GROWTH AND SURVIVAL OF BOTTOM OYSTER *Crassostrea gasar* CULTURED IN THE NORTHEAST AND SOUTH OF BRAZIL

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ABSTRACT

This study evaluated the growth, survival, and time to reach the minimum market size (50 mm shell height) of the bottom oyster *Crassostrea gasar* with seeds produced at hatchery. Culture areas were located in the States of Maranhão [1-Morro do Meio (MM); 2-Torto (TT)] and Santa Catarina [1-São Francisco do Sul (SFS); 2-Florianópolis (SB)]. Eight thousand seeds were transferred to each location and cultivated from June 2012 to July 2013. Oyster growth in Santa Catarina was bigger than in Maranhão. The ideal cultivation time was of 8 months, when animals had an average shell height of 71.96(±8.05) mm in SFS; 55.31(±6.05) mm in SB; and 46.92(±9.11) mm in TT. Morro do Meio (MM) was considered unsuitable for *C. gasar* growth, as the average shell height was 36.20(±12.40) mm after a 13-month cultivation. Survival rates varied throughout the year: 79.82-99.69% in SFS; 80.00-99.81% in SB; 90.59-98.21% in TT; and 64.98-96.54% in MM.

Key words: total wet weight; shell height; culture; native oyster; *Crassostrea gasar*.

CRESCIMENTO E SOBREVIVÊNCIA DA OSTRA DE FUNDO, *Crassostrea gasar*, CULTIVADA NO NORDESTE E SUL DO BRASIL

RESUMO

Este estudo avaliou o crescimento, a sobrevivência e o tempo para atingir o tamanho mínimo de comercialização (50 mm altura da concha), da ostra-de-fundo *Crassostrea gasar* com sementes produzidas em laboratório. As áreas de cultivo foram localizadas nos Estados do Maranhão [1-Morro do Meio (MM); 2-Torto (TT)] e Santa Catarina [1-São Francisco do Sul (SFS); 2-Florianópolis (SB)]. Oito mil sementes foram transferidas para cada local e cultivadas entre junho de 2012 e julho de 2013. O crescimento dos indivíduos em Santa Catarina foi superior ao observado no Maranhão ($p<0,05$). O tempo ideal de cultivo foi de 8 meses, quando os animais apresentaram média de altura da concha de 71,96(±8,05) mm em SFS; 55,31(±6,05) mm em SB; e 46,92(±9,11) mm no TT. A área do Morro do Meio (MM) foi considerada inadequada para o cultivo de *C. gasar* devido ao baixo crescimento ao final de 13 meses 36,20(±12,40) mm. As taxas de sobrevivência variaram entre: 79,82-99,69% em SFS; 80,00-99,81% em SB; 90,59-98,21% no TT; e 64,98-96,54% no MM.

Palavras-chave: peso total; altura de concha; cultivo; ostra nativa; *Crassostrea gasar*.

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INTRODUCTION

Bivalve molluscs respond for most of the mariculture production, corresponding with 60.3% of the marine food cultured in 2012 (FAO, 2014). Among the cultured bivalve species, oysters of the genus *Crassostrea* stand out for their economic importance with an average production of 4.6 million tons per year (FAO, 2010). In Brazil, oyster production is linked to three *Crassostrea* species: two native species, *Crassostrea gasar* (=*Crassostrea brasiliana*) and *Crassostrea rhizophorae*, and the Pacific oyster *Crassostrea gigas*. According to the latest official statistics, the total oyster production was 3,771.4 t in 2011 with 67.35% (2,538.4 t) coming from the oyster farming and 32.7% from the native species capture (BRASIL, 2013). In the same year, the State of Santa Catarina produced 2,285 t of *C. gigas* (SANTA CATARINA, 2015).

Analyzing data from fishery and aquaculture production (BRASIL, 2013; SANTA CATARINA, 2015) *Crossostrea. gigas* contribute with 60.6% of the total oyster production and 90% of the cultured oysters, while the native species represented 39.4% and 10%, respectively,. However, *C. gigas* is restricted to few regions, with colder seawater temperatures, since higher temperatures throughout the year can compromise growth and survival rates (POLI, 2004). Thus, the expansion of oyster farming in the tropical regions is linked to domestication and the development of technological basis for native species. The bottom oyster *C. gasar* stands out among the potential native species for oyster culture, since it reaches larger sizes than *C. rhizophorae* (CHRISTO and ABSHER, 2006), and it has been farmed with relative success in the states of Paraná (BALDAN and BENDHACK, 2009) and São Paulo (MIGNANI *et al*., 2013; COLLAÇO *et al*., 2014; DOI *et al*., 2015).

Studies with Brazilian native oysters may be controversial until the 21th century, due to the taxonomic uncertainty within the genus *Crassostrea* and lack of genetic analysis. Based on morphological characters, RIOS (2009) considered the existence of only one native oyster species, *C. rhizophorae*. However, based on genetic markers IGNACIO *et al*. (2000) confirmed the presence of two distinct species (*C. rhizophorae* and *C. brasiliana*). It was later found that *C. brasiliana* has no genetic differentiation from *C. gasar* and it is a junior synonym of the latter (VARELA *et al*., 2007; MELO *et al*., 2010; LAZOSKI *et al*., 2011). Thus, previous studies may have included one or even both species in their analysis (LOPES *et al*., 2013; CASTILHO-WESTPHAL *et al*., 2015).

