Morphometric analysis of *Capitella capitata* (Polychaeta, Capitellidae)

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ABSTRACT. Accurate size measurements are fundamental in characterizing the population structure and secondary production of a species. The purpose of this study was to determine the best morphometric parameter to estimate the size of individuals of *Capitella capitata* (Fabricius, 1780). The morphometric analysis was applied to individuals collected in the intertidal zones of two beaches on the northern coast of the state of São Paulo, Brazil: São Francisco and Araçá. The following measurements were taken: the width and length (height) of the 4th, 5th and 7th setigers, and the length of the thoracic region (first nine setigers). The area and volume of these setigers were calculated and a linear regression analysis was applied to the data. The data were log-transformed to fit the allometric equation $y = ax^b$ into a straight line ($log_y = log_a + b * log_x$). The measurements which best correlated with the thoracic length in individuals from both beaches were the length of setiger 5 ($r^2 = 0.722$; $p<0.05$ in São Francisco and $r^2 = 0.795$; $p<0.05$ in Araçá) and the area of setiger 7 ($r^2 = 0.705$; $p<0.05$ in São Francisco and $r^2 = 0.634$; $p<0.05$ in Araçá). According to these analyses, the length of setiger 5 and/or the area of setiger 7 are the best parameters to evaluate the growth of individuals of *C. capitata*.

KEYWORDS. Capitellidae, *Capitella capitata*, beaches, intertidal, morphometry.

RESUMO. Análise morfométrica de *Capitella capitata* (Polychaeta, Capitellidae). Medidas de tamanho precisas são fundamentais para a caracterização da estrutura populacional e produção secundária de uma espécie. O objetivo deste estudo foi determinar o melhor parâmetro morfométrico para estimar o tamanho de indivíduos de *Capitella capitata* (Fabricius, 1780). A análise morfométrica foi aplicada em indivíduos coletados na zona entremarés de duas praias da costa norte do estado de São Paulo, Brasil: São Francisco e Araçá. Foram efetuadas as seguintes medidas: a largura e comprimento dos setígeros 4, 5 e 7, e o comprimento da região torácica. A área e o volume destes setígeros foram calculados e uma análise de regressão linear foi aplicada a estes dados. Os dados foram transformados em logaritmo para ajustar a equação alométrica $y = ax^b$ em uma reta ($log_y = log_a +b * log_x$). As medidas que apresentaram melhor correlação com a região torácica (nove primeiros setígeros) nos indivíduos das duas praias foram o comprimento do setígero 5 ($r^2 = 0{,}722$; $p<0{,}05$ em São Francisco e $r^2 = 0{,}795$; $p<0{,}05$ em Araçá) e a área do setígero 7 ($r^2 = 0{,}705$; $p<0{,}05$ em São Francisco e $r^2 = 0{,}634$; $p<0{,}05$ em Araçá). De acordo com estas análises, o comprimento do setígero 5 e/ou a área do setígero 7 são os melhores parâmetros para avaliar o crescimento de indivíduos de *C. capitata*.

PALAVRAS-CHAVE. Capitellidae, *Capitella capitata*, entremarés, morfometria, praias.

The polychaete *Capitella capitata* (Fabricius, 1780) is a non-selective deposit-feeding burrowing worm (Fauchald & Jumars, 1979) found worldwide, from the intertidal to the deepest regions (Hutchings, 2000). Electrophoretic analysis and morphological studies conducted by Grassle & Grassle (1974, 1976) and Amaral (1980), respectively, revealed that *C. capitata* consists of a complex of as many as six sibling species that have similar adult reproductive modes, larval development and enzyme patterns for some genetic loci. Although some authors recognize that several different species are present under the concept of *C. capitata* (Bridges *et al.*, 1994; Bridges, 1996; Holmer *et al.*, 1997; Cohen & Pechenik, 1999; Pechenik *et al.*, 2000), sometimes species-level distinctions are not possible, as noted by Méndez *et al.* (1997).

Capitella capitata is frequently found in high abundance in organically enriched environments (Reish, 1980), and is widely used as an indicator of organic pollution or environmental disturbances (Grassle & Grassle, 1974; Warren, 1976, 1977; Reish, 1979; James & Gibson, 1980; Grizzle, 1984; Tsutsumi & Kikuchi, 1984; Tsutsumi, 1987, 1990; Tsutsumi *et al.*, 1990; Bridges *et al.*, 1994; Méndez *et al.*, 1997; Amaral *et al.*, 1998). High densities of *C. capitata* can be attributed to an opportunistic life history that allows rapid colonization of organically enriched and/or disturbed habitats (Grassle & Grassle, 1974). Rapid growth, maturity at a small body size and extended reproductive periods are ontogenetic features that allow this species to exploit disturbed habitats. Changes in the structure of benthic communities due to chronic environmental stress are typically characterized by the dominance of opportunistic taxa such as *C. capitata* (Bilyard, 1987; Warwick *et al.*, 1987; Dauer, 1993).

