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The planktonic copepod communities from the southern Mediterranean Sea (Algeria, Tunisia) with a re-description of *Paracalanus indicus* Wolfenden 1905 (Copepoda: Calanoida)

Meriem KHELIFI-TOUHAMI[1*], Rachid SEMROUD[2], El Hadi HAMDI[3], Makhlouf OUNISSI[1], Ahcène HARIDI[1], Mohamed NÉJIB DALY[3] and Patricia AISSA[3]

(1) *Faculty of Sciences, University of Annaba, BP 12 El Hadjar, Annaba, Algeria*

* *Corresponding author: Fax: 213 38 871 062. E-mail: khelifi_meriem@yahoo.fr*

(2) *ISMAL, Dely Brahim, Alger, Algeria*

(3) *Faculty of Sciences, University of Carthage 7 novembre, Bizerte, Tunisia*

Abstract: The composition, diversity and ecological affinities of pelagic copepods from the eastern Algerian coast and the contiguous Tunisian littoral (Bizerte shelf) were studied. The synthesis of the results showed peculiarities of the communities inhabiting these shelf waters. One hundred forty three copepod species were identified from which *Copilia lata* Giesbrecht 1891 is recorded for the first time in the Mediterranean Sea. The copepods of the continental shelf of eastern Algeria seemed to be abundant and highly diversified. Ecological affinities revealed the influence of local and regional oceanographic conditions. *Paracalanus indicus* Wolfenden 1905 was recorded for the first time in the Algerian and Tunisian coastal waters. Because of the close morphological characteristics of *P. indicus* and *P. quasimodo* Bowman 1971 inhabiting the Atlantic Ocean, a compared study to distinguish between both species was undertaken. Despite its abundance in the Algero-Tunisian coast, representing 46% of total copepods, *P. indicus* was not found in the Mediterranean oriental basin or the north occidental part of the Mediterranean Sea. Although with careful morphological study, it is very difficult to distinguish between the two species.

Résumé : *Les peuplements de copépodes planctoniques du sud méditerranéen (Algérie, Tunisie) avec une redescription de* Paracalanus indicus *Wolfenden 1905 (Copepoda: Calanoida).* La composition, la diversité et les affinités écologiques des copépodes pélagiques de la côte est algérienne et du littoral tunisien (Bizerte) voisin ont été explorées. La synthèse des résultats a montré que ces eaux côtières étaient peuplées de communautés caractéristiques. Cent quarante trois espèces de copépodes ont été identifiées dont *Copilia lata* Giesbrecht 1891 est observée pour la première fois en Méditerranée. Les peuplements de copépodes du plateau continental de l'est algérien apparaissent riches et très diversifiés. Leurs affinités écologiques révèlent l'influence des conditions océanographiques locales et régionales. *Paracalanus indicus* Wolfenden 1905 est pour la première fois observé dans les eaux côtières algériennes et tunisiennes. En raison des caractères morphologiques peu distinctifs entre *P. indicus* et *Paracalanus quasimodo* Bowman 1971 peuplant l'Atlantique, une étude comparative pour différencier les deux espèces a été réalisée. Malgré sa forte abondance dans les eaux algéro-tunisiennes, représentant jusqu'à 46% des copépodes totaux, *P. indicus* n'a été rencontré ni dans le bassin oriental ni dans la partie nord du bassin occidental de la Méditerranée. Une étude morphologique minutieuse ne suffit pas à distinguer les deux espèces.

Keywords: Copepods ● *Paracalanus indicus* ● Zooplankton ● Coastal Waters ● Mediterranean Sea

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Introduction

Research on marine zooplankton and pelagic copepods has become rare in Algerian coasts, since the intensive and famous works of Rose in the beginning of the last century and those of Bernard in 1950-55. Since that time, only three articles had considered copepods (Seguin, 1972; Ounissi et al., 1998; Ounissi & Khélifi-Touhami, 1999). Therefore, the Algerian coasts are subject to interesting oceanographic phenomena (penetration, crossing and accumulation of Atlantic water) and the Mediterranean is changing in many ways (Béthoux et al., 2002). As indicators of environment, the study of copepods may allow to explain some local or regional oceanographic situations. Tropicalisation of the Mediterranean is demonstrated by transportation of copepods by the Atlantic water (Razouls & Durand, 1991) and particularly from the Red Sea and Indian Ocean (Lakkis, 1984 & 1990; Lakkis et al., 2002). The synthesis works from the 25 past years on the pelagic copepod classification from the Mediterranean (Kovalev & Shmeleva, 1982; Gaudy, 1985, Estrada et al., 1987; Razouls & Durand, 1991, Razouls, 1995; Razouls et al., 2005-2007) revealed the allochtonous intrusions of Atlantic and Indian species. In the Mediterranean Sea, the paracalanidae family which counts 7 species has been revised many times since the works of Rose (1930). In fact, several authors agree that some difficulties in the identification arise within the *parvus* group (Bowman, 1971; Bradford, 1978; Kang, 1996). Bowman (1971) has demonstrated that some specimens from several regions identified as *Paracalanus parvus* (Claus, 1863), were actually *Paracalanus indicus* Wolfenden 1905 (Mediterranean Sea, Atlantic and Indian oceans) or *Paracalanus quasimodo* Bowman 1971 (S-W Atlantic). The confusion within the *parvus* group still exists and is extensively treated at a genetic level (Bucklin et al., in prep.).

Moreover, the species *Paracalanus indicus* has been observed in eastern Algerian coasts in high densities (Ounissi & Khelifi-Touhami, 1999). The confusion previously existing between the species *Paracalanus quasimodo* and *P. indicus* has been removed by F. Ferrari, C. Razouls (pers. com. 1999; see also Ounissi et al., 1998).

In this paper, we give a broad synthesis on the diversity and the main ecological characteristics of copepods from the eastern Algerian coast and we give a short re-description of *Paracalanus indicus,* focusing on the distinction between this species and *Paracalanus quasimodo* inhabiting the Atlantic Ocean.

