



Spatio-temporal Variability of *Oithona brevicornis* (Copepoda, Cyclopoida) Population Dynamic and Reproductive Parameters in Fresco lagoon (Côte d'Ivoire)

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Abstract - Spatio-temporal variations of *Oithona brevicornis* abundance, biomass and reproductive parameters were investigated monthly in Fresco lagoon from August 2013 to July 2014 in five stations. Results show that *O. brevicornis* population abundance, biomass and reproductive parameters are marked by dry season values statistically higher than those obtained during the rainy season. During all seasons, highest abundance and biomass values were obtained in sampling sites far from the Fresco lagoon channel. *O. brevicornis* population reproductive parameters estimate during the present study: ovigerous female abundance (AF_w), egg-females ratio (E/F), eggs production rate (EPR), weigh-specific eggs production (SEPR) and secondary production of females (SPF) show the same spatio-temporal variation. *O. brevicornis* abundance, biomass and reproduction parameters spatio-temporal variation in Fresco lagoon is mainly linked to water salinity, transparency and turbidity variation. Favorable conditions for its reproduction, development and proliferation are found during the dry season with salinity fluctuating between 5.8 and 27.5 (mean: 16.58) associate with low turbulence conditions and high transparency.

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Key-words: *Oithona brevicornis* / eggs production / spatio-temporal variation / Fresco lagoon.

1 Introduction

Copepods are a highly diverse group of crustaceans (13 000 species) (Boxshall and Defaye, 2008). They are aquatic animals, primarily marine (≈ 78% of copepods total diversity), which although also occur in ground water (Galassi, 2001), and in almost all freshwater habitats from the largest ancient lakes to subterranean waters, from pools of glacial meltwater to hot springs, and from hypersaline lakes to phytotelmata (Boxshall and Defaye, 2008). They were the main component of the zooplankton in coastal and oceanic environments: e.g. 68 to 98% (with an annual mean of 84.8%) in the Cananéia Lagoon (São Paulo, Brazil) (Ara, 2004), 81% in Grand-Lahou lagoon (Côte d'Ivoire) (Etilé *et al.*, 2009), 77% of total zooplankton in the Southwestern Atlantic Ocean (Thompson *et al.*, 2013), and 98% in Fresco lagoon (Côte d'Ivoire) (Etilé *et al.*, 2018). Marine copepods are considered as ecologically and economically important organism in assessing the fish stock since it is serving as prime feed for most of the brackish water and marine fishes (Santhanam and Perumal, 2012).

Indeed, they form a link in the food web between the primary producing phytoplankton and the plankton-feeding fish. Moreover, most of the economically important fish depend on copepods and other zooplankton during their early life stage (larval fish stage) as well as adult stages of some fish such as spot (*Leiostomus xanthurus*) (Govoni and Chester, 1990); European anchovy (*Engraulis encrasicolus*) (Conway *et al.*, 1998); Atlantic mackerel (*Scomber scombrus*) (Ringuette *et al.*, 2002); Zoblaidy (*Pampus argenteus*), Suboor (*Tenualosa illisha*), Beyah (*Liza subviridis*) (Al-Yamani *et al.*, 2011). In addition, copepods have an important role in biogeochemical cycles recycling nutrient in the ocean (Atienza *et al.*, 2006) and are also known to have a potential role in retarding the vertical flux of particles by ingesting (coprophagy) and/or fragmenting (coprorhexy) large size zooplankton fecal pellets (Gonzales and Smetacek, 1994).

Among these copepods, Oithonids are the most successful free-living cyclopoids in the marine epipelagic ecosystem and occur in the world ocean at

relatively high numerical densities (Nielsen and Sabatini 1996, Hopcroft *et al.*, 1998) due to their high production turnover rates (Gallienne and Robins, 2001). *Oithona* spp. are now known to contribute significantly to the standing stock of copepods in many marine ecosystems despite scientific knowledge biased about the quantitative importance of many small copepod species such as *Oithona* spp. (size < 200 μm) due to the recommended use of nets with a mesh size $\geq 200 \mu\text{m}$ for sampling of copepods in marine ecosystem (UNESCO, 1968). For example *Oithona* species constitute 10 to 50% and 20 to 70% of total copepods biomass and production, respectively in the North Sea (Nielsen and Sabatini, 1996); and 17% of total copepods biomass (Mean) in Southwestern Atlantic Ocean (Thompson *et al.*, 2013). *Oithona* spp. are also reported as main species in several coastal and estuarine lagoons: e.g. Cananéia Lagoon in Brazil (Ara, 2004), Grand-Lahou and Fresco lagoon in Côte d'Ivoire (Etilé *et al.*, 2009 and 2018) and Guaraíras lagoon in Northeastern Brazil (Almeida *et al.*, 2012). *Oithona* species numerical predominance in these ecosystems may be linked to their ability, as the other small cyclopoids, to exploit microbial food webs more efficiently than calanoid copepods (Nielsen and Sabatini, 1996). A review of Zamora-Terol (2013) reported that *Oithona* species are present in polar, temperate, subtropical, and tropical water, in epipelagic and mesopelagic environment, in estuaries, mangroves, continental shelves and open Ocean. This wide distribution and high abundance converts *Oithona* genus of worldwide ecological importance in marine and coastal pelagic environment. In Côte d'Ivoire, *Oithona brevicornis* is the main zooplankton species in Grand-Lahou lagoon (Mean: 28 % of to zooplankton abundance) (Etilé *et al.*, 2009) and in Fresco lagoon (56% of to zooplankton abundance) (Etilé *et al.*, 2018), contrary to Ebrié lagoon (Pagano and Saint-Jean, 1994) and Aby-Tendo-Ehy lagoons system (Monney *et al.*, 2015) where respectively *Acartia clausi* and *Lecane leontina* were the main species. Studies focus on biology and ecology of zooplankton species have mainly been performed in the Ebrié (Saint-Jean and Pagano, 1983 and 1984; Pagano and Saint-Jean, 1985 and 1989; Pagano *et al.*, 2003 and 2004; Kouassi *et al.*, 2001 and 2006) and Grand-Lahou (Etilé *et al.*, 2012 and 2015) lagoons. In spite of the numeric dominance of *oithona brevicornis* in lagoons of Côte d'Ivoire, and their important roles in ecosystem functioning of these ecosystems, few works have been dedicated to the survey of their biology and ecology (Etilé *et al.*, 2012).

