FEEDING FREQUENCY AFFECTS GROWTH OF JUVENILE COBIA *Rachycentron canadum* CULTURED IN NEAR-SHORE CAGES

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ABSTRACT

Growth performance of juvenile cobia *Rachycentron canadum* (15.7 ± 0.4 g; mean ± SD) reared in 1 m^3 near-shore cages, 24.0 ± 2.1 ºC, fed a Brazillian commercial feed (45% crude protein and 16% lipid) until apparent satiation, in a single feeding (F1), two (F2) or three (F3) feedings per day, for 30 days was assessed. The initial stocking density was 0.6 kg m^{-3}. Production performance of juvenile cobia was significantly affected by feeding frequency. Groups fed two and three equal feedings per day presented greater and more efficient growth than F1 groups. There was no difference between F2 and F3 treatments for weight gain (15.6 ± 1.5 g and 16.3 ± 2.0 g, respectively), specific growth rate (SGR: 2.3 ± 0.3% and 2.5 ± 0.4% of body weight per day, respectively) and feed conversion ratio (FCR: 2.3 ± 0.2 and 2.5 ± 0.3, respectively). However, these parameters were reduced in F1 treatment (weight gain of 8.4 ± 1.1 g; SGR = 1.4 ± 0.2% and FCR = 3.2 ± 0.6) ($P<0.05$). The coefficient of variation was inversely proportional to the increase in feeding frequency. There was no significant difference in terms of survival rates, being superior to 90% in all treatments. We suggest that growth performance of juvenile cobia cultured in near-shore cages can be optimized at a feeding frequency of two times a day, facilitating husbandry procedures and minimizing costs related to labor and vessel utilization.

Keywords: feed management; growth performance; marine fish

EFEITO DA FREQUÊNCIA ALIMENTAR NO CRESCIMENTO DE JUVENIS DE BIJUPIRÁ *Rachycentron canadum* CRIADOS EM TANQUES TIPO "NEAR-SHORE"

RESUMO

O desempenho de juvenis de bijupirá *Rachycentron canadum* (15,7 ± 0,4 g; média ± DP) criados em tanques-rede de 1 m^3, em uma baía protegida, 24,0 ± 2,1 °C, alimentados com uma ração comercial brasileira (45% de proteína bruta e 16% de gordura) até saciedade aparente, alimentados em uma (F1), duas (F2) e três (F3) refeições por dia, durante 30 dias, foi avaliado. A densidade de estocagem inicial foi de 0,6 kg m^{-3}. O desempenho de produção de juvenis de bijupirá foi afetado significativamente pela frequência alimentar. Grupos alimentados duas e três vezes ao dia apresentaram um crescimento maior e mais eficiente do que os grupos F1. Não houve diferença entre os tratamentos F2 e F3 para o ganho em peso (15,6 ± 1,5 g e 16,3 ± 2,0 g, respectivamente), taxa de crescimento específica (TCE: 2,3 ± 0,3% e 2,5 ± 0,4% do peso corporal diário, respectivamente) e conversão alimentar aparente (CAA: 2,3 ± 0,2 e 2,5 ± 0,3, respectivamente). No entanto, os tratamentos F2 e F3 promoveram melhores resultados comparados ao tratamento F1 (ganho em peso: 8,4 ± 1,1 g; TCE = 1,4 ± 0,2%; CAA = 3,2 ± 0,6) ($p<0,05$). O coeficiente de variação foi inversamente proporcional ao aumento da frequência alimentar. Não houve diferença significativa para taxa de sobrevivência, sendo superior a 90% em todos os tratamentos. Este trabalho sugere que o desempenho do crescimento de juvenis de bijupirá criados em condições do presente estudo pode ser otimizado quando alimentados duas vezes ao dia, facilitando os procedimentos de criação e minimizando os custos relacionados com mão-de-obra e embarcação.

