Acta Scientiarum 22(2):439-444, 2000.
ISSN 1415-6814.

Growth and metabolic parameters of red tilapia reared in floating net cages in a small reservoir

Paulo César Falanghe Carneiro[1]*, Elisabeth Criscuolo Urbinati[1,2] and Damares Perecim Roviero[2]

*[1]Centro de Aqüicultura, Universidade Estadual Paulista, Rodovia Carlos Tonanni, km 05, 14870-000, Jaboticabal-São Paulo, Brazil. [2]Depto. Morfologia e Fisiologia Animal/FCAVJ, Universidade Estadual Paulista, Rodovia Carlos Tonanni, km 05, 14870-000, Jaboticabal-São Paulo, Brazil. *Author for correspondence.*

ABSTRACT. The objective of this study was to provide information on growth and metabolic parameters of red tilapia reared in cages in a small reservoir. Twelve floating net cages (5 m^3) placed in an 1-ha reservoir were stocked with 25, 50, 75 and 100 sex-reversed red tilapias/m^3, fed with two commercial floating feeds (32 and 28% crude protein), during 213 days. No effect ($P>0.05$) of stocking density was observed at the end of the experimental period on body weight, body length, condition factor, feed conversion rate, survival rate, mean daily weight gain and specific growth rate. No differences ($P>0.05$) on liver glycogen, liver somatic index (LSI), and total liver lipid were verified among the tested densities. However, blood glucose decreased slightly ($P>0.05$) from the onset of the experiment to the 64th day, and then returned to initial values from the day 118 on. Liver glycogen showed the highest value ($P<0.05$) at the 64th day, and total liver lipid, at the end of the experimental period ($P<0.001$) Otherwise, K showed higher values ($P<0.05$) at the 28th, 64th, and 213th days. Dissolved oxygen and water transparency decreased along the experimental period. The poor growth, FCR, and the changes on metabolic parameters observed in this experiment might have been caused by environmental stimuli, such as poor water quality, despite the different densities tested in the study.

Key words: cage, growth, metabolism, red tilapia, stress.

RESUMO. Parâmetros de crescimento e metabólicos da tilápia vermelha criada em tanques-rede flutuantes em açude de pequeno porte. O objetivo deste estudo foi gerar informação sobre parâmetros de crescimento e metabólicos da tilápia vermelha criada em tanques-rede num açude de pequeno porte. Foram instalados 12 tanques-rede flutuantes (5m^3), em um açude de 1 ha, estocados com 25, 50, 75 e 100 tilápias vermelhas revertidas por m^3, e alimentadas com duas rações extrusadas comerciais (32 e 28% PB), durante 213 dias. Não foram observadas diferenças significativas ($P>0,05$) entre as diferentes densidades de estocagem ao final do período experimental com relação aos parâmetros de crescimento: peso corporal, comprimento total, fator de condição, conversão alimentar aparente, taxa de sobrevivência, ganho de peso médio diário e taxa de crescimento específico. Também não foram observadas diferenças significativas ($P>0,05$) no glicogênio hepático, índice hepato-somático e lipídio hepático entre as densidades testadas. Contudo, a glicemia apresentou uma pequena diminuição entre o início do experimento e o 64º dia, retornando ao nível inicial a partir do 118º dia. O nível de glicogênio hepático foi mais elevado ($P<0,05$) no 64º dia, e o lipídio hepático apresentou maior valor no final do período experimental ($P<0,001$). Os valores mais elevados do fator de condição foram observados nos dias 28, 64 e 213. Com relação à qualidade da água, o oxigênio dissolvido e a transparência diminuíram ao longo do período experimental. Os baixos índices de crescimento e conversão alimentar aparente, além das alterações metabólicas registrados neste experimento, podem ter sido causados por estímulos ambientais, principalmente a baixa qualidade da água, independentemente das diferentes densidades de estocagem testadas neste estudo.

