Moroccan Journal of Chemistry
ISSN: 2351-812X
http://revues.imist.ma/?journal=morjchem&page=login
Beddiar & al. / Mor. J. Chem. 8 N°2 (2020) 486-496

# Physico-chemical and Biological Evaluation of the Quality of Surface Water in the Wadi El-Melha Watershed (North-East Algeria)

**Beddiar Marwa [a] *, Benchalel wafa [a], Boucetta sabrine [a], Bouslama Zihad [a], Elmsellem Hicham [b]**

[a] *Laboratory of Ecology of Terrestrial and Aquatic System «ECOSTAQ», Badji Mokhtar University - Annaba, Algeria.*
*(b). Laboratoire de chimie appliquée et environnement (LCAE), Faculté des Sciences, B.P. 717, 60000 Oujda, Morocco*

** Corresponding author:*
Beddiar_marwa@yahoo.co
*Received 10 Feb2020, Revised 20 Feb 2020, Accepted 27 April 2020*

## Abstract

This environmental study targeted the ecological assessment and classification of the waters' state of health at the level of the Wadi El-Melha watershed flowing from Lake Mellah (northeast of Algeria) through Physico-chemical parameters measured in situ and measured in the laboratory, and the biological quality achieved through Odonates as bio indicators of ecological potential in watercourses. The aim is to conserve the potential of the ecosystem (biotope, habitat and reproduction of species, flow of water, rambling of the bed). The waters' quality of the Wadi El-Melha watershed seems to be generally good at the end of this study despite some recognized disturbances in some sections, which are essentially linked to alterations by, nitrites nitrates and phosphates which in places influence the quality of the surveyed river. In terms of biological quality which was assessed using ecological indices, the results revealed a stability of the stand during the study period. The odonatological procession is diverse (Shannon index H'= 2.26), and it is in equilibrium (equitability index E = 0.90). Based on the classification proposed by [1], Wadi El-Melha is among the "middle" rivers, meaning a "moderately polluted" classification.

**Keywords**: *Wadi El-Melha, North-eastern Algeria, physico-chemical parameters, biological quality, ecological indices, Ecological classification.*

## 1. Introduction

The sustainable use of water resources for their exploitation in different aspects is essential for the life of our society and one of the challenges to be met by future generations. So, the management of running waters is of great importance for the maintenance of good water quality, both sanitary and environmental. It depends largely on the conservation of biodiversity in these running waters [2]. Fluvial ecosystems support very rich and diverse assemblages, with developed adaptations that allow them to prosper in these environments, and which, at the same time, make them very vulnerable to possible alterations in the habitat. Deterioration of biodiversity has been proven to alter the performance of ecosystems because of the loss, in numbers, of trophic levels in the aquatic ecosystems [3].

The rivers and streams of El-Kala region are ecosystems of great biological and ecological value. However, they are among the most fragile and vulnerable to environmental changes, especially those related to disturbances that have anthropic origin. In recent decades, one of the major impacts on running water has been the deliberate modification of watercourses by the construction of dams and reservoirs which modify the ecological characteristics of their basins [4-5]. Moreover, the pollution of their waters by domestic and industrial waste, the intensive use of fertilizers and pesticides in agriculture, have also largely contributed to eutrophication and contamination of running water ecosystems [6]. Odonata (dragonflies and damselflies) are a flagship group of insects that are an important part of aquatic ecosystems. Their sensitivity to environmental conditions makes odonates excellent indicators of of human impacts, especially contamination [7-8]. They are therefore widely used to monitor the ecological integrity or degradation of aquatic ecosystems [9-10-11-12-13]. Having remained little studied in Algeria for a long time, knowledge of watercourses and their fauna of odonates did not increase significantly until the early 1990s. The number of data then increased from 1993 onwards owing to the work of several researchers who have mainly targeted the fresh waters of the eastern region of the country and the most recent of which are those of [14-15-16-5-17-18]. To control water quality, biological monitoring has been established at the level of the Wadi El-Melha watershed flowing from Lake Mellah (northeast of Algeria) during the year 2017-2018. Several abiotic variables were recorded, and fauna of odonates was simultaneously sampled. Analysis of the collected specimens and their indices (Shannon-Wiener or Margalef, equitability...), the classification of [1] and physico-chemical parameters of the sampling area were used for quality of habitat and to provide information on the pollution trends of the running waters of the area.

Our wish is to sensitize managers and decision-makers in understanding the way in which anthropogenic disturbances modify natural hydrological regimes, and how they lead to permanent changes in the ecological processes. The aim is a better conservation of the rivers of Numidia and Algeria as well as the populations of vulnerable species whose bio-indicative value to determine the quality of environments is essential.