The population dynamics and the factors affecting the growth and secondary production of *C. capitata* have been studied by Warren (1976), Tenore (1977, 1981, 1982), Chesney (1985), Forbes & Lopez (1987, 1990a,b), Tsutsumi (1987, 1990), Grémare *et al.* (1989), Tsutsumi *et al.* (1990), Bridges *et al.* (1994), Bridges (1996), Martin & Grémare (1997) and Méndez *et al.* (1997), and for other polychaete families by Zajac (1991), Santos (1991, 1994), Ambrogi *et al.* (1993), Lardicci *et al.* (1997), Omena & Amaral (2000) and Souza & Borzone (2000), among others. These kinds of studies on sandy beaches are important for better understanding of the community structure in this ecosystem (Holland & Polgar, 1976). However, the population dynamics of *C. capitata* on intertidal sandy beaches are poorly known, although these habitats are ecologically important (Amaral *et al.*, 1998) and a valuable assessment tool in coastal environmental management (Arias & Drake, 1994).

Body-size relationships are essential in understanding population processes such as recruitment, growth and secondary productivity (Tsutsumi, 1987, 1990;

Qian *et al.*, 1990; Steimle *et al.*, 1990; Méndez *et al.*, 1997; Omena & Amaral, 2000). However, with soft-bodied taxa such as marine polychaetes, body length can vary with the fixation process, and the field sampling procedures typically result in a large proportion of incomplete individuals for which body length cannot be determined directly (Warwick & Price, 1975; Desrosiers *et al.*, 1988). One of the problems in studying the population structure of polychaetes is to establish an appropriate methodology to measure the animals. Most previous studies on the growth of *C. capitata* have been based on the total length of the thoracic region, and/or the length of a single thoracic setiger. The purpose of our study was to determine the best morphometric parameter to estimate the size of individuals of *C. capitata* from two sandy beaches before studying its population dynamics, secondary production and its role as pollution indicator.

MATERIAL AND METHODS

Specimens of *C. capitata* were collected from two beaches located on the mainland side of São Sebastião Channel (northern coast of state of São Paulo, Brazil): São Francisco (23°53'S, 45°24'W) and Araçá (23°49'S, 45°25'W). São Francisco Beach has a narrow intertidal zone and a gentle slope, and the sediment is composed of a mixture of sand and stones of different sizes. The site is located close to urban areas and is exposed to domestic sewage. Araçá Beach is a low-hydrodynamics, less exposed region, with some mangrove vegetation; the sediment is predominantly composed of fine sand and very fine sand. Because of the proximity to the city of São Sebastião, this beach is exposed to both domestic sewage and frequent oil spills from a local oil terminal (Ductos e Terminais Centro Sul – DTCS). In addition, since 1996 there has been a constant discharge of sewage from an underwater outlet (Amaral *et al.*, 1998).

Three core samples were taken every two weeks from November 2002 to March 2003, during spring tides, with a 0.01 m^2 cylindrical sampler inserted to a depth of 20 cm. Each sample was partitioned into upper and lower 10-cm fractions. The two fractions were processed differently. The upper 10 cm of sediment was sieved through 0.500, 0.250 and 0.125 mm mesh sieves. The sediment that remained on the last two sieves was processed further, using a flotation technique to collect larvae and juveniles. The flotation technique (modified after Anderson, 1959) consisted of saturating and agitating the sediment with seawater hyper-saturated with sugar (2.5 l seawater: 1 kg sugar) and then passing the supernatant through a 0.125 mm mesh sieve. The lower 10 cm of sediment was sieved through 1.000 and 0.500 mm mesh sieves. The collected individuals of *C. capitata* were relaxed in 5% $MgCl_2$, fixed in 6% formalin and preserved in 70% ethanol.

All the examined individuals of *C. capitata* belong to a single species, according to morphological observations during the sorting and measuring processes, using a stereomicroscope and a microscope, when necessary, fitted with a graduated eyepiece. Because the morphological features of this species are the same as those described for *C. capitata*, we will continue to use this species name until a worldwide revision of the genus is accomplished. The width (W) and length (L) were measured for setigers 4, 5 and 7 (Fig. 1). In addition, the length of the thoracic region (first nine setigers) was measured (as recommended by Warren (1976) and Méndez *et al.* (1997). The thoracic length is a precise measure as a reference parameter of the worm's size, because these animals are rarely collected entire. The area and volume of setigers 4, 5 and 7 were calculated using the formulae: external area = $2\pi(W/2)L$ and volume = $(\pi(W/2)^2)L$, considering each setiger as a cylinder. The relationship between l/w of setigers 4, 5 and 7 was also examined. The sizes of the individuals from the two beaches were compared through a Z-test applied to the values of length of setiger 5 (L5) and length of the thoracic region. The size classes of L5 were established for both beaches (Tab. I).

