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BIOECOLOGY OF *CALOPTERYX HAEMORRHOIDALIS* (ZYGOPTERA, ODONATA) IN RESPONSE TO ENVIRONMENTAL FACTORS IN THE BRABTIA SECTOR STREAMS, EL-KALA, ALGERIA: IMPLICATIONS FOR ECOHYDROLOGICAL BIOMONITORING

Wafa BENCHALEL[1], Marwa BEDDIAR[1*], Sabrine BOUCETTA[1], Zihad BOUSLAMA[1]

[1] Laboratory of Ecology of Terrestrial and Aquatic System «EcoSTaq», Badji Mokhtar University, Annaba, Algeria

Abstract: Aspects of the phenology, reproductive biology and larval cycle of natural populations of the *Calopteryx haemorrhoidalis* (Vander Linden, 1825) are described. Populations of this species in Brabtia sector (eastern Numidia, North-East Algeria) were studied between March 2017 and April 2018. An overview of the current state of the population is provided. The streams of Eastern Numidia have suffered over recent years from major disturbances including the effects of 20 rapid climate changes. Although the status of autochthony is preserved in the site, the populations are currently diminished compared to that recorded two decades ago. Aspects of the species reproductive behavior, biology, and ecology are reported. The species is univoltine with a direct development in 12 larval stages. The effects of some climatic conditions, particularly air temperature, included an extension of the adult phenology period. The species is unable to tolerate a certain amount of stress similar to stagnant water species. The correlation established between the abundance of *C. haemorrhoidalis* and the physico-chemical parameters from the principal correspondence analysis (PCA) shows an ecological gradient, in the distribution of the species, significantly ($P<0.001$) explained by a requirement for dissolved oxygen, both temperatures and pH.

Keywords: *Calopteryx haemorrhoidalis; adult and larva phenology; PCA, Hierarchical ecological status, habitat type.*

INTRODUCTION

Wetlands are prime breeding sites for animal species of great interest for regional or even national biodiversity; such as Odonata. Dragonflies and damselflies are a flagship group of insects that form an important component of aquatic ecosystems. Their sensitivity to environmental conditions makes odonates excellent biological indicators of environmental conditions (Samways and Sharratt, 2010) Hence, they are very useful for monitoring the ecological integrity or degradation of aquatic ecosystems (Chovanec and Waringer, 2001; Ferreras-Romero et al., 2009) and assessing habitat restoration measures (Samways and Taylor, 2004). Numidia (north-eastern Algeria) is known to be an odonate biodiversity hotspot, with a high rate of endemism at least six endemic species is recorded, according to (Riservato, 2009; Benchalel and Samraoui, 2012). The biology and ecology of many species of Numidia remain unknown and *Calopteryx haemorrhoidalis*; (Vander Linden, 1825) is one of them. With *Calopteryx exul (*Selys, 1853) it represents the only two species of the family of the calopterygids present in the north-east of Algeria. The species is usually only found in spring-fed freshwater and associated waterways originating in mountainous areas (Riservato,2009; Benchalel and Samraoui, 2012). Even if the species is classified as of the Least Concern (LC) on a world level (Riservato, 2009), the populations in this region are very vulnerable to climate warming and anthropic disturbance of their reproductive habitats (Benchalel and Samraoui, 2012).

This study is devoted to *C. haemorrhoidalis* of El-Kala National Park in streams sections that cross the reserve of Brabtia. The work was undertaken because significant habitat degradation was noticed in past decades (including waterway modifications in the Brabtia reserve, continuous water pumping and large accumulations of pasture debris and organic waste (Benchalel and Samraoui, 2012).

Hydrological conditions, such as discharge and water disturbance, play important roles in aquatic ecosystem functioning (Doretto et al., 2018; Ahmad et al., 2014). Hence, alterations in water quality, hydrological and physicochemical features of rivers were found to cause profound changes in diversity and abundance patterns of aquatic macroinvertebrates (Bona et al.,2008; Al-Shami.,2011). Prior to conducting this study, the only available data on the species was limited to observations and imago captures during the 1990s (Samraoui and Menaï,1999; Benchalel and Samraoui,2012), and to aspects of its phenology at wadi Bouarroug during the 2015s (Benchalel et al., 2018).

However, intensive studies at particular localities in the stream on the relative abundance, phenology and the larval cycle hither to have been absent. Such work is urgently needed to enable basic scientific data to be collected to help support an information database for this regional heritage area. Specific information about by how much the populations and their reproduction habitats have changed is required to help their

*Correspondence: Beddiar Marwa, Laboratory of Ecology of Terrestrial and Aquatic System «EcoSTaq», Badji Mokhtar University, Annaba, Algeria, Beddiar_marwa@yahoo.com

preservation and prioritize conservation measures. Consequently, adult phenology, reproductive behavior, habitat type, the larval stages, and growth were systematically studied as follows.

MATERIALS AND METHODS

Study Area

Sampling was carried out in the El-Kala National Park (EKNP), which covers a total area of 5,500 ha (Boukhatem, 2017) and is the most diversified complex in Algeria (Benyacoub et al., 1998). For better administrative management in the field, the EKNP has been divided into 03 sectors: the Bougous sector which covers an area of 24,500 ha of the park, the sector of Oum Teboul which covers an area of 25,938 ha of the park and the Brabtia sector which covers an area of 26,000 ha of the park.

Its water is in the form of water bodies of various sizes and nature (Tonga Lake 2700 ha, Lake Oubeira 2200 ha, El-Mellah Lagoon 860 ha), underground aquifers and springs (source of Bouglèz, source of Bourdim and source of El-Bhaim. As well as an important network of Wadis (in the South-East, are located Wadi Bougous, Wadi Melloula which join Wadi El-Kebir; Wadi El-Hout, Wadi El-Eurg, Wadi Messida are in the East, Wadi Bouarroug, Wadi Mellah, Wadi Reguibet, Wadi Nhal, Wadi Boumerchene, Wadi L'Gràa, Wadi Demat Rihane are in the West) Chaabas are dug by erosion (Benyacoub et al.,1998).

The information presented here was collected in five valleys (Wadi Bouarroug, Wadi Mellah, Wadi Demat Rihane, Wadi Nhal, Wadi Reguibet) in the Brabtia sector of El-Kala National Park (Figure.1), in north-eastern Algeria over a period of one year (March 2017-April 2018). The details of habitats are given in (Table 1).