## 2. Materiel and methods

### *2.1. Study area*

Wadi El-Melha comes from the southern edge of Lake Mellah (Fig.1). The latter is considered the only lagoon in the country and is classified as an integral area of El Kala National Park and a wetland [19]. Lake Mellah is mainly supplied in the South by Wadi Bouarroug and Wadi El-Melha as well as the discharges from the treatment plant. In the North, Wadi Reguibet and Wadi Boumalek contribute relatively little to its supply. Wadi El-Melha crosses in a loop from East to West, over a length of 7 kilometers, the National Park of El Kala, to finally branch out into a small network of small wadis and chaabats , and it disappears at the feet of Keflahrech, Jebel Koursi and the Kourrata forest. The stream is subject to continuous water pumping, intense pasture and accumulation of organic waste downstream. A Very dense vegetation colonizes its banks and is home to relatively large biodiversity. The vegetation varies according

to the altitude and has a visible Mediterranean-type layout.

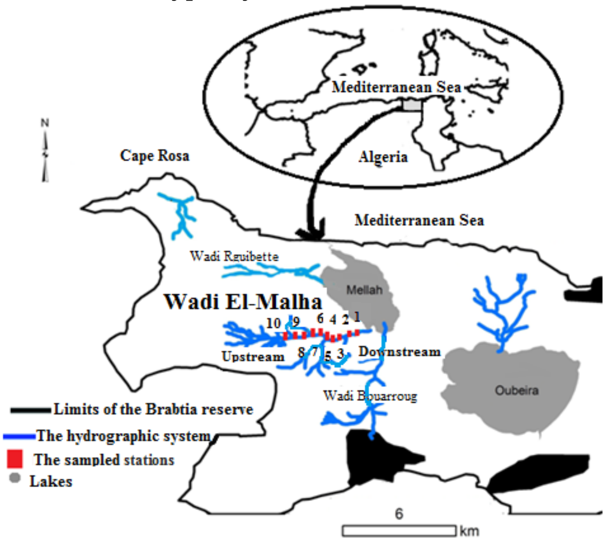


**Figure1.** Wadi El-Malha catchment basin and geographical limits of sampling stations.

### *2.2. Sampling methodology*

Along Wadi El-Melha, ten sampling stations located from lover downstream between N ° 36.52.07.0 E 008.17.35.1 and N ° 36.51.21.4 E 008.19.38.3 respectively were sampled. The sampling station are chosen according to the hydrological importance and the accessibility to the river **(Fig.1).** The notion of ecosystem integrity or health requires taking simultaneously into account chemical, physical and biological parameters [20]. Our study will include a hydrobiological study based on observations and measurements made at a monthly frequency from April 2017 to May 2018. During field trips, the physico-chemical parameters (air and water temperature, Ph, dissolved oxygen and conductivity) are recorded in situ using a multi-field parameter at the level of the chosen geographic locations from the lover downstream to Lake Mellah. The water samples taken in each station at a depth of 30 cm below the surface are stored at 4 ° C in polyethylene bottles, clean and sterilized for laboratory analysis of the remaining physico-chemical parameters (nitrates (NO3-), nitrites (N02-) and phosphator ($PO_4^{3-}$) in accordance with the HACH procedure manual [21]. The Odonates sampling method is mainly based on the observation of adults within a radius around the water for a given time always between (9h - 14h). Our method of counting on "time-count transects" is very similar to that used by [21]. For very territorial dragonflies (Anisoptera), it is enough to be posted on the banks and to wait a few minutes in order to follow the dominant males and the females in search of places of laying. Damselflies (Zygoptéres) are sought mainly on the banks or in the vegetation bordering the Wadi. The identification of imagos (flying adults) sometimes requires a net capture to observe the specific criteria (guide and identification key) [23]. However, in many cases, the use of binoculars and photographys appears to be sufficient to determine the morphological criteria. The various observations concerning the reproductive behavior of the imagos were noted (Ténéral, Immature / Mature, Tandem, Copulation, Oviposition). The larvae were sampled using an aquatic insect net, then they were identified in the laboratory to confirm the autochtonous species.

### *2.3 Data analysis*

The data processing method is based on analysis of variance (ANOVA) used to analyze the differences among group means in a sample. The Pearson correlation coefficient is a measure of the strength of the linear relationship between two variables, and it takes values in the closed interval [−1, +1]; it testifies a strong positive correlation of the

dependent variable with the independent variable. Ecological indices of stand diversity and structure are the mathematical expressions that provide the best information on stand structure and diversity. The measurement of taxonomic richness, diversity and fairness are useful for characterizing a stand, the overall comparison of different stands or the state of the same stand studied at different times [24]. The application of ecological indices, as descriptors of the state of the environment, was determined using the model proposed by [1]. The pollution parameters are classified according to five quality classes corresponding to the standard colors.

