# Bio–ecology of *Potamon algeriense* (Herbst, 1785) (Crustacea, Decapoda) in eastern Morocco

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**Abstract**

*Bio–ecology of* Potamon algeriense *(Herbst, 1785) (Crustacea, Decapoda) in eastern Morocco.* To contribute to the knowledge of *Potamon algeriense* bio–ecology in eastern Morocco and the Moulouya watershed, a total of 90 stations were surveyed between 2013 and 2016. Of these, only 14 stations (out of the 90 surveyed) were positive concerning the occurrence of this species, which was found to be limited to the middle and lower watercourses of the Moulouya watershed, and specifically to Oued Za, Zegzel and the lower watercourse of the sub–basin Mouth of the Moulouya. The results of the statistical analyses showed that the main factors influencing the distribution and abundance of *Potamon algeriense* were temperature, $BOD_5$, and conductivity.

Key words: Anthropogenic activities, Freshwater crab, eastern Morocco, Moulouya

**Resumen**

*Bioecología de* Potamon algeriense *(Herbst, 1785) (Crustacea, Decapoda) en Marruecos oriental.* Para contribuir al conocimiento de la bioecología de *Potamon algeriense* en Marruecos oriental y la cuenca hidrográfica del río Muluya, se estudiaron 90 estaciones entre 2013 y 2016, de las que solo 14 albergaban a esta especie, que se observó se encontraba limitada a los cursos de agua medio e inferior de la cuenca hidrográfica del río Muluya y más concretamente a las zonas de Oued Za, Zegzel y el curso inferior de la subcuenca de la desembocadura del río Muluya. Los resultados de los análisis estadísticos mostraron que los principales factores que influyen en la distribución y la abundancia de *Potamon algeriense* fueron la temperatura, la $BOD_5$ y la conductividad.

Palabras clave: Actividades antropogénicas, Cangrejo de agua dulce, Marruecos oriental, Muluya

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## Introduction

The Potamoidea Ortmann, 1896 superfamily includes two families, namely, Potamidae Ortmann, 1896 and Potamonautidae Bott, 1970. In North Africa, each one is represented by one genus, *Potamon* Ortmann, 1896, and *Potamonautes* MacLeay, 1837, respectively (Cumberlidge, 1999, 2009; Brandis et al., 2000).

The family Potamidae comprises 95 genera and more than 505 species that are distributed throughout the southern Palaearctic and eastern zoogeographic regions (Cumberlidge et al., 2008, Yeo et al., 2008). The representative of this family in North Africa and the Maghreb is *Potamon algeriense* (Herbst, 1785). Bott (1967) established this taxon as the subspecies *Potamon fluviatilis algeriensis*, and Pretzmann (1976) treated it as the subspecies *Potamon fluviatilis berghetripsorum*. This species was later revised to *Potamon (Eutelphusa) algeriense* by Brandis et al. (2000), and it is treated here as *Potamon algeriense* following the opinion of Cumberlidge (1998).

The species is included in the subfamily Potaminae Ortmann, 1896, whose members are located around the Mediterranean, the Middle East and the Himalayas (Cumberlidge, 2010). In fact, *P. algeriense* represents the most western extension of this subfamily in North Africa. It is found in the temperate rivers of the Maghreb and in seasonal dry–water bodies in arid climates where crabs tend to be semi–terrestrial and live in burrows (Bott, 1967; Brandis et al., 2000).

The species is found only in the northwestern African region, specifically in Morocco, Algeria and Tunisia (Cumberlidge, 2009). In Morocco, the species has been recorded from the Rif in the watershed of the Oued Laou near Chefchaouen, from the Middle Atlas in the Oued Oum Rbia basin (Aymerich, 2002), and from Eastern Morocco (García et al., 2010).

The species seems to inhabit almost any type of freshwater habitat, including springs and their outfalls, streams, and mountain rivers at altitudes ranging between 9 and 875 m. They are usually found under stones or dead logs, in full water, or in the riparian area. The burrows are dug in the muddy soil and can be 30–40 cm deep with water at the bottom. Younger specimens are also present in the water. Adults can be found far from the water, in dried river beds and even in the forest (Beni Snassen) at night. In seasonal rivers such as Oued Cherraa, the species tends to be semi–terrestrial, and during drought, it digs galleries near watercourses (Bott, 1967; Brandis et al., 2000). *P. algeriense* is an omnivore: its diet consists of invertebrates, earthworms, crustaceans (including small individuals of the same species), cadavers, and detritus of any kind. Adult individuals occupy a more favorable area for availability of food than juveniles who rely on small prey such as batrachian eggs, fish and vegetable waste.

Despite the wide distribution of *P. algeriense* in the Maghreb, its distribution is discontinuous and fragmented. The decrease in its populations in Morocco is worrying. Indeed, this species has not been seen for many years in Oued Sebou (Provinces of Fez and Kenitra) (Cumberlidge, 2010). *P. algeriense* is threatened with extinction due to anthropogenic activity by industrial and domestic liquid waste (García et al., 2010).