Most studies on growth of Brazilian native oysters were carried out in the Southeast and South regions, through spat collection in the wild, without the confirmation of species identity or knowledge about oyster`s age (PEREIRA *et al*., 1991; PEREIRA and SOARES, 1996; PEREIRA *et al*., 2001; GALVÃO *et al*., 2009; BARBIERI *et al*., 2012). The only research works on oyster growth with genetic identification was conducted in the South. LOPES *et al*. (2013) evaluated the growth of seeds produced in the laboratory in two farming areas of Santa Catarina, and MONTANHINI-NETO *et al*. (2013) evaluated the weight gain of seeds collected in the state of Paraná.

Seed supply is a critical element for marine bivalve culture (GOSLING, 2003; FERREIRA *et al*., 2011) and it has been hindering the cultivation of *C. gasar* in Brazil. Although the use of artificial collectors to obtain oyster seeds in the wild is an advantageous method (FERREIRA and OLIVEIRA-NETO, 2007), the results of TURECK (2010) and MONTANHINI-NETO *et al*. (2013) demonstrated that *C. gasar* spat collection is difficult due to the occurrence of overlapping settlement periods with other oyster species. When obtaining seeds using artificial collectors is not viable, seed production in hatcheries is an efficient approach (FERREIRA and OLIVEIRA-NETO, 2007).

Studies on the cultivation of *C. gasar* in the North and Northeast are still scarce, although these regions show the highest percentage of mangrove ecosystem areas in Brazil, where *C. gasar* is commonly found (NASCIMENTO, 1991).

Thus, this study evaluated survival and growth of the bottom oyster *C. gasar* from seeds produced in laboratory and cultivated in the State of Santa Catarina (South Region) and in the State of Maranhão (Northeast Region). To the best of our knowledge, this is the first work on growth performance of *C. gasar* in the Northeast with prior information about oyster age and species' genetic identity.

METHODS

Experimental design was completely randomized with four treatments, represented by the cultivation sites and eight experimental units (EU), represented by lantern-net in Santa Catarina and mesh bags in Maranhão.

Obtaining seeds

Seeds were produced at the Laboratory of Marine Molluscs of the Federal University of Santa Catarina (LMM-UFSC) using sixth generation *C. gasar* broodstocks, free of notifiable parasites (SÜHNEL *et al.*, 2016), held in Praia do Sambaqui, Florianópolis (Figure 1). Larvae culture and settlement were performed according to the methodology described by SILVEIRA *et al.* (2011). The age of the animals used in this study refers to the number of days from the fertilization to the sampled date, and it is described as "days of age" (DA).

Field experiment

The experiment was carried in two farming areas located in Santa Catarina and two in Maranhão (Figure 1), between June 2012 and July 2013. In Santa Catarina, seeds were taken to Babitonga Bay (SFS), São Francisco do Sul (26°28'S; 48°50'W) and to Sambaqui Beach (SB), Florianópolis (27°35'S; 48°32'W). In Maranhão, the two farming areas were located in the Parnaíba River Delta Araioses city: one in Morro do Meio (MM) (02°44'S; 41°58'W) and the other in Torto (TT) (02°47'S; 41°55'). Oyster seeds of same height (5.85 ± 2.00 mm) and age (60 to 65 days old) were shipped in styrofoam boxes to the farming areas at Santa Catarina and Maranhão. In each studied farm area, eight EUs were used, with 1,000 seeds per EU, totaling 8,000 seeds for each studied location. The culture technique was adopted according the environment conditions and the type of culture commonly used by producers at each state.

In Santa Catarina, where farms areas are located in the ocean near the coast (most bay regions), the depths are between 4 and 40 m, the oyster were cultured in longlines (lantern-net). In Maranhão, where the farms areas are located in riverbanks in estuarine areas, with strong tidal variation (2 to 4 m), the oysters were cultured in off-bottom culture using mesh bags.

The seed stocking density was calculated considering the internal area of EU and was standardized by 100% occupancy of each lantern-net floor and each mesh bag during all experimental period, without overlapping the individuals. Handling consisted of fouling removal, EU repair (if necessary) and stocking density control. In both States, nursery phase lasted for 90 days, intermediate phase 90 days and final phase 210 days, totaling 390 days of culture.

