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Full Length Research Paper

Models test in the evaluation of *Cyathura carinata* growth

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ABSTRACT

Previous studies on the Ria Formosa (southern Portugal) benthic communities have shown that *Cyathura carinata* (Krøyer, 1847) is a common and abundant species, with a key role in food web transfers as a prey for birds and fish. The aim of the present study was to describe its life cycle, population dynamics and productivity. Samples of *Cyathura carinata* (Isopoda), taken in 388th days in the intertidal zone of the Ria Formosa lagoon yielded mean annual densities of 213 individuals/m^2. Analysis of population density values in the Ria Formosa in comparison with other estuaries indicates that this species exhibits a regular year-round distribution pattern, independent of geographic location. Using modal progression analysis of the six cohorts identified, the life span of Ria Formosa *C. carinata* was estimated at approximated 19 months. The recruitment period ranged from mid-April to October and three new cohorts were recognized.

Keywords: Intertidal community, dynamic mode, *Cyathura carinata*.

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INTRODUCTION

Cyathura carinata (Krøyer, 1847) (Isopoda, Anthuridae) is a detritivorous isopod, which lives in muddy or sandy sediments of intertidal zones and is widely distributed along the European coast, from the Baltic to the Mediterranean (Cruz et al., 2003; Cruz et al., 2003).

Being one of the key species of the intertidal mud flats, this isopod was found to be most abundant in a eutrophic area, where seasonal macro-algal blooms and organic matter usually occur. Some authors refer a 2-year life span, even though, 80 to 90% of the individuals die at 1 year old, revealing a strong post-reproduction mortality; evidenced protogynous hermaphroditism and presented a high growth production and a low turnover ratio (Cruz et al., 2003; Cruz et al., 2003; Jadzewski, 1969; Burbanck and Burbanck, 1974). A latitudinal gradient reflected in the life features of *C. carinata* was described. *C. carinata* seemed to temporarily benefit from the presence of organic matter and presence of green macro-algal since that they could provide higher energy resources and protection against predators. While some studies have reported data on the biology and the behaviour of *C. carinata* (Jadzewski, 1969; Burbanck and Burbanck, 1974; Bamber, 1985; Ferreira et al., 2004; Ólafsson and Persson, 1986; Cruz et al., 2003; Cruz et al., 2003), little is known about this species' population dynamic models in the lagoon Ria Formosa, southern Portugal. Adult individuals of *C. carinata* are tubicolous, and since they are incapable of swimming have limited mobility, which results in disjunction and a stable population (Bamber, 1985). This allows the species to maintain stable densities during long periods of time in specific locations (Burbanck and Burbanck, 1975). For this reason, this species is convenient for ecological studies. *Cyathura* is considered an "indicator organisms" in estuaries given its tolerance to fluctuating environmental conditions (Burbanck et al., 1979). The length of an organism, at any stage of its life cycle, is an important characteristic. The growth of one organism, at every moment of its life, depends on the size previously reached (Pauly, 1998). Thus, the growth is an important parameter that depends on several biological factors such as genes, physiology, breed and moults that affect the development of a population. The 'genes', their physiology (Pauly, 1998) and their ecology is what determines the growth of the *C. carinata*. Factors such as food resources (food available), environment (physical, chemical and sedimentological) and biological (mostly breeding season) influence growth, being instrumental in the structure and size of the population, although comply intertwined with the dynamic aspects of own species and the interaction with other species.

For the isopod *C. Carinata*, some studies suggest that a factor that regulates the growth of the organism is the temperature (Ferreira et al., 2004; Marques et al., 1994; Cruz et al., 2003) showing the lowest growth rates in winter comparatively to summer period. However, it also seems that cessation of growth exist during the breeding period (Bamber, 1985; Cruz et al., 2003), in which the female carries the eggs and also if they have a moulting process, they lose it.

The aim of this study was to simulate the growth of the isopod *C. carinata* using simple equation subject Bertalanffy growth to external variables (temperature, salinity, and organic matter) and compare the results of applying this model to the model without action variables and the external model seasonally adjusted Von Bertalanffy, and modified by Gaschutz et al. (1980).