## 3. Results

### *3.1. Environmental factors analysis*

The obtained results revealed two ecologically separate periods, a period of low water (May - October) and a period of high water (November - April). The measured physicochemical parameters are shown in **Figure 2.** The air temperature shows similar variations at the ten sampling points. The maximum value is observed in low water and it is 32.8 ° C , and the minimum value is obtained in high water and it is 20.2 ° C. The spatio-temporal evolution of water temperature indicates a minimum value of 16.2 ° C in high water, and a maximum value of 23.9 ° C in low water. The pH did not show significant fluctuations during the study period. A neutral to slightly alkaline pH is recorded with an average minimum value of 8.4 in low water, and a maximum of 9.5 in high water. The analysis of variance with a classification criterion (ANOVA) ($\alpha \leq 0.05$) showed a very highly significant difference between the two hydrological seasons (high water and low water) for water and air temperature and pH. Dissolved oxygen during the annual cycle has reached a maximum of 8.96 mg.l-1 in high water. Then, there is a gradual decrease in the oxygen content to reach the minimum value of 8.1 mg.l-1 noted in low water. ANOVA did not show any significant difference between the ten sampling points for dissolved oxygen saturation **(Tab. 1).** The average conductivity values recorded during the study period fluctuate between 265.1 µs / cm in (high water) and 306.2 µs / cm in (low water). Due to the very close values of the recorded conductivity, ANOVA is not necessary.

**Table 1**. ANOVA with a controlled factor of the variations of the air and water temperature, pH and Dissolved Oxygen in Wadi El-Melha

| | Source | DDL | Sum of squares | Average of squares | F | Pr > F |
|---|---|---|---|---|---|---|
| **Water and Air temperature** | Model | 3 | 240,8331 | 80,2777 | 856,0443 | < 0,0001*** |
| | Error | 16 | 1,5004 | 0,0938 | | |
| | Total corrected | 19 | 242,3335 | | | |
| **pH** | Model | 3 | 4,4003 | 1,4668 | 42,4200 | <0,0001*** |
| | Error | 16 | 0,5532 | 0,0346 | | |
| | Total corrected | 19 | 4,9536 | | | |
| **Dissolved Oxygen** | Model | 3 | 0,1058 | 0,0353 | 0,8671 | 0,4784 **N.S** |
| | Error | 16 | 0,6506 | 0,0407 | | |
| | Total corrected | 19 | 0,7564 | | | |

***DDL:** Degree of freedom;* ***SCE:** Sum of squared deviations;* $\boldsymbol{F_{obs}}$***:** Fisher Test;* ***P:** Meaning threshold*

For the pollution parameters (**Fig. 3**) The waters of Wadi El-Malha show nitrites contents between 0.65 and 0.89 mg / L in low water, and presents values between 0.14 and 0.2 mg / L for high water. Nitrites indicate the state of

fertilization of water and their presence promotes the development of phytoplankton (green water). The Nitrite content during the study period shows a growth from upstream to downstream, and the recorded values are higher than the Algerian standard for surface water (less than 0.2 mg / l). The nitrates contents fluctuate between 0.75 mg / L and 1.3 mg / L in low water and 1.79 and 2.3 mg / L for high water. A clear increase in nitrates is recorded from upstream to downstream of the watercourse. Phosphorus has values ranging between 5.9 and 17.3 mg / L in low water and 8.2 and 14.3 mg / L in high water. The recorded levels are higher than the Algerian nomes (less than 10 mg / l).

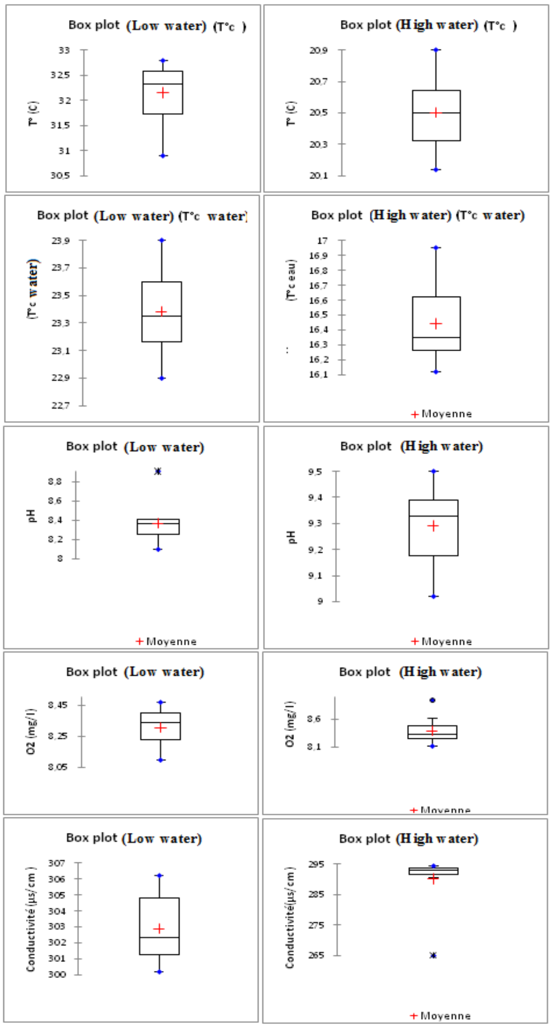


**Figure 2.** Box plot showing the variation of air and water temperature, hydrogen potential (pH), dissolved oxygen (mg / l) and conductivity during the study period.