Palavras chave: manejo alimentar; desempenho zootécnico; peixe marinho

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INTRODUCTION

Cobia, *Rachycentron canadum*, is a pelagic finfish distributed in tropical and subtropical oceans, except in the central and eastern Pacific (SHAFFER and NAKAMURA, 1989). A great amount of research effort has been dedicated to this species and most of them reported good perspective for its commercial culture, especially in cage culture (BENETTI *et al*., 2010), attributable to its excellent aquaculture features including natural spawning in captivity (FRANKS *et al*., 2001; ARNOLD *et al*., 2002), good feed conversion ratio, rapidly gaining weight up to 6 kg at the first year (SU *et al*., 2000; CHOU *et al*., 2001; SAMPAIO *et al*., 2011) and great flesh quality (SU *et al*., 2000), supplying the growing sashimi market (LIAO *et al*., 2004).

It's known that aquafeeds are usually the most costly part of a finfish production. In cobia cage culture, the food also constitutes a high percentage of the growout expenses (LIAO *et al*., 2004). Feeding regimes are among the different aquaculture management practices that can maximize feeding efficiency, and consequently growth (TRUSHENSKI *et al*., 2012a). The proper use of feeding regimes (feeding rate and frequency) is an efficient way to reduce costs, improving fish growth (GODDARD, 1996; LAWRENCE *et al*., 2012), intensifying production systems and homogenizing fish size (CHIU *et al*., 1987; BOUJARD and LEATHERLAND, 1992; AZZAYDI *et al*., 1998). Therefore, these practices are essential to minimize food waste, improve water quality in culture system and achieve uniformity in size classes (DWYER *et al*., 2002; TUCKER *et al*., 2006), and in some cases they can also interfere in the use of nutrients in the diets (MIHELAKAKIS *et al*., 2002).

If feeding rate and frequency are not adequate, they can result in serious and undesirable consequences. For instance, if feeding regimes are underestimated it can reduce growth and increase cannibalism's rate (FOLKVORD and OTTERA, 1993). On the other hand, if this balance is shifted to overestimation, it will result in food waste, deterioration of water quality and reduced production (BOOTH *et al*., 2008).

The optimum feeding regime depends on the fish species, age, size, stocking density, environmental factors, food quality and culture system (GIBERSON and LITVAK, 2003; CHO *et al*., 2003). DWYER *et al*. (2002) studied the effect of feeding rate on yellowtail flounder, *Limanda ferruginea* and reported that there was an increase in growth performance with increasing feeding frequency. The same pattern was observed in other species (GIBERSON and LITVAK, 2003; SILVA *et al*., 2007; BOOTH *et al*., 2008; TRUSHENSK *et al*., 2012a). However, the decrease in the feeding frequency favored the growth of channel catfish, *Ictalurus punctatus* (ANDREWS and PAGE, 1975), grouper *Epinephelus tauvina* (CHUA and TENG, 1978) and korean rockfish, *Sebastes schlegeli* (LEE *et al*., 2000).

Despite the importance of this study and the large amount of research on feeding frequency available in marine fish literature (ANDREWS and PAGE, 1975; BUURMA and DIANA, 1994; SALAMA, 2008; BOOTH *et al*., 2008; LEE and PHAM, 2010; TRUSHENSKI *et al*., 2012b), there is little information on this topic for cobia. In this sense, this study evaluated the influence of feeding frequency on production performance of juvenile cobia cultured in near-shore cages.

MATERIAL AND METHODS

Experimental fish

Juveniles of cobia *Rachycentron canadum* were acquired from the Hatchery Redemar LTDA, located in the municipality of Ilha Bela, São Paulo State, Brazil, and transported to the Ilha Grande Bay, Jaconema Beach, Angra dos Reis, Rio de Janeiro State, Brazil. A thousand and five hundred fish were acclimated in three near-shore cages of 12 m^3 (3x2x2 m), at a stocking density of 0.6 kg m^{-3} for 15 days.

During the acclimation period, fish were fed a Brazillian commercial diet (45% crude protein and 16% lipid).

Experimental design

After the acclimation period, 360 juveniles with weight of 15.8 ± 0.4 g (mean ± SD) and total length of 14.3 ± 0.0 cm were randomly re-stocked into nine floating cages with a mesh size of 3 mm and a usable volume of 1m^3 (1.4x1x1 m), achieving a stocking density of 0.6 kg m^{-3}. The experimental cages were fixed into a floating platform anchored 10 m deep and 50 m away from the shore.