The goal of the present study was to provide information on population dynamic and reproductive parameters of *O. brevicornis* variation in the

environmental context of the Fresco lagoon, to analyse the main variation factor and to contribute to a better knowledge of the biology and the ecology of this species in climatic and environmental context of Côte d'Ivoire.

2 Materials and methods

Study area

Our survey environment (Fresco lagoon, Figure-1) is a minor lagoon, with a basin of 6 km long and stretches on a larger of 2 to 4 Km between 5°40' and 5°70' N and between 5°32 and 5°38' W, with a total area varying from 17 to 29 km². It communicates with the Atlantic Ocean through a channel which was open during our data collection. The Fresco lagoon undergoes the influence of 4 small forests rivers: Bolo (84 km), Niouniourou (140 km), Gnou (12 km) and Guitako (5 km). However, the Bolo and Nioumouzou, which are the two main rivers discharge their waters mainly in the Atlantic ocean through a pass. The lagoon shores are marshy in places, particularly along the estuaries, and there are areas subject to seasonal inundation immediately behind the marshes. There are small mangrove stands inside the lagoon mouth, and some swamp forest occurs at the river mouths. In Fresco lagoon localization zone rainy season lasts from April to July and October to November while the dry season lasts from December to March and August-September.

Data collection

During this study, zooplankton and environmental variables were recorded monthly from August 2013 to July 2014 in five stations (Figure 1). The physical and chemical parameters (temperature, salinity, dissolved oxygen, conductivity, turbidity and pH) were measured in water surface, with a scientific portable multi-parameter probe. The transparency was measured using a Secchi disk. Water samples were collected and preserved at 4°C for subsequent analyses of nutrients: Phosphate (PO₄³⁻), Nitrite (NO₂) and Ammonium (NH₄⁺), according to protocols described by Strickland and Parsons (1972). Suspended solids were determined according to the protocol described by Aminot and Chaussepied (1983).

For zooplankton sampling, a plankton net of 64 μm of mesh opening size was used, then samples collected were conserved in formalin (5%). *Oithona brevicornis* was identified using the following works: Wiafe and Frid (2001), Al-Yamani *et al.* (2011). The copepods were identified and counted under a dissecting microscope (magnification: 400). The stages (adult males, adult females with and without egg sac, 1 to 5 grouped copepodids stages) were counted on the entire sample or, for the most abundant, on subsamples made with wide bore piston Eppendorf pipettes of 1 and 5 ml. Copepod density,

expressed as numbers per liter (ind.l^{-1}), was calculated by dividing the number of organisms estimated in each sample by the volume of water filtered in the field (i.e.

cylinder defined by the net opening area and the station depth).

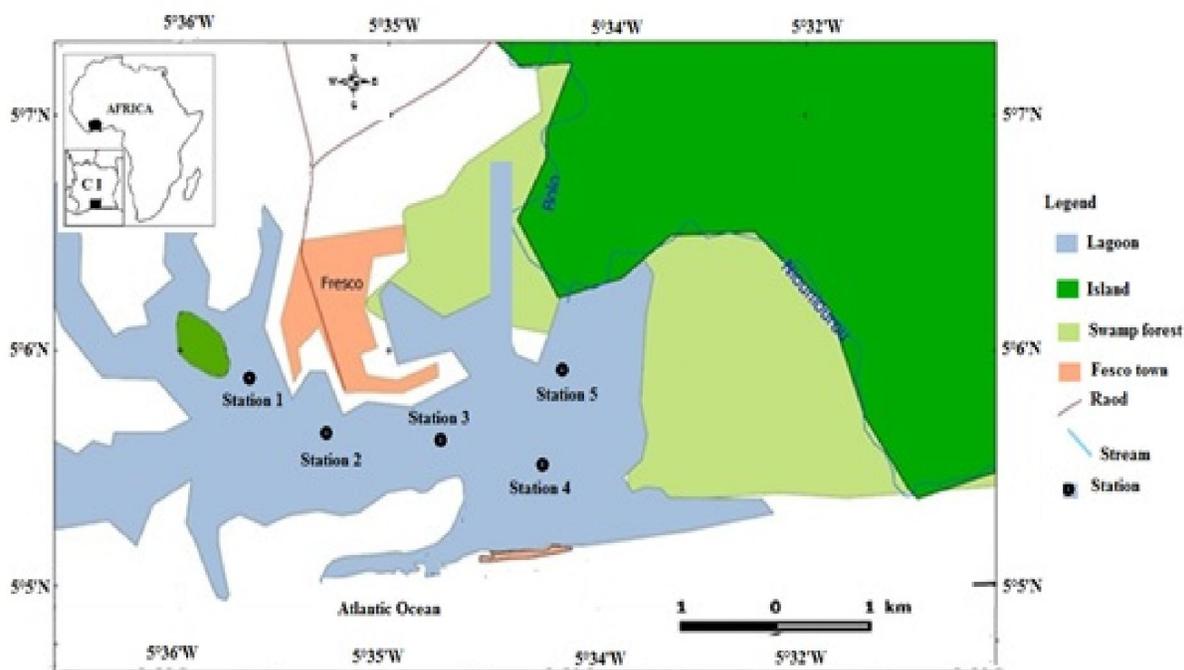


Figure-1: Sampling stations localization in the Fresco lagoon (Côte d'Ivoire)

The individual weights (expressed as dry weight, DW) were estimated from their body size using the length (L in mm)-weight (DW in μg) relationship proposed by Saint-Jean and Pagano (1987): $DW = 5.557 L^{3.35}$.

