BOLETIM DO INSTITUTO DE PESCA
ISSN 1678-2305 online version
Scientific Article

DIFFERENT DENSITIES OF COMMON SNOOK REARED IN MARINE CAGES IN SOUTHERN BRAZIL*

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* This study was financed in part by the Fundação de Amparo à Pesquisa e Inovação do Estado de Santa Catarina (FAPESC) (nº 7048/2010-3) and Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) (nº 406844/2012-7). This paper is part of Fabiano Müller SILVA' doctoral thesis, which is deposited in its entirety in UFSC digital repository (https://repositorio.ufsc.br/handle/123456789/173030).

Received: February 19, 2021
Approved: August 23, 2021

ABSTRACT

Two growth stages of juvenile snook (*Centropomus undecimalis*) under three different densities were evaluated: 10, 20, and 40 fish m^{-3}, in 2.5-m^3 cages with 12-mm mesh. In phase I, snooks of 72.0 g and 21.2 cm were raised for 270 days. In phase II, snooks of 204.6 g and 29.2 cm were raised for 202 days. The average water temperature and salinity were 24.3°C and 34.5, respectively, at Santa Catarina Island, Brazil. The data were evaluated using regression models. Density increase did not influence survival rate, with 51.0% (phase I) and 88.7% (phase II). The density of 20 fish m^{-3} provided the best results, such as body weight, in the two phases, with 215.7 and 364.7 g, respectively. Water temperature was the main limiting factor for the growth of snook. Therefore, in a subtropical climate, it is recommended to start growing in the spring (> 24°C) and avoid handling fish when the temperature is below 20°C. Regression analysis on the final weight showed that densities of 24 fish m^{-3} could be indicated for common snook under the conditions of this study.

Keywords: productivity; marine fish farming; performance indicators; growth-out.

DIFERENTES DENSIDADES DE ROBALO FLECHA CRIADOS EM TANQUES REDE MARINHOS NO SUL DO BRASIL

RESUMO

Foram avaliadas duas fases de crescimento de juvenis de robalo flecha (*Centropomus undecimalis*) sob três diferentes densidades: 10, 20 e 40 peixes m^{-3}, em tanques rede de 2,5 m^3 com malha de 12 mm. Na fase I, robalos de 72,0 g e 21,2 cm foram criados por 270 dias. Na fase II, robalos de 204,6 g e 29,2 cm foram criados por 202 dias. A temperatura e salinidade médias da água foram 24,3°C e 34,5, respectivamente, na Ilha de Santa Catarina, Brasil. Os dados foram avaliados por modelos de regressão. O aumento da densidade não influenciou a taxa de sobrevivência, 51,0% (fase I) e 88,7% (fase II). A densidade de 20 peixes m^{-3} proporcionou os melhores resultados, como peso corporal, nas duas fases, 215,7 g e 364,7 g, respectivamente. A temperatura da água foi o principal fator limitante para o crescimento do robalo. Portanto, em um clima subtropical, recomenda-se começar a crescer na primavera (> 24°C) e evitar o manuseio de peixes quando a temperatura estiver abaixo de 20°C. A análise de regressão do peso final mostrou que densidades de 24 peixes m^{-3} podem ser indicadas para robalo nas condições deste estudo.

Palavras-chave: produtividade; piscicultura marinha; indicadores de desempenho; crescimento.

INTRODUCTION

The common snook *Centropomus undecimalis*, also known as robalo in most countries of the Americas, is distributed from the Atlantic Ocean at the western coast of the United States to Santa Catarina State in southern Brazil (Rivas, 1986). It is diadromous, euryhaline, and estuarine dependent and occurs in rivers, estuaries, coastal lagoons, and near rocky shores (Muller and Taylor, 2000; Taylor et al., 2000; Tavares and Luque, 2003; Pope et al., 2006). Snook distribution decreases in cold and freezing climates (Gilmore et al., 1983) as the snook is stenothermic and highly sensitive to cold temperatures; the first sign of cold stress is the cessation of feeding (14.2ºC), followed by loss of equilibrium (12.7ºC) and death (12.5ºC) (Shafland and Foote, 1983; Blewett and Stevens, 2014; Purtlebaugh et al., 2020). Therefore, its geographical distribution is restricted by a temperature of 15ºC in winter (Howells et al., 1990; Adams et al., 2012).

The species is considered a good candidate for aquaculture because of favorable zootechnical characteristics such as rapid growth, a highly economic feed conversion rate, and the potential to gain high biomass in the nursery and in grow-out systems (Alvarez-Lajonchère and Tsuzuki, 2008). It has been studied for many years in the United States, Mexico, and Brazil (Tucker, 1987, 1998; Taylor et al., 1998; Cerqueira et al., 2020; Gracia-López et al., 2003; Ibarra-Castro et al., 2011; Passini et al., 2018; Oliveira et al., 2019; Arenas et al., 2021), although it is not yet commercially reared.

However, other similar species, namely the European seabass *Dicentrarchus labrax* and the Asian seabass or barramundi *Lates calcarifer*, are widely cultivated around the world (Moretti et al., 1999). They are grown-out in different production systems such as nurseries, water recirculation systems, and cages. Seabass aquaculture production was 191 thousand tonnes valued at 1089 million USD in 2016, while seabream production was 186 thousand tonnes valued at 977 million USD (Llorente et al., 2020). Aquaculture production occurs in two phases: a hatchery-pregrowing phase, which produces fish of 1 to 20 g in three to eight months (temperature-controlled hatcheries), and then an on-growing phase to 250–450 g in 12 to 20 months (sea cages in natural waters). The main market product is the 250–400-g pan-sized fish, but there is growing interest in the production of larger fish (800 g to 1 kg) to sell whole or as processed fillets (EUMOFA, 2018). The production of barramundi is concentrated in Asia, grown mostly in floating cages, and marketed between 350 and 500 g (fish portion); a minor amount of 1–3 kg fish is sold as fillets (FAO, 2009).

Although many researchers have reported seed production and physioecological results, to date, there have been few data published on common snook reared in cage culture.

Most marine fish farming production, such as salmon culture, uses floating cages (Liao and Leaño, 2008). This system improves productivity indices with less physical space and rearing time than traditional ones (Beveridge, 2004). Identifying the ideal support capacity of a production system, using a higher stocking density, and maintaining optimal growth and survival rates, results in high productivity, lower operating costs, and lower production costs, generating an economy of scale (Björnsson, 1994; Llorente et al., 2020).