The main aim of this manuscript was to contribute to the knowledge of the bio–ecology of *P. algeriense* in the watershed of Moulouya and Eastern Morocco, to update the information on its geographical distribution in the studied region, and to highlight the species preferences in terms of type of habitat and the physico–chemical quality of the water.

## Material and methods

### Study area

Morocco is currently divided, according to the new administrative division, into 12 regions including the Oriental Region (fig. 1A), which occupies the entire eastern side of the country and covers an area of 88,681 km$^2$. This area is bounded to the north by the Mediterranean Sea, to the east and south by the Morocco–Algerian border, and to the west by the administrative regions of Tangier–Tetouan, Al Hoceima, Fez Meknes, and Draa–Tafilalt.

The Oriental region includes the wilaya of Oujda (Oujda–Angad prefecture) and the provinces of Berkane, Taourirt, Jerada, Nador, Figuig, Driouch, and Guercif. The watershed of the Moulouya (74,000 km$^2$) (fig. 1A), which includes nearly 44,000 km$^2$ to the east of Morocco, covers much of the Oriental region. It is located between parallels 36 and 39 degrees north and the meridians 5.5 and 7 degrees west. With a length of 600 km, the Moulouya is the largest North African river flowing into the Mediterranean. It starts at the junction of the High and Middle Atlas chains, and flows primarily along a southwest–northeast axis. Its main tributaries, Anzegmir Wadi, Melloulou Wadi and Za Wadi, are perennial, while others flow only during floods (3–5 floods on average per year). The river flows through various Mediterranean bioclimatic zones (Berrahou et al., 2001).

### Surveys

The field surveys were carried out between 2013 and 2016. To update the rare data on the bio–ecology of *P. algeriense* in Moulouya's watershed and eastern Morocco, we prospected 45 stations along the Moulouya and its respective tributaries, Oued Anzegmir, Oued Melloulou and Oued Za. These surveys were supplemented by data from more than 45 other stations spread throughout eastern Morocco, from Nador, Saida and Béni Snassen in the north, to Figuig in the southeast, and Talessint and Bouanane in the southwest.

Sampling for *P. algeriense* was carried out by a turbid net in aquatic environments, while the search for adults outside the water was carried out by hand or with the aid of clamps. These operations took about one hour of excavation at each station. All captured specimens were released into their natural habitats after being sexed and measured, and after additional information was taken.

