Journal of Materials and Environmental Sciences
ISSN : 2028-2508
CODEN : JMESCN

J. Mater. Environ. Sci., 2019, Volume 10, Issue 1, Page 88-94

http://www.jmaterenvironsci.com

Inter-annual spring variations inmorpholigicparameters length, biovolumeof AcartiaClausi (Copepoda) in the central Moroccan Atlantic coasts

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Received 01 Jan 2019,
Revised 12 April 2019,
Accepted 14 April 2019

Keywords
- ✓ *Morphometry*
- ✓ *Acartia*
- ✓ *Spring variations*
- ✓ *Prosome*
- ✓ *Urosome*

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Abstract

The present work is a temporal follow-up of the morphometric variations of the size (prosome), the body volume and the proportion (prosome / urosome) of the Acartia Clausi copepod, which were studied over a period of (1999, 2000, 2003, 2004, 2007, 2008 and 2017) in the coastal area of Agadir. Strong morphological differences were observed between the populations collected by the different samples. These variations are influenced by changes in environmental parameters (temperature) in each year. This study shows that the size of copepods inhabiting a given ecosystem varies with time in relation to changes in major environmental factors (temperature). This result shows that the variation in size is mainly due to the prosome, whereas the urosome is less dependent on ecological changes during growth

1. Introduction

The Moroccan Atlantic coast, especially the area of Agadir is influenced by one of the five world currents generating upwelling. Indeed, this area is characterized by the proximity of the upwelling of Cap Ghir, which takes place throughout the year, and brings a cold water rich in nutrients (Hagen et al., 1996; Nykjær and Van Camp, 1994; Salah et al., 2012)[1-3].

Zooplankton is permanently subjected the forcing of physical changes in the water column. Consequently, it is considered as a biological indicator of hydrological and environmental perturbations (Beaugrand and Kirby, 2010).This is the case of many species of zooplankton including copepods which have a short lifespan, and rapidly respond to environmental perturbations and development rate is closely linked to environmental factors. Copepods are essential components of marine zooplankton communities because of their important role in the transfer of matter and energy from primary producers to higher trophic levels (Calbet et al., 2000). Also, as a prey for fish at different stages of development, knowledge of copepod abundance and biomass at spatial and temporal scales remains a key element for all approaches to the marine ecosystem (Irigoien et al., 2008). The dynamics of copepods are closely associated with those environmental factors such as intensity and seasonal variability of upwelling and hydrodynamic characteristics [3]. The size of adult copepods depends on environmental factors, like salinity, temperature and nutrients that act during larval development [7]. The distribution of calanoid copepod populations is mainly controlled by water temperature, salinity and food [9]. *Acartia clausi* is a cosmopolitan species, present in most oceans except along the coasts of South Africa, Antarctica and Central Pacific [8]. It is a dominant species in the copepod communities, also it is known by a spatio-temporal distribution related to hydrological conditions, seasonal variability, availability of food[10,11]. This species plays an important role in the pelagic feeding network and is a main prey for fish larvae [12]. The long-term monitoring of this species can allow us to detect the effect of the environmental factors on this species of zooplankton [13]. The objective of our work is to study the spring morphological variations of *Acartia.clausi*, which is the most abundant copepod in this area, and to link these variations to environmental factors especially the temperature, that is the primary factor influencing copepod growth [16].

2. Material and Methods

The study site has been chosen for its high ecological value as it is the area of upwelling (Hagen et al., 1996; Nykjær and Van Camp, 1994; Salah et al., 2012).

