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GSC Biological and Pharmaceutical Sciences

e-ISSN: 2581-3250, CODEN (USA): GBPSC2

Journal homepage: <https://www.gsonlinepress.com/journals/gscbps>

(RESEARCH ARTICLE)



Effects of environmental parameters on the nycthemeral migratory behaviour of copepod species in the Al Massira reservoir, Morocco

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Publication history: Received on 23 November 2020; revised on 12 December 2020; accepted on 15 December 2020

Article DOI: <https://doi.org/10.30574/gscbps.2020.13.3.381>

Abstract

To improve our knowledge of nocturnal and diurnal migratory activity in copepods and in order to assess the effect of abiotic parameters on this activity, we have undertaken at the level of the Al Massira dam reservoir (dam located on the wadi Oum Erbia, in Morocco) the monitoring of the migration of the main species, during a 24-hour nycthemeral cycle. To be done; the measurement and sampling step is carried out every 4 hours; at different depths of the prospected station. The temperature, pH, dissolved oxygen and chlorophyll *a* measurements are taken. The systematic position of the main species of copepods and their density are determined.

Most of the results obtained show that the main species of copepods inventoried within the reservoir are *Neolovenula alluaudi* and *Acanthocyclops robustus*. The nauplii of these two species present the maximum of densities at a depth of -5 m at 12 h; i.e. 70400 individual / m³ (ind / m³). The development stages of *N. alluaudi* are preferentially concentrated at -2 m at midnight, with 1900 ind / m³, while at 12 h and 16 h this density is less than 500 ind / m³. The maximum density for the stages of *A. robustus* is noted at midnight on the surface (at -5 m), i.e. 3400 ind / m³ for C1-2 and 3200 ind / m³ for stages C3-4-5 at -2 m at the same time. Therefore, the migratory behavior of these species seems to depend on the temperature, the concentration of dissolved oxygen and the variation of the food during the different phases of the cycle.

Keywords: Nycthemeral migration; Copepods; Dam; Abiotic parameters

1. Introduction

Zooplankton migration is a phenomenon observed in many marine and freshwater species. The classic pattern of these migrations consists of a rise in the upper layers at dusk, with a maximum surface density around midnight. Some authors observe a bimodal rhythm with a descent to the deep layers in the middle of the night and at dawn [1, 2]. Most of the studies carried out on these mechanisms consider that environmental factors induce these migratory movements. Indeed, the authors have demonstrated the presence of a relationship between temperature, dissolved oxygen, chlorophyll *a* content and migration [3]. The effect of predation [4] and the influence of hydrological and hydrodynamic factors on the migratory behavior of certain zooplankton species Berge *et al.* [5] have also aroused the interest of the authors.

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At the national level, researchers have studied the migration of zooplankton, particularly in lagoon and estuarine environments [6, 7]. At the level of the Al Massira dam reservoir, no study has been carried out on this subject. The objective of this work is on the one hand to study the nycthemeral migration of two species of copepods that are the most representative of the environment and on the other hand to study the effect of environmental factors on this migratory behavior. The ultimate goal of this study is to understand the mechanism of this ecosystem of great water interest.

2. Material and methods

2.1. Study site

The Al Massira reservoir was filled in February 1979 and is considered the centerpiece of the development plan for the watershed of the Oum Er Rbia wadi. It is located in the province of Settat, 120 km south-east of Casablanca (Fig. 1).

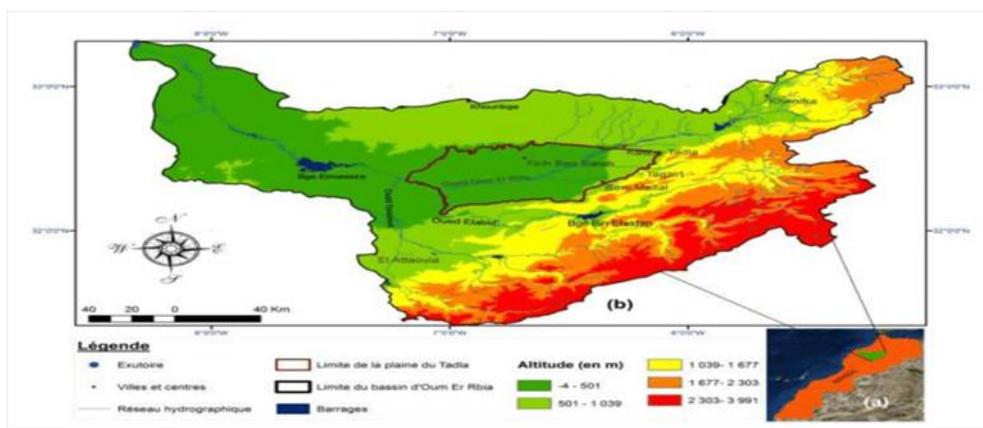


Figure 1 Oum Er Rbia river

The main characteristics of the reservoir are given in Table 1.

Table 1 Morphometric characteristics of the Al Massira reservoir.

Parameters	Values
Watershed area	28.5 km ²
Maximum depth	40 m
Average depth	20 m
Length	30 Km
Width	10 Km
Volume	280.106 m ³

The coordinates are 32 ° 28'32 " north and 7 ° 32'15 " west. The atmospheric temperature is 18.5 ° C at 8 p.m. The water resources of the Oum Er Rbia wadi watershed are on the one hand from surface origin from three large wadis and on the other hand from groundwater from water tables.