METHODOLOGY

Study site and field program

The Ria Formosa, located at the southern coast of Portugal, extends for about 55 km. It constitutes a true barrier-island system and the climate is of the Mediterranean type, with hot, dry summers and mild winters. As the Ria Formosa receives no permanent freshwater input, salinity ranges between 35.5 and 36.9 PSU except for short periods after heavy rainfall during winter. The total area covered by water during spring tides varies between 14.1 and 63.1 km^2. Three sampling sites were selected according to their distance from the ocean (Cais Novo, Ramalhete and Quinta do Lago). Station Cais Novo is located on the Faro Channel, near the ocean. Quinta do Lago represents the interior most sites, and Ramalhete is located between Cais Novo and Quinta do Lago. At Ramalhete, the sediment is colonized by *Zostera nolti* (Hornemann, 1832) and seaweeds at the lower levels. At Quinta do Lago there were neither seaweed nor seagrass. At Cais Novo there were a few seaweeds at the upper levels (Figure 1).

A sequential sampling program was carried out at these sites. Replication was determined by the rank-frequency diagram method. Samples were collected fortnightly.

At each station, samples were taken in the littoral zone during low tide, at five equidistant levels between high and low water, since previous work showed that the distribution of *C. carinata* densities in the intertidal zone varies as a function of the distance to the water level at low tide (Cruz et al., 2003). Level A was the highest level and level E was the lowest. At each level, six random samples were taken using a manual core sampler (internal diameter = 12 cm). The core was pressed down approximately 20 cm into the sediment and then each 2,262 dm^3 core was individually passed through a 0.5 mm mesh sieve. The sieve residues were preserved in a solution of 70% ethanol with Rose Bengal. The following variables were determined in the field: temperature *in situ*; salinity (refract meter); dissolved oxygen (Winkler method described in Grasshoff et al. (1983)); pH; suspended matter (total suspended solids dried at 103 to 105°C (Anonymous, 1985). Nitrite, nitrate, and phosphate concentrations were determined in the laboratory following the methods described in (Strickland and Parsons, 1972). Sediment samples were preserved in a thermally controlled container during transport to the laboratory for the analyses of organic contents. Sediment samples were drie d for two days at 60°C, and then incinerated for 12 h at 450°C in a muffle furnace. Analyses of the sediments were realized seasonally. The organisms were counted and their cephalic length was measured with a precision of 0.02 mm.

Model description - Research hypothesis

To separate cohorts of isopods *C. carinata*, we used the method of Cassie (1954, 1963), which allows a clear separation without overlapping cohorts. The frequency distribution of the lengths estimated was compared with the observed distribution of Chi-square and Fisher G (Sokal and Rohlf, 1995).

The expression of growth may consider the absolute growth viz. absolute changes in length or weight or a relative increase, viz. changes in the variable length dimension and weight relative to the body in question in a range of given time.

A model was developed then for the cohort of C3 and C4. For cohort C3, their evolution can be followed from the beginning to the end of the sampling period. The C4 was the first cohort recruitment observed in this species and it could track the progress by the end of the sampling period. For cohorts have also been developed other similar models, however, they are not described here, as the number of observations was quite low.

The model pretends to simulate the growth of isopods *C. carinata* (Krøyer) during its life by using the Von Bertalanffy growth proposed and developed by Beverton and Holt (1957 in Rafail [1973]) subject to external variables (that is, environmental factors). The results obtained by this model were compared with the results obtained by applying the growth function and Von Bertalanffy growth model modified Von Bertalanffy (Gaschutz et al., 1980).

Since the formulation of the problem, hypothesis construction is an important step in any research process. These are based on claims about the probability distributions of populations or of some of its parameters. The assumptions made are:

H_1: "The growth curves considered (Von Bertalanffy model, modified model (Gaschutz et al., 1980) original model and subject to environmental variables, differ".

H_2: "The simple growth model of Von Bertalanffy and developed by Beverton and Holt (1957 [Rafail, 1973]), represents the best growth *C. carinata*".

H_3: "The simple growth model of Von Bertalanffy and developed by Beverton and Holt (1957 [Rafail, 1973]), taking into account the environmental variables to represent better growth *C. carinata*".

Growth equations and their derivatives

The function of the Von Bertalanffy growth (CVB) introduced by Von Bertalanffy in 1938 and developed by Beverton and Holt (Rafail, 1973) is the growth model used by most biologists. Its expression is:

$$L_t = L_\infty (1 - e^{-K(t-t_0)}) \tag{1}$$

where:

L = the average length in time t,
L∞ = is the asymptotic length or the theoretical maximum the body can achieve,
K = constant for the rate at which L ∞ is reached.
a = the theoretical age at which the average would be zero length (Sparre, 1985)

The derivative of this function can be given by:

