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Seasonal Dynamics of Crustacean Zooplankton Related to Physical and Chemical Parameters in a Recently Constructed Reservoir

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Abstract: The spatio-temporal distribution of crustacean zooplankton in relation to environmental factors was studied in the Yacoub El Mansour Reservoir in a semi-arid climate in the province of El Haouz, Oued N'fis River, located 65 km south of Marrakech, Morocco. The samples were taken during two annual cycles, 2012 and 2013. In this study, six species of crustacean zooplankton of two groups, copepods and cladocerans, were identified. *Daphnia lumholtzi* was the most abundant species, accounting for 58.26% of the total zooplankton density. We recorded a low zooplankton specific richness and a great spatial heterogeneity. A canonical correspondence analysis (CCA) showed that hydrodynamics of the ecosystem, trophic relationships and environmental factors were generally responsible for the spatial and temporal distribution of these zooplankton species.

Key words: copepods, cladocerans, reservoir, limnology

Introduction

The biodiversity of aquatic ecosystems is threatened by hydrological dysfunctions, anthropogenic pollution, habitat fragmentation, overexploitation of some aquatic species, invasive organisms and climate change (Underwood et al. 2006). Databases on "macroscopic diversity" such as birds, mammals or higher vegetation have been produced (Saadi 2002). However, data on "microscopic diversity", particularly those of microfauna and algal microflora, are still fragmented, especially in freshwater ecosystems. Moreover, in recently watered reservoirs, the significant amount of organic matter from the flooded zones could stimulate bacterial production and lead to a high amount of heterotrophic and mixotrophic organisms. These could serve as a food source for crustacean zooplankton (Paterson 1997). Zooplankton plays a critical role in aquatic food chains, as it is an important source of food for planktivorous fish and invertebrates. Also, it intensely grazes on algae, bacteria, protozoa and others invertebrates (Balvay 1990).

Zooplankton community responds rapidly to environmental change because most species have very short-lived generations (Champeau 1970). It reacts to a wide variety of disturbances including the quantity of nutrients (Pace 1986, Dodson 1992), acidification of water (Brett 1989, Keller & Yan 1991), as well as sediment inputs into the environment (Paterson 2014). The study of these organisms remains a necessity for developing effective strategies for hydraulic and trophic resources management. In Morocco, few studies have been carried out on zooplankton in reservoirs, such as Lalla Takerkoust (Tifnouti 1993), Hassan I (Benzekri 1992), El Kansra (Fqih Berrada et al. 2000), Mansour Eddahbi Reservoirs (Sadani 2005) and Zima and Sedd-El-Messjoun Lakes (Saadi 1994, 2002).

Zooplankton in the Yacoub El Mansour Reservoir has never been studied, which prompted us to explore the interrelations between crustacean zooplankton and different physical and chemical parameters of a recently watered reservoir under semi-arid climate.

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Materials and Methods

Study area

The Yacoub El Mansour Reservoir is located on the N'fis' River, 65 km south of Marrakesh City. It is about 20 km upstream the Lalla Takerkoust Reservoir and 1.5 km north of the Ouirgane Village. Owing to its reserve of 70,000,000 m^3, the dam improves the regulation capacity of the N'fis' River in the Lalla Takerkoust Reservoir. Also, it decreases water loss downstream. The dam is built using concrete compacted with a ruler. It is 70 m in height, with a crest length of 233 m. This dam helps to increase the water volume of the N'fis River; this volume reaches 85,000,000 m^3 per year during filling period (Fig. 1).

Sampling

We sampled three stations in the same area and at several depths at each station. We analysed two axes of variation: spatial and temporal, during two annual cycles from January 2012 to December 2013. Sampling was done monthly in autumn and winter and fortnightly in summer and spring from the following stations:

Dam station (S1): located at the bridge. At this station, samples were taken at different depths: surface area, -1, -2.5, -5, -10, -15, -19.5 m, 1 m of the bottom and the bottom (Fig. 1).

Littoral stations: (S2) located at the inflow of the Ouirgane River and (S3) located at the inflow of the N'fis River (Fig. 1).

The water samples at S1 were taken using a closed bottle of the Van Dorn type with a 2 L capacity, while those from the littoral stations were taken directly from the surface, with a 2 L volume sampler as well. The zooplankton was collected using a 50 µm plankton net, 50 cm in diameter, collected in jars and fixed with 5% formalin. Because of their low densities, the zooplankton species were counted from the complete samples in a Dolfus tank, using a binocular magnifying glass. Species determination was done following Dussart (1969) for Copepoda and Amoros (1984) for Cladocera.