2.2. Sampling

The water and zooplankton samples are sampled at the deepest point of the reservoir (Fig. 2), located between -35 and -40 m.

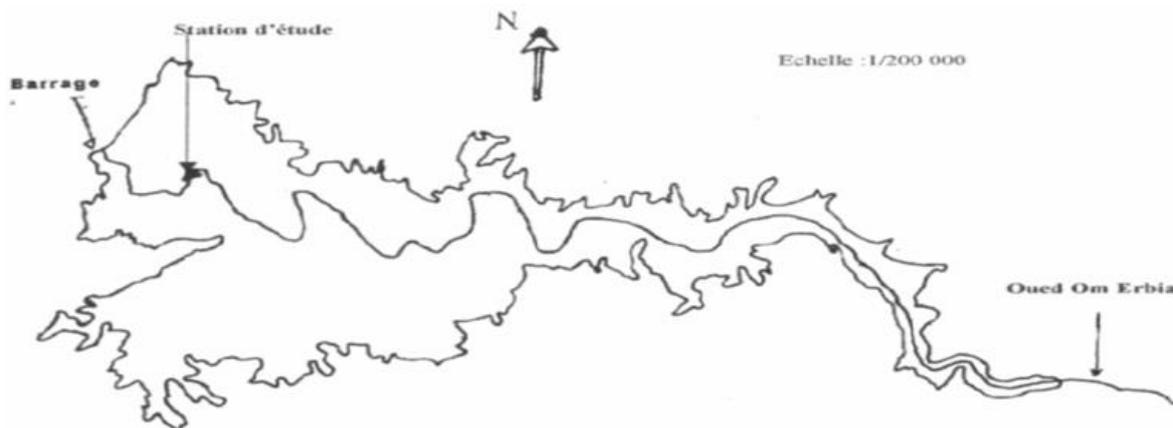


Figure 2 Al Massira reservoir morphology and sampling station.

Samples were collected every four hours during a 24 hour cycle. The different depths are: -0.2 m; -2 m; -5 m; -10 m; -15 m; -20 m; -25; -30 m and -35 m. Samples are taken using a sealing bottle with a capacity of 2.5 l, at the rate of 4 samples per depth. A total volume of 10 liters of water is filtered through an 80 μm mesh vacuum cloth.

2.3. Physico-chemical parameters

The parameters measured in the water at the different depths of the study station are:

- The temperature, measured with an ordinary thermometer, graduated to 1 / 10th.
- The pH, measured in situ using a WTW type pH meter, to 1 / 10th of a unit.
- Dissolved oxygen, evaluated by the volumetric method of Winkler. The fixation of the O₂ is carried out in the field as soon as the sample is taken and is carried out according to the method of Rodier [8].

2.4. Chlorophyllian pigments

Chlorophyll *a* contents are measured in water at depths of 5 and 15 m. 0.5 L samples are filtered using a glass microfiber filter (GF / C). The contents are determined from the equation of Lorenzen [9] and are expressed in mg / m³.

2.5. Counting zooplankton

After sampling and filtering the water from the different depths, the biological samples are immediately fixed in a 4% formalin solution. In the laboratory, the samples are stained with Rose Bengal and observed under a binocular magnifying glass at high magnification (x 50). The counting is carried out on a Dolffus tank after homogenization in a 10% glycerin alcohol solution. Enumeration of copepods included nauplii (N), copepodites (C) and adults. For nauplii, this count is made from N1 to N6, all stages combined. For the copepodites, in order to minimize possible errors of identification, we have grouped stages C1 and C2 on the one hand and C3, C4 and C5 on the other. The enumeration in adults is carried out in males, non-ovigerous females and ovigerous females of all the species encountered.

3. Results and discussion

3.1. Physico-chemical parameters

The vertical profiles of the temperatures recorded (Fig. 3) show a certain variation in the thermal gradient of the water column during the cycle. The thermal difference between the bottom and the surface does not exceed 4 °C (20.5 and 17 °C at 24 h) at night and 6.5 °C during the day (22 and 17 °C at noon).

