Cyclopoid copepods in a subtropical coastal area (Ubatuba, Brazil): growth rates and production.

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INTRODUCTION: Zooplankton production in tropical and subtropical waters of the South Atlantic is overlooked and known mainly for adult copepods. Immature stages are known to have higher abundances and different growth rates and the study of such stages is necessary to increase accuracy on production estimates. Since the cyclopoids are a key compartment of tropical pelagic ecosystems (Figure 1), artificial cohort experiments (size classes: 50-80, 80-100, 100-150 and 150-200 µm) were performed to determine growth of 5 taxa of immature cyclopoid copepods (*Dioithona oculata*, *Oithona* spp., *O. plumifera*, *Oncaea* spp. and *Corycaeus* spp.).

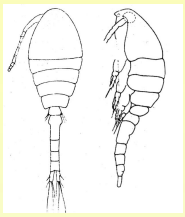

Figure 1: *Diothona oculata*, one of the dominant cyclopoid species in the study (CVI Pr: 361±43 µm).

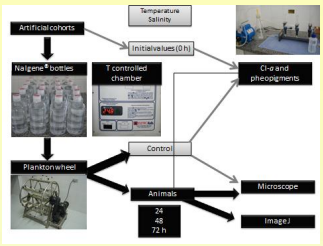

Figure 2: Artificial cohort experimental setting, showing the controlled variables

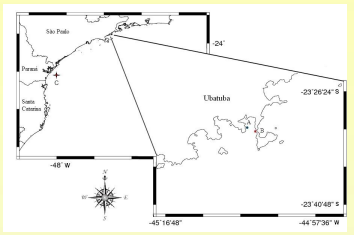

Figure 3: Study area (Brazilian southeastern coast).

METHODOLOGY: Experiments were conducted in 2009 and 2010 summer and winter and 2011 summer in Ubatuba, southeast coast of Brazil (Figure 2). Temperature, salinity, chlorophyll-*a* and pheopigments were controlled during the incubations and correlated with growth rates. Cohort experiment modified from Kimmerer & Mckinnon (1987). Growth rates (*g*) calculated as described by Hirst *et al.* (2003) and compared with the regressions from Hirst & Bunker (2003). Biomass was estimated by length-weight regressions to allow the production assessment.

RESULTS & DISCUSSION: Growth rates obtained by the experiments were significantly different from those estimated by Hirst & Bunker model (Table 1) Growth rates did not show significant seasonal variation and were similar between the cohort size classes, except for *Oithona* spp., where *g* was significantly higher in the smaller classes (Table 2). The lowest g values were observed for *O. plumifera* (0.08 ± 0.06 d-1), while the highest were presented by *Oncaea* spp. (0.27 ± 0.21 d-1) and *Oithona* spp. (0.25 ± 0.19 d-1). Oithonids displayed the highest abundance, biomass and production (Figure 4). Mean *g* values for each taxa at the different cohort sizes are shown at Table 3. Mean growth (0.27 ± 0.17 d-1), biomass (0.51± 0.40 mg C m-3) and production (0.09± 0.05 mg C m-3 d-1) of immature stages of cyclopoids was similar to other tropical areas. Chlorophyll-*a* concentration was not considered a limiting factor on copepod growth in this subtropical region.

Table 1: *p* values for the linear regressions between the measured and the estimated growth by the Hirst & Bunker (2003) equations. I: equations independent of developmental stage and II: equations for juvenile stages.

Taxa	I (all stages)	II (juveniles)
Oithona spp.	0,349	**0,013**
O. plumifera	0,968	0,912
Dioithona oculata	0,443	0,14
Oncaeidae	0,271	0,306
Corycaeus spp.	0,827	0,4

Table 2: Comparison between average growth values between the seasons (summer and winter), between the sampled years and between cohort size classes. *Kruskal-Wallis* was used for multiple comparisons, followed by *Student-Newman-Keuls* or *Mann-Whitney* between the groups. Smaller cohorts: 50-80 + 80-100 ; larger cohorts: 100-150 + 150-200; *: p < 0.001.

Taxa	Summer x Winter	2009 x 2010 x 2011	Smaller x larger Cohorts
Oithona spp.	0,728	0,385	>*
Oncaeidae	0,738	0,122	0,505

Table 3: growth rates for the studied taxa, for each artificial cohort size class (µm). The number of experiments is displayed between parentheses..

Taxa	50-80	80-100	100-150	150-200	Median
Oithona spp.	0,4 ± 0,36 (7)	0,29 ± 0,12 (8)	0,12 ± 0,08 (7)	0,17 ± 0,14 (9)	0,24± 0,17 (31)
O. plumifera	0,19 (1)	0,06 (2)	0,14 (2)	0,07 (3)	0,1± 0,07 (8)
Dioithona oculata	0,27 (1)	0,31 (1)	0,23 (2)	0,11 (2)	0,21± 0,1 (6)
Oncaea spp.	0,22 ± 0,17 (5)	0,38 ± 0,21 (5)	0,28 ± 0,19 (6)	0,24 (2)	0,29± 0,19 (18)
Corycaeus spp.	-	0,31 (3)	0,33 (2)	0,28 (2)	0,56± 0,29 (7)

Table 4: cyclopoid copepod *g* obtained by the artificial cohort method described by Kimmerer & McKinnon (1987) for tropical and subtropical environments. T: temperature, H: incubation period, Biomass: D: direct; ID: indirect. .

Location Species	T (°C)	Biomass estimates	Growth rates (d^{-1})	H (h)	Authors
Indian Ocean Cyclopoid guild	21-31	ID	C:0,28 N: 0,38	48 24	McKinnon & Duggan (2003)
Great Barrier reefs Cyclopoid guild	22-30	ID	C: 0,16-0,48	48	McKinnon *et al.* (2005)
Eastern sea, China Cyclopoid guild	24,9 ± 3,4	ID	N: 0,05-0,5 C: 0,05-0,4	24-48	Lin *et al.* (2012)
Southeastern Brazilian Coast					
Oithona spp.	18-27	ID	0,02-1,55; N: 0,21-0,45	24-72	Martinelli-Filho (2013)
O. plumifera			0,03-0,54; N: 0,07-0,19 C: 0,03-0,09	72	
Dioithona oculata			0,01-0,46; N: 0,28-0,34	72	
Corycaeidae			0,01-1,23	48-72	
Oncaeidae			0,01-0,82; N: 0,03-0,46	24-72	

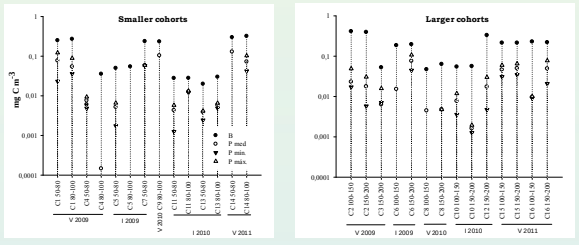

Figure 4: Biomass (B), median (P med.), minimum (P min.) and maximum (P max.) production for *Oithona* spp. from summer 2009 to summer 2011.

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