Palavras-chave: crescimento, estresse, metabolismo, tanque-rede, tilápia.

Fish production in cages has increased in Brazil during the last decade. The low cost of cage construction and the enormous area of impounded water available have stimulated this activity. Cage culture is a good alternative to produce fish in water bodies where conventional fish culture is not suitable (Schmittou, 1993).

Tilapia is a suitable species for cage culture (Balarin and Haller, 1982; Philippart and Ruwet 1982; Keenleyside, 1991) due to its flexibility and ability to accept artificial feed.

The rapid increase of aquaculture has brought the attention toward important aspects, such as the response of the fish to handling stress. Intensive culture systems, such as cage culture, frequently bring with them a range of stressors that fish would not normally face in the wild and the option to move away from a hostile environment is not generally available to them (Fletcher, 1997). Therefore, special cares, concerning the properly stocking density, feed practices, and water quality, are necessary to be understood for those who want to start an intensive system of fish production. The development of an understanding of the role of stress responses in fish is the key to a better understanding of the problems associated with the intensive culture of fish during their whole or partial life cycle (Donaldson, 1981).

The stocking density is one of the factors that affect the production of fish in intensive culture systems. The optimum stocking density is the largest number of fish that can be efficiently produced up to a harvestable size in a given volume of water. However, efficient production refers not only to maximum yield, but also to the weight of fish that can be yielded with a reasonable feed conversion rate in the shortest period of time to desired harvestable size (Schmittou, 1969). High stocking density is a stressing agent which might influence the growth and feed conversion in fish (Vijayan and Leatherland, 1988)

As long as fish reared in cages are not allowed to look for natural sources of food, the producer is required to provide them nutrients, at the properly quantity and excellent quality. Concerning feed practices in cage aquaculture, many other aspects such as pellet size, place and time of feeding, must be considered by the producers (Beveridge, 1996).

Fish reared in cages is not able to seek better sites for water quality in the water body where the cages are located. Poor water quality, or even fluctuations in its physical and chemical parameters, may cause significant reductions in appetite, growth and food conversion rate (FCR). Fish show a wide range of responses to stressful stimuli. Many of these reactions are readily apparent, such as death, lose of appetite, or behavioral changes. Alternatively, they might show no abnormal mortality rates, feed and behave normally, but convert food less efficiently. Poor FCR can be good monitors of the extent to which fish are, or have been, stressed because, they indicate that an increased proportion of the ration may be expended in metabolic processes, other than growth, perhaps due to the energy lost in physiological stress responses (Smart, 1981). Therefore, under aquaculture conditions, on which the environmental stress may have continuous or chronic nature, the stress response can promote damaging effects on fish health by increased susceptibility to disease, delayed reproductive process, besides depressed growth rate (Pickering, 1993).

Stress responses may also include changes in plasma hormones and changes on the levels of metabolites in the blood and tissue of fish (Barton *et al.*, 1988). The mobilization of carbohydrates is one of the processes which occur in stressing condition. Blood glucose is probably the most common metabolic measurement during the stress response in fish (Wedemeyer *et al.*, 1990). In addition, liver glycogen and total liver lipid are also good stress indicators (Hattingh, 1976; Janssens and Waterman, 1988; Morales *et al.*, 1990).

The objective of the present study was to provide information on growth and metabolic parameters of red tilapia, commercially used by many Brazilian fish farmers, reared in floating net cages in a small reservoir.

Material and methods

This study was carried out from May to December at the Aquaculture Center of Sao Paulo State University (Caunesp), Jaboticabal, Sao Paulo State, Brazil (21°15’22”S; 42°18’48”W; 595m). Twelve 5.0m^3 cages were placed in an 1-ha reservoir, depth of 3.0 m, in three lines of four cages each, 1.3 m apart, and stocked with 25, 50, 75 and 100 sex-reversed red tilapia/m^3. The initial fish weight and standard length were 47.8 g and 10.3 cm respectively.

