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# Importance of hydrological parameters in the distribution of planktonic eggs and larvae in an upwelling zone (Imessouane Bay, Moroccan Atlantic Coast)

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## ABSTRACT
The present study aimed to evaluate the spring biodiversity of planktonic eggs and larvae in Imessouane Bay and to assess their variability according to the hydrological parameters of the environment. Twenty seven biological and hydrological samples were taken at three stations during a three-month period (March, April and May 2018). The qualitative study revealed the presence of 26 taxa, divided into six major groups, of those the Arthropod larvae were the most dominant (43.16%). The maximum abundances of planktonic eggs and larvae were recorded during May, as the richest month in terms of diversity (25 taxa). The principal component analysis of the hydrological parameters made it possible to define a temporal organization dominated by 3 groups. The canonical correspondence analysis exhibited that certain environmental parameters are essential factors for the functioning and the spatiotemporal variability of the planktonic communities.

**Keywords:** Biodiversity; eggs and larvae planktonic; Imessouane Bay; Arthropod larvae; hydrological parameters.

## INTRODUCTION
The Atlantic coast of Morocco is one of the pelagic ecosystems where fish production is very important (Berraho 2007). This richness is related to the phenomenon of upwelling, which is the origin of a nutrient supply favouring the photosynthesis in the superficial waters and, consequently, the production of the whole food web (Makaoui *et al.* 2005). On the other hand, the marine resources are known by the great variability of their abundances on the spatio-temporal scale (Somoue *et al*. 2013), which constitutes an obstacle for the understanding of the functioning of the marine ecosystem. It is, therefore, necessary to consider the eggs and larvae to characterize the planktonic marine wildlife (Salehzadeh *et al.* 2019). This is valid not only for ecological studies but also for the purpose of more or less long-term predicting the possibilities and strategies of the marine fisheries of commercially valuable species. Indeed, the success or failure of the recruitment is largely conditioned by the planktonic phase (Berraho *et al.* 1996, Benchalel *et al.* 2018).
The present work aimed to evaluate the spring taxonomic composition of planktonic eggs and larvae at the Moroccan Atlantic coast, particularly Imessouane Bay (80 km north of Agadir), and to analyze the spatio-temporal variations of this plankton group according to the hydrological parameters.

## MATERIALS AND METHODS
### Sampling and analysis of samples
Three stations were sampled during spring 2018 whose coordinates are (Fig. 1):
Station 1: (30 ° 50'20"N, 9 ° 49'58"W).
Station 2: (30 ° 49'22"N, 9 ° 49'30"W).
Station 3: (30 ° 49'71"N, 9 ° 49'83"W).

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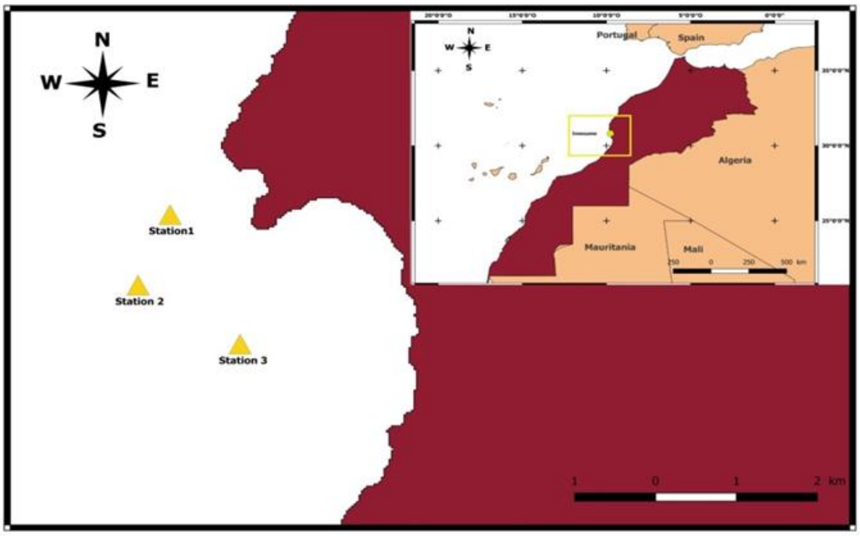


**Fig. 1**. Map of sampled stations.

At each station, two samples were taken:
1- Hydrological sample for the measurement of physico-chemical parameters: temperature, pH, conductivity, salinity, turbidity, dissolved oxygen, nitrites and orthophosphates.
2- Biological sample for the determination of planktonic species.

The planktonic samples were taken using two plankton nets, differentiated by the respective mesh spaces of 100 µm and 500 µm. For each station, vertical lines were conducted to a depth of 10 m and samples were kept in 5% formalin.
The identification and counting the planktonic larvae and eggs were made using an inverted microscope and a count of platinum Bogorov 22 mL (80 × 100 mm).
Due to the low abundance of the larvae, the samples were subjected to full counting without splitting. The densities of planktonic eggs and larvae were expressed in individuals/$m^3$.

**Statistical processing and data analysis**
Hydrological parameters were processed by Principal Component Analysis (PCA), justified by the different nature of the variables considered and their unit of measurement. This method aimed to evaluate the relative importance of each element in the structure of the whole (Pronier 2000).
The relationships between the environmental characteristics and the planctonic densities of different taxa identified were studied using the canonical correspondence analysis (CCA) or correspondence analysis on instrumental variables (AFCVI) (Ter Braak 1986; Lebreton *et al.* 1988), whose objective was to simultaneously process two data tables (environmental variables and faunal variables) for the same surveys.

