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MORPHOMETRY AND RELATIVE GROWTH OF POPULATIONS OF *TANAIS DULONGII* (AUDOIN, 1826) (TANAIDACEA: TANAIDAE) IN PRISTINE AND IMPACTED MARINE ENVIRONMENTS OF THE SOUTHWESTERN ATLANTIC

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ABSTRACT

Life history strategies are closely related to environmental conditions and biotic and abiotic factors play a major role conditioning several traits as growth rates, sexual maturity, size and morphometric differences. We compare body dimensions, relative growth patterns, and size of sexual differentiation between populations of *Tanais dulongii* (Audoin, 1826) that live in two contrasting habitats in order to determine if they differ in life history traits. Some 900 individuals were collected (150 males, 150 females and 150 juveniles from each site) in a rocky shore with a lower anthropic impact (La Estafeta) and a polluted area (Mar del Plata Harbor) and thirteen body dimensions between sexes and environments were compared. Relative growth rates were determined establishing the relationship between total length (TL) and the rest of body dimensions with reduced major axis method (RMA). Regression slopes were employed to test the degree of isometry or allometry. MDS and SIMPER analyses were used to plot and identify morphometric differences between sexes and populations. TL and the rest of body dimensions were longer in La Estafeta than in Mar del Plata, and degree of sexual differentiation was larger in La Estafeta (ca. 3.5 mm) than in Mar del Plata (1.75 mm). RMA showed differences among sites: in Mar del Plata growth of most dimensions was positively allometric in adults, but in La Estafeta half of the measured dimensions had positive allometric growth for both sexes and half had isometric or negative allometric growth. Juveniles of both sites showed a positively allometric growth. MDS established a clear separation between sites and sexes. SIMPER showed that TL, cheliped length, cheliped width, and antennule peduncle length contributed most to differences between sexes, and TL (mainly) and the rest of variables (in minor degree) in the dissimilarities between sites. We believe that the differences observed between populations of *T. dulongii* are due to phenotypic plasticity in this species in response to environmental differences.

KEY WORDS: impacted environment, morphometric analysis, pristine environment, relative growth, *Tanais dulongii*

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INTRODUCTION

Tanaidacea include approximately 1200 species that live from deep water to coastal marine and freshwater environments (Blazewicz-Paszkowycz et al., 2012). Due to their small size (less than 7 mm) and their benthic life cycle (Schram, 1986; Blake and Scott, 1997) this order has lower dispersal rates; so life history strategies are closely related to environmental factors (Thiel, 2003) and these organisms have been used as indicators of environmental health (Chintiroglou et al., 2004; de la Ossa-Carretero et al., 2010; Pelletier et al., 2010). Biotic and abiotic factors play a major role in growth rates of crustaceans, generating differences in relative growth and size of sexual maturity in populations under different environmental conditions (Benetti and Negreiros-Fransozo, 2004; Remerie et al., 2005; Anastasiadou et al., 2009). Morphometric analyses, powerful tools for detecting these differences among populations, have been performed mainly in decapods (Felder and Lovett, 1989; Fransozo et al., 2003; Mariappan and Balasundaram, 2004; SanVicente-Añorve et al., 2008; Anastasiadou et al., 2009). Very few studies on morphometry, relative growth and sexual dimorphism, classical issues in basic decapod research (Hartnoll, 1978, 1982; Clayton, 1990), have been directed at tanaidaceans.

Tanais dulongii (Audouin, 1826) (= *T. cavolinii*) is a marine species that lives on hard bottoms and builds tubes that are used as feeding and breeding sites (Johnson and Attramadal, 1982; Borrowsky, 1983). Many tanaidaceans have a wide range of reproductive strategies that frequently includes sequential hermaphroditism, mainly with protogynous life cycles, and various degrees of sexual polymorphism (Schram, 1986). However hermaphroditism has not been reported in *T. dulongii* and individuals are clearly dimorphic (Hamers and Franke, 2000), except the few intersex individuals found in Argentine populations (only 2 of 31,769 individuals; Rumbold, 2012). This species is distributed around the world (Sieg, 1980). It is regarded as a native on the coasts located from Norway to the Mediterranean Sea (Andersson, 1978; Holdich and Jones, 1983; Perez-Ruzafa and Sanz, 1993) and has invaded the coasts

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of southestern Australia (Hutchings et al., 1993) and eastern North America (Sieg, 1980); it does not have formal status yet as an invader along the coasts of southweastern South America (Orensanz et al., 2002). Studies of behavior, development, and population dynamics of *T. dulongii* have occurred (Johnson and Attramadal, 1982; Borrowsky, 1983; Perez-Ruzafa and Sanz, 1993; Hamers and Franke, 2000; Rumbold et al., 2012), but interpopulational comparative morphometric and relative growth analysis is lacking.

The objective of this study was to examine and compare body dimensions, relative growth patterns, and size of sexual differentiation between two populations of *T. dulongii* that live in two contrasting habitats in a small geographic area: a rocky shore with relative lower human impact, and a polluted harbor area. We sought to corroborate if tanaidacean populations that live under different environmental conditions differ in life history traits.

MATERIALS AND METHODS

Study Sites

Organisms were collected in Mar del Plata Harbor (38°02′S, 57°32′W) and in the intertidal of La Estafeta (38°10′S, 57°38′W; Fig. 1). Mar del Plata