Regression analysis was used to evaluate the relationship between each parameter and the length of the thoracic region. Data were log-transformed to fit the allometric equation $y=ax^b$ into a straight line ($\log_y=\log_a + b*\log_x$), where b is the slope; its values will show positive allometry, negative allometry or isometry (Teissier, 1960;

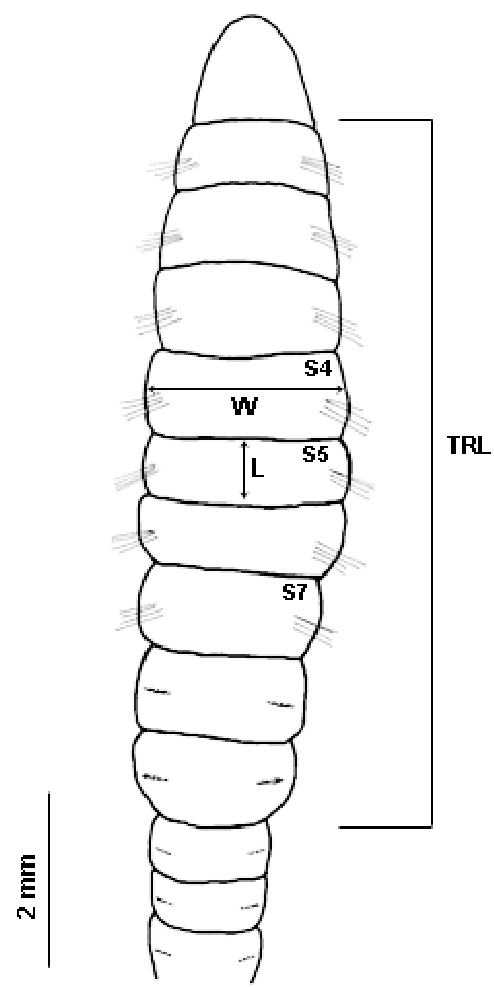


Figure 1. *Capitella capitata* (Fabricius, 1780), dorsal view of the worm (L, length of the setiger; TRL, thoracic region length; S4, setiger 4; S5, setiger 5; S7, setiger 7; W, width of the setiger).

GOULD, 1966). Student's *t*-test was used to compare b critical values of allometry: 1 (X and Y have the same measure); 0.5 (X is a measure of area and Y is a linear measure); 0.33 (X is a measure of volume and Y is a linear measure).

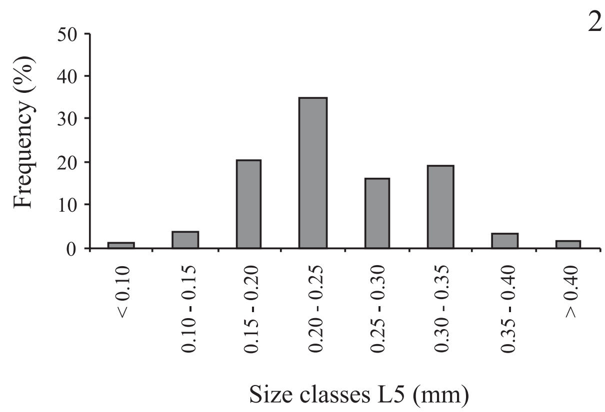
RESULTS

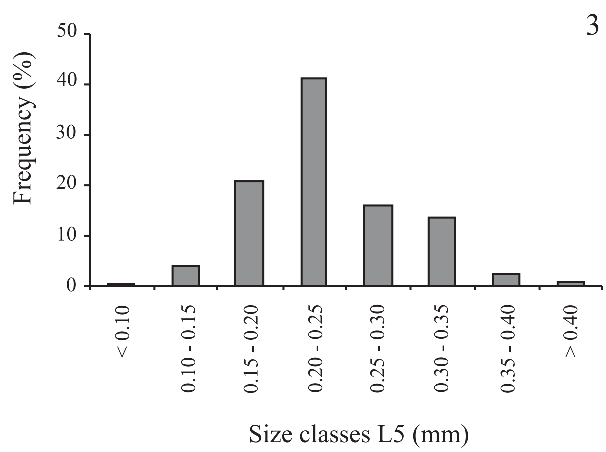
For São Francisco Beach, the relationship between thoracic length and the size of setigers 4 and 5 was examined using 1,581 individuals; and that between thoracic length and the size of setiger 7 was examined using 1,578 individuals (three specimens did not have the complete thoracic portion). For Araçá Beach, the relationship between thoracic length and the size of setigers 4, 5 and 7 was examined using 511 individuals. Individuals collected in São Francisco Beach were significantly larger than those collected in Araçá for both length of setiger 5 (L5) and length of the thoracic region ($Z = 3.15$; $p<0.05$ and $Z = 5.80$; $p<0.05$). The length of setiger 5 (L5) ranged from 0.049 to 0.80 mm (mean 0.25 mm, sd = 0.067 mm) in individuals from São Francisco Beach (Fig. 2), and from 0.05 to 0.460 mm (mean 0.242 mm, sd = 0.059 mm) in individuals from Araçá Beach (Fig. 3). The length of the thoracic region ranged from 1.02 to 19.42 mm (mean 2.22 mm, sd = 0.58 mm) in individuals from São Francisco Beach, and from 0.80 to 3.28 mm (mean 2.10 mm, sd = 0.32 mm) in individuals from Araçá Beach. The most frequent size class interval for both São Francisco and Araçá beaches (38.4% and 41.2%) was in size class L5, ranging from 0.20 to 0.25 mm (Figs. 2, 3).

