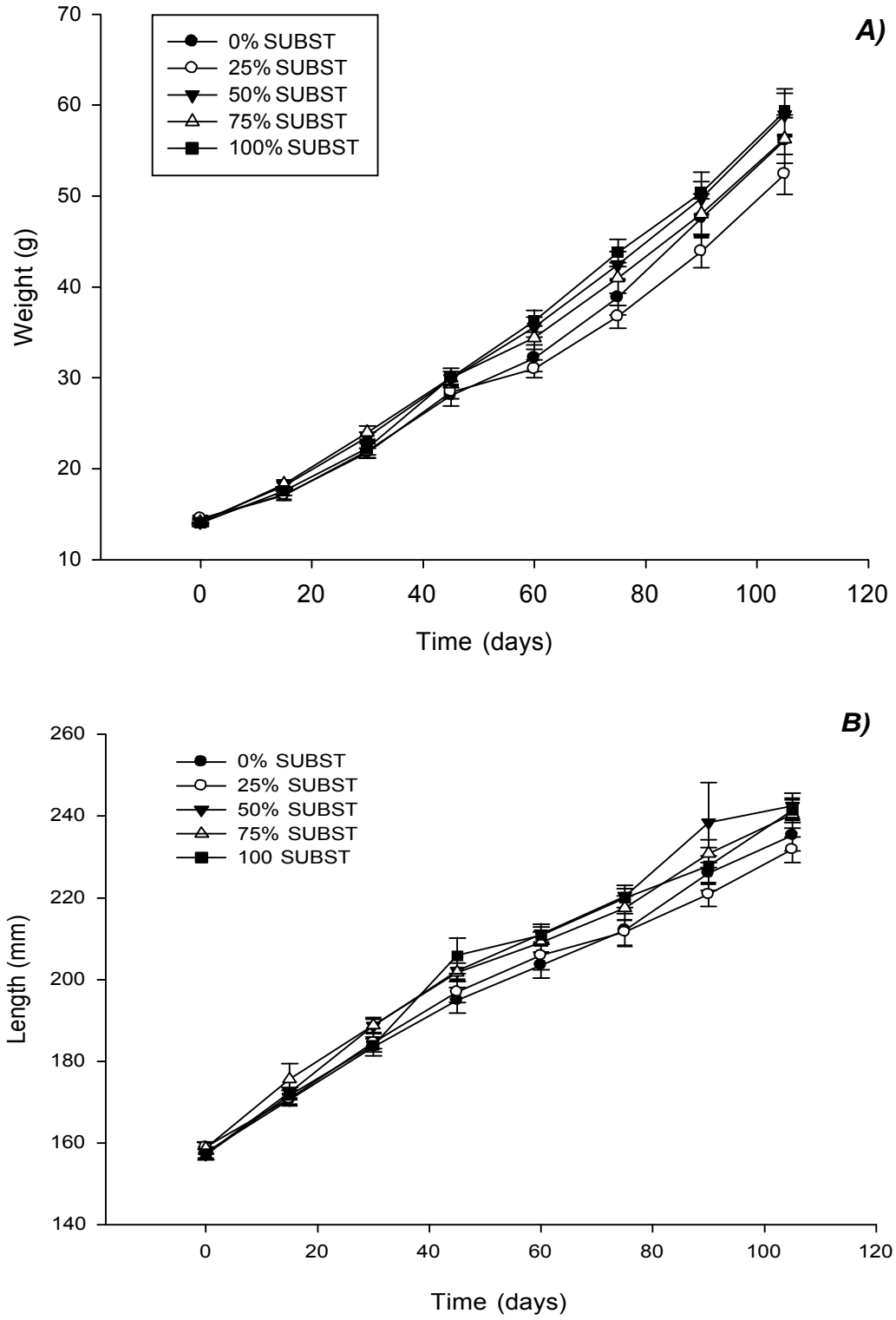

Figure 4. *Average values for (±SD) weight (A) and length (B) in tropical gar juveniles fed with different rates of fish meal substitution (0, 25, 50, 75 and 100%) with meat meal.*