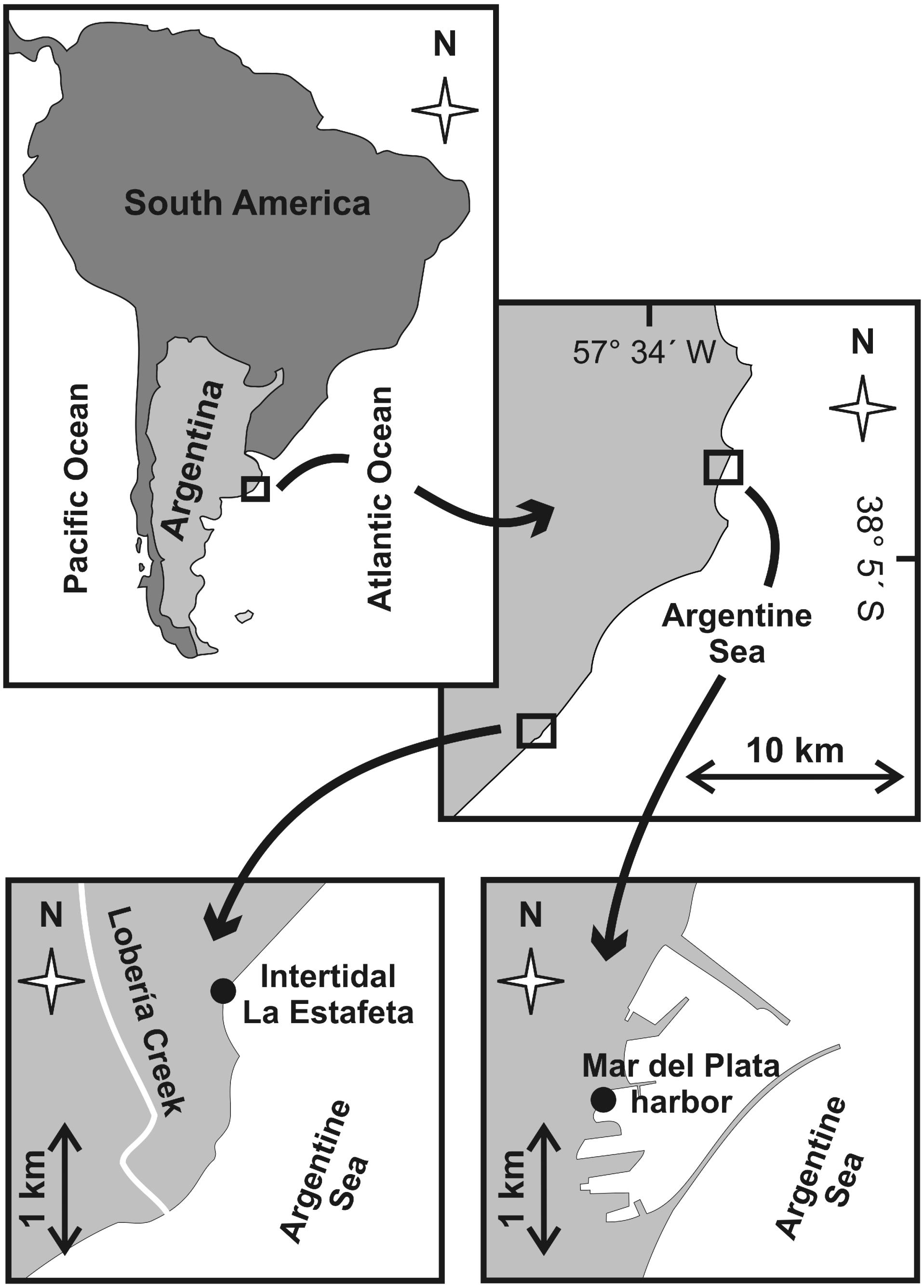

Fig. 1. Geographical localization of the study sites (●) intertidal La Estafeta and Mar del Plata Harbor, Buenos Aires, Argentina.

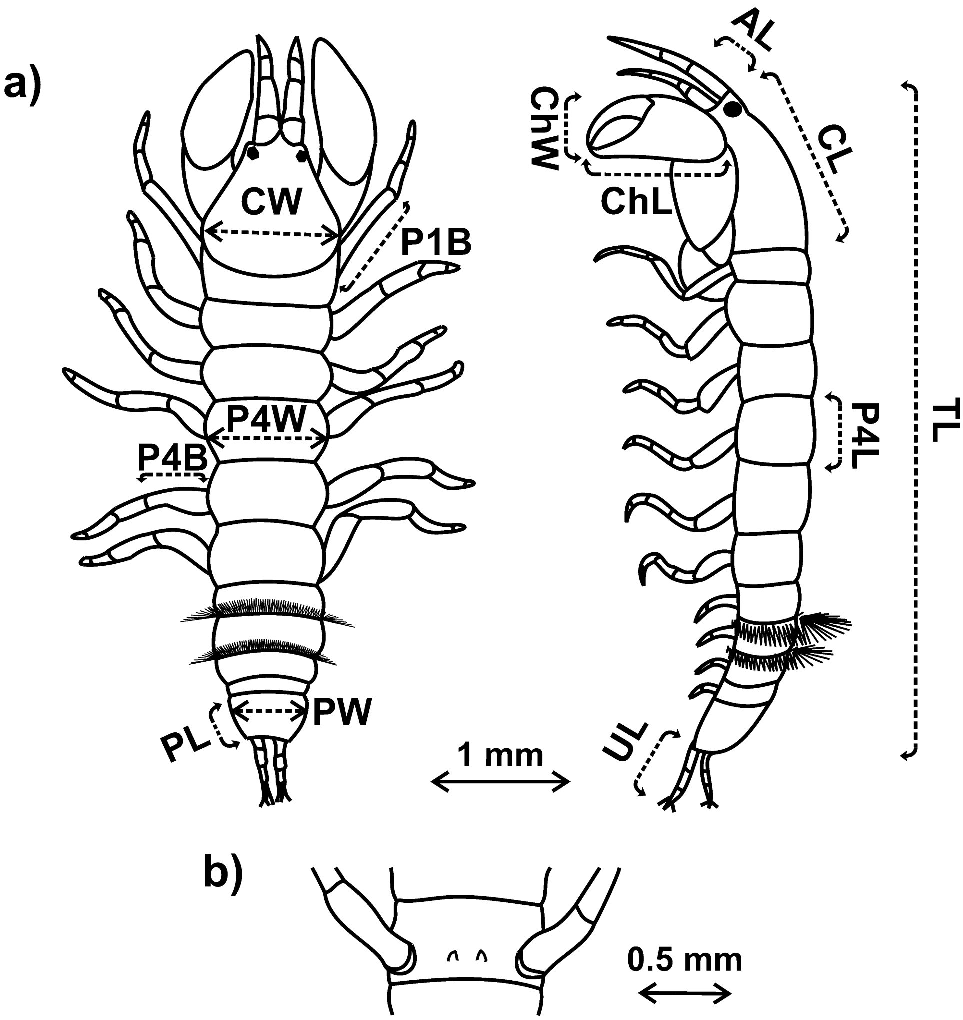

Fig. 2. (a) Dorsal and lateral view of *T. dulongii* to show morphometric measurements; (b) ventral view of pereionite VI of males with genital cones. For abbreviations, see text.

is a semi-closed harbor that presents typical characteristics of a polluted environment: high levels of organic matter from sewage and biogenic sources, hydrocarbons from ships and factories, low salinity and pH, and anoxic conditions due to low turbulence (Rivero et al., 2005; Albano et al., 2013). Despite these conditions, there is an extremely diverse biota with ascidians and polychaete tubes that provide refuges for fishes, molluscs, crustaceans, and nematodes (Albano and Obenat, 2009; Albano et al., 2013). La Estafeta is an open rocky shore located 15 km south of Mar del Plata Harbor characterized by a consolidated sediment (loess) and many tide pools due to the effect of erosion (Baeza et al., 2010; Rumbold et al., 2012). It does not possess sewage pipes or drains and, being surrounded by cliffs, is less accessible; consequently it has a lower degree of human impact (Rumbold et al., 2012). The intertidal is 70 m wide when tides recede; algae present in the substrate (mainly *Corallina officinalis* and *Ulva rigida*) serve as sites for feeding, breeding, and shelter to a variety of invertebrates that live there (Rumbold et al., 2012). Both sites are subjected to a microtidal regime with mean amplitude of 0.8 m (Isla, 2004).