## RESULTS AND DISCUSSION
### Hydrology
**Temperature (T)**
The temperature values measured at the three stations during the study period (Fig. 2) ranged from 19.2 °C to 21.9 °C. At the end of spring, there was a remarkable increase in temperature. These temperature variations followed those of the regional climate. Indeed, the average seawater temperature is related to weather conditions as the surface layer is subjected to the direct influence of the regional climate characterized by a cold- and a warm-seasons (Chaouay *et al.* 2016).

**Hydrogen potential (pH)**
The values indicated that the pH (Fig. 3) is alkaline at all the stations studied. These values vary between 8.75 and 8.85, close to the seawater pH values, i.e. 8.3 (Aminot & Kerouel 2004). The low pH alterations recorded at these stations may be attributed to the alkalizing action of seawater. Indeed, the carbon dioxide present in the seawater

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is found in the forms of free $CO_2$, bicarbonate ions $HCO^{3-}$ and carbonate ion $CO_3^{2-}$. The carbonate and bicarbonate ions together act as a buffer which is opposed to pH variations of water: The $CO_2$ absorption results in the formation of bicarbonate from $H^+$ ions and $CO_3^{2-}$, inhibiting subsequent decrease in pH (Ezzaouaq 1991; El Blidi & Fekhaoui 2003; Himmi *et al.* 2005).

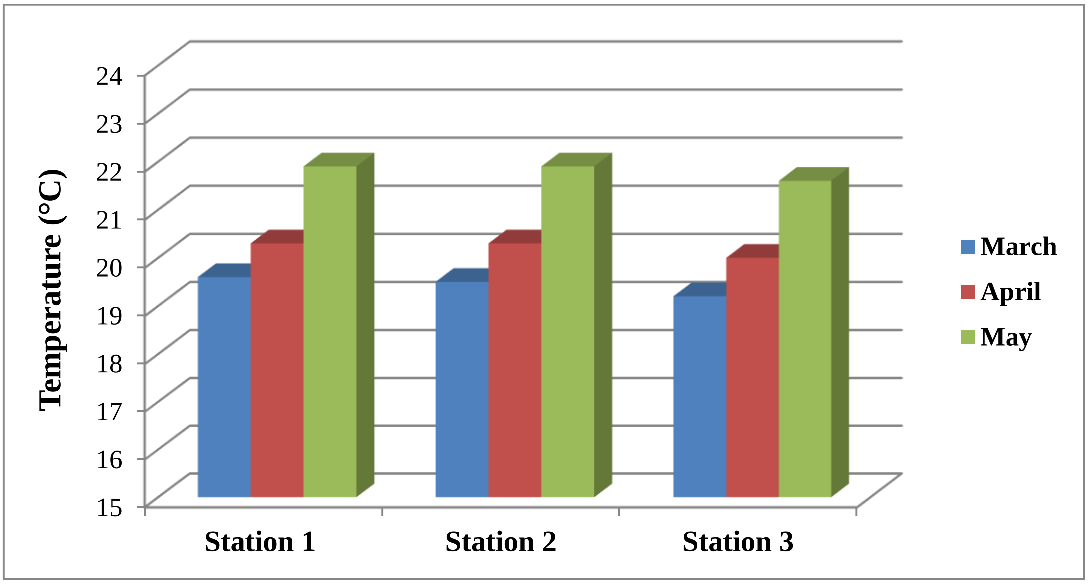


**Fig. 2.** Spatio-temporal variability of the seawater temperature of Imessouane Bay.

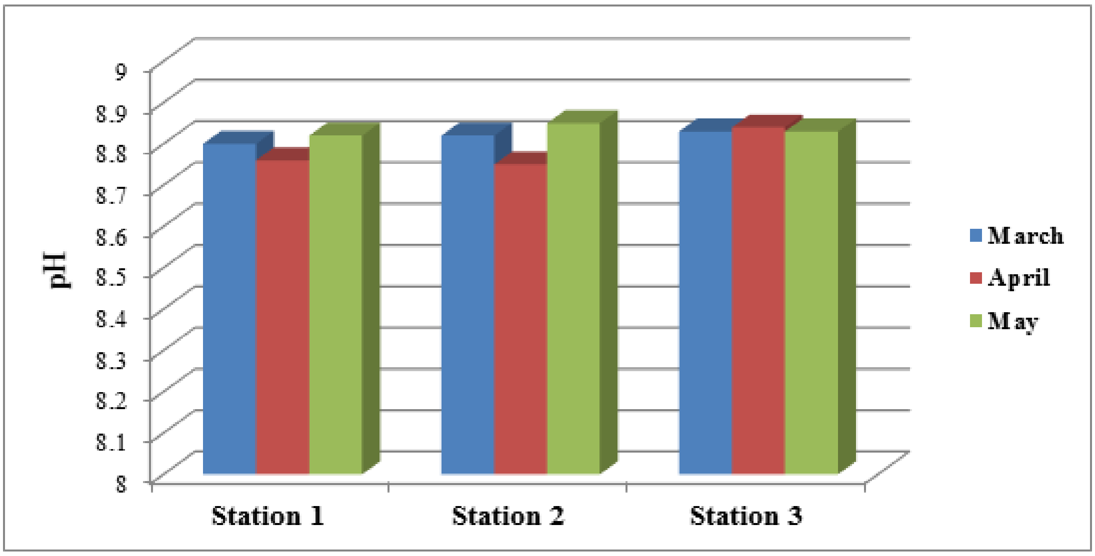


**Fig. 3.** Spatio-temporal variability of the pH of seawater in Imessouane Bay.

**Salinity (Sa)**

The salinity values in the study site varied between 36.1 g $L^{-1}$ during March and 36.8 g $L^{-1}$ in May (Fig. 4). Indeed, during the dry season, high evaporation induces a raise in the salinity of the water, unlike the rainy season where the rainfall inflows lower the value of this parameter.