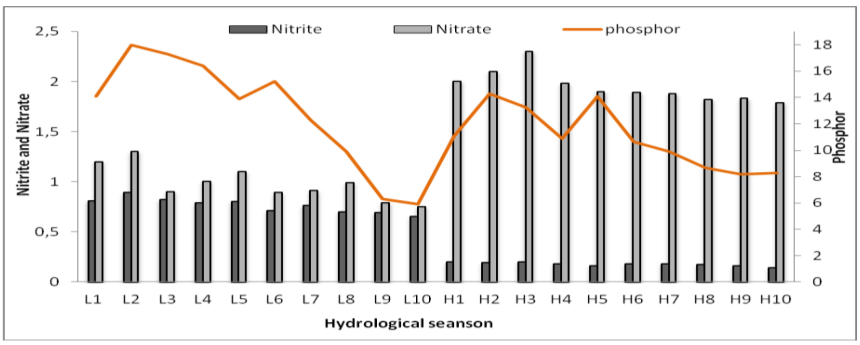


**Figure 3.** Distribution of frequencies between different species of Odonata at Wadi El-Malha (Survey period: 2017/2018).

### 3.2. *Diversity and Community Structure of Odonates*

A total of 1937 individuals were counted during the sampling period. The total number of species is 12, divided into seven families: Calopterygidae, Lestidae, Platycnemidae, Coenagrionidae, Gomphidae, Libellulida. Five species belong to the Zygoptera sub-order and seven to the Anisoptera. Autochthony is confirmed for nine (9) species out of the twelve (12) inventoried. The overall relative frequency **(Fig.4)** revealed that the species *Ischnura graellsii* is the most frequent, representing 24.57% of the total population, followed by *Orthetrum coerulescens* with 15.69% *Calopteryx haemorrhoïdalis* (12.13%). The other nine species (*Ceriagrion tenellum; Anax imperator; Platycnemis subdilatata; Chalcolestes viridi; Gomphus lucasii; Crocothemis erythraea; Trithemis annulata; Sympetrum striolatum; Boyeria irene*) are represented by the respective percentages of 8.36%; 7.84%; 7.12%; 5.21%; 5.16%; 3.82%; 3.66% and 2.89%.

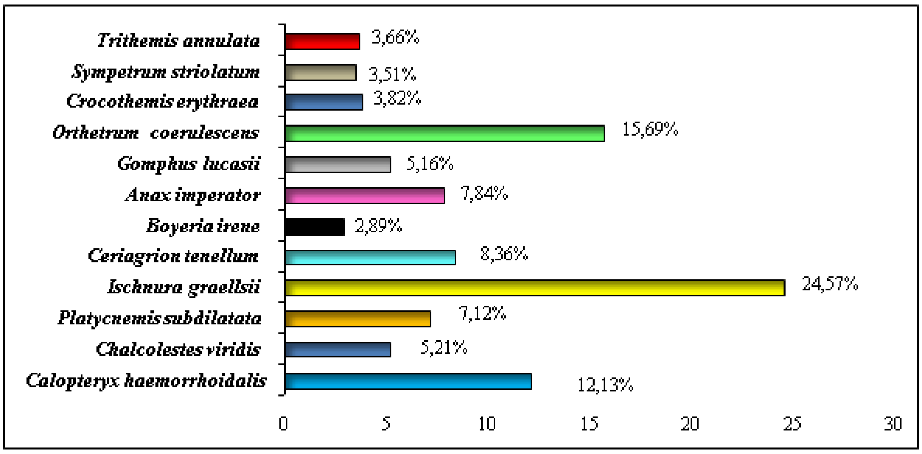


**Figure 4.** List of Odonate species inventoried and abundance frequencies. (odonatological season 2017).

### 3.3. *Analysis with biological diversity index*

Statistical study of ecological index (specific richness (S), Shannon index (H'), Margalef (R), Simpson (D) and equitability (E') revealed a stable population along the El-Melha Wadi. We note that the stand is clearly balanced during the months of May and September **(Fig.5)**.

