

SURVEY AND REPARTITION OF ODONATOFAUNA IN THE LOTIC AND LENTIC WATERS OF THE DJURDJURA AND SOUMMAM REGIONS OF KABYLIA (NORTH CENTRAL ALGERIA)

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Abstract

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The aim of this study is to examine the Odonata fauna structure and composition in Kabylia's wetlands (central north Algeria) by sampling 36 potential sites (16 wadis and 20 water reservoirs) in the two main departments of this region, namely, the Kabylia of Djurdjura (Tizi Ouzou) and the Kabylia of Soummam (Bejaia). This region has one of the most important hydrographic systems in Algeria and a wide range of exceptional wetlands due to its important rainfall regime. A lack of studies, especially in the western part of the region (Tizi Ouzou), prompts a specific inventory and ecological analysis of the Odonata population over a period of 6 months (from April to September 2021). Forty species of Odonata have been recorded in Kabylia, of which *Pyrrhosoma nymphula* represents a new record for Algeria, raising the reference list to 64 species. There are four northern African endemic species and among these, we report on the rediscovery of the critically endangered (EN) *Calopteryx exul* in Algeria, recorded in the 19th century and deemed to have been extinct after an absence of more than a century; *Gomphus lucasii* is assessed as vulnerable (VU) and *Enallagma deserti* and *Platynemis subdilatata* are judged as least concern (LC).

Key words: North Africa, elevation gradients, Odonata, wetlands, distribution.

Introduction

Odonata are one of the most ancient lineages of winged insects. They are regarded as an important predator across their complex life cycle stages in aquatic systems (Bybee et al., 2016; Stoks, Cordoba-Aguilar, 2012). About 6,392 species have been reported worldwide, but many more remain to be discovered (Paulson, Schorr, 2022). The study of the composition and structure of insect populations, Odonata, in particular, as aquatic insects, can give us a comprehensive overview of the dynamics of their habitats. They are known to be key organisms in aquatic community functioning (Corbet, 1999); moreover, they are regarded as an indicator of faunal richness (D'Aguilar, Dommange, 1998) and health of freshwater ecosystems (Hart et al., 2014). Studies over the past several years have revealed that odonates can be also used to evaluate climate change (Termaat et al., 2019), to monitor and manage freshwater habitats (Chovanec et al., 2015), as well as to serve as good indicators of land use intensification

(Rocha-Ortega et al., 2020). Their natural environment is lamentably within the most threatened ecosystems on the planet (Campbell, 2020; Lubanga et al., 2021) due to the combination of climate change and anthropogenic disturbance (Hassall, 2015; Nagy et al., 2019; Rocha-Ortega et al., 2020).

The study of Algerian odonates dates back to the 18th century (Selys-Longchamps, 1849), though a significant amount of odonatological research has been published recently (Demnati et al., 2019). New records of different species in new sites have been published, including species of conservation concern such as *Calopteryx exul*, *Urothemis edwardsii*, and *Lindenia tetraphylla* (Khelifa et al., 2016; Khelifa, Mellal, 2017; Khelifa, Zebba, 2018; Chelli et al., 2019, 2020; Zouaimia et al., 2022). Odonatofauna of Algeria comprises only 1% of the species recognized currently worldwide with 64 species (Taleb et al., 2022; Khelifa et al., 2021). This rate does not accurately reflect the real local diversity by virtue of the fact that Algeria is a very large country in North Africa, and surveys for Odonata are often very localized; most of

them were concentrated in Numidia, in the extreme northeast of the country. Indeed, the distribution and status of dragonflies are fairly well documented in this territory. However, similar knowledge has not been accumulated in the Kabylia region. Before the current study, the available data on Kabylia dragonflies was limited to the work carried out by Chelli in the eastern part of this region (Chelli, Moulai, 2019a,b; Chelli et al., 2019, 2020), but in its western part, not much data is available on this taxon.

There is an urgent need for more field studies and to focus observations on particular and isolated habitats like mountain streams, which do not receive much attention despite the potential presence of rare specialist species (Dijkstra, Schröter, 2020). As a consequence, the present study was carried out in the Kabylia region to improve the knowledge of this taxon and close the gaps in our understanding of the diversity and ecology of dragonflies in various aquatic habitats, with the main purpose of updating the list of odonata in the northern region.