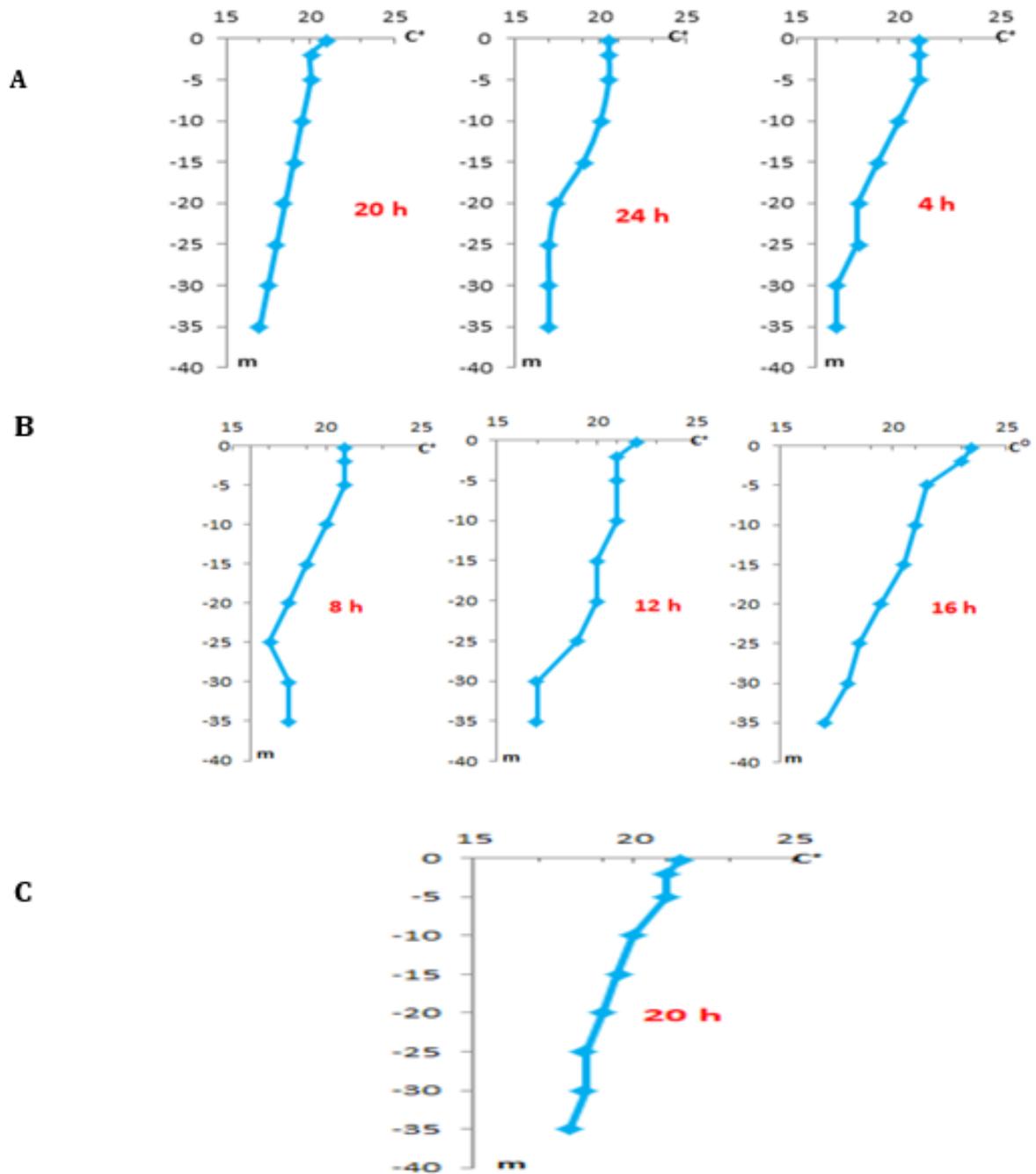


Figure 3 Distribution of temperature during the nycthemeral cycle. (A = distribution of Temperature during the night of nycthemeral cycle; B = distribution of Temperature during the day of nycthemeral cycle; C= vertical temperature profiles to complete the 24 hour cycle).

The pH values do not show any significant variation between the surface and the bottom. They do not exceed one unit during the whole nycthemeral cycle (Fig. 4). The most marked variations are 7.5 to -5 m and 8.5 to -10 m, recorded at 4 p.m.