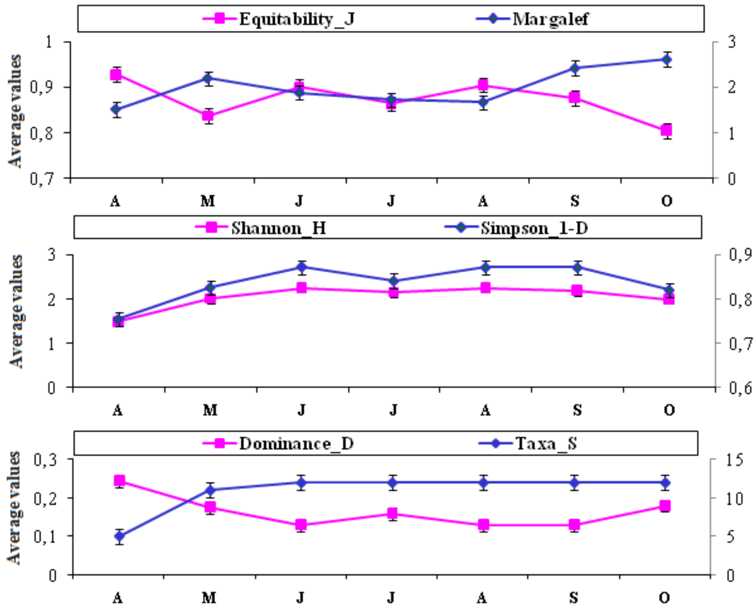


**Figure 5.** Monthly changes in ecological index (Richness; Shannon index; Margalef index; equitability and Simpson's index

### *3.4. Classification of ecological potential of Wadi El- Malha*

Shannon Wiener's index has also been used to study temporal changes in diversity related to the increase or reduction of pollution [26].The Shanon H index obtained (H '= 2.26) shows that the ecological state of Wadi El-Melha is "**Moderate**", and it classifies it as "**Moderately polluted**"

**Table 2 :** Classification scheme of Wadi El-Malha based on diversity index (H') (from [1]).

| | Quality Status | H' | Classification of habitats |
|---|---|---|---|
| | Bad | **0 < H ' ≤ 1,5** | Azoic to very highly polluted |
| | Poor | **1,5 < H' ≤ 3** | Highly polluted |
| | **Moderate** | **3 < H' ≤ 4** | **Moderately polluted** |
| | Good | **4 < H' ≤ 5** | For transitional zones |
| | High | H'>5 | Reference sites |

## 4. Discussion

### *4.1. Environmental factors analysis*

The wetlands of northeastern Algeria are very vulnerable as they are indirectly threatened by the loss or severe modification of their freshwater habitats [27-24].The environmental parameters of the habitats and the physicochemical indicators of water quality are often subject to anthropogenic disturbances that modify the characteristics of the water and affect its quality [28]. The need for interpretation of benthic macro invertebrate data and its use in detecting anthropogenic stress, disturbance and change has led to the development of a large number of numerical concepts and techniques: diversity indices, multivariate tools, graphical representations, indicator species, biotic indices [29-30]. Odonates are an important component of the ecosystem of the aquatic environments , and their presence is therefore a sure indication of the faunistic richness of freshwater [24]. Among the physicochemical indicators of water quality, temperature is an important environmental factor for aquatic life, and it has important ecological implications [31]. Thus, it controls all biological processes (reproduction, growth, thermal preference, etc.) related to a given environment [32]. In odonates, its impact is important on eggs, emergences, adult phenology and also on the development and growth of larvae [33-34]. The air and water temperatures recorded along Wadi El-Melha during the study period (low and high water) follow the seasonal norms of the region and indicate that the water in this watercourse is favorable for aquatic life. In fact, repeated peaks in temperature favors the development of micro-organisms and therefore the consumption of oxygen and, consequently, the reduction of the dissolved oxygen content which is essential to the life of the organisms in the watercourses [35]. The pH, or hydrogen potential, characterizes the acidity or alkalinity of water. It is an indicator of the quantity and nature of mineral ions in solution in water. This parameter makes it possible to estimate the degree of aggressiveness of water and its suitability for the superior animal life. The values recorded during the study period did not show significant variations. The water of Wadi El-Melha is moderately neutral to slightly alkaline, which is favorable for aquatic life. Quantification of the concentration of dissolved oxygen in the water of a hydro system is a fairly important factor since it is involved in the majority of chemical and biological processes in these aquatic environments [36]. It is also one of the most sensitive parameters to pollution because it tells us about the extent of pollution and, therefore, the extent of self-purification in a river. The recorded values (8.1mg/l - 8.96 mg/l) indicate a good oxygenation of the waters of Wadi El-Malha which is favorable to the maintenance of even the most sensitive and low ecological valence species such as *Calopteryx heamorrhoidalis*