Fish were fed a Brazillian commercial diet (45% crude protein and 16% lipid), until apparent satiation, in a single feeding (F1 – 08:00 h), two (F2 – 08:00 and 17:00 h) or three (F3 – 08:00, 13:00 and 17:00 h) feedings per day. The experiment was conducted in triplicate.

Biometrics were realized at the beginning of the experiment, and every 15 days upon completion of 30 days, totaling three biometrics. During handling procedures, 40 fish per tank were transferred into a 110 L plastic tank and anesthetized with 20 ppm of eugenol (Lysanda, Brazil) during 3-5 minutes in order to avoid stress that may cause undesirable consequences such as mortality. Graduated ictiometer (cm) was used to measure total length and analytical balance (0.01 g) to estimate weight.

Water quality parameters (pH, salinity, dissolved oxygen and temperature were measured once daily with Hanna HI9828 (Hanna Instruments Brazil, São Paulo, Brazil).

Production performance parameters including survival, weight gain, feed conversion ratio, specific growth rate, condition factor, daily feed consumption and coefficient of variation were calculated as follow:

Weight Gain (g) = (final weight – initial weight);

Feed Conversion Ratio (FCR) = (total amount of feed fed during a period) / (total wet weight gained by fish);

Specific Growth Rate (SGR, % of body weight day^{-1}) = [ln (final weight) x ln (initial weight)]/ (number of days) x 100;

Condition Factor (CF) = [(weight)/$(length)^3$] x 100;

Daily Feed Consumption (DFC, %) = Daily Feed Consumption / (final weight – initial weight) x 100;

Coefficient of variation (CV, %) = Standard deviation (40 organisms per sample)/average individual weight of each organism per sample x 100.

Statistical analysis

As no difference was detected between triplicates in each treatment, data were pooled for statistical analysis. All production performance data were analyzed by one-way analysis of variance (ANOVA) with Statistic 7.0. In the event of significant ANOVA findings, Tukey's HSD pairwise comparison tests were used to determine differences among means, and significance was determined based on alpha level of 0.05.

RESULTS

The water quality parameters were 24.0 ± 2.1 °C (mean ± SD), 6.0 ± 0.6 mg L^{-1} of dissolved oxygen, 31.0 salinity and pH of 7.8 ± 0.4.

Survival was not affected by treatments, with all treatments exhibiting higher survival rates (Table 1). Production performance of juvenile cobia was significantly affected by feeding frequency (Table 1, Figure 1). Fish fed at higher frequencies (F2 and F3 groups), presented significantly higher production performance in comparison to those fed a single feeding (F1).

Table 1. Production performance of juvenile cobia fed a Brazilian commercial feed until apparent satiation in a single feeding (1x; F1), two (2x; F2) or three (3x; F3) equal feedings per day, cultured in 1 m^3 near-shore cages. Values represent means ± SE. Values with the same letter in the same column are not significantly different (P<0.05).

Feeding Frequency (treatments)	Survival (%)	WG[a] (g)	SGR[b] (%BW day^{-1})	CV[d] (%)	CF[e] (%)	DFC[f] (%)	FCR[c]
1x (F1)	90 ± 3.53	8.4 ± 1.10b	1.4 ± 0.18b	30.6 ± 0.10c	0.52 ± 0.01c	1.08 ± 0.05b	3.2 ± 0.65b
2x (F2)	95 ± 5.00	15.6 ± 1.55a	2.3 ± 0.30a	22.0 ± 0.20b	0.57 ± 0.00a	1.21 ± 0.04ab	2.3 ± 0.18a
3x (F3)	95 ± 7.07	16.3 ± 2.05a	2.5 ± 0.40a	16.9 ± 0.80a	0.55 ± 0.00b	1.36 ± 0.05a	2.5 ± 0.31a

[a] WG: weight gain; [b] SGR: specific growth rate in percentage of body weight day^{-1}; [c] FCR: feed conversion ratio; [d] CV: coefficient of variation; [e] CF: condition factor; [f] DFC: daily food consumption