Statistical analysis and biologic indices

We determined the importance of the various correlations between the zooplankton and hydrophysical and chemical variables using canonical correspondence analysis CCA (Ter Braak 1986), using XLSTAT software.

Diversity was calculated monthly at each station, using the Shannon index (Shannon 1948):

$$H = - \sum_{i=1}^{s} (ni / N) \log (ni / N),$$

where H = Shannon's index of species diversity; ni = number of individuals for each species; N = total number of individuals; S = total number of species in the community (richness).

Equitability (or evenness, E) can be expressed as:

$$E = H / H_{max}$$

Results

Six zooplankton species were identified during the period of our study: four from Cladocera and two from Copepoda. A spatio-temporal variation in zooplankton density was recorded (Fig. 2). The biannual cycle was marked by a maximum number of species in early autumn of the first year (2012) and in spring during the second year (2013). The low specific richness affected both groups and more particularly that of the copepods, which were found throughout the sampling period but with a low abundance of 17.88% compared to the total zooplankton abundance. This group was represented by *Tropocyclops prasinus* (Fischer, 1860), with 5.70% (in relation to the total number of individuals). The species appeared to be more numerous in 2013 with a maximum number of individuals (78 ind/L) in April and less in 2012 (Fig. 3). *Acanthocyclops einslei* (Mirabdullayev & Defaye, 2004) (5.56%) reached its maximum density in January 2013, with 63 ind/L. The copepodite stages were present throughout the study period and represented 48.37% of the copepods and 8.65% of the whole crustacean zooplankton density (Fig. 3). Generally, the community was dominated by the cladocerans (82.11%). The maximum peak of their density was in September 2012 and March 2013. During the first sampling campaigns, cladocerans density was very low or null and the individuals were replaced by resting eggs at S1 station. At the dam station (S1), dominant was *Daphnia lumholtzi* (Sars, 1885) (58.26%), a perennial species in this lake and with a maximum development in spring (729 ind/L) (Fig. 3). It was followed by *Ceriodaphnia dubia* (Richard, 1894) with an abundance of 14.97%. This species reached its maximum (557 ind/L) in September, while the other two cladocerans, *Daphnia pulex* (Leydig, 1860) and *Bosmina longirostris (*O.F. Muller, 1785), had lower abundance: 6.04% and 2.84%, respectively. Densities of *D. pulex* increased towards the end of spring and autumn with a maximum of 73 ind/L. *Bosmina longirostris* was with a maximum peak in February – 71 ind/L. At the two littoral stations S1 and S2 (Fig. 4), dominated *D. lumholtzi* with a maximum in January 2012 of 430 ind/L at S2 and 30 ind/L at S3.

The influence of 11 physical and chemical parameters (temperature, pH, conductivity, dis-