The annual hydrological cycle of the streams is characterized by low flow in summer and autumn (low water season -L-) and high flow in winter and spring (high water season -H-) (Belouahem et al., 2009).

This unique ecosystem presents a great diversity of plant species. With about 80 species, about ten of which are rare and / or confined to the El-Kala region alone. Among which we can mention: *Alnus glutinosa*, *Salix pedicellata*, *Salix triandra*, *Ranunculus flammula*, *Rhynchospora glauca*, *Cyperus flavescens*, *Carex pendula*, *Heliosciadum crassipes*, *Linaria cirrhosa*.

Table 1.

Table of site names, code, Lengths (km), geographic coordinates, and outlet of the watercourse.

Site	Code	Length(km)	longitude	latitude	Outlet of the valley
Wadi Bouarroug	St.1	5	8,32767	36,8484	Lake Mellah
Wadi Demat Rihane	St.2	1.5	8,38334	36,8689	Lake Oubeira
Wadi Malha	St.3	7	8,31057	36,8683	Lake Mellah
Wadi Nhal	St.4	3.5	8,23553	36,9325	Cap Rosa Beach
Wadi Reguibet	St.5	8	8,26402	36,9027	Lake Mellah

The Ripisylves is dominated by the *Alnus glutinosa*, the *Fraxinus sp.* and the *Populus sp.*. Other parts of the streams are dominated by herbaceous vegetation including patches of *Juncus maritimus*, *Iris pseudacorus*, *Laurus nobilis*, and *Osmunda regalis*; plants that offer little shade and protection. Aquatic plants include *Potamogeton nodosus*, *Carex distachya*, *Callitriche obtusangula*, *Scirpus supinus* and *Poa trivialis* (Benchalel,2018).

Sampling Waters

The waters were sampled at a depth of 30 cm below the surface for physicochemical analyses (Hunt et al.,1992). Sampling took place at an interval of 7 days during a complete annual cycle (March 17-April-18). The sampling frequency is more regular during the "low water season" (May to October) than those during the "high-water season" (November to April).

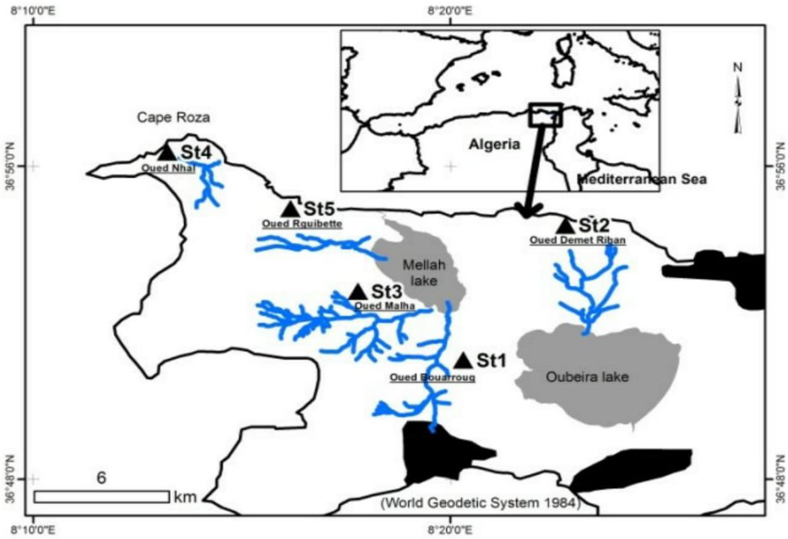

Fig.1. Map of the five Study area and geographical limits of *Calopteryx haemorrhoidalis* sampling sites in sector of Brabtia

The water samples are taken at each site in the morning between 9 and 10 hours, period when the samples of Odonates are easier. They are kept at 4 ° C in polyethylene bottles, clean and sterilized for laboratory analysis in accordance with the HACH procedure manual (Bellil et al., 2016). Physico-chemical parameters (conductivity, pH, temperature, oxygen dissolved) are immediately analyzed in situ respectively with a conductivity meter WTW LF 318 / SET (accuracy 2 μs / cm); a pH meter WTW 330i / SET (precision 0.1) and a WTW Multiline P3 pH / Oxi-SET oximeter (accuracy 0.1 mg l-1 ° C). The nitrates and nitrites are analyzed in the laboratory respectively according to the diazotization method, and the Nessler method. The environmental characteristics acting on each sampling site were established according to the model described in detail by (Natuurtijdschriften 2019).

Phenology Of Imagoes And Reproductive Behaviour

The five (05) wadis chosen in the Brabtia sector were sampled regularly, from March 2017 to April 2018, along the rivers where *C. haemorrhoidalis* was the most widely spread.

The seasonal trend of species emergence was surveyed from May 1 to August 15, 2017, according to the census of teneral individuals. This procedure was also adopted for smaller zygopteran and gomphid species which emerge, often in high numbers, and stay around the emergence sites for a few days. We do not deal with exuviae recognition since this is very difficult for the calopterygids as the exuviae are so fragile. Our method of counting on "time-count transects" is very similar to that used by (Tourne et al., 2014). Counting of the tenerals was undertaken semi-quantitatively by walking along the water edge for ca. 30 min. around noon on each occasion. Weather conditions on census days, usually air and water temperatures, were recorded; these days were selected when wind speed was at or near zero.

In order to get a perspective on relative abundance and phenology during the reproductive period, census of mature individuals within their reproductive site was carried out weekly again at around noon during warm days from May 1 to September 25, 2017. The hour of counting approximately coincided with the peak of daily activity of the species (11:00-13:00). Active individuals were also searched for between 15-30 minute intervals, above the water, in and above the vegetation in the area surrounding each wadi. Every immature/mature individual identified was counted and recorded with regard to sex, and the incidence and performance of tandem or copulation. The information about their reproductive behavior (tandem, copulation, and oviposition), the substrates chosen for egg laying and the time taken for laying was recorded. Submerged plants, on which females deposit their eggs into the cavities made by the ovipositor, were brought back to the laboratory and used in larva cycle follow-up studies.

Larva Phenology

Freshly emerged prolarvae from eggs oviposited by females into aquatic plants in *situ*, were separated and dispersed into small laboratory aquaria. The breeding method used in the laboratory (Pellerin and Pilon, 1978) makes it possible to monitor the larvae individually under controlled conditions, from egg-laying to emergence. Rearing was carried out in the laboratory at a temperature of 20◦ C 1◦C, with a l2h + l2h light-dark cycle.