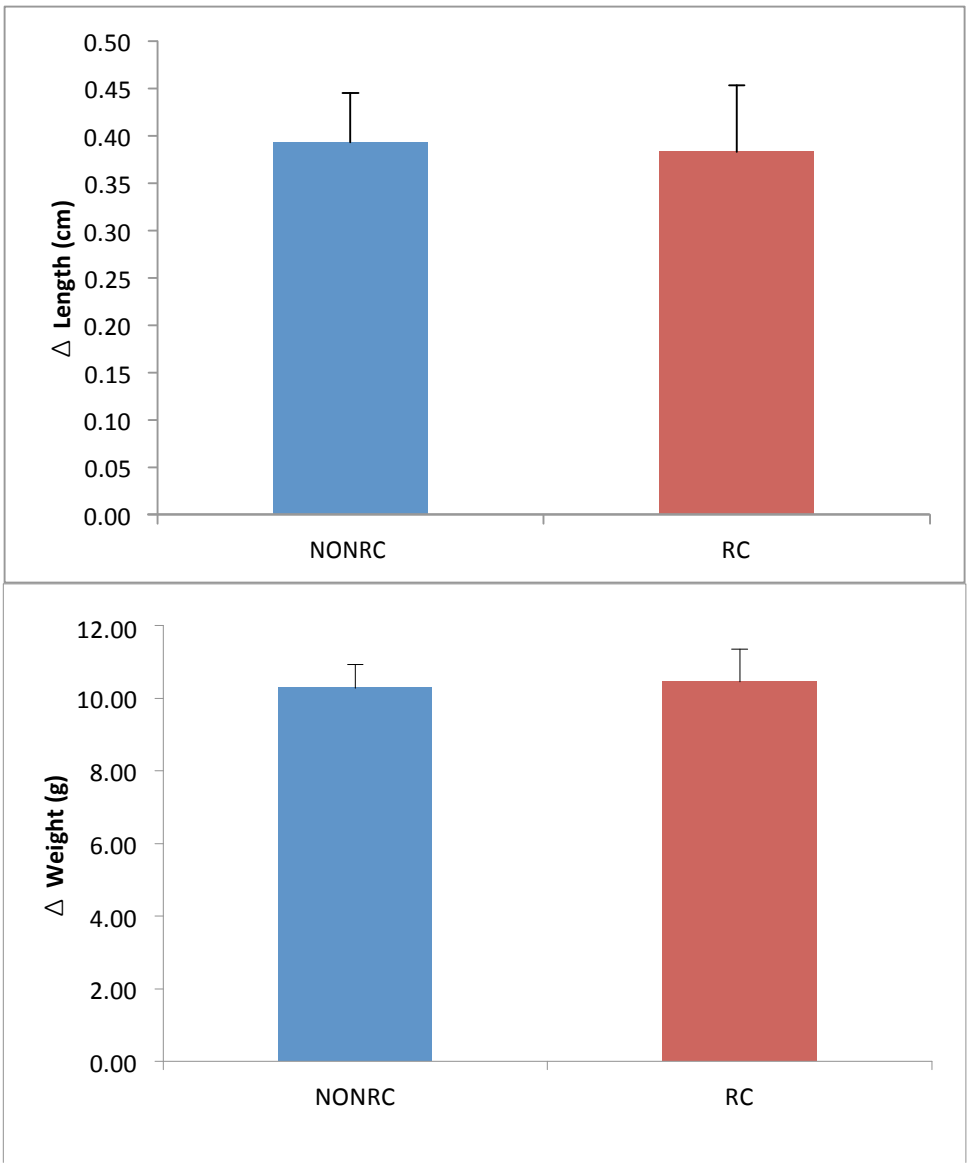

Figure 5. *Increase in length and weight of Cuban gars in experiment 1b. NONRC = Non-recirculating filtration, RC = recirculating filtration. ANOVA indicated no significant differences in growth between treatments; bars indicate one standard error.*