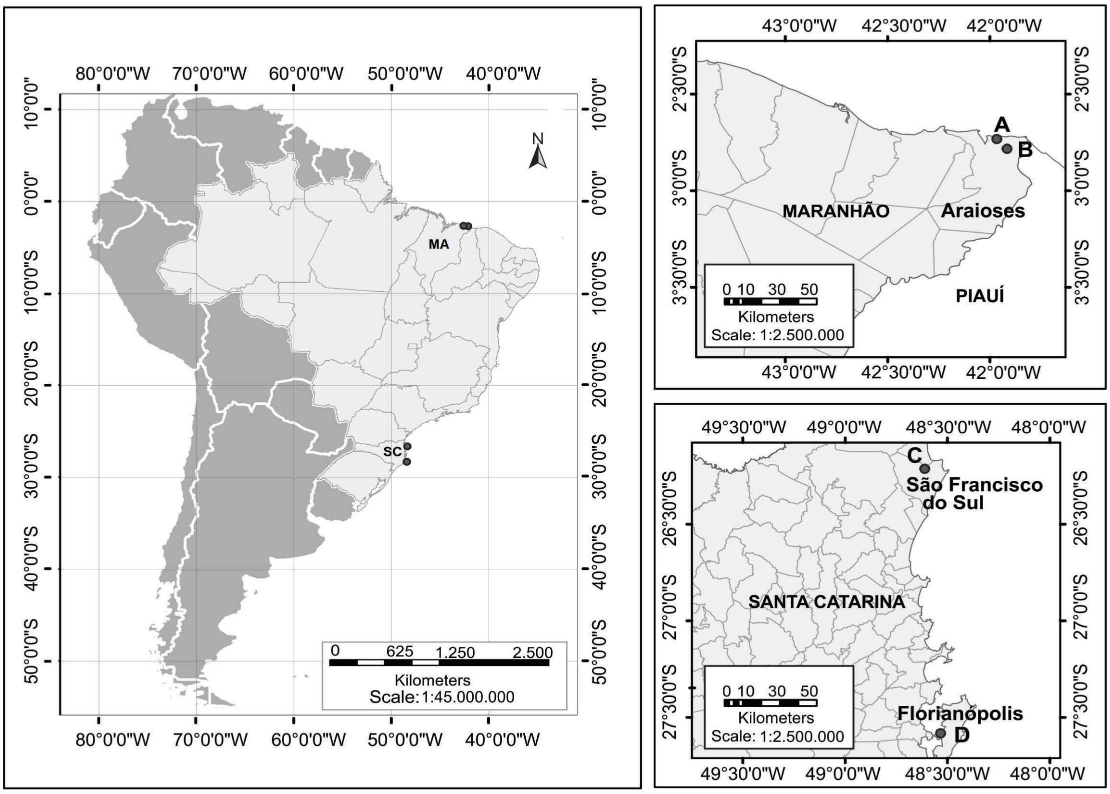

Figure 1. Culture areas in the state of Maranhão, city of Araioses: A = MM (Morro do Meio, 02° 44'S and 41° 58'W) and B = TT (Torto, 02° 47'S and 41 ° 55'W). Areas in the State of Santa Catarina: C = SFS (São Francisco do Sul; 26° 28'S and 48° 50'W) and D = SB (Sambaqui, municipality of Florianopolis; 27° 35'S and 48° 32'W).

In Santa Catarina, for both areas, EU remained submerged throughout the study period, except during the animal handling. The floor of lantern-net in each phase was the same (1,970 cm^2). Handling of animals in nurseries lantern-nets was carried out every two weeks and for animals in intermediate and final lantern-nets was monthly. Seeds number at nursery phase for each lantern-net floor was initially 1,000 seeds (using eight lantern-nets with 2 mm mesh), and according to the animal growth the seeds were transplanting to two floors, conditioning 500 individuals per floor.At intermediate (mesh with 10 mm) and final lantern-net (mesh with 30 mm), the oysters were transplanting to four floors and the number of individuals per floor was 200 to 250 (according oyster growth) and 60 to 80 oysters, respectively.

In Maranhão, oysters were exposed to air two times daily for 15 to 30 minutes in TT and 60 to 150 minutes in MM, due to tidal variations. The area of mesh bag (mesh with 2 mm) nursery phase was 2,000 cm^2 (40x50 cm; called B1) and 4,000 cm^2 (80x50 cm; called B2), according to the seeds growth, and 4,000 cm^2 at intermediate (mesh with 10 mm) and final (mesh with 20 mm) phases. Fouling removal was weekly during the first month and biweekly after the second month of culture. Seeds number at nursery phase per bag (B1) was initially 1,000 seeds (using eight bags), and according to the animal growth the seeds were transplanting to B2. At intermediate and final phases, the number of oyster per bag was 400 to 500 (according oyster growth) and 200 to 300, respectively.

Monthly, survival, shell height (n=800) and total wet weight (n=40), of oyster in each area were measured. Survival at nursery phase was estimated by counting three samples taken from the total volume of oysters, and at intermediate and final phases counting the total number of live and dead specimens. Before biometrics, oysters from each EU in nursery and intermediate phase were screened, separated into size classes and quantified by size class in order to ensure the sample representativeness. After this procedure, 100 individuals per EU were randomly taken for measurements. For nursery phase, the number of oysters per size class was estimated using three counting samples of specific volume (according to the screen used) and for intermediate and final phases, the total number of oyster per EU. Animal discard, when necessary, was also performed to keep the number of oysters in each size class. Also, monthly the percentage of oysters that reached the minimum commercial size (50 mm) for each EU, was accounted.

Seawater parameters

Seawater surface salinities and temperatures (20 cm deep) were monthly recorded, using manual refractometers and thermometers, respectively.

Statistical analyses

Data of survival and growth (shell height, total wet weight and percentage of oyster with size up to 50 mm) were first checked for normality (Kolmogorov-Smirnov test) and homogeneity of variance (Brown-Forsythe test) than submitted to analysis of variance (ANOVA). When significant differences were found, Tukey's pair-wise comparisons were performed at a 5% significance level. Statistical analysis was performed using the computer package SAS® (2003). The von Bertalanffy growth function model was fitted to the growth data and the growth constants (K) and asymptotic maximum height and weight ($L\infty$) were calculated for each area using the NLIN procedure in SAS, version 9.1 (SAS Institute, Cary, NC, USA). The phi-prime (φ') growth performance index (MUNRO and PAULY, 1983) was measured according BAGUR *et al*. (2013) ($\varphi = \log K + 2 \times \log L\infty$) to compare growth amongst areas.