**Conductivity (σ)**

The average conductivity values exhibited significant variations (Fig. 5). They oscillate between 46.2 ms $cm^{-1}$ in March and 55.6 ms $cm^{-1}$ in May. The reason for this increase lies on the saltwater concentration due to the decreased rainwater inflow at the end of the study period (27 mm in March and 10 mm in May).

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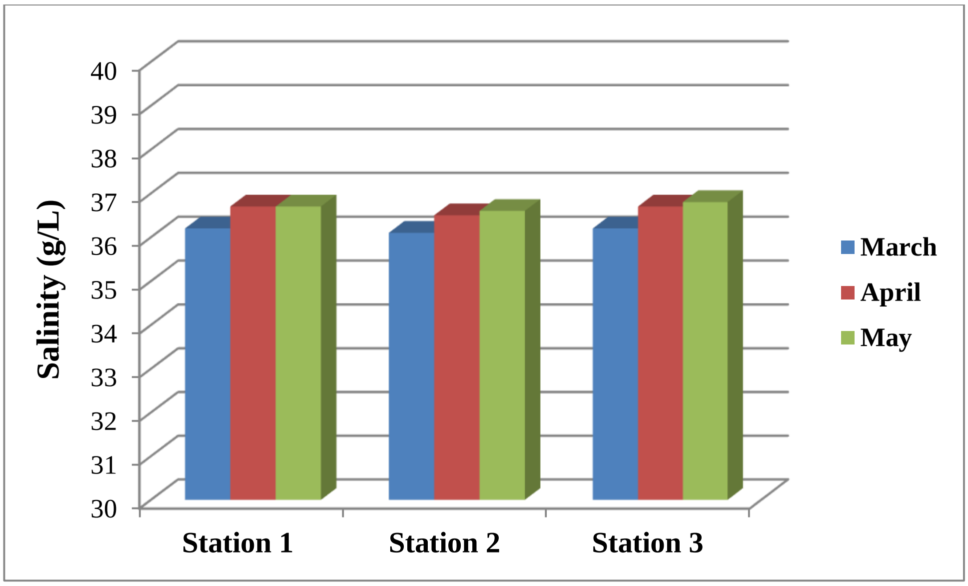


**Fig. 4.** Spatio-temporal variability of seawater salinity in Imessouane Bay.

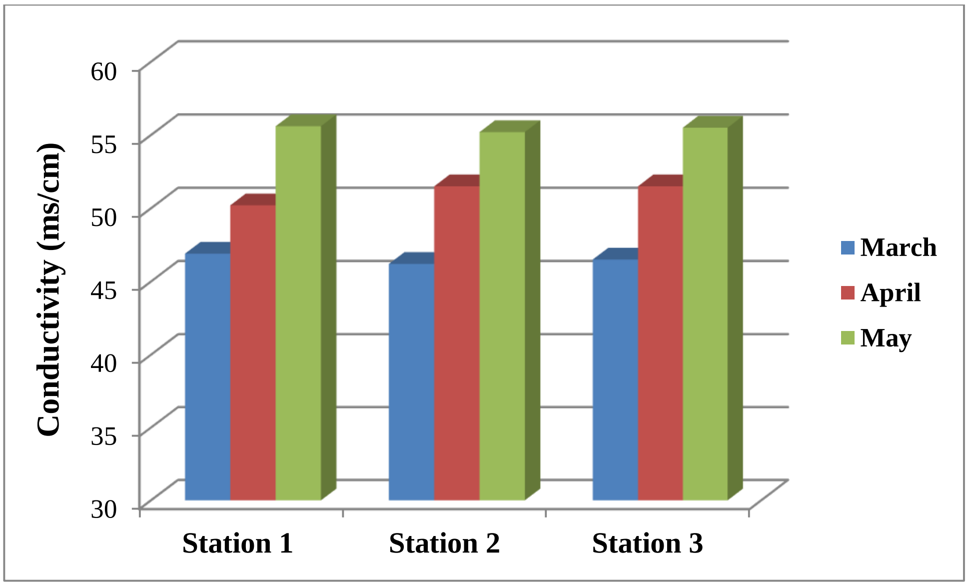


**Fig. 5**. Spatio-temporal variability of the conductivity of seawater in Imessouane Bay.

**Turbidity**

Turbidity values in the study area ranged from 1.01 NTU in March through 2.91 NTU in May (Fig. 6), coinciding with the periods of fluorescence and strong phytoplanktonic surge. The water transparency is attenuated by the density of the phytoplankton cells, thus increasing water turbidity (Lakkis & Zeidane 1987).

**Dissolved oxygen (DO)**

The variability of dissolved oxygen exhibited higher concentrations in May (9.48 mg $O_2$ / L) compared to those in March (6.39 mg $O_2$ / L) (Fig. 7). In spring, the development of phytoplankton and the increased primary production favour the oxygenation of the superficial layers. These values are comparable to previous results in the same region (Ait-Talborjt *et al.* 2016 a).