Field and Laboratory Procedures

We collected samples from July to September 2009 and from March 2010 to March 2011. Algal patches, sediment, and polychaete tubes were scraped up with spatulas in both environments. Samples were fixed in 70% alcohol. In the laboratory, organisms were separated from the extracted material, and sexed using a stereoscopic microscope. Sexual differentiation was based on the presence of genital cones in male pereonite VI. Individuals that measured less than the smallest identifiable males were classified as juveniles, except those that had visible ovisacs (Rumbold et al., 2012).

Thirteen body dimensions were measured with a graduated eyepiece in 900 individuals (150 males, 150 females and 150 juveniles from each site): total length (TL), carapace length (CL), carapace width (CW), pereionite 4 length (P4L), pereionite 4 width (P4W), cheliped length (ChL), cheliped width (ChW), antennule peduncle length (AL), pleotelson length (PL), pleotelson width (PW), pereiopod 1 basis (P1B) and pereiopod 4 basis (P4B), uropod length (UL) (Fig. 2). Morphological terminology followed Larsen (2003).

Statistical Analysis

To evaluate differences in size of body dimensions among males and females of different sites a two-way ANOVA was used (factors: sex and site). In the case of juveniles, one-way ANOVA was used to compare differences between sites (Zar, 1999). Pos-hoc comparisons were performed with a Student Newman Keuls (SNK) test (Zar, 1999).

To analyze relative growth, the relationship between TL and the rest of body dimensions were adjusted to a power function ($y = ax^b$) and logarithmically linearized ($\log y = \log a + b \log x$, Hartnoll, 1982). All dimensions were log transformed before computing the regression equation (Hartnoll, 1982). As TL and the rest of body dimensions are measured with error, the model fitting was performed for each sex using reduced major axis method (RMA), a form of Model type II regression recommended in allometric analysis when both axes have the same magnitude of error (Ricker, 1972; McArdle, 1988). RMA analyses were conducted in R 2.13.0 (R Development Core Team, 2011) with the "lmodel2" package (Legendre, 2008). The slope of the regression line (b) represents the relative growth constant, and was used to test the degree of allometry: isometry ($b = 1$), negative allometry ($b < 1$) or positive allometry ($b > 1$) (Hartnoll, 1982). The statistical significance of b departures from 1 ± 0.1 was tested by Student's t-test (Clayton, 1990). Slopes and constants (a) of regression lines were compared among males and females from each site, and between sites for each sex. Constants were tested by Student's t-test and, if this test was significant a subsequent Student's t-test for slopes was applied (Zar, 1999). Differences were considered statistically significant when $P < 0.05$ (Zar, 1999).

A non-parametric multidimensional analysis was conducted to determine the main dimensions related to differences between sexes and populations. Data were square root transformed prior to analysis, and similarity matrices were calculated using the Euclidean distance index (Clarke and Warwick, 1994). Multidimentional scaling (MDS) was used to plot the differences observed (Clarke and Warwick, 1994). SIMPER (similarity percentage) analysis was used to detect significant discriminating body dimensions (Clarke and Warwick, 1994).

RESULTS

Tanais dulongii was always longer in La Estafeta than in Mar del Plata harbor, and females were always longer than males ($P < 0.001$, two-way ANOVA; $P < 0.05$, SNK test; Fig. 3; Tables 1 and 2). The minimum size of sexual differentiation of males and females in La Estafeta was 3.5 and 3.31 mm, respectively, while in Mar del Plata harbor it was 1.75 mm in both sexes.

All body dimensions measured in adults were also larger in La Estafeta than in Mar del Plata harbor ($P < 0.001$, two-way ANOVA). Females had longer P4L than males in both environments ($P < 0.05$, SNK test) whereas males presented higher values of CL, CW, ChL, ChW, AL and P1B ($P < 0.05$, SNK test). P4W, P4B and PL did not differ between sexes in Mar del Plata ($P > 0.05$, SNK test); P4B and PL did not differ in both sexes ($P > 0.05$, SNK test) but P4W was wider in males in La Estafeta ($P < 0.05$, SNK test). PW and UL were slightly higher in females of Mar del Plata, whereas these dimensions were higher in males of La Estafeta ($P < 0.05$, SNK test). All dimensions had higher values in juveniles at La Estafeta than in Mar del Plata ($P < 0.001$, one-way ANOVA; Table 3).

The RMA regression lines of all dimensions *versus* LT were significant ($P < 0.05$; Fig. 4). Growth of most dimensions was positively allometric in males and females in Mar del Plata harbor ($P < 0.05$, Student's t-test; Table 4), except CL and CW, which were negatively allometric ($P < 0.05$, Student's t-test) and isometric ($P > 0.05$, Student's t-test) respectively. Half dimensions measured in La Estafeta had a positive allometric growth in both sexes ($P > 0.05$, Student's t-test; Table 5) and half had isometric ($P > 0.05$, Student's t-test) or negative allometric growth in males (CL, CW, P4W, AL, UL and P1B; $P > 0.05$, Student's t-test)

