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Spatio-temporal Variability of *Acartia clausi* (Copepoda, Calanoida) Population Structure, Abundance, Body Length, and Biomass in a Tropical Coastal Lagoon (Grand-Lahou, Côte d'Ivoire)

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ABSTRACT: The spatial and seasonal variations of *Acartia clausi* population structure, abundance, biomass and body length variation in relationship to environmental variables were investigated in the Grand-Lahou lagoon at 21 stations from January to December 2004. *A. clausi* abundance, biomass and body (prosome) length showed considerable seasonal and spatial variation. On average, total population abundance and biomass obtained during the dry season (Mean: 7.11 ind/l and 9.08 µgC/l respectively) were higher than that those which have gotten during the wet season (Mean: 2.98 ind/l and 2.76 µgC/l respectively). The same tendency was registered for prosome length of all development stages, with 275-1000 µm during the dry season versus 225-975 µm during the wet season. *A. clausi* population (without the nauplii) was dominated by copepodids stages in all seasons. During the dry season, on average, copepodids stages constituted 76.65% of total density and 52.98% of total biomass. During the wet season, copepodids stages represented 92.23% of total density and 72.42% of total biomass. In the adults stages, on average females (F) were more numerous than males (M), with a sex ratio (M/F) of 0.75. However, males were slightly more abundant than females during the dry season (February to April and September) with sex ratio (M/F) range from 1.10 to 1.46. Correlation on data of this study analyses showed that spatio-seasonal variations of *A. clausi* abundance, Biomass and Body length were mainly linked to water salinity, pH, transparency and dissolved oxygen, phosphates and nitrates concentrations.

Keywords: *Acartia clausi*, Population Structure, Abundance and Biomass, Body Length, Tropical Lagoon

Introduction

Zooplankton plays a major role in the functioning and the productivity of aquatic ecosystems through its impact on the nutrient dynamics and its key position in the food webs. Besides most zooplanktonic organisms can have herbivorous detritivorous diet and exert a strong grazing impact on the phytoplanktonic (Atienza et al., 2016) and protoplankton (Londsale et al., 2000) biomass. They also constitute a food source for organisms of the upper trophic levels such as planktivorous fish larvae and carnivorous invertebrates as chaetognaths (Reiss et al., 2005).

Among zooplankton organisms, copepods are probably the most numerous multicellular on the earth (Mauchline, 1998). They are distributed throughout the ocean and their margins extend into freshwaters. Because of their dominance, copepods influence the functioning of ecosystem aquatics. Some species within certain genera of copepods are key species in the ecosystems in which they are abundant. In coastal ecosystems, Acartiidae and other families are known to have key species (Mauchline, 1998). According to Boyer (2012) who makes a literature review on the Acartiidaes, it represents a family very extensively widespread being part of the 10 families of copepods the most observed on the

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planet. Acartiidaes family is composed of 5 genuses (*Acartilla, Paracartia, Paralabidocera, Pteriacartia* and *Acartia*) and 83 species of which *Acartia clausi*. Copepods from the genus *Acartia* play an important role in the food webs of estuaries in both tropical and sub-tropical areas (Mauchline, 1998) and generally, show highest biomass values in most shallow enclosed bays and estuaries (Leandro et al., 2007).

In Côte d'Ivoire, *A. clausi* is presented in all lagoon systems, with however highest density and biomass in Ebrié (Pagano & Saint-Jean, 1994) and Grand-Lahou lagoons (Etilé et al., 2009). Because of their numeric dominance and their possible influence on Ebrié lagoon functioning, several studies were focused on *A. clausi*, mainly on its biology and ecology: eggs production rhythm (Saint-Jean and Pagano, 1983), vertical migrations and feeding rhythms (Kouassi et al., 2001), spawning rate diel variation and effects of environmental factors (Pagano et al., 2004). All these studies have mainly been performed in the Ebrie´ Lagoon. In the other lagoons of Côte d'Ivoire, surveys on the biology and ecology of *A. clausi* are inexistent. In Grand-Lahou lagoon, studies on copepods biology and ecology have been focused on *Oithona brevicornis* (Etilé et al., 2012) and *Pseudodiaptomus hessei* (Etilé et al., 2015).
The aim of investigation is to study the spatio-temporal variations of abundance and biomass of *A. clausi* population in the Grand-Lahou lagoon, in relation to environmental factors to assess their contribution to production and energy flow in this aquatic ecosystem.

Materials and methods

Study area

Grand-Lahou lagoon (Figure 1) is a brackish lagoon located in the south of Côte d'Ivoire, between 5°07' and 5°14' N, and between 5° and 5°25' W (Durand and Skubich, 1979) with a main basin in an orientation East-west (parallel to the Atlantic coast) on 50 km (Lae, 1982). This lagoon is situated in a region under the influence of the subequatorial climate characterized by two wet (rainy) seasons (May to July and October to November) and two dry seasons (December to April and August to September). The Grand-Lahou lagoon is a shallow basin (mean depth of 3 m) with a total area of about 190 km^2 (Lae, 1982) and subdivided into four geographical zones: Tagba lagoon (57 km^2), Makey lagoon (28 km^2), Tadio lagoon (90 km^2) and Niouzoumou lagoon (15 km^2). Tagba lagoon has a permanent communication with the Atlantic Ocean through the Grand-Lahou channel and is mainly under oceanic influence during the dry season. It receives freshwater inputs of three main rivers (Boubo, Go, Bandama) during the rainy season (May to July and October to November). Makey lagoon is mainly under the influence of Boubo and Go River during the months of May to July and October to November (wet season). Oceanic influence on this zone is moderate during the dry season. Tadio lagoon receives mainly water inputs of Boubo River when there are floods in May to July and October to November. Niouzoumou lagoon is a site safe from freshwater inputs, with the exception of diffuse dripping waters, under relative oceanic influence during the dry season and representative of the enclosed sector of the Grand-Lahou lagoon.

However, previously studies on Grand-Lahou lagoon focused on hydroclimat (Durand and Skubich, 1979; Etilé, 2004) subdivided it into two main zones: an estuarine zone located on the east side including Tagba and Mackey lagoons and a western zone, composed of Tadio and Niouzoumou lagoons. During this study 21 sampling stations were sampled monthly from January to December 2004 at 21 stations, with 7, 5, 4 and 5 sampling sites respectively in Tagba (stations 1-4 and 19-21), Makey (5-9), Tadio (10-13) and Niouzoumou (11-18) lagoons (**Figure 1**).