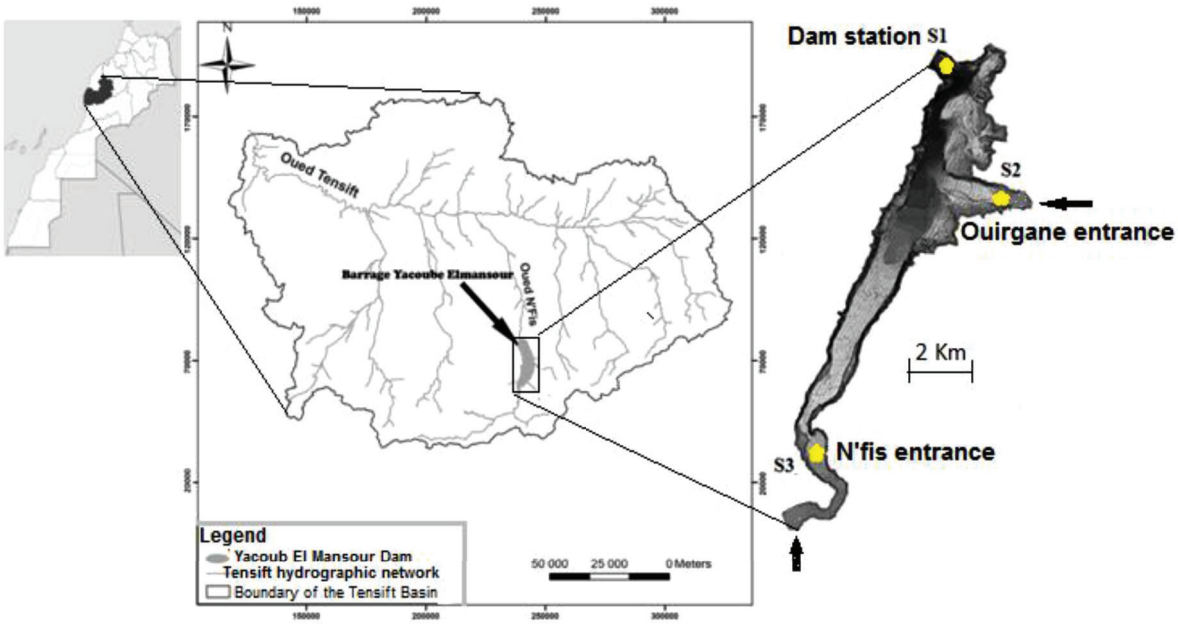

Fig. 1. Geographical location of the Yacoub El Mansour Reservoir in the Tensift El Haouz Basin, Morocco.

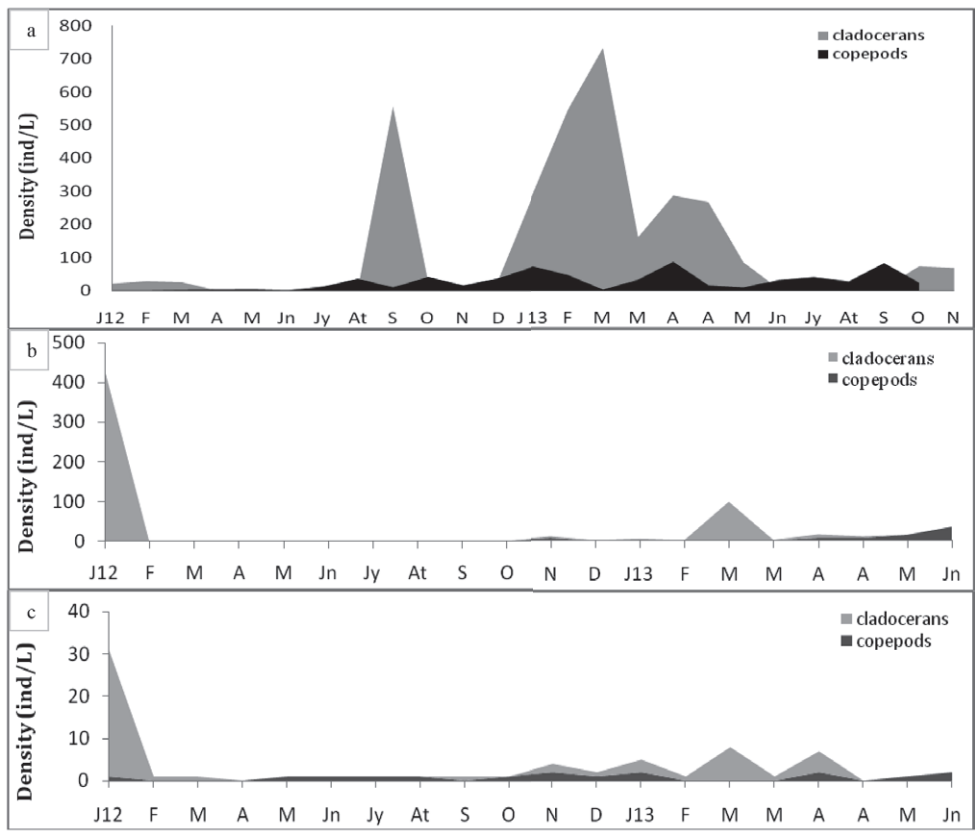

Fig. 2. Temporal variations of zooplankton density at the dam station S1 (a) and at the two littoral stations S2 (b) and S3 (c).

solved oxygen, total phosphorus, orthophosphates, nitrites, nitrates, ammonium and chlorophyll *a*) on the different zooplankton species in the Yacoub El Mansour Reservoir was assessed using Canonical Correspondence Analysis (CCA). The first two axes of the CCA represented 45.12% and 30.78% of the total inertia, respectively. The first factor axis (F1) was strongly associated with *C. dubia* (C.b), con-