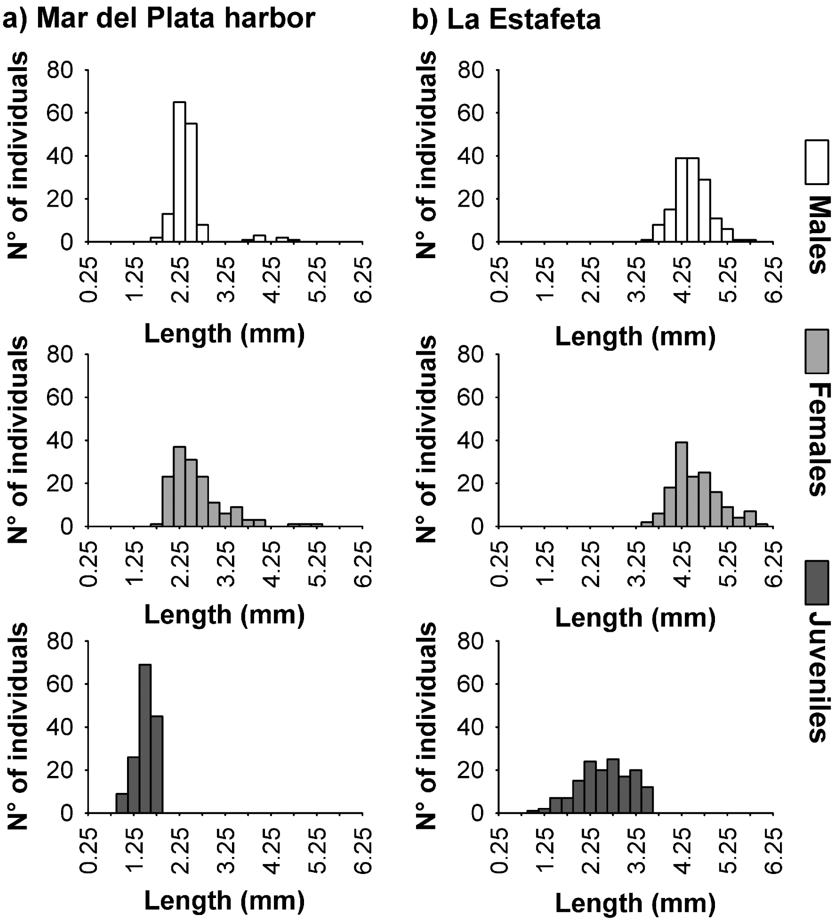

Fig. 3. Length frequency distribution of males, females and juveniles of *T. dulongii* for populations of (a) Mar del Plata Harbor and (b) La Estafeta.

Table 1. Summary statistics of morphometric measurements for individuals of *T. dulongii* from Mar del Plata Harbor and La Estafeta. (M: males; F: females; J: juveniles).

Character	Sex	Mar del Plata Harbor (mm)		La Estafeta (mm)	
		Mean ± SD	Range (min-max)	Mean ± SD	Range (min-max)
TL	M	2.34 ± 0.44	1.75-4.69	4.38 ± 0.38	3.50-5.69
	F	2.53 ± 0.59	1.75-5.25	4.47 ± 0.52	3.31-5.94
	J	1.39 ± 0.20	0.80-1.75	2.47 ± 0.57	1.00-3.48
CL	M	0.59 ± 0.09	0.48-1.11	1.00 ± 0.06	0.79-1.17
	F	0.55 ± 0.11	0.32-1.11	0.91 ± 0.10	0.63-1.17
	J	0.33 ± 0.05	0.20-0.51	0.55 ± 0.13	0.25-0.88
CW	M	0.55 ± 0.10	0.32-1.05	1.02 ± 0.07	0.79-1.20
	F	0.52 ± 0.12	0.32-1.01	0.95 ± 0.10	0.73-1.24
	J	0.31 ± 0.05	0.15-0.44	0.58 ± 0.13	0.25-0.88
P4L	M	0.25 ± 0.05	0.16-0.57	0.45 ± 0.06	0.32-0.67
	F	0.30 ± 0.08	0.16-0.63	0.48 ± 0.08	0.32-0.73
	J	0.14 ± 0.03	0.08-0.20	0.25 ± 0.07	0.10-0.43
P4W	M	0.50 ± 0.10	0.29-1.05	0.99 ± 0.08	0.79-1.20
	F	0.50 ± 0.12	0.32-1.01	0.95 ± 0.11	0.70-1.27
	J	0.28 ± 0.05	0.15-0.44	0.56 ± 0.14	0.25-0.88
ChL	M	0.71 ± 0.14	0.48-1.43	1.31 ± 0.12	0.92-1.59
	F	0.47 ± 0.13	0.29-0.98	0.88 ± 0.10	0.63-1.14
	J	0.26 ± 0.06	0.13-0.51	0.52 ± 0.14	0.20-0.83
ChW	M	0.38 ± 0.07	0.25-0.67	0.62 ± 0.07	0.44-0.79
	F	0.23 ± 0.06	0.13-0.54	0.40 ± 0.05	0.25-0.54
	J	0.13 ± 0.03	0.08-0.25	0.23 ± 0.06	0.10-0.38
AL	M	0.38 ± 0.06	0.27-0.59	0.56 ± 0.05	0.45-0.68
	F	0.21 ± 0.05	0.13-0.43	0.38 ± 0.04	0.21-0.48
	J	0.12 ± 0.03	0.05-0.27	0.23 ± 0.06	0.09-0.38
PL	M	0.15 ± 0.05	0.11-0.54	0.36 ± 0.05	0.27-0.55
	F	0.15 ± 0.05	0.09-0.32	0.35 ± 0.05	0.21-0.48
	J	0.09 ± 0.02	0.05-0.14	0.21 ± 0.06	0.07-0.36
PW	M	0.25 ± 0.06	0.14-0.59	0.56 ± 0.05	0.39-0.66
	F	0.26 ± 0.07	0.14-0.63	0.54 ± 0.08	0.34-0.77
	J	0.15 ± 0.03	0.05-0.21	0.32 ± 0.09	0.13-0.50
UL	M	0.28 ± 0.06	0.18-0.61	0.56 ± 0.05	0.41-0.68
	F	0.30 ± 0.07	0.21-0.63	0.53 ± 0.07	0.36-0.72
	J	0.17 ± 0.03	0.07-0.27	0.31 ± 0.09	0.11-0.50
P1B	M	0.32 ± 0.07	0.25-0.66	0.67 ± 0.05	0.50-0.81
	F	0.30 ± 0.08	0.18-0.61	0.55 ± 0.06	0.38-0.72
	J	0.17 ± 0.03	0.09-0.23	0.34 ± 0.09	0.13-0.55
P4B	M	0.26 ± 0.06	0.18-0.57	0.53 ± 0.05	0.41-0.75
	F	0.25 ± 0.07	0.16-0.59	0.46 ± 0.05	0.32-0.61
	J	0.14 ± 0.03	0.07-0.21	0.29 ± 0.08	0.11-0.45

and females (CL, CW, P4W, ChL, P1B and P4B; $P > 0.05$, Student's t-test). Juvenile growth was isometric (CL and CW; $P > 0.05$, Student's t-test) or positive allometric (the other dimensions, $P > 0.05$, Student's t-test) in both sites.