Sampling and data analysis

Zooplankton (*Acartia clausi*) and environmental factors were sampled monthly from January to December 2004. Zooplankton was collected using a zooplankton net, with 64-µm mesh openings. All sampling was performed during the daytime (07:00-17:00) by vertical hauls from the bottom to the surface.

Samples were immediately preserved in a mixture of lagoon water and borax-neutralized formalin at a final concentration of 5%. *A. clausi* was identified using Rose (1933), Tregouboff and Rose (1957), and Wiafe and Frid (2001). During this study, only copepodids and adults stages were identified and counted under a stereoscopic microscope.

The physical and chemical parameters (temperature, salinity, dissolved oxygen (DO), conductivity, turbidity, and pH) were measured at the surface and near the bottom, with a portable multi-parameter profiler, TURO T-611 (Turo Technology PTY LTD, Australia). The transparency was measured with a Secchi disk. Water samples were collected with a Niskin bottle and preserved at 4°C for subsequent analyses of nutrients (phosphate, nitrite, and nitrate) with a Technicon sensor III auto-analyzer (model AA3; Technicon Instrument Corporation, USA), according to protocols described by Strickland and Parsons (1972).

Individual weights (dry weight, DW) were estimated from their prosome body size using the length (Lc, mm)-weight (DW, µg) relationship proposed by Saint-Jean and Pagano (1987) with $DW = 4.33\ Lc^{1.97}$ for copepodids stages C1-C2 and $DW = 11.67\ Lc^{3.205}$ for copepodids C3-C5 and adults stages (males and females). The prosome body length was measured under a dissecting microscope (at a magnification of 400x) using an ocular micrometer (with a precision of ± 10 µm). Specimens of a mixed set of at least 30 individuals from all 21 stations were measured. Individual DWs were converted into carbon (C) using a C/DW ratio of 0.045 (Pagano and Saint-Jean, 1993).

Simple Pearson's correlation coefficients were used to test the effects of environmental parameters on *Acartia clausi* abundance, biomass, prosome lengths and sex ratio. Besides, one-way analyses of variance (ANOVA) were performed to test the effects of seasons and stations distribution on environmental variable studied and on *A. clausi* density, biomass and prosome lengths. All calculations were performed after logarithmic transformation of the data in order to tend towards normal distributions. All steps of this method were computed using Statistica 7.1 software.

Results

Environmental variables spatio-temporal variations

In this study, environmental variables showed no significant difference ($p > 0.05$) between the surface and bottom. Surface-bottom differences occurred only occasionally in the rainy season, at stations near the Grand-Lahou Channel (mainly at stations 1, and 19-21), with slightly higher salinities and lower temperatures in the bottom layer than at the surface.

In this fact, we only considered the mean surface-bottom values for the following description of variations in environmental variables. Significant differences between dry and wet seasons were found for different parameters studied (ANOVA, $p < 0.05$), excepted for dissolved oxygen (ANOVA, $p > 0.05$).

Grand-Lahou water salinity varied between 0 and 31 according to the stations and the seasons, with an annual mean of 10.16. On average, water salinity showed highest values during the dry season in all stations excepted in stations 11-14 (**Figure 2A**). During the dry season salinity shows spatial variation marked by highest values (15 to 22) observed near of the Grad-Lahou channel (stations 1-2 and 19-20) with a progressive reduction of salinity far from the channel. During the wet season, lowest values (2.94 to 6.55) were obtained in stations 1 to 10 and 21 versus highest ones in stations 11 to 20 (6.65-14.02). Conductivity showed the same spatial and seasonal variation pattern as salinity (**Figure 2B**). Temperature and pH also showed the same seasonal variations as salinity and conductivity, with in general, highest values during the dry season (**Figures 2C and D**). Dissolved oxygen concentration is relatively low (0-14 mg/l, mean: 3.13 mg/l), with highest values observed during the wet season in the majority of the stations (1.56-4.90 mg/l, mean: 3.54 mg/l) versus lowest values during the dry season (1.41-3.81 mg/l, mean: 2.75 mg/l) (**Figure 2F**).

Turbidity, nitrate and nitrite presented the same seasonal variations with highest values during the dry season (figures 2G, I and J, respectively). The spatio-temporal variation of phosphates was marked generally by the highest values (0.55 to 1.47 µmol/l) in dry season and the lowest ones (0.33 to 1.40 µmol/l) in rainy season in stations far from the Grand-Lahou channel (4 to 19). On the other hand, in stations near the channel (stations 1-3, and 20-21) dry season values of phosphates is lowest (0.36 to 1.56 µmol/l) than during the wet season (0.62 to 1.72 µmol/l) (**Figure 2H**).

Acartia clausi stages composition, abundance and biomass spatio-temporal variation

Acartia clausi was a perennial species in the Grand-Lahou lagoon, with spatio-temporal abundance and biomass variation (**Figure 3**). Total population abundance and biomass variations (Figure 3A, B) were marked by dry season values (3.05 to 15.43 ind/l and 2 to 20.12 µgC/l, respectively) highest than that those of the wet season (0.28 to 4.95 ind/l and 0.28 to 7.09 µgC/l, respectively) in stations 1 to 15. In the other stations (16-21) no seasonal abundance and biomass variations were recorded, with respectively 0.42 to 5.49 ind/l and 0.49 to 7.17 µgC/l during the dry season versus respectively 0.16 to 6.15 ind/l and 0.20 to 7.52 µgC/l.

The same seasonal tendency was observed at all stages of *A. clausi* population (Figure 3C-J). On average, *A. clausi* total population abundance and biomass obtained during the dry season (respectively 7.11 ind/l and 9.08 µgC/l) were statistically higher than that those gotten during the wet season (respectively 2.98 ind/l and 2.76 µgC/l) (ANOVA, $p < 0.05$).

A. clausi population (without the nauplii) was dominated by copepodids stages in all seasons

(**Figure 4**). During the dry season, on average, copepodids stages constituted 76.65% of *A. clausi* total density and 52.98% of total biomass. During the wet season, copepodids stages represented 92.23% of total density and 72.42% of total biomass. In the adults stages (7-23% of total density and 28-47% of total population biomass according the season), on average females (F) were more numerous than males (M), with a sex ratio (M/F) of 0.75. However, males were slightly more abundant than females during the dry season (February to April and September) with sex ratio (M/F) ranged from 1.10 to 1.46. During the dry season, ratio sex spatial variation is marked by males dominance in adult population in the sampling sites 2 to 8 and 16 (55 to 75% of adult abundance, with a ratio sex (M/F) varying from 1.12 to 3.22)). During the wet season, adults males were absent of the stations 18 and 19. Beside, excepted at stations 3, 20 and 21, males abundance in adults stages was lower than those of females (15 to 43% of adult abundance, with a ratio sex (M/F) varying from 0.17 to 0.76). So, adult females abundance outnumbered males abundance during the wet season where *A. clausi* total abundance was relatively low.