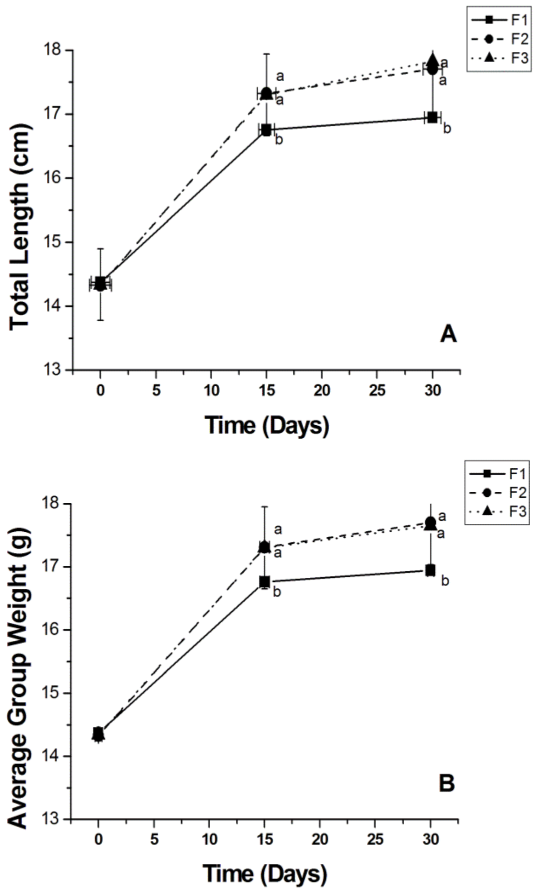

Figure 1. Total length (A) and average weight (B) (mean ± SE) of juvenile cobia *Rachycentron canadum* cultured in 1 m³ near-shore cages, fed a Brazillian commercial feed until apparent satiation in a single feeding (F1), two (F2) or three (F3) equal feedings per day, during 30 days culture. Different letters on the same day mean difference between treatments (P<0.05).

In terms of growth, there was no significant difference between F2 and F3 treatments in total length and weight, weight gain and SGR (Table 1). However, these parameters were reduced in F1 treatment.

The coefficient of variation (Table 1) was inversely proportional to increasing feeding frequencies, F1 and F3 treatments, and the condition factor was higher at the F2 group, followed by F3 and then F1 groups.

The FCR was significantly different among treatments, with F1 group exhibiting the highest value, and no significant difference was found between F2 and F3 groups (Table 1; Figure 2). The daily food consumption was lower in the F1 treatment compared to treatment F3. The F2 treatment presented no statistical difference among F1 and F3 treatments.

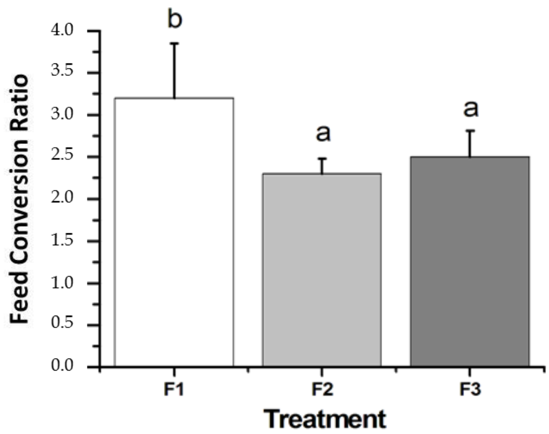

Figure 2. Feed conversion ratio (FCR) of juvenile cobia *Rachycentron canadum* cultured in 1 m³ near-shore cages, fed a Brazillian commercial feed until apparent satiation in a single feeding (F1), two (F2) or three (F3) equal feedings per day, during 30 days culture. Different letters mean difference between treatments (P<0.05).

DISCUSSION

The water physical and chemical parameters during the experimental period were within the optimal range for cobia culture (SAMPAIO *et al.*, 2010, 2011).

In some species, survival rate may be influenced by feeding frequency as a result of the cannibalistic behavior (CARLOS, 1988; GOLDAN *et al.*, 1997) associated with food availability (WANG *et al.*, 1998). Cannibalism is often observed in both cobia production phases, the larviculture and the first growout period (FAULK *et al.*, 2007).