Material and Methods

Coastal zooplankton samples were taken during several cruises as follow:

- El Kala: 18 and 27 May 1996
- Annaba: February, March and August 2002; March and April 2003
- Bizerte: January and August 2002 (only *Paracalanus indicus* population have been considered here).

Thirty five vertical tows were realized from bottom to surface between 12 and 110 m depth in 10 stations (Fig. 1) using a WP2 net in Annaba, a Japanese net (30 cm opening diameter, 100 µm mesh size) in El Kala and a plankton net (20 cm opening, 200 µm mesh size) in Bizerte. Using so different mesh sizes introduces in fact some errors in comparing regional copepod densities. This should be taken into account for any plankton quantitative studies. Simultaneously, temperature and salinity measures were taken at the surface and at 50 m depth (stations 4 to 7) using a thermosalinometer Kent EIL 5005. In stations 1 to 7, current velocity and direction were taken at surface and at 50 m depth using a currentmeter T.D.CM2.

All the samples were preserved in a 4% formaldehyde solution and zooplankton analysis was realized on four fractions each one representing 1/20 to 1/2 of the sampled volume, according to the plankton density. The species identification however concerned the whole sample. Abundance was expressed in individual per m^3.

The description of *Paracalanus indicus* was established considering the morphological differences existing between the Algerian and Tunisian specimens (more than 10,000 individuals from Algerian and Tunisian samples) and the literature data mentioned above. The measure of *Paracalanus indicus* length was made on more than 30 female and 27 male specimens.

Results

Hydrology

In the Gulf of Annaba, surface salinity values ranged from 36.5 to 37.6 and temperature varied from 14.0°C in winter (February) to 28.0°C in summer (August). In May 1996, salinity values in El Kala varied between 36.7 at the surface and 37.2 in deep waters. The temperature reached 21.4°C at the surface and 15.0°C in the depths. The Bay of Bizerte had a salinity ranging between 31.0 and 36.3 during winter (January) and 37.7 during summer (August). The temperature varied from 13.0 in winter to 28.5°C in summer.

External waters moved eastward (Fig. 1), as a branch of modified Atlantic water, with velocities varying between 10 $cm.s^{-1}$ and 25 $cm.s^{-1}$. The residual current changed direction becoming southward in inner waters. This circulation allows some renewing of bays and inner waters particularly in winter and spring.

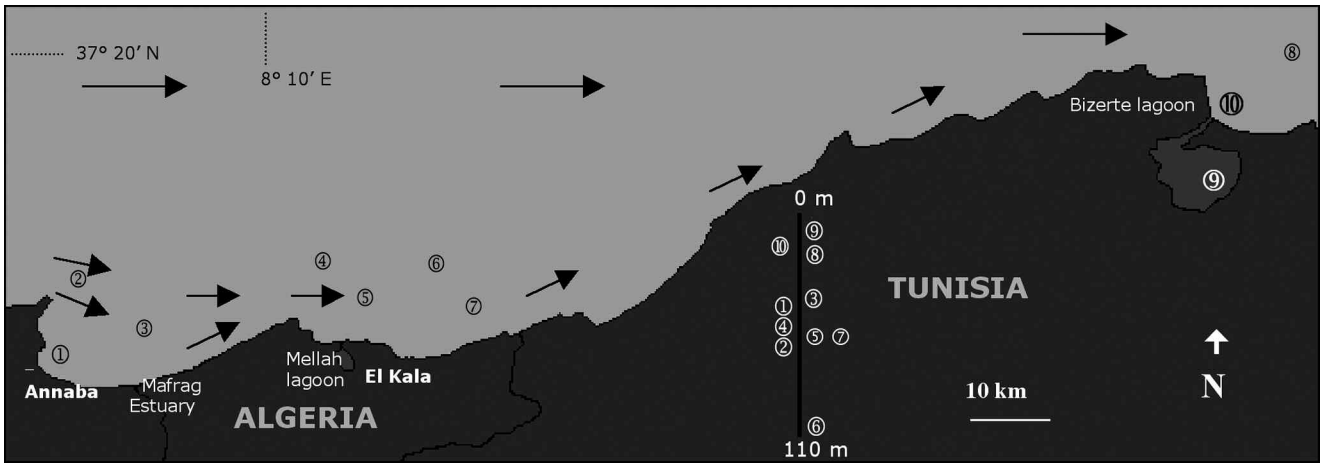

Figure 1. Map of the sampled areas: Gulf of Annaba, El Kala shelf and the bay of Bizerte, with the depth of the sampled stations. Arrows indicate the major current directions.

Figure 1. Carte représentant les zones échantillonnées : Golfe d'Annaba, plateau d'El Kala et baie de Bizerte, avec la profondeur des stations étudiées. Les flèches représentent la direction du courant.