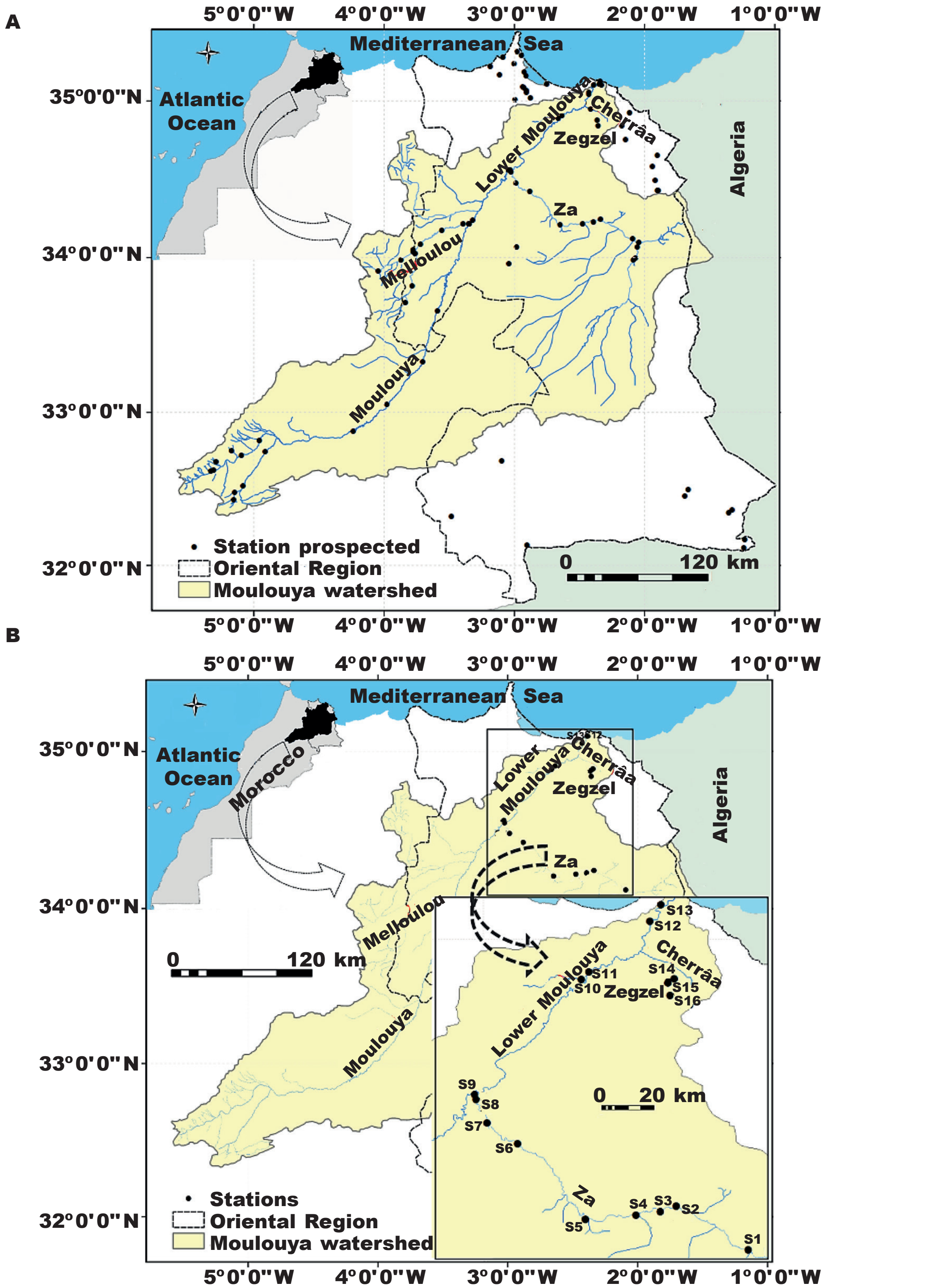


Fig. 1. A, studied localities of the Oriental Region of Morocco and the Moulouya River basin; B, distribution area of *Potamon algeriense* in the study area.

*Fig. 1. A, localidades estudiadas de la región oriental de Marruecos y la cuenca hidrográfica del río Muluya; B, área de distribución de* Potamon algeriense *en la zona de estudio.*

In order to contribute to the study of its diet, and in addition to our harvested field data, we kept an adult couple and two juveniles in conditioned tanks in the laboratory. They were fed on various resources found in their living environment. The animals were released into their natural habitats once the study was completed.

Water sampling

From each station, two replicates of water samples were taken in polyethylene bottles of 500 ml (the results of which are their averages). The water samples were preserved with 2 ml of concentrated hydrochloric acid (pH = 2). According to standard norms ISO 5667–6 (1990), ISO 5667–2 (1991) et ISO 5667–3 (1994), the water samples were conveyed to a cooler at a low temperature (± 4 °C) to stop metabolic activity of organisms in the water. The following physico–chemical parameters were measured in the laboratory: sulfates ($SO_4^{2-}$), biological oxygen demand after five days ($BOD_5$), orthophosphates ($PO_4^{3-}$), ammonium (mg $N–NH_4$),and nitrates (mg $N–NO_3$). These parameters are determined according to the standards AFNOR (1997) and Rodier et al. (1996). Conductivity, pH, dissolved oxygen, and temperature were measured (in situ) in the field.

Statistical processing of data

Statistical analyses were carried out using software R in version 3.3.1.

To determine the ecological factors governing the distribution and abundance of *P. algeriense*, we subjected a matrix of nine abiotic parameters, representing the average of the different descriptors measured in the 16 stations of the lower Moulouya river (annex 1), to a normed principal component analysis.

## Results and discussion

Distribution and habitat types

In the Moulouya watershed and in eastern Morocco, the distribution of *P. algeriense* was limited to the sub–watersheds of Oued Za from S1 to S9 (High Plateaux), the Oued Zegzel–Cherrâa complex from S14 to S16 (Beni Snassen), and Lower Moulouya from the two dams to the pre–mouth area from S10 to S13 (see fig. 1B), where healthy populations were detected and adults reached a maximum carapace length of 50 millimetres.

Analysis of the physical–chemical parameters of the different stations sheltering *P. algeriense*

Of the 16 stations selected, *P. algeriense* occurred in all but two (stations S7 and S13).

Annex 1 presents the nine physico–chemical variables measured at each of the 16 stations:

Apart from a slight alkalinity observed in S11, pH values showed neutrality in most stations (annex 1). This is probably due to the presence of carbonates that buffer the waters flowing to the Moulouya Wadi, streaming and infiltrating into the maro–dolomitic and calcareous cover (Taybi, 2016).

In the wadi of the Moulouya, the temperature of the water is linked to local conditions (climate, duration of sunshine, flow and altitude) and to seasonality (Taybi, 2016). During the study period, average temperatures do not exceed 23 °C. Given the lack of sampling during winter, our study does not reveal the lowest temperature at which the crab remains active.

The conductivity of the Moulouya waters fluctuates in time and space, and generally increases from upstream to downstream (Taybi, 2016). The stations with a positive occurrence of the species studied were characterized by acceptable conductivity values, fluctuating between 305 $\mu s.cm^{-1}$ recorded in upstream Oued Zeghzel and about 1,700 $\mu s.cm^{-1}$ downstream from Oued Moulouya.

