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THE ODONATA OF WADI ISSER (KABYLIA, ALGERIA): STATUS AND ENVIRONMENTAL DETERMINANTS OF THEIR DISTRIBUTION

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RÉSUMÉ.— *Les Odonates de l'Oued Isser (Kabylie, Algérie) : statut et déterminants environnementaux de leur distribution*.— Une étude odonatologique a été réalisée durant six mois successifs, de mai à octobre 2013 à l'Oued Isser, situé dans le nord centre algérien, une région pratiquement inexplorée auparavant. Un total de 19 espèces d'Odonates a été enregistré durant l'échantillonnage mensuel de six stations. Il est à noter la présence de *Lestes numidicus* et de *Platycnemis subdilatata,* endémiques du Maghreb. Nos résultats étendent considérablement vers l'ouest la distribution connue de *L. numidicus*, ayant un statut « données insuffisantes » (DD) sur la liste rouge de l'UICN. À la lumière de la présente étude, on ne propose aucun changement de la classification de la Liste Rouge de l'IUCN à l'exception de *L. numidicus* qui devrait être classé comme quasi menacé (NT), dans l'attente de nouvelles prospections. Les résultats suggèrent également que la richesse spécifique varierait positivement le long de l'Oued Isser avec la densité de la végétation riveraine. À l'opposé, elle pourrait également être négativement corrélée à la pollution, un facteur important et récurrent de l'érosion de la biodiversité des cours d'eau maghrébins.

SUMMARY.— An odonatological study was carried out during six successive months, from May to October 2013, at Wadi Isser located in the practically unexplored Central North of Algeria. A total of 19 species of Odonata were recorded during the monthly sampling of six stations. Noteworthy was the record of *Lestes numidicus* and *Platycnemis subdilatata,* both Maghrebian endemics. Our results extend considerably towards the west the known distribution of *L. numidicus*, a data deficient (DD) species on the Mediterranean IUCN Red-List. In the light of the present study, no changes in the IUCN Red List classification is proposed with the exception of *L. numidicus* which should be classified as Near-Threatened (NT), pending further investigations. Results also suggest that the variation of the species richness along Wadi Isser may be related to environmental factors. Species richness was positively associated to the density of the riverine vegetation. In contrast, species richness could also be negatively correlated to pollution, an important and recurrent factor of the erosion of biodiversity of Maghrebian watercourses.

Odonata are intimately associated with wetlands and they present a challenging variety in life cycle patterns, a renewed source of wonder and fascination for biologists and naturalists alike (Grand & Boudot, 2007; Corbet & Brooks, 2008). They have become essential tools for the ecological evaluation of aquatic ecosystems and bio-monitoring of wetlands (Chovanec & Waringer, 2001; Steward & Downing, 2008). Pollution and other anthropogenic impacts negatively affect Odonata communities and reduce the biodiversity of wetlands (Clark & Samways, 1996). Thus, the potential of Odonata as bio-indicators is now widely accepted (Chovanec, 2000; Hofmann & Mason, 2005; Simaika & Samways, 2008; Arnaldo *et al*., 2010), and they are frequently used to monitor the ecological integrity of freshwater ecosystems (Oertli, 2008; Ferreras-Romero *et al*., 2009), to assess habitat restoration (Samways & Taylor, 2004), and to study the effects of global climate change (Ott, 2008). Odonata are also known to be key organisms in the functioning of aquatic communities (Corbet, 1999).

In the Mediterranean area, dragonflies and damselflies constitute a main component of running waters, and they have also been used to evaluate the ecological state of local watersheds

(Clausnitzer & Jödicke, 2004; Pinto *et al*., 2004). The Mediterranean basin is known as a hotspot of global biodiversity with a high level of endemism (Riservato *et al*., 2009) but its rare and unique habitats are under increasing anthropogenic pressures (Blondel *et al*., 2010).