Abundance and richness of copepods

Among 400 zooplankton taxa, 143 copepods were recorded in eastern Algeria. The major fraction of copepods comprised rare species and only 25 were regularly present in the samples (Table 1). However a big taxonomic richness was observed in the whole region: 123 species in Annaba, 58 species off El Kala. The main components of copepods showed neritic affinity: *Clausocalanus* spp, *Paracalanus indicus*, *Acartia* spp, *Centropages kroyeri* Giesbrecht, 1892, *Centropages typicus* Kröyer, 1849, *Corycaeus typicus* (Kröyer, 1849), *Euterpina acutifrons* (Dana, 1847), *Farranula rostrata* (Claus, 1863), *Oithona nana* Giesbrecht, 1892, *Oithona helgolandica* Claus, 1863, *Oithona setigera* (Dana, 1849), *Oncaea venusta* Philippi, 1843, *Temora stylifera* (Dana, 1849) (Table 1). Distribution, affinities and abundance of copepods are given in Table 1 in which it can be seen that the prospected area shelters dense and much diversified copepod populations of various affinities: 103 oceanic, 34 deep, 20 Atlantic affinity species, 17 neritic and over 15 coastal taxa. Typical inner water species were found few in the prospected zone but develop dense populations: *Acartia clausi* Giesbrecht, 1889, *Acartia discaudata mediterranea* Steuer, 1929, *P. indicus, E. acutifrons, O. nana, C. kröyeri*. Oceanic affinity populations were quite frequent: *Clausocalanus* spp., *Calocalanus* spp, *Calanus helgolandicus* (Claus, 1863), *Mecynocera clausi* Thompson, 1888, *Corycaeus* spp. In addition, the bathypelagic and mesopelagic species were very numerous but weakly abundant: *Pleuromamma abdominalis* (Lubbock, 1856), *P. xiphias* (Giesbrecht, 1889), *Eucalanus hyalinus* (Claus, 1886), *Candacia* spp, *Heterorhabdus papilliger* (Claus, 1863), *Heterostylites major* (Dahl, 1894), *Oncaea conifera* Giesbrecht, 1891, *Copilia mediterranea* (Claus, 1863), *C. mirabilis* Dana, 1849, *C. quadrata* Dana, 1849, *C. vitrea* (Haeckel, 1864), *Lubbockia aculeate* Giesbrecht, 1891.

Moreover, it is interesting to point out the presence of Atlantic water indicator species, which occur in this geographical area: *Acartia danae* Giesbrecht, 1889, *Centropages violaceus* (Claus, 1863), *C. bradyi* Wheeler, 1901, *C. gracilis* (Dana, 1849), *Ctenocalanus vanus* Giesbrecht, 1888, *Paracalanus indicus, Pleuromamma abdominalis, P. xiphias, Isias clavipes* Boeck, 1864 and *Copilia lata*.

In addition, *Copilia lata* was recorded for the first time in the Mediterranean. Only females have been collected; the males have never been observed. Low densities were recorded in the gulf of Annaba: 0.1 to 0.4 ind.m^{-3} while in El Kala continental shelf (Table 1) *Copilia lata* was not rare presenting densities ranging from 5 to 9 ind.m^{-3}.

Abundance and re-description of Paracalanus indicus

High densities were recorded in El Kala continental shelf: up to 899 ind.m^{-3} while Annaba and Bizerte coasts showed lower and similar densities: 1.17 to 72.7 ind.m^{-3} (Table 2).

In Tunisian waters where the species was recorded for the first time, densities decreased from the inner waters to the lagoon. Even though *Paracalanus indicus* is known as a neritic species, it was absent in the polluted inner waters.

As described in Bowman (1971), Björenberg (1981) and Bradford et al. (1999) keys and as it was observed in our study, the genus *Paracalanus* is characterized for the female by:

(1) First leg basipod with inner marginal seta,

Table 1. List and abundance (ind m^{-3}) with range, mean and standard deviation (SD) values of copepods from the eastern Algerian coast and their major ecological characteristics. c: coastal, n: neritic, o: oceanic, D: deep, S: superficial, A: Atlantic species affinity, +: presence.

Tableau 1. Liste et abundance (ind m^{-3}) avec la gamme, la moyenne et les valeurs de l'écart-type (SD) des copépodes de la côte est algérienne et leurs principales caractéristiques écologiques. C : côtière, n : néritique, o : océanique, D : profonde, S : superficielle, A : espèce à affinité Atlantique, + : présence.