Fish were fed four times a day with commercial floating feeds. In the first 60 days fish fed a 32% crude protein feed (4 mm pellet), replaced by a 28% crude protein feed (8 mm pellet) in the rest of the experimental period.

An 1-HP electric paddle wheel aerator was set near the cages to increase the dissolved oxygen and the water circulation through the cages (Boyd, 1991). Water temperature, conductivity, transparency, total alkalinity, dissolved oxygen, total ammonia ($N\text{-}NH_3$) and nitrite (NO_2^-) were measured once a week at 0830 a.m. (Boyd and Tucker, 1992).

Blood and liver were sampled at the days 0, 28, 64, 118, and 213 after the beginning of the experiment and processed for determination of blood glucose (King and Garner, 1947), liver glycogen (Carrol *et al.*, 1956) and total liver lipid (Bligh and Dyer, 1957). At the samplings, the fish were weighed and measured to determine growth and health condition, as well as the feed efficiency.

Specific growth rate (G, % body weight/day) was calculated from $G = 100 \times (\ln W_f - \ln W_i) / t$, where W_f = weight at the end of the experimental period (g), W_i = weight at the onset of the experiment (g), and t = time in days of the period. Mean daily weight gain (MDWG, g/day) was calculated from $MDWG = (W_f - W_i) / t$. Condition factor (K) was calculated from $K = 100 \times W / L^3$, where W = weight (g) and L = standard length (cm). Liver somatic index (LSI, %) was calculated from $LSI = 100 \times (lw/bw)$, where lw = liver weight and bw = body weight. Feed conversion ratio (FCR) was calculated from FCR = dry weight fed (g) / live weight gain of fish (g) during the experimental period.

The experiment was randomly designed. Growth and metabolic parameters were analyzed by a two-way (densities and experimental period) analysis of variance (ANOVA), and the means were compared by Tukey test (SAS System 6.12).

Results

Table 1 presents the average values of food conversion rate (FCR), body weight (W_f), and standard length (L_f) of red tilapia at the end of the experimental period. There were no significant differences ($P>0.05$) on FCR, W_f and L_f between the four stocking densities after 213 days. Mean daily weight gain and specific growth rate were also determined at the end of the experiment, and showed no difference ($P>0.05$) between treatments (1.00 g/day and 0.79 %/day, respectively). Despite the slow growth verified in this study, high survival rate was found, although survival had not been different ($P>0.05$) between treatments (96.9%).

Table 1. Food conversion rate (FCR), average final weight (W_f) and standard length (L_f) of red tilapia reared in floating net cages at 25, 50, 75 and 100/m^3 for 213 days

Treatment	FCR	W_f (g)	L_f (cm)
T25	2.71 ± 0.15^a	251.5 ± 36.3^a	17.75 ± 2.68^a
T50	2.74 ± 0.07^a	265.7 ± 30.7^a	18.21 ± 2.75^a
T75	2.98 ± 0.06^a	252.7 ± 27.0^a	17.80 ± 2.69^a
T100	2.72 ± 0.12^a	268.4 ± 33.7^a	17.99 ± 2.71^a

Data are presented as means ± s.d. (n = 3 for FCR and n=12 for W_f and L_f); Values followed by the same letter do not differ statistically ($P>0.05$)

The water quality parameters during the experimental period were: conductivity, 58 µS/cm^2 (50-80), total alkalinity, 28 mg$CaCO_3$/L (21-34), $N\text{-}NH_3$ <0.15 mg/L, NO_2^- <0.02 mg/L, and pH 7.3 (6.3-7.8). Water temperature was below 22°C during the first half of the experiment (Figure 1), increasing after 118 days and coinciding with a more significant fish growth. Dissolved oxygen and water transparency decreased along the experimental period, reaching the lowest values at the end of the 213-day period (2.4 mg/L and 20 cm respectively - Figure 2).