In fish culture, stocking density is closely related to survival rate, growth, shape, health, water quality, and production (Ambrosio et al., 2008; Costa et al., 2013). Increasing the population density of fish can increase the production per unit area; however, this can cause stress in fish, affecting growth factors, feed efficiency, feeding rate, and digestion rate (Wedemeyer, 1997; Rowland et al., 2006), although the results depend on the species studied.

Considering the positive characteristics of common snook for high-density cultivation and the success of marine fish farming in cages in various regions of the world, we evaluated the performance of *Centropomus undecimalis* juveniles in marine cages with different stocking densities in a subtropical environment.

MATERIALS AND METHODS

Fish origin

All procedures involving fish were performed according to the Ethics Committee on Animal Use of UFSC (PP00861/CEUA/PROPESQ/UFSC/2013). Juveniles of the common snook were obtained from hormonal-induced reproduction and larviculture procedures previously developed (Cerqueira et al., 2017). Before the experiments, the fish remained in a 10-m^3 circular tank inside a greenhouse at a temperature around 28°C until reaching 72.0 ± 7.1 g of weight and 21.2 ± 0.7 cm of total length (Passini et al., 2019).

Location and experimental units

The experiment was carried out in Sambaqui Cove, North Bay of Santa Catarina Island (27º29'18.26''S and 48º32'29.25''W, Brazil). The experimental units were 12 circular floating cages with a 1.5-m diameter, 2.0 m high, and an effective volume of 2.5 m^3. The nets were made in nylon multifilament with a 12-mm mesh size. A bird protection net was placed 1.0 m above the surface of the water and served also to avoid fish scape. The cages were attached to two 100-L mooring buoys forming a longline system installed at 200 m parallel from the coastline, with a water depth of 3.4–4.6 m depending on the tidal range.

Experimental design and rearing conditions

We evaluated two grow-out phases under three stocking densities: 10, 20, and 40 fish m^{-3}, with four replicates. In the first phase (Experiment 1), snooks with an initial body weight of 72.0 ± 7.1 g and a total length of 21.2 ± 0.7 cm were raised for 270 days (summer to winter). In the second phase (Experiment 2), snooks with an initial body weight of 204.6 ± 25.7 g and a total length 29.2 ± 1.3 cm were raised for 202 days (spring to summer).

In the first 3 months, fish were fed a commercial diet (45% crude protein) extruded at 4.0 mm, formulated for carnivorous fish (Table 1). Feed was manually delivered once every morning at 3.0% of the biomass. Thereafter, they were fed another diet (40% crude protein) extruded at 6.0 mm at 2.0% of the biomass per day (Table 1). We adjusted the feeding rate every 2 weeks, adding 10% to the initial biomass value (Ostini et al., 2007) and discounting losses from mortality. During winter, with temperatures below 20°C, the feeding rate decreased to 1.0% of the biomass.

Table 1. Composition of the commercial diets, according to the labels.

Nutrients	4 mm	6 mm
Crude protein (%)	45	40
Moisture (%)	10	10
Crude fat (g kg^{-1})	120	100
Ash (g kg^{-1})	140	130
Crude fiber (g kg^{-1})	45	45
Calcium (g kg^{-1})	15-25	10-25
Phosphorus (g kg^{-1})	10	10
Vitamin C (mg kg^{-1})	600	600

Sampling and growth parameters

Fish were anesthetized with 75 mg L^{-1} benzocaine (Passini et al., 2018) for individual weighing and length measurement at the start of both trials (day 0), at days 90, 190, and 270 in the first experiment, and at days 80 and 202 in the second experiment. After each sampling, the cages were cleaned with a high-pressure washer to eliminate fouling.

Growth and rearing performance were assessed based on body weight, BW (g), total length, TL (cm), survival, S (%), biomass, B (kg), and feed consumption, FC (kg). Performance calculations were made using the following formulae:

- Fulton's condition factor, K = 100 x BW/TL^3;
- Daily weight gain, DWG (g) = (BWf - BWi)/T;
- Specific growth rate, SGR (%BW/day) = 100 [(lnBWf - lnBWi)/T;
- Feed efficiency ratio, FER (%) = WG/FC x 100;
- Yield (kg m^{-3}) = (Bi - Bf)/2.5;

where T: experiment duration (days), i: initial, f: final.

Water quality analysis

Every morning, the following seawater quality parameters were measured: 1.5 m-depth temperature using a remote sensor (HOBO TidbiT v2, Onset Computer Co., Bourne, USA), surface salinity using a hand refractometer (Model 211 ATC, Mar do Sul, Florianópolis, Brazil), 1.5 m-depth dissolved oxygen using a portable digital analyzer (AT 155, Alfakit Ltda., Florianópolis, Brazil), and transparency using a Secchi disk.

Statistical analysis

The dependency of growth and rearing performance (effects) on stocking density (cause factor) was tested by regression analysis. Models (linear, quadratic, cubic, exponential, or logarithmic) were selected according to significance (p <0.05), the coefficient of determination (R^2), and the phenomenon under study (Bhujel, 2008).

For both experiments, data of survival, daily weight gain, and feed efficiency ratio were submitted to the Shapiro-Wilk test to verify normality and to Levene´s test to verify homogeneity of variance. Subsequently, bifactorial ANOVA tested the effect of stocking density in different seasons of the year. Tukey's test was used for comparisons among means (p <0.05).

RESULTS

Water quality

In Experiment I, the mean water temperature was 22.7°C (16.9–31.0°C); in Experiment II, it was 25.4°C (19.8–31.1°C). Temperatures varied according to the seasons (Figure 1). Dissolved oxygen ranged from 4.6 to 7.1 mg L^{-1}, with a mean of 6.1 mg L^{-1}. Salinity ranged from 30 to 35, with a mean of 34.5. The Secchi depth ranged from 30 to 160 cm, with 78 cm on average.