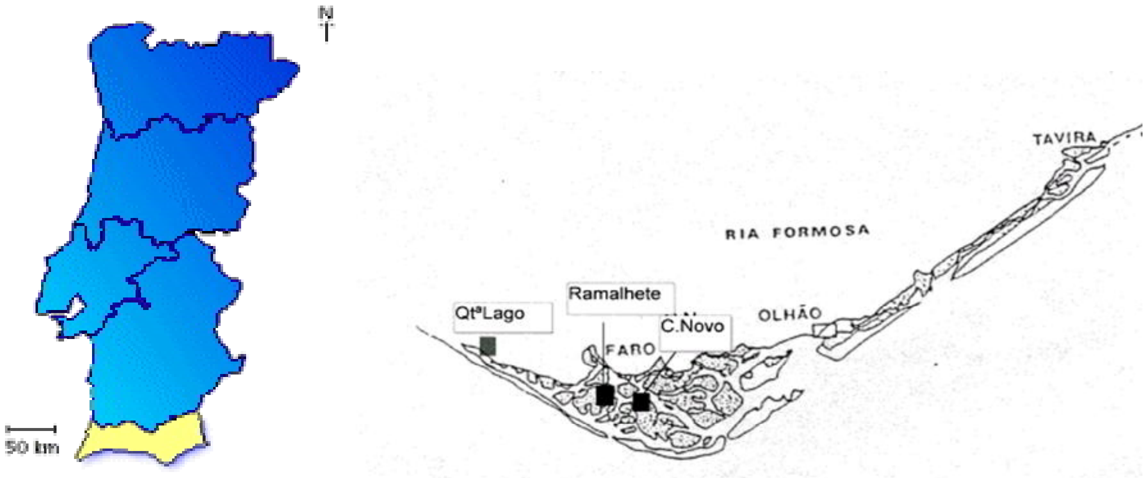

Figure 1. Map of Portugal showing localities of sampling sites in the Ria Formosa: Quinta do Lago, Ramalhete, and Cais Novo.

$$\frac{dL}{dt}=KL_{\infty}e^{-K(t-t_0)} \tag{2}$$

This growth model expressed how long as the function of age.
The most commonly used model to describe the growth of crustaceans, which is considered the seasonal and may be expressed by the following equation (Gaschutz et al., 1980).

$$L_t=L_{\infty}\left(1-e^{-\left[KD\left(t-t_0\right)+C\left(KD/2\pi\right)\sin 2\pi\left(t-t_s\right)\right]}\right)^{1/D} \tag{3}$$

Where:
Lt = length of the body at the time t;
L∞ = L is the maximum length that can reach the body;
K = a constant intrinsic growth. This value represents the intrinsic growth rate;
a = the theoretical age at which the average length would be zero;
ts = time interval between the beginning (where t = 0) and the first pivot point; growth curve is expressed by an approximately sinusoidal with a period of one year;
C = constant whose values depend on the species, and between 0 and 1, in tropical seasonal variation is minimal, while in cold climates, where growth is often near zero, the change is greatest.
D = parameter that expresses metabolic deviations Von Bertalanffy rule. The metabolism of an organism is proportional to a power of ⅔ the weight thereof.

When information about the type of metabolism of the organism under consideration is available, then the value of D can be obtained from equation (Gaschutz et al., 1980). Due to lack of information about the type of metabolism in *C. carinata*, we set D with a value of 1.

The derivative of this equation is expressed as follows:

$$\frac{dL}{dt}=K(L_{\infty}-DL)(1+C\cos(2\pi(t-t_s))) \tag{4}$$

Where k is divided by 365 to enable simulation daily for one year.

Table 1. Application of mathematical model of the growth for the cohort in a C3 and C4 *C. carinata*, respectively. The parameter values calculated without seasonal adjustment.

Cohorts	L∞	T_0	K	D	r^2
C3	1.6	-0.7688	0.54702	1	0.836
C4	1.6	-0.1709	0.79363	1	0.984

Growth parameters

For the initial growth function, that is, without seasonal adjustment, the parameter estimates for the cohort of C3 and C4 are shown in Table 1 and estimates of seasonally adjusted parameter for these cohorts are referred to in Table 2.

To test the hypothesis described above we used remaining multiple correlation values between the observed values of the average length and average cephalic length estimated growth models.

Comparisons of the growth functions were performed using logarithmic transformation of the data, and the estimation of the regression function for each of growth relative to the observed data. We applied an analysis of covariance (ANCOVA), which allowed us to determine whether the slopes of each regression functional relationship or were of a population or different populations. When differences were detected implemented a procedure PBS (*Post-hoc*) (Sokal and Rohlf, 1995).