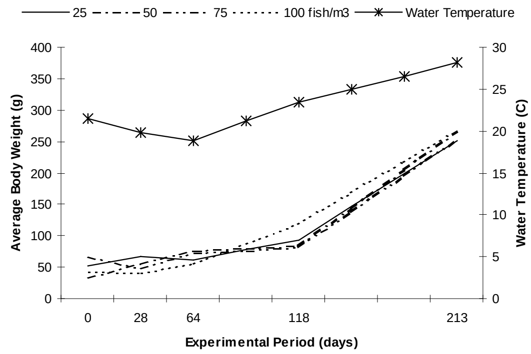

Figure 1. Water temperature and average body weight of red tilapia reared for 213 days in 5-m^3 floating net cages

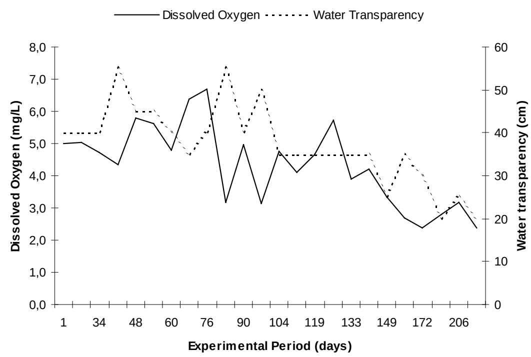

Figure 2. Dissolved oxygen and water transparency of the 1-ha reservoir containing twelve 5-m^3 cages with red tilapias during 213 days

Three 24-hour samplings of water were accomplished during the period in which fish presented better growth (August, October, and December) to verify the changes of dissolved oxygen. Figure 3 shows that dissolved oxygen altered during each 24-hour sampling period, and decreased from August to December.

Condition factor and the metabolic parameters (blood glucose, liver glycogen, total liver lipid, and liver somatic index - LSI) did not present any difference between the different stocking densities, but through the period (Table 2 and Figure 4). Blood glucose decreased slightly ($P>0.05$) from the onset of the experiment to the 64th day, and then returned to initial values after 118 days of trial. The highest level of liver glycogen was verified at the day 64, and similar changes were observed for LSI, during the 213-day period. Total liver lipid presented the highest value at the end of the experiment ($P<0.001$) and condition factor increased significantly ($P<0.05$) at the days 28 and 64, returning to the initial values at the 118th day, and increasing again at the end of the trial period.

Figure 3. Dissolved oxygen of the 1-ha reservoir containing twelve 5-m^3 cages with red tilapias during three 24-hour periods

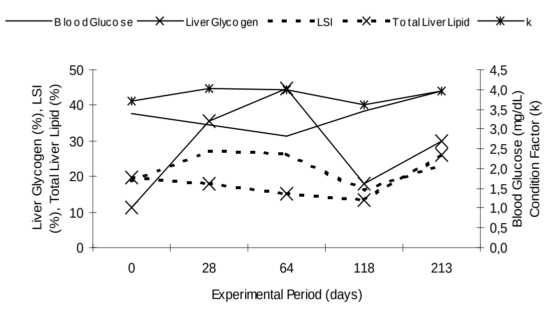

Figure 4. Metabolic parameters and condition factor of red tilapia reared in floating net cages for 213 days

Discussion

The stocking densities used in this study did not show any effect neither on growth nor on metabolic parameters of red tilapia reared in floating net cages (Table 1). However, there were significant changes in most of the analyzed parameters along the experimental period (Table 2).

According to Coche (1982), stocking densities much higher than those of the present experiment may be used in cage culture of tilapia. Then, the highest stocking density used in the present study might not have been high enough to impair growth.