Experiment 1

The effect of stocking density was significant on many linear growth and rearing performance variables (Table 2). An increase in stock density decreased weight, length, daily weight gain, specific

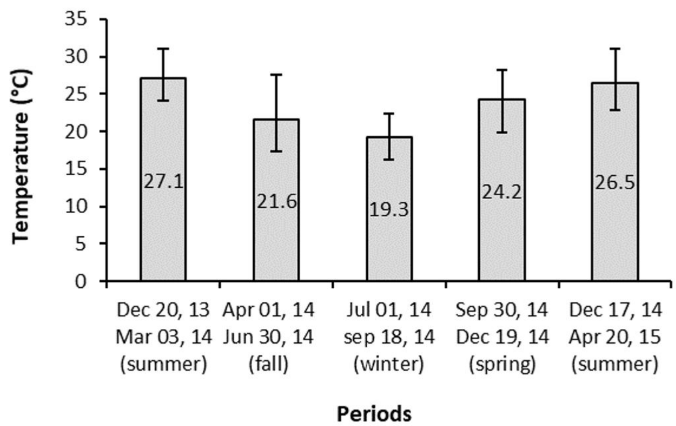

Figure 1. Mean water temperatures in different periods (sampling dates) of the study. Bars show minimum and maximum values.

Table 2. Growth performance (means ± SD) of common snook in cages with three stocking densities in phase 1 (n = 4).

Variables	Density (fish m^{-3}) 10	20	40	Regression equation
Initial weight (g)	71.8±8.6	72.8±8.3	71.5±7.9	
Final weight (g)	200.8±15.3	215.7±23.6	167.3±28.8	y = 219.95-1.23x; R^2 = 0.7457
Initial total length (cm)	21.2±0.9	21.3±0.9	21.1±0.8	
Final total length (cm)	29.6±0.7	29.8±1.3	27.7±1.5	y = 30.54-0.65x; R^2 = 0.8361
Daily weight gain (g)	0.48±0.02	0.53±0.04	0.36±0.01	y = 0.5471-0.0045x; R^2 = 0.7652
Specific growth rate (% day^{-1})	0.38±0.01	0.40±0.02	0.31±0.00	y = 0.4246-0.0025x; R^2 = 0.651
Condition factor (K)	0.77±0.00	0.79±0.00	0.78±0.01	
Survival (%)	52.0±2.8	53.0±8.0	48.0±1.5	
Initial biomass (kg)	1.78±0.04	3.64±0.03	7.15±0.11	y = 179.50x; R^2 = 0.9988
Final biomass (kg)	2.61±0.20	5.62±0.68	8.07±0.27	y = 1409+173x; R^2 = 0.9041
Yield (kg m^{-3})	1.05±0.08	2.25±0.31	3.23±0.11	y = 563+69x; R^2 = 0.9041
Feed consumption (kg)	9.54±0.54	20.76±0.41	35.22±1.25	y = 3330+1014x; R^2 = 0.973
Feed efficiency ratio (%)	8.6±2.3	9.6±3.6	2.6±0.7	y = 0.0970-0.0018x; R^2 = 0.5306

growth rate, and feed efficiency ratio. In contrast, feed consumption, biomass, and yield values followed an increasing trend.

Both temperature and stocking density had significant effects (p <0.001) on daily weight gain (Figure 2), although there was no significant interaction (p = 0.06). At densities of 10 and 20 fish m^{-3}, regardless of the season, the growth was greater than 40 fish m^{-3}.

Concerning the feed efficiency ratio there was a similar trend, with significant effects of both factors (p <0.001) and no significant interaction (p = 0.11). In summer, feed efficiency was higher than in fall and winter, and densities of 10 and 20 fish m^{-3} had higher values than 40 fish m^{-3} (Figure 3).

Experiment 2

The effect of stocking density was significant on most variables, except for survival (Table 3). The quadratic model was appropriate for all growth variables (final weight and length, condition factor, daily weight gain, specific growth rate, and feed efficiency ratio). In most of them, 20 fish.m^{-3} presented the best results. The linear regression model was appropriate for the rearing performance variables (feed consumption, final biomass, and yield).

For the final weight and the condition factor, the quadratic equation showed that the maximum values of these parameters would be obtained at a density of approximately 25 fish m^{-3} (Figure 4).

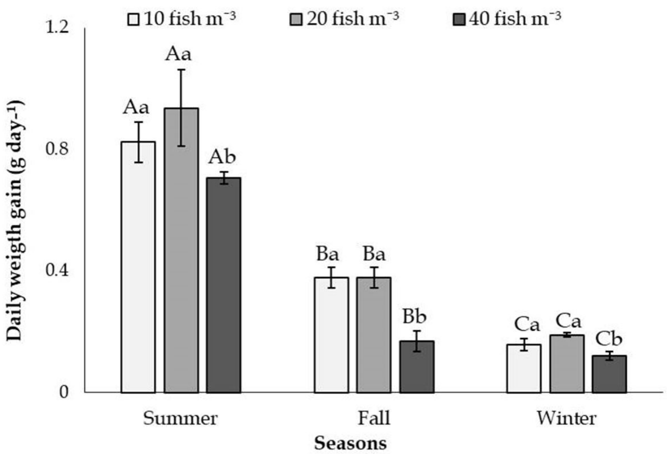

Figure 2. Daily weight gain of common snook reared in cages at three stocking densities according to the season of the year in phase 1. Bars show mean ± SD (n = 4), and significant differences are indicated by different letters (lowercase for densities within each season; uppercase for seasons within each density).

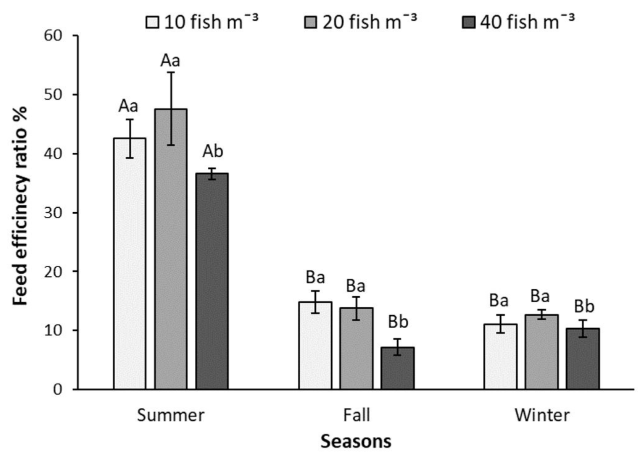

Figure 3. Feed efficiency ratio of common snook reared in cages at three stocking densities according to the season of the year in phase 1. Bars show mean ± SD (n = 4), and significant differences are indicated by different letters (lowercase for densities within each season; uppercase for seasons within each density).