In North Africa and in the Maghreb (Morocco, Algeria, and Tunisia), in particular, the odonatofauna is relatively well known although new species are still being added (Samraoui *et al*., 2003; Ferreira *et al*., 2014; Korbaa *et al*., 2014). In contrast, the other countries (Mauritania, Western Sahara and Libya) remain clearly underprospected (Dumont, 1976, 1978; Boudot, 2010; Ferreira *et al*., 2011). For North Africa, 93 species of Odonata have been identified (Boudot, 2010; Ferreira *et al*., 2014). Algeria and Morocco are concerned by almost 70 % of the available literature, a strong indicator of survey effort, while the most arid countries contribute with very few publications and an impoverished fauna. Libya, Egypt, and Tunisia are in an intermediate position (Boudot, 2010). The first Algerian findings in odonatology date back to the 19th century (Samraoui & Menaï, 1999) with our knowledge of the odonatological fauna of the country improving significantly in the last two decades and 64 species recorded (Samraoui & Menaï, 1999; Samraoui *et al*., 2003; Dumont, 2007). The majority of the published studies on the Algerian odonatofauna are focused on the north-eastern part of the country, mainly in Numidia (Samraoui *et al*., 1998; Samraoui, 2009; Samraoui & Corbet, 2000a,b). This area hosts an exceptional aquatic biodiversity (Samraoui & de Bélair, 1997, 1998) with a recorded total of 45 Odonata species (approximately ¾ of the Algerian odonatofauna) (Samraoui & Corbet, 2000a). In order to fill important gaps in our knowledge of regions barely explored in the past, we set out to study the hydrographic network of Wadi (Oued) Isser which is part of the Kabylian watercourses. This area has a semi-arid Mediterranean climate, hot and dry summers, relatively cold winters, and an average annual rainfall of 400mm. Wadi Isser represents an important watershed, and its odonatological fauna has never been before the focus of a systematic survey.

This current study is thus complementary to previous surveys of the Algerian odonatofauna and it has multiple objectives:(1) obtain a check-list of the odonatofauna of Wadi Isser in a previously uncharted area, (2) record the spatial and temporal distributions of the Odonata of this temporary watercourse, and (3) lay the foundation for a future identification of environmental factors that drive these distributions.

MATERIALS AND METHODS

PRESENTATION OF THE STUDY AREA:

The Isser valley is situated approximately 70 km south-east of Algiers and it overlaps many wilayas: Medea, Bouira, Tizi Ouzou and Boumerdes. It occupies a surface of 3615 km^2 (Fig. 1). It is located upstream of the dam of Beni Amrane and it presents an elongated shape on the South-Western axis (Aïn Boucif / Beni Slimane) to the North-East where it is bordered by the Mediterranean Sea. In the North, Djebel Tamesguida, part of the Tellian Atlas chain, culminates at 1130 m and Djebel Dira, part of the chain of the Bibans in the South, towers at 1810 m. The two chains are separated by the plain of Aribs which lies at an altitude of 550 m.

The Wadi Isser valley is made up in its major part of soft rocks: marls and clays. It is vulnerable to strong floods and erosion. It is also characterized by a sparse vegetal cover located in the center and representing 20 % of the total surface. The rest of the surface i.e. 80 % is occupied by agriculture dominated mainly by cereal and fodder. In the bottom of the Isser valley, we mainly come across annual cultures and in decreasing surfaces, cultures and arboriculture. The soft nature of the substrate (marls and clays) and the irregular hydric regimes have contributed to the development of a dense hydrographic network. The vegetation cover (wood and undergrowth), is rare and usually degraded, and it makes the erosion particularly active in presence of soft lithological materials and an unfavourable hydric regime (irregular and violent floodings). Flood intensities vary according to the slope, the lithological nature of the soils and the exerted anthropogenic pressure (deforestation, excessive pasture, unsuitable agriculture) (Larfi & Remini, 2006). The Isser valley receives its first watercourses from a chain named Kef Lakhdar and from the occidental portion of a chain named Dira. Wadis that descend from Kef Lakhdar's chain are called Oued El-Maleh. Those that descend from Djbel Dira are called Oued Halleba and Oued Zeroua. Near their confluence, which gives way to Wadi (Oued) Isser, passes the motorway which links Algiers to Aumale by Tablat. Initially, Wadi Isser flows towards the West before bending with an acute angle towards the North-East to cross the mountains through the Palestro gorge.