and *Gomphus lucasii* [37]. Conductivity is used to assess the amount of salts dissolved in water [38]. Conductivity is also a function of ( is dependent on ) water temperature, and it is higher as the temperature increases [39]. Its values recorded in Wadi El-Melha remain in favour of good quality water for animal life. Overall, the levels of pollution parameters, Nitrites, nitrates and phosphor showed a slight increase from upstream to downstream, mainly in low water, and the recorded values are higher than the Algerian norm for surface waters. Nitrites indicate the state of fertilization of the water, and their presence promotes the development of phytoplankton. Temporal variation in nitrate appears to be related to atmospheric inputs and leaching from surrounding soils. Indeed, some authors have found that the evolution of nitrates is closely dependent on rainfall [40-41-42-43-44] also reported that nitrogen inputs in lake environments are related to precipitation, to tributary surface or groundwater, and to biological fixation by prokaryotic microorganisms. These inputs from surface waters depend on their flow rate and their proximity to pollution sources (downstream of cities and farmland). Phosphor in aquatic environments is rapidly assimilated by plants, but they are also rapidly recycled [45]. Their concentration in aquatic ecosystems is caused by urban discharges and is mainly conditioned by the litho logical nature of the watershed, the pH of the environment and the balance of its consumption, and excretion by living organisms [45]. Here, the maximum levels of pollution parameters are more marked on the small stretches downstream of the river, where concentrations of dwellings and urban and agricultural discharges are the highest, mainly at sampling stations (1-2-3-4-5).

### *4.2. Diversity and community structure of Odonates*

Such monitoring to classify watercourses is always associated with biological tools that are sensitive to physicochemical and hydro morphological changes. Thus, a group of species indicating disturbance or pollution concerning an ecosystem can be assembled for use in classification methods. The need for interpretation of biological data and its use in the detection of anthropogenic disturbance has led to the use of biotic indices to detect disturbance in aquatic ecosystems. Among them, diversity indices are essentially an approach to the biological quality through community structure [29]. The species richness includes 12 species divided into 7 families. The autochthonous status is confirmed for 9 species. The species *Ischnura graellsii* is the most frequent, followed by *Orthetrum coerulescens* and then *Calopteryx haemorrhoidalis*. The other 9 species are represented in relatively low percentages (< 9 %).

Imagos began to fly from April onwards, and their presence in the riparian zone is becoming increasingly important with increasing temperatures and the onset of the warm season, which is consistent with observations over two decades in the same region [4-46-47]. After the acquisition of sexual maturity, the mature imagos gather on the banks for reproduction. The Shannon-Wiener Diversity Index is, without undoubtedly one of the most widely used diversity indices in the assessment of pollution in aquatic communities. However, the use and interpretation of this indicator and others (Simpson, number of species...) has been the subject of much debate [48-49]. In this study, ecological indices show some stability in the stand. The odonatological procession is diversified (Shannon's Index H'= 2.26), and it is clearly balanced in May and September (Equitability Index E= 0.90). Nevertheless, ecological indices remain dependent on sample size and habitat type. Their value is relatively low in transitional waters such as lagoons, deltas or estuaries, even when they are undisturbed. It is therefore difficult to use them as a descriptor of the state of an environment unless threshold values are determined beforehand for each type of habitat and for a given sample area.

Thus, and based on the classification proposed by [1], Wadi El-Melha is among the "**Medium**" rivers, meaning a "**Moderately polluted**" classification. This seems to be the consequence of growing human activity, which has a negative impact on wetlands and watercourses in particular. As they are fragile, the species living there are particularly affected. The profound alterations that these areas are undergoing exceed the adaptive capacities of many specialized species. Although they are considered to be sligntly sensitive bio-indicators since they are quite tolerant to

environmental changes, the decline of these dragonfly populations will reflect the overall poor state of our natural heritage. Moreover, global change is not limited exclusively to naturally occurring changes (abiotic and climatic conditions). It is largely the result of a large and growing human ecological footprint. Habitat fragmentation and destruction are strongly linked to agricultural intensification and urbanization. These two phenomena also contribute to the decline or even extinction of many species.

## 7. Conclusion

The results of the water quality analysis of the Wadi El-Melha watershed generally show good water despite the few disturbances recognized in certain sections. These disturbances are essentially linked to alterations by nitrites, nitrates and phosphates which influence in places the quality of the watercourse. The classification of ecological potential using diversity indices revealed the ecological status of Wadi El-Melha as moderately polluted. The effect of the anthropogenic impact recorded during the 2017/2018 monitoring, in particular the contamination of water on aquatic fauna including the Odonata, is obvious. The management of running waters is of great importance for the maintenance of good water quality, both sanitary and environmental.

**Acknowledgments**

This study was supported by MESRS [Project of university research-training PRFU (ex. CNEPRU) Number: D01N01UN230120150004].

## References

[1] N.Simboura et A. Zenetos, Benthic indicators to use in ecological quality classification of Mediterranean soft bottoms marine ecosystems, including a new biotic index, *Medi. Mar. Scien.*, 3 (2) (2002) 77-111.

[2] M. Fernández Díaz, Estudio faunístico y ecológico de los coleópteros acuáticos (Adephaga y Polyphaga) en la cuenca del río Ávia (Ourense, NO España): Distribución espacial y temporal, Degree Thesis, Universidad de Vigo, Vigo, Spain (2003).

[3] J. E. Duffy et al., The functional role of biodiversity in ecosystems: incorporating trophic complexity, *Ecol. Let.*, 10 (200) 522–538.