Development model

The development of the model was to determine which parameters might have an effect on growth performance *C. carinata*. Initially, we examined the possible relationship between the increases in cephalic lengths in time and variation in environmental parameters considered essential for the growth of *C. carinata* (Table 3). The relationship between environmental parameters and the increase in the average length calculated from modal analysis was determined using the multiple regression models. The determination of the various factors in the equation is made by the method of least squares. The model was fitted to the data according to the

Table 2. Application of mathematical model of the growth data in the cohort in A C3 and C4 *C. Carinata*, respectively. The parameter values calculated seasonally adjusted.

Cohorts	$L\infty$	T_0	K	D	C	T_S	R^2
C3	1.6	-0.5608	0.65705	1	1.0124	0.1480	0.958
C4	1.6	-0.1964	0.76868	1	0.1742	0.5396	0.989

Table 3. The mean values of the environmental parameters measured in the system of Ria Formosa lagoon between November 1990 and December 1991. (Code: TEMP = Temperature (°C), SAL = Salinity (PSU), pH = pH, NO_2 = Nitrite (m.mol L^{-1}), NO_3 = Nitrate (m.mol L-1); PO_4 = Orthophosphate (m.mol L^{-1}.); MSUSP = Suspended matter (MG.L^{-1}); MORG = Organic matter in the sediment (%).

Days	Temp	Sal	Morg	pH	NO_2	NO_3	PO_4	Msusp
0	13.50	25.30	2.73	7.90	0.49	0.87	1.01	0.19
19	12.90	20.70	3.29	8.00	0.36	1.36	0.69	0.84
30	14.40	23.95	2.90					
47	13.60	27.20	2.52	8.60	0.46	2.38	0.81	0.03
61	11.90	25.10	2.46					
76	12.90	23.00	1.89	8.90	0.27	1.38	0.55	0.02
90	13.30	28.50	2.53	8.70	0.31	1.49	1.21	0.06
105	17.20	25.00	2.46	8.60	0.30	1.62	0.80	0.16
122	19.20	28.50	2.64	8.50	0.29	1.18	1.00	0.36
136	15.30	25.50	2.75	7.60	0.30	1.22	1.00	0.03
151	23.80	30.80	2.82	8.00	0.36	0.24	0.82	0.05
166	24.90	31.80	3.16	8.30	0.23	0.74	0.51	0.02
181	23.00	29.40	2.78	8.20	0.25	1.10	0.57	0.01
195	26.30	28.90	2.94	8.10	0.21	0.48	1.31	0.04
210	26.60	31.30	3.71	8.20	0.47	0.99	0.92	0.07
226	26.60	36.50	3.53	8.20	0.31	0.27	0.85	0.08
239	26.30	36.50	3.29	8.10	0.27	1.27	0.97	0.09
255	26.30	32.80	3.73	8.20	0.27	0.84	0.77	0.11
270	26.40	40.00	3.55	8.10	0.33	0.65	1.18	0.04
284	26.30	38.20	2.97	8.20	0.48	1.04	0.89	0.10
299	24.70	33.00	3.35	8.20				
314	19.50	37.00	3.05	8.10	0.40	1.05	0.92	0.03
329	18.60	34.35	3.69					
343	16.80	31.70	2.72	8.30	0.34	0.33	0.64	0.03
356	15.40	33.45	2.74					
371	14.10	35.20	3.31	8.30	0.43	0.84	0.84	0.03
388	15.70	34.33	4.12					

approach of "Forward Stepwise or Enter", available in SPSS.

The equations incorporate the following environmental parameters: temperature, salinity, and organic matter (Table 4). A multiple regression analysis can be drawn, among other things, the beta coefficients, which are standardized regression coefficients, uninfluenced by the units of measurement or X or Y can be used for comparison (Pestana and Gageiro, 2008).

The values obtained in the multiple regressions described above for cohorts C3 and C4 are used to define the external variables that influence the growth of the cohorts according to Von Bertalanffy model without adjustment.

The increases in growth of *C. carinata* were calculated from the definition of the instantaneous growth rate (CTI) or specific

Table 4. Values used for the simulation of the growth model, taking into account environmental parameters: temperature, salinity and organic matter, in *C. carinata* (product coefficients between the beta and the adjusted coefficient of determination).

Cohorts	C3	C4
Temperature (ºC)	-0.186	-0.017
Salinity (PSU)	-0.071	0.002
Organic matter	-0.105	0.009

expressed as follows:

$$TCI = \frac{\ln(Ct2) - \ln(Ct1)}{t2 - t1} * 100 \qquad (5)$$

(Adapted from Weatherley and Gill, 1987)

Where: CT1 and CT2 are the average total length at time t1 and t2. Several features related to growth and temperature. In this case we chose to use the function developed by the temperature (Pestana and Gageiro, 2008):

$$FT^{t} = K20 * KOT^{t-20} \qquad (6)$$

When KOT and K20 are constants. If K20 is equal to unity and equal to 1.05 KOT, the FT will vary around the unit, between 0.5 and 1.5 (Jørgensen and Bendoricchio, 2001). Temperature values above the mean value will result in values greater than one FT, and values below the average value for values below 1 m. When this function is multiplied by the growth rate will influence the population growth, "up" growth, when you have values greater than 1, and the slowdown in growth, when values are below 1.