Table 3. Growth performance (means ± SD) of common snook reared in cages at three stocking densities in phase 2 (n = 4).

Variables	Density (fish m^{-3})			Regression equation
	10	20	40	
Initial weight (g)	202.9±26.8	203.6±37.1	207.5±33.6	
Final weight (g)	329.2±38.2	364.7±104.6	315.4±63.1	$y = 253.52+9.55x-0.20x^2$; $R^2 = 0.8355$
Initial total length (cm)	29.4±1.2	28.8±1.9 b	29.4±1.7	
Final total length (cm)	34.9±0.3	35.3±0.5	34.2±0.3	$y = 35.48-0.027x$; $R^2 = 0.3931$
Daily weight gain (g day^{-1})	0.63±0.04	0.80±0.08	0.53±0.04	$y = 0.064x-0.001x^2$; $R^2 = 0.6909$
Condition factor (K)	0.77±0.01	0.83±0.02	0.78±0.01	$y = 0.6686+0.0131x-0.0002x^2$; $R^2 = 0.8168$
Survival (%)	91±13	82±2	93±3	
Initial biomass (kg)	5.07±0.04	10.18±0.21	20.75±0.21	$y = -234.7+523.9x$; $R^2 = 0.9991$
Final biomass (kg)	8.10±0.31	14.96±0.76	29.20±1.72	$y = 735x$; $R^2 = 0.9808$
Yield (kg m^{-3})	3.24±0.13	5.98±0.30	11.68±0.69	$y = 288.09x$; $R^2 = 0.9598$
Feed consumption (kg)	13.96±0.58	27.40±0.67	57.40±2.26	$y = 1573x$; $R^2 = 0.9878$
Feed efficiency ratio (%)	19.89±1.2	23.74±2.4	16.39±1.5	$y = 0.195-0.001x$; $R^2 = 0.3759$
Specific growth rate (g day^{-1})	0.24±0.01	0.29±0.02	0.21±0.02	

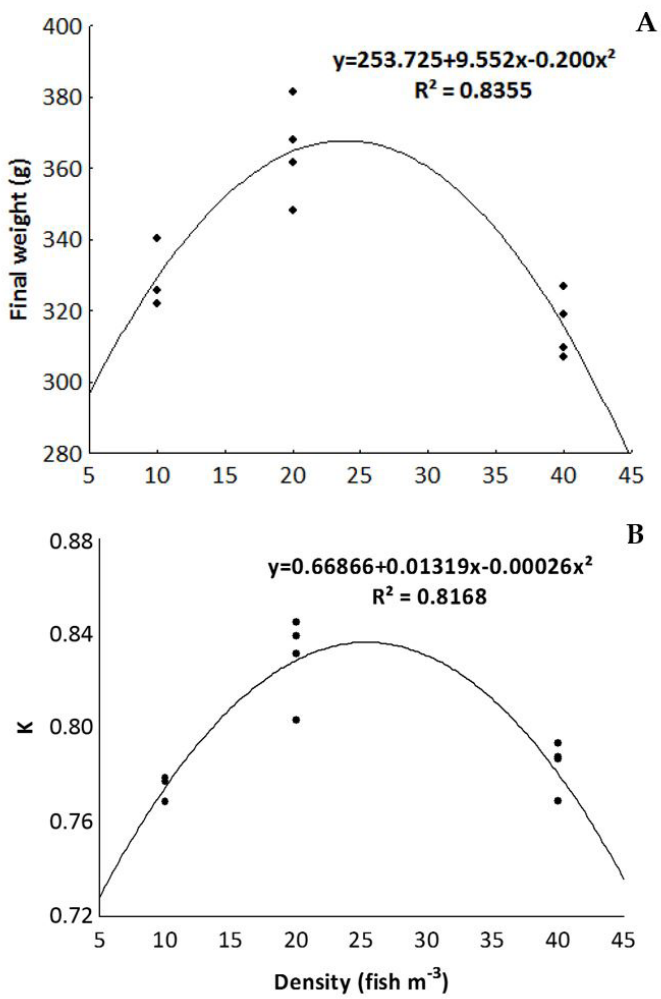

Figure 4. Final weight (A) and condition factor K (B) of common snook reared in cages at three stocking densities in phase 2.

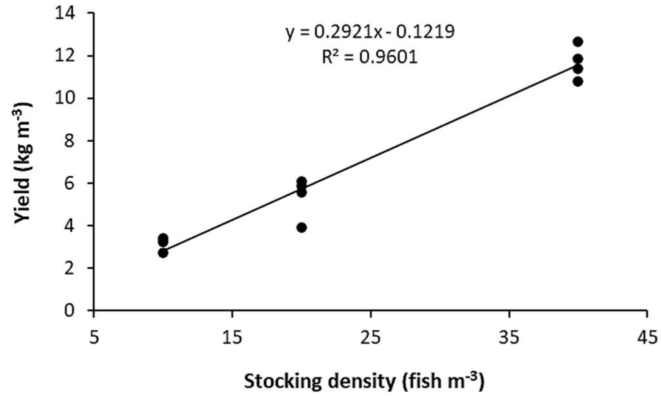

Figure 5. Yield (kg m^{-3}) of common snook reared in cages at three stocking densities in phase 2.

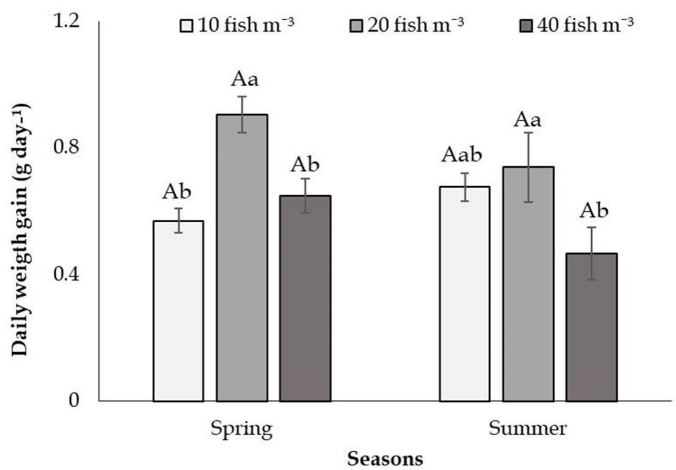

Figure 6. Daily weight gain of common snook reared in cages at three stocking densities according to the season of the year in phase 2. Bars show mean ± SD (n = 4), and significant differences are indicated by different letters (lowercase for densities within each season; uppercase for seasons within each density).