Table I. Size classes of length of setiger 5 (L5) for individuals of *Capitella capitata* (Fabricius, 1780) from São Francisco and Araçá Beaches, SP, Brazil.

Size Classes
<0.10 mm
0.10 - 0.15 mm
0.15 - 0.20 mm
0.20 - 0.25 mm
0.25 - 0.30 mm
0.30 - 0.35 mm
0.35 - 0.40 mm
>0.40 mm

The regression analyses revealed strong relationships between almost all the parameters and the thoracic region (Tabs. II, III). The strongest correlations in individuals for both collecting sites were found for the length of setiger 5 (L5), $r^2= 0.722$ (São Francisco) and $r^2= 0.795$ (Araçá), and for the area of setiger 7 (A7), $r^2=0.705$ (São Francisco) and $r^2= 0.634$ (Araçá) (Tab. II, III; Fig. 4-7). The results from Student's *t*-test comparing b with critical values of allometry revealed significant negative allometric growth for all parameters (Tab. II, III).





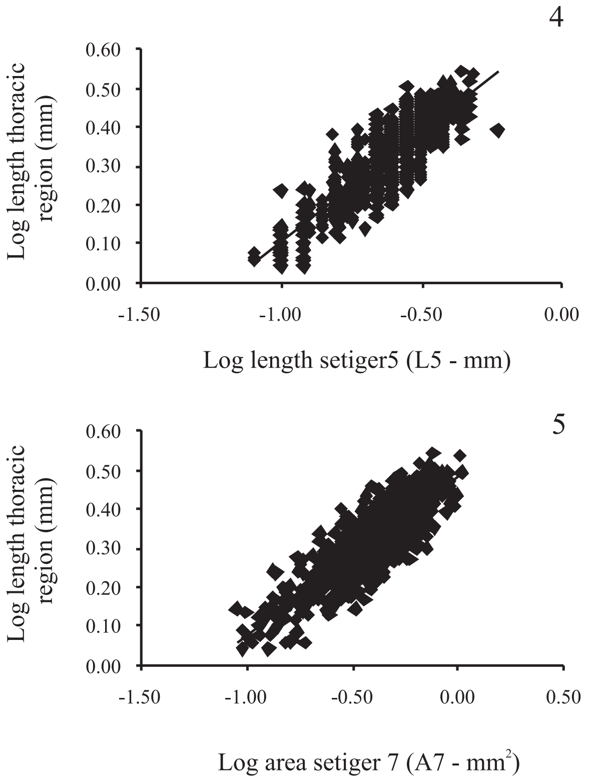
Figures 2, 3. Relative frequency of size class distribution of the length of setiger 5 (L5 - mm) for individuals of *Capitella capitata* (Fabricius, 1780) collected in: 2, São Francisco Beach, SP, Brazil; 3, Araçá Beach, SP, Brazil.

Table II. Relationship between the length of the thoracic setigers (nine setigers) and each allometric parameter of *Capitella capitata* (Fabricius, 1780) from São Francisco Beach, SP, Brazil (Par, Parameters; N, number of individuals; *a*, Y-intercept; *b*, regression coefficient; r^2, coefficient of determination; p, significance of *t*; *, $p \leq 0.05$; *t*, Student *t*-test comparing b with critical values of allometry; TRL, thoracic region length; W, width (mm); L, length (mm); V, volume (mm^3); A, area (mm^2); 4, setiger 4; 5, setiger 5; 7, setiger 7).

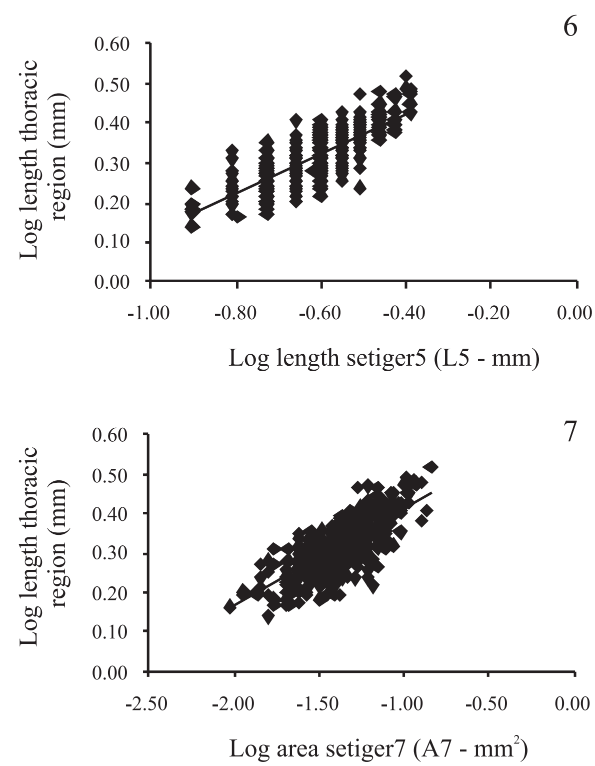
Par	N	log(*a*)	*b*	r^2	p	*t*	p	$TRL=a Par^b$
W4	1581	0.483	0.628	0.398	*	-19.58	*	$=3.041W4^{0.628}$
W5	1581	0.447	0.573	0.385	*	-23.72	*	$=2.799W5^{0.573}$
W7	1578	0.508	0.656	0.410	*	-17.20	*	$=3.221W7^{0.656}$
L4	1581	0.636	0.467	0.546	*	-48.45	*	$=4.325L4^{0.467}$
L5	1581	0.674	0.569	0.722	*	-47.89	*	$=4.721L5^{0.569}$
L7	1578	0.719	0.631	0.681	*	-33.54	*	$=5.236L7^{0.631}$
V4	1581	0.640	0.250	0.613	*	-16.00	*	$=4.365V4^{0.250}$
V5	1581	0.592	0.236	0.625	*	-18.80	*	$=3.908V5^{0.236}$
V7	1578	0.663	0.265	0.641	*	-16.00	*	$=4.602V7^{0.265}$
A4	1581	0.471	0.354	0.646	*	-20.86	*	$=2.958A4^{0.354}$
A5	1581	0.439	0.355	0.694	*	-24.17	*	$=2.748A5^{0.355}$
A7	1578	0.489	0.409	0.705	*	-13.00	*	$=3.083A7^{0.409}$