Relationships between *Acartia clausi* abundance and biomass and environmental parameters

The relationship between *Acartia clausi* and environmental parameters was analyzed in this study by using the Spearman correlation coefficients. Results are shown in the Tables I.

During the dry season, total population abundance and biomass of *A. clausi* were positively and significantly correlated with dissolved oxygen and phosphate concentrations. In addition, females and males adults' abundance and biomass were also positively and significantly correlated with dissolved oxygen and phosphates concentrations.

On the other hand total population abundance and biomass of *A. clausi* were negatively and significantly correlated with nitrates. Besides, all development stages of this species (copepodids, females and males adults) were negatively and significantly correlated with nitrates.

During the wet season, all *A. clausi* stages (excepted males adults) and total population abundance and biomass were negatively and positively correlated with nitrates concentrations in Grand-Lahou lagoon. Copepodids stages C4-5 and females adults abundance and biomass were also negatively and positively correlated with nitrates concentration. During this season, females adults abundance were positively and significantly correlated with water salinity in Grand-Lahou lagoon.

***Acartia clausi* Body length spatio-temporal variability and relationships to environmental parameters**

Acartia clausi population size (prosome lengths) varied according season and lagoon geographical zones (**Table II**). During the dry season, prosome lengths of all stages were higher than those of the wet season. During the dry and the wet seasons, the prosome lengths of copepodids (C1-3 and C4-5), females and males adults showed a spatial variation marked by values in East zone (Makey and Tagba lagoons) higher than west zone (Tadio and Niouzoumou lagoons). Beside, in adult population, there is a sexual dimorphism with females lengths (675-1000 µm) higher than those of males (650-875 µm) during the dry and the wet season.

During the dry season, prosome lengths of all *A. clausi* stages were positively and significantly correlated with water salinity, conductivity and transparency (**Table III**). Significant and positive correlations were also found for pH and copepodids stages C1-3 and C4-5 and males adults lengths. In addition, significant and positive correlations were obtained between nitrates concentration and *A. clausi* population length excepted for copepodids stages C1-3. In contrast, *A. clausi* population lengths were significantly and negatively correlated with water temperature and phosphates concentrations. Besides, negative correlation was also found between all stages lengths of *A. clausi* and dissolved oxygen concentration and turbidity. But this correlation was significant only between dissolved oxygen and males adults length. During the wet season, prosome lengths of all *A. clausi* stages were also positively and significantly correlated with water salinity, conductivity, pH and transparency (**Table III**). In opposition, *A. clausi* population prosome lengths were significantly and negatively correlated with water turbidity, and phosphates and nitrates concentrations.

Discussion

Data from the present study shows that *Acartia clausi* is constantly present in Grand-Lahou lagoon with maximal density and biomass during the dry season and in Tadio and Niouzoumou lagoon during the wet season. Seasonal variations of *A. clausi* abundance and biomass in this study is similar to the one of the total zooplankton abundance and biomass in Grand-Lahou lagoon (Etilé et al., 2009), of *Oithona brevicornis* (Etilé et al., 2012) and of *Pseudodiaptomus hessei* (Etilé et al., 2015) in this coastal ecosystem. Similar seasonal pattern in *A. clausi* abundance and biomass was also observed in Ebrié lagoon (Pagano and Saint-Jean, 1989 and

1994), and of other congeneric and copepods species in tropical region, e.g., *A. tonsa* and *A. lilljeborgii* in the Curuçá Estuary (Brazil) (respectively Magalhães et al., 2009 and Costa et al., 2009). On the other hand, this seasonal variation of *A. clausi* abundance and biomass in Grand-Lahou lagoon contrast with the tendency observed in other tropical regions for congeneric species and other copepods species: e.g. *A. tonsa* in Curuçá Estuary (Amazon coast, Brazil) (Costa et al., 2009), *A. lilljeborgii*, *A. tonsa*, *Pseudodiaptomus marshi* and *Subeucalanus pileatus* in Amazon estuary (Taperaçu, Northern Brazil) (Magalhães et al., 2011) and *P. marshi* in Taperaçu Estuary (Amazone Coast, Brazil) (Magalhães *et al*., 2011).

Highest abundance and biomass of copepods during the dry and warm season may be explained mainly by temperature and food (quantity and quality) influence. Beside, higher temperature enhances zooplankton growth, sexual maturation, and reproduction (De Azevedo and Bonecker, 2003). Temperature is also mentioned as an environmental factor to which seasonal drive seasonal variations in zooplankton metabolism, ingestion, development and reproductive rate (Amblard and Pinel-Alloul, 1995). According to Üstün and Bat (2014), in Sinop Inner Harbor (southern Black Sea), temperature and chlorophylle-a concentration affect the egg production rate (EPR) of *Acartia (Acartiura) clausi*, with on the one hand, a negative correlation (r: -0.375, p: 0.035, P < 0.05) between EPR and water temperature and on the other hand a positive and statistically meaningful correlation was found between chlorophyll-a concentration and the EPR (r: 0.498, p: 0.007, P<0.01).

According to Marques et al. (2007) and Leite et al. (2009) reported by Magalhães et al. (2011), variability in abundance, biomass and productivity of copepods in estuaries and lagoon has been associated with the combined effects of regional climatology and local hydrological factors, in addition to other multifactorial patterns involving both biotic and abiotic parameters.

In the present study, if maximum abundance and biomass of *Acartia clausi* were obtained during the dry and warm season which corresponds to high oceanic influence in Grand-Lahou lagoon, negative correlations were noted between its abundance and biomass and the parameters as salinity, conductivity, pH and transparence during this period. In contrary, these parameters were positively correlated to *A. clausi* abundance and biomass during the wet season. It suggests that *A. clausi* are a range of preferred salinity and other conditions. Its expansion is then maximal when the salinity optimum is approached, but weak or hopeless when the salinity approaches or passes its tolerance limits. In Grand-Lahou lagoon, during the dry season, *A. clausi* salinity tolerance limit approaches near the Grand-Lahou channel (stations 1-2 and 20-21) where salinity range of 22 to 30 was measured and presents weakest densities (< 4 ind/L) and biomass (< 3 µgC/L).