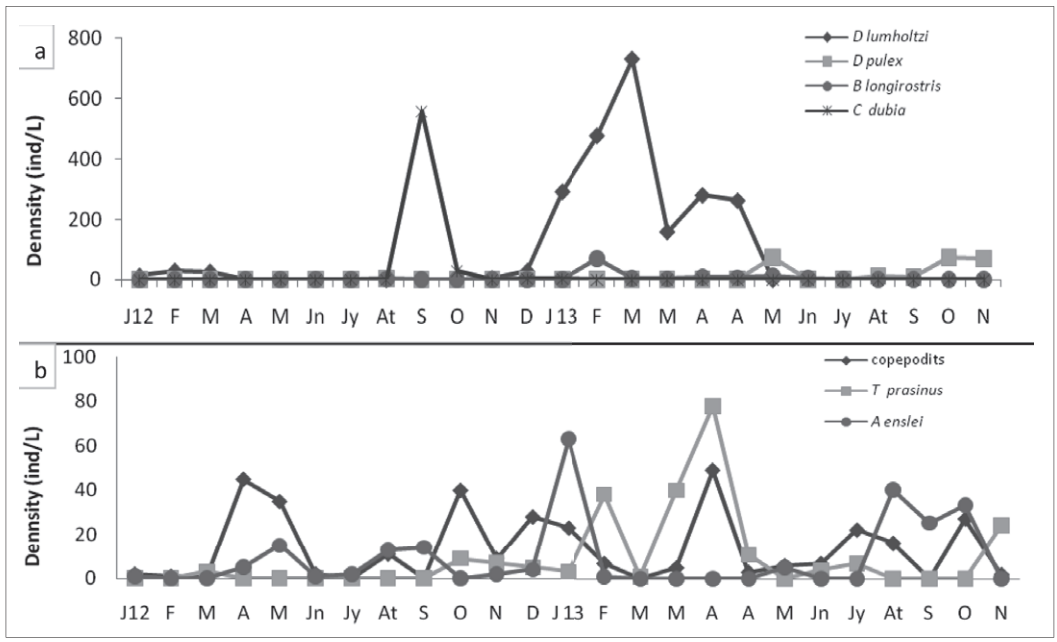

Fig. 3. Temporal variation of the different species of cladocerans density (a) and copepods density (b) at the dam station (S1).

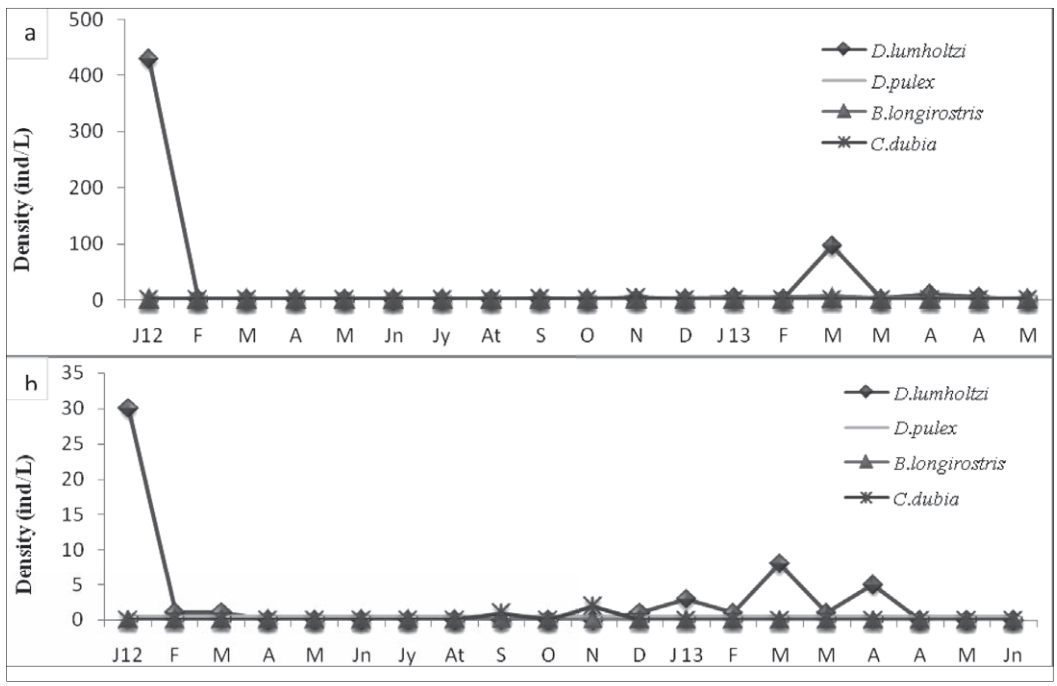

Fig. 4. Temporal variation of the different species of cladocerans density at the littoral stations S2 (a) and S3 (b).