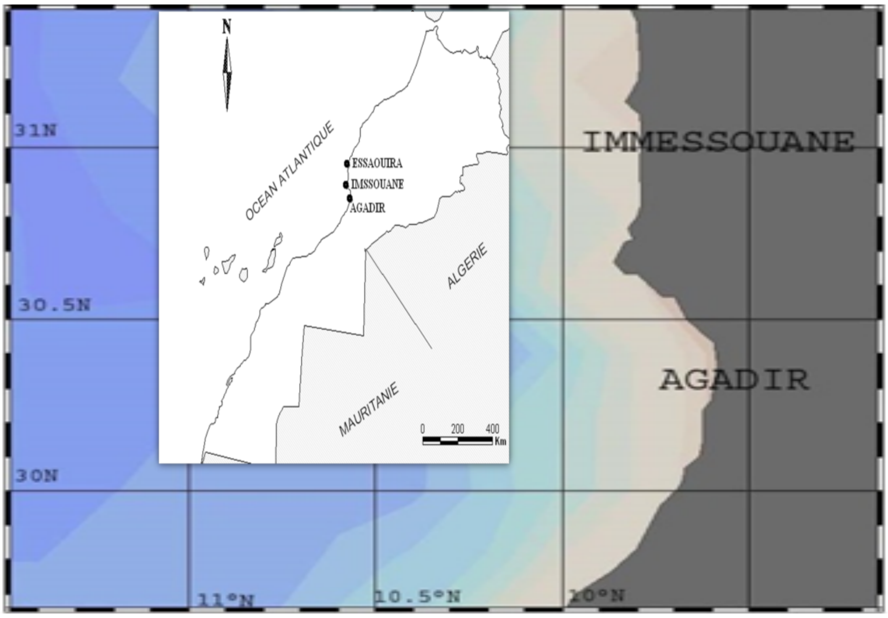
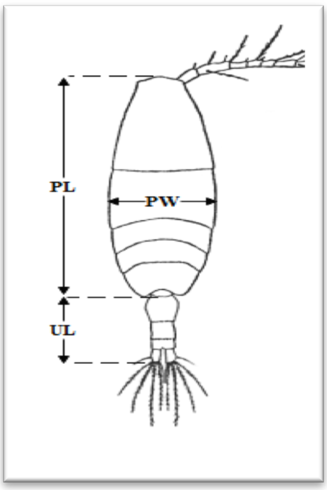


Figure 1:Location of the study area bay of Imessouane.

The temperature values were obtained from the World Ocean Data Base 2013 (WOD13); which provide the Global Oceans Data base (https://www.nodc.noaa.gov). The data is processed by ocean data view (ODV) [17].
The study took place from 1999 to 2017 with seven samples of Acartia clausi. The copepods were sampled with 500-µm mesh plankton net between 0 to 20 m of depth.Samples were fixed in formalin (5%). For every sample, fifty individuals of Acartia clausi were selected and measured. The length, width and height of the prosome and the length and width of the urosome were measured for each individual and each sample with an inverted microscope using a micrometer. The volume of each individual was estimated according to Chojnacki and Fernández-Araoz(Chojnacki and Hussein, 1983; Fernández-Araoz, 1994)



$$V = \frac{\pi(PL.PW.PH)}{6} + \frac{\pi(UL.UW^2)}{4}$$

Where V is the volume in (mm)

PL: prosome's length in (mm)
PW: prosome's width in (mm)
PH :prosome's height in (mm)
UL: urosome's length in (mm)
UW :urosome's width in (mm)

The individual volume (V), prosome length (PL), and width (PW) relationship were determined for each date by regression tests. The coefficient of determination (R^2) was used to study the independent force of the variables in predicting the volume. The statistical analyzes were made by the R software.

3. Results and discussion

Environmental variables

The temperature values recorded in the study area during the sampling dates are shown in Table 1, where it is possible to observe the trend of spring variability of temperature during the study period. Temperature values usually show large inter-annual amplitude between 1997 to 2017, ranging from 16 ° C in 1999 to 19.75 ° C in 2007. (Figure 3 and Table 1).

Table 1: Minimum and maximum temperatures values for each period (WOD 2013)

Date	Temperature ◦C	
	Maximum	**Minimum**
1997	18.87	17.77
1998	19.17	18.47
1999	18	16
2000	18.6	17.17
2001	18.88	17.33
2002	18.1	17.72
2003	19	18
2004	19.5	18
2005	17.43	17.02
2006	17.51	16.47
2007	19.75	18.5
2008	18.44	17.55
2009	17.53	16.86
2010	18.49	17.76
2011	18.63	17.77
2012	17.46	16.32
2013	18.51	17.05
2014	18.11	16.6
2015	18.12	16.44
2016	18.46	16.82
2017	18	17.3