The high variability in fish size in the culture tanks is frequently associated with cannibalism (GREAVES and TUENE, 2001), which is not desirable in aquaculture (SCHNAITTACHER *et al.*, 2005). In this sense, the coefficient of variation (CV) is an important parameter to evaluate size variation induced by the effect of feeding competition or hierarchy (AYDIN *et al.*, 2011). In this study, the CV of juvenile cobia was affected by different feeding frequencies, being inversely proportional to the increase in feeding frequency. In other words, increasing feeding frequency results in greater food availability, lower feeding competition and lower CV. Despite the difference in CV among treatments, survival was not affected, remaining above 90% in all treatments.

Concerning growth performance and utilization of food, there was an influence of feeding frequency on weight gain, SGR, CV, condition factor, DFC and FCR. In this study, feeding fish once a day resulted in reduced values of growth parameters, and also higher values of FCR and CV, when compared with two (F2) and three (F3) feedings per day. RUOHONEN *et al*. (1998) reported a higher SGR for rainbow trout, *Oncorhynchus mykiss* fed three times a day than fed twice a day. Conversely, BOOTH *et al*. (2008) found higher SGR in juveniles silver seabream, *Pargus auratus*, fed twice daily until apparent satiation in comparison to those fed four, six and eight times a day. The same results were observed by DWYER *et al*. (2002) for juvenile yellowtail flounder, *Limanda ferruginea*, and WEIRICH *et al*. (2006) for florida pompano, *Trachinotus carolinus*. Then, the way feeding frequency affects fish performance is species-specific and may be influenced by other variables such as age, temperature, pH and salinity of the culture water (GIBERSON and LITVAK, 2003)

According to WEIRICH *et al*. (2006), digestion efficiency may increase with increasing feeding frequency, since the ingested volume in each feeding event is inversely proportional to feeding frequency. However, fish growth related with the increase in feeding frequency is limited, when this increase no longer affects growth performance (LIU and LIAO, 1999; LEE *et al*., 2000). These studies corroborate with the present findings, in which juvenile cobia fed three times a day exhibited similar growth to those fed twice a day.

One common way to explain the influence of feeding frequency on fish growth is the amount of food fish can ingest, i.e., feed intake (XIE *et al*., 2011). Fish fed three times a day have greater opportunity to consume food than fish fed once a day. This may justify the lower growth and lower feed intake presented in F1 treatment in comparison to F3 treatment. However, F2 treatment demonstrated no difference in feed intake when compared to either treatments, F3 and F1, and it still exhibited similar growth to F3 treatment.

WEIRICH *et al*. (2006) reported that most carnivore fish have short digestive tract and rapid food transit. The nutrients in a single large meal might not be as effectively digested and absorbed during a short transit period as the nutrients in a smaller meal, because digestive efficiency is affected by the efficiency with which digestive enzymes contact food particles in the gut. Overfeeding may be more difficult to digest in a short period of time, resulting in poor growth (LAZO *et al*., 1998). On the other hand, when feeding frequency increases (shorter interval among feeding events), food passes through the digestive tract more quickly, resulting in an inefficient digestion (LIU and LIAO, 1999). In addition, several feedings during the day increase fish swimming activity, which can result in higher energy demand and lower growth rate (JOHANSEN and JOBLING, 1998). These assumptions support the present findings, which no significant difference was noticed in growth performance among fish fed twice or three times a day, with an interval between feeding events of nine and four to five hours for F2 and F3, respectively.

The condition factor was also affected by different feeding frequencies, and treatment F2 presented the highest value rate, followed by F3 and then F1. The condition factor is a quantitative measure of fish welfare, which is used to evaluate the variation of the expected weight over the fish length, as an indicative of differences in fat and nutritional status, adaptation to the environment, sexual maturity and life stages (LE CREN, 1951). TRUSHENSKI *et al*. (2012b) reported condition factor values for juvenile cobia similar to our study.

The FCR found in the present study (2.3-3.2) was quite high in comparison to those described in published literature on cobia growth. BENETTI *et al*. (2010) reported a FCR of 1.30 for juvenile cobia, while DENLINGER (2007) described a FCR varying from 1.01 to 1.45. This disparity may be associated with food quality, which directly affects the FCR. In Brazil, there is a lack of commercial feed for marine finfish, highlighting the importance of developing a more adequate feed for key cultured species including cobia.