RESULTS

Oyster survival

Oyster non-cumulative survival during the experimental period was between 79.82 to 99.69% in SFS, 80.00 to 99.81% in SB, 90.59 to 98.21% in TT and 64.98 to 96.54% in MM. No significant difference in oyster survival was observed between SFS and SB, and between TT and SFS areas. Survival was significantly higher in TT than in SB ($p<0.05$), and it was lower ($p<0.05$) in MM compared to the three other areas (Table 1).

Oyster growth - Shell height and total wet weight

Animal shell heights (Figure 2a) were different ($p<0.05$) between the four culture areas. Largest individuals in height where observed in SFS, followed by SB, TT and MM.

Despite having different ($p<0.05$) shell heights, the oysters from SFS, SB and TT sites showed a similar growth pattern (Figure 2a). At these sites, the animals had a continuous growth ($p<0.05$) until they reached between 270 (SFS and TT) and 305 (SB) days of age (7th and 8th months of field culture, respectively). From these months of culture to the end of the experiment, average shell height for each site showed no difference ($p<0.05$). Growth pattern in MM was different compared to the other areas. It was observed continuous height growth ($p<0.05$) in the first two months of culture. After 270 DA (7th month of culture) growth remained stagnant until individuals have completed 390 DA (11th month of culture).

In relation to the oyster total wet weight, significant differences ($p<0.05$) were observed between the four culture areas. At the end of the experiment, the average total wet weight was higher ($p<0.05$) in SFS (66.58 ± 18.50 g), followed by SB (40.51 ± 10.06 g), TT (24.80 ± 8.79 g) and MM (23.40 ± 16.73 g). Weight showed no continuous growth and fluctuated throughout the experiment period (Figure 2b).

The growth curves adjusted by von Bertalanffy model are shown in Figure 3. The phi-prime growth performance index was similar between SB and TT. The higher value of this index was observed in SFS and the lowest value was observed in MM (Table 2).

Table 1. Non-cumulative survivals of the bottom oyster *Crassostrea gasar* cultivated in the States of Santa Catarina (SFS and SB) and Maranhão (TT and MM), Brazil between June 2012 and July 2013. Where SFS = São Francisco do Sul; SB = Sambaqui; TT = Torto; and MM = Morro do Meio. Values followed by equal letters in the same row do not differ at 5% significancy.

Year	Month	Survival (%)			
		Culture areas			
		SFS	SB	TT	MM
2012	July	99.31 ± 0.79 a	98.81 ± 0.75 a	98.21± 1.02 a	93.73 ± 3.72 b
	August	99.69 ± 0.37 a	99.81 ± 0.25 a	97.72 ± 1.36 a	96.54 ± 2.58 a
	September	90.44 ± 2.45 a	93.44 ± 6.12 a,b	95.45 ± 2.42 b	83.15 ± 9.26 c
	October	93.82 ± 4.07 a	93.56 ± 4.57 a	97.32 ± 2.15 a	80.84 ± 8.59 b
	November	85.93 ± 2.76 a	90.12 ± 4.01 b	92.41 ± 3.29 c	88.07 ± 5.31 d
	December	95.43 ± 1.46 a	96.79 ± 2.09 a	96.04 ± 3.13 a	82.16 ± 3.44 b
	January	90.83 ± 6.09 a	81.05 ± 5.01 b	92.50 ± 2.43 a	86.08 ± 5.10 c
	February	79.82 ± 6.89 a	80.42 ± 3.24 a	93.50 ± 1.39 b	64.98 ± 11.7 c
	March	91.12 ± 3.04 a	84.36 ± 4.98 b	93.95 ± 2.58 a	85.30 ± 8.60 b
2013	April	92.94 ± 3.44 a	80.00 ± 2.62 b	91.81 ± 3.46 a	84.07 ± 7.10 b
	May	93.18 ± 3.08 a	91.54 ± 2.40 a	94.70 ± 3.11 a	93.68 ± 4.20 a
	June	95.96 ± 1.98 a	95.40 ± 2.70 a	90.59 ± 4.87 b	87.99 ± 8.75 b
	July	97.54 ± 2.12 a	95.81 ± 1.79 a,b	92.47 ± 2.68 b	93.75 ± 4.39 a,b