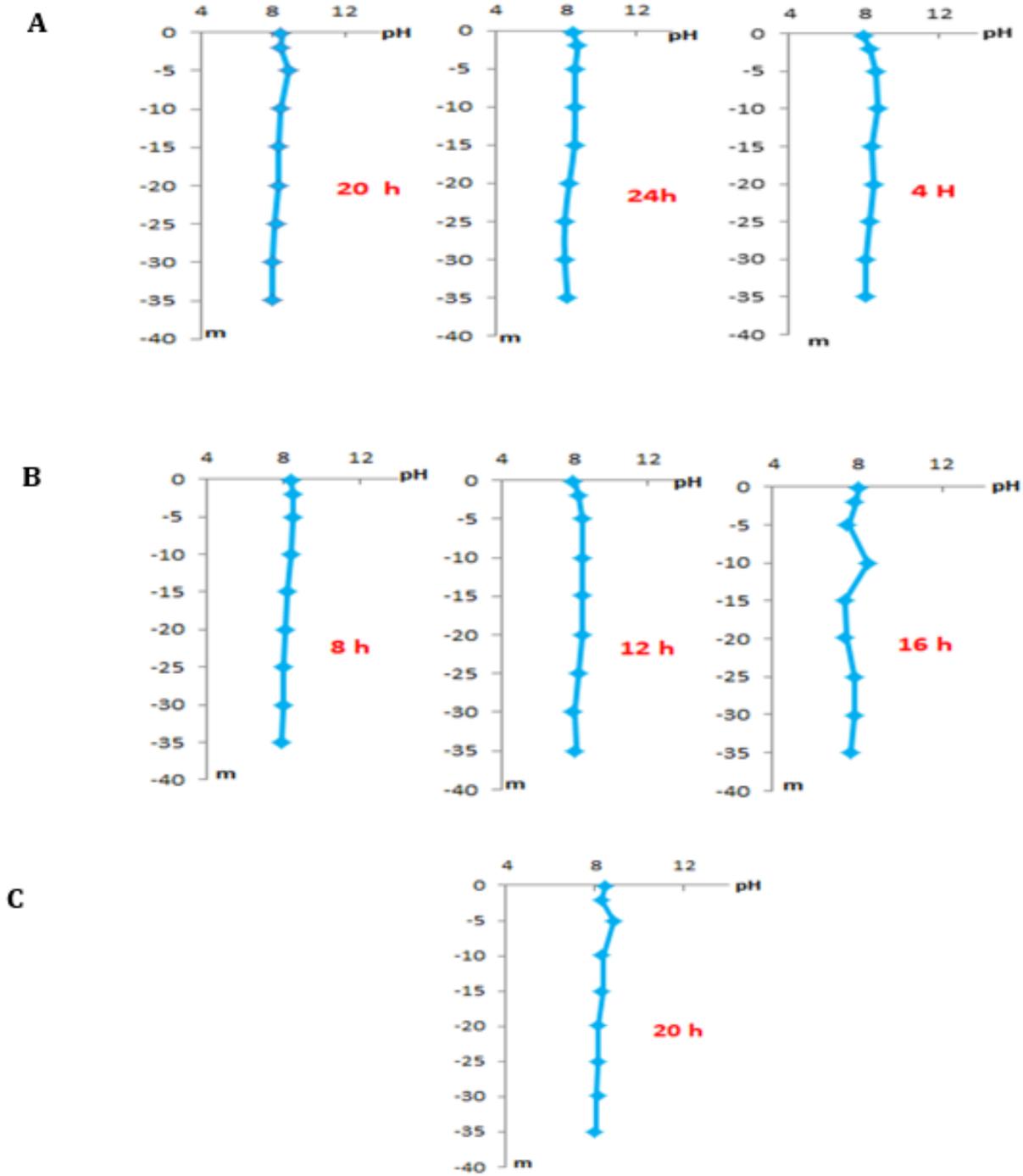


Figure 4 Distribution of pH during the nycthemeral cycle (A = Distribution of pH during the night of nycthemeral cycle; B = Distribution of pH during the day of nycthemeral cycle; C= vertical pH profiles to complete the 24 hour cycle)

The dissolved oxygen contents are mainly noted between the bottom and the surface (Fig. 5). The maximum and minimum values are respectively 10.4 mg /l at -2 m and 3.7 mg /l at -35 m, respectively at 20 h and at 12 h.

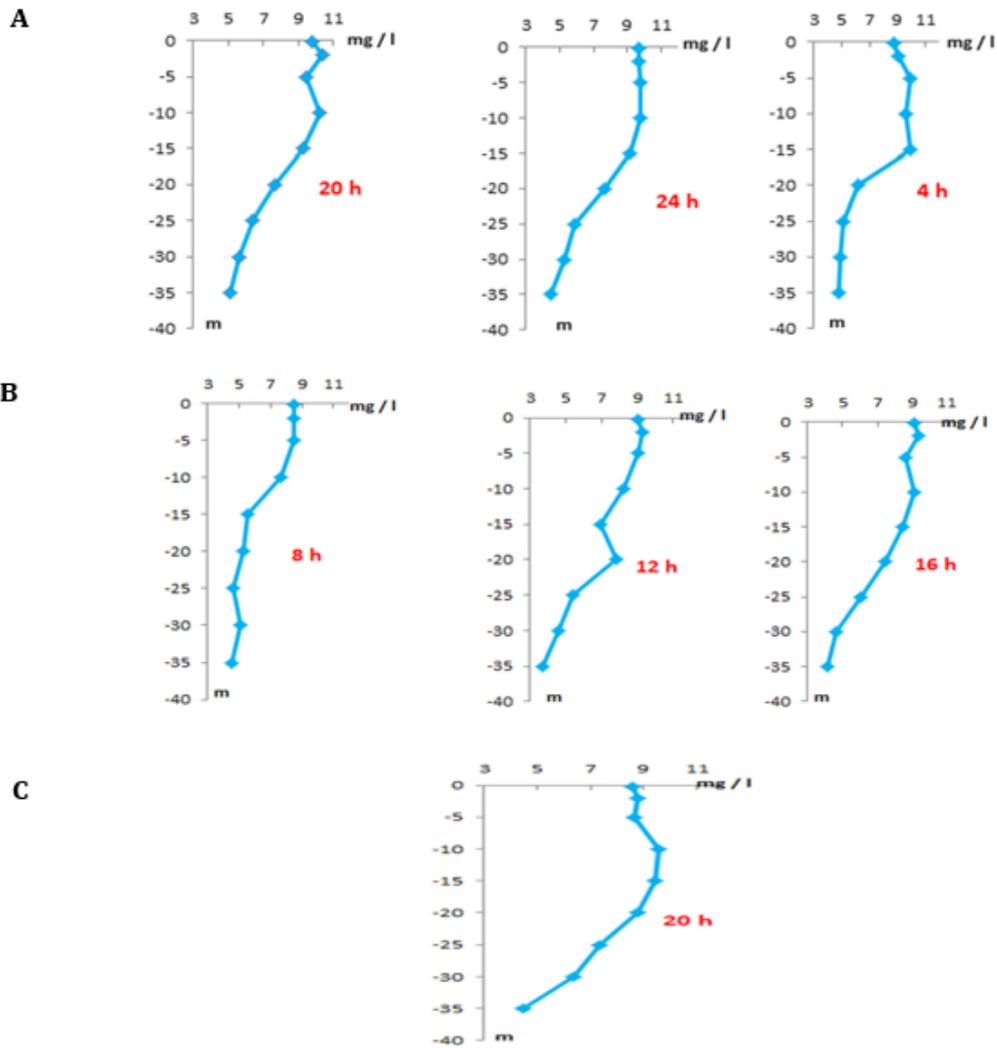


Figure 5 Distribution of dissolved O₂ concentration during the nycthemeral cycle. (A = Distribution of dissolved O₂ during the night of nycthemeral cycle; B = Distribution of dissolved O₂ during the day of nycthemeral cycle; C= vertical dissolved O₂ profiles to complete the 24 hour cycle).