ductivity (Cond) , dissolved oxygen (Do) and nitrate (NO_3), while the second factor axis (F2) was strongly related to *D. pulex* (D.p), filling volume (Fv) and chlorophyll *a* (chl *a*). In addition, dissolved oxygen was negatively correlated with temperature (Tem) and positively correlated with NO_3, total phosphorus (Pt) and orthophosphates (PO_4). *Daphnia lumholtzi* and *B. longirostris* were associated with high values of dissolved oxygen, total phosphorus and orthophosphates during the months of February – April 2012, whereas *D. pulex*, *A.einslei* and *T. prasinus* were associated with high values for pH, nitrates and chl *a*. *Ceriodaphnia dubia* was associated with the highest volume of filling (Fv) and nitrites (NO_2), but in the CCA ordination diagram this cladocerans species occupied an aberrant position due to its occurrence only in September 2012 (Fig. 5).

We recorded low values for the Shannon index (Fig. 6). At the dam station (S1) the minimal value (0.04) was obtained in February, when *D. lumholtzi*

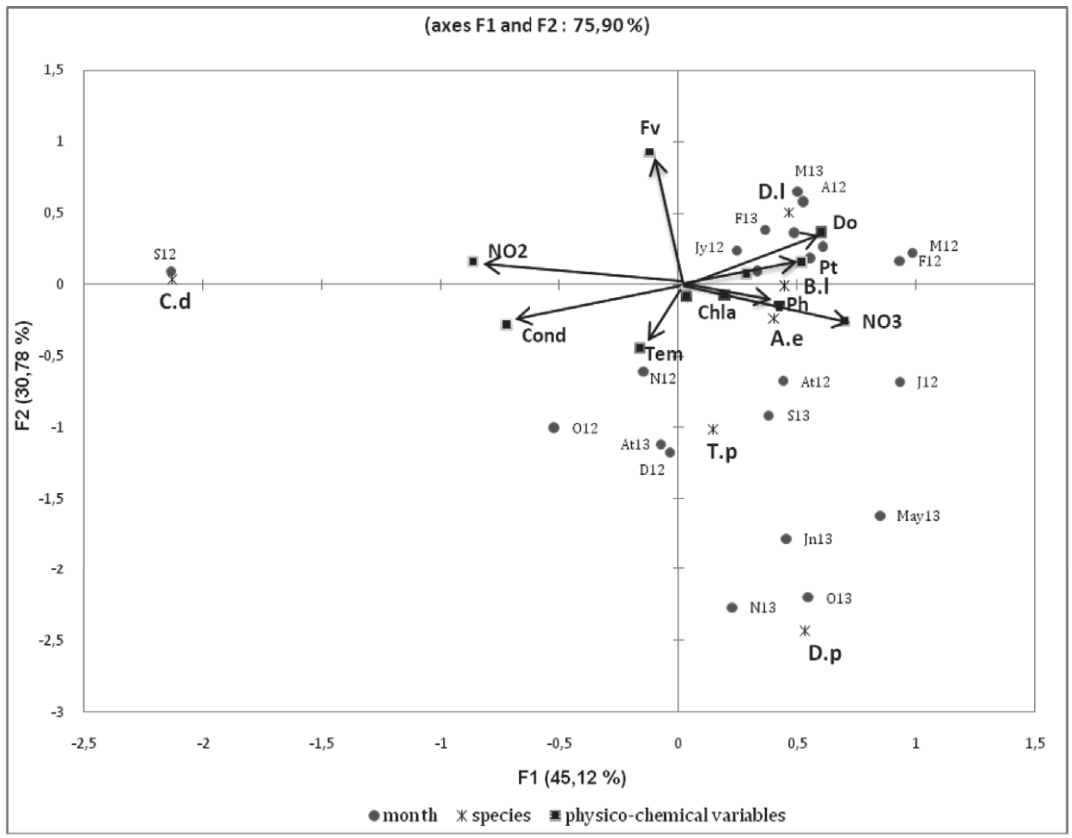

Fig. 5. CCA ordination diagram with zooplankton species and environmental variables in Yacoub El Mansour Reservoir: Daphnia lumholtzi (D.l), Ceriodaphnia dubia (C.d), Daphnia pulex (D.p), Bosmina longirostris (B.l), filling volume (Fv), total phosphorus (Pt), Orthophosphates (PO4), nitrites (NO2), nitrates (NO3), ammonium (NH4), chlorophyll a (Chl), dissolved oxygen (Do), conductivity (Cond), Temperature (Temp) and pH, January 2012 or 2013 (J12 or 13), February (F), March (M), April (A), June (Jn), July(Jy), August (At), September (S), October (O), November (N), December (D).