The waters of the positive stations for *P. algeriense* had high to acceptable levels of dissolved oxygen. A maximum of 11.5 $mg.l^{-1}$ was recorded at station S14, which is a rheocrenous source very rich in macrophytes.

The values recorded in major ions ($NH_4$, $NH_3$, $SO_4$ and $PO_4$) and $BOD_5$ in the waters of the studied stations (annex 1) make it possible to place these waters in general in the grid of good quality (ABHM, 2012), with the exception of the station S6 which recorded relatively high values. Indeed, this station located downstream of Oued Za receives discharges of domestic and industrial waste water from peripheral agglomerations (Mabrouki et al., 2016a; Bensaad et al., 2017).

The freshwater crab thus appears to be relatively demanding in terms of the physico–chemical quality of the water (fig. 2). Thus, in the Moulouya watershed and in Eastern Morocco, the species is present only in richly oxygenated and weakly mineralized neutral waters, with low concentrations of major ions and $BOD_5$. Concerning temperature, it is difficult to accurately judge its interval in the study area since no sampling was done during the flood season, but the species seems to prefer temperatures cooler than 23 °C.

Statistical analysis

The principal component analysis of the different mesological parameters of the prospected stations shows that the first two axes, F1 and F2 (fig. 3), hold most of the information since they represent 75.14 % of the total inertia. Examination of the correlations between the axes and the various mesological components studied explains the significance of each axis in the structured distribution of the station cloud and the relation between abundance and environmental variables.

The F1 axis (62.75 % of total inertia) was negatively correlated with the pollution parameters ($BOD_5$, r = –0.91) and positively with dissolved oxygen (r = 0.87). The axis F1 therefore expresses a gradient

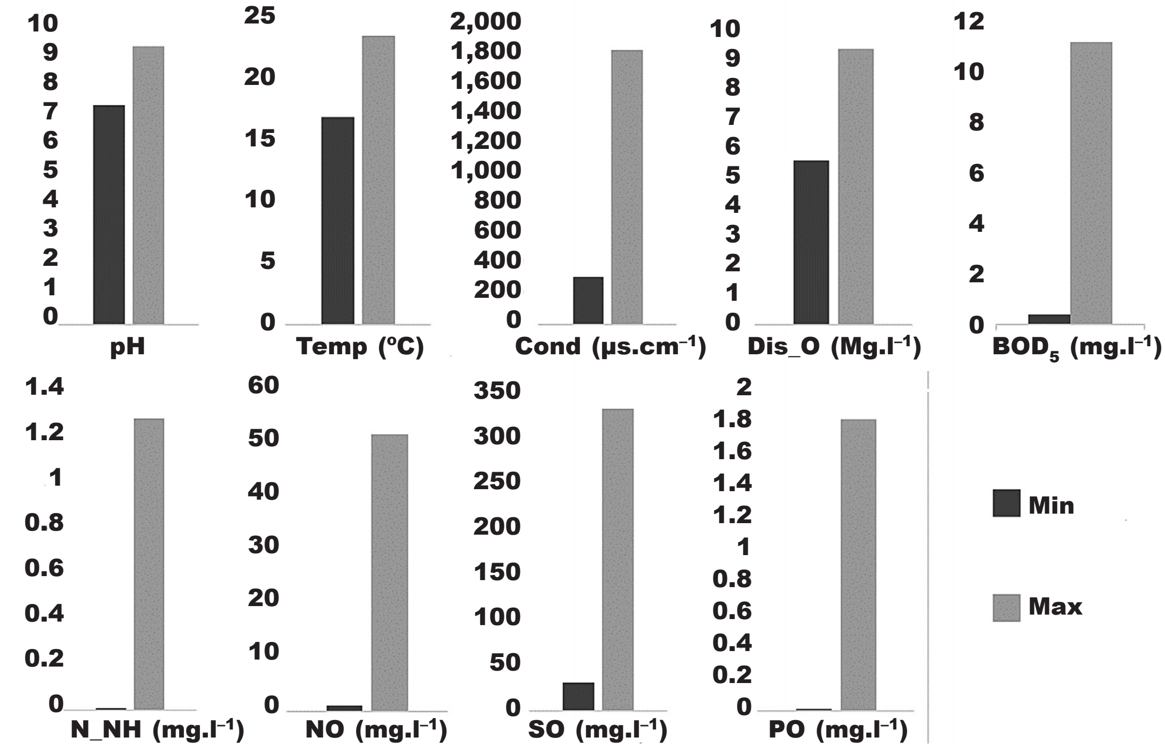


Fig. 2. Graphs showing the tolerance interval of *Potamon algeriense* in relation to the abiotic descriptors studied.

*Fig. 2. Gráficos del intervalo de tolerancia de* Potamon algeriense *en relación con los descriptores abióticos estudiados.*

of pollution by separating the most polluted station to the left (S7: on Oued Za River) and the most oxygenated stations to the right.