3. 2. Chlorophyllian pigments

The chlorophyll a contents were measured at a depth of 5 and 15 m; the results are reported in Fig. 6. The maximum concentration is 8.87 mg / m³ at 12 h and the minimum is 1.72 mg / m³ at 4 h; respectively at -5 and -15 m.

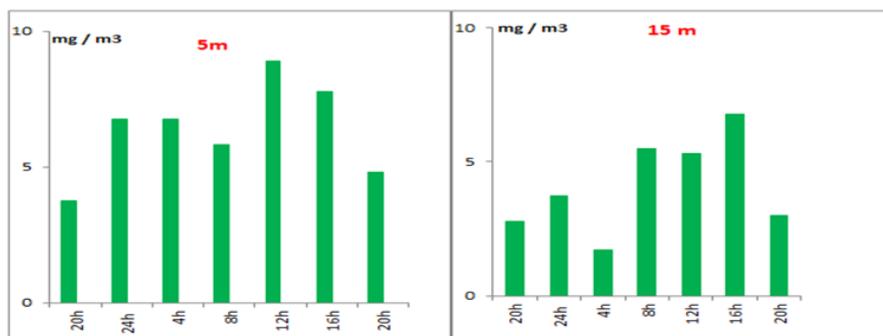


Figure 6 Nycthemeral variation of chlorophyll a, at 5 and 15m.

3.2. Zooplankton density *Neolovenula alluaudi*

The main species of copepods encountered during the study cycle are: *Acanthocyclops robustus* and *Tropocyclops prasinus*. Night-time migration was monitored for the most representative species, in particular *A. robustus* and *N. alluaudi*. The nauplii of these species are well represented and occupy the layers of water located between the surface and -30 m (Fig. 7). The maximum number is noted at -5 m, or 70400 ind / m³ at 12 h. At a depth of 35 m, the densities are very low to zero.

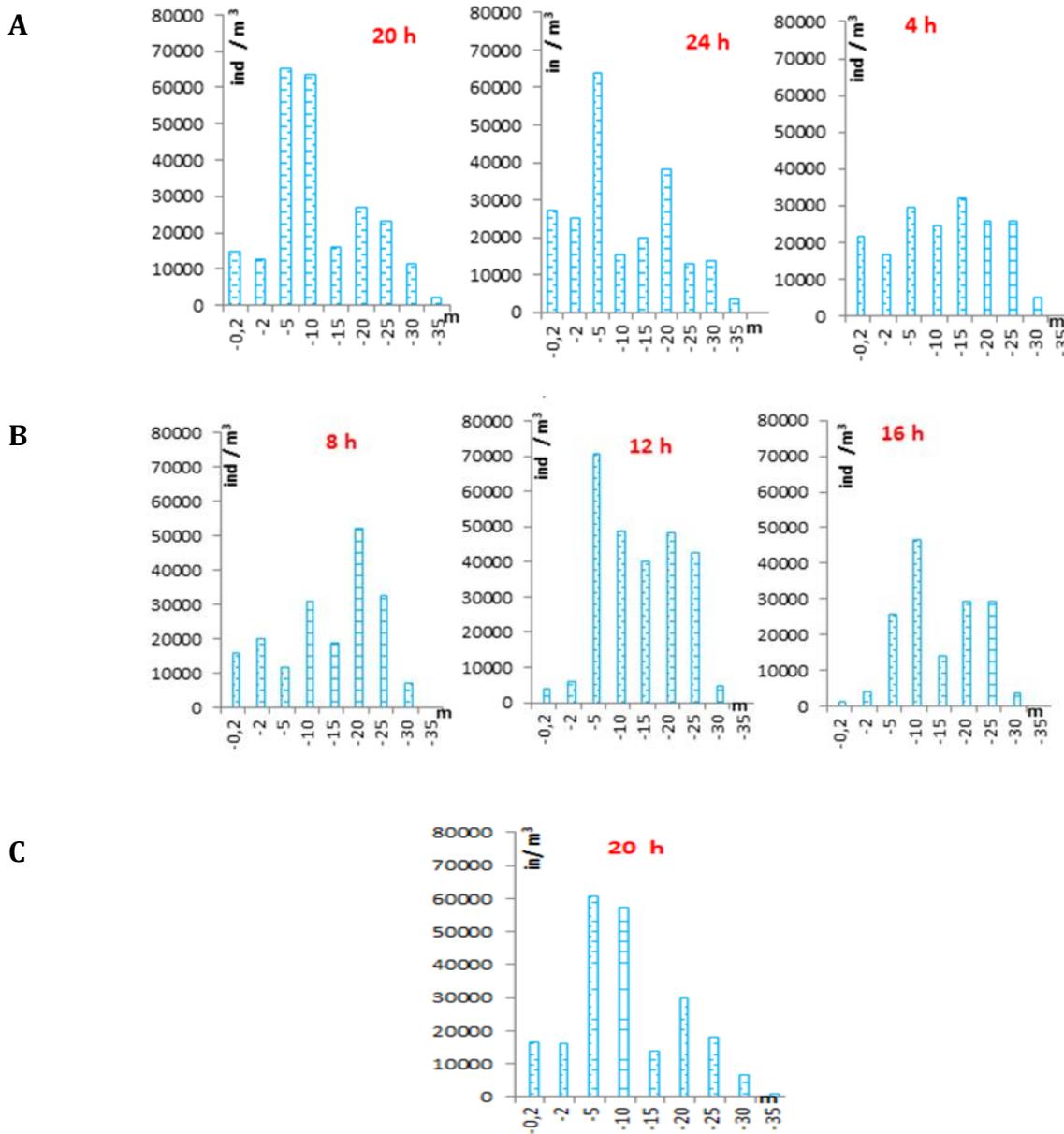


Figure 7 Abundance of nauplii during the nycthemeral cycle. (A = Abundance of nauplii during the night of nycthemeral cycle; B= Abundance of nauplii during the day of nycthemeral cycle; C = Abundance of nauplii at 20 h, to complete the 24 hour cycle.)