The relative growth constant (b) of all regression lines differed significantly between males and females from each site (in all cases $P < 0.001$, Student's t-test). Moreover, these values also differed between sites in males and females (in all cases $P < 0.001$, Student's t-test). The comparison of constants (a) of juvenile regression lines showed significant difference (in all cases $P < 0.001$, Student's t-test), except for ChW ($P = 0.089$, Student's t-test). The subsequent slope (b) analysis established that regression equation for ChW were different between sites ($P < 0.001$, Student's t-test).

MDS analysis of all body dimensions established a clear separation between sites and sexes (Stress: 0.02; Fig. 5). The SIMPER analysis showed that four dimensions contributed most to differences between sexes in both sites accounting for 70% of total dissimilarities: TL, ChL, ChW and AL (Table 6). On the other hand, the SIMPER analysis comparing body dimensions between populations determined the same pattern for males and females, in which TL contributed most to dissimilarities (ca. 30%), and the rest of dimensions presented similar percentages of differences between sites, ranging from 3 to 9% (Table 7).

DISCUSSION

The results of this study indicate that two populations of *T. dulongii* that live in contrasting habitats differ in size of adults and in degree of sexual differentiation, as has

Table 2. Results of two-way ANOVA for comparison of morphometric measurements between males and females of *T. dulongii* for different study sites. df, degrees of freedom; MS, mean squares.

Comparison	Source of variation	df	MS	*F*	*P*
TL	Sex	1	3.09	13.02	<0.001
	Site	1	593.39	2498.97	<0.001
	Sex × Site	1	0.35	1.46	0.227
	Error	596	0.24		
CL	Sex	1	0.65	73.83	<0.001
	Site	1	22.41	2553.40	<0.001
	Sex × Site	1	0.11	12.31	<0.001
	Error	596	0.01		
CW	Sex	1	0.41	41.02	<0.001
	Site	1	29.83	2969.04	<0.001
	Sex × Site	1	0.09	9.29	0.002
	Error	596	0.01		
P4L	Sex	1	0.27	56.40	<0.001
	Site	1	5.58	1163.74	<0.001
	Sex × Site	1	0.02	3.35	0.068
	Error	596	0.01		
P4W	Sex	1	0.06	5.49	0.020
	Site	1	33.39	3127.01	<0.001
	Sex × Site	1	0.05	4.91	0.027
	Error	596	0.01		
ChL	Sex	1	16.85	1114.81	<0.001
	Site	1	38.04	2516.76	<0.001
	Sex × Site	1	1.32	86.98	<0.001
	Error	596	0.02		
ChW	Sex	1	5.37	1438.25	<0.001
	Site	1	6.53	1749.14	<0.001
	Sex × Site	1	0.22	59.48	<0.001
	Error	596	0.01		
AL	Sex	1	4.73	1803.24	<0.001
	Site	1	4.73	1806.24	<0.001
	Sex × Site	1	0.01	2.69	0.102
	Error	596	0.01		
PL	Sex	1	0.01	0.45	0.502
	Site	1	6.69	3105.29	<0.001
	Sex × Site	1	0.01	3.45	0.064
	Error	596	0.01		
PW	Sex	1	0.01	0.07	0.793
	Site	1	13.38	3064.27	<0.001
	Sex × Site	1	0.04	9.82	0.002
	Error	596	0.01		
UL	Sex	1	0.01	0.76	0.384
	Site	1	9.72	2401.50	<0.001
	Sex × Site	1	0.11	27.08	<0.001
	Error	596	0.01		
P1B	Sex	1	0.73	167.83	<0.001
	Site	1	13.50	3094.01	<0.001
	Sex × Site	1	0.28	64.55	<0.001
	Error	596	0.01		
P4B	Sex	1	0.22	68.64	<0.001
	Site	1	8.35	2575.73	<0.001
	Sex × Site	1	0.12	35.94	<0.001
	Error	596	0.01		

Table 3. Results of one-way ANOVA for comparison of morphometric measurements between juveniles of *T. dulongii* for different study sites. df, degrees of freedom; MS, mean squares.

Comparison	Source of variation	df	MS	*F*	*P*
TL	Site	1	88.59	483.26	<0.001
	Error	298	0.18		
CL	Site	1	3.71	373.71	<0.001
	Error	298	0.01		
CW	Site	1	5.55	545.29	<0.001
	Error	298	0.01		
P4L	Site	1	0.86	301.42	<0.001
	Error	298	0.00		
P4W	Site	1	5.91	537.35	<0.001
	Error	298	0.01		
ChL	Site	1	4.96	425.48	<0.001
	Error	298	0.01		
ChW	Site	1	0.70	273.84	<0.001
	Error	298	0.00		
AL	Site	1	0.96	383.81	<0.001
	Error	298	0.00		
PL	Site	1	1.15	563.01	<0.001
	Error	298	0.00		
PW	Site	1	2.05	486.59	<0.001
	Error	298	0.00		
UL	Site	1	1.33	312.64	<0.001
	Error	298	0.00		
P1B	Site	1	2.05	483.77	<0.001
	Error	298	0.00		
P4B	Site	1	1.71	506.39	<0.001
	Error	298	0.00		

been noted in other species of tanaidaceans (Mendoza, 1982; Masunari, 1983; Modlin and Harris, 1989; Kneib, 1992; Leite et al., 2003; Pennafirme and Soares-Gomes, 2009). Adults were twice as large in TL in La Estafeta as in the harbor at Mar del Plata; the values observed in La Estafeta were consistent with those recorded in open marine European populations (Johnson and Attramadal, 1982; Perez-Ruzafa and Sanz, 1993; Hamers and Franke, 2000). In addition, the maximum observed size of juveniles, i.e., the minimum size of adults, was also twice as large in La Estafeta. In both sites, females were larger than males, as previously observed in this species (Hamers and Franke, 2000).

Changes in growth rates were related with the transition between juvenile and adult phases as observed in other peracarids, specifically amphipods (Harrison, 1940; Tsoi and Chu, 2005). Growth is positively allometric in juveniles, probably because energy is mainly used for somatic growth; in adults, one expects a shift in energy investment from somatic growth to maturity of gonads and development of structures related to reproduction, such as ovisacs in females or large chelipeds in males (Hartnoll, 1978, 1982; Fonseca and D'Incao, 2003). These changes in allometric ratios were observed in some body dimensions in La Estafeta, whereas they were not detected in Mar del Plata, probably because organisms achieved only smaller sizes. Moreover, the similarities found in growth slopes between sexes in La Estafeta and Mar del Plata would indicate that environmental factors influence the growth rate of both sexes in each site equally. Juvenile growth was similar in both populations, so differences in size ranges would suggest a longer duration of this stage in La Estafeta.