The body size (total length, excluding the furcal silks) were measured under a dissecting microscope (magnification 400) using an ocular micrometer (precision $\pm 10 \mu\text{m}$), on a sample of at least 30 individuals (if possible) in each station and per month. The individual dry weights were converted into carbon (C) using a C/DW ratio = 0.045 (Pagano and Saint-Jean, 1993). Sex ratio (SR) in *O. brevicornis* population is estimated by dividing total adult female (F_t , ovigerous + non-ovigerous) abundance by adult male (M) abundance. The percentage of ovigerous females on each sampling was calculated as the quotient of the estimated abundance of ovigerous females (AF_w) with respect to the total number of females (F_t). The weigh-specific eggs production rate of the adult females ($SEPR$, in $\mu\text{g}/\mu\text{g}/\text{d}$ or $1/\text{d}$) was estimated according to the equation: $SEPR = (W_e \times NEF) / (D_e \times W_f)$, where W_e and W_f : individual weights of eggs and females respectively, NEF : number of eggs per female and D_e : duration of the embryonic development. The weight of eggs (W_e) was supposed to be constant and equal to $0.012 \mu\text{gC}$

(Pagano and Saint-Jean, 1994). The duration of the embryonic development (D_e , in d) was calculated as a function of temperature (T , in $^{\circ}\text{C}$) according to the relationship calculated by Pagano and Saint-Jean (1994) from the data of Uchima (1979): $D_e = 589 \times T^{-1.716}$. The eggs-female ratio (E/F) is given by the following equation: $E/F = (NEF_w \times NF_w) / N_{Ft}$, Where NEF_w : Number of egg per ovigerous female (clutch size), NF_w : Number of ovigerous females and N_{Ft} : total number of adult females (ovigerous + non-ovigerous).

The Number of egg per ovigerous female is estimated by numbering the egg in a set of at least 30 ovigerous females per sample. Average egg diameter (D) was obtained by measuring the diameter of each egg from a total of 120 eggs from different ovigerous females under a dissecting microscope (magnification 400). Egg production rates (EPR , $\text{eggs female}^{-1} \text{day}^{-1}$) were determined using the number of eggs per female (NEF) (or egg-female ratio, E/F) and the duration of the embryonic development (D_e) according to Edmondson (1971): $EPR = NEF \times 1/D_e$. The secondary production of female (SPF , in $\mu\text{gC l}^{-1} \text{d}^{-1}$) was obtained by multiplying the biomass of female and the weigh specific egg production rate of the adult females ($SEPR$) according Dvoretzky and Dvoretzky (2009a).

Analytical procedure

Simple Pearson correlation coefficients were used to test the effects of environmental factors on *Oithona brevicornis* abundance, biomass and reproductive parameters (AF_w, NEF, EPR, SEPR, and SPF). One-way analyses of variance (general linear model) were performed to test the effects of month and seasons; and stations on *O. brevicornis* density, biomass and reproductive parameters. All calculations were performed after adequate transformation (logarithmic) of the data in order to tend towards normal distributions. All steps of this method were computed using Statistica 7.1 software.

3 Results

Environmental parameters

Environmental parameters measured in Fresco lagoon during this study show remarkable seasonal variability (Table I). Water temperature varied from 20.00 to 32.60 °C depending on the sampling sites and periods. Highest values were always recorded during

the wet season (27.00-31.90°C, mean: 29.98°C) versus 20.00 to 32.60°C during the dry season (27.95°C). Similar seasonal variation was also obtained with pH, turbidity, nitrites, phosphates and suspended solids, with respectively 7.1-9.18 (Mean: 8.17), 15.60-114.70 ntu (Mean: 39.28 ntu), 0.26-26.66 µmol/l (Mean: 10.32 µmol/l), 32.30-96.90 (Mean: 62.51 µmol/l) and 18.40-48.40 mg/l (Mean: 37.68 mg/l) obtained during the wet season, versus respectively 6.75-8.63 (Mean: 7.78), 2.80-30.90 ntu (Mean: 12.99 ntu), <0.01-1.23 µmol/l (Mean: 0.30 µmol/l), 0.11-3.92 (Mean: 0.94 µmol/l) and 7.80-71.30 mg/l (Mean: 35.07 mg/l) during the dry season, with statistically meaningful seasonal difference ($p < 0.05$) for water turbidity, nitrite and phosphates values. In contrast, salinity, conductivity, dissolved oxygen, transparency, and ammonium concentration present spatio-temporal variation characterized by highest values obtained during the dry season, with statistically meaningful seasonal difference ($p < 0.05$).

Table I: Means and seasonal variability of Environmental parameters measured in Fresco lagoon from August 2013 to July 2014

Variables	Dry Season			Rainy Season		
	Moyennes	Minimum	Maximum	Moyennes	Minimum	Maximum
Température (°C)	27.95	20.00	32.60	29.98	27.00	31.90
Salinité (mg/l)	16.58	5.80	27.50	8.31	0.00	15.00
Conductivity (µS/cm)	24.80	0.09	54.50	18.28	3.90	28.30
Dissolved Oxygen mg/l	5.09	0.75	13.20	4.88	4.25	5.60
Transparency (m)	0.72	0.30	1.60	0.33	0.20	0.50
pH	7.78	6.95	8.63	8.17	7.01	9.18
Turbidity (ntu)	12.99	2.80	30.90	39.28	15.60	114.70
Nitrite (µmol/l)	0.30	< 0.01	1.23	10.32	0.28	26.68
Phosphate (µmol/l)	0.94	0.11	3.92	62.51	32.30	96.90
Ammonium (mg/l)	8.16	0.01	102.00	0.04	0.03	0.06
Suspended solids (mg/l)	35.07	7.80	71.30	37.68	18.40	48.40

Oithona brevicornis population abundance and biomass spatio-temporal variation

Oithona brevicornis population abundance and biomass (respectively 11-112 ind.l⁻¹ and 2-16 µgC.l⁻¹) estimated in Fresco lagoon during the present study is marked by dry season values statistically higher than those obtained during the rainy season (respectively < 0.01-39 ind.l⁻¹ and < 0.01-4 µgC.l⁻¹) (Figure 2A & B). During all seasons, highest *O. brevicornis* abundance (18 to 112 ind.l⁻¹) and biomass (4 to 16 µgC.l⁻¹) values were obtained in sampling site 1 to 3 (sites far from the Fresco lagoon channel) versus lowest values observed in sites near the channel (St4 and St5) (respectively < 0.01 to 14 ind.l⁻¹ and < 3 µgC.l⁻¹) (Figure 2). In addition, let's note that, in June-July and in October where water salinity is ≤ 5, *O. brevicornis* population disappears completely.