The copepodite stages C1-2 and C3-4-5 of the species *N. alluaudi* concentrate between the surface and - 2 m during the night. The maximum densities are 1900 ind / m³ at 24 h at the surface and 800 ind / m³ at 4 h at -2 m. During the day, these stages mainly colonize the water column (-5; -20) m, the highest densities are 1500 ind / m³ for stages C1-2 and 460 ind / m³ for C3-4-5 at 4 p.m. and 5 m deep. As for the non-ovigerous males and females, they are present in the column (-0.2; -30) m at any time of the cycle. From -30 m, the densities become low both during the day and at night. On the other hand, ovigerous females exhibit low densities at all depths and at all times of the cycle (Fig. 8).

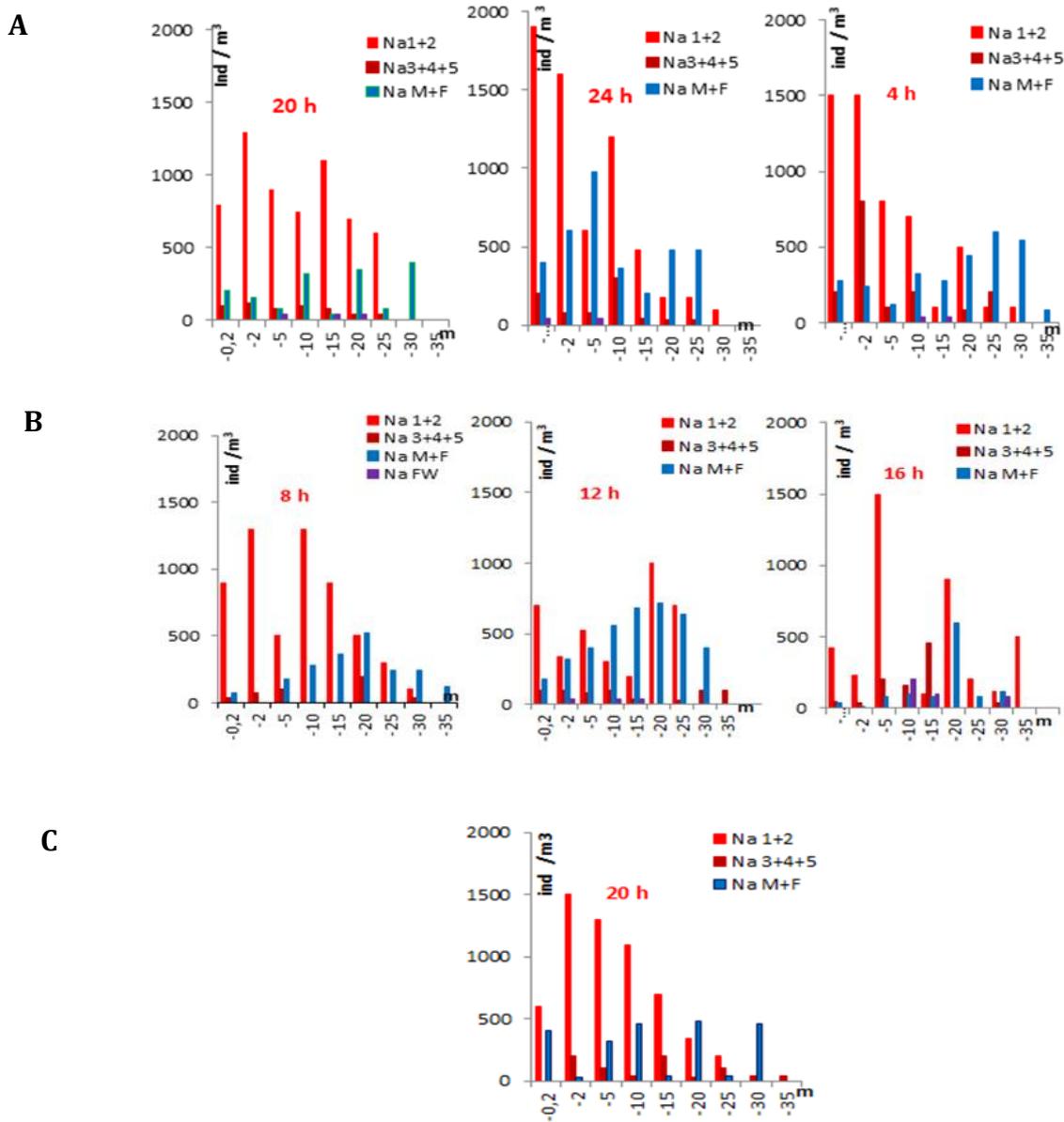


Figure 8 Abundance of *Neolovenulla alluaudi* during the nycthemeral cycle. (A = Abundance of *Neolovenulla alluaudi* during the night of nycthemeral cycle; B= Abundance of *Neolovenulla alluaudi* during the day of nycthemeral cycle; C = Abundance of *Neolovenulla alluaudi* at 20 h, to complete the 24 hour cycle)