Oyster growth - Size above 50 mm

Only oysters grown in Santa Catarina reached an average shell height above 50 mm (Figure 2a). In SFS, less than 1.0% of oysters above 50 mm were observed on the third month (150 DA). This percentage increases in the 4th (180 DA), 5th (210 DA) and 6th month (240 DA) of culture, with 21.2% 53.0% and 99.8%, respectively. After 7th month of culture, 100% of the animals were larger than 50 mm. At the end of the 8th month, 95.8% had shell height ≥ 60 mm and 60.1% ≥ 70 mm. In SB, less than 1.0% of oysters above 50 mm were recorded on the 4th month of culture (180 DA). On the 6th month (240 DA), 55.6% of the animals were size up 50 mm. At the end of the 8th month, this percentage increase to 82.1% and where 24.1% of the animals had shell height ≥ 60 mm. Oysters ≥ 70 mm occurred after 5th to 13th month of culture, but the amount was about 1% of the sampled animals per month during that period. Oysters grown in Maranhão did not reach an average shell height above 50 mm. At both areas, the highest average was recorded after 13th month of culture, corresponding to 48.90 ± 8.65 mm in TT and 36.20 ± 12.40 mm in MM. In TT, the first oysters above 50 mm were observed at the 3th month of culture (150 DA), representing 1.9% of the sampled animals. However, after the 8th month (300 DA), only 27.9% of the oysters presented shell height ≥ 50 mm, about 8% of the individuals were ≥ 60 mm height and 1% ≥ 70 mm. At the end of the experiment, 31% of the animals showed size up 50 mm, but there was no change in the percentages of oysters above 60 and 70 mm. In MM, the maximum percentage (3.53%) of oysters above 50 mm height was observed in the 8th month (300 DA).

During this period, 0.72% of the animals showed size ≥ 60 mm height. The highest percentage (1%) of oysters above 70 mm height was after 420 DA. As observed for growth in shell height, percentages of oysters above 50 mm were higher between the 8th and the 9th month of culture (300-330 DA), decreasing in the following months, except in TT.

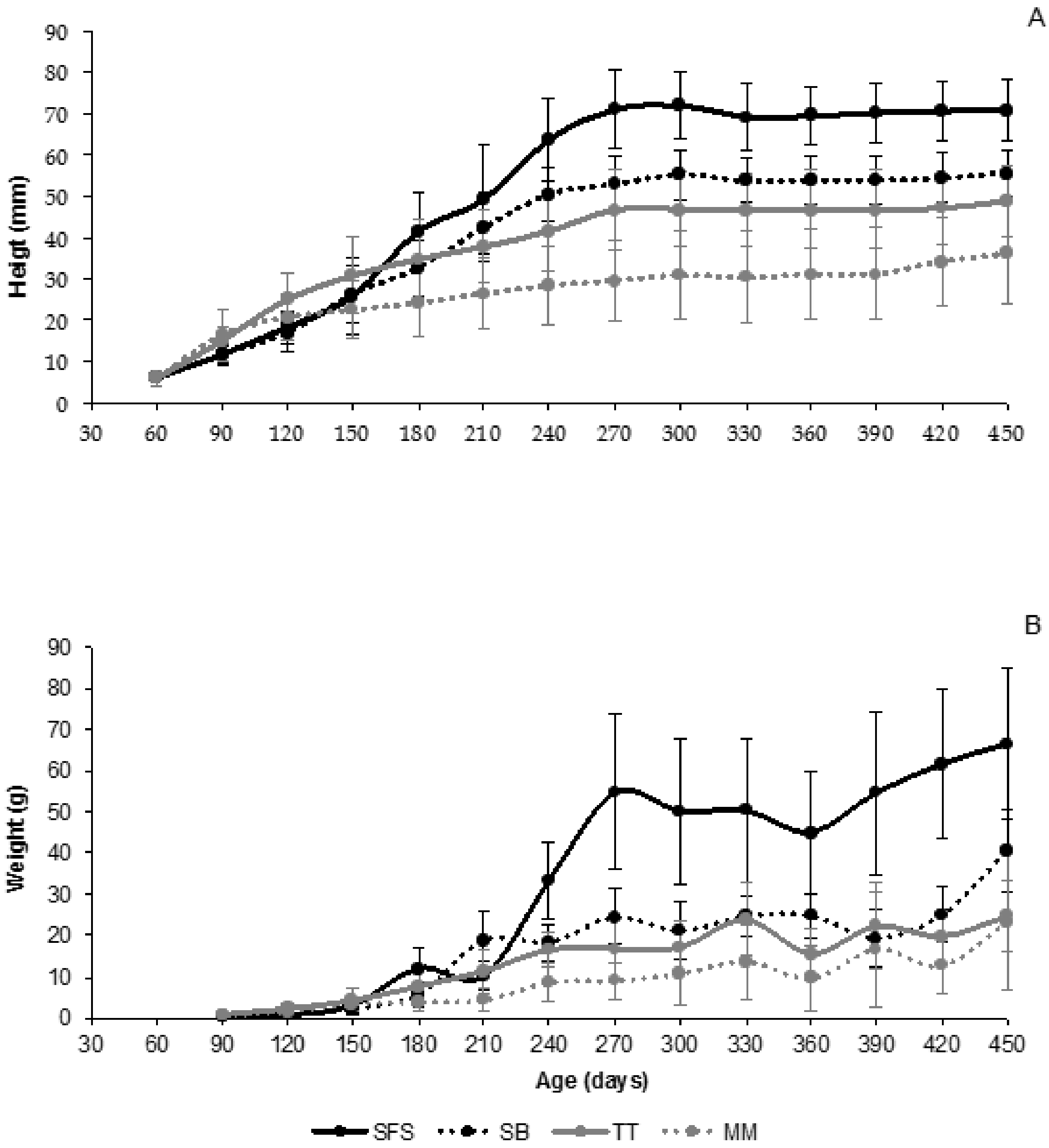

Figure 2. Average shell height (A) and total wet weight (B) of *Crassostrea gasar* cultured in Santa Catarina (SFS and SB) and Maranhão (TT and MM), Brazil. Where SFS = São Francisco do Sul; SB = Sambaqui; TT = Torto; and MM = Morro do Meio.