The total absence of *P. algeriense* in station S7 is certainly due to pollution caused by the liquid and industrial discharges that this station receives from the province of Taourirt (Mabrouki et al., 2016a; Bensaad et al., 2017).

The F2 axis (12.39 % of the total inertia) respectively translates two environmental gradients, temperature and conductivity, and isolates the station closest to the Mediterranean, S13. The relatively high salinity of this station explains the absence of *P. algeriense* in S13. The maximum abundance of *P. algeriense* was recorded in low conductivity waters (S14, S15 and S16).

The correlation ratio of the environmental parameters of the environment (fig. 3D) with the abundance of *P. algeriense* shows that the latter is positively correlated with dissolved oxygen (r = 0.75), and negatively with $BOD_5$ (r = –0.62), conductivity (r = –0.62) and temperature (r = –0.59). The results of the analyses show that *P. algeriense* prefers oxygenated water, and that high conductivity and pollution are among other factors limiting its abundance.

## Conclusion

Despite efforts to conserve the aquatic ecosystems of the Moulouya watershed and eastern Morocco, severe degradation continues to accelerate. This deterioration is becoming more and more worrying because of the multiplication of sources of pollution of domestic, industrial, and agricultural origin (Taybi et al., 2016a; Mabrouki et al., 2016a, in press a; Bensaad et al., 2017; Ramdani et al., 2017; Yahya et al., 2017). This anthropogenic activity, aggravated and accentuated by episodes of drought, results in a loss of aquatic biodiversity (Berrahou et al., 2001; Millán et al., 2016; Taybi, 2016; Taybi et al., 2016b; Mabrouki et al., 2016b, 2017b, in press a, in press b).

The results of this study show that *P. algeriense* is restricted to the northeastern part of the study area, the Moulouya watershed, where it prefers oxygenated water with a low to medium conductivity. Our results also strongly suggest that the large reduction in its regional range is caused by anthropogenic pollution. With these unmeasured anthropogenic activities, the regional distribution of many species has declined sharply or disappeared (Taybi, 2016; Mabrouki, 2017; Taybi et al., 2017a, 2017b). However, further surveys