During the night, most of the populations of all stages of development of *A. robustus* are concentrated between the surface and -5 m; i.e. 3400 ind / m³ at 24 h for C1-2 at -2 m and 3200 ind / m³ at the same time on the surface for C3-4-5. During the day, these densities are higher in the water column (-5; -20) m; i.e. 1000 ind / m³ at 12 h at -15 m for C1-2 and 4800 ind / m³ for C3-4-5 at 16 h at the same depth. Adults (males and females) and ovigerous females follow a migratory pattern comparable to that of *N. alluaudi* (Fig. 9).

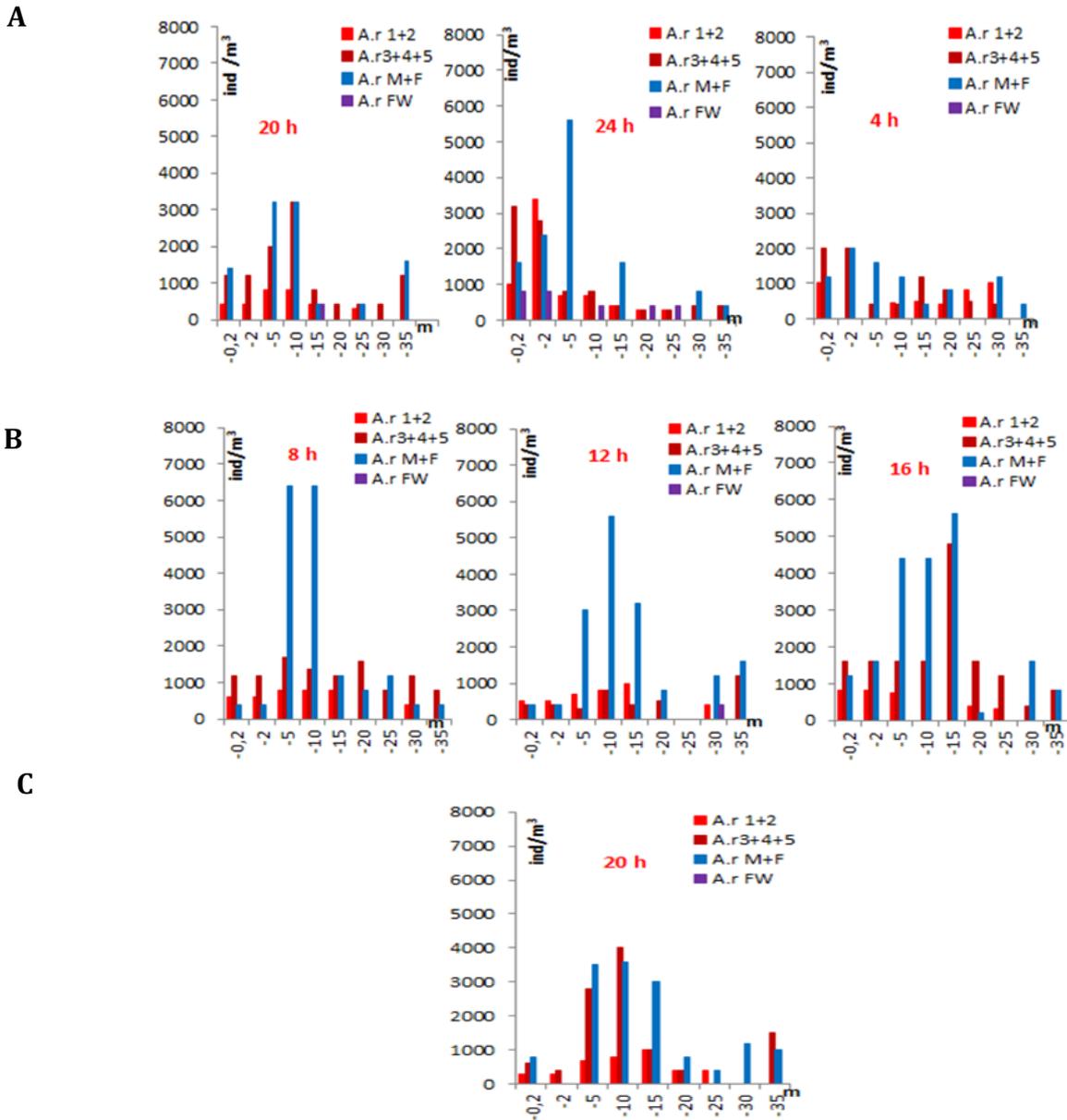


Figure 9 Abundance of *Acanthocyclops robustus* during the nycthemeral cycle. (A = Abundance of *Acanthocyclops robustus* during the night of nycthemeral cycle; B= Abundance of *Acanthocyclops robustus* during the day of nycthemeral cycle; C = Abundance of *Acanthocyclops robustus* at 20 h, to complete the 24 hour cycle.)

PCA's results were reported in (Fig. 10). The analysis has six variables (density, temperature, depth, dissolved O₂, pH and Chlorophyll *a*) and two modalities which are depth and sampling time. Axes F1 and F2 respectively present 58% and 16% of the information (Fig. 10 A) with a total of 74% of the total variability. The latter is 76%, 74% and 78% respectively in (Fig. 10 B, C and D). At a depth of 2 m, the density of the two copepod species *N. alluaudi* and *A. robustus* appears to depend on dissolved oxygen, temperature and chlorophyll *a*.