**Nitrites**

The nitrite levels displayed low values throughout the study period, ranging from 1.425 mg $L^{-1}$ in May to 1.7 mg $L^{-1}$ in March. (Fig. 8). Generally, the nitrogen content of seawater is highest in winter and then drops gradually

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by summer. However, the deep waters are generally rich in nitrogen and phosphates, compared to the lower values at the surface waters (Lakkis & Zeidane 1987).

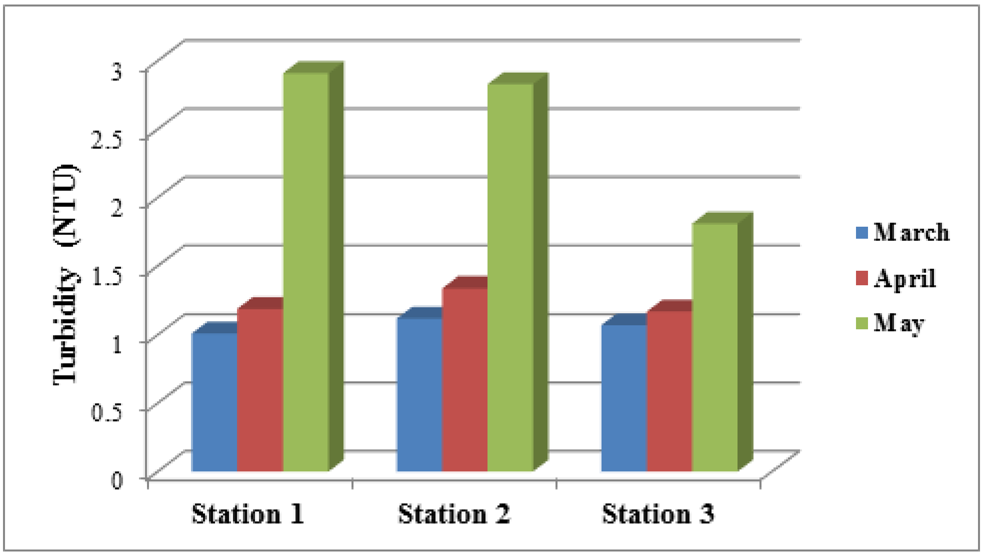


**Fig. 6.** Spatio-temporal variability of the turbidity of the seawater of Imessouane Bay.

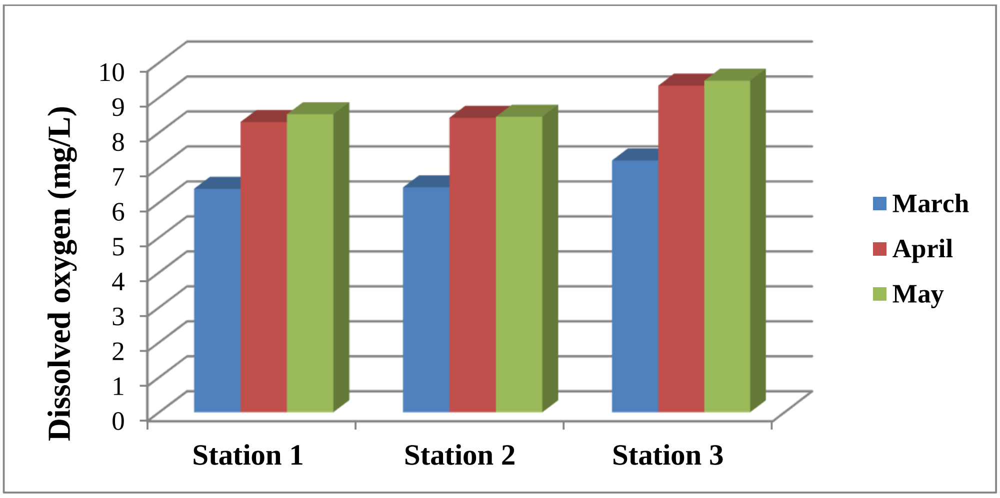


**Fig. 7.** Spatio-temporal variability of the dissolved oxygen of the seawater of Imessouane Bay.

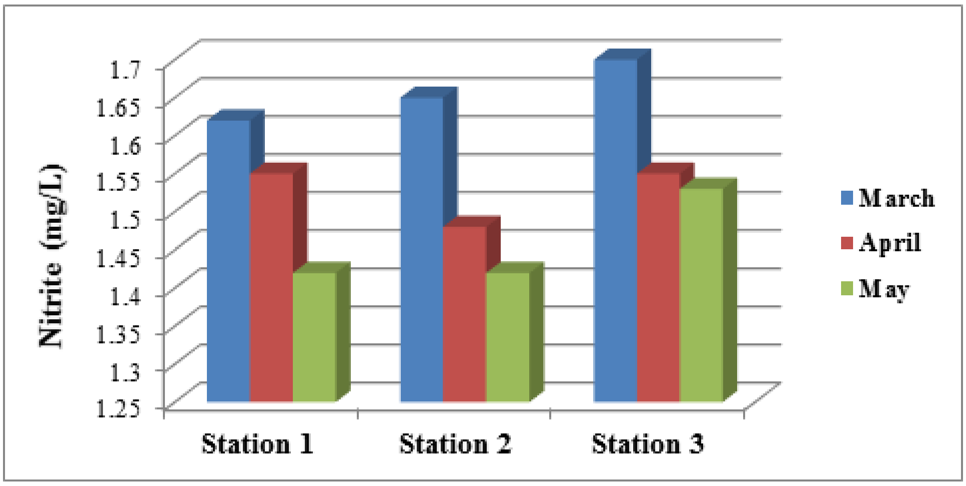


**Fig. 8**. Spatio-temporal variability of seawater nitrites from Imessouane Bay.

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**Orthophosphate**

Orthophosphate levels ranged from 0.06 in May to 0.28 mg $L^{-1}$ in March. The maximum value was recorded in March at station 2 (Fig. 9). The shift from the maximum values in March to the minimum in May is related to the nutrients (phosphate, nitrate, and silicate) consumption by phytoplankton for growth and development. This period is therefore marked by a phytoplankton bloom.