dominated, with a density of 475 ind/L. The maximum value (1.36) was observed in December. The values of the equitability index (E) were below 0.6 during the two annual cycles.

The study of the vertical distribution of zooplankton showed that the zooplankton is concentrated over the first 10 meters (Fig. 7).

Discussion

The abundance and specific zooplankton richness in the Yacoub El Mansour Reservoir were low compared to those found in other Moroccan Reservoir: eight crustaceans zooplankton at the Lalla Takerkoust Reservoir (Tifnouti 1993) and 12 at the Hassan I Reservoir (Benzekri 1992). This was confirmed by the low values for the Shannon index (Fig. 6), which indicated the presence of dominant species. Its maximum value could be explained by the coexistence of the six species studied in the Yacoub El Mansour Reservoir. That was confirmed by the values of the equitability index (E), which emphasised the imbalance of the ecosystem and the poor distribution of species over the time of the study. Indeed, the Yacoub El Mansour Reservoir has started operating only recently. Also, the period of study coincided with a period of frequent draining especially during 2012. This has generated a short retention time in the reservoir (Benzha 2005). The impact of draining on the zooplankton populations has been underlined by many authors (Coman 2006, Axelson 1961). Brook & Woodward (1956) found that high rates of water turnover can cause quantitative and qualitative variations of the plankton in the lakes. In general, the low abundance of cladocerans and copepods is associated with environmental conditions, caused by the hydrodynamics of the reservoir, such as the low water volume, short residence time and morphometry (Isumbisho 2006). Predation by planktivorous fish and the poor availability of food sources, may also lead to a reduction in the species richness of the reservoir (Achembach & Lampert 1997). According to an earlier study on the Yacoub El Mansour Reservoir (Hammou 2014), its phytoplankton community was not very diversified and quantitatively only a few species played a decisive role in this lake. This may