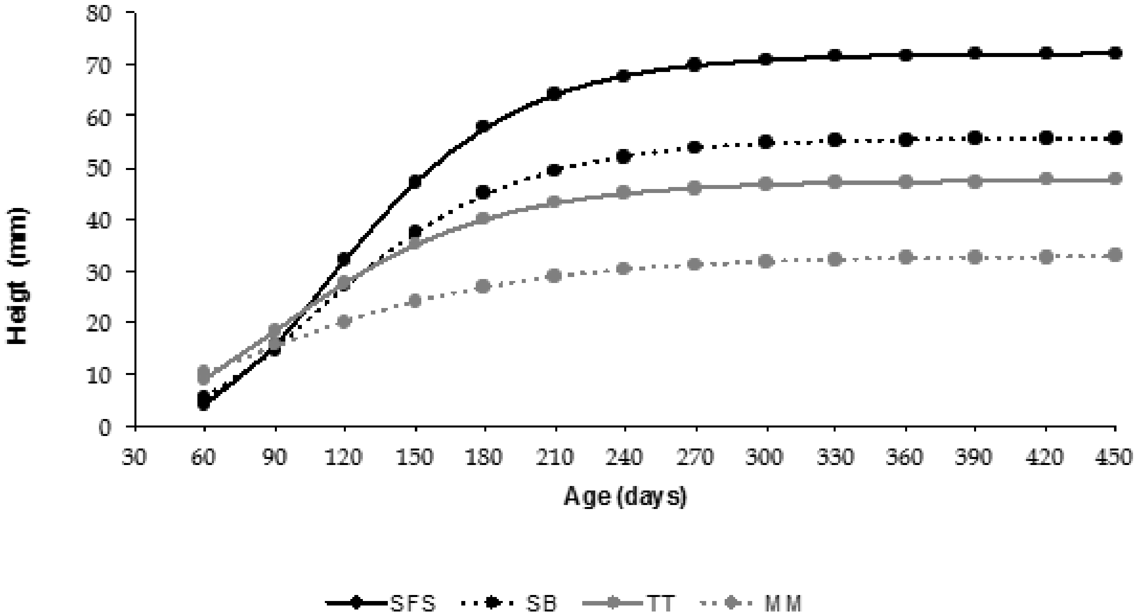

Figure 3. Growth curves of *Crassostrea gasar* fitted using Von Bertalanffy growth equation. Culture areas in Santa Catarina: SFS = São Francisco do Sul, and SB = Sambaqui; culture areas in Maranhão: TT = Torto, and MM = Morro do Meio

Table 2. Performance indexes and von Bertalanffy growth parameters to oyster *Crassostrea gasar* cultured in the States of Santa Catarina (SFS and SB) and Maranhão (TT and MM), Brazil. SFS = São Francisco do Sul; SB = Sambaqui; TT = Torto; MM = Morro do Meio; $L\infty$ = Asymptotic shell height, K = Von Bertalanffy growth constant; t_0 = von Bertalanffy growth parameter; and φ' = phi-prime growth performance index.

Culture area	$L\infty$	K	t_0	φ'
SFS	72.16 ± 1.36	0.021	4.02 ± 1.03	2.05
SB	55.75 ± 0.77	0.020	5.14 ± 0.75	1.79
TT	47.54 ± 0.79	0.019	8.84 ± 1.12	1.63
MM	32.9 ± 1.18	0.014	10.18 ± 1.29	1.18

Seawater parameters

Seawater temperatures in Santa Catarina were similar in both culture areas (SFS and SB) (Figure 3a), ranging from 17 to 28°C in SFS and from 15 to 27°C in SB, with 12°C between winter and summer. The lowest temperatures were observed from June to August 2012, increasing during October and September. From March on the temperatures went down, reaching low levels in July 2013. In Maranhão, the seawater temperature also showed a similar pattern in the two studied sites and remained continuous throughout the year (Figure 3a), ranging from 27 to 30°C in TT and from 26 to 29°C in MM.

Seawater salinities were different among the four studied farm areas throughout the experimental period (Figure 3b). In the South, salinities ranged from 33 to 36 in SB, and from 25 to 33 in SFS, but remained during most of the study period between 30 and 33. In the Northeast, salinities ranged from 5 to 32 in TT, and from 25 to 37 in MM, with higher values (35 to 37) between July and November.

DISCUSSION

Survival rates of *C. gasar* observed over 13 months of culture in the present study (Table 1) were considered suitable for Brazilian oyster farming, compared to the available published data. For *Crassostrea* sp. cultured in Cananéia estuary, São Paulo, PEREIRA *et al.* (2001) reported survivals from 64% to 90.1% over 10 months of culture, while

GALVÃO *et al*. (2009) recorded survivals between 19.7 and 27.7% over three months. In Ubatuba, São Paulo, GALVÃO *et al*. (2009) found 74.8% survival for *Crassostrea* sp. in the first three months of culture and 48.0% in the next three months.