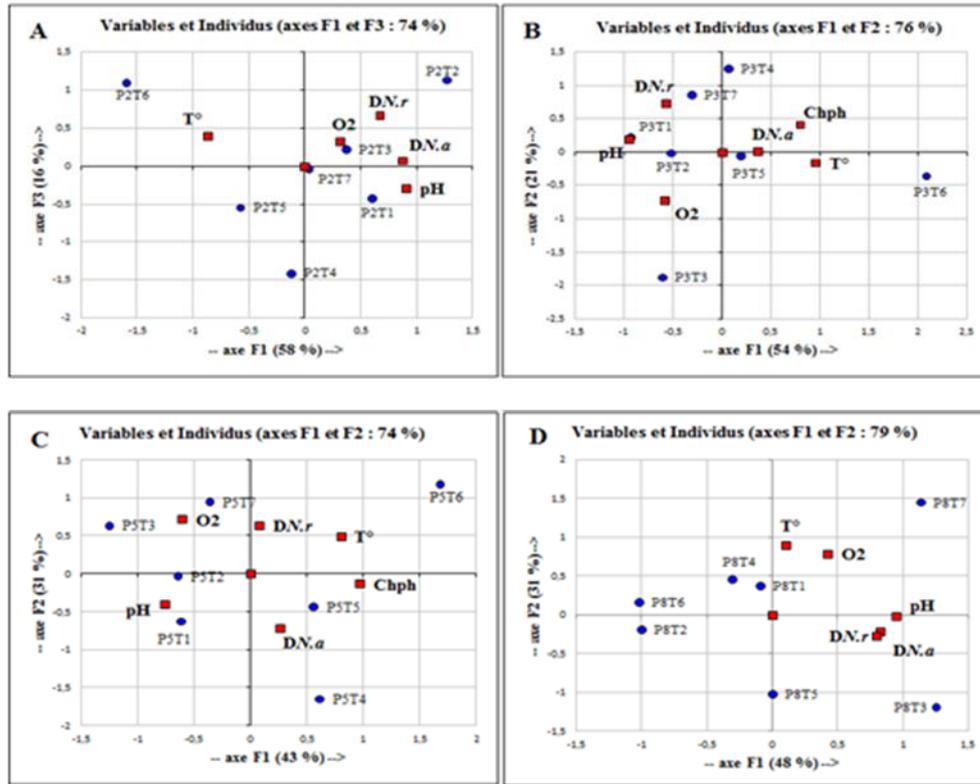


Figure 10 Principal component analysis of the variables (density, temperature, depth, dissolved O₂, pH, chlorophyll *a*) as a function of time sampling at different depths (A,B,C and D).

Depths in A, B, C and D -2 m (P2); -5 m (P3); -15 m (P5) and -30 m (P7).

Picking time = 20 h (T1) ; 24 h (T2) ; 4 h (T3) ; 8 h (T4) ; 12 h (T5) ; 16 h (T6) ; 20 h (T7).

It would appear that this difference in migration depends on the physiological state and that each of the stages of development requires different optimal conditions. This has been noted in the copepod *Calanus finmarchicus bay* Taude [10] and in several other zooplankton species bay Wissel et al. [11]. The density of young people; nauplii and copepodites; is higher compared to that of adults, which could be explained by the strong predation of fish preferentially on young compared to adults [12].

The maximum density of *N. alluaudi* and *A. robustus* is nocturnal, a situation noted both in the genus *Acartia* [13] and in other species of copepods and cladocerans [14, 15, 16]. Daylight appears to be the environmental factor that governs copepod migration [17, 18, 19, 20, 21]; Darkness would protect the visibility of these crustaceans against various predators. The effects of physico-chemical parameters on behavior. The authors have focused on the vertical distribution of zooplankton and on the one hand on the variation in dissolved O₂ concentration [22, 23] and on the other hand on a temperature gradient [24, 25, 26]. The nutritional factor was also taken into account in the present study by the evaluation of chlorophyll *a*. The aphotic zone being poor in phytoplankton consumable by herbivorous zooplankton, the latter would rise to the surface layers during the night to take advantage of the abundance of food [27].

4. Conclusion

The study of the nycthemeral cycle carried out in the Al Massira reservoir revealed the migratory activity of the copepods *Neolovenula alluaudi* and *Acanthocyclops robustus*, the most represented species in this ecosystem.

Nauplii of these two species show the greatest number at -5 m at 12 h. The copepodite stages are concentrated at night, between the surface and - 2 m or -5 m; respectively for *N. alluaudi* and *A. robustus*. The latter has a greater density of these stages.

The adults have the maximum density between -5 and -10 m as for that of ovigerous females, it is much lower.

According to the principal component analysis, the parameters influencing this migratory activity are different depending on the species considered and depend on the water column and the time of the cycle. In fact, the nycthemeral migration of the two species appears to depend mainly on temperature, dissolved oxygen and chlorophyll *a*.

The various stages of development of the same species do not necessarily show the same migratory behavior.

Compliance with ethical standards

Acknowledgments

The authors wish to thank the services of the Water Basin Agency of wed Oum Erbia Settat for their fruitful help and availability of data.

Disclosure of conflict of interest

We have no conflicts of interest to disclose

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