Data Analysis

Three approaches are used to analyze the data:

i) the analysis of variance with two classification criteria (AV2) thanks to the XL Stat 2018 package (STATSOFT France, 2018) is used on transformed data to test the inter-variation of the measured water quality parameters (Rodier,1971) The Hartlet test is used to check the homogeneity of the variances. Significant differences between sites are determined using the Tukey test (SNK). ii) Odonate (*C. haemorrhoidalis*) abundance data were transformed in XL STAT 2018 into a log (x + 1) transformation to normalize and stabilize the variance. Relative abundance corresponds to the total number of individuals counted per station and month. iii) Principal Correspondence Analysis (PCA) using the package XL stat 2018 to establish Significant correlations between Abundance and environmental variables. The Tukey (SNK) test allowed the selection of all environmental factors that contribute significantly to the distribution of *C. haemorrhoidalis* along the Brabtia Reserve. This method eliminates all Environmental variables with an inflation factor greater than 10 (Ter Braak and Smilauer, 1999). These variables correlated with other variables have a weak influence on the distribution of invidious.

RESULTS

Environmental Factors Analysis

The results of the analysis of the physicochemical characteristics of the water quality of the five stations are summarized in Figure 2.

With the exception of pH, with a minimum value of 6.5 at St.1 and a maximum of 9.50 at station St.2 in "High Water", the other parameters show very highly significant differences ($P < 0.05$) inter-station.

Monthly records of air and water temperature revealed a minimum heat recorded during the "high water season" of 17°C and 11.7°C at St.4 respectively. Then, a gradual increase in temperature is recorded during the "low water season" with a maximum of 32.8 ° C at St.3 and 24.3 ° C at St.2 respectively (Fig.2).

The dissolved oxygen values reached a maximum of 8.99 $mg.l^{-1}$ at St.4 in low water. Then, there is a gradual decrease in the oxygen content to reach the minimum value of 7.7$mg.l^{-1}$. Conductivity values range from 240 µs / cm in (St.4) to 315.9 µs / cm in (St.2) at low water.

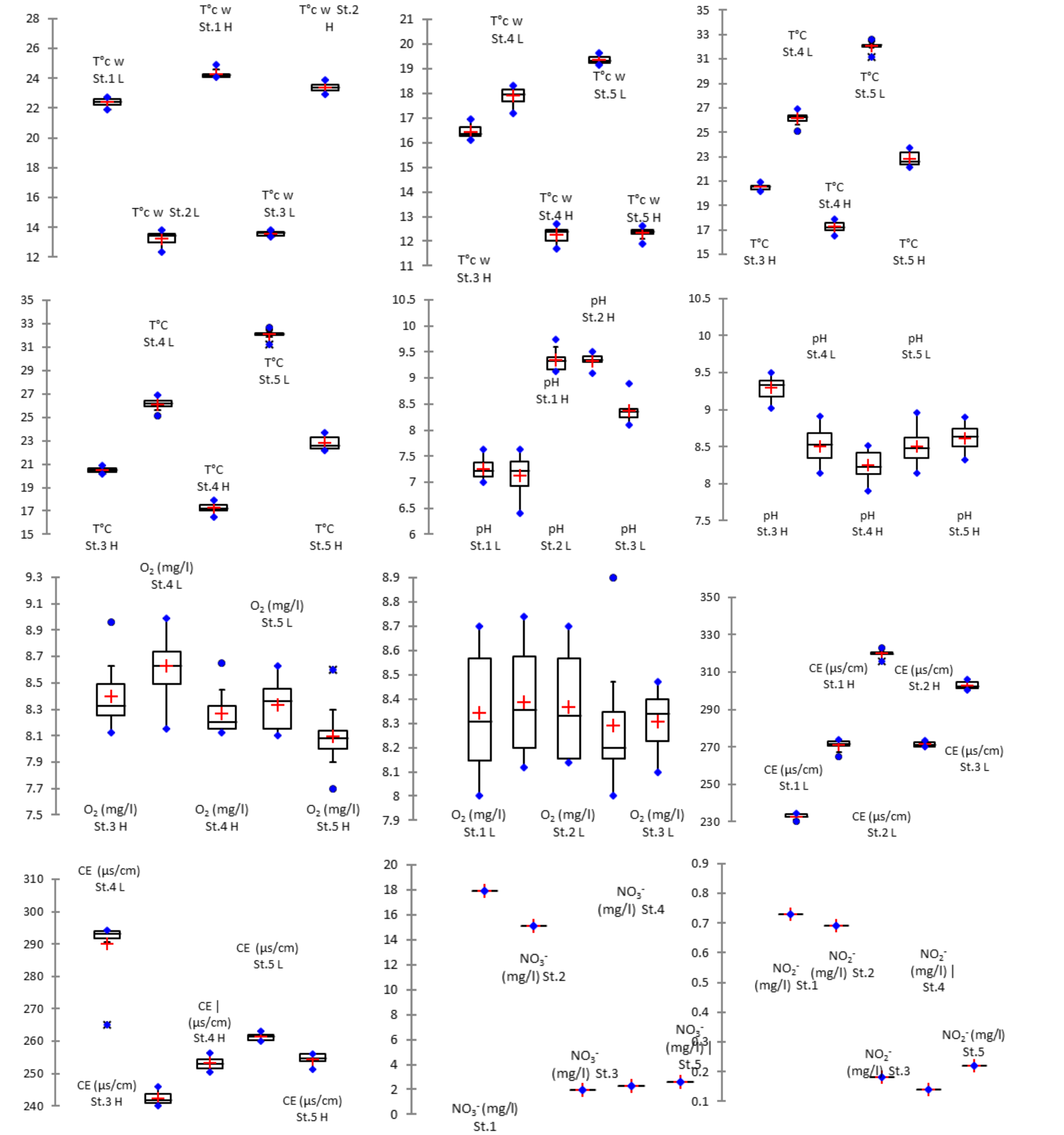

Fig.2. Box plot showing the variation of hydrogen potential (Conductivity) during the study period (2017-2018) all along the Brabtia study area(St.1: Oued Bouarroug, St.2: Oued Demat Rihane, St.3: Oued Malha, St.4: Oued Nhal and St.5: Oued Reguibette). **(H: High water [A-17; N]; L: Low water[M-S]; w: water).**

Phenology Of Imagoes, Relative Abundance, And Reproductive Behavior

Monitoring of the *C. haemorrhoidalis* populations allowed the autochthonous status of the species to be validated for Brabtia study area. Grouped into small numbers, imagoes mainly occupy not very sunny and shaded zones of the rivers with herbaceous vegetation, especially emergent aquatic plants are favored. Generally, herbaceous vegetation along the stream banks provides important shelter for adults and tenerals. The flight period of the species extends from April to November 2017 (Figure 3). The first tenerals were seen from April when the average temperature reached 28.3 ∘ C.