Table III. Relationship between the length of the thoracic setigers (nine setigers) and each allometric parameter of *Capitella capitata* (Fabricius, 1780) from Araçá Beach, SP, Brazil (Par, Parameters; N, number of individuals; *a*, Y-intercept; *b*, regression coefficient; r^2, coefficient of determination; p, significance of *t*; *, $p \leq 0.05$; *t*, Student *t*-test comparing b with critical values of allometry; TRL, thoracic region length; W, width (mm); L, length (mm); V, volume (mm^3); A, area (mm^2); 4, setiger 4; 5, setiger 5; 7, setiger 7).

Par	N	log(*a*)	*b*	r^2	p	*t*	p	TRL=aPar^b
W4	511	0.363	0.141	0.062	*	-35.79	*	$=2.307W4^{0.141}$
W5	511	0.413	0.373	0.171	*	-17.42	*	$=2.588W5^{0.373}$
W7	511	0.471	0.485	0.215	*	-12.56	*	$=2.958W7^{0.485}$
L4	511	0.679	0.548	0.608	*	-23.79	*	$=4.775*L4^{0.548}$
L5	511	0.640	0.526	0.795	*	-26.33	*	$=4.365L5^{0.526}$
L7	511	0.649	0.515	0.628	*	-26.94	*	$=4.456L7^{0.515}$
V4	511	0.513	0.141	0.302	*	-24.00	*	$=3.258V4^{0.141}$
V5	511	0.572	0.208	0.467	*	-12.20	*	$=3.732V5^{0.208}$
V7	511	0.633	0.227	0.513	*	-10.30	*	$=4.295V7^{0.227}$
A4	511	0.417	0.190	0.356	*	-28.18	*	$=2.612A4^{0.190}$
A5	511	0.445	0.345	0.586	*	-11.92	*	$=2.796A5^{0.345}$
A7	511	0.489	0.369	0.634	*	-10.92	*	$=3.083A7^{0.369}$



Figures 4, 5. *Capitella capitata* (Fabricius, 1780) from São Francisco Beach, SP, Brazil. 4, linear regression between length of the thoracic region and length of setiger 5; 5, length of the thoracic region and the area of setiger 7.



Figures 6, 7. *Capitella capitata* (Fabricius, 1780) from Araçá Beach, SP, Brazil. 6, linear regression between length of the thoracic region and length of setiger 5; 7, length of the thoracic region and the area of setiger 7.

DISCUSSION

In general, the study of size-dependent processes in polychaetes requires identifying parameters other than total body length or body weight, because of the high percentage of individuals that are damaged during sample collection and processing. When entire individuals are available, total body length has been shown to be a good growth estimator in diverse polychaete taxa such as eunicids (FAUCHALD, 1991) and sabellids (KEMP, 1988), while other taxa such as spionids may show significant distortion in body dimensions during relaxation or preservation, causing concern about the reliability of body length as a growth estimator (YOKOYAMA, 1988). Sclerotized body parts, such as pharyngeal jaws, can be reliable body-size estimators for those taxa that possess such structures (OLIVE & GARWOOD, 1981; GLASBY, 1986). Other structures used as growth estimators in polychaetes include peristomial width in the nereidid *Neanthes succinea* (Frey & Leuckart, 1847) (CAMMEN, 1980), anterior setiger width in the spionid *Scolelepis gaucha* (Orensanz & Gianuca, 1974) (Santos, 1991, 1994), total setiger number in the spionid *Dipolydora armata* (Langerhans, 1880) (Lewis, 1998), and parapodial parameters in nereidid species (Ben-Eliahu, 1987).