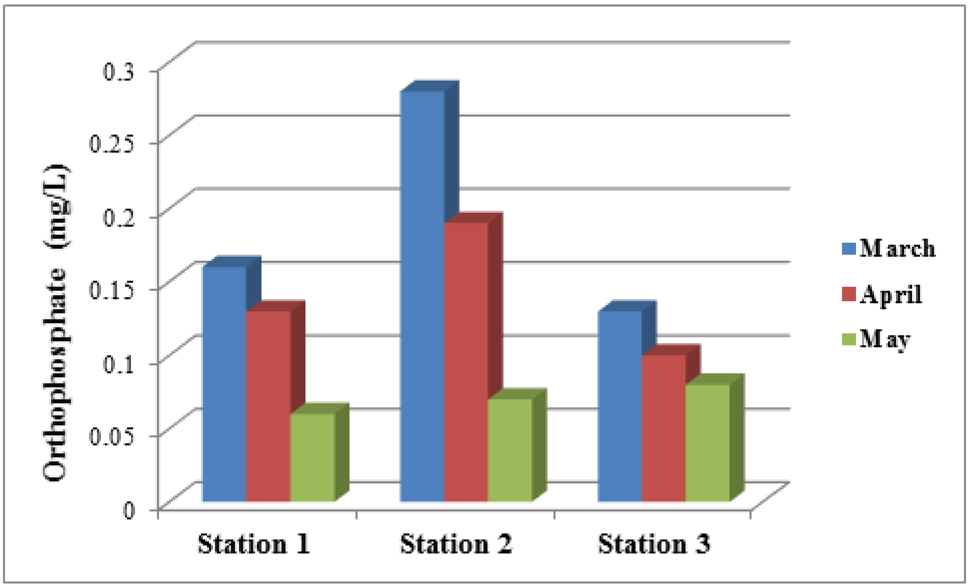


**Fig. 9**. Spatio-temporal variability of orthophosphates in the seawater of Imessouane Bay.

**Correlation between hydrological parameters (PCA)**

The PCA is performed on a data matrix consisting of 9 samples (3 stations × 3 months) concerning the 8 variables measured (water temperature, pH, salinity, conductivity, turbidity, dissolved oxygen, nitrite ions, and orthophosphates). The eigenvalues of the PCA of the two components F1 and F2 and their contribution to the total inertia are illustrated in Fig. 10. We found that the first two factors alone account for 84.52% of the dispersion of the cloud, which makes it possible to neglect the other factors. The F1 axis exhibited a positive correlation with turbidity, temperature, conductivity, dissolved oxygen and salinity, while a negative correlation with nitrites and orthophosphates. The pH alterations were not significant, so they displayed a positive correlation with both axes. Turbidity, temperature and nitrites were positively correlated with the F2 axis, while negatively with conductivity, dissolved oxygen, salinity and orthophosphate.

Overall analysis (Fig. 11) makes it possible to define a typology and a temporal organization dominated by the individualization of 3 groups GI, GII, and GIII:

- Group I (GI) includes samples from March at the three stations which are characterized by a high content of $NO^{2-}$ and $PO_4^{3-}$, while low values of temperature and salinity which is explained by the contribution of freshwater.
- Group II (GII) is an intermediate phase between group I and III. It is characterized by an increased dissolved oxygen concentration and salinity, while decreased nutrient levels that could be attributed to their use by phytoplankton for its development.
- Group III (GIII) concerns to samples taken in May, characterized by an increase in temperature, salinity, conductivity, dissolved oxygen, while a decrease in nutrient levels as a result of phytoplankton development.

**Spatio-temporal distribution of planktonic eggs and larvae**

Fig. 12 illustrates the comparison of the spatio-temporal variability of each faunal group at the three stations. The highest dominations were recorded for arthropod larvae exceeding 4900 individuals/$m^3$ in total.

These results are consistent with previous work (Lakkis & Zeidane 1988) which asserts that this period corresponds to the first phytoplankton bloom of the year, followed by abundant populations of herbivorous filter-feeders that may be either copepod larvae or decapod ones, especially larvae of the petunidae, caridae and spring brachyures. Within the arthropod group, densities of copepod larvae (nauplius and copepodites) reached 2231 ind/$m^3$. This value is close to that already reported: 2087 ind/$m^3$ for copepod larvae (Ait-Talborjt *et al.* 2016 b).

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The echinoderm larvae and ichtyoplankton were undergone a gradual increase during the study period. The highest density of these two faunal groups was recorded in May at station 3. Similar studies on the Lebanese coasts showed that a large concentration of unfertilized eggs was observed during the same period, especially at the port stations (Lakkis & Zeidane 1989). In the present study, high densities of cnidarians and mollusks larvae were recorded during May at station 1. The annelid larvae exhibited considerable abundance especially at the end of the study period (May). The largest numbers were recorded at station 2. In fact, the polychaete larvae displayed a great abundance during this period and constituted the first meroplanktonic group inhabiting the pelagic column (Laubier 1966).