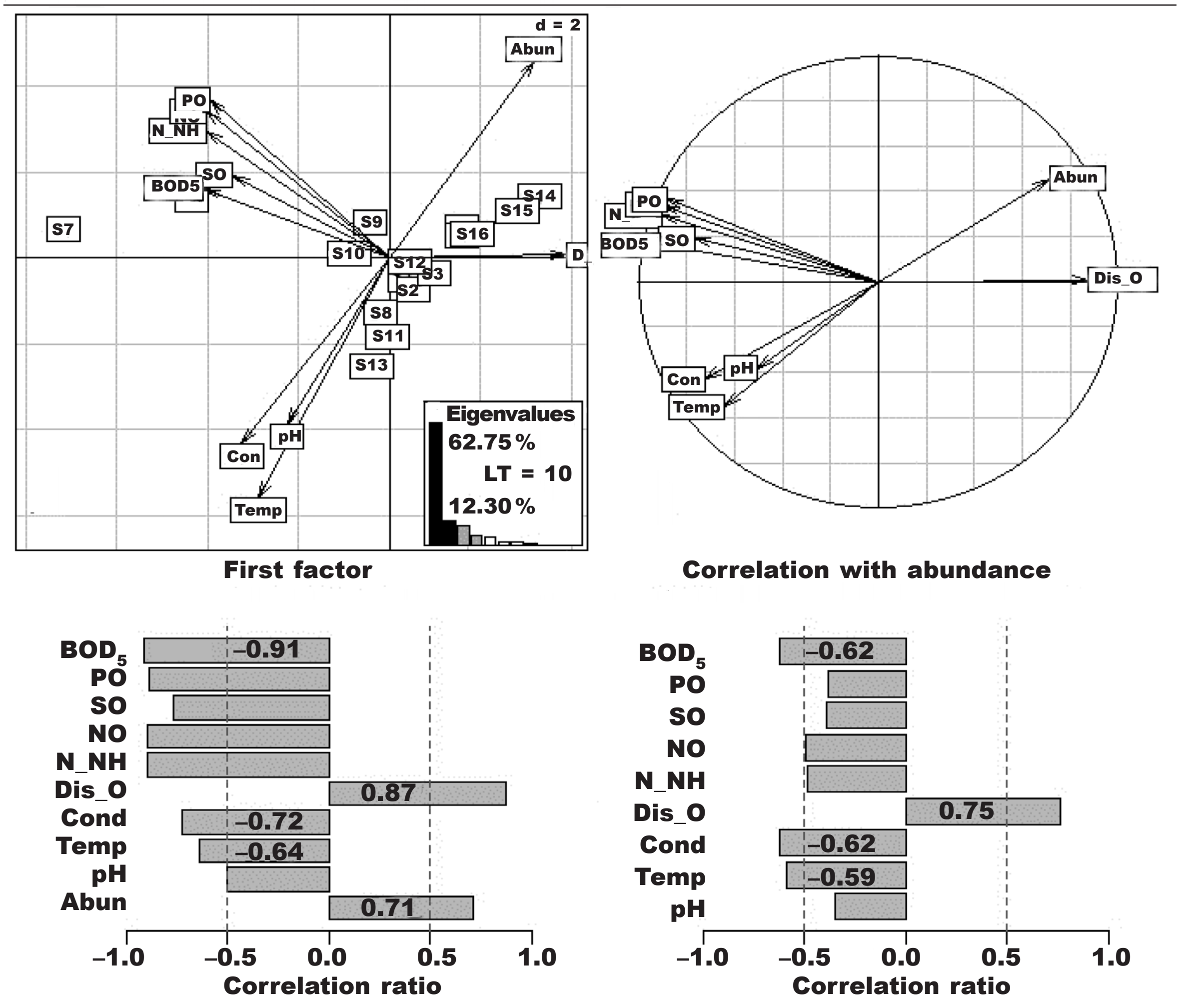


Fig. 3. A, biplot of the principal component analysis (PCA) in plane F1–F2 presenting the physical–chemical parameters and the stations; B, correlation circle of the PCA; C, correlation relationship between the physical–chemical parameters and the first axis of the PCA; D, correlation relationship between physical–chemical parameters and abundance.

*Fig. 3. A, diagrama de dispersión biespacial (biplot) del análisis de componentes principales (ACP) en el plano F1–F2 en el que se presentan los parámetros fisicoquímicos y las estaciones; B, círculo de correlaciones del ACP; C, correlación entre los parámetros fisicoquímicos y el primer eje de ACP; D, correlación entre los parámetros fisicoquímicos y la abundancia.*

targeting inaccessible areas could increase the known range occupied by *P. algeriense* in eastern Morocco and the basin of Moulouya River. Indeed, a new survey carried out in 2017 not far from the town of Guercif (34º 13' N – 3º 19' W) has allowed to expand the distribution of the species in the study area.

## References

ABHM (Agence du Bassin Hydraulique de la Moulouya), 2012. *Etat de la qualité des ressources en eau dans le bassin de la Moulouya 2011–2012*. ABHM, Oujda.

AFNOR (Association française de Normalisation), 1997. *Qualité de l'eau. Recueil des Normes Françaises Environnement*, Tomes 1, 2, 3 et 4. AFNOR, Saint Denis.

Aymerich, M., 2002. Carnets de Voyages Naturalistes au Maroc. http://geos nature.org/carnet_07_08_2002.html

Bensaad, H., Mabrouki, Y., Taybi, A. F., Chafi, A., 2017. Assessment of wastewater discharges from Taourirt City on the water quality of the Oued Za (Eastern Morocco). *Journal of Materials and Environmental Science,* 8(7): 2365–2371.

Berrahou, A., Chavanon, G., Belloulali, A., Richoux, P., 2001. Études sur la Basse Moulouya (Maroc