This species population structure is characterized by copepodids stages abundance dominance all seasons (62 to 83%; < 1 to 75 ind.l⁻¹) and by adults females dominance in biomass term (47-67%; 0 to 10 µgC.l⁻¹) (Figure 2C & E). Adults males was the stage the less abundant (<1 to 3%; ≈ 0 to 3 ind.l⁻¹), with lowest biomass (1-4%; < 1 µgC.l⁻¹) in *O. brevicornis* population sampled in Fresco lagoon during this study (Figure 2C & D). The same tendency is observed for all population stages (copepodids, ovigerous and non-ovigerous females, and adults males).

Reproductive parameters spatio-temporal variation

In adult's population, females (F) were more numerous than males (M), with a mean sex ratio (F/M) of 25:1. On average, females represent 91% of total adults population versus < 10% for males (Figure

3). In station 5 (st5), adult population is almost entirely composed of females (96%). Besides, adult populations of *O. brevicornis* were obtained with highest abundance during the dry season, mainly in the sampling sites far from the channel (st1 to st3). *Oithona brevicornis* ovigerous females were obtained in the lagoon all season.

However, Ovigerous females highest abundance were recorded during the dry season (0.41 to 8.36 ind.l⁻¹), with corresponding biomass of 0.12 to 2.48 µgC.l⁻¹. During the dry season, highest abundance and biomass of ovigerous females of this species were recorded in stations far from the channel (respectively 4-8 ind.l⁻¹, 1.18-2.48 µgC.l⁻¹) versus respectively < 1 ind.l⁻¹, and < 1 µgC.l⁻¹ in sampling sites near the channel (stations 4 and 5). During the rainy season, they were obtained, with low abundance (0.12-0.18 ind.l⁻¹), only the station far from the channel. They are completely absent in the lagoon during the months of June-July and October corresponding to the rainy period where water is ≤ 5. *O. brevicornis* ovigerous females represented on average 19% of total female abundance during the dry season, versus only 2.55% of total female abundance during the rainy season.

Oithona brevicornis Clutch size varied from 10 to 20 eggs, with a mean of 14.57 eggs/ovigerous females. The mean egg diameter (D) of *O. brevicornis* sampling in Fresco lagoon mainly during the dry season was 50 µm.

The egg-females ratio (E/F) is significantly higher during the dry season (0.74 to 3.39 eggs/female, mean: 2.26 eggs/female) than during the rainy season (0.67 to 1.90 eggs/female, mean: 1.27 eggs/female). As for the ovigerous females abundance, during the dry season, highest egg-females ratio in stations far from the channel (st1 to st3) were higher (2.57 to 3.39 eggs/female) than in the sampling near the channel (st4 and st5, 0.74 to 1.71 eggs/female) (Figure 4A). During the rainy season, the egg-female

ratio is hopeless in stations near the channel (st4 and st5) due to ovigerous females absence in these sampling sites. In the other stations, this ratio varied from 0.67 to 1.86 eggs/female) (Figure 4A). The same spatio-temporal variation is observed for the over reproductive parameters: Eggs production rate (EPR, Figure 4B), Weigh-specific eggs production (SEPR, Figure 4C) and Secondary production of females (SPF, Figure 4D).

***Oithona brevicornis* population abundance, biomass and reproductive parameters relationship with fresco lagoon environmental parameters**

Correlation study focuses on *O. brevicornis* abundance, biomass and reproductive parameters reveal that, in Fresco lagoon, salinity was the main environmental factor affecting this species population spatio-temporal variation. Indeed, all *O. brevicornis* stages abundance and biomass increase significantly with an increasing of water salinity (Table II and III). Besides with salinity, several other significant correlations were also found between *O. brevicornis* abundances, biomass and reproductive parameters and environmental variables. Female adults without eggs sac abundance and biomass show significant and positive correlation with water transparency on the one hand, and significant and negative with water temperature (Table II). Ovigerous females and males population abundance and biomass were significantly and positively correlated to conductivity. Also, during the dry season that *O. brevicornis* population abundance and biomass were highest, and that ovigerous females and males were the most abundant, all reproductive parameters of *O. brevicornis* estimated (NEF, SEPR, EPR and SPF) show significant and positive correlation with conductivity and pH. Weigh-specific eggs production and Secondary production of females were positively and significantly correlated with temperature and suspended solids.