This feature is designed for an optimum temperature of 20°C. Since the optimum temperature for the development of *C. carinata* is unknown we to modify the function and observed how the optimal average temperature vary. In addition to the parameters considered in the model, were also considered other environmental parameters.

The function is thus adapted according to the methodology (Gamito, 1997). For the environmental factor has a positive effect on the development of a cohort for:

$$FFactor_t = (K + K_f)^{Factor_t - FM} \qquad (7)$$

Where K = 1.00 and K_f varies with the environmental factor and its "importance" in the development cohort.

If the factor has a negative effect on the development of the cohort, then the following expression is used:

$$FFactor_t = (K + K_f)^{FM - Factor_t} \qquad (8)$$

In this case, the environmental factor values considered over the medium will slow the growth of the population.

The software used to operationalize the model was the package “Stella (10.0.6).”

RESULTS

The multiple regression results obtained for cohorts identified C3 and C4 were:

Cohort C3:

Y = 0.021463 + (XTemp * - 0.00036) + (XPSU - 0.000147 *) + (* -0.002173 XOrgMatter); R^2 = 0.499 (9)

Cohort C4:

Y = 0.005335 + (0.000273 * XTemp) + (XPSU - 0.000045 *) + (* -0.001568 XOrgMatter) ; R^2 = 0.147 (10)

For our model, we used the product of the beta coefficients and the coefficient of determination (Table 4).

Conceptual diagram represents C3 cohort growth models tested, that is, the growth model according to Von Bertalanffy growing original function without adjustment, the growth model according to von Bertalanffy increasing function of modified seasonally adjusted (Gaschutz et al., 1980) and the original model of Von Bertalanffy considering environmental variables resulting from the application of the multiple regression technique (Figure 2).

The values used in the simulations of the growth of C3 and C4 cohorts are presented in Table 5 and 6.

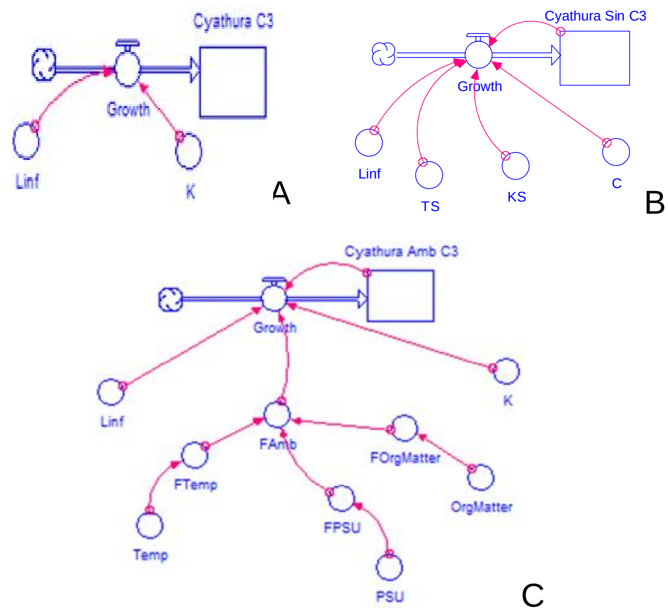

Figure 2. Conceptual model for simulating the growth of the cohort isopod *C. carinata* C3 according to the original function of the von bertalanffy growth without seasonal adjustment (A), the growth model according to the function of the Von Bertalanffy growth seasonally adjusted modified Gaschutz *et al*. (1980) (B) and the original model Von Bertalanffy considering environmental variables (C). (CODE: Temp = Temperature (°C), PSU = Salinity (PSU), OrgMatter = Organic matter).

Comparative study

Application of growth models for the cohort was obtained for C3 (Table 7) and the growth curves shown in Figure 3. We can see that the baseline growth observed experimental models and simple theme sinusoidal growth pattern of external variables (temperature, salinity, and organic matter) are the best choice in terms of graphics. The C3Amb was coincident with C3sin curve.

This can also be seen in the analysis of the values obtained from the multiple correlations between growth models used and the length and half the circumference observed, obtained by modal analysis.