In contrary to this situation, in the zones far from the channel with minimum oceanic influence (optimum conditions), *A. clausi* presents highest densities (3 to 15 ind/L) and biomass (7 to 20 µgC/L) during the dry season. During the wet season, *A. clausi* development optimum conditions were gotten in stations 11 to 19 (Tadio and Niouzoumou lagoons) which are less influenced by flood water of Boubo River from May to July and by those of Boubo, Go and Bandama Rivers on October-November. During this wet season, collapse of *A. clausi* densities (< 2 ind/L) and biomass (< 3 µgC/L) in stations 1 to 10 and 20-21 (Tagba and Makey lagoons) could be linked to high influenced of flood water of Boubo, Go and Bandama Rivers during this period, with their dilution effect which create tolerance limit conditions for *A. clausi* in this zone.

These spatio-temporal variations of *A. clausi* abundance and biomass may also link to food availability and quality. Indeed, *A. clausi* is known to feed mainly on particles (seston) of sizes varying between 6 and 21 µm (Kouassi et al., 2001). Thus, if the environmental conditions that favour the development of these particles are not united to one moment and/or in a zone of the lagoon, it could explain these observed spatio-temporal variations.

These tolerance limit and optimum conditions could explain spatio-temporal difference of *A. clausi* prosome lengths in Grand-Lahou lagoon. Indeed prosome length of this specie was characterized on the one hand by Prosome lengths of all development stages in during the dry season (275-1000 µm) higher than those of the wet season (225-975 µm), and on the other hand by copepodids (C1-3 and C4-5), females and males adults prosome lengths in East zone (Makey and Tagba lagoons) (225-925 µm) lower than West zone (Tadio and Niouzoumou lagoons) (300-975 µm) during the wet seasons.

Seasonal and spatial variations of body length of copepods were mentioned in several studies (Riccardi and Mariotto, 2000; Ara, 2001 & 2002; Gaudy and Verriopoulos, 2004; Bozskurt and Can, 2014). Seasonal variation of prosome length of *A. clausi* in this study was opposed to those the copepods *A. lilljeborgi* (Ara, 2001), *Temora turbinata* (Ara, 2002), *A. tonsa* (Gaudy and Verriopoulos, 2004), *Thermocyclops crassus* and *Eudiaptomus drieschi* (Buzkurt and can, 2014). Greatest lengths of these copepods species were observed at colder temperatures during colder months (winter), and the lowest lengths were observed at warmer temperatures (summer). For these authors, copepod body length is inversely related to temperature which is the main environment factor to explain these copepods body length variation. Body size variation of copepods was also linked to food by these authors. According to Mauchline (1998) food quality and quantity, population density and salinity were mentioned as other factors influencing copepods body length. In our study, *A. clausi* prosome length was positively and significantly correlated to conductivity, salinity, pH and transparency, and inversely correlated to phosphate and nitrate. However, salinity can be considered as the main factor influencing the prosome length variation in Grand-Lahou lagoon.

A. clausi population structure was characterized by copepodids numerical dominance (mean: 76.65 to 92.23% of population abundance according seasons). Besides, in adult population, on average females (F) were more numerous than males (M), with a sex ratio (M/F) of 0.75. However, males were slightly more abundant than females during the dry season (February to April and September) with sex ratio (M/F) range from 1.10 to 1.46. Younger (copepodids) stages dominance in copepods population structure was also mentioned in previously studies, e.g. Ara (2001) (*A. lilljeborgi*), Ara (2002) (*Temora turbinata*) and Etilé *et al.* (2015) (*Pseudodiaptomus hessei*).

Adult female's abundance numerical dominance on males is mentioned by Zallaba and Gaudy (1996) on *A. tonsa* population and by Ara (2001) on *A. lilljeborgi* population. This result contrasts with the one of Hirst et al. (2010) in *A. omeri* where sex ratios in adults are significantly biased toward females. Acording to Ara (2001), numerical dominance of adult females could result from the greater sensitivity of males to hydrographic instability (i.e. low salinity). For Hirst et al. (2010), females dominance in adult population may be linked to adult males greatest mortality rates (from physiological limits on age or predation). According to Mauchline (1998), this may also due to by the fact that copepods males population longevity is shorter than that of the females.

Several other factors are signaled by Mauchlime (1998) as factors influencing the sex ratio in copepods population, i.e. the food regime, temperature variation, copepod population density, predation rate. In this study, sex ratio (M/F) of adult population of *A. clausi* vary seasonally, with values during the dry season highest that those of the wet season. Besides, sex ratio of adult population was positively correlated with total density of the *A. clausi* population and when the total population abundance decreases, males diminish and females abundance outnumbered the one of the males. Similar observation was also made by Zallaba and Gaudy (1996) on *A. tonsa* population in La Habana Bay (Cuba). These authors interpret this result as a homeostatic mechanism for the regulation of the population. During wet season, periods of low abundance of *Acartia* species, a higher proportion of females are available for egg production, thus favouring a rapid recovery of the population level.

Conclusion

This was the 1st study to examine *Acartia clausi* population structure and abundance, biomass and body length variation in Grand-Lahou Lagoon in relationship to environmental variables. Results show important spatial and seasonal variation of *A. clausi* abundance, biomass and body length, with highest values in the dry season and in the lagoon west region (Tadio Niouzoumou) during the wet season. Total population abundance and biomass of *A. clausi* in Grand-Lahou lagoon were correlated positively and significantly to dissolved oxygen and phosphates concentrations and negatively and significantly to nitrates concentrations during the dry season. In the wet season, *A. clausi* total abundance and biomass were negatively and significantly correlated to nitrates. All stages of *A. clausi* showed body length positively and significantly correlated to water salinity, conductivity, pH, transparency and negatively and significantly correlated to phosphates.

Conflicts of interests: Authors should declare that they have no competing interests.