		Gulf of Annaba															El Kala shelf		
		February 2002			March 2002			August 2002			March 2003			April 2003			May 1996		
Taxa	Ecological characteristic	Range	Mean	SD	Range	Mean	SD	Range	Mean	SD	Range	Mean	SD	Range	Mean	SD	Range	Mean	SD
Acartia clausi Giesbrecht, 1889	**nS**							8.4 - 10.42	6.3	1.4							150 - 924	507.8	328.1
Acartia danae Giesbrecht, 1889	**AoS**				0.67 - 1.01	0.4	0.2	0.75	0.3					1.17	0.3		1.5 - 8.5	2.5	5.0
Acartia discaudata mediterranea Steuer, 1929	**cS**				1.26 - 2.3	0.9	0.7				0 - 24.23	8.1		0.67 - 4.67	1.6	2.2	43 - 103.6	36.7	42.9
Acartia grani Sars, 1904	**oS**							6.25	2.1										
Acartia latisetosa (Kichagin, 1873)	**cS**																+		
Acartia longiremis (Lilljeborg, 1853)	**S**							+											
Acartia negligens Dana, 1849	**oS**							4.17	1.4										
Aetideus armatus (Boeck, 1872)	**oSD**				+						+								
Archescolecithrix auropecten (Giesbrecht, 1892)	**oD**										1.17	0.4							
Calanus helgolandicus (Claus, 1863)	**ocS**	1.2 - 4.9	2.7	2.1	1.34	0.3								2	0.5		+		
Calocalanus contractus Farran, 1926	**oAS**										1.17 – 4.66	1.9	2.5				4.9 - 18.1	7.3	7.2
Calocalanus pavo (Dana, 1849)	**oAS**	2.4	0.6		1.26 4.02	1.8	1.4	2.08	0.7					0.67 – 1.07	0.4	0.3	25.1	6.3	
Calocalanus pavoninus Farran, 1936	**oS**				2.52	0.6		1.5	0.5			0.9					3.3 - 14.2	4.4	7.7
Calocalanus plumulosus (Claus, 1863)	**oS**	9.9	2.5		2.01 - 3.02	1.3	0.7	0.75	0.3								7.1 - 29.9	9.2	16.1
Calocalanus spp.					1.01 - 2.3	0.8	0.9												
Calocalanus styliremis Giesbrecht, 1888	**oAS**				1.01	0.3		1.2	0.4		2.33-2.8	1.7	0.3	0.39 – 8.53	3.3	3.6	65.3 - 191.8	99.5	63.1
Calocalanus tenuis (Farran, 1926)	**o**	2.4	0.6		1.34 - 10.06	5.6	3.6				0 – 1.17	0.4		1.07	0.3				
Candacia armata (Boeck, 1872)	**oS**																1.4 - 7.3	2.2	4.2
Candacia bipinnata (Giesbrecht, 1889)	**oD**				+														
Candacia curta (Dana, 1849)	**oS**	+																	
Candacia longimana (Claus, 1863)	**oD**	+																	
Candacia maxima Vervoort, 1957	**oD**	+																	
Candacia varicans (Giesbrecht, 1892)	**oD**				+														
Centropages brachiatus (Dana, 1849)	**nS**	+																	
Centropages bradyi Wheeler, 1901	**oAS**													1.1	0.3		+		
Centropages chierchiae Giesbrecht, 1889	**cS**				0.67	0.2					1.87 – 7	3.0	3.6	1.1	0.3				
Centropages gracilis (Dana, 1849)	**AS**																2.9	0.7	
Centropages kroyeri Giesbrecht, 1892 +	**cS**	4.6	1.1		4.6 - 8.8	3.4	3.0	27.1	9.0		0 – 5.4	1.8		1.2 – 2.3	0.9	0.8	16.5 - 106	48.2	45
Centropages ponticus Karavaev, 1894	**nS**																		
Centropages typicus Kröyer, 1849	**nS**	9.1 - 1.2	2.6	5.6	6.0 - 29.5	15.2	10.1				1.9 - 2.3	1.4	0.3	5.3 - 8.2	3.4	2	227.6 - 249.2	239.1	11.2
Centropages violaceus (Claus, 1863)	**oAS**							0.75	0.3								+		
Clausocalanus arcuicornis (Dana, 1849)	**oS**				2.52	0.6		1.2	0.4								417.2 - 548.9	487.4	54.2
Clausocalanus furcatus (Brady, 1883)	**oS**	14.9 - 46.1	24,3	14,6	10.1 - 44.2	25.3	15	1.2 – 14.6	10.0	7.6	3.7 - 12.8	7.3	4.8	1.2 - 16.7	8.4	6.5	6.4 - 193.2	91.2	84.1
Clausocalanus jobei Frost & Fleminger, 1968	**nS**	7.4 - 36.4	18,9	13,9	4.0 - 18.8	7.4	7.8	0.3	0.1		10.5 - 14.9	8.5	3.1	0.8 - 53.7	18.9	23.7			
Clausocalanus lividus Frost & Fleminger, 1968	**oS**	9.1 - 71.8	34.5	29.2	8.8 - 38.9	11.9	21.3	0.7 – 3.6	2.1	1.4	1.17	0.4		2.33 – 13.33	3.9	7.8			
Clausocalanus mastigophorus (Claus, 1863)	**oS**				+						+			+					

Table 1 continued

Clausocalanus parapergens Frost & Fleminger, 1968	**oS**	2.5	0.6										0.7 - 1.2	0.5	0.4			
Clausocalanus pergens Farran, 1926	**oS**	9.0	2.3							1.17	0.4		0.4 - 1.3	0.7	0.5			
Clytemnestra rostrata (Brady, 1883)	**oS**									1.17	0.4							
Clytemnestra scutellata Danna, 1849	**oS**				2.3	0.6										1.5 - 2.6	1	0.8
Copilia lata Giesbrecht, 1891	**oAS**	0.2	0.05		0.12 - 1.3	0.4	0.9			0.2	0.4		0.1 - 0.2	0.1	0.1	4.9 - 8.5	5.4	2
Copilia mediterranea (Claus, 1863)	**oSD**	+																
Copilia mirabilis Dana, 1849	**oSD**															+		
Copilia quadrata Dana, 1849	**oSD**															+		
Copilia vitrea (Haeckel, 1864)	**oSD**															2.4	0.6	
Corycaeus agilis Danna, 1849	**oS**	+																
Corycaeus clausi F. Dahl, 1894	**oS**	4.5	1.1		1.3 - 2.7	1.5	0.7	0.25	0.1	1.17	0.4		1.07	0.3				
Corycaeus crassiusculus Danna, 1849	**oS**				2,01	0,5		0,25	0,1							8 - 14.9	9	3.5
Corycaeus flaccus Giesbrecht, 1891	**oS**	+								+								
Corycaeus furcifer Claus, 1863	**oAS**									1.2 – 2.8	1.3	1.2						
Corycaeus giesbrechti F. Dahl, 1894	**oS**	3.6	0.9		1.0	0.3												
Corycaeus latus Dana, 1849	**oS**	4.5	1.1		1.0 - 2.3	0.8	0.9						1.2	0.3				
Corycaeus lautus Dana, 1849	**oS**															+		
Corycaeus limbatus Brady, 1883	**oS**				1.3 - 2.3	0.9	0.7			1.9	0.6					+		
Corycaeus ovalis Claus, 1863	**oS**															4.3 - 4.4	2.2	0.1
Corycaeus speciosus Dana, 1849	**oS**				0.7	0.2				0.9	0.3		2.3	0.6				
Corycaeus typicus (Kröyer, 1849)	**noS**				1.3 - 2.0	0.8	0.5	2.7	0.9				4.3	1.1		17.7 - 36	27.8	8.2
Corycaeus sp.					7.5	1.9												
Ctenocalanus vanus Giesbrecht, 1888	**oAS**									3.5	1.2							
Delius nudus (Sewell, 1929)	**oAS**	+																
Eucalanus elongatus (Sars, 1905)	**oSD**	+														+		
Eucalanus hyalinus (Claus, 1866)	**oSD**															+		
Euchaeta marina (Prestandrea, 1833)	**oS**	+																
Euchaeta hebes Giesbrecht, 1888	**oS**	+																
Euchirella rostrata (Claus, 1866)	**oSD**	+																
Euterpina acutifrons (Dana, 1847)	**cS**	4.6 -18.1	5.7	9.6	11.3 - 13.8	6.3	1.7	1.2 - 2.1	1.1	0.6	3.5 - 18.8	11.8	7.8	0.7 - 12.8	6.8	5.8	23.1-115.1	76.2	40.5
Farranula curta (Farran, 1911)	**oS**							+											
Farranula rostrata (Claus, 1863)	**nS**	7.3 -13.6	9.9	2.7	1.0 - 6.9	2.8	2.8	2.5 - 4.2	2.2	1.2	0.9	0.3		1.17 - 2.7	1.0	1.1	15.6 - 90.7	44.6	32.7
Haloptilus acutifrons (Giesbrecht, 1892)	**oD**	+																
Heterorhabdus compactus (Sars, 1900)	**oD**	+																
Heterorhabdus papilliger (Claus, 1863)	**oD**				0.7	0.2												
Heterostylites major (F. Dahl, 1894)	**oD**															+		
Isias clavipes Boeck, 1864	**Ac**															1.4 - 17.1	6.6	7.9
Labidocera wollastoni (Lubbock, 1857)	**oAS**				+													
Lubbockia aculeata Giesbrecht, 1891	**oSD**															+		
Lucicutia flavicornis (Claus, 1863)	**oD**									1.2	0.4							
Lucicutia longicornis (Giesbrecht, 1895)	**oD**	+																
Macrosetella gracilis (Dana, 1848)	**oS**	+																
Mecynocera clausi I. C. Thompson, 1888	**oAS**	4.5	1.1		2.3 - 6.0	2.1	2.6	0.5	0.2		0.9	0.3		2.7	0.7		5.7 - 31.9	19.4	10.7
Microsetella norvegica (Boeck, 1864)	**nS**															8.2 - 19.8	11.2	5.7
Microsetella rosea (Dana, 1847)	**oS**	+														6.5 - 11.7	9.2	2.2
Miracia minor T. Scott, 1894	**oAS**	+																