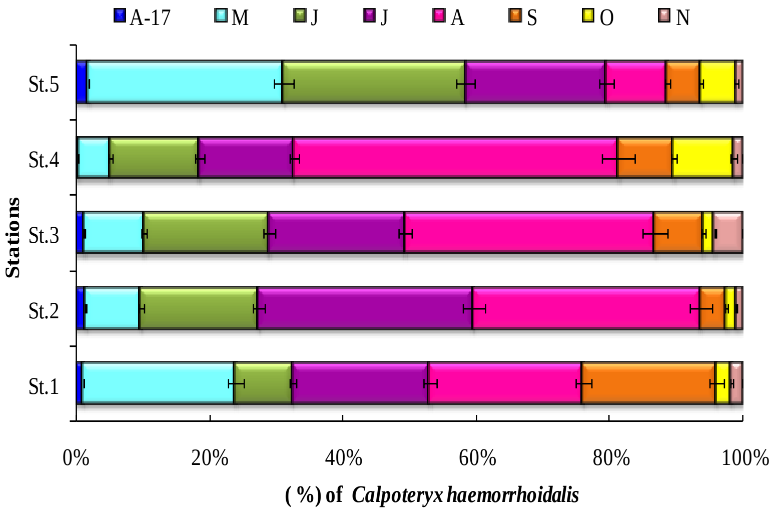

Fig.3. Relative Abundance (%) of *Calopteryx haemorrohidalis* during the study period (2017-2018) along a Brabtia study area. (St.1: wadi Bouarroug, St.2: wadi Demat Rihane, St.3: wadi Malha St.4: wadi Nhal and St.5: wadi Reguibette).

Most imagoes were however mainly observed between July and August as numbers peaked when the average temperature suddenly increased to 32,08◦C in July at St.2. This main emergence phase was also the most favorable time for finding Numidia species.

A total of 3275 individuals of *C. haemorrhoidalis* were inventoried. In terms of relative abundance, the maximum rates were recorded in August with a frequency of 48.66%) observed in St.4 (Fig. 3).

Depending on the station, the analysis of variance one-way (AV1) showed a very significant difference ($P<0.0001$) for the numerical distribution of *C. haemorrhoidalis*.

Depending on the months of the odonatological season (A-17-N), the analysis of variance one way (AV1) showed a difference very highly significant ($P <0.0001$).

Thus, the highest frequencies of the species are observed in full summer (July and August) with peaks in decreasing order, St.4≥St.3≥St.2≥St.1≥St.5 observed in August. In April and November, low frequencies were observed for all the stations studied.

The percentage of males in the emerging population of *C. haemorrhoidalis* (Immature/Mature) observed in the most abundant site in August (N=170) was, during the seasonal peak of emergence,(78♀, 92♂) 54.11%.

Males do not move very far from the water's edge and did defend a reproductive area against rivals. Male and the females mated while flying in the « tandem » position, where the female is firmly held by the male. Thus, rival males are unable to participate. Sperm transfers from the male to the female and the two partners take a particular position, the «copulatory heart» (Fig.4). Egg deposition is endophytic and it happens in tandem immediately after mating. Average laying time taken is 41,8 ± 65,20 minutes (N = 15 pairs) with a preference for soft plant stems (e.g. *Juncus maritimus*) and dead branches immersed in water (Fig.4).

Fig.4. Reproductive behavior in *C. haemorrhoidalis* (monitoring 2017-2018). (copulation and oviposition).

Under laboratory conditions, the eggs, inserted into hollow, tender stems, hatched after two weeks giving birth to free pro larvae, the first larval stage of the development cycle. Because of their fragility and lack of suitable food source, the percentage of mortality in cultured pro larvae increased with time: it was 48% at D =7 days after hatching (n = 70 pro larvae) and 100% at D = 15 days.

Phenology Of Larvae

After the death of all pro larvae cultured in the laboratory, the larval phenology of the species was established from larvae collected in situ and raised in the laboratory. The collected larvae were small and thin. The body of the larva is protected by a very solid membrane and as the larva grows, this membrane becomes too small, and the larva must shed the membrane regularly to reach the pre-imaginal stage. After this stage, the larva is ready to emerge and leave the aquatic environment.

C. heamorrhoidalis is univoltine species (with one generation per year), hence the larvae collected at the beginning of the odontological season from April to August are mainly late instars of the same cohort (stages 7, 8,9 and 10). This coincides with the emergence period. From the end of September and throughout the winter, the population mainly consists of young larvae resulting from the recent laying activity (Fig.5).