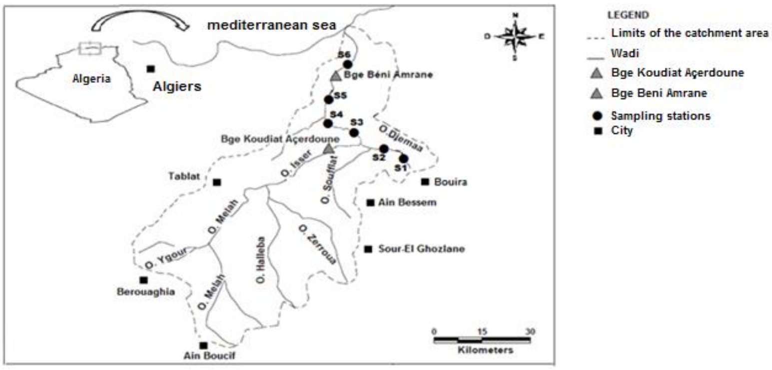

Figure1.— Localization of sampled stations in the catchment area of Wadi Isser.

SAMPLING

Six stations have been prospected in the Isser watershed, two of them are located on an affluent of the main watercourse of Wadi Isser (Tab. I). Monthly sampling was carried out from May to October 2013. The environmental features of each station were recorded through a range of descriptors (air and water temperatures, conductivity, current speed, water depth, vegetation cover, dissolved oxygen, pH). All six stations were sampled during the same day and at each location, adult Odonata were collected using a hand net. Samples were carried out to the laboratory in plastic boxes for identification using keys like that of Grand & Boudot (2007).

TABLE I

List of surveyed stations

Stations code	Stations (locality)	Standard habitat	Altitude (m)	Latitude	Longitude
S1	Wadi Djamaa	Affluent	371	36°26'01	003°50'50
S2	Wadi Djamaa	Affluent	328	36°27'09	003°50'11
S3	Wadi Isser	Middle course	179	36°29'44	003°42'30
S4	Wadi Isser	Middle course	154	36°32'44	003°39'23
S5	Wadi Isser	Downstream	72	36°31'26	003°34'55
S6	Wadi Isser	Downstream	51	36°41'09	003°37'08

STATISTICAL ANALYSIS

Data were analysed to characterize the distribution of different species along Wadi Isser valley and to evaluate potential association between species assemblages and environmental variables. Spearman's correlation tests were carried out to identify possible associations between species richness and descriptors. We performed a co-inertia analysis to look for a common structure between two matrices: a "species" table and an "environment" table (Dolédec & Chessel, 1994). The overall correlation between the recorded species and the environmental descriptors was measured by the vectorial correlation coefficient «RV» which varies between 0 (all the species are independent of environmental variables and 1 which indicates that both tables are homothetic (Borcard *et al*., 2011). All the statistical analyses were performed using the R program (R Development Core Team 2014).