Table 1 continued

Nannocalanus minor (Claus, 1863)	**oS**				2.01	0.5		1.7	0.6					1.2 - 1.3	0.6	0.1	21.5 - 85.3	48.1	27
Neocalanus gracilis (Dana, 1849)	**oS**	+																	
Oculosetella gracilis (Dana, 1849)	**oS**	+																	
Oithona brevicornis Giesbrecht, 1891	**cS**				5.04	1.3													
Oithona helgolandica Claus, 1863	**nS**	12.4 - 26.7	18.8	6.9	3.8 - 18.4	11.5	6	1.2 – 5.5	3.6	2.2	56.5 - 94.3	78.7	19.7	0.4 - 3,7.3	23.6	16.1	351.8 -503.3	415.3	66.6
Oithona linearis Giesbrecht, 1891	**cS**	+																	
Oithona nana Giesbrecht, 1892	**cnS**				0.7	0.2		0.2	0.1		9.3 - 131.9	50.5	70.5	0.8 - 10.5	3.1	5.5	228.2 - 613.4	477.5	171.6
Oithona plumifera Baird, 1843	**ocS**				+												60.8 - 127	93.9	33.9
Oithona robusta Giesbrecht, 1891	**coS**							+											
Oithona setigera (Dana, 1849)	**nS**	4.6 - 13.6	6.4	4.6	2.0 - 6.0	2.6	2.2	2.4 – 6.2	4	2	5.6 - 12.8	6.1	5.1	1.17 - 4.3	2.6	1.3			
Oithona similes Claus, 1866	**nS**	+																	
Oithona spp.					5.4 - 6.3	2.9	0.7				0.9	0.3							
Oncaea borealis Sars, 1918	**o**	+																	
Oncaea conifera Giesbrecht, 1891	**oD**																+		
Oncaea curta Sars, 1916	**oD**	+																	
Oncaea englishi Heron, 1977	**oSD**				3.8	0.9													
Oncaea exigua Farran, 1908	**o**	+																	
Oncaea media Giesbrecht, 1891	**oD**				13.9 - 46	15	22.7										2.7 - 6.9	2.4	3
Oncaea mediterranea (Claus, 1863)	**oSD**				2.0 - 11.3	3.3	6.6				4.7	1.6							
Oncaea minuta Giesbrecht, 1892	**o**	9.1	2.3		1.3	0.3													
Oncaea notopus Giesbrecht, 1891	**D**	+																	
Oncaea obscura Farran, 1908	**o**	+																	
Oncaea rotundata Boxshall, 1977	**D**				2.5	0.6													
Oncaea spp.					30.2 - 40.9	17.8	7.5	1.2	0.4		3.5 - 32.31	18.2	14.4	1.1	0.3				
Oncaea subtilis Giesbrecht, 1892	**o**																5.5 - 6	2.9	0.4
Oncaea tenella Sars, 1916	**o**	+																	
Oncaea venusta Philippi, 1843	**nSD**	4.5 - 106.5	45.8	43.3	6.3 - 91.1	46.7	48.5	7.2 - 8.3	5.2	0.8	16.2 - 274.2	143.7	129	1.9 - 5,2.3	27.4	21.7	299.6 - 655.9	544.6	165.8
Pachos punctatum (Claus, 1863)	**oS**	+																	
Paracalanus aculeatus Giesbrecht, 1888	**nS**	+															+		
Paracalanus denudatus Sewell, 1929	**nS**	+																	
Paracalanus indicus Wolfenden, 1905	**cS**	4.5 - 10.9	4.5	3.4	3.8 - 6.9	5.2	1.5	16.8 - 66.7	27.8	35.3	12.8 - 72.7	40.6	30.2	1.2 -17.1	12.8	8.6	198.9 - 899	614	332.1
Paracalanus nanus Sars, 1907	**S**	+																	
Paracalanus parvus (Claus, 1863)	**cS**																+		
Paracandacia simplex (Giesbrecht, 1863)	**oS**	+																	
Paraeuchaeta sp.	**oD**	+																	
Paraoithona parvula Farran, 1908	**cS**	+																	
Phaenna spinifera Claus, 1863	**oD**	+																	
Pleuromamma abdominalis (Lubbock, 1856)	**oD**																4.2	1	
Pleuromamma borealis (F. Dahl, 1893)	**oD**	+																	
Pleuromamma gracilis (Claus, 1863)	**oD**	+																	
Pleuromamma piseki Farran, 1929	**oD**	+																	
Pleuromamma xiphias (Giesbrecht, 1889)	**oD**																16.6	4.1	
Pontella lobiancoi (Canus, 1888)	**oAS**	+																	
Pontella mediterranea (Claus, 1863)	**oS**	+																	
Rhincalanus cornutus (Dana, 1849)	**oAS**				0.7	0.2													
Rhincalanus gigas Brady, 1883	**oSD**	**+**																	