In order to establish whether there were significant differences between the models using an ANCOVA, the

Table 5. The growth parameters defined for the simulation of the growth model of von bertalanffy without seasonal adjustment and the growth MODEL OF Von Bertalanffy considering environmental variables (temperature, salinity, and organic matter) (Consider: D = 1 and L∞ = 1.6).

Cohorts	T_0	K	r^2	Initial value	Initial value without adjustment	Initial value with external variables
C3	-0.768	0.547	0.836	0.397	0.549	0.397
C4	-0.170	0.793	0.984	0.247	0.203	0.247

Table 6. The growth parameters defined for the simulation of the growth model of Von Bertalanffy modified seasonally adjusted [Pauly, 1998]) (Consider: D = 1 and L∞ = 1.6).

Cohorts	T_0	K	C	T_S	R^2	Initial value	Initial value on Stella
C3	-0.5608	0.657	1.012	0.148	0.958	0.397	0.395
C4	-0.1964	0.768	0.174	0.539	0.989	0.247	0.232

Table 7. Average length of circumference c. carinata observed and obtained by modal analysis; C3 = average length cephalic original function estimated by Von Bertalanffy; C3AMB = average length cephalic original function estimated by Von Bertalanffy considering environmental variables and function values C3SIN = Half head length estimated by Von Bertalanffy growth seasonally adjusted (Pauly, 1998).

Time (days)	Cehalic lenght observed C3	C3	C3Amb	C3Sin
0	0.397	0.549	0.397	0.395
19	0.471	0.579	0.471	0.464
30	0.521	0.595	0.509	0.506
47	0.673	0.621	0.567	0.57
61	0.541	0.641	0.621	0.621
76	0.598	0.662	0.678	0.672
90	0.704	0.682	0.724	0.715
105	0.731	0.702	0.76	0.755
122	0.823	0.725	0.788	0.794
136	0.836	0.743	0.816	0.819
151	0.848	0.762	0.834	0.841
166	0.877	0.781	0.844	0.857
181	0.863	0.799	0.855	0.867
195	0.891	0.816	0.865	0.873
210	0.843	0.833	0.873	0.876
226	0.857	0.851	0.878	0.877
239	0.900	0.866	0.881	0.877
255	0.887	0.883	0.886	0.877
270	0.860	0.899	0.889	0.879
289	0.881	0.914	0.891	0.883
299	0.900	0.929	0.896	0.891
314	0.905	0.944	0.904	0.903
329	0.902	0.958	0.917	0.919
343	0.930	0.972	0.933	0.939
356	0.946	0.984	0.953	0.96
371	1.018	0.997	0.979	0.986
388	1.019	1.011	1.004	1.015

logarithmic values calculated from the average length cephalic observed and estimated for each growth model. The covariance analysis results are shown in Table 8.

For a significance level we can conclude 0:05 reject the null hypothesis, therefore accept H_1: "The growth curve under consideration Von Bertalanffy model, modified

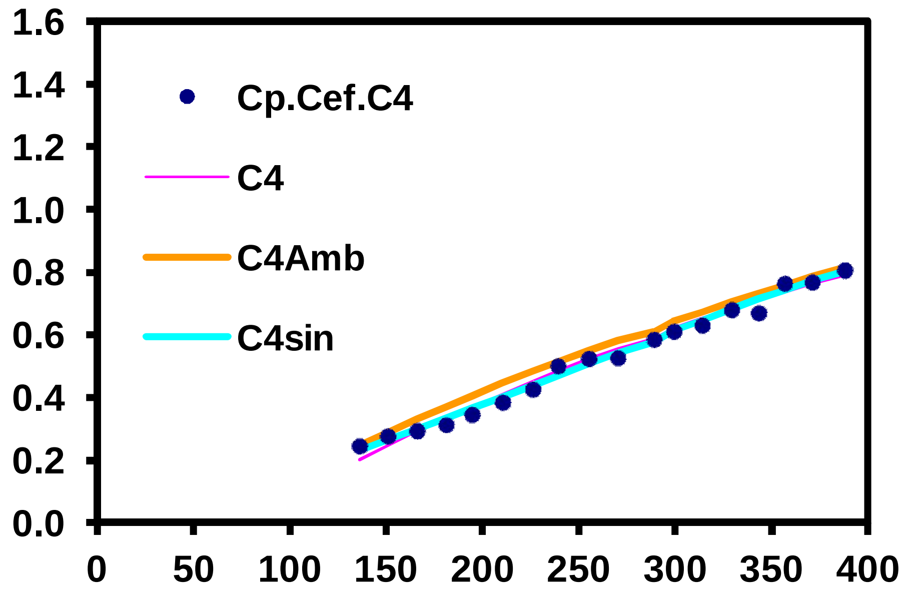

Figure 3. Evolution of growth in *C. carinata* (Krøyer) - mean observed and obtained by modal analysis and models: The original function of Von Bertalanffy growth (--- C4) original function of Von Bertalanffy growth considering environmental variables (-- C4AMB) function and the Von Bertalanffy growth adjusted [Pauly, 1998] (--- C4SIN).