Morphometric and biovolume variables

The mean morphometric variables vary from year to year. The average length of the prosome recorded the highest value in 2004 with 0.87 mm, followed by the value recorded in 2000 with 0.83 mm and low values in 1999, 2007 and 2017 with values less than 0.76 mm. The length of the urosome recorded values that ranged between 0.16 and 0.19 mm during the years 1999 until 2008, however the high value were reaching in 2017 over 0.22 mm.The individual biovolume also varies from year to year with minimum values less than 0.024 mm^3 in 1999, 2007 and 2017; and maximum values superior of 0.032 mm^3 in 2000, 2004 and 2008.Considering the ratio of the length of the prosome and the length of the urosome (PL / UL), the prosome's length has an important influence on the variation of the PL / UL ratio than the urosome's length (Table 2 and figure 4

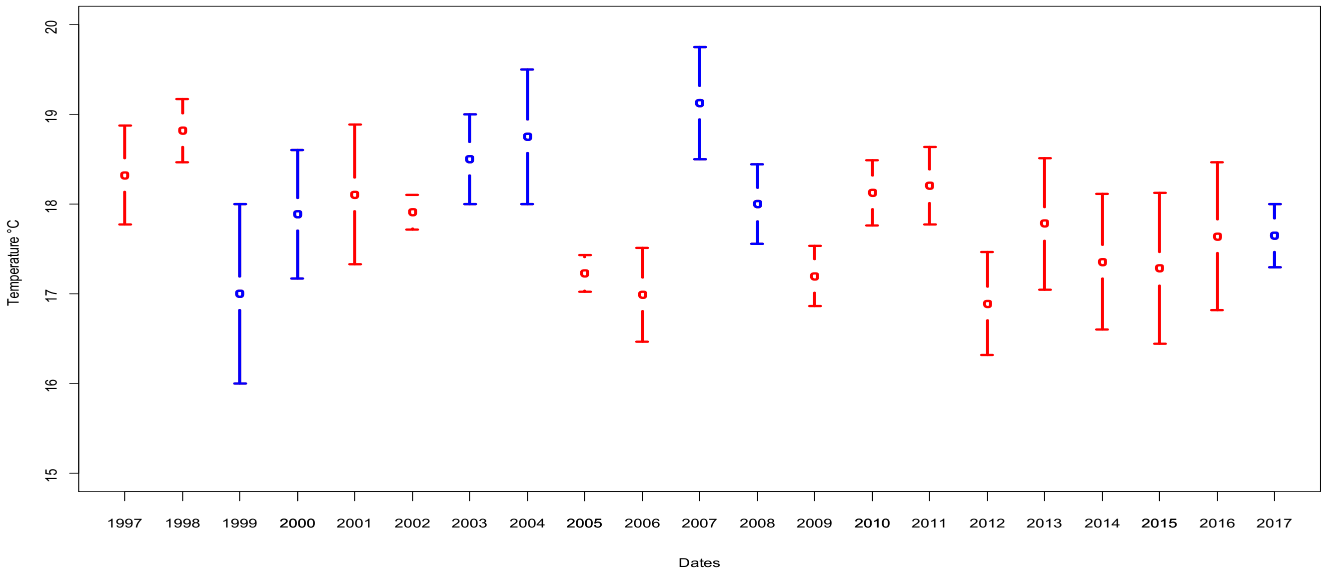


Figure 3: Temperature variation during the sampling periods (1997-2017)

Table2: Mean (M) ± standard error (SE) of Acartiaclausi, morphometric variables and individual volume. Coefficient of variation in (CV) of prosome length (PL), prosome width (PW) and biovolume.