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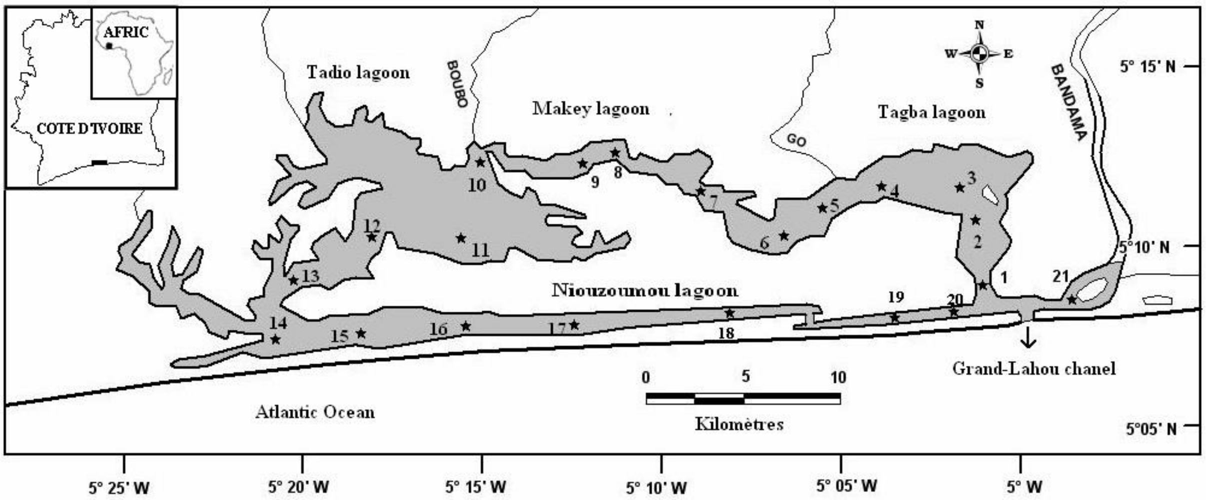
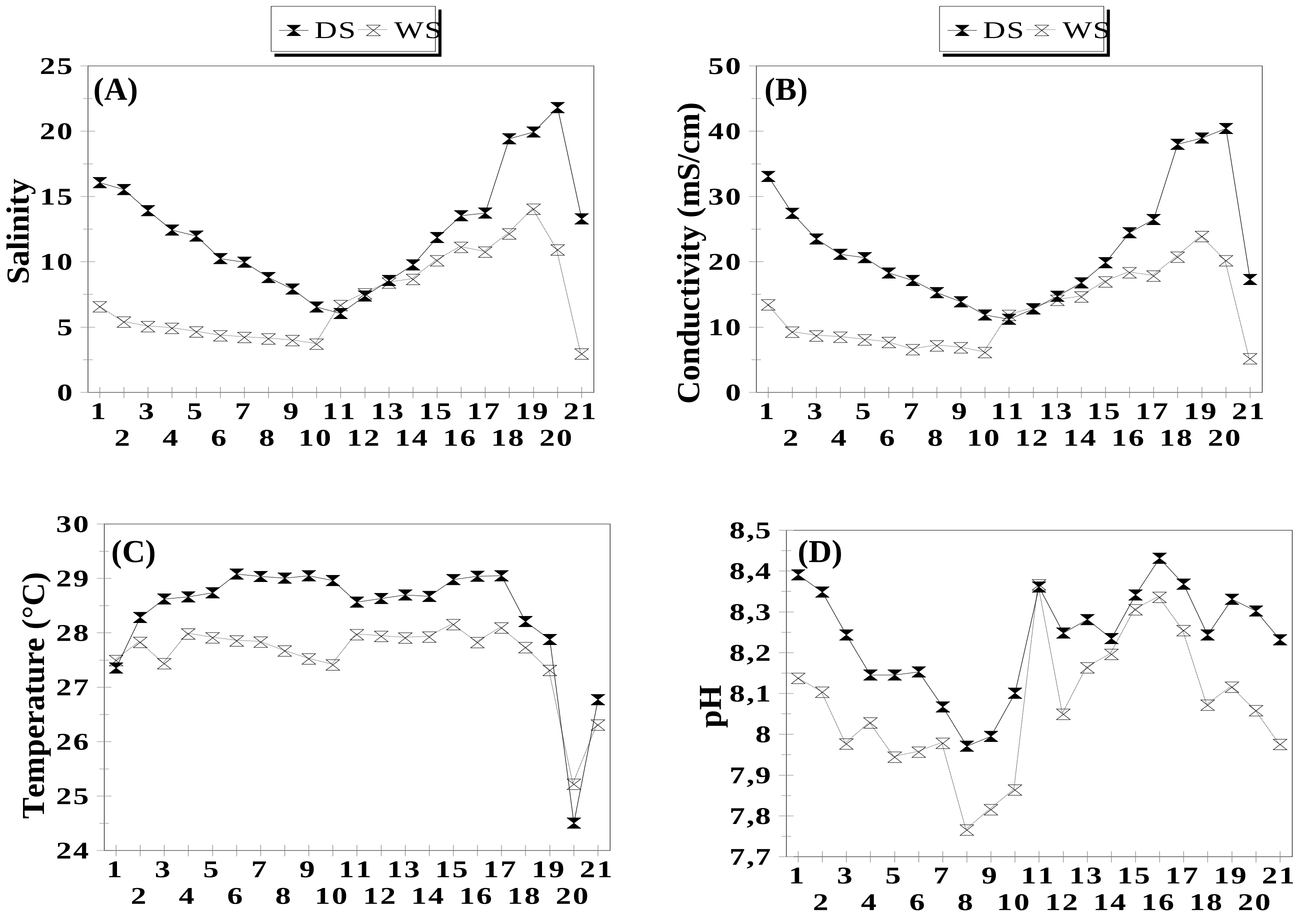


Figure 1. Location of sampling stations in Grand-Lahou Lagoon, Côte d'Ivoire.

Figure 2. Spatial variations in environmental variables during the 2 seasons (Dry Season (DS), Wet Season (WS) in Grand-Lahou Lagoon, (A)-Salinity, (B)-Conductivity, (C)-Temperature, (D)-pH