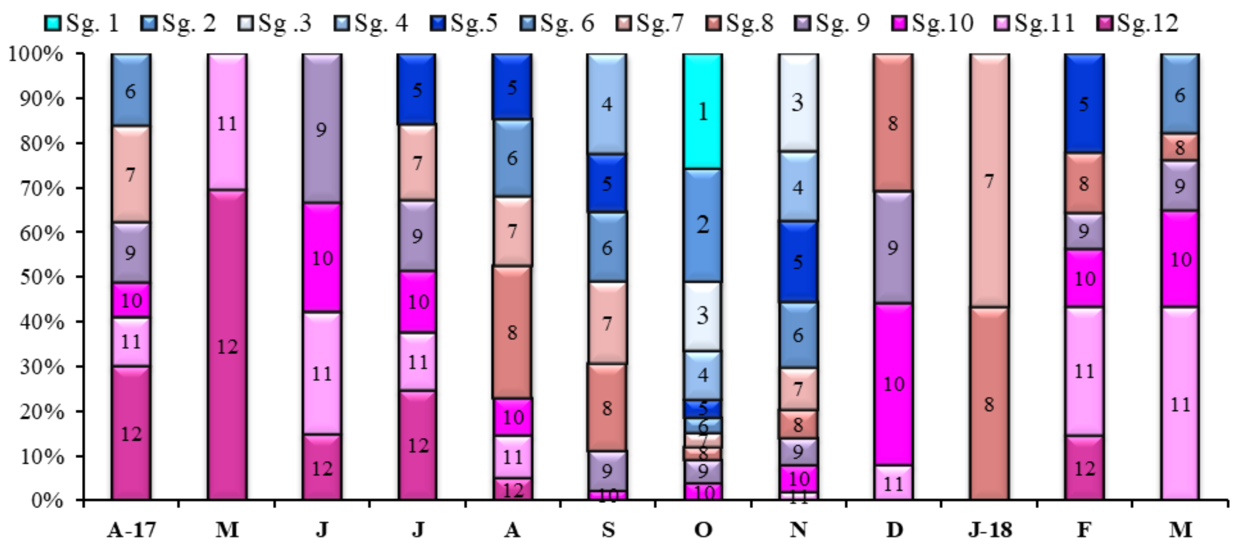

Fig.5. Larval phenology of *Calopteryx haemorrhoidalis* in Brabtia sector (monitoring 2017-2018). Sg.= stage (from 1 to 12).

Variation Of The Species Abundance With Physico Chemical Parameters

The first two axes of the PCA account for 51.48% variance (Figure 6 a).The total inertia explained by the two axes is 1,59.

In addition to these three factors (O_2 and temperatures “water and air”), the PCA reveals that the pH, the conductivity favors a good frequency of *C. haemorrhoidalis* this is observed in St.3 L (Fig.6b). The share of inertia significantly explained by environmental factors represents 26,91%.

These factors are dissolved oxygen temperature of the water and air. PCA shows highly positive correlations between the relative abundance of *C. heamorrhoidalis* and dissolved oxygen, water temperature and air temperature for (St.5, St.4, St.3, and St. 2) in low water (May-September).

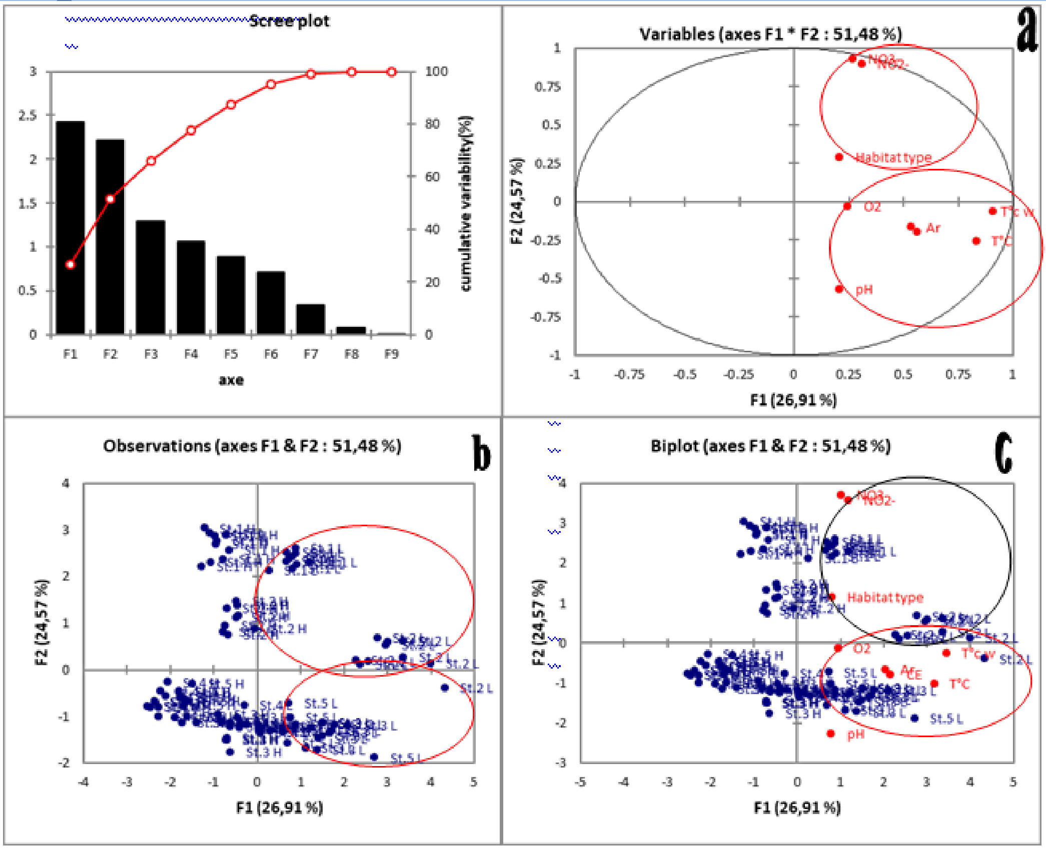

Fig. 6. Principal component analysis (PCA) performed between environmental factors and the relative abundance of Odonata *Calopteryx heamorrhoidalis*. **(H: High water; L: Low water).**

As for The St.2L is marked by the high rate of dissolved oxygen, and it had a good habitat type of Odonata (*C. haemorrhoidalis*) (Fig. 6 c).

Figure 6b allowed us to prioritize (hierarchy) all sampling stations along the Brabtia reserve using the 'good ecological status' bioindicator of running waters (*C. haemorrhoidalis*). The latter is observed on the F2 axis (24.57%) of variance in descending order of: St.2 L> St.1 L> St.4 L> St.5 L= St.3 L.

DISCUSSION

Odonata from Algeria are indirectly threatened by the loss or severe modification of their habitats. Environmental parameters of habitat and physicochemical indicators of water quality are often subject to spatiotemporal variations induced by anthropogenic activities that modify the characteristics of water and affect its quality as it has been demonstrated by (Moussa et al.,2013).

The present study is a first ecological characterization as well as a contribution to the study of the physico-chemical quality of five rivers in the sector of Brabtia (Numidie Orientale) characterized by a rich abundance of *C. haemorrhoidalis* for more than two decades (Benchalel and Samraoui, 2012). It provides the first review of changes in the phenology of *C. haemorrhoidalis* in relation to current climate and anthropogenic pressures.

Corbet and Hoess,1998, highlighted three potential responses to persistent climate change: (i) the species can disappear, (ii) the species can adapt in situ, (iii) the species can migrate to areas with a more tolerable climate.