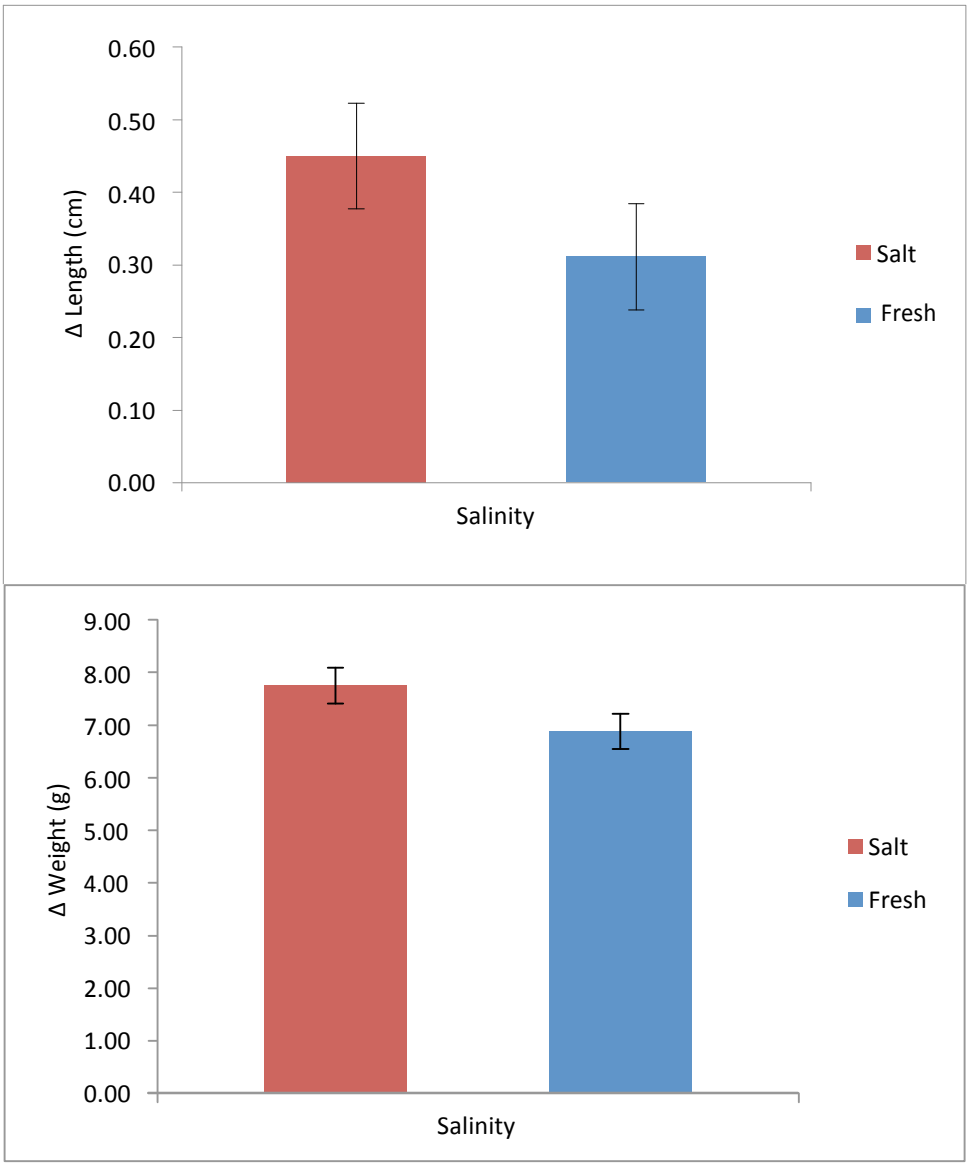

Figure 6. *Increase in length and weight of Cuban gars in experiment 1b. Salt = 10 ppt, Fresh = 0 ppt (freshwater). ANOVA indicated no significant differences in growth between treatments; bars indicate one standard error.*