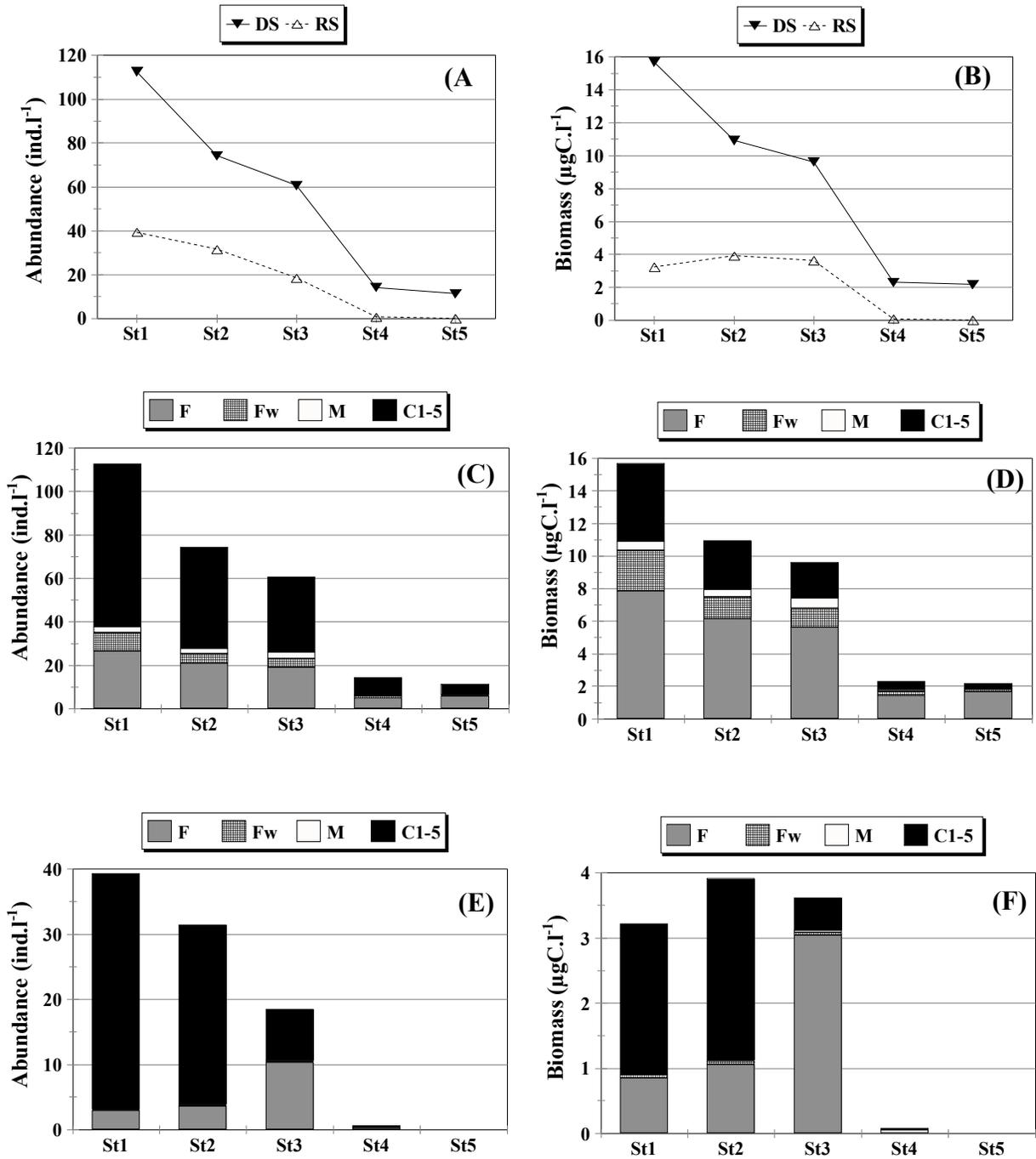


Figure 2: Spatio-temporel variation of *Oithona brevicornis* total population abundance (A) and biomass (B), and spatial variation of relative abundance and biomass of different stages of *Oithona brevicornis* population during the dry (C & D) and the rainy (E & F) seasons (DS: Dry Season, RS: Rainy season).

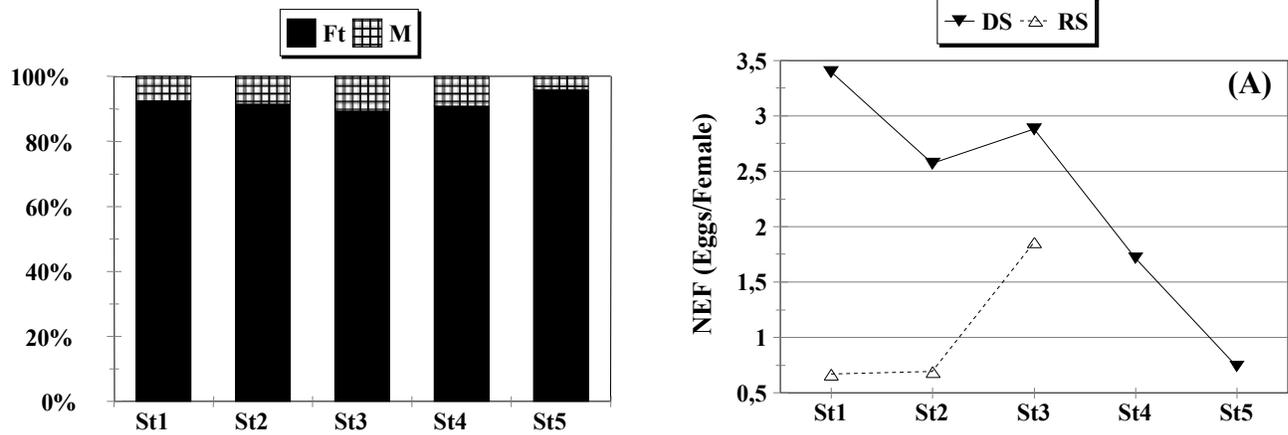


Figure 3: Spatial variation of *Oithona brevicornis* population sex composition in Fresco lagoon (Ft: total females, M: males).