The values of final biomass and yield increased significantly with increasing stocking density. Figure 5 shows the yield at the evaluated densities, where yield at 40 fish m^{-3} (11.6 kg m^{-3}) was significantly higher than yield at 20 fish m^{-3} (5.9 kg m^{-3}) and at 10 fish m^{-3} (3.2 kg m^{-3}).

Data analysis assessing the effects on zootechnical parameters at different storage densities (10, 20, and 40 fish m^{-3}) showed no interaction effect between density and the different seasons on survival. Both density and season did not interfere with survival: 95.3% in spring and 93.4% in summer.

For daily weight gain, there was an interaction between density and season. At a density of 20 fish m^{-3}, the animals had a higher DWG than at densities of 10 and 40 fish m^{-3} for spring. However, in the summer, a density of 10 fish m^{-3} (0.68 g day^{-1}) did not differ statistically from that of 20 fish m^{-3} (0.74 g day^{-1}) (Figure 6). In the same season, a density of 40 fish density yielded 0.47 g day^{-1}.

Fish performance for each density evaluated did not present a statistical difference between spring and summer. For the plain feed efficiency, there was an interaction between density and season. At a density of 20 fish m^{-3}, the animals performed better in spring (36.49%) compared to summer (21.47%) (Figure 7).

Spring did not influence the FER at different densities, whilst summer was best for a density of 10 fish m^{-3}. The lower density behaved similar in different seasons, where the values were close to 23.4% (spring) and 21.8% (summer). The density of 40 fish m^{-3} showed the best result in spring (25.65%) and the worst in summer (14.45%).

Regarding the specific growth rate, we found an interaction effect between density and season. Spring and summer did not change the SGR in at a density of 10 fish m^{-3} but had an impact of the SGR at densities of 20 and 40 fish m^{-3}, with better results in spring (Figure 8).

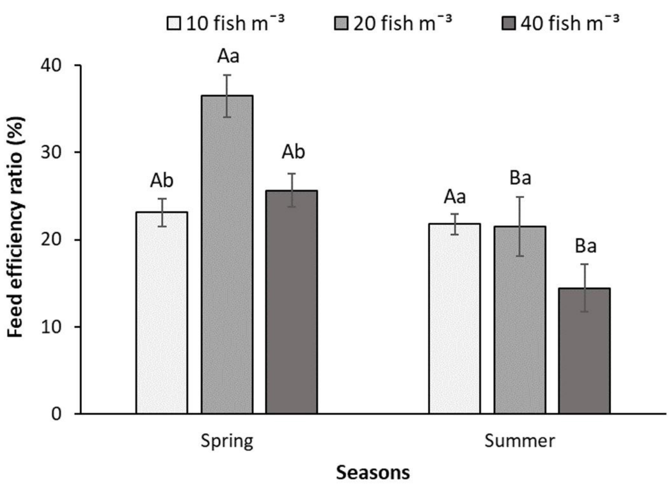

Figure 7. Feed efficiency ratio of common snook reared in cages at three stocking densities according to the season of the year in phase 2. Bars show mean ± SD (n = 4), and significant differences are indicated by different letters (lowercase for densities within each season; uppercase for seasons within each density).

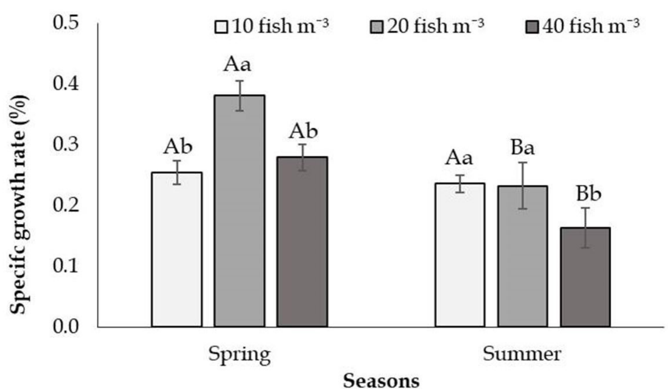

Figure 8. Specific growth rate of common snook reared in cages at three stocking densities according to the season of the year in phase 2. Bars show mean ± SD (n = 4), and significant differences are indicated by different letters (lowercase for densities within each season; uppercase for seasons within each density).

DISCUSSION

Overall feed efficiency rates throughout common snook cultivation in cages were low in both experiments, especially in Experiment 1. Feed efficiency during the first growth phase (70 to 200 g) in this study was below 10%, that is, more than 10 kg of feed were spent to fatten 1 kg of snook. Even in marine fish farming, the cost of food is the main cost of production, reaching 75% of the variable cost (Bjørndal and Tusvik, 2019), and feed efficiency of this magnitude can make the production of any species unfeasible.

The commercial diet used for this study, despite being recommended for carnivorous fish, may not be suitable for common snook, as these recommendations generally rely on the knowledge about freshwater carnivorous fish such as trout (Tsuzuki and Berestinas, 2008). In a study with fat snook juveniles, the use of feed for marine shrimp had a better zootechnical performance than using feed for carnivorous fish (Tsuzuki and Berestinas, 2008). Silvão and Nunes (2017) evaluated the effects of different dietary amino acid compositions for *C. undecimalis* and found a greater ability of snook to gain weight and increase nutrient retention when the dietary protein was of animal origin, such as protein from poultry by-product meal, with a composition of dietary amino acids more balanced in relation to that of fish muscle. David et al. (2019), comparing diets without carbohydrates (60.59 g of crude protein) and with 15.25 g of carbohydrates (46.62 g of crude protein) in the fattening of common snook in a recirculation system, at an average temperature of 28.29 ºC, found an increase in weight by 22.20% for fish fed the diet without carbohydrates.

Another factor that influenced feed efficiency in this study was temperature. Generally, at lower temperatures, the growth of snooks decreased and the feed efficiency decreased. This fact explains the better feed efficiency in the second experiment, as it was carried out in the spring and summer. Cerqueira et al. (2020) found that fat snook (*C. parallelus*) do not feed at temperatures below 14°C; as the temperature increases, consumption increases proportionally up to 30°C, and above this level, the fish return to decreased consumption. There is a need to carry out more studies on nutritional requirements and feed management of snook under the conditions of environmental variation, such as temperature changes.