CONCLUSION

According to the present findings, we suggest that the feeding frequency of twice (F2) feeding events per day would be more suitable for juvenile cobia cultured in near-shore cages. It is important to highlight that feeding frequency of twice per day may be more advantageous when compared to three feedings per day due to lower labor costs and reduced utilization of vessel, being more feasible for near-shore cultures.

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REFERENCES

ANDREWS, J.W. and PAGE, J.W. 1975 The effects of frequency of feeding on culture of catfish. *Transactions of the American Fisheries Society*, *104*(2): 317-321.

ARNOLD, C.R.; KAISER, J.B.; HOLT, G.J. 2002 Spawning of cobia (*Rachycentron canadum*) in captivity. *Journal of the World Aquaculture Society*, *33*(2): 205-208.

AYDIN, I.; KÜÇÜK, E.; ŞAHIN, T.; KOLOTOĞLU, L. 2011 The effect of feeding frequency and feeding rate on growth performance of juvenile black sea turbot (*Psetta maxima*, Linneaus, 1758). *Journal of Fisheries Sciences*, *5*(1): 35-42.

AZZAYDI, M.; MADRID, J.A.; ZAMORA, S.; SÁNCHEZ-VÁZQUEZ, F.J.; MARTÍNEZ, F.J. 1998 Effect of three feeding strategies (automatic, *ad libitum* demand-feeding and time-restricted demand-feeding) on feeding rhythms and growth in European sea bass (*Dicentrarchus labrax* L.). *Aquaculture*, *163*(3-4): 285–296.

BENETTI, D.D.; O'HANLON, B.; RIVERA, J.A.; WELCH, A.W.; MAXEY, C.; ORHUN, M.R. 2010 Growth rates of cobia (*Rachycentron canadum*) cultured in open ocean submerged cages in the Caribbean. *Aquaculture*, *302*(3-4): 195-201.

BOOTH, M.A.; TUCKER, B.J.; ALLAN, G.L.; FIELDER, D.S. 2008 Effect of feeding regime and fish size on weight gain, feed intake and gastric evacuation in juvenile Australia snapper *Pagrus auratus*. *Aquaculture*, *282*(1-4): 104-110.

BOUJARD, T. and LEATHERLAND, J.F. 1992 Circadian rhythms and feeding time in fishes. *Environmental Biology Fish*, *35*(2): 109–131.

BUURMA, B.J. and DIANA, J.S. 1994 Effects of feeding frequency and handling on growth and mortality of cultured walking catfish *Clarias fuscus*. *Journal of the World Aquaculture Society*, *25*(2): 175–182.

CARLOS, M.H. 1988 Growth and survival of bighead carp (*Aristichthys nobilis*) fry fed at different intake levels and feeding frequencies. *Aquaculture*, *68*(3): 267–276.

CHIU, Y.N.; SUMAGAYSAY, N.S.; SASTRILLO, M.A.S. 1987 Effect of feeding frequency and feeding rate on the growth and feed efficiency of milkfish *Chanos chanos* juveniles. *Asian Fisheries Science*, *1*(1): 27–31.

CHO, S.H.; LIM, Y.S.; LEE, J.H.; LEE, J.K.; PARK, S.; LEE, S.M. 2003 Effect of feeding rate and feeding frequency on survival, growth, and body composition of ayu post-larvae *Plecoglossus altivelis*. *Journal of the World Aquaculture Society*, *34*(1): 85–91.

CHOU, R.L.; SU, M.S.; CHEN, H.Y. 2001 Optimal dietary protein and lipid levels for juvenile cobia (*Rachycentron canadum*). *Aquaculture*, *193*(1-2): 81-89.

CHUA, T.E. and TENG, S.K. 1978 Effects of feeding frequency on the growth of young estuary grouper, *Epinephelus tauvina*, cultured in floating net-cages. *Aquaculture*, *14*(1): 31-47.

DENLINGER, B.L. 2007 *Testing aquaculture performance of juvenile cobia* ***Rachycentron canadum,*** *using diets containing different percentages of protein and fat*. Miami. 17p. (M.A. Thesis. University of Miami, Rosenstiel School of Marine and Atmospheric Science).