Material and methods

Area and study sites

The Kabylia region (Fig. 1), which covers an area of 32 486 km² (0.6% of Algeria's territory), is a mountainous coastal region in central northern Algeria, which runs from Thénia (west) to Bejaia (east), and from the Mediterranean Sea (north) to the valley of Soummam (south). It covers two provinces of Algeria: (1) the Great Kabylia (GK) or Kabylia of Djurdjura (Tizi Ouzou) and

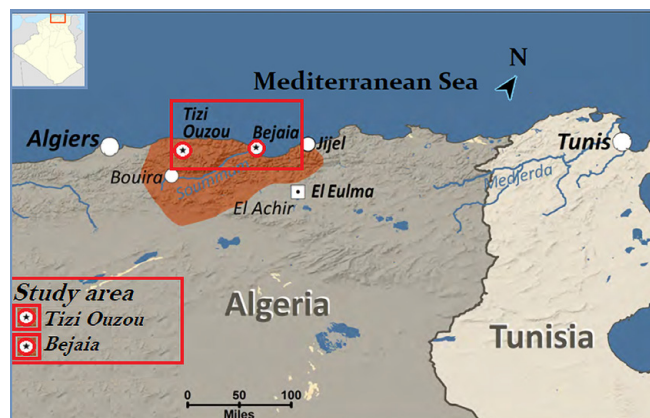


Fig. 1. Limits and geographic location of the study region of Kabylia in North Algeria.

(2) the Little Kabylia (LK) or Kabylia of Soummam (Bejaia). Kabylia is a homogeneous natural region in terms of its physical features (90% mountainous relief) and its vegetation cover (60% forest and scrubland) (Dahmani, 2004). It is characterized by a Mediterranean climate with a relatively cold and rainy winter and a hot and dry summer (more than 1,000 mm of rainfall per year). Emberger pluviothermic quotient Q2 places this region in humid bioclimatic stages to subhumid with variations to mild

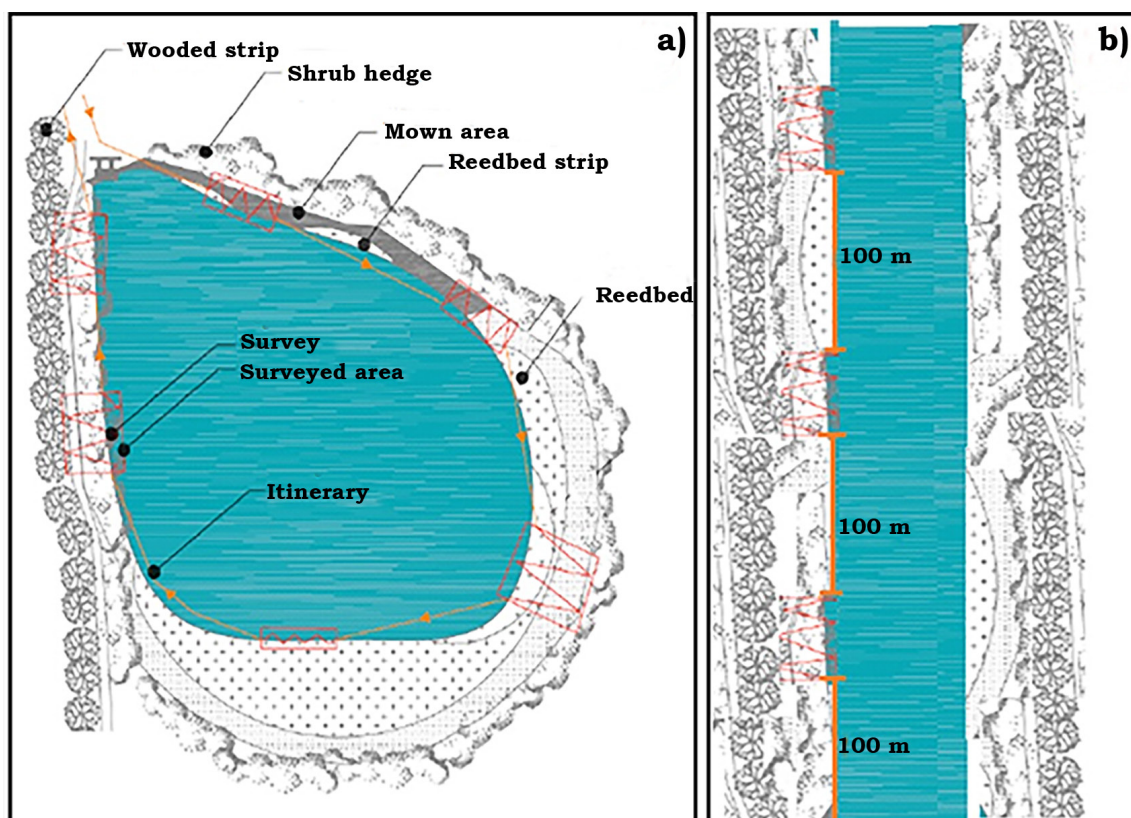


Fig. 2. Schematic representation of the Odonata survey protocol (Indermuehle et al., 2008): (a) stagnant water (SW), (b) running water (RW).