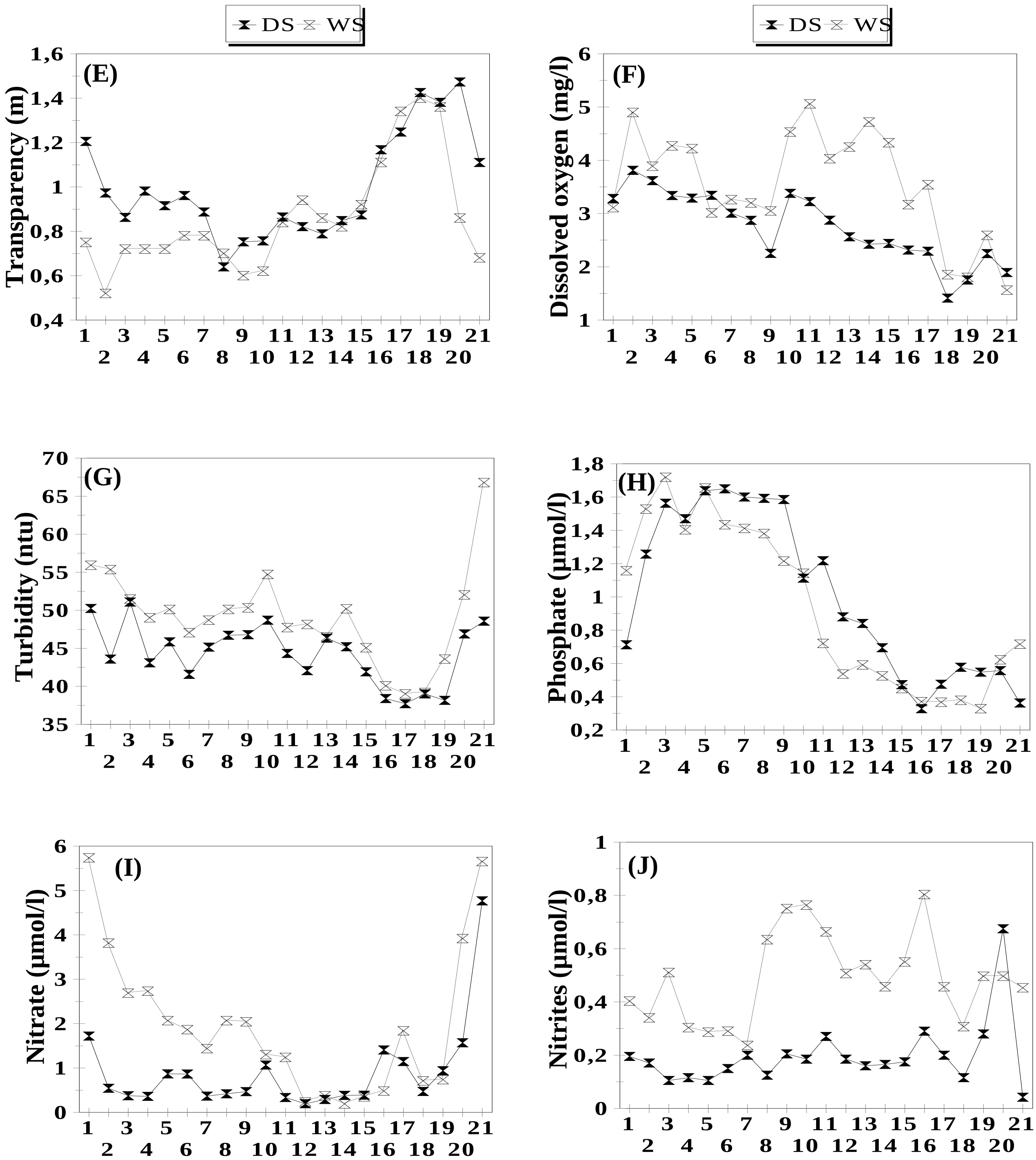
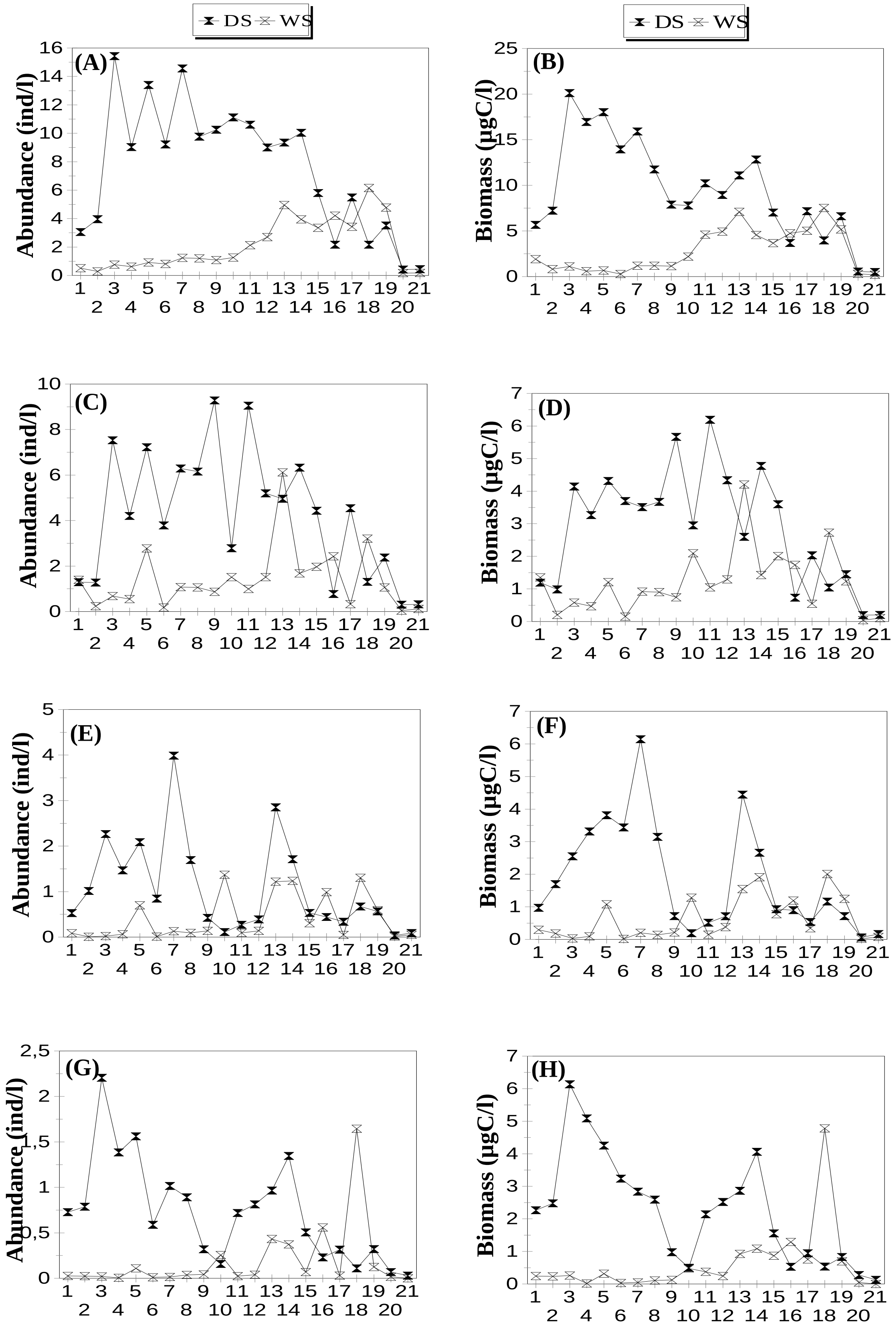