DWYER, K.S.; BROWN, J.A.; PARRISH, C.; LALL, S.P. 2002 Feeding frequency affects food consumption, feeding pattern and growth of juvenile yellowtail flounder (*Limanda ferruginea*). *Aquaculture*, *213*(1-4): 279-292.

FAULK, C.K.; KAISER, J.B.; HOLT, J.G. 2007 Growth and survival of larval and juvenile cobia *Rachycentron canadum* in a recirculating raceway system. *Aquaculture*, *270*(1-4): 149-157.

FOLKVORD, A. and OTTERA, H. 1993 Effects of initial size distribution, day length, and feeding frequency on growth, survival, and cannibalism in juvenile Atlantic cod (*Gadus morhua* L.). *Aquaculture*, *114*(3-4): 243-260.

FRANKS, J.S.; OGLE, J.T.; LOTZ, J.M.; NICHOLSON, L.C.; BARNES, D.N.; LARSEN, K.M. 2001 Spontaneous spawning of cobia *Rachycentron canadum*, induced by human chorionic gonadotropin (HCG), with comments on fertilization, hatching and larval development. *Proceedings of the Gulf and Caribbean Fisheries Institute*, *52*(4): 589-609.

GIBERSON, A.V. and LITVAK, M.K. 2003 Effect of feeding frequency on growth, food conversion efficiency, and meal size of juvenile atlantic sturgeon and shortnose sturgeon. *North American Journal of Aquaculture*, *65*(2): 99-105.

GODDARD, S. 1996 *Feed management in intensive aquaculture*. New York: Chapman and Hall. 194p.

GOLDAN, O.; POPPER, D.; KARPLUS, L. 1997 Management of size variation in juvenile gilthead sea bream (*Sparus aurata*), I: particle size and frequency of feeding dry and live food. *Aquaculture*, *152*(1-4): 181–190.

GREAVES, K. and TUENE, S. 2001 The form and context of aggressive behaviour in farmed atlantic halibut (*Hippoglossus hippoglossus* L.). *Aquaculture*, *193*(1-2): 139-147.

JOHANSEN, S.J.S. and JOBLING, M. 1998 The influence of feeding regime on growth and slaughter traits of cage-reared Atlantic salmon. *Aquaculture International*, *6*(1): 1–17.

LAWRENCE, C.; BEST, J.; JAMES, A.; MALONEY, K. 2012 The effects of feeding frequency on growth and reproduction in zebrafish (*Danio rerio*). *Aquaculture*, *368-369*: 103-108.

LAZO, J.P.; DAVIS, D.A.; ARNOLD, C.R. 1998 The effects of dietary protein level on growth, feed efficiency and survival of juvenile Florida pompano *Trachinotus carolinus*. *Aquaculture*, *169*(3-4): 225–232.

LEE, S. M. and PHAM, M.A. 2010 Effects of feeding frequency and feed type on the growth, feed utilization and body composition of juvenile olive flounder, *Paralichthys olivaceus*. *Aquaculture Research*, *41*(9): e166-e171.

LEE, S.; HWANG, U.; CHO, S.H. 2000 Effects of feeding frequency and dietary moisture content on growth, body composition and gastric evacuation of juvenile Korean rockfish (*Sebastes schlegeli*). *Aquaculture*, *187*(3-4): 399-409.

LE CREN, E.D. 1951 The length-weight relationship and seasonal cycle in gonad weight and condition in the perch (*Perca fluvialis*). *Journal of Animal Ecology*, *20*(2): 201-219.

LIAO, C.I.; HUANG, T.S.; TSAI, W.S.; HSUEH, C.M.; CHANG, E.M.L. 2004 Cobia culture in Taiwan: current status and problems. *Aquaculture*, *237* (1-4): 55-165.

LIU, F.G. and LIAO, I.C. 1999 Effect of feeding regime on the food consumption, growth, and body composition in hybrid striped bass *Morone saxatilis* X *M. chrysops*. *Fisheries Science*, *6*(1): 513–519.

MIHELAKAKIS, A.; TSOLKAS, C.; YOSHIMATSU, T. 2002 Optimization of feeding rate for hatchery-produced juvenile gilthead sea bream *Sparus aurata*. *Journal of the World Aquaculture Society*, *33*(2): 169-175.