Table 1. Sampling sites, geographic location, altitude, and habitat characteristics of the study sites.

Typical habitat	Study stations	Code	Localities	Region	Altitude (m)	Latitude	Longitude
Running water (RW)	Thighilt Hadj Ali	St1	Larbaa Nath irathen	Great Kabylia Tizi Ouzou (GK)	900	36°39'03"N	4°11'00 „E
	Assif Ath Agad	St2	Ouacif		851	36°23'06"N	4°10'11"E
	Assif El Hammam	St3	Ait ouabane		700	36°29'53"N	4°17'19"E
	Thala Oumellal	St4	Foret Darna		1095	36°30'03"N	4°18'11"E
	Tamda Bawda	St5	Tirourda		1135	36°29'29 „N	4°37'9 „E
	Aflis Oulili	St6	Ait Alaoua		1183	36°28'28"N	4°21'41"E
	Station Biologique	St7	Thala rana-Bouira		1305	36°10'69"N	4°03'17"E
	Laanser Avarkane	St 8	Thala rana-Bouira		838	36°06'70"N	4°03'23"E
	Reserve Intégrale Ikharadhen	St9	Thala guilef		1450	36°43'51 „N	4°18'12 „E
	Assif Laazib	St10	Tikdjda		1500	36°27'28 „N	4°06'35 „E
	Oued Sebaou	St11	Freha		200	36°27'28 „N	4°06'35 „E
	Oued Aguerioune	St23	Darguina	Little Kabylia Bejaia (LK)	47	36°34'46"N	5°20'52"E
	Oued Djemaa	St 24	Boukhelifa		39	36°37'57"N	5°09'31"E
	Oued Saket	St25	Toudja		06	36°49'35"N	4°56'20"E
	Oued Soummam	St26	Akbou		165	36°25'35"N	4°32'40"E
	Oued Bousselam	St27	Bouhamza		240	36°25'15 „N	4°37'9 „E
Stagnant water (SW)	Retenue Collinaire Zaouiya	St12	Makouda	Great Kabylia Tizi Ouzou (GK)	79	36°45'50"N	4°03'41"E
	Retenue Collinaire Imaloussen	St13	Timizart		160	36°46'22"N	4°12'51"E
	Retenue Collinaire Souamaa	St14	Boubhir		231	36°40'51"N	4°21'14"E
	Retenue Collinaire Boufhimia	St15	Draa El mizane		314	36°33'43"N	3°48'37"E
	Barrage Taksebt	S16	Irdjen – Beni aissi		110	36°40'39"N	4°07'01 „E
	Barrage Djebba	St17	Ouagnoune		560	36°46'27"N	4°12'36 „E
	Barrage Tizi ghenif	St18	Tizi ghenif		312	36°34'50"N	3°47'29 „E
	Barrage DEM	St19	Draa El mizane		279	36°34'00"N	3°50'24 „E
	Barrage Tilsedit	St 20	Boucheloul_bouira		458	36°20'53"N	4°03'38 „E
	Lac Ouguelmim	St 21	Ait bouadou		1700	36°27'48"N	4°04'05"E
	Mare Azazga	St 22	Foret ath ghobri		556	36°45'58"N	4°23'44"E
	Lac Mezaia	St28	Bejaia	Little Kabylia Bejaia (LK)	17	36°44'51"N	5°03'11"E
	Marais Tamelaht	St29	Bejaia		01	36°42'59"N	5°04'49"E
	Barrage Betlou	St30	El Kseur		43	36°41'23"N	4°54'18"E
	Barrage Tichi Haf	St31	Bouhamza		300	36°25'8 „N	4°41'58 „E
	Etang Agoulmime Averkane	St 32	Adekar		1264	36°41'47"N	4°36'09"E
	Marre Ikher	St33	Tibane		1065	36°37'09"N	4°38'09"E
	Marre Ouroufel	St34	Akfadou		1360	36°38'41"N	4°34'42"E
	Marre Tala Guizane	St35	Chemini		1572	36°37'42"N	4°34'03"E
	Marre Alsus	St36	Tifra		590	36°40'02"N	4°39'56"E

and warm winter (Daget, David, 1982). This vast territory is dotted with lakes, marshes, lagoons, dams, and high-mountain forest ponds. The whole region is drained by several important rivers and smaller coastal wadis with a very irregular but permanent regime. The most important rivers are the Isser, Sebaou, and Soummam River (with its two tributary streams: Sahel and

Boussellam wadi). It should be noted that the Soummam River had been classified in 2012 as a wetland of international importance in the Ramsar Convention.