Dates	N	PL (mm)			PW (mm)			PH (mm)			UL (mm)			UW (mm)			V (mm^3)		
		M	SE	CV	M	SE	CV	M	SE	CV	M	SE	CV	M	SE	CV	M	SE	
1999	50	0.713	0.079	0.111	0.247	0.014	0.059	0.247	0.015	0.059	0.166	0.029	0.173	0.050	0.004	0.088	0.023	0.005	0.22[illegible]
2000	50	0.839	0.043	0.051	0.267	0.015	0.061	0.267	0.016	0.061	0.196	0.013	0.067	0.057	0.004	0.076	0.032	0.004	0.13[illegible]
2003	50	0.804	0.058	0.073	0.252	0.013	0.052	0.252	0.013	0.052	0.191	0.013	0.072	0.057	0.004	0.085	0.027	0.004	0.14[illegible]
2004	50	0.879	0.042	0.048	0.283	0.023	0.082	0.283	0.023	0.082	0.165	0.012	0.073	0.057	0.006	0.111	0.037	0.006	0.17[illegible]
2007	50	0.754	0.056	0.074	0.236	0.027	0.118	0.236	0.028	0.118	0.167	0.020	0.119	0.058	0.005	0.085	0.023	0.005	0.24[illegible]
2008	50	0.823	0.050	0.060	0.269	0.017	0.054	0.269	0.017	0.064	0.186	0.016	0.090	0.054	0.005	0.102	0.032	0.005	0.16[illegible]
2017	50	0.762	0.039	0.051	0.237	0.014	0.059	0.248	0.014	0.058	0.229	0.021	0.094	0.06	0.002	0.033	0.023	0.003	0.14[illegible]

Regression test of prosome length (PL) - width (PW) related to individual Biovolume (V)

The regression tests for *A.clausi* PL and PW vs. V were performed from the data of the dates of the study period. For all dates, the (R^2) was higher in the PW vs V relationship than in the PL vs V relationship. The maximum value was recorded in 2007 (95.4%), while the minimum value was noted in 2003 with 74.9% for the relation PW vs V. This means that PW is the best predictor of the volume. For 1999, similar R^2 values were obtained in the PW vs. V (85%) and in the PL vs. V (83%). For 2000, the R^2 was higher in the PW vs. V (88.7%) than in the PL vs. V (31.8%). The latter means that PW was the best predictor in 2000, accounting for nearly 89% of the total variance. Similarly, the regression tests for 2003, 2004, 2007, 2008, and 2017 gave significant results (Table 3) with higher R^2 in the PW vs. V relationships in the PL vs. V.