Characterization Of The Stations, Water Quality And Availability

The quality of surface waters is characterized by the various substances they contain, their quantity and their effect on aquatic ecosystems and human health. These substances can be either of natural origin (bicarbonates, sulfates, sodium, calcium, magnesium, potassium, nitrogen, phosphorus ...), or stem from human presence (wastewater) or industrial and agricultural activities. It is the concentration of these different elements which determines the quality of water and makes it possible to know if it is suitable for a particular use (Dussart,1966; Thioulouse and Dray,2007).

From a physical-chemical point of view, concentrations of nitrite and nitrate are significantly higher (P<0.001) at the St.3 (Wadi El-Malha) level, located downstream of Lake El-Mellah suffering from mineral and agricultural pollution. Water containing nitrates is to be considered suspicious because a deterioration in microbiological quality is often associated with it (Kherifi and Kherici-Bousnoubra,2017).

Overall, nitrite concentrations are low (<0.5 $mg.l^{-1}$) and comparable to those reported by (Derradji et al.,2007) to El-Kebir Wadi. Nitrites come either from an incomplete oxidation of ammonia (nitrification is not completed), or a reduction of nitrates under the influence of a denitrifying action.

The surface water studied is oxygenated for all stations including St.1 (Wadi Bouarroug) and St.4 (Wadi Nhal). The latter have a higher flow rate compared to other stations (Kherifi et al.,2019).

Dissolved oxygen concentrations are well above 5 mg l-1, which is required for the survival of aquatic living organisms (Izonfuo and Bariweni, 2010).

As for the pH values, they are around 7 at all the stations and reflect well the lithology at the level of the Brabtia sector and the sodium bicarbonate facies of its running waters (Chaïb and Samraoui,2011).

The only significant increase in pH recorded at St.5 (Wadi Reguibett) is due to its proximity to marine waters. It should be noted that a sharp increase in pH in water may be toxic to aquatic fauna by inducing an increase in toxic ammonia concentrations (Coimbra et al.,1996).

Overall, the abiotic parameters recorded during the study period were not very variable in the five study stations, except for the 'habitat type', which is more stable and more diverse along the ST.2 (Wadi Demet Errihane) and ST.1 (Wadi Bouarroug). In fact, at the Brabtia sector, we are witnessing a degradation of the riparian forest causing not only erosion of the banks and destabilization of the trees, shrubs, and fauna associated with them, but also an increase in the temperature of the water. Warm waters increase primary production and thus reduce the dependence of aquatic food webs on non-native carbon sources (Clapcott and Barmuta,2010).

Indeed, in odonates, temperature is a major abiotic factor because of its impact on eggs, emergence timing, and adult phenology, as well as on larva development (Pritchard and al.,2000).

Water temperature also influences the emergence pattern and, particularly, its onset (Corbet et al., 2006; Boudot,2008). It is also decisive since hot water always contains less oxygen than freshwater, which penalizes the odonatofauna which is more specialized and demanding in terms of the quality and stability of its living environment.

The results obtained revealed that *C. haemorrhoidalis* is distinguished from other species of the same stations by its requirements regarding the choice of "typical habitat".

The species is more abundant according to the model: St.4≥St.3≥St.2≥St.1≥St.5 and seems very revealing of the health of the environment which shelters it in view of its requirement vis- to dissolved oxygen.

Stenoecious species, it requires specialized habitat conditions with clear and well-oxygenated waters, with a regular flow throughout the year and a favorable temperature ensured by a dense and appropriate vegetal curtain of the different ripisylve (Alder, Ash, Poplar, Willow and Elm) along the valleys which are numerous in the sector of Brabtia and of which the most important is that of Wadi El-Kebir.

C. hemorrhoidalis flight period ranged from Avril to November 2016, but this is not in perfect agreement with the known flying period (May-August) recorded at the same site two decades ago (Benchalel and Samraoui,2012). It is also noteworthy that the species in question was observed flying in the Brabtia sector until the end of December in the year 2015 (Benchalel et al.,2018).

Each species possesses a threshold beyond which emergence is triggered (Farkas et al.,2012). In the study area, the average temperature varied markedly from one year to the next. Its values reveal a strongly increasing gradient, particularly accentuated during the summer of 2015. Thus, the year 2015 ranks well ahead of the hottest years. The month of September itself exceeded 27◦C, higher than ever previously recorded for that month (22◦C recorded in 1993) and explaining the extension of the emergence period and therefore the phenology of the species. (Benchalel et al.,2018).

In this study, the emergence and appearance of the first tenerals was observed from April 2017 when the average temperature reached 28◦ C. However, the majority of the population was mainly visible from July to the end of August, considered the most favorable period for finding the species in this region.

Studies have shown that, for the same species, the beginning of the emergence can vary from one site to another or from one year to another because of the differences in spring temperature fluctuations (Farkas et al.,2012).

Shade is also known to influence the distribution and abundance of odonates and riparian site selection of odonates (Samways and Sharratt,2010). Earlier emergence, as well as range expansion of odonates, have been recorded in Britain where climate change and warmer late springs are suspected as being involved in the cause (Parr,2010).

Following peak emergence in July and August, immature individuals gradually disappeared from the stream banks to take refuge in the adjacent and sunny areas in search of food and for the acquisition of sexual maturity.

The signs of maturity are more visible in males, especially during the warmer months. They materialize by the coloring of the bottom of the last abdominal segments, from pink to bright red.

Reproduction And Climate

Mature imagos fly above water from branch to branch, and almost never depart from it. Territoriality determines the ability of males to defend a stretch of bank along the stream. *C. haemorrhoidalis* did particularly show territoriality at the reproductive sites, unlike some Zygoptera of the same course, such as *Platycnemis subdilatata, Ischnura graellsii* (Benchalel and Samraoui,2012).

The sex rate in favor of males is probably linked to reproductive behavior because it is known that territorial males generally wait for females at a «rendez vous » place (Boudot, 2008).

This territorial behavior is a strategy adopted in the genus *Calopteryx* to allow easier access to reproduction. Indeed, the *Calopteryx* males surviving in the study site and remaining in the territories the longest were more likely to be territorial and obtained more mating.

Males defend the territory so that females use it for spawning. Endophyte spawning is under the control of the male and the female can lay completely submerged underwater.

Copulation in odonates requires the cooperation of the female because she has to raise her abdomen to allow intromission. Nevertheless, in the case of *C. haemorrhoidalis*, usually, males apparently force copulation and seize females to lay eggs.