Table 8. ANCOVA table for comparing the values of the logarithm of the average head length *C. carinata* (Kroyer) and logarithm of the observed results obtained by implementing the functions of growth, relative to C3 cohort.

Source of variation	Sum of squares	Degree of freedom	Mean square	Teste F	Critical value
Between b	0.014329	2	0.007165		
Error	0.027888	75	0.000372	19.26767	3.13
Total	0.042217	77			

model for [Gaschutz et al., 1980] original model and subject to environmental variables, differ". The F-statistic obtained (19.26767), belongs to the critical region, RA = [3.13, + ∞].

The percentage value explained by the difference between "b" (beta) was 39%, and the remaining variation due to other environmental factors such as nitrites, nitrates or phosphates, among others.

The method of STP (post-hoc, [Rafail, 1973]) showed that the difference between the previously recorded b (slope) of the regression is due to heterogeneity between the beta (slope) value of the growth model of Von Bertalanffy and models dealing with seasonality or introducing external variables that don't differ between the two models viz. seasonal model of Von Bertalanffy and the same model with the introduction of external variables (Table 9).

$$SS_{Crítico} = (k-1) * \bar{S}^2_{XY} * F_{\alpha\left[(K-1);\sum(a-2k)\right]} \tag{11}$$

Cohort models showed C4 as in the above case a good fit to the experimental data (Figure 4.). The ANCOVA statistical comparison test, comparing the length distributions (Tables 10 and 11) revealed no significant differences between the logarithms of the values obtained by the application of growth models and the common logarithm of the observed average cephalic length (p > 0.05).

The values of the Pearson correlation coefficient for cohort C3

From the analysis of correlations it can be observed that the growth model, taking into account the seasonal adjustment and growth model taking into account external variables, have higher values of linear association (0.98) for the linear association value (0.92) obtained for growth model of Von Bertalanffy. Observed C4 cohort behavior was the same in terms of the amount of linear association values and was high, exceeding 0.99. These results are

Table 9. Values SS (sum of squares) for the STP process (POST-HOC) [Strickland and Parsons, 1972] conducted for the cohort C3. SS value (between B1, B2 AND B3) = 0.014329> = 0.00237718.

STP (Sum of squares, SS)	Von Bertalanffy b_1	Von Bertalanffy subject to environmental variables, b_2
Von Bertalanffy subject to environmental variables, b_2	0.0100795 (> SS critical value = 0.00237718)	
Von Bertalanffy sazonal, b_3	0.011375 (>SS critical value = 0.00237718)	0.3914 itical value = 0.00237718)

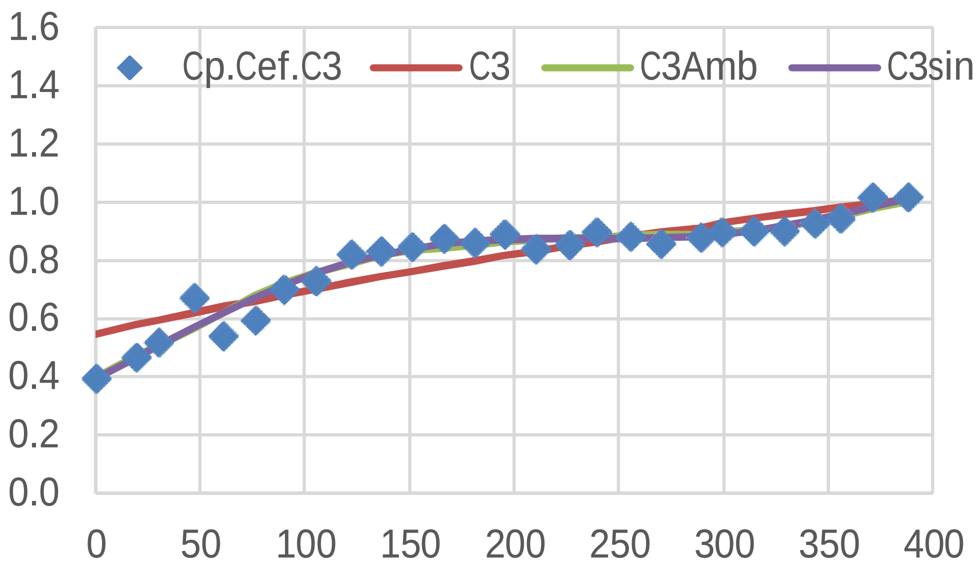

Figure 4. Evolution of growth in *C. carinata* (Krøyer) - calculated as modal analysis and models: The original function of VON BERTALANFFY growth (--- C3), the original function of Von Bertalanffy growth considering environmental variables (---C3AMB) function and the Von Bertalanffy growth adjusted (Gaschutz et al., 1980) (--- C3SIN).