Water temperature also had a strong influence on the survival of snook. The low survival achieved during the first phase (56%) resulted from the management biometrics in late fall, added to the low temperatures of the day (18ºC). In the first weeks after this management, it was possible to observe approximately 30% of mortalities in the experimental units. When the seasonal factor was included in the analysis, it had a significant effect (p <0.001) on the survival rate: 98.6% ± 2.9% in summer, 91.2 ± 6.7% in fall, and 55.9 ± 5.1% in winter. During the winter, the average temperature was 19.36°C, with a minimum of 16.9°C, close to the known tolerance limit for the species (Gilmore et al., 1983; Shafland and Foote, 1983; Howells et al., 1990; Adams et al., 2012; Blewett and Stevens, 2014; Purtlebaugh et al., 2020). The survival of approximately 91% during the hottest periods (spring and summer) corroborates the results of Ostini et al. (2007), who obtained high survival rates (96.7 and 99.2%) for the growth of common snook in cages at an average temperature of 22.6°C and at densities of 20 and 40 fish m^{-3}.

Density had no effect on survival, but during phase 1 (70 to 200 g), it had a negative linear relationship with the following zootechnical parameters: FW, DWG, SGR, and FER. Ostini et al. (2007) found a similar result in the pre-fattening of common snook with a density of 20 fish m^{-3} in the weight range of 32.5 to 125.9 g. However, it is noteworthy that for the pre-fattening phase, the densities used for marine fish farming worldwide are higher. In Asia, barramundi pre-fattening is performed in 50-m^3 cages with an initial density of 40–50 fish m^{-3} until the fish reach 150 to 200 g, and subsequently, the population density decreases to 10–20 fish m^{-3} (Tiensongrusmee et al., 1989). In grouper cultivation, the densities used until the end of cultivation range from 20 to 100 fish m^{-3} (Liao and Leaño, 2008).

In addition to density, temperature clearly influenced the zootechnical parameters of common snook cultivated in cages at sea. Daily growth and feed efficiency rate during summer were two to four times higher than those during fall or winter (Figures 2 and 3). The best specific growth rate obtained in this study was 0.82% day^{-1} reached in the summer of phase 1 (27.16°C), closer to the thermal comfort of the species (Winner et al., 2010), at the density of 20 fish m^{-3}. David et al. (2019) found SGR values close to 0.84% day^{-1} for common snook at 28.59ºC in a recirculation system. Souza-Filho and Cerqueira (2003), in the experimental cultivation of juvenile snook (~ 60 g), with a temperature between 23.3 and 30.6 ºC, presented mean TCE values of 0.7% day^{-1}. Liebl et al. (2016), in net cages in freshwater, also observed a significant reduction in common snook comparing the summer growth with the fall and winter seasons.

In phase 2 of the cultivation (200 to 350 g), the season did not significantly interfere with the zootechnical performance of the common snook, as this phase occurred in spring and summer. However, the density presented a greater interference with the growth parameters in phase 2, with a quadratic relation of density with the parameters FW and DWG. This difference in density response between the different phases may be related to the final biomass reached in each phase. While in phase 1, the final productivity reached in the cage with higher density was, on average, 3.2 kg m^{-3}, in phase 2, this productivity reached 11.6 kg m^{-3}. Thus, in phase 2, it was possible to observe an optimal density for the cultivation of common snook under these conditions, which was 24 fish m^{-3}, representing a productivity of approximately 7.1 kg m^{-3} with fish having a harvest weight above 300 g (Figure 4). These densities and harvest weights are close to those used commercially for European sea bass (*D. labrax*) and sea bream (*S. aurata*) (Trapani et al., 2014).

The condition factor is often used in fish biology studies as an indicator of the physiological state of animals and is based on the assumption that fish with higher weight at a given length are in a better condition (Lima-Junior et al., 2002). The cultivation density of common snook showed a quadratic relationship with the condition factor. Figure 4 shows that the density with the highest condition factor for the common snook was 25.4 fish m^{-3}, a density close to that obtaining the best growth. The condition factor values found in this study were similar to those found in other studies with common snook (Souza-Filho and Cerqueira, 2003; Noffs et al., 2013).

CONCLUSIONS

Based on our results, stocking density influenced the final weight and daily growth of common snook (*C. undecimalis*) during the two cultivation stages. In the final stage, at the density of 40 fish m^{-3}, it was possible to reach an average productivity of 11.6 kg m^{-3} with a final weight above 300 g for the cultivation of common snook in net cages at sea. However, under these experimental conditions, the density that would provide the highest final weight is 24 fish m^{-3}.

Temperature had a great influence on the growth and survival of the common snook throughout the cultivation period, which may be a limiting factor to produce this species in regions with a subtropical climate, such as in Santa Catarina. The handling of common snook at temperatures below 20ºC is not recommended to avoid mortalities, as observed in this study.

REFERENCES

Adams, A.J.; Hill, J.E.; Kurth, B.N.; Barbour, A.B. 2012. Effects of a severe cold event on the subtropical, estuarine-dependent common snook, *Centropomus undecimalis*. Gulf and Caribbean Research, 24(1): 13-21. https://doi.org/**10.18785/gcr.2401.03**.

Alvarez-Lajonchère, L.S.; Tsuzuki, M.Y. 2008. A review of methods for *Centropomus* spp. (snooks) aquaculture and recommendations for the establishment of their culture in Latin America. Aquaculture Research, 39(7): 684-700. https://doi.org/**10.1111/j.1365-2109.2008.01921.x**.

Ambrosio, P.P.; Costa, C.; Pablo, S.; Flos, R. 2008. Stocking density and its influence on shape of Senegalese sole adults. Aquaculture International, 16(4): 333-343. https://doi.org/**10.1007/s10499-007-9147-5**.

Arenas, M.; Álvarez-González, C.A.; Barreto, A.; Sánchez-Zamora, A.; Suárez-Bautista, J.; Cuzon, G.; Gaxiola, G. 2021. Physiological and metabolic protein-sparing effects of dietary lipids on common snook *Centropomus undecimalis* (Bloch, 1792) juveniles. Aquaculture Nutrition, 27(4): 1089-1102. https://doi.org/**10.1111/anu.13250**.