The behavioral interactions that occur among fish in intensive aquaculture systems can be a significant source of stress. Dominance hierarchy is based largely on fish size and can be established quickly in many species, particularly at low rearing densities. As observed in this experiment, size variation was very high at the end of the experimental period (Table 1). The slower growth of subordinated fish in social hierarchies is due to a combination of reduced access to feed, the caloric energy costs of chronic stress, and the anorexia that generally occurs in chronically stressed animals (Wedemeyer, 1997).

The environmental stress provoked by the decaying water quality might also have affected the growth parameters at the 213th day, such as final weight and length, MDWG, G, and FRC (Table 1). Despite no significant difference between the stocking densities, MDWG and G found in this study were much lower than those observed by Coche (1982) and Watanabe *et al.* (1990), and FCR showed poorer values than those obtained by Ernst (1989) and Clark *et al.* (1990a,b).

The water quality parameters (conductivity, total alkalinity, ammonia, nitrite, and pH) varied within suitable ranges for tilapia according to Boyd (1990) and Hassan (1992). However, the low temperatures recorded during the first half of the trial period might have influenced the slow growth of the fish (Caulton, 1982). In addition, dissolved oxygen and water transparency values were below the acceptable levels for tilapia reared in cages (Coche, 1982), during the second half of the experimental period (Figure 2). According to Schmittou (1993), cage culture is not recommended in water bodies where water transparency is less than 40 cm.

Table 2. Blood glucose (mg/dL), liver glycogen (%), liver somatic index (LSI, %), total liver lipid (%), and condition factor (K) of red tilapia reared in floating net cages for 213 days

Experimental Period (days)	Blood Glucose (mg/dL)	Liver Glycogen (%)	LSI (%)	Total Liver Lipid (%)	Condition Factor (K)
0	37.6 ± 15.4^{ab}	1.02 ± 0.65^{c}	1.69 ± 0.33^{c}	1.78 ± 0.27^{b}	3.71 ± 0.54^{b}

28	34.5 ± 15.0 [b]	3.19 ± 0.90 [b]	2.43 ± 0.52 [a]	1.63 ± 0.24 [bc]	4.01 ± 0.34 [a]
64	31.2 ± 14.3 [b]	4.03 ± 0.91 [a]	2.39 ± 0.78 [ab]	1.36 ± 0.31 [cd]	4.00 ± 0.46 [a]
118	38.4 ± 13.8 [a]	1.63 ± 1.14 [c]	1.46 ± 0.54 [c]	1.19 ± 0.23 [d]	3.62 ± 0.43 [b]
213	43.8 ± 12.0 [a]	2.70 ± 0.53 [b]	2.08± 0.55 [b]	2.33 ± 0.37 [a]	3.97 ± 0.54 [a]

Data are presented as means ± s.d. (n = 12); Values followed by the same letter in the same column do not differ statistically (P>0.05)

The normal dissolved oxygen cycle during a 24-hour period is very similar to those observed in Figure 3. Phytoplankton eliminates oxygen through the photosynthesis process in the presence of sun light. At night, the respiratory process takes place, and the plants and all kind of organism present in the water body, consume oxygen. The more phytoplankton organisms present in the water (or the lower the water transparency), the greater the variation of the oxygen levels during a 24-hour period. (Esteves, 1988).

In spite of the three 24-hour cycles of oxygen have a regular pattern, marked reduction in the dissolved oxygen levels was observed in August and December. Besides, a greater variation of the dissolved oxygen levels was observed in the third 24-hour period, probably caused by the increasing euthrophycation of the reservoir water, due to the increasing input of nutrient, mainly fish feed. As described by Smart (1981), poor water quality, or even fluctuations in water quality, may cause significant reductions in appetite, growth and food conversion efficiency, and these changes may be responses to stressful stimuli.

Besides the poor water quality, several other factors probably influenced the growth and metabolic responses. The ontogeny of the stress response or the stage of development of the fish might also have influenced the extent to which they responded to stress along the experimental period (Barton, 1997). The rearing environment inside the cages by itself might also have affected those metabolic changes, acting as a chronic stressor.