oriental): 7 – Les Coléoptères aquatiques de l'oued Za. *Bulletins mensuels–Société linnéenne de Lyon,* 70(5): 127–131.
Bott, R., 1967. Potamidae (Crustacea, Decapoda) aus Afghanistan, Westasien und dem Mittelmeerranum (Eine Revision der Untergattung *Potamon* s str.). *Videnskabelige Meddelelser fra Dansk Naturhistorisk. Foren.:* 7–43.
Brandis, D., Storch, V., Türkay, M., 2000. Taxonomy and zoogeography of the freshwater crabs of Europe, North Africa and the Middle East. *Senckenbergiana biologica,* 2: 5–56.
Cumberlidge, N., 1998. The African and Madagascan freshwater crabs in the Zoologische Staatssammlung, Munich (Crustacea, Decapoda, Brachyura, Potamoidae). *SPIXIANA*, 21(3): 193–214.
– 1999. The freshwater crabs of West Africa. Family Potamonautidae. In: *Faune et Flore Tropicales*, 35: 1–382. Institut de recherche pour le développement–IRD (ex–ORSTOM), Paris.
– 2009. Freshwater Crabs and Shrimps (Crustacea: Decapoda) of the Nile Basin. In: *The Nile. Origin, Environments, Limnology and Human, Use,* chapter 27: 547–561 (H. J. Dumont, Ed.). *Monographiae Biologicae*, 89. Springer, New York.
– 2010. The status and distribution of freshwater crabs, In: *The Status and Distribution of Freshwater Biodiversity in Northern Africa*, 6: 71–78 (N. García, A. Cuttelod, D. Abdul Malak, Eds.). IUCN, Gland, Switzerland, Cambridge, UK, and Spain.
Cumberlidge, N., Daniels, S. R., Sternberg, Rv., 2008. A revision of the higher taxonomy of the Afrotropical freshwater crabs (Decapoda: Brachyura) with a discussion of their biogeography. *Biological Journal of the Linnean Society,* 93: 399–413.
García, N., Cuttelod, A., Abdul Malak, D. (Eds.), 2010. The Status and Distribution of Freshwater Biodiversity in Northern Africa. IUCN, Gland, Switzerland, Cambridge, UK, and Malaga, Spain.
Mabrouki, Y., 2017. Comparative study of the longitudinal distribution of the benthic invertebrates of the two catchments: Za and Melloulou (tributaries of the Moulouya). PhD Thesis, Univ. Mohamed Premier, Oujda Morocco (in French).
Mabrouki, Y., Taybi, A. F., Bensaad, H., Berrahou, A., 2016a. Variabilité spatio–temporelle de la qualité des eaux courantes de l'Oued Za (Maroc Oriental). *Journal of Materials and Environmental Science,* 7(1): 231–243.
Mabrouki, Y., Taybi A. F. & Berrahou, A. (in press a). L'évolution spatio–temporelle de la qualité des eaux courantes de l'Oued Melloulou (Maroc). *Revue des sciences de l'eau,* 30.2.
Mabrouki, Y., Taybi, A. F., Chavanon, G., Vinçon, G., Berrahou, A., 2016b. Contribution à l'étude des plécoptères dans le Maroc Oriental et le bassin versant de la Moulouya et leur distribution en fonction des étages bioclimatiques. *Journal of Materials and Environmental Science,* 7(6): 2178–2193.
Mabrouki, Y., Taybi, A. F., El Alami, M. & Berrahou, A., 2017b. New and interesting data on distribution and ecology of Mayflies from Eastern Morocco (Ephemeroptera), *Journal of Materials and Environmental Science,* 8(8): 2832–2859.
Mabrouki, Y., Taybi, A. F., Berrahou, A., Chaabane, K., Legssyer, B. (in press b). Case study of the freshwater shrimp *Atyaephyra desmarestii* (Millet, 1831) (Crustacea, Decapoda) in the watershed of Moulouya and Eastern Morocco. *Vie et Milieu*.
Millán, A., LMohdi, O., Antonio, Carbonell, J., Taybi, A. F., Dakki, M., 2016. A new species of *Aphelocheirus* (Hemiptera: Heteroptera: Aphelocheiridae) from Morocco. *Zootaxa,* 4173(6): 577–582.
Pretzmann, G., 1976. *Fluviatilis berghetripsorum* nov. subspec, eine neue Süsswasserkrabbe aus Marokko. *Ann. naturhist. Mus. Wien*, 80: 451–452.
Ramdani, M., Taybi, A. F., Mabrouki, Y., Haloui, B., El Asri, O., Elmsellem, H., El Khiati, N., Mostareh, M., 2017. The spatial variability of water quality in the Mediterranean of eastern Morocco. *Moroccan Journal of Chemistry,* 5(2): 227–235.
Rodier, J., Bazin, C., Broutin, J. P., Chambon, P., Champsaur, H., Rodi, L., 1996. *L'analyse de l'eau*, 8ème édition. Edition Dunod, Paris, France.
Taybi, A. F., 2016. Hydrobiological study of the Moulouya: Structure of the biodiversity and longitudinal zonation of benthic invertebrates. PhD Thesis, Univ. Mohamed Premier, Oujda, Morocco (in French).
Taybi, A. F., Mabrouki, Y., Berrahou, A., Chaabane, K., 2016a. Évolution spatiotemporelle des paramètres physicochimiques de la Moulouya. *Journal of Materials and Environmental Science,* 7(1): 272–284.
Taybi, A. F., Mabrouki, Y., Berrahou, A., Peris–Felipo, F. J., Chaabane, K., 2016b. Contribution à l'étude de la relation «plante–hôte–parasite» entre *Elodea canadensis* Michx., *Hydrellia* sp. (Diptera) et *Ademon decrescens* (Nees, 1811) (Hymenoptera, Opiinae) dans le bassin versant de la Moulouya (Maroc), *Journal of Materials and Environmental Science,* 7(7): 2445–2452.
Taybi, A. F., Mabrouki, Y., Chavanon, G., Millán, A., Berrahou, A., 2017b. New data on aquatic beetles of Morocco (Coleoptera Adephaga: Gyrinidae, Haliplidae and Dytiscidae). *Baltic Journal of Coleopterology,* 17(1): 83–106.
Taybi, A. F., Mabrouki, Y., Ghamizi, M., Berrahou, A., 2017a. The freshwater malacological composition of Moulouya's watershed and Oriental Morocco. *Journal of Materials and Environmental Science,* 8(4): 1401–1416.
Yahya, H. S. A., Taybi, A. F., Mabrouki, Y., Fahsi, A., Chafi, A., Chafik, Z., 2017. The Metallic pollution in the groundwater of Triffa Plain (Eastern Morocco), *Journal of Materials and Environmental Science,* 8(9): 3372–3381.
Yeo, D. C. J., Ng, P. K. L., Cumberlidge, N., Magalhaes, C., Daniels, S. R., Campos, M., 2008. Global diversity of crabs (Crustacea: Decapoda: Brachyura) in freshwater. In: Freshwater Animal Diversity Assessment. *Hydrobiologia,* 595: 275–286.