The SIMPER analyses for both populations revealed that the differences of dimensions of the same structures directly or indirectly involved in reproductive issues, were related to sexual dimorphism: TL, ChL, ChW and AL. The differences in total length between sexes in both populations of *T. dulongii* that we registered, which have been reported previously in other tanaidaceans (Mendoza, 1982; Leite, 2003). Hamers and Franke (2000) established that the development of females comprises more instars than males in laboratory cultures of *T. dulongii* and, consequently, this difference would be reflected in their respective sizes. Furthermore, larger sizes would favor an increase in fecundity and fitness in females (Rumbold, 2012), while smaller sizes in males may provide them a greater mobility, increasing the number of mates and reducing the risks of predation, since during the breeding period males migrate from tube to tube searching for ovigerous females (Johnson and Attramadal, 1982; Borrowsky, 1983). Cheliped and antennules were used as a diagnostic character in sex differentiation in Tanaidacea (Heard et al., 2003). It has been shown (Johnson and Attrammadal, 1982; Highsmith, 1983) that the increased size of chelipeds in males not only allows them to grasp the female's cheliped during copulation, but also as defense structures during agonistic encounters. The larger size of male antennules, reported here for the first time in *T. dulongii*, suggests a chemosensory role for them in the interaction with

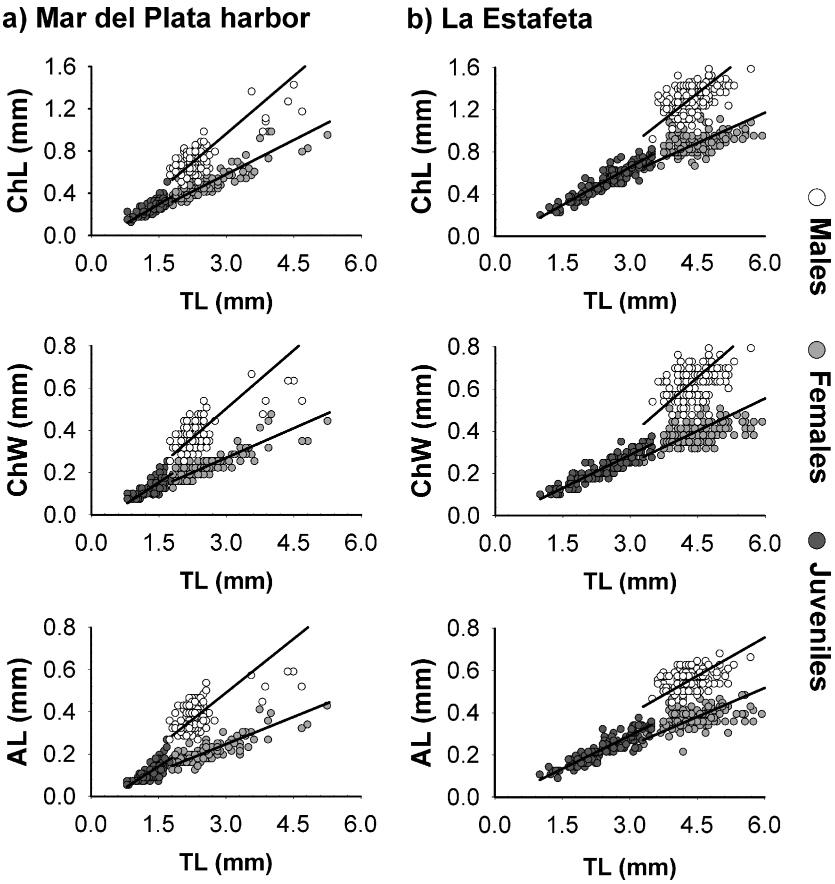

Fig. 4. Relative growth and main morphometrical differences between males, females and juveniles of *T. dulongii* for populations of (a) Mar del Plata Harbor and (b) La Estafeta. The allometric relation and regression equations are given in Tables 2 and 3. For abbreviations, see text.

females during reproduction, in the detection of food, and in confrontations with other males (Johnson and Atrammadal, 1982; Highsmith, 1983).

A clear morphometric discrimination between both populations was demonstrated by SIMPER analysis comparing body dimensions. According to this analysis, the parameter of total length (TL) mainly contributed to dissimilarities between sites; the rest of variables contributed to a smaller extent. In addition, this pattern was similar in males and females, suggesting that the observed differences are independent of sex.

The present study suggests that the differences observed between populations of *T. dulongii* could indicate a phenotypic plasticity in response to environmental differences (Stearns, 1992) as occurs in *Monokalliapseudes schubarti* (Mañé-Garzon, 1949), one of the most studied tanaidaceans in South America, that has a great plasticity in life history strategies related to environmental issues (Pennafirme and Soares-Gomes, 2009). Salinity, availability of refuge sites, food, temperature, oxygen, and organic matter have great influence on life history of tanaidaceans (Stoner, 1983; Modlin and Harris, 1989; Kneib, 1992; Hamers and Franke, 2000; Leite et al., 2003; Guerra-García et al., 2009). Although environmental effects on life history has been demonstrated in many crustaceans, most works dealing with relative growth agree that it is not easy to determine which of these elements has the greatest impact on growth since it could depend on a combination of several of them (Remerie et al., 2005).

Two environmental conditions differ clearly between sites and should be considered in order to explain the observed differences: food availability and pollution. On one hand, it has been shown that food has a direct effect on growth rate and sexual maturation of peracarids (Tararam et al., 1990; Gergs and Rothhaupt, 2008). Thus, if there are differences between quality or food availability, changes in maturity rates of gonads could generate different sizes of sexual differentiation, and therefore, variations in the duration of puberty and adulthood (Hartnoll, 1982). On the other hand, the inner part of Mar del Plata harbor presents high levels of polycyclic and aliphatic hydrocarbons from oil combustion related to commercial and recreational traffic, a wide variety of sterols from sewage and high concentrations of phosphorus, nitrogen, organic matter and phytopigments, indicatives of a high rate of eutrophication, although it has been suggested that the environmental impact is low over the macroinfauna (Albano et al., 2013). However, the effects of pollutants depend to a large extent on the degree of environmental sensitivity of species (Pelletier et al., 2010). The tolerance to the presence of contaminants is high in some tanaidaceans (Pennafirme and Soares-Gomes,

Table 4. Results of the regressions analysis of morphometric dimensions of the population of *T. dulongii* from Mar del Plata Harbor. M, males; F, females; J, juveniles; r, Pearson's correlation coefficient; t $(b = 1)$, Student's t-test for slope; ns: not significant; * significant by Student's t-test $(P < 0.05)$; 0, isometry; +, allometric positive; –, allometric negative.