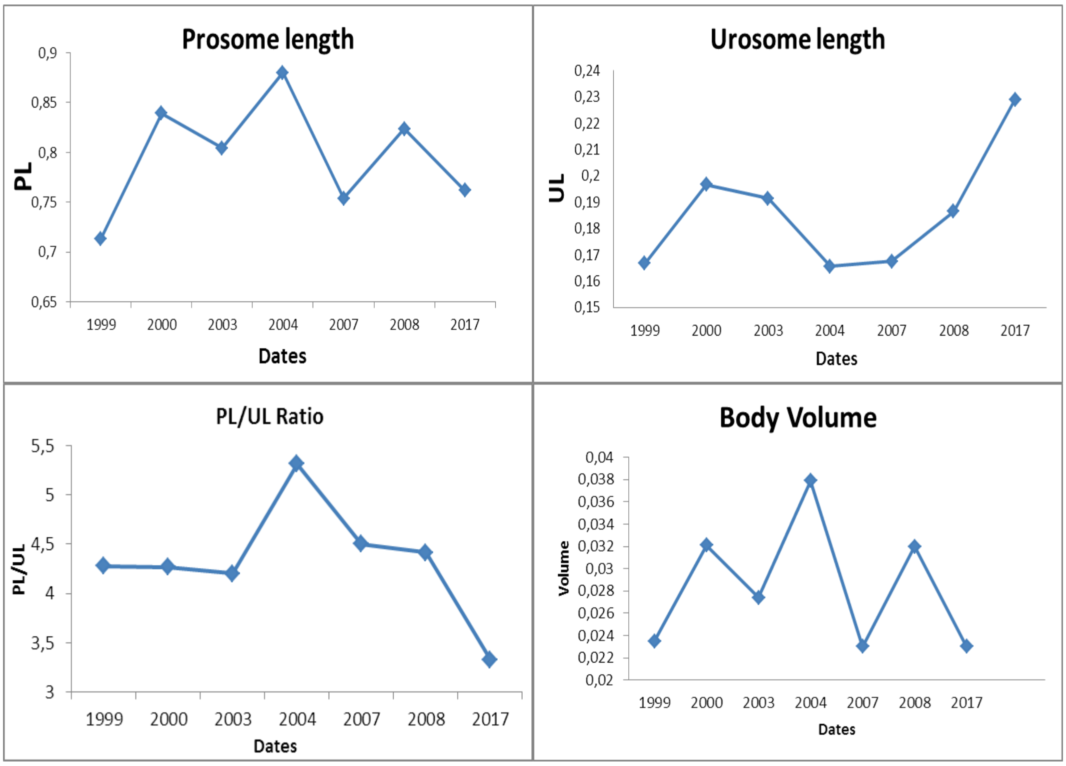


Figure 3: The variation in the prosome length of the (LP), the urosome length (LU), the individual biovolume (V) and the PL / UL ratio during the study period (1999-2017)

Comparison of regression lines

In order to simplify the number of measured morphological dimensions for biovolume estimation, the power function ($y = ax^{\beta}$) was applied between the geometrically estimated volume and the following body dimensions: PL, PW. The power function has been adopted because it is general utility to describe the relationship between size and biovolume in copepods [15]. The results of the covariance analysis for the *A.clausi* regression lines are in Table 3.

Table3: The equations of the linear regression test of the length of the prosome of *A.clausi* (PL) and the width of the prosome (PW) with respect to the volume (V) for each date, and (N) number of observations

Dates	N	Equation	R^2	P
1999	50	V= - 0.020+0.061 PL	0.830	<0.0001
		V= - 0.059+0.334 PW	0.850	<0.0001
2000	50	V= -0.016+0.058 PL		<0.0001
		V= -0.036+0.256 PW	0.318 0.887	<0.0001
2003	50	V= - 0.011+0.047 PL		<0.0001
		V= -0.039+0.264 PW	0.478 0.749	<0.0001
2004	50	V= -0.037+0.086PL		<0.0001
		V=-0.041+0.281PW	0.298 0.940	<0.0001
2007	50	V= -0.037+0.079PL	0.621	<0.0001
		V=-0.023+0.198PW	0.954	<0.0001
2008	50	V= -0.032+0.078PL	0.527	<0.0001
		V=-0.047+0.294PW	0.899	<0.0001
2017	50	V= -0,0259+0,064PL	0,537	<0.0001
		V= -0,031+0,230PW	0,89	<0.0001

This study questioned the influence of temperature on the size and biovolume of A.clausi. Temperature has a major influence on the development and growth of A.clausi[18,19]. Our results for the years 1999 and 2017 have amplitude of variation of the temperatures less than 18 ° C and are correlated with the size of the prosome and the biovolume of A.clausi, this confirms this influence. A wide range of temperature that exceeds 18°C was recorded in 2000, 2003, 2004 and 2008 promotes a significant size and biovolume of A.clausi. However the high amplitude of temperatures that exceeds 19.5 °C recorded in 2007 may be at the origin of the reduction in size and biovolume.

The literature found on the effect of temperature on marine copepods is quite extensive [9,18,20–24],the temperature and other parameters such as water supply and PH influence copepod size [22–25], in our study this influence appears very clear during the period of study.

In general, there is a negative correlation between the size of prosome and temperature, it is clearly observed in 1999, 2004 and 2017. This result is consistent with the results found by other studies that explain this negative correlation with the relationship between the size of the body and the temperature that affects the metabolic copepods [26–30] . It has been stated that the inverse relationship between length of A.clausi and temperature could be an evolutionary adaptation to a fluctuating environment [31].

With regard to A.clausi size–volume regressions, the prosome width was the best individual bio-volume predictor for the all date's data. Resulting general equations of individual volume vs. prosome length or prosome width of this species show a different behavior of each variable against volume.

Conclusion

This study measured morphometric values for *A.clausi* that is show a big variation during the study period. For *A.clausi*, measured morphometric values are higher in 2000, 2003, 2004 and 2008 than in 1999, 2007 and 2017. The size of this specie evidenced annual variation linked to temperature amplitude.

In conclusion, the morphometric variations found in *A.clausi* reflect the response of populations to important factors in this ecosystem: temperature.

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(2019) ; http://www.jmaterenvironsci.com