Figure 2. (Continued), (E)-Dissolved oxygen, (F)-Phosphate, (G)-Transparency, (H)-Nitrate, (I)-Turbidity and (J)-Nitrite


DS WS
(A)
Abundance (ind/l)
(B)
Biomass (µgC/l)
(C)
Abundance (ind/l)
(D)
Biomass (µgC/l)
(E)
Abundance (ind/l)
(F)
Biomass (µgC/l)
(G)
Abundance (ind/l)
(H)
Biomass (µgC/l)

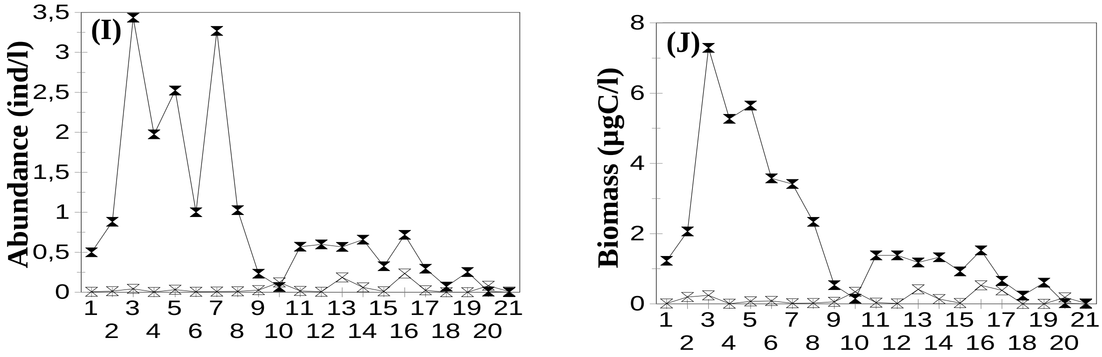


Figure 3. Spatial variations in the absolute densities and biomass of the different developmental stages of *Acartia clausi* in Grand-Lahou Lagoon during the two seasons (Dry Season: C and D and Wet Season: E and F), (A and B: Total population, C and D: Copepodids stages C1-3, E and F: Copepodids stages C4-5, G and H: adults females, I and J: adults males).

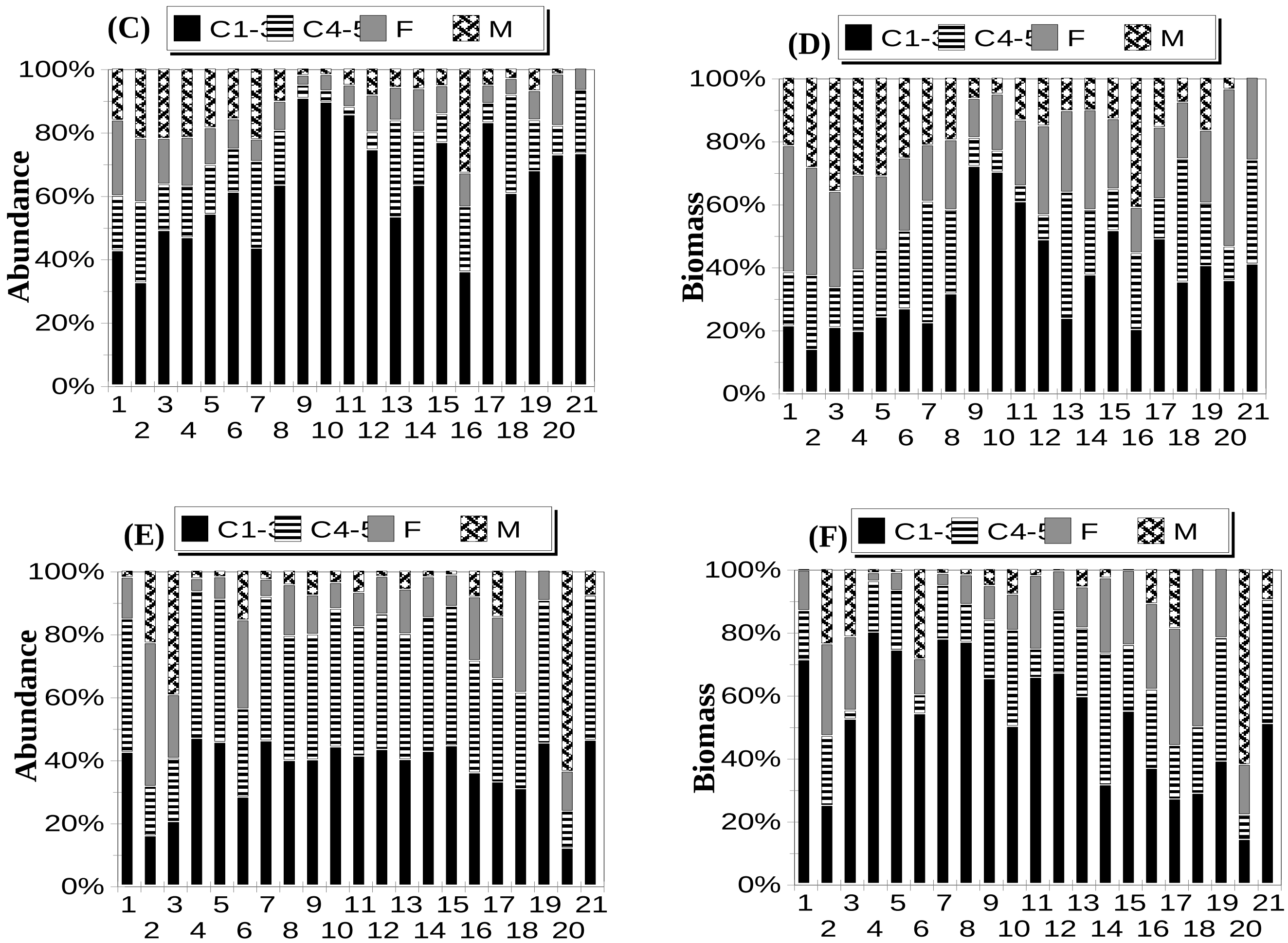


Figure 3. Spatial variations in the absolute (A and B) and relative (C to F) densities and biomass of the different developmental stages of *Acartia clausi* in Grand-Lahou Lagoon during the two seasons (Dry Season: C and D and Wet Season: E and F), (C1-5: copepodids stages, M: males, F: female.