The geographic area selected for this work included only the departments of Tizi Ouzou and Bejaia. Our study sites were selected mainly based on their accessibility and in places relatively

clear of vegetation, including various kinds of wetlands divided into two categories: lotic or running water (RW), represented by 16 wadis, and lentic or stagnant water (SW) with 20 reservoirs, the majority being ponds, dams, and a few lakes. These water points are distributed along an altitudinal gradient between 1 m and 1700 m above sea level (a.s.l.). Their main characteristics are given in Table 1.

Odonata sampling

Our study took place from April to September 2021. Our visits were carried out in the morning (09:00–11:00 hours) and late afternoon (16:00–18:00 hours), periods when adult dragonflies are active in the region. An additional period of 20 min was allocated to the immediate surroundings of each habitat (herbaceous and woody vegetation, etc.) to record sheltered adults. Thirty-six sites were studied, ranging from 1 to 1700 m a.s.l. (Table 1). We visited each site twice per month. The surveys were conducted using two types of procedure. In watercourses (RW), a transect of 1000 m of bank line was sampled. Transects were divided into ten 100-m sections (Fig. 2b). Each stretch of the watercourse was surveyed from one of the banks by walking slowly and regularly to identify individuals in the vegetation and over the water. In the case of SW, it was sufficient to walk around the edges of each water body (Fig. 2a). The capture was performed using a butterfly net. The species caught were identified using an aplanatic magnifying glass and relevant identification guides (D'Aguilar, Dommanget, 1998; Grand, Boudot, 2006; Dijkstra, Schröter, 2020). Specimens raising doubts were kept for careful examination in the laboratory. Our sampling was adequate to determine species richness and the assemblage composition of odonates (Khelifa et al., 2016).

Data analysis

Statistical analyses were carried out with R 4.0.2 (R Development Core Team, 2021). For a better analysis of the composition and structure of the Kabylia odonotofauna, a treatment of richness, abundance, and diversity was performed. To characterize species diversity in the freshwater community, Shannon's index (H'), which accounts for both abundance and evenness of the species detected, was estimated with the equation $H' = -\sum_{i=1}^R p_i \times \ln p_i$, where p_i is the proportion of species i relative to the total number of species in the site and R is richness. A Pielou's evenness index was applied: $J' = H'/H'_{\max}$. Spearman correlations were carried out to reveal the potential relationship between the species richness and elevations for the two categories of habitats (lotic and lentic water system). Values as presented as mean $\pm$ standard deviation (SD).

Results and discussion

Odonata species inventoried

The checklist and status of Odonata species recorded in the different lotic and lentic habitats of Kabylia region during the sampling period are given in Table 2. The taxa of the "family" group are presented in a systematic order, and those of the "genus" and "species" groups are presented in an alphabetical

order. The status of recorded species is taken from the Mediterranean and North African IUCN (The International Union for Conservation of Nature) Red Lists (Riservato et al., 2009; Samraoui et al., 2010).

During the study period, a total of 41 species of Odonata (14 damselflies and 27 dragonflies) belonging to seven families were recorded in the lotic and lentic waters of the Kabylia region. More than half of the species belonged to Anisoptera (66%), and Libellulidae was the most dominant family with 15 taxa, accounting for 36.5% of all Odonata recorded (Table 2). The eastern part (LK) of the study area with its 37 species was more diverse than the western part (GK) which recorded only 29 species. On the other hand, in this department, we report *Pyrrhosoma nymphula* as a new record for Algeria. This raises the number of species of the reference list established by Samraoui, Menai (1999) to 64 species. Among all recorded species, 25 were common to both departments. Thirty-three (i.e., 80%) of the listed odonotofauna were assessed in the IUCN Red List Category (Northern Africa) as least concern (LC) (Riservato et al., 2009; Samraoui et al., 2010). However, the Kabylia odonotofauna included four northern African endemic species, namely, the rediscovery of the critically endangered (EN) *Ca. exul* in Algeria, recorded in the 19th century and deemed to have been extinct after an absence of more than a century; *Gomphus lucasii* assessed as vulnerable (VU); and *Enallagma deserti* and *Platycnemis subdilatata* judged as LC. In addition to this Maghreb group, we can add another four threatened species: *Aeshna affinis*, *A. isocetes*, and *Sympetrum sanguineum* as VU; *Onychogomphus costae* and the new species *Pyrrhosoma nymphula* assessed as near threatened (NT).