Stress leads to an increased energy demand, causing mobilization or synthesis of glucose from stored reserves. The fish in this study were exposed to stress for long periods of time without the scope to resolve the stressor, with the result that metabolism also remained geared up during the whole period (Pankhurst and Van der Kraak, 1997).

The effect of stress can be viewed in the context of reducing the metabolic scope for activity of the fish (Fry, 1947). Presumably, if a portion of the energy budget of the fish, within its scope for activity, is required to cope with stress, then less energy will be available for other performance components (Schreck, 1982). One such performance component of interest directly related to metabolism, and affected by stress, is growth (Pickering, 1992).

It was observed in this study that water quality of a small reservoir can be deteriorated after a short period of time if fish are reared in cages placed in it. This experiment also reinforced that poor water quality is very unsuitable for production of red tilapia in cages.

Stress is unavoidable in intensive aquaculture. While severe stress can result in massive mortalities, sublethal stress can compromise various physiological and behavioral functions, leading to suppressed growth rate, and contributing to suboptimal production. The recognition of stressed states, as well as the management of fish health are therefore critical to the success of an aquaculture operation.

References

Balarin, J.D.; Haller, R.D. The intensive culture of tilapia in tanks, raceways and cages. In: Muir, J. F.; Roberts, R. J. (ed). *Recent advances in Aquaculture*, London: Croom Helm, 1982. p. 267-355.

Barton, B.A. Stress in finfish: past, present and future - a historical perspective. In: Iwama, J.K. *et al.* (eds.). *Fish stress and health in aquaculture*, Cambridge: University Press, 1997. p. 1-34.

Beveridge, M. *Cage aquaculture*. Cambridge: University Press, 1996.

Bligh, E.G.; Dyer, W.J. A rapid method of total lipid extraction and purification. *Can. J. Bioch. Physiol.*, *37*:911-917, 1957.

Boyd, C.E. *Water quality in ponds for aquaculture*. Auburn: Auburn University, 1990.

Boyd, C.E. Experiences in evaluating surface and diffused-air aerators. *Am. Fish. Soc. Symp., 10*:465-473, 1991.

Boyd, C.E.; Tucker, C.S. *Water quality and pond soil analyses for aquaculture*. Auburn: Auburn University, 1992.

Carrol, N.V.; Longley, R.W.; Roe, J.H. The determination of glycogen in liver and muscle by use of anthrone reagent. *J. Biol. Chem., 220*:583-593, 1956.

Caulton, M.S. Feeding, metabolism and growth of tilapias: some quantitative considerations. In: Pullin, R.S.V.; lowe-McConnel, R.H. (eds.). *The biology and culture of tilapias.* Manila: Iclarm Conference Proceedings, 1982. p. 157-180.

Clark, J.H.; Watanabe, W.O.; Ernst, D.H. Effect of feeding rate on growth and feed conversion of Florida red tilapia reared in floating marine cages. *J. World Aquacult. Soc. 21*: 16-24, 1990a.

Clark, J.H.; Watanabe, W.O.; Olla, V.L.; Wicklund, R.I. Growth, feed conversion and protein utilization of Florida red tilapia fed isocaloric diets with different protein levels in seawater pools. *Aquaculture, 88*:75-85, 1990b.

Coche, A.G. Cage culture of tilapias. In: Pullin, R.S.V.; lowe-McConnel, R.H. (eds.). *The biology and culture of tilapias.* Manila: Iclarm Conference Proceedings, 1982. p. 205-246.

Donaldson, E.M. The pituitary-interrenal axis as indicator of stress in fish. In: Pickering, A.C. (ed). *Stress and Fish*. London: Academic Press, 1981. p. 11-47.

Ernst, D.H. Production of Florida red tilapia in seawater pools: nursery rearing with chicken manure and growout with prepared feed. *Aquaculture, 80*:247-60, 1989.