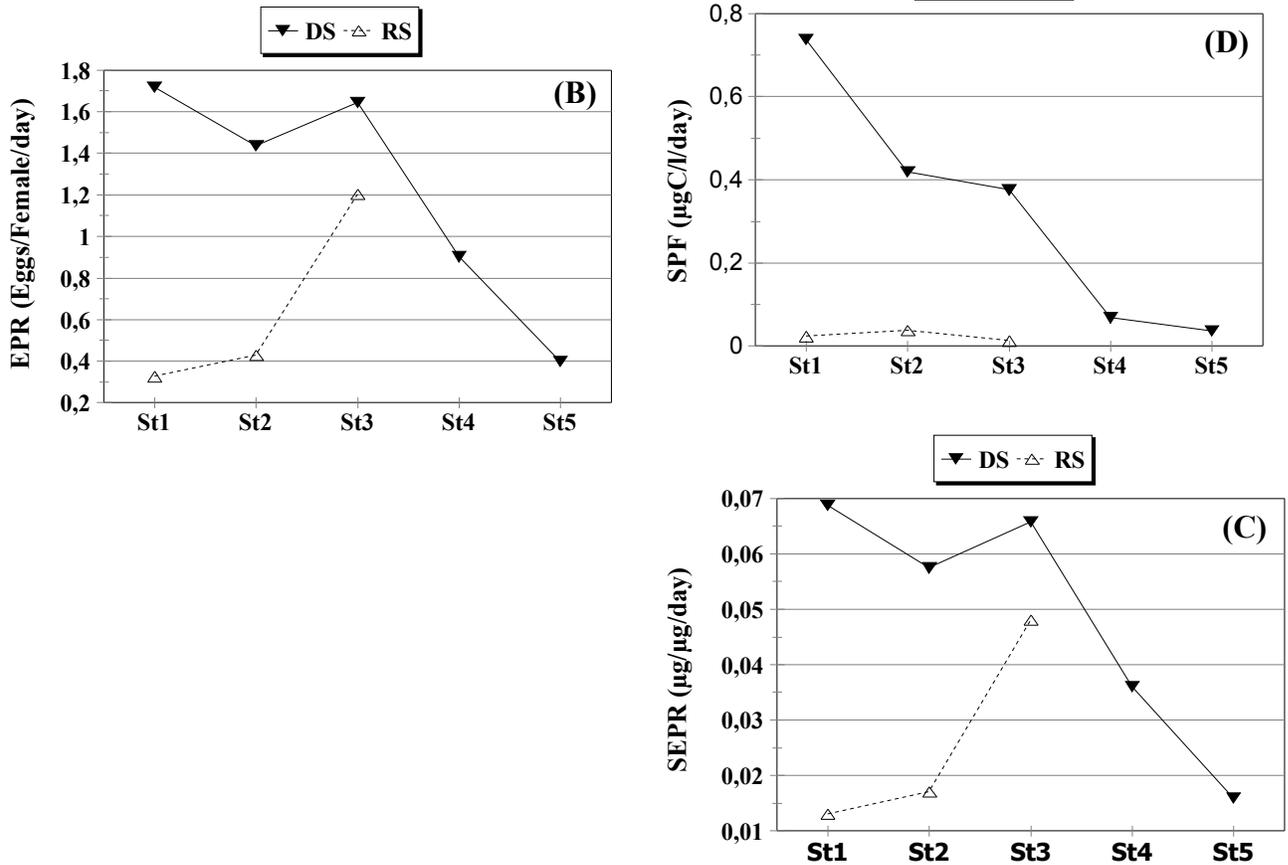


Figure 4: Spatio-temporel variation of *Oithona brevicornis* reproductive parameters (DS: Dry Season, RS: Rainy Season, NEF: Number of Eggs per Female, EPR: Eggs Production Rates, SEPR: Weigh-Specific Eggs Production, SPF: Secondary Production of Females).

Table II. Simple Pearson correlation coefficients (Rs) relating the physical and chemical parameters to the abundance and biomass of the *O. brevicornis* total population and various stages

	Temperature	Salinity	Conductivity	DO	Transparency	pH	Turbidity	Nitrite	Phosphates	Ammonium	MES
Abun F	-0.323*	0.582***	0.209	-0.073	0.327*	0.079	-0.385	-0.157	-0.129	0.257	-0.047
Abun Fw	-0.156	0.509**	0.412**	-0.064	0.188	0.166	-0.309	-0.253	-0.146	0.168	0.127
Abun M	-0.247	0.584***	0.307*	0.109	0.222	0.102	-0.262	-0.159	0.067	0.211	-0.043
Abun C1-5	-0.281	0.355*	0.204	-0.153	0.152	0.265	-0.054	-0.038	-0.059	0.010	0.067
Abun total	-0.235	0.093	0.115	-0.264	0.043	0.153	0.029	-0.039	-0.067	-0.009	0.247
Bio F	-0.323*	0.582***	0.209	-0.073	0.327*	0.079	-0.385	-0.157	-0.129	0.257	-0.047
Bio Fw	-0.156	0.509**	0.412**	-0.064	0.188	0.166	-0.309	-0.253	-0.146	0.168	0.127
Bio M	-0.247	0.584***	0.307*	0.109	0.222	0.102	-0.262	-0.159	0.067	0.211	-0.043
BioC1-5	-0.281	0.355*	0.204	-0.153	0.152	0.265	-0.054	-0.038	-0.059	0.010	0.067
Bio total	-0.281	0.499**	0.251	-0.133	0.251	0.165	-0.257	-0.144	-0.129	0.134	0.093

F: Adult female without eggs sac; Fw: Ovigerous females; M: males; C1-5: Copepodids; Abun total: *O. brevicornis* population total abundance; Bio total: *O. brevicornis* population total biomass; DO, dissolved oxygen. Significant correlation: * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

Table III. Simple Pearson correlation coefficients (Rs) relating physical and chemical parameters to reproductive characteristics of *Oithona brevicornis*

	Temperature	Salinity	Conductivity	DO	transparency	pH	Turbidity	Nitrite	Phosphates	Ammonium	MES
NEF	0,246	0,054	0,501***	0,086	-0,233	0,209	-0,031	-0,258	-0,045	0,055	0,111
SEPR	0,425**	-0,019	0,488**	0,120	-0,245	0,262	-0,018	-0,203	-0,036	0,005	0,219
EPR	0,425**	-0,019	0,488**	0,120	-0,245	0,262	-0,018	-0,203	-0,036	0,005	0,219
SPF	0,005	0,260	0,423 **	0,003	-0,127	0,215	-0,088	-0,142	-0,008	0,202	0,089

NEF: number of eggs per female; SEPR (Gf): Weight-Specific Egg Production Rate; EPR: Egg Production Rate; SPF: Secondary Production of Females; DO: Dissolved Oxygen. Significant correlation: * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

4. Discussion

The present study was the first attempt to investigate *Oithona brevicornis* population dynamic and reproductive parameters variations of in Fresco lagoon, and the second on lagoons of Côte d'Ivoire. It constitutes the main species from lagoons of Côte d'Ivoire (Etilé et al., 2009 and 2018) excepted in Aby-Tendo-Ehy lagoon system where *Lecane luna* and *Brachionus plicatilis* were the mains species (Money et al., 2015).