[4] W. Benchalel et B. Samraoui, Caractérisation écologique et biologique de l'odonatofaune de deux cours d'eau méditerranéens : l'oued El-Kébir et l'oued Bouaroug (Nord-Est de l'Algérie), *Medi.*, (118) (2012) 19‐27.

[5] W. Benchalel, S. Merah, Z. Bouslama, M. Ramdani, H. Elmsellem, et R. Flower, Odonata as indicators of environmental impacts in rivers, case of wadi El-Kébir-East (northeastern Algeria) , *Moro. J. Chemy.*, 5 (4) (2017) 610-621.

[6] PL. Miller (1992).The effects of oxygen lack on egg hatching in an Indian dragonfly, Potamarcha congener. *Physi Ento*17(1992) 68-72.

[7] T. E. Clark et M. J. Samways, Dragonflies (Odonata) as Indicators of Biotope Quality in the Kruger National Park, South Africa , *J. Appl. Ecol.*, 33(5) (1996) 1001.

[8] M. J. Samways et N. J. Sharratt, Recovery of Endemic Dragonflies after Removal of Invasive Alien Trees, *Conse.Bio.*, 24(1) (2010) 267‐277.

[9] E. Schmidt**,** Habitat inventarization, characterization and bioindication by a "representative spectrum of Odonata Species (RSO)", *Odonatologica*, 14 (1985) 127-133.

[10] E. Castella, Larval Odonata distribution as a describer of fluvial ecosystems: the Rhone and Ain rivers, France, *Adva. Odona.*, 3(1) (1987) 23–40.

[11] A. Chovanec et J. Waringer, Ecological integrity of river-floodplain systems assessment by dragonfly surveys (Insecta: Odonata) , *Regul. Rivers: Res. Mgmt.*, 17(4‑5)(2001) 493‑507.

[12] A. Chovanec, J. Waringer, R. Raab, et G. Laister, Lateral connectivity of a fragmented large river system: assessment on a macroscale by dragonfly surveys (Insecta: Odonata) , *Aquatic Conserv: Mar. Freshw. Ecosyst.*, 14(2) (2004) 163‑178.

[13]M. Ferreras-Romero, J. Márquez-Rodríguez, et A. Ruiz-García, Implications of anthropogenic disturbance factors on the Odonata assemblage in a Mediterranean fluvial system , *Inter .J. Odona.*, 12 (2) (2009) 413‑428.

[14] B. Samraoui et al., Afrotropical libellulids in the lake district of El Kala, NE Algeria, with a rediscovery of Urothemis e. edwardsi (Selys) and Acisoma panorpoides ascalaphoides (Rambur) (Anisoptera: Libellulidae). *Odona.* 22(3) (1993) 365-372.

[15] B. Samraoui et R. Menaï, A contribution to the study of Algerian odonata. , *Inte. J. Odona*, 2 (2) (1999) 145‑165.

[16] B. Samraoui et P. S. Corbet , The Odonata of Numidia. Part I: status and distribution. *Inter .J. Odona.*, 3 (1) (2000) 11-25.

[17] R. Khelifa, M. Kl Mellal, A. Zouaimia,H. Amari ,R. Zebsa, S. Bensouilah, Al. Laouar et M. Houhamdi, On the restoration of the last relict population of a dragonfly Urothemis edwardsii Selys (Libellulidae: Odonata) in the Mediterranean , *Insect. J. Conserv*, 20 (5) (2016) 797‑805.

[18] I. Djemai et F.Bounaceur, Diversité de l'Odonatofaune dans quelques stations lotiques des Monts de Chréa , *Rev Écol-Envir*, (13) (2017) 31-39.

[19] Ramsar convention, article 3 of law n ° 11-02 of February 17, 2011.

[20] A. Genin, Effects of seamount topography and currents on biological process. Dissertation, University of California, San Diego, CA (1997)

[21] M. Bellil, Z. Benhamana, et N. E. Benhamiche, Contribution à l'étude des qualités physiques des sources karstiques de la région Nord-Ouest de Bejaia, (2016)

[22] A. Tourne *et al.*, Directive cadre européenne sur l'eau: proposition d'un outil d'analyse et de participation pour améliorer la qualité des milieux aquatiques , *Tech. Scien.Méth*, (4) (2014) 25–36.

[23] J. Aguillar(D') , J. L. Dommanget et R. Prêche, Guide des libellules d'Europe et d'Afrique du Nord.Neuchâtelund Paris (Delachaux&Nistlé) ;341S., 40 Farbafle,125 verbreitungs batterie,zahlveiche Schwarzwei Babbidungen-ISBN2-603-00566-9 (1985). .

[24] J. Aguillar(D'), J. L. Dommanget.Guide des libellules d'Europe et d'Afrique du Nord : l'identification et la biologie de toutes les espèces, Delachaux et Nistlé,Neuchâtel.Paris ;1ere édition(1998) ,463 .