Esteves, F.A. *Fundamentos de limnologia*. Rio de Janeiro: Finep, 1988.

Fletcher, T.C. Dietary effects on stress and health. In: Iwama, J.K. *et al.* (eds.). *Fish stress and health in aquaculture*, Cambridge: University Press, 1997. p. 95-118.

Fry, F.E.J. *Effects of the environment on animal activity*. Toronto: University of Toronto Press, 1947.

Hassan, R. Acute ammonia toxicity of red tilapia and seabass. *Fish. Bul. Malaysia, 73*:1-8, 1992.

Hattingh, J. Blood sugar as an indicator of stress in the freshwater fish, *Labeo capensis* (Smith). *J. Fish Biol., 10*:191-195, 1976.

Janssens, P.A.; Waterman, J. Hormonal regulation of gluconeogenesis and glycogenolisis in carp (*Cyprinius carpio*) liver pieces cultures *in vitro*. *Comp. Biochem. Physiol., 91A*:451-455, 1988.

Keenleyside, M.H.A. *Cichlid fishes:* behaviour, ecology and evolution. London: Chapman & Hall, 1991.

King, E.J.; Garner, R. J. Colorimetric determination of glucose. *J. Chem. Pathol., 1*: 30-33. 1947.

Morales, A.E.; Garcia-Rejón, L.; Higuera, M. Influence of handling and/or anesthesia on stress response in rainbow trout: effects on liver primary metabolism. *Comp. Physiol., 95A*: 87-93, 1990.

Pankhurst, N.W.; Van der Kraak, G. Effects of stress on reproduction and growth of fish. In: Iwama, J.K. *et al.* (eds.). *Fish stress and health in aquaculture*, Cambridge: University Press, 1997. p. 73-94.

Philippart, J.C.; Ruwet, J.C. Ecology and distribution of tilapias. In: Pullin, R.S.V.; lowe-McConnel, R.H. (eds.). *The biology and culture of tilapias.* Manila: Iclarm Conference Proceedings, 1982. p. 15-59.

Pickering, A.D. Rainbow trout husbandry: management of the stress response. *Aquaculture, 100*:125-139, 1992.

Pickering, A.D. Growth and stress in fish production. *Aquaculture, 111*:51-63, 1993.

Schmittou, H.R. The culture of channel catfish *Ictalurus punctatus* (Rafinesque) in cages suspended in ponds. *Proc. Annu. Conf. Southest. Assoc. Game Fish Comm., 23*:226-244, 1969.

Schmittou, H.R. *High density fish culture in low volume cages*. Singapore: American Soybean Association, 1993.

Schreck, C.B. Stress and rearing of salmonids. *Aquaculture, 28*:241-249, 1982.

Smart, G.R. Aspects of water quality producing stress in intensive fish culture. In: Pickering, A.C. (ed.). *Stress and Fish*. London: Academic Press, 1981. p. 277-294.

Vijayan, M.M.; Leatherland, J.F. Effect of stocking density on the growth and stress-response in brook charr. *Salvelinus fontinalis*. *Aquaculture, 75*:159-170, 1988.

Watanabe, W.O.; Clark, J.H.; Dunham, J.B.; Wicklund, R.I.; Olla, B.L. Culture of Florida red tilapia in marine cages: the effect of stocking density and dietary protein on growth. *Aquaculture, 90*:123-134. 1990.

Wedemeyer, G.A.; Barton, B.A.; McLeay, D.J. Stress and acclimation. In: Schreck, C.B.; Moyle, P.B. (eds.). *Methods for fish biology.* Bethesda: American Fisheries Society, 1990. p. 451-489.

Wedemeyer, G.A. Effects of rearing conditions on the health and physiological quality of fish in intensive culture. In: Iwama, J.K. *et al.* (eds.). *Fish stress and health in aquaculture.* Cambridge: University Press, 1997. p. 35-72.

Received on July 26, 1999.
Accepted on May 30, 2000.