During the present study, *O. brevicornis* population abundance and biomass (respectively 11-112 ind.l⁻¹ and 2-16 µgC.l⁻¹) estimated in Fresco lagoon were marked by dry season values significantly higher than those obtained during the rainy season (respectively $< 0.01-39$ ind.l⁻¹ and $< 0.01-4$ µgC.l⁻¹). Similar seasonal variation of abundance and biomass of zooplankton, with highest values obtained during the dry season, is also reported in other lagoons of Côte d'Ivoire: Grand-Lahou lagoon (Etilé et al., 2009), Aby-Tendo-Ehy lagoons system (Monney et al., 2015), Ebrié lagoon, sector I: Aghien (Aka et al., 2016), Ebrié lagoon, sector IV and V (Appiah et al., 2018), Fresco lagoon (Etilé et al., 2018). Besides, copepods species population abundance and biomass values higher during the dry season than the rainy season is also reported in other tropical lagoons: *O. brevicornis* in Grand-Lahou lagoon (Etilé et al., 2012), *Pseudodiaptomus hessei* in Grand-Lahou lagoon (Etilé et al., 2015), *Acartia clausi* in Ebrié lagoon (Pagano and Saint-Jean, 1989 and 1993) and in Grand-Lahou lagoon (Etilé et al., 2017). In addition, all reproductive parameters estimated in Fresco lagoon: Ovigerous

female abundance (AF_w), Clutch size (CS), Number of Eggs per Female (NEF), Eggs Production Rates (EPR), Weigh-Specific Eggs Production Rate (SEPR), Secondary Production of Females (SPF) present higher values during the dry season comparatively to the rainy season.

This seasonal fluctuation of *Oithona brevicornis* abundance, biomass and reproductive parameters may be linked to the fact that during the dry season favorable conditions for its reproduction and development are found. Indeed, during the dry season, in Fresco lagoon, water salinity considerate as the major structuring factor for the composition and the distribution of zooplanktonic taxa in tropical and temperate regions lagoon (Arfi et al., 1987; Attayde and Bozelli, 1998; Etilé et al., 2009) fluctuate between 5.8 and 27.5, corresponding to the extreme salinity tolerance values for *O. brevicornis* (5 and 30 in Ebrié Lagoon reported by Arfi et al., 1987). It could be bound also to fact, during the dry season, salinity mean values in Fresco lagoon (present study: 16.58) is not far from of range values of 10 to 15, considerate as an optimal window of salinity for successful development and growth of an estuarine species (Mauchline, 1998), whereas rainy season salinity values fluctuate between 0 to 15, with an average value of 8.31 below of this optimal window of salinity.

In addition to salinity, during the dry seasons, others conditions as transparency increase (seasonal average values per station: 0.60 to 0.87 m, versus 0.22 to 0.40 m during the rainy season) associate with low turbulence conditions (10 to 17 ntu, versus 22.35 to 73 ntu during the rainy season) in the Fresco lagoon,

mainly in sector far from of the opening of the lagoon on the Atlantic ocean (Fresco channel) and the mouth of Bolo-Niourouniourou rivers (St1 to St3), stimulate the reproduction and development of *Oithona brevicornis* and enhance its density and biomass.

It would explain ovigerous females higher abundance during the dry season (0.41 to 8.36 ind.l⁻¹ versus < 0.2 ind.l⁻¹ during the rainy) and mainly in sampling sites far from of the opening of the lagoon on the Atlantic ocean (Fresco channel) and the mouth of Bolo-Niourouniourou rivers (St1 to St3) (3.98 to 8.36 ind.l⁻¹ versus < 1 ind.l⁻¹ in the sampling sites near the channel and the mouth of Bolo-Niourouniourou rivers: St4 and St5). The same spatio-temporal variation is also observed with adult male population abundance confirming thus importance of salinity, transparency and low turbidity on reproduction of *O. brevicornis* in Fresco lagoon. Nevertheless, lowest abundance of ovigerous females in stations near the mouth of Bolo-Niourouniourou rivers and the channel, may be due to turbulence in these sites (mechanical stress) create by rivers water outflow and by the waves (in the present study), which cause egg sac detachment from the body the adult females, mainly when egg sacs are in a late developmental stage (Zamora-Terol *et al.*, 2014a). It also reported that low salinity in an estuarine zone might cause losses of egg sacs (Timofeev, 2000). So therefore, according to Zamora-Terol *et al.* (2014a), the loss of egg sacs from the adult females contributes to involve a bias in estimation of the number of ovigerous females. So, *O. brevicornis* density and biomass droop during the rainy season and in the mouth of Bolo-Niourouniourou rivers (station 4) and near the Fresco channel (station 5) during the dry season on the one hand, and almost absence of ovigerous female and male adults on the other hand, could be linked probably to physiological stress at these turbid environment with low transparency associated to relative low salinity condition. The positive relationship between salinity and *O. brevicornis* reproductive parameters in the present study conflicts with results of Pagano and Saint-Jean (1994) which found no significant effect of salinity on the production of *O. brevicornis* in Ebrié Lagoon (Côte d'Ivoire) and contrasts also with those of Dvoretzky and Dvoretzky (2009a) on *O. similis* reproductive characteristic (ovigerous females, EPR, SEPR and SPF) which significantly decreased with salinity in Kola bay (Barents Sea). This situation contrasts also with in cold and temperate regions where generally, temperature is considerate as the main factor affecting *Oithona* species (Dvoretzky and Dvoretzky, 2009b; Zamora-Terol *et al.*, 2013 and 2014a) and others copepods (*Acartia longiremis* and *Temora longicornis*) reproductive parameters (Dvoretzky and Dvoretzky, 2014).