Beveridge, M. 2004. Cage Aquaculture. 3rd ed. New York: Wiley-Blackwell. 380p.

Bhujel, R.C. 2008. Statistics for aquaculture. 1st ed. Iowa: Wiley-Blackwell. 240p.

Bjørndal, T.; Tusvik, A. 2019. Economic analysis of land based farming of salmon. Aquaculture Economics & Management, 23(4): 449-475. https://doi.org/**10.1080/13657305.2019.1654558**.

Björnsson, B. 1994. Effects of stocking density on growth rate of halibut (*Hippoglossus hippoglossus*) reared in large circular tanks for three years. Aquaculture, 123(3-4): 259-270. https://doi.org/**10.1016/0044-8486(94)90064-7**.

Blewett, D.A.; Stevens, P.W. 2014. Temperature variability in a subtropical estuary and implications for Common Snook *Centropomus undecimalis*, a cold-sensitive fish. Gulf of Mexico Science, 32(1): 44-54. https://doi.org/**10.18785/goms.3201.04**.

Cerqueira, V.R.; Carvalho, C.V.C.; Sanches, E.G.; Passini, G.; Baloi, M.; Rodrigues, R.V. 2017. Manejo de reprodutores e controle da reprodução de peixes marinhos da costa brasileira. Revista Brasileira de Reprodução Animal, 41(1): 94-102.

Cerqueira, V.R.; Passini, G.; Carvalho, C.V.A.; Sterzelecki, F.; Cipriano, F.S. 2020. Cultivo de robalo-flecha (*Centropomus undecimalis*) e robalo-peva (*Centropomus parallelus*). In: Baldisserotto, B. (ed.). Espécies nativas para piscicultura no Brasil. 3. ed. Santa Maria: Editora da UFSM. p. 449-474.

Costa, C.; Menesatti, P.; Rambaldi, E.; Argenti, L.; Bianchini, M.L. 2013. Preliminary evidence of colour differences in European sea bass reared under organic protocols. Aquacultural Engineering, 57: 82-88. https://doi.org/**10.1016/j.aquaeng.2013.08.001**.

David, L.H.C.; Pinho, S.M.; Correia, D.; Tsuzuki, M.T.; Emerenciano, M.G.C.; Mello, G.L. 2019. Desempenho zootécnico e rendimento de filé do robalo-flecha alimentado com diferentes dietas comerciais. LABOMAR, 52(1): 69-80.

EUMOFA – European Market Observatory for Fisheries and Aquaculture Products. 2018. Case study: seabass in the EU. Price structure in the supply chain for seabass. Brussels: European Commission. 47p. https://doi.org/**10.2771/74704**.

FAO – Food and Agriculture Organization of the United Nations. 2009. Cultured Aquatic Species Information Programme. *Lates calcarifer* (Block, 1790) [online]. URL: <http://www.fao.org/fishery/culturedspecies/Lates_calcarifer/en>.

Gilmore, R.G.; Donahoe, C.J.; Cooke, D.W. 1983. Observações sobre a distribuição e biologia do robalo, *Centropomus undecimalis* (Bloch). Florida Scientist, 46: 313-336.

Gracia-López, V.; García-Galano, T.; Gaxiola-Cortés, G.; Pacheco-Campos, J. 2003. Efecto del nivel de proteína en la dieta y alimentos comerciales sobre el crecimiento y la alimentación en juveniles del robalo blanco, *Centropomus undecimalis* (Bloch, 1792). Ciencias Marinas, 29(4B): 585-594. http://dx.doi.org/**10.7773/cm.v29i42.198**.

Howells, R.G.; Sonski, A.J.; Shafland, P.L.; Hilton, B.D. 1990. Lower temperature tolerance of snook, *Centropomus undecimalis*. Northeast Gulf Science, 11(2): 155-158. https://doi.org/**10.18785/negs.1102.08**.

Ibarra-Castro, L.; Alvarez-Lajonchère, L.; Rosas, C.; Palomino-Albarrána, I.G.; Holt, J.; Sanchez-Zamora, A. 2011. GnRHa-induced spawning with natural fertilization and pilot-scale juvenile mass production of common snook, *Centropomus undecimalis* (Bloch, 1792). Aquaculture (Amsterdam, Netherlands), 319(3-4): 479-483. https://doi.org/**10.1016/j.aquaculture.2011.07.014**.

Liao, I.C.; Leaño, E.M. 2008. The aquaculture of groupers. 1st ed. Keelung: Asian Fisheries Society, National Taiwan Ocean University, The Fisheries Society of Taiwan, World Aquaculture Society. 241p.

Liebl, F.; Amaral Junior, H.; Garcia, S.; Souto, L.; Carvalho, C.V.A.; Cerqueira, V.R. 2016. Desempenho de juvenis de robalo-flecha e robalo-peva submetidos a diferentes densidades de estocagem em água doce. Boletim do Instituto de Pesca, 42(1): 145-155. https://doi.org/**10.20950/1678-2305.2016v42n1p145**.

Lima-Junior, S.E.; Cardone, I.B.; Goitein, R. 2002. Determination of a method for calculation of allometric condition factor of fish. Acta Scientiarum, 24: 397-400.

Llorente, I.; Polanco, J.F.; Diez, E.B.; Odriozola, M.D.; Bjørndal, T.; Asche, F.; Guillen, J.; Avdelas, L.; Nielsen, R.; Cozzolino, M.; Luna, M.; Sánchez, J.L.F.; Luna, L.; Aguilera, C.; Basurco, B. 2020. Assessment of the economic performance of the seabream and seabass aquaculture industry in the European Union. Marine Policy, 117: 103876. https://doi.org/**10.1016/j.marpol.2020.103876**.

Moretti, A.; Fernandez-Criado, M.; Cittolin, G.; Guidastri, R. 1999. Manual on hatchery production of seabass and gilthead seabream. Rome: Italy: FAO. 194p.

Muller, R.G.; Taylor, R.G. 2000. Stock assessment update of common snook, *Centropomus undecimalis*. St. Petersburg: Florida Marine Research Institute. 48p.

Noffs, A.P.; Tachibana, L.; Santos, A.A.; Ranzani-Paiva, M.J.T. 2015. Common snook fed in alternate and continuous regimens with diet supplemented with *Bacillus subtilis* probiotic. Pesquisa Agropecuária Brasileira, 50(4): 267-272. http://dx.doi.org/**10.1590/S0100-204X2015000400001**.