Structure of the Odonata communities

Species richness was variable in the study sites. Table 3 shows that of the 41 species of Odonata recorded in the two departments of Kabylia, eight are strictly linked to lotic waters and 10 others prefer lentic waters, while 21 species are common to both types of water. Ten species appear to have a wide altitudinal distribution, ranging from low altitudes to high altitudes exceeding 1000 m. They are *Calopteryx haemorrhoidalis*, *Lestes virens*, *Coenagrion caerulescens*, *Ischnura graellsii*, *Aeshna affinis*, *A. mixta*, *Anax imperator*, *Orthetrum cancellatum*, *Sympetrum fonscolombii*, and *S. striolatum*. All of these species, with the exception of the first, appear to be equally indifferent to the types and flow regimes of the water. On the other hand, nine are observed only at low altitude: the four Gomphidae (*Gomphus lucasii*, *Onychogomphus costae*, *O. forcipatus*, and *O. uncatus*), in the company of *Calopteryx exul* are observed exclusively in lotic water; on the other hand, *Orthetrum trinacria* and *Selysiotthemis nigra* are noted only in SW, while *Trithemis annulata* and *Tr. kirbyi* mark their presence in both habitats. Five others seem to prefer medium and high altitudes, as they are only seen above 500 m. They are *Chalcolestes viridis*, *Lestes barbarus*, *Boyeria irene*, *Sympetrum meridionale*, and *S. sanguineum*. However, the species *Aeshna cyanea* seems to prefer high-altitude streams above 1000 m, as it was only recorded at the Ait Alaoua stream (St6) in GK at 1183 m a.s.l.

The richness and spatial distribution of odonates in the two Kabylia regions, as well as their abundance, can be attributed to

Table 2. Checklist and status of Odonata species recorded in the two water types of the Kabylia region.

Suborder	Family	Species	Tizi Ouzou (GK)	Bejaia (LK)	IUCN Red List Status
Zygoptera (34%)	Calopterygidae (5%)	<i>Calopteryx haemorrhoidalis</i> (Vander Linden, 1825)*	+	+	LC
		<i>Calopteryx exul</i> Selys, 1853	-	+	EN
	Lestidae (10%)	<i>Chalcolestes viridis</i> (Vander Linden, 1825)*	+	+	LC
		<i>Lestes barbarus</i> (Fabricius, 1798)	-	+	LC
		<i>Lestes virens</i> (Charpentier, 1825)	-	+	LC
		<i>Sympecma fusca</i> (Vander Linden, 1820)*	+	+	LC
	Platycnemididae (2%)	<i>Platycnemis subdilatata</i> Selys, 1849*	+	+	LC
	Coenagrionidae (17%)	<i>Ceriagrion tenellum</i> (Villers, 1789)*	+	+	LC
		<i>Coenagrion scitulum</i> (Rambur, 1842)	-	+	NT
		<i>Coenagrion caerulescens</i> (Fonscolombe, 1838)	+	-	LC
		<i>Enallagma deserti</i> (Selys, 1871)*	+	+	LC
		<i>Erythromma lindenii</i> (Selys, 1840)*	+	+	LC
		<i>Ischnura graellsii</i> (Rambur, 1842)*	+	+	LC
		<i>Pyrrhosoma nymphula</i> (Sulzer, 1776)***	+	-	NT
Anisoptera (66%)	Aeshnidae (19.5%)	<i>Aeshna affinis</i> Vander Linden, 1820*	+	+	VU
		<i>Aeshna cyanea</i> (O.F. Müller, 1764)	+	-	
		<i>Aeshna isocles</i> (O. F. Müller, 1767)	-	+	VU
		<i>Aeshna mixta</i> Latreille, 1805*	+	+	LC
		<i>Anax imperator</i> Leach, 1815*	+	+	LC
		<i>Anax parthenope</i> (Selys, 1839)*	+	+	LC
		<i>Boyeria irene</i> (Fonscolombe, 1838)	+	-	NT
		<i>Hemianax ephippiger</i> (Burmeister, 1839)*	+	+	LC
	Gomphidae (10%)	<i>Gomphus lucasii</i> Selys, 1849	-	+	VU
		<i>Onychogomphus costae</i> Selys, 1885	-	+	NT
		<i>Onychogomphus forcipatus</i> (Linnaeus, 1758)*	+	+	LC
		<i>Onychogomphus uncatus</i> (Charpentier, 1840)	-	+	LC
	Libellulidae (36.5%)	<i>Brachythemis impartita</i> (Karsch, 1890)*	+	+	LC
		<i>Crocothemis erythraea</i> (Brullé, 1832)*	+	+	LC
		<i>Diplacodes lefebvrii</i> (Rambur, 1842)	-	+	LC
		<i>Orthetum cancellatum</i> (Linnaeus, 1758)*	+	+	LC
		<i>Orthetrum chrysostigma</i> (Burmeister, 1839)*	+	+	LC
		<i>Orthetrum coerulescens</i> (Fabricius, 1798)*	+	+	LC
		<i>Orthetrum nitidinerve</i> (Selys, 1841)*	+	+	LC
		<i>Orthetrum trinacria</i> (Selys, 1841)*	+	+	LC
		<i>Selysiothemis nigra</i> (Vander Linden, 1825)	-	+	LC
		<i>Sympetrum fonscolombii</i> (Selys, 1840)*	+	+	LC
		<i>Sympetrum meridionale</i> (Selys, 1841)*	+	+	LC
		<i>Sympetrum sanguineum</i> (O. F. Müller, 1764)	-	+	VU
		<i>Sympetrum striolatum</i> (Charpentier, 1840)*	+	+	LC
		<i>Trithemis annulata</i> (Palisot de Beauvois, 1807)*	+	+	LC
		<i>Trithemis kirbyi</i> Selys, 1891	-	+	LC
	Total	41	29	37	