In addition to salinity action on *Oithona* species reproduction, several other factors as food (quality and quantity) are also mentioned as factor affecting copepods eggs production. Indeed, chlorophyll a for example is reported to have a significant relationship with *O. similis* EPR in the Scotia Sea (Ward and Hirst, 2007), and with *Pseudocalanus elongatus* EPR in the North Sea (Drif *et al.*, 2010), while EPR of *Oithona* spp. is reported to show a significantly positive relationship with protozooplankton biomass and water temperature, but not with phytoplankton concentration in the coast of West Greenland (Zamora-Terol *et al.*, 2014b). Protozooplankton and other small phytoplankton, ciliate and dinoflagellates (*Oxyrrhis marina*) are beside well documented as the main food resource for *Oithona* genera species: i.e. *O. davisae* (Saiz *et al.*, 2003; Zamora-Terol and Saiz, 2013), *Oithona similis* (Castellani *et al.*, 2005; Nishibe *et al.*, 2010), *Oithona nana* (Atienza *et al.* 2006). According to Mauchline (1998), seasonal variation of clutch size of copepods may be linked to seasonal change in the body sizes of adult females of many species. This seasonal change in body sizes of adult females of some copepods species. According the same author, copepods body length variation may be closed to several factors as food quality and quantity, population density and salinity.

The present study show that *Oithona brevicornis*'s clutch size varied from 10 to 20 eggs, with a mean of 14.57 eggs/ovigerous females. It is in the same size order that the clutch size of the congeneric species *O. rigida* (11.6 ± 1.24 to 21.0 ± 1.63 eggs) (Santhanam and Perumal, 2012) and *O. attenuate* (Mean clutch sizes ranged between 14 and 15 eggs/female) (Zamora-Terol *et al.*, 2014a). However, this clutch size is relatively higher than the one of *O. brevicornis* reported in Grand-Lahou lagoon by Etilé *et al.* (2012) (10 to 16 eggs/ovigerous females, with a mean of 13.41 eggs, and in Ebrié lagoon by Pagano and Saint-Jean (1994) (1-10 eggs/female). However, *O. brevicornis*'s clutch size obtained in the present study is weaker comparatively with the one of the congeneric species *O. similis* obtained by Dvoretzky and Dvoretzky (2009a) (20 to 26 eggs). Variability of clutch size may be linked to body size of these different species cited especially as according to Mauchline (1998), the number of eggs in a brood or egg mass and in a clutch increase with increasing prosome length or weight of females.

The present study, focus on *O. brevicornis* population dynamic and reproductive parameters variability in Fresco lagoon, show that in adult population females (F) were more numerous than males (M), with a mean sex ratio (F/M) of 25:1. On average, females represent 91% of total adult population versus < 10% for males. This sex ratio in

Oithona brevicornis population in favour of females is in agreement with those of sex ratio reported in Grand-Lahou (Etilé *et al.*, 2012). Adult females abundance outnumbered males abundance in other copepods populations is also reported by scientific literature: *Oithona davisae* (Uye and Sano, 1995), *Acartia tonsa* (Burris and Dam, 2015), *Pseudodiaptomus hessei* (Etilé *et al.*, 2015), *Acartia clausi* (Etilé *et al.*, 2017). These results contrast, on the other hand, with those reported by Devreker *et al.* (2008 and 2010) concerning *Eurytemora affinis*, and by Ara (2002) concerning *Temora turbinata*, with the sex ratio in favour of males. Skewed sex ratios in copepods populations can be the result of various factors. According to Irigoien *et al.* (2000), food concentration and quality had an effect on the sex ratio of adult *Calanus* spp., with higher percentages of males obtained with increased food concentration. For Kiorboe (2006) and Hirst *et al.* (2010), sex-ratios towards dominance of females in copepods adult population are mainly due to differential mortality due to predation between females and males in adult stage, with higher predation on males. According to Hirts and Ward (2008), this highest predation on males comparatively to females is due to the active mate finding behavior of the males, compared to the passive behavior of the females, which may increase encounter rates with predators and these make males more visible and hydromechanically detectable for predators. For Mauchline (1998), shorter life span of males is least partly responsible for the bias in sex ratios in favour of females. This thesis contrasts with the one of Hirts and Ward (2008) which concludes that physiological longevity is not the primary cause of the strong sex ration skew in adult *Oithona* but predation.

Another reason of female dominance in copepods species population is due the fact that female have comparatively higher feeding efficiency and are reported to be voracious feeders than their male, so they might have utilized the food-rich environment more efficiently than the males (Vineetha *et al.*, 2015), what can help them to be dominant in their common environment. Additionally, factors such as water temperature (Devreker *et al.*, 2010), presence of contaminants in an environment polluted (Forget-Leray *et al.*, 2005) are reported to have an influence on copepod species population (*Eurytemora affini*) sex ratios.

Conclusion

This study provides for the first time information on *Oithona brevicornis* population dynamic in Fresco lagoon. In addition, it provides information on the spatial and seasonal variation of its population reproductive parameters in relation with environmental factors. *O. brevicornis* population

abundance, biomass and its reproduction parameters spatio-temporal variation are mainly linked to salinity, water transparency and turbidity variation. Favorable conditions for its reproduction, development and proliferation are found during the dry season with salinity fluctuating between 5.8 and 27.5 (mean: 16.58) associate with low turbulence conditions and high transparency.

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