In the present study, we examined various setiger characteristics compared to thoracic length as estimates of body size in order to measure size-dependent processes in future studies of *C. capitata*, based on the results from Warren (1976) and Méndez *et al.* (1997). After sample processing, most individuals of this important species are frequently broken into pieces or missing their posterior ends; however, the thoracic region is rarely damaged. Previous studies of the population dynamics and secondary production of *C. capitata* have estimated body size using parameters such as the width of various thoracic setigers (Tsutsumi, 1987, 1990) and thoracic length (Warren, 1976; Méndez *et al.*, 1997). A review of the literature concerning estimating growth in *C. capitata* indicates that most authors used thoracic parameters such as thoracic length or the length or width of a single thoracic setiger. For example, Tsutsumi & Kikuchi (1984) found a strong correlation ($r^2 = 0.962$) between body weight and maximum thoracic width for *C. capitata* in Japan, and also that few specimens of this species were damaged during sample processing (Tsutsumi, 1987, 1990). When laboratory growth studies are performed, there are sufficient numbers of entire individuals of *C. capitata* to allow the use of total body length (Tenore, 1982; Chesney, 1985; Tenore & Chesney, 1985), wet weight (Tenore, 1983; Phillips & Tenore, 1984; Chesney & Tenore, 1985) or body volume (Bridges *et al.*, 1994; Bridges, 1996). Calculation of body volume typically uses thoracic setiger measurements. Qian (1994) cautioned about the use of wet weight, because it is greatly affected by the weight of the gut contents. Although individuals of *C. capitata* were significantly different in size between the two beaches studied, our results show that the length of setiger 5 and the area of setiger 7 are the most appropriate parameters to estimate body size for these populations. We recommend the use of setiger 5 length, because the thoracic region is almost always intact and this parameter is easily accessible for measurement.

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REFERENCES

Amaral, A. C. Z. 1980. Breve caracterização dos gêneros da família Capitellidae Grube (Annelida, Polychaeta) e descrição de *Nonatus longilineus* Gen. sp. nov. **Boletim do Instituto Oceanográfico 29**(1):99-106.

Amaral, A. C. Z.; Morgado, E. H. & Salvador, L. B. 1998. Poliquetas bioindicadores de poluição orgânica em praias paulistas. **Revista Brasileira de Biologia 58**(2):307-316.

Ambrogi, R.; Fontana, P. & Riccobene, P. 1993. Population dynamics and secondary prodution of th spionid polychaete *Prionospio caspersi* in front of the Po River Delta. **Vie et Milieu 43**:165-172.

Anderson, R. O. 1959. A modified flotation technique for sorting bottom fauna samples. **Limnology and Oceanography 4**:223-225.

Arias, A. M. & Drake, P. 1994. Structure and production of the benthic macroinvertebrate community in a shallow lagoon in the Bay of Cadiz. **Marine Ecology Progress Series 115**:151-167.

Ben-Eliahu, M. N. 1987. An approach to nereidid morphometry. **Bulletin of the Biological Society of Washington** (7):169-173.

Bilyard, G. R. 1987. The value of benthic infauna in marine pollution monitoring studies. **Marine Pollution Bulletin 18**(11):581-585.

Bridges, T. S. 1996. Effects of organic addition to sediment, and maternal age and size, on patterns of offspring investment and performance in two opportunistic deposit-feeding polychaetes. **Marine Biology 125**(2):345-357.

Bridges, T. S.; Levin, L. A.; Cabrera, D. & Plaia, G. 1994. Effects of sediment amended with sewage algae, or hydrocarbons on growth and reproduction in two opportunistic polychaetes. **Journal of Experimental Marine Biology and Ecology 177**:99-119.

Cammen, L. M. 1980. A method for measuring ingestion rate of deposit feeders and its use with the polychaete *Nereis succinea*. **Estuaries 3**(1):55-60.

Chesney Jr., E. J. 1985. Laboratory studies of the effect of predation on production and the production: biomass ratio of the opportunistic polychaete *Capitella capitata* (type I). **Marine Biology 87**:307-312.

Chesney, E. J. & Tenore, K. R. 1985. Effects of predation and disturbance on the population growth and dynamics of the polychaete *Capitella capitata* (Type I). **Marine Biology 85**:77-82.

Cohen, R. A. & Pechenik, J. A. 1999. Relationship between sediment organic content, metamorphosis, and postlarval performance in the deposit-feeding polychaete *Capitella* sp. I. **Journal of Experimental Marine Biology and Ecology 240**(1):1-18.

Dauer, D. M. 1993. Biological criteria, environmental health and estuarine macrobenthic community structure. **Marine Pollution Bulletin 26**(5):249-257.

Desrosiers, G.; Vincent, B.; Retière, C. & Boucher, L. 1988. Compairison de critères utilisables pour l'étude de la structure des populations du polychète *Nereis virens* (Sars). **Canadian Journal of Zoology 66**(6):1454-1459.

Fauchald, K. 1991. A morphometric study of eunicid polychaetes from Belize, Werstern Caribbean Sea. **Ophelia Supplement 5**:47-53.