Notes: + - presence of species; - - absence of species; * - common species; GK - Great Kabylia; *** - new species; LK - Little Kabylia; LC - least concern; EN - endangered; NT - near threatened; VU - vulnerable.

Table 3. Odonata association with elevation and habitat type.

Species	Elevation (m)			Habitat type	
	-500 m	500–1000 m	+1000 m	Running water (RW)	Stagnant water (SW)
<i>Calopteryx haemorrhoidalis</i>	+	+	+	+	-
<i>Calopteryx exul</i>	+	-	-	+	-
<i>Chalcolestes viridis</i>	-	+	+	+	+
<i>Lestes barbarus</i>	-	+	+	-	+
<i>Lestes virens</i>	+	+	+	+	+
<i>Sympecma fusca</i>	+	-	+	+	+
<i>Platycnemis subdilatata</i>	+	-	+	+	-
<i>Ceriagrion tenellum</i>	+	-	+	+	+
<i>Coenagrion scitulum</i>	+	-	+	+	+
<i>Coenagrion caerulescens</i>	+	+	+	+	+
<i>Enallagma deserti</i>	+	-	+	-	+
<i>Erythromma lindenii</i>	+	-	+	+	+
<i>Ischnura graellsii</i>	+	+	+	+	+
<i>Pyrrhosoma nymphula</i>	-	-	+	+	-
<i>Aeshna affinis</i>	+	+	+	+	+
<i>Aeshna cyanea</i>	-	-	+	+	-
<i>Aeshna isoceles</i>	+	+	-	-	+
<i>Aeshna mixta</i>	+	+	+	+	+
<i>Anax imperator</i>	+	+	+	+	+
<i>Anax parthenope</i>	+	-	+	+	+
<i>Boyeria irene</i>	-	+	+	+	-
<i>Hemianax ephippiger</i>	+	-	+	-	+
<i>Gomphus lucasii</i>	+	-	-	+	-
<i>Onychogomphus costae</i>	+	-	-	+	-
<i>Onychogomphus forcipatus</i>	+	-	-	+	-
<i>Onychogomphus uncatus</i>	+	-	-	+	-
<i>Brachythemis impartita</i>	+	+	-	-	+
<i>Crocothemis erythraea</i>	+	+	-	+	+
<i>Diplacodes lefebvrei</i>	+	-	-	-	+
<i>Orthetrum cancellatum</i>	+	+	+	+	+
<i>Orthetrum chrysostigma</i>	+	+	-	+	+
<i>Orthetrum coerulescens</i>	+	-	+	+	+
<i>Orthetrum nitidinerve</i>	+	+	-	+	+
<i>Orthetrum trinacria</i>	+	-	-	-	+
<i>Selysiothemis nigra</i>	+	-	-	-	+
<i>Sympetrum fonscolombii</i>	+	+	+	+	+
<i>Sympetrum meridionale</i>	-	+	+	-	+
<i>Sympetrum sanguineum</i>	-	+	+	-	+
<i>Sympetrum striolatum</i>	+	+	+	+	+
<i>Trithemis annulata</i>	+	-	-	+	+
<i>Trithemis kirbyi</i>	+	-	-	+	+

the nature and condition of the aquatic habitats studied and the various pressures affecting them. There was no significant correlation between species richness and elevation (Spearman correlation: $r = 0.14$, $p = 0.54$) (Fig. 3) in SW, whereas a significant negative relationship (Spearman correlation: $r = -0.56$, $p = 0.02$) (Fig. 3) was detected in RW between species richness and elevation. The richness of the Odonata species decreased along the

elevation gradient, a common pattern previously recorded for odonates in other geographic regions (Corbet, 1999) and for many taxa around the globe (Rahbek et al., 2019). The aquatic habitats of LK are considerably richer in species than those of GK (Table 4). This can be explained by the cumulative effects of urban and industrial wastewater as well as agricultural activities. Indeed, the majority of the sites surveyed in Tizi Ouzou region