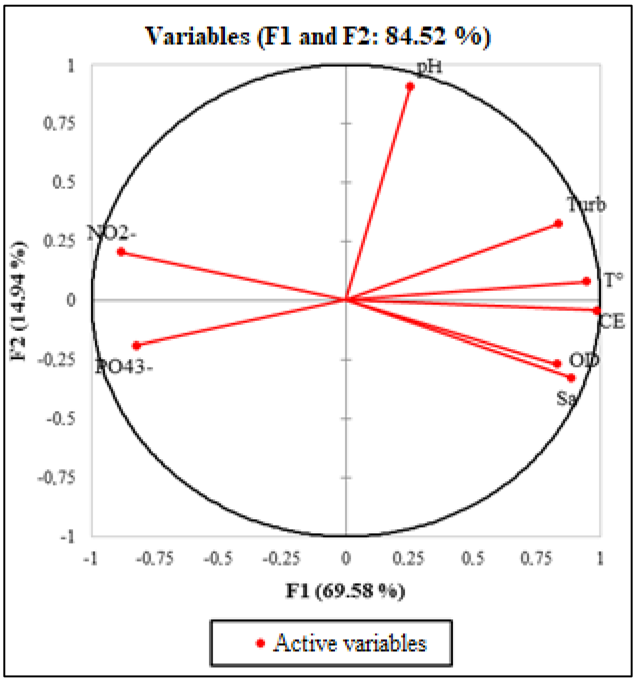


**Fig. 10.** PCA graphical approach to physico-chemical parameters in seawater according to F1× F2 (correlation circle).

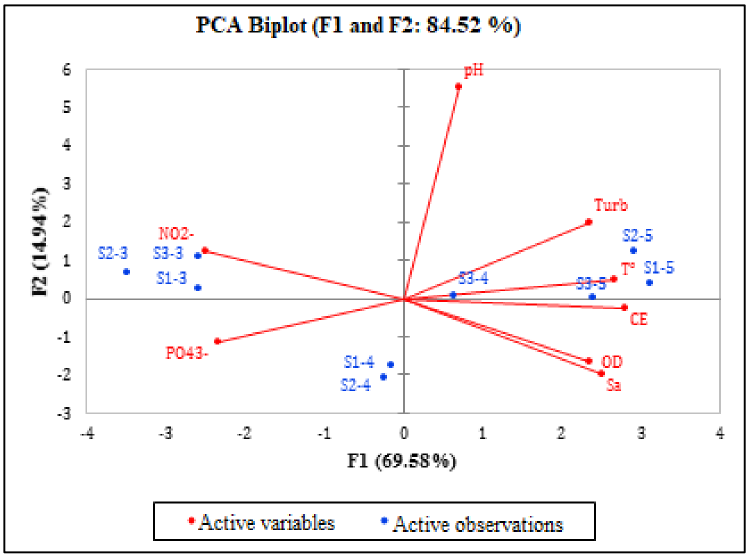


**Fig. 11.** PCA graphical approach of physico-chemical parameters in seawater according to F1× F2 (Graph of observations).

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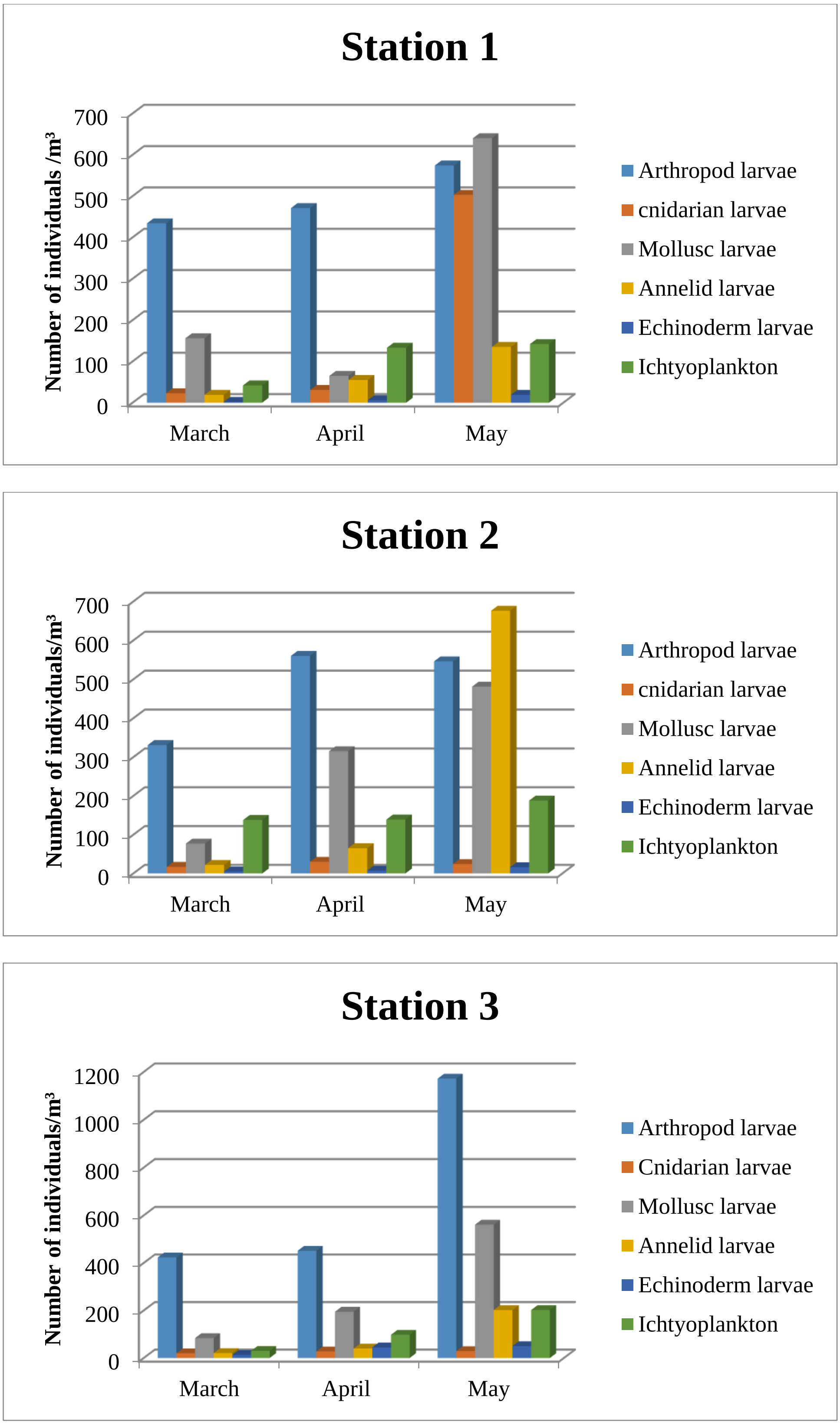