RUOHONEN, K.; VIELMA, J.; GROVE, D.J. 1998 Effects of feeding frequency on growth and food utilization of rainbow trout (*Oncorhynchus mykiss*) fed low-fat herring or dry pellets. *Aquaculture*, *165*(1-2): 111-121.

SALAMA, A.J. 2008 Effects of different feeding frequency on the growth, survival and feed conversion ratio of the asian sea bass *Lates calcarifer* juveniles reared under hypersaline seawater of the red sea. *Aquaculture Research*, *39*(6): 561-567.

SAMPAIO, L.A.; TESSER, M.B.; WASIELESKY JR., W. 2010 Avanços da maricultura na primeira década do século XXI: piscicultura e carcinocultura marinha. *Revista Brasileira de Zootecnia*, *39*(1): 102-111.

SAMPAIO, L.A.; MOREIRA, C.B.; MIRANDA-FILHO, K.C.; ROMBENSO, A.N. 2011 Culture of cobia *Rachycentron canadum* (L) in near-shore cages off the Brazilian coast. *Aquaculture Research*, *42*(6): 832-834.

SCHNAITTACHER, G.; WILLIAM, K.V.; BERLINSKY, D.L. 2005 The effects of feeding frequency on growth of juvenile Atlantic halibut, *Hippoglossus hippoglossus* L. *Aquaculture Research*, *36*(4): 370–377.

SHAFFER, R.V. and NAKAMURA, E.L. 1989 *Synopsis of biological data on the cobia* ***Rachycentron canadum*** *(Pisces: Rachycentridae)*. FAO Fisheries Synopsis. Washington, DC, USA. 21p.

SILVA, C.R.; GOMES, L.C.; BRANDÃO, F.R. 2007 Effect of feeding rate and frequency on tambaqui (*Colossoma macropomum*) growth, production and feeding costs during the first growth phase in cage. *Aquaculture*, *264*(1-4): 135-139.

SU, M.S.; CHIEN, Y.H.; LIAO, I.C. 2000 Potential of marine cage aquaculture in Taiwan: cobia culture. In: INTERNATIONAL SYMPOSIUM ON CAGE AQUACULTURE IN ASIA, 1., Taiwan, 2-6/Nov./1999. *Proceedings…* Asian Fisheries Society, Manila, and World Aquaculture Society, Bangkok. p.97-106.

TRUSHENSKI, J.; ROMBENSO, A.; SCHWARZ, M.H.; BOWZER, J.; GAUSE, B.; DELBOS, B; SAMPAIO, L.A. 2012a Feeding rate and frequency affect growth of juvenile Atlantic Spadefish. *North American Journal of Aquaculture*, *74*(1): 107-112.

TRUSHENSKI, J.; SCHWARZ, M.H.; BERGMAN, A.; ROMBENSO, A.N.; DELBOS, B. 2012b DHA is essential, EPA appears largely expendable, in meeting the n-3 long-chain polyunsaturated fatty acid requirements of juvenile cobia *Rachycentron canadum*. *Aquaculture, 326-329*: 81-89.

TUCKER, B.J.; BOOTH, M.A.; ALLAN, G.L.; BOOTH, D.; FIELDER, D.S. 2006 Effects of photoperiod and feeding frequency on performance of newly weaned Australian snapper *Pagrus auratus*. *Aquaculture*, *258*(1-4): 514-520.

WANG, N.; HAYWARD, R.S.; NOLTIE, N.B. 1998 Effect of feeding frequency on food consumption, growth, size variation, and feeding pattern of age-0 hybrid sunfish. *Aquaculture*, *165*(3-4): 261–267.

WEIRICH, C.R.; GROAT, D.R.; REIGH, R.C.; CHESNEY, E.J.; MALONE, R.F. 2006 Effect of feeding strategies on production characteristics and body composition of florida pompano reared in marine recirculating systems. *North American Journal of Aquaculture*, *68*(4): 330-338.

XIE, F.; AI, Q.; MAI, K.; XU, W.; MA, H. 2011 The optimal feeding frequency of large yellow croaker (*Pseudosciaena crocea*, Richardson) larvae. *Aquaculture*, *311*(1-4): 162-167.