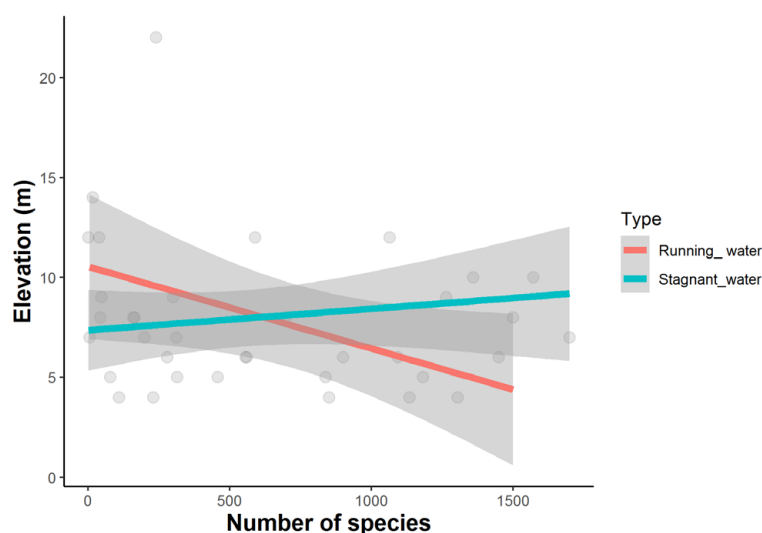


Fig. 3. The relationship between species richness of odonate adults and elevation for the two categories of habitats (lotic and lentic water system).

Table 4. Species diversity indices for lotic and lentic water in the two study zones of Kabylia region.

Study zone	Water type	S	N	H'	H' max	J'
Great Kabylia (GK)	Running water (RW)	18	687	3.12	3.50	0.89
	Stagnant water (SW)	16	445	2.88	3.12	0.92
Little Kabylia (LK)	Running water (RW)	26	2823	3.10	4.08	0.76
	Stagnant water (SW)	29	4768	2.43	3.58	0.67

Notes: S – species richness; N – species abundance; J' – Pielou's evenness index; H' – Shannon index.

(GK) are located near habitation zones and/or on the outskirts of agricultural fields, suggesting that the water quality of some habitats in this region cannot support pollution-sensitive species such as Gomphidae and Calopterygidae and more than 70% of the taxa found along these sites are ubiquitous species. It was also in the LK region that the greatest abundances of individuals were noted: 2,823 individuals in RW and 4,768 individuals in SW. These rather high values in this region can be explained by the strong proliferation of Lestidae and Coenagrionidae, especially in the forest lakes and ponds present in this region. In fact, in this area, more than 80% of the population is concentrated on three species, namely, *Lestes virens*, *Chalcolestes viridis*, and *Ischnura graellsii*. There was an inequitable distribution of individuals among the different taxa, with a value of 0.67 for Pielou's evenness index (Table 4), which could only be explained by the predominance of some species over others. On the other hand, GK was the area that contained the best structured and most stable odonatological communities in both lotic and lentic waters with respective equitability values of 0.89–0.92 (Table 4). This is probably due to the rather open and sunny structure of these habitats, which consequently offer ideal conditions for Odonata settlement.

Comments on some special concern regional species

***Pyrrhosoma nymphula* (Sulzer, 1776):** The first record of *P. nymphula* dates back to the work of Boudot et al. (2009) in the Moroccan highlands (Middle Atlas Mountains), where it was considered a glacial relic. In 2014, the species was reported for the first time in Tunisia in Khroumirian streams, in the north-west of the country (Korbaa et al., 2014). In Algeria, despite an increase in odonatological surveys during the last decade (Senouci, Bounaceur, 2018; Chelli, Moulaï, 2019; Demnati et al., 2019; Khelifa, 2019), *Pyrrhosoma* has never been confirmed anywhere. Its first appearance dates back to 23 June 2021, when two male individuals of this species were collected during a survey at Ait Alaoua (St6), a relatively fast-flowing stream within a forest of evergreen oak in GK at 1,183 m a.s.l., (36°28'28"N, 4°21'41"E), 30 km southeast of Tizi Ouzou city (Table 1). This is the only locality known for this species in the entire country, and this observation extends its range to North Africa (Taleb et al., 2022).