Table 1 continued

Sapphirina auronitens-sinuicauda Lehnhofer, 1929	**oS**	+																				
Sapphirina intestinata Giesbrecht, 189	**oS**																			2.9	0.7	
Sapphirina iris Dana, 1849	**oS**																			4.2	1	
Sapphirina maculosa Giesbrecht, 1892	**oS**	+																				
Sapphirina nigrom aculata Claus, 1863	**oS**																			2.6	0.6	
Sapphirina opalina Dana, 1849	**oS**					1.3	0.3															
Sapphirina scarlata Giesbrecht, 1891	**oS**	+																				
Scolecithricella dentata (Giesbrecht, 1892)	**oS**	+																				
Scolecithrix bradyi Giesbrecht, 1888	**oD**	1.2	0.3																			
Scolecithrix danae (Lubbock, 1856)	**oS**					1.0	0.3															
Subeucalanus. crassus (Giesbrecht, 1888)	**oS**					+																
Subeucalanus. monachus (Giesbrecht, 1888)	**oAS**																			2.6	0.6	
Temora stylifera (Dana, 1849)	**nS**	9.0 - 13.6	8.8	2.4	9.2 – 22.8	13.8	6.2	1.2 -2.5	1.9	0.7	2.8 – 8.2	3.7	3.8	0.7 – 2.3	1.3	0.9	181.2-307.6	239	62.8			
Vettoria granulosa (Giesbrecht, 1891)	**nS**	+																				
Xanthocalanus agilis Giesbrecht, 1892	**oAD**	+																				
Total		118.2 - 270.2	201.8	62.9	176.4 - 339.8	218.6	80.9	39.8-160.4	81.9	68	364.9 - 459.7	396.9	54.4	20.2 – 205.3	126	77.8	3,493 - 5,312	4,329	847.2			

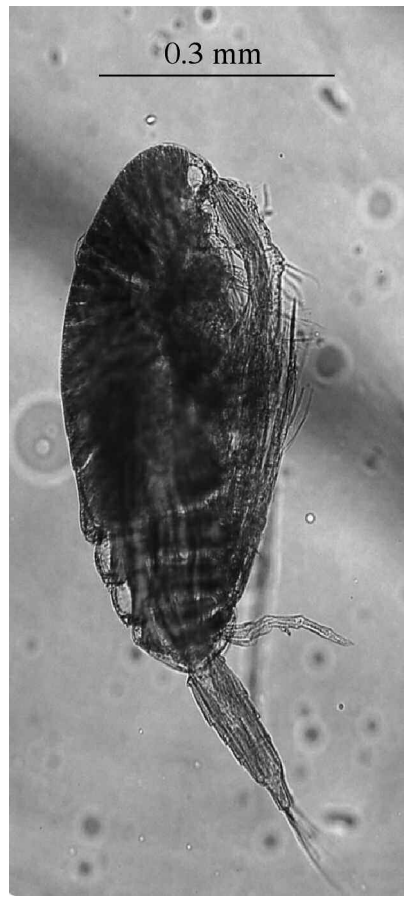

Figure 2. *Paracalanus indicus*. Male: lateral view.
Figure 2. *Paracalanus indicus*. Mâle : vue latérale.

(2) Third to forth leg exopod 3 external edge at least partly serrated and

(3) Both leg 5 developed, symmetrical and 2-3 segmented.

The male (Fig. 2) has:

(1) A cephalic hump on the lateral view and

(2) The right leg 5 is 2-3 segmented.

Paracalanus indicus female has:

(1) First antenna shorter than body and extending beyond anal segment (Fig. 3),

(2) Outer distal of exopod 3 of legs 2, 3 serrate and 4 naked (Fig. 4),

(3) Basipod 1 of legs 1-4 covered with developed ornamentation (Fig. 4),

(4) A prosome three times longer than the urosome (Fig. 3),

(5) A dorsal hump slightly developed (Fig. 3) and

(6) Leg 5 symmetrical and 3 segmented (Fig. 5).

Paracalanus indicus male has:

(1) Outer distal of exopod 3 of legs 2-4 serrate,

(2) The right leg 5 is 2 segmented and the left 5 segmented (Fig. 5).

Table 2. Abundance (ind m^{-3}) of *Paracalanus indicus* in the sampled areas.
Tableau 2. Abondance (ind m^{-3}) de *Paracalanus indicus* dans la zone étudiée.

Station	May 1996	February 2002	March 2002	August 2002	March 2003	April 2003	January 2002	August 2002
1 (Annaba)		4.6	3.8	66.7	36.4	17.1		
2 (Annaba)		9.9	6.0		12.8	21		
3 (Annaba)		10.9	4.0			12		
4 (El Kala)	899							
5 (El Kala)	864.6							
6 (El Kala)	493.6							
7 (El Kala)	198.9							
8 (Bizerte)							135.8	57.2
9 (Bizerte)							86.5	
10 (Bizerte)							170.8	37.2

Figure 3. *Paracalanus indicus*. Female: lateral view. a: dorsal hump.
Figure 3. *Paracalanus indicus*. Femelle : vue latérale. a : bosse dorsale.