**Fig. 12.** Spatiotemporal variability of the major faunistic groups identified in Imessouane Bay.

The overall distribution of planktonic larvae and eggs identified in Bay Imessouane during the study period (Fig. 13) shows that arthropods are the most dominant and most diverse with 43.16% of total planktonic larvae and eggs, followed by molluscs 21.77% and then ichthyoplankton by 19.64%. The dominance of arthropods in our

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results, particularly that of copepods, is in accordance with other works conducted in Moroccan coasts (Thiriot 1978; Benbakhta 1994; Ait-Talborjt *et al.* 2016).

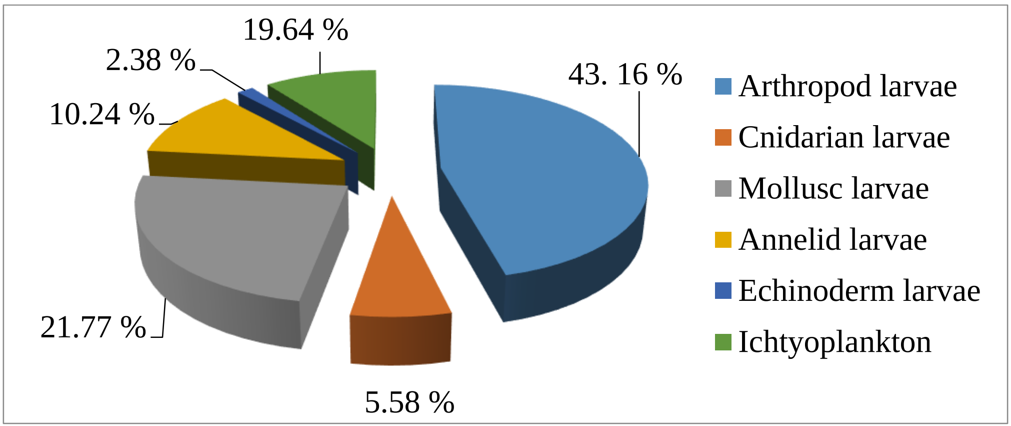


**Fig. 13.** Distribution of major faunal groups in Imessouane Bay.

**Environmental and larval diversity parameters**

The canonical correspondence analysis (CCA) was performed in order to attribute the abundance of six faunal groups represented in our study site: Arthropod larvae (Arth), echinoderm larvae , polychaete larvae, mollusc larvae, cnidaria larvae and ichtyoplankton larvae to the different physicochemical variables measured.

The eigenvalues of CCA (Table 1) indicated that most of the inertia was represented by the first axis (53.96%), followed by the second axis (32.65%), constituting 92.5% of the total inertia. This means that the two-dimensional representation of CCA is sufficient to analyze relationships between sites, faunal groups, and variables.

**Table1.** Distribution of inertia between the axes of physicochemical parameters and faunal groups in seawater according to F1 × F2 plan.

| | F1 | F2 | F3 | F4 | F5 |
|---|---|---|---|---|---|
| Eigenvalue | 0.138 | 0.084 | 0.016 | 0.014 | 0.004 |
| Inertia constrained (%) | 53.961 | 32.654 | 6.256 | 5.625 | 1.504 |

The relationship between the density of mollusc larvae and environmental factors (Fig. 14) indicated that the presence of this faunistic group is related to a high rate of salinity and dissolved oxygen but low content of nitrites and orthophosphates.

The polychaete larvae seem to be more sensitive to pH. The highest abundance in this group was recorded at a maximum pH value (8.85).

The arthropod larvae, as well as eggs and fish larvae, are related to the group of stations characterized by high levels of nitrite and orthophosphate.

The echinoderm larvae are more abundant in May at station 3 and have a correlated distribution at highly oxygenated sites.

The cnidarians larvae, meanwhile, seem to be influenced by temperature, turbidity, and salinity and exhibit a large abundance in May at station 1.