Table I. Simple Pearson correlation coefficients (Rs) relating physical and chemical parameters to *Acartia clausi* stages development and total abundance and biomass in Grand-Lahou lagoon during the dry and the wet seasons.

		Abundance					Biomass				
Seasons	**Parameters**	**C1-3**	**C4-5**	**F**	**M**	**Total**	**C1-3**	**C4-5**	**F**	**M**	**Total**
Dry	Conductivity	- 0,605**	0,003	- 0,213	- 0,097	-0,187	- 0,655***	- 0,047	-0,199	- 0,077	-0,173
	Salinity	- 0,627*	- 0,027	- 0,243	- 0,144	-0,218	- 0,691	- 0,101	-0,238	- 0,129	-0,214
	pH	- 0,396	- 0,318	- 0,250	- 0,207	-0,258	- 0,363	- 0,361	-0,300	- 0,155	-0,283
	Dissolved Oxygen	0,239	0,351	0,597**	0,645**	0,600**	0,295	0,399	0,612**	0,692**	0,658**
	Turbidity	0,135	0,001	0,158	- 0,045	0,087	0,047	- 0,042	0,088	- 0,065	0,084
	Transparency	- 0,692***	- 0,270	- 0,436*	- 0,283	-0,383	- 0,692***	- 0,251	-0,403	- 0,238	-0,379
	Temperature	0,425	0,232	0,140	0,343	0,236	0,416	0,358	0,242	0,318	0,282
	Phosphates	0,573**	0,521*	0,613**	0,644**	0,636**	0,574**	0,600**	0,679***	0,658**	0,709***
	Nitrates	- 0,675**	- 0,503*	- 0,647**	- 0,486*	-0,609**	- 0,675***	- 0,452*	-0,632**	- 0,447*	-0,588***
	Nitrites	- 0,122	- 0,458*	- 0,389	- 0,313	-0,381	- 0,124	- 0,465*	-0,479	- 0,323	-0,428
Wet	Conductivity	0,134	0,199	0,475*	- 0,023	0,199	0,245	0,425*	0,657	- 0,006	0,462
	Salinity	0,157	0,227	0,477*	- 0,019	0,222	0,264	0,443*	0,677***	0,001	0,486*
	pH	0,119	0,139	0,287	0,088	0,145	0,232	0,351	0,608**	0,126	0,390
	Dissolved oxygen	0,299	0,152	0,116	0,354	0,261	0,283	0,186	0,247	0,327	0,227
	Turbidity	- 0,270	- 0,323	- 0,430	0,157	-0,304	- 0,329	- 0,394	-0,556**	0,034	-0,504*
	Transparency	0,227	0,315	0,422	- 0,156	0,272	0,314	0,429	0,604**	- 0,127	0,509*
	Temperature	0,209	0,091	0,074	- 0,065	0,162	0,232	0,177	0,249	0,022	0,271
	Phosphates	- 0,217	- 0,457*	- 0,549*	0,008	-0,278	- 0,292	- 0,578**	-0,635**	0,057	-0,504*
	Nitrates	- 0,606**	- 0,718***	- 0,696**	- 0,140	-0,635**	- 0,629**	- 0,706**	-0,726***	- 0,072	-0,703***
	Nitrites	0,211	0,309	0,419	0,542	0,213	0,208	0,181	0,371	0,396*	0,202

1-3, C4-5: Copepodids, M: Males adults, F: female adults, *p < 0.05; **p < 0.01; ***p < 0.001.

Table II: *Acartia clausi* population stages prosome lengths according to season and geographical zone in Grand-Lahou lagoon

	Prosome length range (µm) (mean)			
	Dry season		**Wet season**	
Developmental stages	**Tagba and Makey lagoons**	**Tadio and Niouzoumou lagoons**	**Tagba and Makey lagoons**	**Tadio and Niouzoumou lagoons**
C1-3 (µm)	275 - 650 (434)	275 - 800 (652)	225 - 550 (396)	300 - 700 (598)
C4-5 (µm)	650 - 825 (747)	650 - 825 (736)	550 - 675 (614)	550 - 825 (716)
Adult males (µm)	775 - 875 (808)	775 - 850 (818)	650 - 800 (712)	775 - 850 (814)
Adult females (µm)	800 - 975 (908)	850 - 1000 (937)	675 - 925 (782)	800 - 975 (913)

Table III. Simple Pearson correlation coefficients (Rs) relating physical and chemical parameters to *Acartia clausi* stages development lengths during the dry season.

Seasons	Variables	C1-3	C4-5	M	F
Dry	Conductivity	0.854***	0.844***	0.872***	0.913***
	Salinity	0.878***	0.858***	0.897***	0.946***
	pH	0.559***	0.647***	0.604***	0.365
	Dissolved oxygen	- 0.192	- 0.416	- 0.450*	- 0.279
	Turbidity	- 0.159	- 0.367	- 0.274	- 0.184
	Transparency	0.748***	0.838***	0.868***	0.837***
	Temperature	- 0.532*	- 0.492*	- 0.541*	- 0.599**
	Phosphates	- 0.534*	- 0.688***	- 0.653***	- 0.408
	Nitrates	0.410	0.450*	0.463*	0.489*
	Nitrites	0.003	0.137	0.162	- 0.109
Wet	Conductivity	0,784***	0,794***	0,792***	0,685***
	Salinity	0,782***	0,830***	0,786***	0,703***
	pH	0,574**	0,643**	0,541*	0,540*
	Dissolved oxygen	-0,226	-0,124	-0,209	-0,164
	Turbidity	-0,451*	-0,551**	-0,493*	-0,555***
	Transparency	0,747***	0,826***	0,778***	0,799***
	Temperature	-0,116	0,226	0,058	0,095
	Phosphates	-0,881***	-0,717***	-0,871***	-0,874***
	Nitrates	-0,469*	-0,460*	-0,509*	-0,574**
	Nitrites	0,390*	0,053	0,270	0,257

C1-3, C4-5: Copepodids, M: Males adults, F: female adults, *p < 0.05; **p < 0.01; ***p < 0.001