Relationship	Sex	Linearized equation ($\log y = \log a + b \log x$)	r	t $(b = 1)$	Allometry
TL vs. CL	M	$\log y = -0.555 + 0.879 \log x$	0.75	-13.38^*	–
	F	$\log y = -0.633 + 0.925 \log x$	0.90	-8.75^*	–
	J	$\log y = -0.621 + 0.989 \log x$	0.68	-1.13 ns	0
TL vs. CW	M	$\log y = -0.626 + 0.997 \log x$	0.76	-0.34 ns	0
	F	$\log y = -0.685 + 1.004 \log x$	0.92	0.50 ns	0
	J	$\log y = -0.653 + 0.989 \log x$	0.75	-1.16 ns	0
TL vs. P4L	M	$\log y = -1.069 + 1.242 \log x$	0.83	25.78^*	+
	F	$\log y = -1.022 + 1.229 \log x$	0.87	25.15^*	+
	J	$\log y = -1.034 + 1.326 \log x$	0.82	34.00^*	+
TL vs. P4W	M	$\log y = -0.692 + 1.063 \log x$	0.77	6.74^*	+
	F	$\log y = -0.737 + 1.081 \log x$	0.89	9.25^*	+
	J	$\log y = -0.72 + 1.175 \log x$	0.71	17.77^*	+
TL vs. ChL	M	$\log y = -0.568 + 1.137 \log x$	0.69	13.89^*	+
	F	$\log y = -0.784 + 1.127 \log x$	0.88	14.27^*	+
	J	$\log y = -0.783 + 1.385 \log x$	0.79	38.78^*	+
TL vs. ChW	M	$\log y = -0.831 + 1.102 \log x$	0.61	10.14^*	+
	F	$\log y = -1.065 + 1.036 \log x$	0.84	4.05^*	+
	J	$\log y = -1.11 + 1.57 \log x$	0.75	53.12^*	+
TL vs. AL	M	$\log y = -0.809 + 1.041 \log x$	0.56	4.15^*	+
	F	$\log y = -1.11 + 1.046 \log x$	0.82	5.12^*	+
	J	$\log y = -1.174 + 1.704 \log x$	0.75	63.27^*	+
TL vs. PL	M	$\log y = -1.353 + 1.355 \log x$	0.68	33.74^*	+
	F	$\log y = -1.383 + 1.379 \log x$	0.81	38.79^*	+
	J	$\log y = -1.227 + 1.222 \log x$	0.64	21.58^*	+
TL vs. PW	M	$\log y = -1.074 + 1.256 \log x$	0.67	24.97^*	+
	F	$\log y = -1.037 + 1.123 \log x$	0.88	13.78^*	+
	J	$\log y = -1.013 + 1.329 \log x$	0.78	33.35^*	+
TL vs. UL	M	$\log y = -1.018 + 1.251 \log x$	0.70	24.91^*	+
	F	$\log y = -0.936 + 1.029 \log x$	0.85	3.25^*	+
	J	$\log y = -0.952 + 1.347 \log x$	0.73	33.95^*	+
TL vs. P1B	M	$\log y = -0.929 + 1.186 \log x$	0.83	20.02^*	+
	F	$\log y = -0.966 + 1.087 \log x$	0.90	9.93^*	+
	J	$\log y = -0.932 + 1.159 \log x$	0.87	17.66^*	+
TL vs. P4B	M	$\log y = -1.02 + 1.181 \log x$	0.83	19.48^*	+
	F	$\log y = -1.059 + 1.134 \log x$	0.90	15.23^*	+
	J	$\log y = -1.058 + 1.363 \log x$	0.84	38.17^*	+

2005), but low in others (Chintiroglou et al., 2004; de la Ossa-Carretero et al., 2010). In the latter, it has been shown that pollutants such as hydrocarbons or organic matter from fish discards and sewage outfalls produces a decrease in population density and consequently a reduction in the size range of adults (Chintiroglou et al., 2004; de la Ossa-Carretero et al., 2010). The differences in sizes found between sites in this study suggest a low tolerance to pollution in *T. dulongii*.

Further research is necessary to elucidate if the described differences in life history and morphometry between populations, in conjunction with the low dispersion rate of tanaidacean in general, and *T. dulongii* in particular (Johnson and Attramadal, 1982; Thiel, 2003), could be related with genetic differences and reproductive isolation between the two populations.

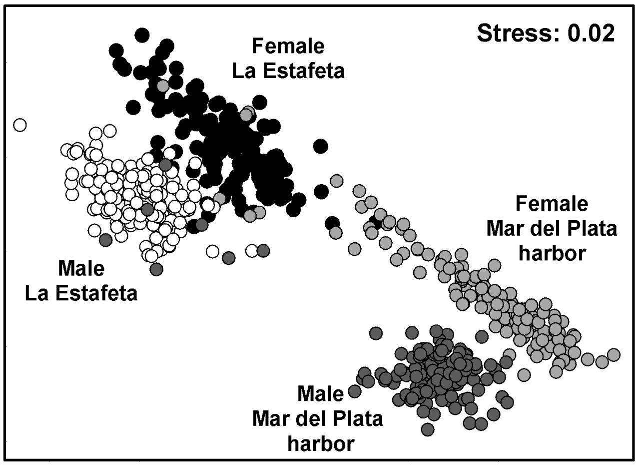

Fig. 5. MDS ordination plot of all body dimensions of different population groups of *T. dulongii* from Mar del Plata Harbor and intertidal La Estafeta.

Table 5. Results of the regressions analysis of morphometric dimensions of the population of *T. dulongii* from intertidal La Estafeta. M, males; F, females; J, juveniles; r, Pearson's correlation coefficient; t ($b = 1$), Student's t-test for slope; ns: not significant; $*$ significant by Student's t-test ($P < 0.05$); 0, isometry; +, allometric positive; –, allometric negative.