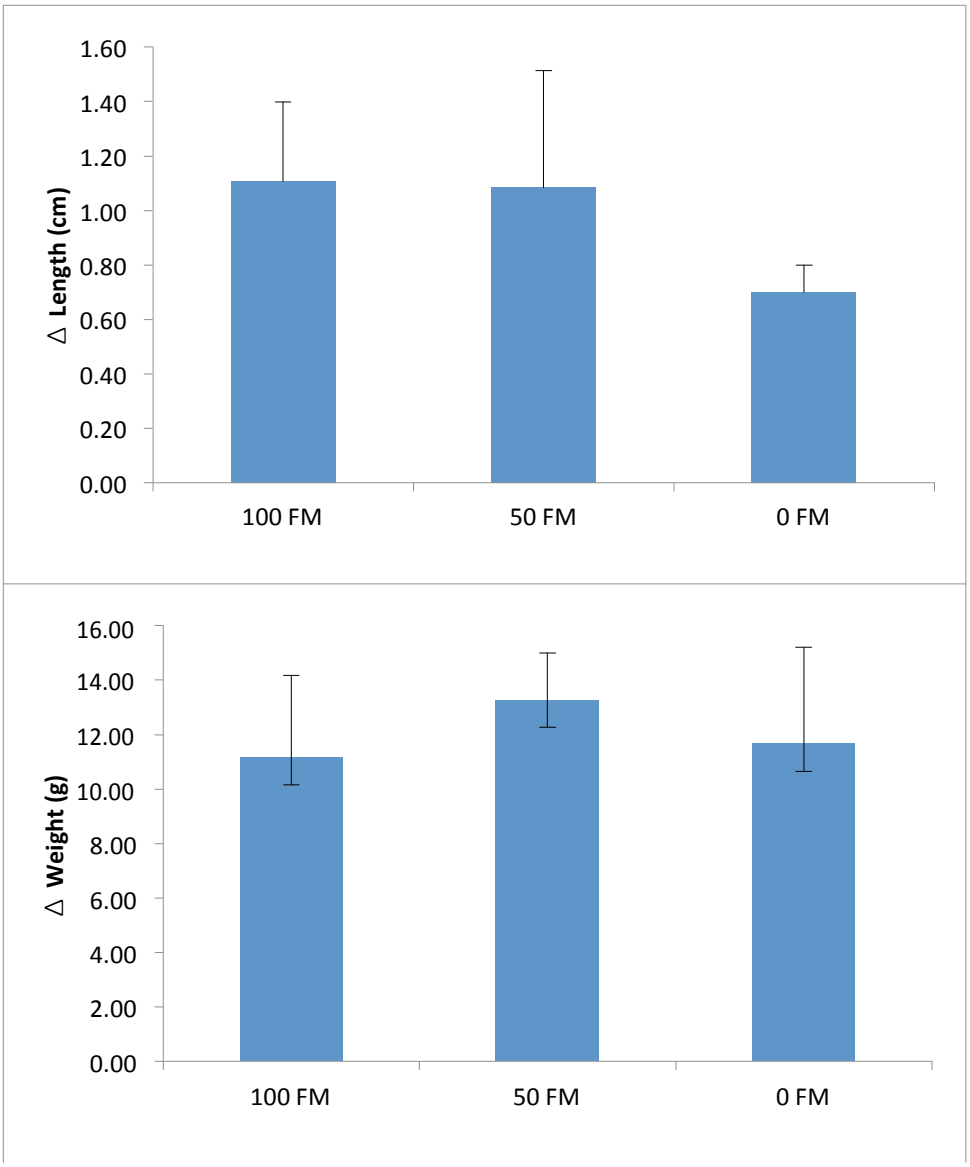

Figure 7. *Increase in length and weight of Cuban gars in experiment 3b. 100 FM = 100% fishmeal, 50 FM = 50% fishmeal, 50% beef by-products, 0 FM = 0% fishmeal, 100% beef by-products. ANOVA indicated no significant differences in growth between treatments; bars indicate one standard error.*