The female of *Paracalanus indicus* of the studied area had a body length of 660 to 990 µm (887 ± 98.1 µm, n = 30). The male body length ranged from 880 to 1050 µm (942.2 ± 43.3 µm, n = 27). Table 3 shows no differences between the females of *Paracalanus quasimodo* and *Paracalanus indicus* in the legs 2-4 armature (Fig. 3) in spite of the serrated outer distal exopod 3 of leg 4 in *P. quasimodo.* Moreover there is no difference in the males as can be shown in Table 3.

Discussion

The pelagic copepods of the eastern Algerian coast were abundant and showed a big taxonomic richness in the sampling period. They showed large cohabitation of various affinities and origins (Atlantic, oceanic, bathypelagic and coastal water) indicating thus the opening of the region to the external water influences.

From a quantitative point of view, copepod populations were largely dominated by neritic species. The majority of the 143 copepods collected were rare, comprising deep and Atlantic affinities species. In this context, the synthesis works on Mediterranean plankton biogeography (Furnestin, 1979; Gaudy, 1985; Moraitou-Apostolopoulou, 1985; Estrada et al., 1987; Scotto di Carlo et al., 1984 & 1991) demonstrated the occurrence of such contingents.

Copilia lata, collected for the first time in our region, is also a new species for the Mediterranean. It is known to be an oceanic species, but it was largely present in neritic waters of the studied area and may be considered as a common component of the south-western Mediterranean pelagic copepods. This occurrence may indicate the influence of external oceanic waters in the region, advecting the modified Atlantic water (Ounissi & Khelifi-Touhami, 1999) to the coastal area. The presence of *C. lata* of south-western Mediterranean may also reflect the tropicalisation of the Sea. Many tropical copepod species penetrate in the Mediterranean from the Red Sea or the Gibraltar strait as a consequence of the general water warming (Lakkis et al., 2002).

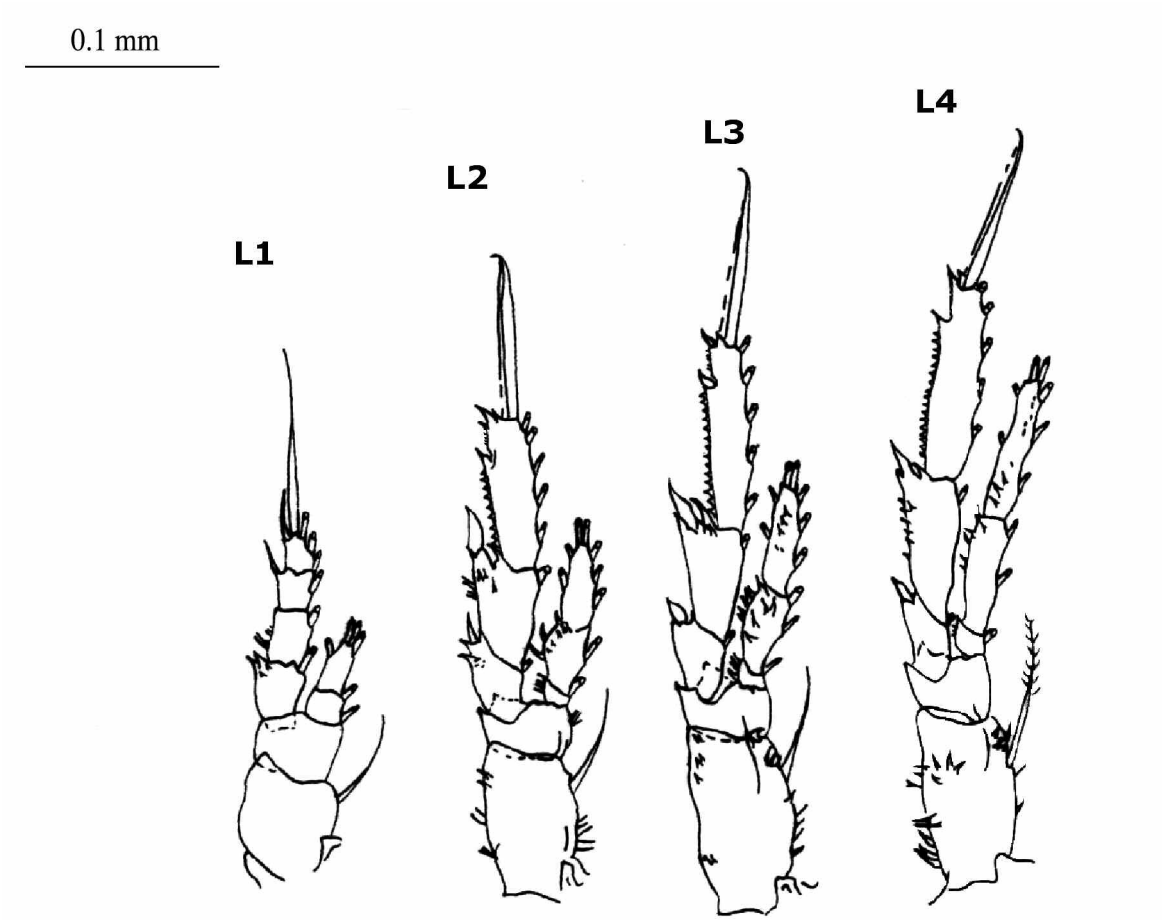

Figure 4. *Paracalanus indicus*. Female: L1-L4 leg 1 to 4.
Figure 4. *Paracalanus indicus*. Femelle : L1-L4 pattes 1 à 4.

On the other hand, if the region is known to be largely influenced by the Atlantic water (Seguin, 1972; Furnestin, 1979), the coastal copepod fauna is more similar to that of the oriental Mediterranean basin than to the occidental basin. This similarity may be expressed by the regular occurrence of *C. kroyeri, Acartia latisetosa, E. acutifrons* (Gaudy, 1985; Moraitou-Apostolopoulou, 1985; Lakkis, 1990). Being an integral part of the Sardinia channel, the studied area is subject to cyclonic eddies and modified Atlantic gyres (Astraldi et al., 1999; Millot, 1999; Testor et al., 2005) that allows supplying additional external and deep species. In a local hydrodynamic context, the neritic inner waters are influenced by eastward residual current (Ounissi et al., 1998) resulting from the general circulation of the modified Atlantic water stream. Consequently, the high copepod richness found in the studied area is to be correlated to such hydrodynamic situations.