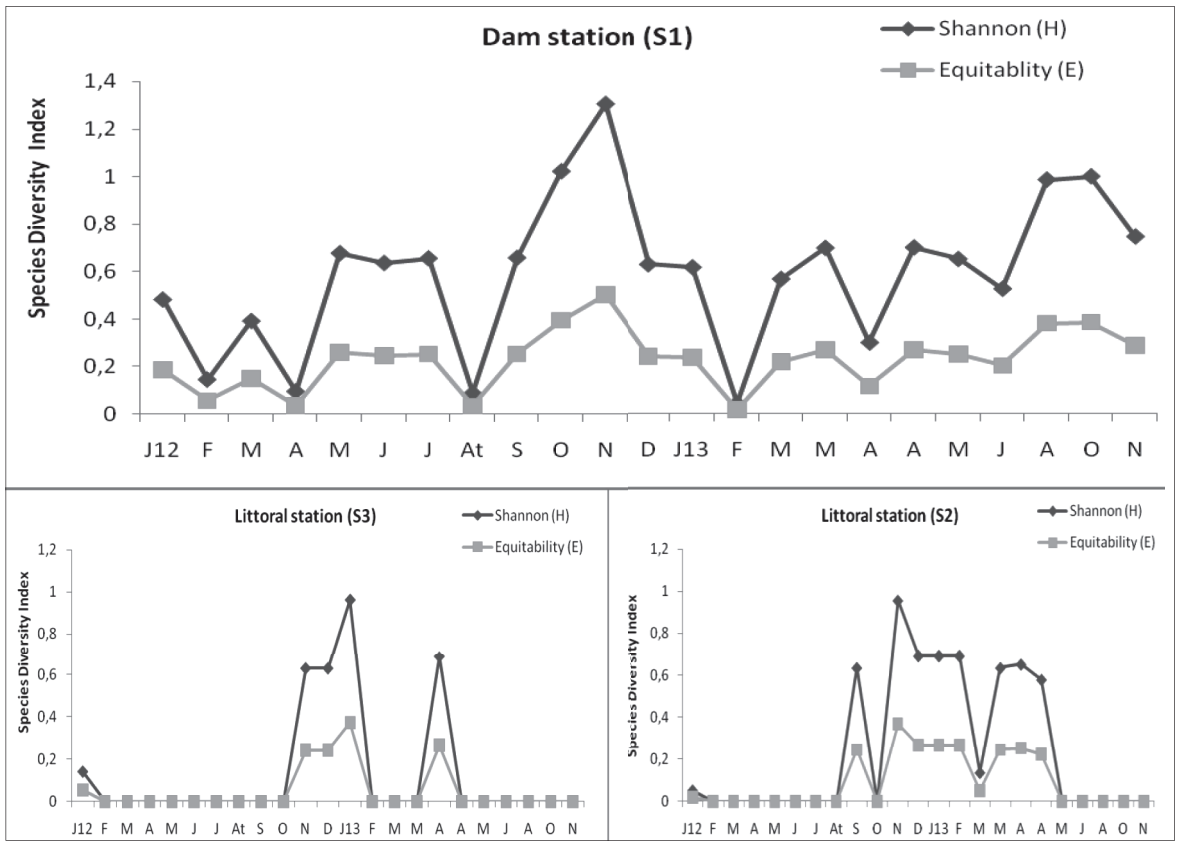

Fig. 6. Monthly dynamics of Shannon diversity index (H) and equitability (E) of zooplankton species in Yacoub El Mansour Reservoir.