The best oyster growth performance in weight and height registered in SFS, followed by SB, TT and MM ($p<0.05$; Figure 2) was supported by the phi-prime growth performance index, which showed similar outcomes (SFS>SB>TT>MM; Table 2). Despite the resembling results in weight and height, the evaluation of growth in height was considered a better tool, since variations in weight can be related to the reproductive cycle (MONTANHINI-NETO *et al*., 2013; LEGAT, 2015).

Among the factors related to the growth of bivalve molluscs described by Gosling (2003), differences in growth of *C. gasar* between the States of Santa Catarina and Maranhão can be attributed to the influences of salinity, tidal amplitude, primary production, culture systems and genetic load. The environmental factors can also be related to the differences in oyster growth between areas within the same state.

Temperature and salinity patterns observed in this study were similar to the results reported in other studies in SFS (LOPES *et al*., 2013), SB (LOPES *et al*., 2013; GOMES *et al*., 2014), TT and MM (Embrapa, unpublished data). Although the influence of environmental factors on bivalve growth is well documented (GANGNERY *et al*., 2003), the synergy among them makes it difficult to estimate the effect of an isolated factor (GOSLING, 2003). In this study, it was not possible to determine the influence of temperature and salinity because data were collected only at the time of biometrics and handling of grow-out structures. Nevertheless, the wide range of salinity variation in TT compared to the other three areas (Figure 3b) did not negatively affect survival rates, which were similar to those in SFS and higher than in SB and MM (Table 1). These findings indicate that *C. gasar* exhibits high tolerance to these environmental fluctuations. These results are corroborated by FUNO *et al*. (2015) who observed high survival rates of *C. gasar* cultured in the salinity range between 10 and 45 under laboratory conditions.

Although salinity variations did not affect survival of *C. gasar* in TT, they may have influenced the oyster growth in this area. Salinity fluctuations are stressors for bivalve molluscs (AKBERALI and TRUEMAN, 1985) and they can compromise the osmotic balance resulting in considerable energy expenditures to adjust the osmotic concentration (CHENG *et al*., 2002). In addition to energy consumption, bivalve molluscs close their valves to avoid physiological problems in stressful situations (AKBERALI and TRUEMAN, 1985) and food uptake does not occur during these periods.

The effect of air exposure on oysters farmed in MM may explain the lowest survival and growth rates observed in this area. Due to the tide variation and culture system, oysters were exposed to air for a long time (60 – 150 min) during the low tide. While exposed to air, the animals had no food available and were subjected to average temperatures up to 35ºC (ALVES *et al*. 2012; 2013). Although some authors recommend exposure of oysters to the air to reduce fouling (PEREIRA *et al*., 2001; GALVÃO *et al*., 2009), the results in MM address questions about the use of this technique in areas with high temperatures (tropical climate). According to ZHANG *et al*. (2006), the lysosomal membrane integrity of the oysters could be damaged when exposed to air, especially at high temperatures. This hypothesis is supported by the higher growth and survival in TT, where the oysters were exposed to the same air temperatures, but just for brief periods (15 - 30 min), remaining submerged most of the time.

On the other hand, oysters probably have grown better in Santa Catarina because they remained submerged throughout the time and did not undergo large variations in salinity during experiment period. In addition, the temperate water of southern Brazil has a higher primary productivity than the tropical water of the northeast region (CASTRO and HUBE, 2012), enhancing food uptake.

Besides the environmental factors, the higher growth observed in Santa Catarina can be related to the interaction between genotype and environment, considering that the broodstock used in this study are cultured in SB area. According to Bourdon (2000), over successive generations, the organisms become genetically adapted to the environmental conditions, which they are subjected to, enabling them to survive and achieve better activity in their source areas. To test this hypothesis, it would be necessary to evaluate the growth performance of seeds produced in Maranhão and Santa Catarina, and also cultured in both states, considering the existing health issues. Despite the differences in genotype x environment interactions, the use of LMM seeds in Maranhão was one way to ensure the use of confirmed *C. gasar* specimens with the same age in TT and MM areas.

The differences in oyster growth observed in the present study between the culture areas in Santa Catarina (SFS > SB) was also reported by LOPES *et al*. (2013). These authors described the estuarine environment of SFS as the most suitable for *C. gasar* culture compared to SB, situated near the beach. In fact, better oyster performance in SFS may be related to the primary productivity of estuarine waters. Estuaries are considered to have the highest biological productivity among aquatic environments, more than a river and the adjacent ocean (MIRANDA *et al*., 2002).

Published data on growth performance of native oysters in Brazil (Table 3) showed similar outcomes to those observed in this study for *C. gasar* in Maranhão. On the other side, our results in Santa Catarina were better compared to these previous data. The most similar results to those reported in here were obtained by LOPES *et al*. (2013), who carried out their experiments in the same areas of Santa Catarina (SB and SFS) and also used seeds produced from the LMM-UFSC hatchery.

The higher growth observed in Santa Catarina can be related to the domestication process of *C. gasar* in the LMM's hatchery. Domestication involves genetic changes in morphology, physiology or animal behavior through the individual selection adapted to cultivation (HARDING, 2007). Once the breeders were more adapted to the farming conditions, there could be a better performance of their progeny. This hypothesis is supported by the differences in oyster growth observed between the present study and LOPES *et al* (2013). In this work, it was used a 6th generation breeding line of the LMM's and the offspring showed higher growth than that recorded by LOPES *et al*., (2013), who used the 2nd generation breeding line. Considering that the potential for bivalve production in Latin America is limited due to the small number of hatcheries and the lack of methodologies for domesticating native species (FAO, 2014), it is crucial for the improvement of oyster production in Brazil to establish hatcheries in other states to promote an effective domestication program with the formation of breeding stocks, continuous supply of seeds, and greater health safe conditions.