Paracalanus indicus (Wolfenden, 1905) was recorded for the first time in the Algerian and Tunisian coastal waters. It can develop high densities (up to 899 ind.m^{-3}) in the continental shelf of El Kala during late spring. In this dry period temperature is above 21.0°C and salinity is up to 36.7-37.2. Comparable distribution may be observed for tropical population in the Brazilian continental shelf off Sergipe and Alagoas (Araujo, 2006). In that area *P. indicus* was more abundant in the rainy months and even reached the maximum value of 2,433 ind.m^{-3}. The author reported that this species was recorded in salinity values from 25.8 to 39.3 and temperature values from 24.0 to 29.5ºC but seems to avoid low salinity waters of the inner shelf. Despite its abundance in the Algero-Tunisian coast, representing up to 46% of total copepods, *P. indicus* was not found in the Mediterranean oriental basin or the north occidental part of the Mediterranean Sea. Its absence in the NE Atlantic (the contiguous potential supplying source, see Greze et al., 1985 and Razouls et al., 2005-2007) is a sign of the isolation in the Mediterranean. Besides, in view of the taxonomic confusion in existing data, it would be prudent to consider the similarities between *P. indicus* and *P. quasimodo*: genetic analyses may precise the state of

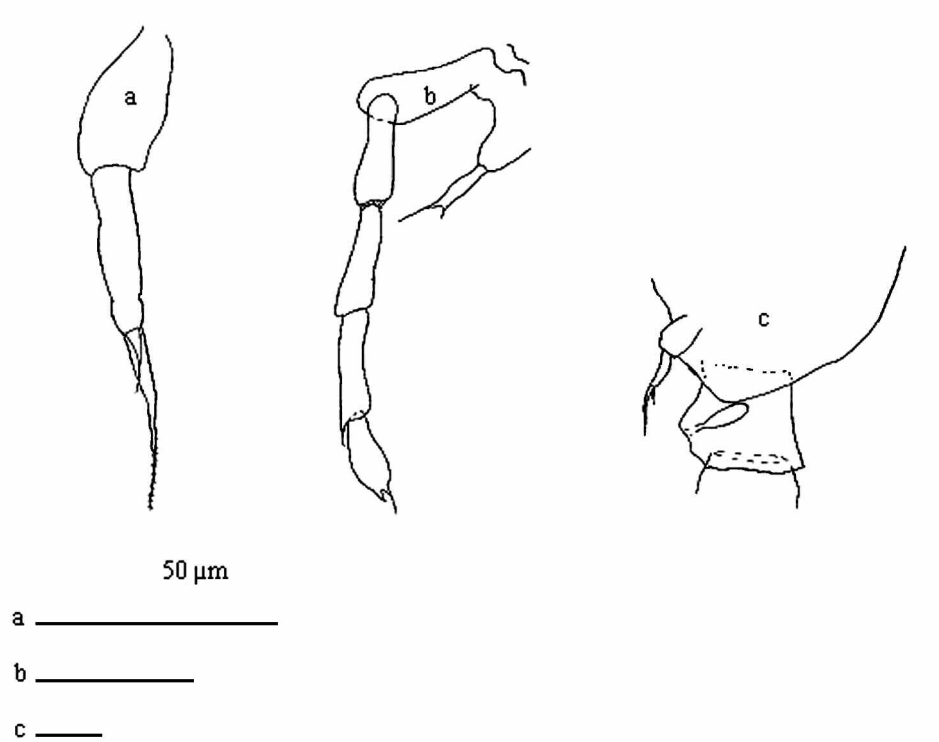

Figure 5. *Paracalanus indicus*. **a.** ♀ leg 5, lateral. **b.** ♂ leg 5, anterior. **c.** ♀ posterior prosome and genital segment, lateral.
Figure 5. *Paracalanus indicus*. **a.** ♀ patte 5, vue latérale. **b.** ♂ patte 5, vue anterieure. **c.** ♀ prosome posterieur et segment génital, latéral.

Table 3. Morphological comparison of *Paracalanus parvus*, *P. indicus* and *P. quasimodo* (Modified from Bradford, 1978). B1: basipod 1, Ex3: exopod 3, Gns: genital segment, L2-4: leg2-4. Authors 1: Bradford (1978), 2: Bowman (1971), 3: Kang (1996), 4: Sewell (1929), 5: Present study.
Tableau 3. Comparaison morphologique de *Paracalanus parvus*, *P. indicus* et *P. quasimodo* (Modifié de Bradford, 1978). B1 : basipodite 1, Ex3 : exopodite 3, Gns : segment génital, L2-4 : leg2-4. Auteurs 1 : Bradford (1978), 2 : Bowman (1971), 3 : Kang (1996), 4 : Sewell (1929), 5 : Présente étude.

Species	Outer distal edge of Ex3 serrate L2	L3	L4	B1 of L2-L4 with many posterior surface spinules	Gns with posterodorsal spinules in ♀	Authors
P. parvus ♀	no	no	no	no	no	1, 2, 3
P. parvus ♂	?	?	?	no		2
P. indicus ♀	yes	yes	no	yes	yes	2, 3, 4
	yes	yes	no	yes	no	1, 5 Fig.4
P. indicus ♂	yes	yes	yes	yes		2, 5
P. quasimodo ♀	yes	yes	yes	yes	no	2
P. quasimodo ♂	yes	yes	yes	yes		2

these species revealing possibly the resemblance of the two populations. We also suggest a full reviewing of species from the *parvus* group (*P. indicus, P. parvus, P. quasimodo*) from the Mediterranean focusing on the possible occurrence of these species.

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