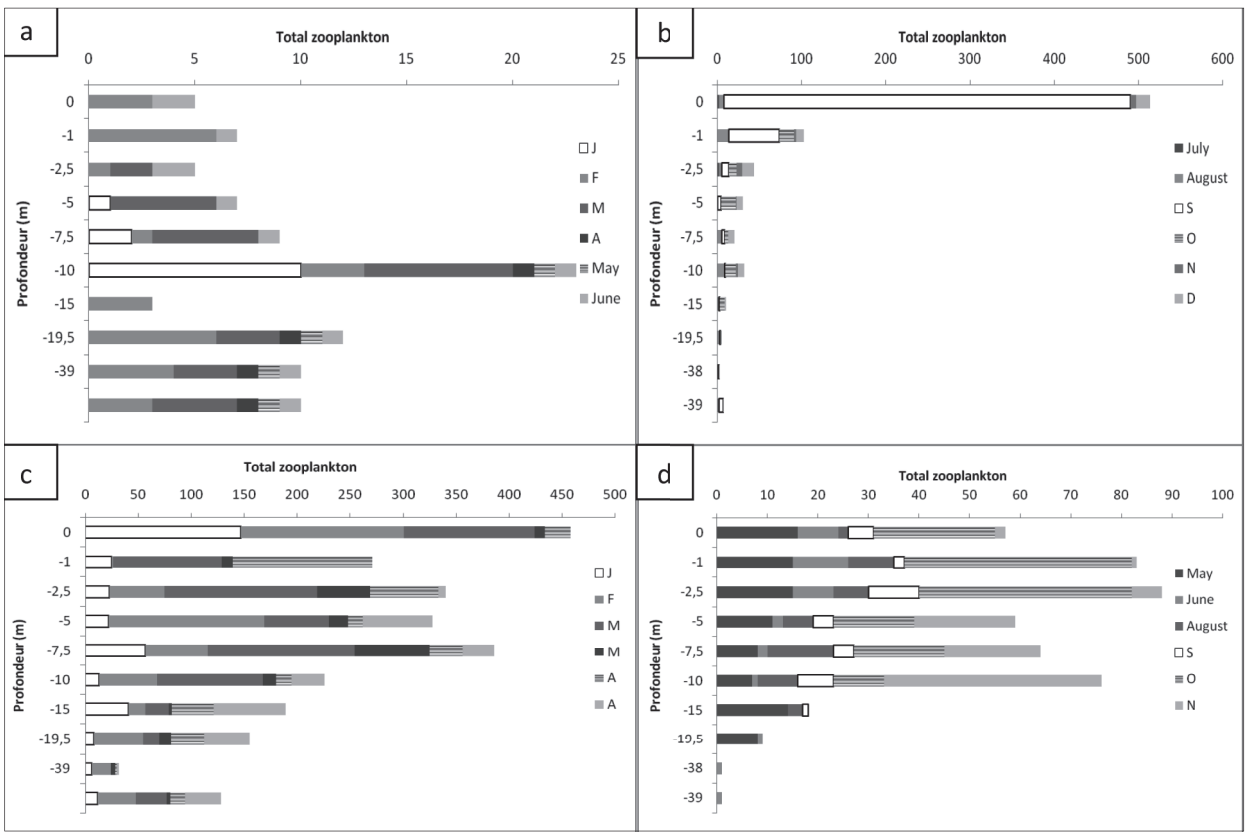

Fig. 7. Vertical profiles of total zooplankton density at dam station (S1), during the two annual cycles 2012 (a and b) and 2013 (c and d).

also explain the low species richness of zooplankton communities in the reservoir.

In the Yacoub El Mansour Reservoir, the arid climate favoured the existence of two periods of abundance during the year: an autumn-spring period favourable for the development of zooplankton and a winter-summer period, characterised by a significant decline of the number of species, their densities and their distributions. During the rainy season, water supplies upstream from the reservoir and precipitation tend to cause small mixtures of water bodies: nutrients are then available in the oxygenated water and are very rapidly assimilated by the invertebrates, which could lead to the development of zooplankton. In addition, some fish take advantage of exogenous inputs during the rainy season, whereas in the dry season some fish consume endogenous material (mainly micro-crustaceans) and consequently cause a decrease in the abundance of the zooplankton population (Horeau et al. 1998). Muylaert (2003) also corroborated the conclusion, that zooplankton biomass generally reaches its peak during rainfall in reservoirs. In spring, physical factors (nutrient input, photoperiod and temperature raise) increase the primary production (phytoplankton) (Cherifi 1992), which increases zooplankton density (Tifnouti 1993). Positive correlations between pH and conductivity with some zooplankton species (see Fig. 5) show that alkaline pH and high conductivity also promote the growth of some zooplankton in the reservoir. This is in agreement with the conclusions of Byars (1960), Hujare (2005) and Mustapha (2009).

At the dam station, the density of the zooplankton species was higher compared to the two littoral stations, due to their relative stability and slower flow velocity. Similar results were found by Tifnouti (1993) for the Lalla Takerkoust Reservoir. In summer, according to the PEG model (Plankton Ecology Group), small cladocerans are replaced by larger cladocerans and adults copepods (Sommer et al. 1986, Lair & Ayadi 1989, Tifnouti 1993). In the Yacoub El Mansour Reservoir, during the summer, most crustacean zooplankters were absent and only a few individuals of Copepoda and Cladocera were recorded, mainly the small *B. longirostris*, which continues its development by parthenogenesis until late spring. Sexual reproduction occurs around June, which ensures the new generation next winter. This type of development is similar to that observed by Tifnouti (1993) for the Lalla Takerkoust Reservoir. In the Yacoub El Mansour Reservoir, this species reaches its maximum density in February, which is in agreement with the results of Vijverberg (1980), which shows that *B. longirostris* is adapted to low temperatures of the environment. The depletion of zooplankton at depths from -15m, particularly at young stages, may be related to the high suspended mater (Tifnouti 1993), or to low availability of food. Juvenile stages preferentially stay in warmer and more nutrient-rich surface waters (Hutchinson 1967, Kerfoot 1980).

Conclusion

The zooplankton in the oligotrophic Yacoub El Mansour Reservoir (Chakir & Saadi 2016), set in 2008, was characterised by a very low number of individuals per litre and a low species richness (four cladocerans and two copepods). The spatial and temporal variations of zooplankton species followed a distribution pattern strongly influenced by conditions. The environmental conditions fluctuated according to the season: water level, temperature, pH, conductivity, dissolved oxygen, suspended matter, total phosphorus, orthophosphates, nitrites, nitrates, ammonium and chlorophyll *a*. Moreover, the floods of the wet season could favour the appearance of sporadic species. Among all the factors, the fluctuations in water level and temperature, associated with the semi-arid climate of the region with a period of great drought, are responsible for the temporal distribution of the species in the Yacoub El Mansour Reservoir. Our findings should be expanded taking into account the other components of the trophic chain, in particular Protozoa, Rotifera, phytoplankton and fish, in order to integrate the "crustacean zooplankton" component into the conceptual models that describe the effect of the manipulations of trophic chains on water quality. Generally, successive draining should be taken into account in the management of the tanks where fish farming is required.

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