The market size of oysters in Brazil varies according to the form of consumption and regional preference. In this study, we evaluated the percentage of oysters above 50 mm, described as the market size by GALVÃO *et al*. (2009) and PEREIRA *et al*. (2003). In Santa Catarina the time to reach oyster size above 50 mm height was lower than the time described by other authors. NASCIMENTO (1991) showed that it is necessary 18 months of culture for *C. brasiliana* and *C. rhizophorae* to reach 70 - 80 mm height. PEREIRA *et al*. (2003) evaluated the growth of *Crassostrea* sp. attached to mangrove roots, and concluded that oysters need at least 19.5 months to reach commercial size (≥ 50 mm).

In this study, a continuous oyster growth was observed in SFS, SB and TT areas until the 8th month of culture, when the animals were approximately 300 days old. From this moment on, there was individual growth, but the average population growth became stagnant. According to these results, it is recommended that *C. gasar* cultivation time in SFS, SB and TT lasts for 7 to 9 months, in order to obtain higher yields. The MM area was considered unsuitable for *C. gasar* culture, due to the low percentage of animals that achieved size above 50 mm.

Although the present study demonstrated that *C. gasar* has good growth prospects, its growth performance after 8-11 months of culture (this study and LOPES *et al*., 2013) is lower than that observed for *C. gigas* farmed in Santa Catarina. MIZUTA *et al*. (2012) reported that *C. gigas* cultured in SC reach 70 - 120 mm shell height in 8 - 13 months. Nevertheless, the growth of *C. gasar* observed in here are similar to that described for *C. gigas* farmed in other countries. The cultivation of *C. gigas* in France can last up to 2 years for oysters to reach the juvenile stage and up to 4 years to reach commercial size (GOSLING, 2003; LAPEGUE *et al*., 2006; FAO, 2015). According to GANGNERY *et al*. (2003), who studied the growth of *C. gigas* in France, oysters with 46.5 - 49.5 mm height (12-13 months age) reached 88.1 - 101.8 mm height after additional 12 months of culture.

In Canada, BROWN and HARTWICk (1988) evaluated the growth of *C. gigas* in 10 areas with different characteristics of temperature, salinity and food availability. According to the performance of cultured oysters, these authors classified these areas as high, medium and low growth. In areas of high growth, after 14 months of culture, oysters with 21.6 mm and 45.2 mm reached 100.2 mm and 108.5 mm, respectively, while in areas of low growth they reached 56.6 mm and 68.9 mm, respectively. In USA, Harding (2007) studied two strains of disease resistant diploid (DEBY) and fast growth triploid *C. virginica* cultured between 2005 and 2007. This author observed that oysters of both strains reached 76 mm shell height 18 months after settlement, while KRAEUTER *et al*. (2007) found that wild individuals of *C. virginica* take about three years to reach around 70 mm.

Table 3. Native oysters *Crassostrea* genus growth evaluating studies in Brazil. Where SC = Santa Catarina; SP = São Paulo; MA = Maranhão; TT = Torto; MM = Morro do Meio. Oyster in studies without genetic confirmation were considered *Crassostrea* sp.

Species	Culture area	Farming (months)	Age (days)	Initial height (mm)	Final height (mm)	Author
***Crassostrea* sp.**	Cananéia (SP)	8	-	5.60 ± 0.06	25.80 ± 0.30	PEREIRA *et al.* (1991)
		8	-	19.60	59.10	
		10	-	5.00 ± 3.23	81.82	PEREIRA SOARES (1996) PEREIRA *et al.* (2001)
***Crassostrea* sp.**	Cananéia (SP)	3	-	21.30 ± 4.50	29.12 ± 3.89	GALVÃO *et al.* (2009)
	Ubatuba (SP)	6	-	22.10 ± 4.20	33.99 ± 5.37	GALVÃO *et al.* (2009)
C. gasar	Florianópolis (SC)	11	390	-	49.65 ± 7.39	LOPES *et al.* (2013)
		8	300	5.85 ± 2.00	55.31 ± 6.05	Present study
	São Francisco do Sul (SC)	11	390	-	61.98 ± 13.04	LOPES *et al.* (2013)
		8	300	5.85 ± 2.00	71.96 ± 8.05	Present study
	Araioses TT MA	8	300	5.85 ± 2.00	46.92 ± 9.11	Present study
	Araioses MM MA	8	300	5.85 ± 2.00	30.97± 10.73	Present study

CONCLUSIONS

Oysters grown in Santa Catarina (São Francisco do Sul and Sambaqui) presented a higher growth than oysters cultured in Maranhão (Morro do Meio and Torto). In São Francisco do Sul, Sambaqui and Torto it is recommended that the cultivation time of *C. gasar* last for 7 to 9 months, in order to obtain higher yields. Morro do Meio was considered unsuitable for farming *C. gasar*, due to the low percentage of animals that achieved commercial size.

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