Table 10. Average cephalic length of *C. carinata* observed and obtained by modal analysis, C4 = estimated by the original function of Von Bertalanffy growth; C4AMB = estimated by the original function of Von Bertalanffy growth considering environmental variables and function C4SIN = Von Bertalanffy estimated seasonally adjusted [Pauly, 1998]).

Time (days)	Cehalic length observed Cohort C4	C4	C4Amb	C4sin
0				
…..				
136	0.247	0.203	0.247	0.232
151	0.277	0.248	0.291	0.267
166	0.295	0.292	0.332	0.301
181	0.314	0.333	0.372	0.335
195	0.346	0.371	0.408	0.367
210	0.387	0.411	0.445	0.401
226	0.426	0.452	0.483	0.438
239	0.504	0.484	0.513	0.469
255	0.526	0.522	0.549	0.507
270	0.529	0.556	0.582	0.543
289	0.586	0.588	0.612	0.577

Table 10. Continues.

299	0.612	0.62	0.643	0.613
314	0.631	0.652	0.673	0.648
329	0.679	0.682	0.704	0.683
343	0.672	0.709	0.732	0.714
356	0.767	0.734	0.758	0.742
371	0.769	0.762	0.787	0.772
388	0.808	0.789	0.815	0.801

Table 11. ANCOVA table for comparing the values of the logarithm of the average head length *C. carinata* and logarithm of the observed results obtained by implementing the functions of growth, relative to C4 cohort.

Source of variation	Sum of squares	Degree of freedom	Mean square	Test F	Critical value
Between b	0.00345	2	0.0017251		
Error	0.02662	48	0.0003549	3.1108	3.198
Total	0.03007	50			

not surprising as the influence of environmental variables is very low (Table 4).

DISCUSSION

Empirical growth models have been proposed to observe the growth of various organisms and to determine their seasonal trend. The model presented for seasonal growth of crustaceans uses a simple growth model of Von Bertalanffy subject to external variables such as temperature, salinity and organic matter. These results may be regarded as interesting in that the temperature and organic matter is undergoing constant changes of external variables in the environment, in particular due to human intervention.

The above model assumes organic matter such as the external variable for the detritivous isopod *C. carinata* and also because lagoon systems are favored sites for scattered fragments detritivores reception of either the system itself or from outside. Regarding temperature, it is known that crustaceans are unable to control their body temperature, which is significant for their metabolic rate, growth and reproductive function (Sastry, 1983). Thus, the outside temperature will play an important role on the life cycle and affect significantly the growth.

There also seems to be a consensus relatively to temperature as a factor that influences the growth of *C. carinata*. Despite the growth took place on a continuous basis throughout the life of *C. carinata*, during the breeding period there is a strong decrease or even cease in their normal growth.

For some cohort, it has been observed that higher temperatures increase the potential of development of *C. carinata* (Marques et al., 1994; Martins et al., 1997)). We observed slightly different results, opposing the previous findings. Thus, the reproductive period influences negatively the growth rate of this isopoda (Cruz et a., 2003; Bellido et al., 2000; Cha et al., 2002; Caddy, 2003; Marques et al., 1994). Nevertheless, high temperature has a positive effect in other cohorts particularly in cohorts of C5 and C6.

As for the effect of this organic matter it seems to have a negative effect on the evolution of C3 cohort growth. However, this may also be related or associated to high temperatures (r = 0.478).

This evolutionary trend growth is usually achieved by using the Von Bertalanffy well seasonally adjusted. However, the use of a simple growth model subject to external variables, considered here, showed almost perfect agreement with the values obtained on the one hand and on the other the growth pattern with seasonal adjustment. In fact, the simulations for cohorts C3 and C4 models in agreement with the experimentally observed data and the model adjusted seasonally.

The model subject to external environmental variables can potentially be used in future studies to analyze and understand the evolution of growth at high temperatures resulting from global warming and for different concentrations of organic matter, since the choice of a growth model can be decisive Simulation results obtained in growth, especially if these are included in the simulation of trophic relationships (Gamito, 1997).

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