Fauchald, K. & Jumars, P. A. 1979. The diet of worms: a study of polychaete feeding guilds. **Oceanography and Marine Biology: an Annual Review 17**:193-284.

Forbes, T. L. & Lopez, G. R. 1987. The allometry of deposit feeding in *Capitella* species I (Polychaeta: Capitellidae): the role of temerature and pellet weight in the control of egestion. **Biological Bulletin 172**:187-201.

___. 1990a. Ontogenetic changes in individual growth and egestion rates in the deposit-feeding polychaete *Capitella* Sp. 1. **Journal of Experimental Marine Biology and Ecology 143**:209-220.

___. 1990b. The effect of food concentration, body size, and environmental oxygen tension on the growth of the deposit-feeding polychaete, *Capitella* species I. **Limnology and Oceanography 35**(7):1535-1544.

Glasby, C. J. 1986. Population structure and reproductive biology of *Ceratonereis limnetica* (Polychaeta: Nereididae) at lower Portland, Hawkesbury River, Australia. **Marine Biology 90**:589-595.

Gould, S. J. 1966. Allometry and size in ontogeny and phylogeny. **Biological Review 41**:587-640.

Grassle, J. P. & Grassle, J. F. 1974. Opportunistic life histories and genetic systems in marine benthic polychaetes. **Journal of Marine Research 32**(2):253-284.

___. 1976. Sibling species in the marine population indicator *Capitella* (Polychaeta). **Science 192**:567-569.

Grémare, A.; Marsh, A. G. & Tenore, K. R. 1989. Secondary production and reproduction of *Capitella capitata* type I (Annelida: Polychaeta) during a population cycle. **Marine Ecology Progress Series 51**:99-105.

Grizzle, R. E. 1984. Pollution indicator species of macrobenthos in a coastal lagoon. **Marine Ecology Progress Series 18**(3):191-200.

HOLLAND, A. F. & POLGAR, T. T. 1976. Seasonal changes in the structure of na intertidal community. **Marine Biology 37**:341-348.

HOLMER, M.; FORBES, V. E. & FORBES, T. L. 1997. Impact of the polychaete *Capitella* sp. I on microbial activity in an organic-rich marine sediment contaminated with the polycyclic aromatic hydrocarbon fluoranthene. **Marine Biology 128**:679-688.

HUTCHINGS, P. A. 2000. Family Capitellidae. *In*: BEESLEY, P. L.; ROSS, G. J. B. & GLASBY, C. J. eds. **Polychaetes and allies: the southern synthesis. Fauna of Australia. Polychaeta, Myzoztomida, Pogonophora, Echiura, Spuncula**. Melbourne, CSIRO Publishing. v.4A, p.67-72.

JAMES, C. J. & GIBSON, R. 1980. The distribution of the polychaete *Capitella capitata* (Fabricius) in docks sediments. **Estuarine and Coastal Marine Science 10**:671-683.

KEMP, P. F. 1988. Production and life history of a deposit-feeding polychaete in an atypical environment. **Estuarine, Coastal and Shelf Science 26**:437-446.

LARDICCI, C.; CECCHERELLI, G. & ROSSI, F. 1997. *Streblospio shrubsolii* (Polychaeta: Spionidae): temporal flutuations in size and reproductive activity. **Cahiers de Biologie Marine 38**:207-214.

LEWIS, J. B. 1998. Reproductio, larval development and functional relationships of the burrowing, spionid polychaete *Dipolydora armata* with the calcareous hydrozoan *Millepora complanata*. **Marine Biology 130**(4):651-662.

MARTIN, D. & GRÉMARE, A. 1997. Secondary production of *Capitella* sp. (Polychaeta: Capitellidae) inhabiting different organically enriched environments. **Scientia Marina 61**(2):99-109.

MÉNDEZ, N.; ROMERO, J. & FLOS, J. 1997. Population dynamics and production of the polychaete *Capitella capitata* in the littoral zone of Barcelona (Spain, NW Mediterranean). **Journal of Experimental Marine Biology and Ecology 218**(2):263-284.

OLIVE, P. J. W. & GARWOOD, P. R. 1981. Gametogenic cycle and population structure of *Nereis diversicolor* and *Neris pelagica* from north-east England. **Journal of the Marine Biological Association of the Unite Kingdom 61**:193-213.

OMENA, E. P. & AMARAL, A. C. Z. 2000. Population dynamics and secondary production of *Laeonereis acuta* (Treadwell, 1923) (Nereididae: Polychaeta). **Bulletin of Marine Science 67**:421-431.

PECHENIK, J. A.; BERARD, R. & KERR, L. 2000. Effects of reduced salinity on survival, growth, reproductive success, and energetics of the euryhaline polychaete *Capitella* sp. I. **Journal of Experimental Marine Biology and Ecology 254**:19-35.

PHILLIPS, N. W. & TENORE, K. R. 1984. Effects of foodparticle size and pelletization on individual growth and larval settlement of the deposit feeding polychaete *Capitella capitata* Type I. **Marine Ecology Progress Series 16**(3):241-247.