[25] R. Barbault, Biodiversity dynamics: from population and community ecology approaches to a landscape ecology point of view. Landscape and Urban Planning 31 (1995) 89±98.

[26]T. H. Pearson et R Rosenberg, Macrobenthic Succession in Relation to Organic Enrichment and Pollution of the Marine Environment. Oceanography and Marine Biology, An Annual Review, 16 (1978) 229-311.

[27] B. Samraoui, *Platycnemis subdilatata*. IUCN 2014. Retrieved February 16, 2015, from www.iucnredlist.org (2010).

[28] A.Moussa, A. Chahlaoui, et H. Rour, Évaluation de la pollution physico-chimique des eaux de l'Oued Khoumane (Moulay Idriss Zerhoun, Maroc), *Int. J. Bio. Chem. Sci*, 6(6) (2013) 7096‑7111.

[29] M. Elliott, Recent developments in marine macrobenthic community analysis.

Proceedings of the 4th National Symposium on Oceanography and Fisheries, Rhodes (isl), Greece), 26-29 April, (1993) 144-155.

[30] M. Elliott, M., The analysis of macrobenthic community data. Marine Pollution Bulletin, 28 (62-64) (1994).

[31] G. Leynaud , Les pollutions thermiques, influence de la température sur la vie aquatique. B.T.I. Ministère de l'agriculture, (1968) 224-881.

[32] A. Aminot et M. Chaussepied, Manuel des analyses chimiques en milieu marin. Editions Jouve, CNEXO, Paris, (1983) p. 395.

[33] J.G. Pilon et M. J. Masseau, The effect of temperature on egg development in Zygoptera: a preliminary discussion, *Advan. Odona.*, 2(1) (1984) 177–193.

[34]G. Pritchard et M. A. Leggott, Temperature, incubation rates and origins of dragonflies, *Advan. Odona.*, 3 (1) (1987) 121–126.

[35] M. Jacques, Océan et climat, Ed. IRD, (2006) 222 p

[36] J. Rodier L'analyse de l'eau. Eaux naturelles, eaux résiduaires, eau de mer.8eme édition, Edit. Dunod, Paris. (1984)1365.

[37] W. Benchalel, A. Bouziane, Z. Bouslama, H. El Mesellem, Roger, et M. RAMDANI, Odonata of Wadi Bouarroug (northeastern Algeria) and environmental determinants of their distribution , *Mor. J. Chemy.*, Mor. J. Chem. 6N°1 (2018) 78-91.

[38] J.Rodier , B. Legube , N. Merlet , L'analyse de l'eau. 9ème édition, Dunod, Paris, (2009)1579 p

[39] F. Rejsek , Analyse des eaux : Aspects réglementaires et techniques. Centre régional de documentation pédagogiqued'Aquitaine (CRDP). Bordeaux. (2002) p.358.

[40] M.S Romdhane, 1986. Lagune de Ghar El Melh. Milieu, Peuplement, Exploitation. Thèse, Université de Tunis. (1986) p.245.

[41] A. Ben Rejeb Jenhani , 1989. Le lac IchkeuJ : Conditions du milieu, peuplements et biomasses phytoplanctoniques. Thèse, Université de Tunis. (1989) p. 209 .

[42] S. Mouelhi , Etude écologique de la retenue de Sidi Salem: aspects physicochimiques des eaux et dynamique des peuplements zooplanctoniques. Thèse de doctorat en sciences biologiques, université de Tunis II, (2000) 21 – 126.

[43] S.Turki, 2002. Contribution à l'étude bio-écologique des rotifères, c1adocères, copépodes des eaux continentales tunisiennes et dynamique saisonnière du zooplancton de la retenue de barrage Bir M'chergua. Thèse de Doctorat en Sciences Biologiques. Université de Tunis El Manar / INSTM. (2002) p.225.

[44] F. Labroue, R. Guéblez, M.Marion , P.Sellier , Journées Rech. Porcine en France, (27) (1995) 175-182.

[45] R. Pourriot et M. Meybeck, Limnologie générale. Masson, Paris, France, (1995) p.956.

[46] R. Menai, Contribution à la mise à jour de l'odonatofaune, Algérienne, thèse de magister. Université d'Annaba (1993).

[47] B. Samraoui et R. Menai , A contribution to the study of the Algerian Odonata. *Inter. J. Odona.*, 2(2) (1999) 145-165.

[48] K.R.Clarke et R. M. Warwick, Change in marine communities: an approach to statistical analysis and interpretation. Plymouth Marine Laboratory, Plymouth (1994) p.144.

[49] S. Jennings et J. D Reynolds, Impacts of fishing on diversity: from pattern to process. In: Effects of fishing on non-target species and habitats, by MJ. Kaiser & S.J. de Groot, Blackwell Science, Oxford (2000) 235-250.