***Calopteryx exul* (Selys, 1853):** This endemic Maghrebien species is confined to North African streams and rivers. It is found from northern Morocco to Tunisia (Boudot et al., 2009) and is currently classified as EN in the IUCN Red Lists of the

Mediterranean and North Africa. In Algeria, this damselfly was not recorded from 1910 (Martin, 1910) until 2007, when a new population was discovered on the Seybouse River in northeast Algeria (Khelifa et al., 2011). Later, an important population of *C. exul* was discovered on the Boussellam wadi in Bejaia (central northern Algeria) by Chelli et al. (2019). Then, in 2022, we encountered a subpopulation composed of a few individuals of this species downstream of the Tichi Haf dam installed on this watercourse, 10 km from the place where the population was recorded by these authors. These few individuals found downstream of the dam is probably the result of the environmental changes causing fragmentation of the initial population due to the construction of the dam on this watercourse. This is in accordance with the observations of Khelifa, Mellal (2017) who reported that the distribution of *C. exul* in the Seybouse River has rapidly declined over the past decade. Many subpopulations have become extinct, mainly due to habitat disturbance, including bank degradation and irrigation. According to Khelifa et al. (2021), its rapid local extirpation rate in the region now suggests that the species should locally be raised to the category of critically EN in accordance with the IUCN criteria B2 and E, which take into account the range size, severity of habitat fragmentation, and local extinction probability over the decade. It should be pointed out that the Boussellam watercourse can be considered the second most important site where this species occurs in Algeria, after the Seybouse watershed. Efficient conservation strategies to protect the overall structure of this stream are necessary.

***Onychogomphus costae* (Selys, 1885):** It is an Ibero-Maghrebian species restricted to the most arid areas in the Iberian Peninsula (Jacquemin, Boudot, 1999). Its range extends from the most arid parts of the Iberian Peninsula to the northern Maghreb, where the species is now better known than in the past (Boudot, De Knijf, 2012). In Morocco, *O. costae* is scattered throughout the country (El Haissofi, 2008); however, in Algeria, it is relatively common in the north-eastern part of the country (Zebsa et al., 2014), but appears to be less common further west (Hamzaoui et al., 2015; Chelli et al., 2020). Its status is listed as NT on all IUCN Red Lists. As part of this study, this Gomphidae seems to be very scarce and not very abundant in the Kabylia region. Indeed, of the 16 wadis surveyed, this species was recorded only in the Boussellam Wadi, which is characterized by its rapid flow, with sand and gravel banks, and bare soil or sparse vegetation. Only a few individuals were recorded over a short period from mid-June to early July.

***Onychogomphus uncatus* (Charpentier, 1840):** This dragonfly is a widespread western Mediterranean species (Boudot et al., 2009). Past records of *O. uncatus* from Algeria are old (Lacroix, 1925; Martin, 1910; Morton, 1905). This species is very rare in Algeria, misidentified (Khelifa et al., 2011) or based on larvae (Benchalel, Samraoui, 2012; Samraoui, Corbet, 2000), and only a few individuals have been collected (Hamzaoui et al., 2015; Chelli, Moulai, 2019a; Chelli et al., 2020). In this study, out of the 16 surveyed wadis, just two contained a few individuals. It is much less common than *O. forcipatus* and *O. costae* due to the ecological requirements of the larvae, which prefers flowing water to rocky sandy substrate and needs clear and well-oxygenated water (D'Aguilar, Dommanget, 1998). Its status in North Africa is listed as LC on the IUCN North African Red List. The status of this Gomphidae should be reconsidered, as this evaluation is quite old and, in the last decade, North African rivers had been

subjected to various anthropogenic impacts. In Algeria, the rarity and population decline of this species is undoubtedly the result of anthropization of its habitats due to gravel extraction and pollution. For this reason, *O. uncatus* requires a special conservation status and its habitats must be preserved.

Conclusion

In conclusion, data presented here could be used for developing new conservation strategies aimed at upgrading the Odonata species status in the Kabylia region as well as in other regions of Algeria. Given the global loss of insects and the necessity of conservation activities (Sánchez-Bayo, Wyckhuys, 2019), increasing our estimations of distribution range and biodiversity in natural environments is a critical step toward better biodiversity management and conservation. Furthermore, long-term conservation monitoring that accounts for yearly changes in species occurrences at the site level that could be induced by habitat degradation is required. In addition, it may be interesting to do large-scale sampling in other nearby regions to more properly assess the distribution and diversity of this taxon.

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