QIAN, P. Y. 1994. Effect of food quantity on growth and reproductive characteristics of *Capitella* sp. (Annelida: Polychaeta). **Invertebrate Reproduction and Development 26**(3):175-185.

QIAN, P. Y.; MCEDWARD, L. R. & CHIA, F. S. 1990. Effects of delayed settlement on survival, growth, and reproduction in the spionid polychaete, *Polydora ligni*. **Invertebrate Reproduction and Development 18**(3):147-152.

REISH, D. J. 1979. Bristle worms (Annelida: Polychaeta). *In*: HART, C. W. & FULLER, S. L. H. eds. **Pollution ecology of estuarine invertebrates**. New York, Academic. p.77-125.

___. 1980. Use of polychaetous annelids as test organisms for marine bioassay experiments. *In*: BUIKEMA JR., A. L. & CAIRNS JR., J. eds. **Aquatic invertebrate bioassays**. Baltimore, American Society for testing and materials. p.140-154.

SANTOS, P. J. P. 1991. Morphodynamical infleuence of a temporary freshwater stream on the population dynamics of *Scolelepis gaucha* (Polychaeta: Spionidae) on a sandy beach in Southern Brazil. **Bulletin of Marine Science 48**(3):657-664.

___. 1994. Population dynamics and production of *Scolelepis gaucha* (Polychaeta: Spionidae) on the sandy beaches of southern Brazil. **Marine Ecology Progress Series 110**:159-165.

SOUZA, J. R. B. & BORZONE, C. A. 2000. Population dynamics and secondary production of *Scolelepis squamata* (Polychaeta: Spionidae) in na exposed sandy beach of southern Brazil. **Bulletin of Marine Science 67**:421-431.

STEIMLE JR., F. W.; KINNER, P.; HOWE, S. & LEATHEM, W. 1990. Polychaete population dynamics and production in the New York Bight associated with variable levels of sediment contamination. **Ophelia 31**(2):105-123.

TEISSIER, G. 1960. Relative growth. *In*: WATERMAN T. H. ed. **The Physiology of Crustacea**. New York, Academic. v.1, p.537-560.

TENORE, K. R. 1977. Utilization of aged detritus derived from different sources by the polychaete *Capitella capitata*. **Marine Biology 44**:51-55.

___. 1981. Organic nitrogen and caloric content of detritus. I. Utilization by the deposit feeding polychaete, *Capitella capitata*. **Estuarine, Coastal and Shelf Science 12**(1):39-47.

___. 1982. Comparison of the ecological energetics of the polychaetes *Capitella capitata* and *Nereis succinea* in experimental systems receiving similar levels of detritus. **Netherlands Journal of Sea Research 16**:46-54.

___. 1983. Organic nitrogen and caloric content of detritus III. Effect on growth of a deposit-feeding polychaete, *Capitella capitata*. **Estuarine, Coastal and Shelf Science 17**(6):733-742.

TENORE, K. R. &. CHESNEY JR., E. J. 1985. The effects of interaction of rate of food supply and population density in the bioenergetics of the opportunistic polychaete, *Capitella capitata* (type I**). Limnology and Oceanography 30**(6):1188-1195.

TSUTSUMI, H. 1987. Population dynamics of *Capitella capitata* (Polychaeta: Capitellidae) in na organically polluted cove. **Marine Ecology Progress Series 36**:139-149.

___. 1990. Population persistence of *Capitella* sp. (Polychaeta: Capitellidae) on a mud flat subject to environmental disturbance by organic enrichment. **Marine Ecology Progress Series 63**(2-3):147-156.

TSUTSUMI, H. & KIKUCHI, T. 1984. Study of the life history of *Capitella capitata* (Polychaeta: Capitellidae) in Amakusa, south Japan including a comparison with other geographical region. **Marine Biology 80**:315-321.

TSUTSUMI, H.; FUKUNAGA, S.; FUJITA, N. & SUMIDA, M. 1990. Relationship between growth of *Capitella* sp. and organic enrichment of the sediment. **Marine Ecology Progress Series 63**(2-3):157-162.

WARREN, L. M. 1976. A population study of the polychaete *Capitella capitata* at Plymouth. **Marine Biology 38**:209-216.

___. 1977. The ecology of *Capitella capitata* in british waters. **Journal of the Marine Biological Association of the United Kingdom 57**:151-159.

WARWICK, R. M.; PEARSON, T. H. & RUSWAHYUNI. 1987. Detection of pollution effects on marine macrobenthos: further evaluation of the species abundance/biomass method. **Marine Biology 95**:193-200.

WARWICK, R. M. & PRICE, R. 1975. Macrofauna production in an estuarine mud flat. **Journal of the Marine Biological Association of the United Kingdom 55**:1-18.

YOKOYAMA, H. 1988. Effects of temperature on the feeding activity and growth of the spionid polychaete *Paraprionospio* sp. (form A). **Journal of Experimental Marine Biology and Ecology 123**(1):41-60.

ZAJAC, R. N. 1991. Population ecology of *Polydora ligni* (Polychaeta: Spionidae). I. Seasonal variation in population characteristics and reproductive activity. **Marine Ecology Progress Series 77**:197-206.

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