Annex 1. The physical–chemical parameters of the studied stations (between 2013 and 2016): L, localities; Alt, altitude (in m); Abun, abundance; pH, hydrogen potential; T, water temperature (in ºC); Cond, conductivity; Dis_O, oxygen dissolved in water; $NH_4$ and $NH_3$, ammonia; NO, nitrates; SO, sulfates; PO, orthophosphates; $BOD_5$, biological oxygen demand.

*Anexo 1. Los parámetros fisicoquímicos de las estaciones estudiadas (entre 2013 y 2016): L, localidades; Alt, altitud (en m); Abun, abundancia; pH, potencial de hidrógeno; T, temperatura del agua (en ºC); Cond, conductividad; O_dis, oxígeno disuelto en agua;* $NH_4$ *y* $NH_3$*, amoníaco; NO, nitratos; SO, sulfatos; PO, ortofosfatos;* $BOD_5$*, demanda biológica de oxígeno.*

| L | GPS | Alt | Abun | pH | T | Cond | Dis_O | N_NH | NO | SO | PO | $DBO_5$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| S1 | 37º 7' 5.7'' N<br>2º 5' 26.8'' W | 875 | 3 | 7.9 | 21.2 | 750 | 7.1 | 0.06 | 3.15 | 160 | 0.09 | 5.92 |
| S2 | 34º 14' 31.61'' N<br>2º 20' 11.98'' W | 785 | 2 | 8.3 | 20 | 570 | 7.15 | 0.025 | 2.71 | 87 | 0.019 | 6.15 |
| S3 | 34º 13' 36.8'' N<br>2º 23' 34.5'' W | 767 | 2 | 7.4 | 20.3 | 640 | 7.11 | 0.01 | 1.27 | 49 | 0.013 | 5.05 |
| S4 | 34º 14' 21.6'' N<br>2º 24' 34.8'' W | 750 | 3 | 7.3 | 16.5 | 890 | 7.71 | 0.014 | 3.27 | 55 | 0.01 | 4.55 |
| S5 | 34º 12' 23.1'' N<br>2º 38' 52.3'' W | 625 | 4 | 7.3 | 17 | 1,237 | 7.4 | 0.027 | 2.75 | 51 | 0.019 | 2.17 |
| S6 | 34º 25' 15.6'' N<br>2º 52' 52.9'' W | 370 | 1 | 7.93 | 21 | 1,655 | 5.21 | 1.266 | 51.55 | 317 | 1.815 | 13.9 |
| S7 | 34º28'44.51''N<br>2º 59' 10.3'' W | 295 | 0 | 8.3 | 24 | 2,280 | 2.92 | 2.075 | 51.75 | 339 | 1.985 | 29.25 |
| S8 | 34º 28' 44.51'' N<br>2º 59' 10.3'' W | 295 | 2 | 7.11 | 23 | 1,750 | 6.75 | 0.127 | 2.77 | 49 | 0.029 | 10.55 |
| S9 | 34º 33' 41.09'' N<br>3º 1' 49.77'' W | 222 | 3 | 7.39 | 19.1 | 1,320 | 7.75 | 0.029 | 14.95 | 300 | 0.865 | 6.87 |
| S10 | 34º 53' 11'' N<br>2º 39' 45'' W | 60 | 4 | 8.31 | 19.5 | 1,655 | 7.65 | 0.095 | 9.11 | 330 | 0.91 | 6.55 |
| S11 | 34º 54' 27.53'' N<br>2º 38' 8.86'' W | 50 | 3 | 8.9 | 21.4 | 1,697 | 8.75 | 0.095 | 2.89 | 219 | 0.021 | 0.43 |
| S12 | 35º 3' 5.7'' N<br>2º 25' 42.4'' W | 9 | 3 | 7.7 | 21.1 | 1,700 | 7.95 | 0.097 | 9.75 | 51 | 0.775 | 2.55 |
| S13 | 35º 5' 51.4'' N<br>2º 23' 19'' W | 3 | 0 | 7.83 | 23.3 | 2,290 | 8.55 | 0.015 | 9.87 | 31 | 0.178 | 2.95 |
| S14 | 35º 2' 16.8'' N<br>2º 25' 36.0'' W | 83 | 8 | 7.5 | 18 | 305 | 11.5 | 0.03 | 2.35 | 30 | 0.007 | 0.34 |
| S15 | 34º 53' 08.3'' N<br>2º 20' 34.1'' W | 268 | 6 | 7 | 19 | 327 | 10.5 | 0.04 | 3.7 | 32 | 0.013 | 0.43 |
| S16 | 34º 50' 20.3'' N<br>2º 21' 21.6'' W | 442 | 5 | 7.3 | 20 | 402 | 8.4 | 0.06 | 5.1 | 40 | 0.156 | 1.23 |