In contrast to European zygopterans (Martens,1992), the reduction in copulation and spawning time adopted in this species and in the majority of local species seems to be an adaptation to cope with the high summer temperatures of southern France, near Mediterranean sea.

This type of adaptation strategy is very widespread in the Mediterranean region because and has been recognized previously (Benchalel and Samraoui, 2012; Benchalel et al.,2018). Other studies have shown that odonates are dependent on the activity on ambient temperature, and also on their ability to regulate their body temperature (Da Silva Monteiro Júnior et al., 2013).

All the prolarvae that hatched in the laboratory died after 15 days, probably because of experimental conditions concerning an aquatic plant habitat did not correspond to those of nature. *C. heamorrhoidalis* is autochthonous and uni- voltine because the larvae collected in situ in early spring reached the pre-imaginal stage before the end of summer.

This cohort then gradually disappeared in early autumn as a new cohort of young larvae, in this case, stages 1,2,3,4, and 5, begin to replace them.

Further study of the larval development cycle should be considered in order to answer and decide on the types of development of this species (number of stages) and in the long term, answer key questions in terms of management.

Variation Of The Species Abundance With Physico Chemical Parameters

Among odonates, climate change may affect both the distribution and characteristics of freshwater habitats (Blenckner et al.,2007).

This study revealed that the species studied occupies very sunny, shallow microhabitats, with heterogeneous substrates and with a sufficient density of riparian vegetation to ensure shade percentages essential during the breeding season.

This preference for habitat selection has also been reported in the genus *Calopteryx* in Seybouse watershed (Khelifa et al.,2016). The results of this study confirm the possible cohabitation of *C. haemorrhoidalis* in the preferred sites of its exogenous congener, but the opposite does not seem to be confirmed yet. The absence of *C. exul* from the Brabtia sector noted in this study confirms its trend for streams above 200 m.s.l.

Water quality and quantity do seem to be a restrictive factor for environmental colonization by *C. haemorrhoidalis* because the species is unable to tolerate a certain amount of stress similar to stagnant water species.

It is also noteworthy, that the life cycle of the species cannot be successful in rivers and streams that reach up that reach up great depths in winter (more than one meter), followed by a drought in summer, as Wadi El-Kébir-east (Benchalel et al.,2017).

The correlation established between the abundance of *C. haemorrhoidalis* and the physico-chemical parameters from the canonical correspondence analysis shows an ecological gradient, in the distribution of the species, significantly (P <0.001) explained by PCA) shows an ecological gradient, in the distribution of the species, significantly (P<0.001) explained by a requirement for dissolved oxygen, both temperatures and pH.

The long-term sustainability and persistence of *C. haemorrhoidalis* in the rivers of the Brabtia sector for more than two decades is a testament to a stable and high-quality natural environment that can support a large food chain, bringing together other insectivorous predators such as fish, amphibians, birds and smaller mammals.

For these rivers, located near large lakes (Mellah and Oubeira), the diversity of Odonata is a valuable element that adds to the vocation of conservation.

As is commonplace in eastern Numidia, modifications to the hydrographic network of the natural reserve of Brabtia, combined with other restructuring work in the Wadi Bouarroug area (Benchalel et al.,2018), are likely to have contributed to a reduction in aquatic ecosystem quality.

This justifies protection measures, especially for the aquatic breeding habitats, that include hydrological management to mitigate climate change, and to ensure that the species currently persisting in areas where it has been recorded at higher abundances, now and in the past (two decades or more ago).

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REFERENCES

Ahmad M., et al.,Biochar as a sorbent for contaminant management in soil and water: A review , Chemosphere, vol. 99, p. 19‑33, 2014.

Al-Shami S A., Md Rawi C S., Ahmad A H., Abdul Hamid S., and Mohd Nor S A, Influence of agricultural, industrial, and anthropogenic stresses on the distribution and diversity of macroinvertebrates in Juru River Basin, Penang, Malaysia , Ecotoxicology and Environmental Safety, vol. 74, n° 5, p. 1195‑1202, 2011.

Bellil M., Benhamana Z., and Benhamiche Z N, Contribution à l’étude des qualités physiques des sources karstiques de la région Nord-Ouest de Bejaia, 2016.

Belouahem-Abed D., Belouahem F., and Bélair G , Biodiversité floristique et vulnérabilité des aulnaies glutineuses de la Numidie algérienne

(NE Algérien) », European Journal of Scientific Research, vol. 32, n° 3, p. 329–361,2009.

Benchalel W., and Samraoui B, 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) , mediterranee, n° 118, p. 19-27,2012.

Benchalel W., Merah S., Bouslama Z., Ramdani M., Elmsellem H., and Flower R, Odonata as indicators of environmental impacts in rivers, case of wadi El-Kébir-East (northeastern Algeria), Moroccan Journal of Chemistry, vol. 5, n° 4, p. 5-4 (2017) 610-6.

Benchalel W ., BouzianeA ., Bouslama Z ., El Mesellem H., Roger F., et Ramdani M, Odonata of Wadi Bouarroug (northeastern Algeria) and environmental determinants of their distribution p. 14, 2018.

Benyacoub S., et al., Plan directeur de gestion du Parc National d'El Kala et du complexe des zones humides », Projet GEF (Global Environment Facility)-Banque Mondiale, vol. 220, 1998.

Bona F ., Falasco E ., Fenoglio S ., Iorio L., and Badino G, Response of macroinvertebrate and diatom communities to human-induced physical alteration in mountain streams, River Research and Applications, vol. 24, n° 8, p. 1068-1081, 2008.

Boudot J P, Selysiothemis nigra (Vander Linden, 1825), nouveau pour le Maroc, et autres observations sur les Odonates du Maghreb nord-occidental (Odonata: Anisoptera: Libellulidae) , Martinia, vol. 24, n° 1, p. 3–29, 2008.

Boukhatem A ., Benslama M., and Abed-Belouahem D, Biodiversity and Ecology of Mosses in Northeastern Algeria: Case of the Watershed Tonga. », p. 10, 2017.

Blenckner T., and al., Large-scale climatic signatures in lakes across Europe: A meta-analysis », Global Change Biology, vol. 13, n° 7, p. 1314–1326, 2007.

Chaïb N., and Samraoui B, Évaluation de la qualité physico-chimique des eaux de l'oued Kébir-Est et de ses principaux affluents (Nord-Est algérien) , Science et changements planétaires/Sécheresse, vol. 22, n° 3, p. 171–177 , 2011.