Relationship	Sex	Linearized equation ($\log y = \log a + b \log x$)	r	t ($b = 1$)	Allometry
TL vs. CL	M	$\log y = -0.47 + 0.734 \log x$	0.75	−28.72*	–
	F	$\log y = -0.659 + 0.95 \log x$	0.90	−5.34*	–
	J	$\log y = -0.656 + 1.014 \log x$	0.68	1.66 ns	0
TL vs. CW	M	$\log y = -0.528 + 0.84 \log x$	0.76	−17.01*	–
	F	$\log y = -0.654 + 0.968 \log x$	0.92	−3.44*	–
	J	$\log y = -0.634 + 1.01 \log x$	0.75	1.19 ns	0
TL vs. P4L	M	$\log y = -1.319 + 1.513 \log x$	0.83	50.23*	+
	F	$\log y = -1.204 + 1.361 \log x$	0.87	38.29*	+
	J	$\log y = -1.079 + 1.207 \log x$	0.82	23.93*	+
TL vs. P4W	M	$\log y = -0.584 + 0.907 \log x$	0.77	−9.49*	–
	F	$\log y = -0.672 + 1.002 \log x$	0.89	0.16 ns	0
	J	$\log y = -0.673 + 1.07 \log x$	0.71	8.19*	+
TL vs. ChL	M	$\log y = -0.6 + 1.117 \log x$	0.69	11.02*	+
	F	$\log y = -0.687 + 0.971 \log x$	0.88	−2.85*	–
	J	$\log y = -0.751 + 1.176 \log x$	0.79	20.43*	+
TL vs. ChW	M	$\log y = -1.028 + 1.282 \log x$	0.61	24.63*	+
	F	$\log y = -1.153 + 1.153 \log x$	0.84	13.99*	+
	J	$\log y = -1.107 + 1.173 \log x$	0.75	19.81*	+
TL vs. AL	M	$\log y = -0.86 + 0.949 \log x$	0.56	−5.17*	–
	F	$\log y = -1.13 + 1.084 \log x$	0.82	8.04*	+
	J	$\log y = -1.086 + 1.142 \log x$	0.75	16.20*	+
TL vs. PL	M	$\log y = -1.432 + 1.538 \log x$	0.68	42.52*	+
	F	$\log y = -1.29 + 1.29 \log x$	0.81	25.79*	+
	J	$\log y = -1.17 + 1.254 \log x$	0.64	28.26*	+
TL vs. PW	M	$\log y = -0.909 + 1.026 \log x$	0.67	2.55*	+
	F	$\log y = -1.17 + 1.39 \log x$	0.88	35.83*	+
	J	$\log y = -0.971 + 1.189 \log x$	0.78	21.14*	+
TL vs. UL	M	$\log y = -0.906 + 1.021 \log x$	0.70	2.00 ns	0
	F	$\log y = -1.018 + 1.14 \log x$	0.85	13.74*	+
	J	$\log y = -1.013 + 1.265 \log x$	0.73	30.28*	+
TL vs. P1B	M	$\log y = -0.76 + 0.911 \log x$	0.83	−9.01*	–
	F	$\log y = -0.888 + 0.97 \log x$	0.90	−3.01*	–
	J	$\log y = -0.912 + 1.113 \log x$	0.87	13.02*	+
TL vs. P4B	M	$\log y = -0.96 + 1.061 \log x$	0.83	5.75*	+
	F	$\log y = -0.987 + 0.997 \log x$	0.90	−0.31 ns	0
	J	$\log y = -1.008 + 1.183 \log x$	0.84	21.09*	+

Table 6. Results of the SIMPER analysis showing the body dimensions of *T. dulongii* that made the greatest contributions to dissimilarity between sexes in each site. Contribution (Contrib.) and Cumulative (Cum.) describe the contribution of each variable to the squared Euclidean distance.

Mar del Plata Harbor					La Estafeta				
Parameter	Average values		Percentage		Parameter	Average values		Percentage	
	Male	Female	Contrib.	Cum.		Male	Female	Contrib.	Cum.
TL	1.52	1.58	22.60	22.60	ChL	1.14	0.94	28.66	28.66
ChL	0.84	0.68	17.81	40.41	ChW	0.79	0.63	17.49	46.15
AL	0.61	0.45	14.32	54.73	TL	2.09	2.11	13.82	59.97
ChW	0.61	0.47	11.54	66.27	AL	0.75	0.61	12.37	72.33
P4W	0.71	0.70	4.90	71.16	P1B	0.82	0.74	4.76	77.09
CW	0.74	0.72	4.63	75.80	CL	1.00	0.95	3.55	80.64
P4L	0.49	0.54	4.57	80.37	CW	1.01	0.97	3.43	84.07
CL	0.77	0.74	4.17	84.54	P4L	0.67	0.69	3.19	87.27
P1B	0.57	0.54	3.67	88.21	P4W	1.00	0.98	2.94	90.21
UL	0.53	0.55	3.26	91.48	P4B	0.72	0.68	2.87	93.08
PW	0.49	0.51	3.16	94.64	PW	0.75	0.74	2.62	95.71
P4B	0.51	0.50	2.99	97.63	UL	0.75	0.73	2.21	97.91
PL	0.37	0.38	2.37	100.00	PL	0.60	0.59	2.09	100.00

Table 7. Results of the SIMPER analysis showing the body dimensions of *T. dulongii* that made the greatest contributions to dissimilarity between sites for each sex. Contribution (Contrib.) and Cumulative (Cum.) describe the contribution of each variable to the squared Euclidean distance. MdP, Mar del Plata Harbor.

Males					Females				
Parameter	Average values		Percentage		Parameter	Average values		Percentage	
	MdP	Estafeta	Contrib.	Cum.		MdP	Estafeta	Contrib.	Cum.
TL	1.52	2.09	32.57	32.57	TL	1.58	2.11	34.92	34.92
ChL	0.84	1.14	9.50	42.07	P4W	0.70	0.98	9.03	43.95
P4W	0.71	1.00	8.44	50.51	ChL	0.68	0.94	8.12	52.07
CW	0.74	1.01	7.37	57.88	CW	0.72	0.97	7.72	59.79
PW	0.49	0.75	6.52	64.40	PW	0.51	0.74	6.33	66.12
P1B	0.57	0.82	6.30	70.70	CL	0.74	0.95	5.81	71.93
CL	0.77	1.00	5.61	76.31	PL	0.38	0.59	5.31	77.23
PL	0.37	0.60	5.09	81.40	P1B	0.54	0.74	5.01	82.24
UL	0.53	0.75	5.07	86.47	UL	0.55	0.73	4.12	86.36
P4B	0.51	0.72	4.71	91.19	P4B	0.50	0.68	4.03	90.39
ChW	0.61	0.79	3.41	94.59	P4L	0.54	0.69	3.27	93.66
P4L	0.49	0.67	3.32	97.91	AL	0.45	0.61	3.25	96.91
AL	0.61	0.75	2.09	100.00	ChW	0.47	0.63	3.09	100.00

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