Oliveira, R.L.M.; Santos, L.B.G.; Silva Neto, N.G.; Silva, S.P.A.; Silva, F.S.; Melatti, E.; Cavalli, R.O. 2019. Feeding rate and feeding frequency affect growth performance of common snook (*Centropomus undecimalis*) juveniles reared in the laboratory. Brazilian Journal of Animal Science, 48: e20170292. https://doi.org/**10.1590/rbz4820170292**.

Ostini, S.; Oliveira, I.R.; Serralheiro, P.C.S.; Sanches, E.G. 2007. Criação de robalo-peva *Centropomus parallelus* submetido a diferentes densidades de estocagem. Revista Brasileira de Saúde e Produção Animal, 8(3): 247-254.

Passini, G.; Carvalho, C.V.A.; Sterzelecki, F.C.; Baloi, M.F.; Cerqueira, V.R. 2019. Spermatogenesis and steroid hormone profile in puberty of laboratory-T reared common snook (*Centropomus undecimalis*). Aquaculture, 500: 622-630. https://doi.org/**10.1016/j.aquaculture.2018.10.031**.

Passini, G.; Sterzelecki, F.C.; Carvalho, C.V.A.; Baloi, M.F.; Naide, V.; Cerqueira, V.R. 2018. 17α-Methyltestosterone implants accelerate spermatogenesis in common snook, *Centropomus undecimalis*, during first sexual maturation. Theriogenology, 106: 134-140. https://doi.org/**10.1016/j.theriogenology.2017.10.015**.

Pope, K.L.; Blankinship, D.R.; Fisher, M.; Patino, R. 2006. Status of the common snook (*Centropomus undecimalis*) in Texas. The Texas Journal of Science, 58: 325-332.

Purtlebaugh, C.H.; Martin, C.W.; Allen, M.S. 2020. Poleward expansion of common snook *Centropomus undecimalis* in the northeastern Gulf of Mexico and future research needs. PLoS One, 15(6): e0234083. https://doi.org/**10.1371/journal.pone.0234083**.

Rivas, L.R. 1986. Systematic review of the Perciform fishes of the genus *Centropomus*. Copeia, (3): 578-611. https://doi.org/**10.2307/1444940**.

Rowland, S.J.; Mifsud, C.; Nixon, M.; Boyd, P. 2006. Effects of stocking density on the performance of the Australian freshwater silver perch (*Bidyanus bidyanus*) in cages. Aquaculture (Amsterdam, Netherlands), 253(1-4): 301-308. https://doi.org/**10.1016/j.aquaculture.2005.04.049**.

Shafland, P.L.; Foote, K.J. 1983. A lower lethal temperature for fingerling snook (*Centropomus undecimalis*). Northeast Gulf Science, 6(2): 175-177. https://doi.org/**10.18785/negs.0602.12**.

Silvão, C.F.; Nunes, A.J.P. 2017. Effect of dietary amino acid composition from proteins alternative to fishmeal on the growth of juveniles of the common snook, *Centropomus undecimalis*. Revista Brasileira de Zootecnia, 46(7): 569-575. https://doi.org/**10.1590/S1806-92902017000700003**.

Souza-Filho, J.J.; Cerqueira, V.R. 2003. Influência da densidade de estocagem no cultivo de juvenis de robalo-flecha mantidos em laboratório. Pesquisa Agropecuária Brasileira, 38(11): 1317-1322. https://doi.org/**10.1590/S0100-204X2003001100010**.

Tavares, L.E.R.; Luque, J.L. 2003. A new species of *Acantholochus* (Copepoda: Bomolochidae) parasitic on *Centropomus undecimalis* (Osteichthyes: Centropomidae) from the coastal zone of the State of Rio de Janeiro, Brazil. Memorias do Instituto Oswaldo Cruz, 98(2): 241-245. https://doi.org/**10.1590/S0074-02762003000200013**.

Taylor, G.R.; Wittington, J.A.; Grier, H.J.; Crabtree, R.E. 2000. Age, growth, maturation, and protandric sex reversal in common snook, *Centropomus undecimalis*, from the east and west coasts of south Florida. Fishery Bulletin. National Marine Fisheries Service, 98(3): 612-624.

Taylor, R.G.; Grier, H.J.; Whittington, J.A. 1998. Spawning rhythms of common snook in Florida. Journal of Fish Biology, 53(3): 502-520. https://doi.org/**10.1111/j.1095-8649.1998.tb00998.x**.

Tiensongrusmee, B.; Budileksono, S.; Cjhanstarasri, S.; Yuwono, S.K.Y.; Santoso, H. 1989. Propagation of seabass, *Lates calcarifer* in captivity. Lampung: FAO Seafarming Development Project. 55p. Avaiable at <http://www.fao.org/3/AB889E/AB889E00.htm>. Accessed in: Dec 10, 2020.

Trapani, A.M.D.; Sgroi, F.; Testa, R.; Tudisca, S. 2014. Economic comparison between offshore and inshore aquaculture production systems of European sea bass in Italy. Aquaculture, 434: 334-339. https://doi.org/**10.1016/j.aquaculture.2014.09.001**.

Tsuzuki, M.Y.; Berestinas, A.C. 2008. Desempenho de juvenis de robalo-peva *Centropomus parallelus* com diferentes dietas comerciais e frequências alimentares. Boletim do Instituto de Pesca, 34(4): 535-541.

Tucker, J.W. 1987. Snook and tarpon snook culture and preliminary evaluation for commercial farming. Progressive Fish-Culturist, 49(1): 49-57. https://doi.org/**10.1577/1548-8640(1987)49<49:SATSCA>2.0.CO;2**.

Tucker, J.W. 1998 Culture of Established and Potential Species - Food Fish. In: Tucker Junior, J.W. (ed.). Marine fish culture. Boston: Springer. Chapter 13, p. 533-574. https://doi.org/**10.1007/978-1-4615-4911-6_13**.

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

Winner, B.L.; Blewett, D.A.; McMichael, R.H.; Guenther, C.B. 2010. Relative abundance and distribution of common snook along shoreline habitats of Florida Estuaries. Transactions of the American Fisheries Society, 139(1): 62-79. https://doi.org/**10.1577/T08-215.1**.