**CONCLUSION**

The present work concerns to the study of spring taxonomic composition of planktonic eggs and larvae in the marine ecosystem of Imessouane Bay, the spatio-temporal variations of these stands and their interaction with the hydrological parameters of the environment. The qualitative study of the zooplankton community of Imessouane Bay revealed the presence of 26 taxa, divided into six major groups, of those the arthropoda larvae were the most

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dominant and the most diversified (43.16%). Furthermore, by a three-month study, May is considered to be the richest in terms of diversity (25 taxa) with a maximum abundance of planktonic eggs and larvae.
The overall analyses of hydrological parameters by PCA indicated a temporal organization dominated by the individualization of 3 groups. The first group comprised the samples of March characterized by high levels of nutrients and low values of the other parameters. The second group was attributed to the April samples and constituted an intermediate phase between the two other groups. It was characterized by a reduction in pH and nutrient levels while an elevation in other parameters. The third group included samples of May, characterized by a decrease in nutrient levels, while an upraise in other parameters.

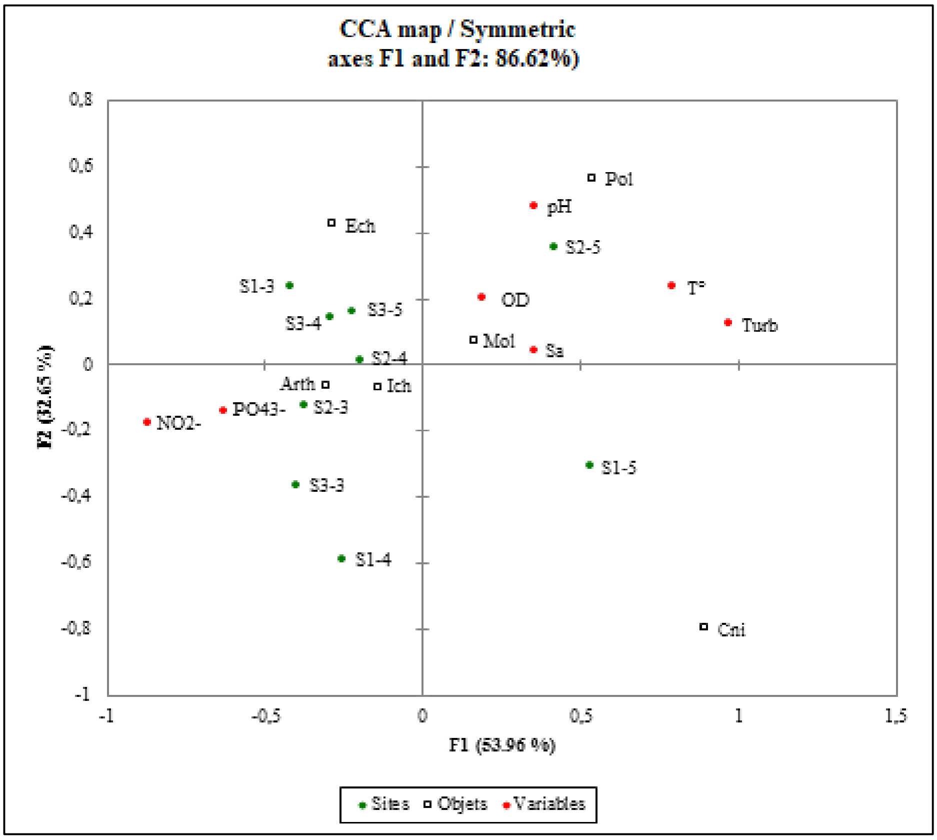


**Fig. 14.** CCA factorial design made by combining the hydrological and taxonomic parameters of Imessouane Bay.

Analysis of the relationship between the abundance of the six groups of planktonic eggs and larvae and the hydrological parameters by CCA exhibited that some environmental parameters are essential factors for the functioning and the spatio-temporal variability of these planktonic communities. Molluscan larvae had high abundances in the presence of high salinity and dissolved oxygen and low nutrient content. Arthropod larvae and ichthyoplankton, however, were more related to the group of stations characterized by high levels of nutrients. Polychaete larvae, meanwhile, seemed to be more sensitive to pH. However, echinoderm larvae displayed a correlated distribution at the highly oxygenated stations, whereas cnidarian larvae appeared to be influenced by temperature, turbidity, and salinity.

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# اهمیت پارامترهای هیدرولوژیک در انتشار تخم‌ها و نوزادان پلانکتونی در یک منطقه فراچاهنده (خلیج ایمسوان، سواحل اطلس مراکش)

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**چکیده**

هدف مطالعه حاضر، بررسی تنوع بهاره تخم‌ها و نوزادان پلانکتونی در خلیج ایمسوان، و ارزیابی توسعه آنها بر اساس پارامترهای هیدرولوژیک محیط بود. ۲۷ نمونه زیست‌شناختی و هیدرولوژیک در ۳ ایستگاه در خلال یک دوره سه ماهه (مارس، آوریل و مه ۲۰۱۸) جمع‌آوری شد. مطالعه کمی وجود ۲۶ تاکسا در ۶ گروه عمده را آشکار کرد که از بین آنها نوزادان بندپایان بیشترین غالبیت (۴۳/۱۶٪) را داشتند. بیشترین فراوانی تخم‌ها و نوزادان پلانکتونی در خلال ماه مه به عنوان غنی‌ترین ماه سال از نظر تنوع زیستی (۲۵ تاکسا) ثبت شد. آزمایش تجزیه به مولفه‌های اصلی پارامترهای هیدرولوژیک (PCA) امکان تعیین سازگان موقت را با غالبیت سه گروه فراهم کرد. آزمایش کونیکال کورسپوندنس آشکار کرد که پارامترهای محیطی معین، عواملی ضروری برای افزایش عملکرد و زمانی-مکانی جمعیت‌های پلانکتونی هستند.

*مؤلف مسئول

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