Chovanec A., and Waringer J, Ecological integrity of river-floodplain systems assessment by dragonfly surveys (Insecta: Odonata), Regul. Rivers: Res. Mgmt., vol. 17, n° 4-5, p. 493-507, 2001.

Clapcott J E., and Barmuta L A, Forest clearance increases metabolism and organic matter processes in small headwater streams, Journal of the North American Benthological Society, vol. 29, n° 2, p. 546–561, 2010.

Coimbra C N ., Graça M A S., and Cortes R M, The effects of a basic effluent on macroinvertebrate community structure in a temporary Mediterranean river, Environmental pollution, vol. 94, n° 3, p. 301–307, 1996.

Corbet P S., and Hoess R, Sex ratio of Odonata at emergence », International Journal of Odonatology, vol. 1, n° 2, p. 99–118, 1998.

Corbet P S ., Suhling F ., and Soendgerath D, Voltinism of Odonata: a review », International Journal of Odonatology, vol. 9, n° 1, p. 1–44, 2006.

Da Silva Monteiro Júnior C., Couceiro S R M ., Hamada N., and Juen L, Effect of vegetation removal for road building on richness and composition of Odonata communities in Amazonia, Brazil », International Journal of Odonatology, vol. 16, n° 2, p. 135–144, 2013.

Derradji F ., Bousnoubra H ., Kherici N ., Romeo M ., and Caruba R, « Impact de la pollution organique sur la qualité des eaux superficielles dans le Nord-Est algérien », Science et changements planétaires / Sécheresse, vol. 18, n° 1, p. 23-27, 2007.

Doretto A., Piano E ., Falasco E ., Fenoglio S ., Bruno M C ., and Bona.F, Investigating the role of refuges and drift on the resilience of macroinvertebrate communities to drying conditions: An experiment in artificial streams, River Research and Applications, vol. 34, n° 7, p. 777-785, 2018.

Dussart L , Limnologie : L'étude des eaux continentales , 1966.

Farkas A ., Jakab T ., Tóth A., Kalmár A F., and Dévai G, Emergence patterns of riverine dragonflies (Odonata: Gomphidae) in Hungary: variations between habitats and years, Aquatic Insects, vol. 34, n° sup1, p. 77–89, 2012.

Ferreras-Romero M ., Márquez-Rodríguez J ., and Ruiz-García A, Implications of anthropogenic disturbance factors on the Odonata assemblage in a Mediterranean fluvial system , International Journal of Odonatology, vol. 12, n° 2, p. 413-428 , 2009.

Hunt D T E ., Johnson I., and Milne R, The Control and Monitoring of Discharges by Biological Techniques », Water and Environment Journal, vol. 6, n° 4, p. 269-276, 1992.

Izonfuo L., and Bariweni A, The Effect Of Urban Runoff Water And Human Activities On Some Physico- Chemical Parameters Of The Epie Creek In The Niger Delta, Journal of Applied Sciences and Environmental Management, vol. 5, n° 1, 2010.

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

Kherifi w., and Kherici-Bousnoubra H, .The correlation between the variability of hydrological parameters with altitude in the El

Taref Region (Nord East Algeria). », LARHYSS Journal P-ISSN 1112-3680/E-ISSN 2602-7828, n° 30, p. 137–147, 2017.

Kherifi W ., Hecini L ., Bekiri F., and Kherici-Bousnoubra H, Faecal contamination of water in the Lake Mellah and its catchment area, north-eastern Algeria, Journal of Water and Land Development, vol. 42, n° 1, p. 110–116,2019.

Martens A, Egg deposition rates and duration of oviposition in Platycnemis pennipes (Pallas)(Insects: Odonata), Hydrobiologia, vol. 230, n° 1, p. 63–70, 1992.

Moussa A ., Chahlaoui A., and Rour H, Évaluation de la pollution physico-chimique des eaux de l'Oued Khoumane (Moulay Idriss Zerhoun, Maroc) , Int. J. Bio. Chem. Sci, vol. 6, n° 6, p. 7096‑7111, 2013.

Natuurtijdschriften .[Consulté le: 25-sept-2019]. [En ligne]. Disponible sur: http://natuurtijdschriften.nl/search?identifier=591695

Parr A , Monitoring of Odonata in Britain and possible insights into climate change », BioRisk, vol. 5, p. 127, 2010.

Pellerin P., et Pilon J G , Etude morphologique des larves de Lestes eurinus Say (Odonata: Lestidae), élevées en laboratoire , Canadian Journal of Zoology, vol. 56, n° 12, p. 2520–2529, 1978.

Pritchard G., Harder L D ., Kortello A ., and Krishnaraj R, The Response of Larval Growth Rate to Temperature in Three Species of Coenagrionid Dragonflies with Some Comments on Lestes Disjunctus (Odonata: Coenagrionidae, Lestidae), International Journal of Odonatology, vol. 3, n° 2, p. 105‑110, 2000.

Riservato E, The Status and Distribution of Dragonflies of the Mediterranean Basin, 2009.

Rodier J , La protection des eaux contre la radioactivité », Bulletin de l'Association pharmaceutique française pour l'hydrologie, n° 4, p. 7–40, 1971.

Samraoui. B et R. Menaï, « A contribution to the study of Algerian Odonata. », *International Journal of Odonatology*, vol. 2, n° 2, p. 145‑165, déc. 1999.

Samways M J., et Taylor S, Impacts of invasive alien plants on Red-Listed South African dragonflies (Odonata), South African Journal of Science, p. 3, 2004.

Samways M J., and Sharratt N J, Recovery of Endemic Dragonflies after Removal of Invasive Alien Trees. Conservation Biology, vol. 24, n° 1, p. 267‑277 , 2010.

Ter Braak C J F., and Smilauer P, Canoco for Windows version 4.02 , Centre for Biometry Wageningen, CPRO-DLO, Wageningen , 1999.

Thioulouse J ., and Dray S, Interactive multivariate data analysis in R with the ade4 and ade4TkGUI packages », Journal of Statistical Software, vol. 22, n° 5, p. 1–14 , 2007.

Tourne A., et al., Directive cadre européenne sur l'eau: proposition d'un outil d'analyse et de participation pour améliorer la qualité des milieux aquatiques , TechniquesSciencesMéthodes,n°4,p.25–36,2014