RESULTS

CHARACTERIZATION OF THE ENVIRONMENTAL CONDITIONS

The recorded values of the water temperature were maximal during the months of May and June (31.4°C). For station 3 and during the month of August, we noticed a slight decrease in the water's temperature related to water release from the dam located upstream to cultivated lands that border the watercourse. Air temperatures reached 40.6°C during August. Water pH was alkaline, oscillating between 8.0 and 8.9. Concerning the salinity, the recorded range (0.4-0.8 ppm) indicated that there was no marked variation in time and place. Water conductivity was high and in the majority of stations, values reached their maximum in June with 1752 µs/cm. Data for oxygen indicated that there was a good oxygenation of water, with values fluctuating between 7.3 mg/l (station 6, in June) and 12.81 mg/l (station 4, in June). The majority of stations presented average to rapid water flow. The speed of water was relatively high in May and moderate in the summer season when the wadis did not dry up. Water's depth exhibited large differences with levels varying between 1 m (station 3 in August) to a few cm and, at times, to complete dryness in some stations (1, 2 and 6). Bed's width also was subject to marked fluctuations during the study period. Aquatic vegetation was extensive in station 3, reduced in downstream stations (5 and 6) and moderate in the upstream stations (1, 2 and 4). Riverine vegetation was dense in the middle section of the valley (stations 3, 4, and 5) and moderate elsewhere. Pollution in the valley was low with only one polluted station (station 2), which received some urban discharges from an agglomeration that was located upstream (Tab. II).

TABLE II

Spatiotemporal variation of environmental parameters along Wadi Isser

		Code	Air T (°C)	Water T(°C)	O2 mg/l	O2 %	pH	Conductivity (µs/cm)	Salinity (ppm)	Current velocity (cm/s)	Width (m)	Depth (cm)	Aquatic vegetation	Riverside vegetation	Pollution	Substratum
Station 1	May	S1M	30,20	26,60	9,50	128,20	8,70	1393,00	0,50	36,60	15,00	30,00	2	2	0	Blocks, gravel, pebbles, sand
	June	S1J	32,60	27,60	8,95	117,60	8,80	1416,00	0,50	32,50	10,00	15,00	2	2	0	
	July	S1JlI	*	*	*	*	*	*	*	*	*	*	*	2	*	
	August	S1A	*	*	*	*	*	*	*	*	*	*	*	2	*	
	September	S1S	*	*	*	*	*	*	*	*	*	*	*	2	*	
	October	S1O	*	*	*	*	*	*	*	*	*	*	*	2	*	
	S Dev		1,70	0,71	0,39	7,50	0,07	16,26	0,00	2,90	3,54	10,61				
Station 2	May	S2M	31,50	27,60	9,70	135,00	8,64	1497,00	0,50	45,50	10,00	50,00	2	2	1	Blocks, gravel, pebbles, sand
	June	S2J	34,70	28,20	10,33	142,50	8,76	1522,00	0,60	34,80	6,00	20,00	2	2	1	
	July	S2JlI	*	*	*	*	*	*	*	*	*	*	*	2	*	
	August	S2A	*	*	*	*	*	*	*	*	*	*	*	2	*	
	September	S2S	*	*	*	*	*	*	*	*	*	*	*	2	*	
	October	S2O	*	*	*	*	*	*	*	*	*	*	*	2	*	
	S Dev		2,26	0,42	0,45	5,30	0,08	17,68	0,07	7,57	2,83	21,21				
Station 3	May	S3M	34,60	29,50	9,80	136,33	8,60	1672,00	0,70	29,40	25,00	20,00	3	3	0	Blocks, gravel, pebbles, sand
	June	S3J	35,90	30,90	9,61	135,00	8,65	1752,00	0,80	22,60	20,00	10,00	3	3	0	
	July	S3JlI	*	*	*	*	*	*	*	*	*	*	*	3		
	August	S3A	38,30	31,30	12,30	157,22	8,42	1731,00	0,70	30,60	30,00	100,0	3	3	0	
	September	S3S	*	*	*	*	*	*	*	*	*	*	*	3	*	
	October	S3O	*	*	*	*	*	*	*	*	*	*	*	3	*	
	S Dev		1,88	0,95	1,50	12,46	0,12	41,48	0,06	4,31	5,00	49,33				
Station 4	May	S4M	35,90	29,80	11,90	152,50	8,70	1398,00	0,50	49,40	8,00	50,00	2	3	0	Blocks, gravel, pebbles, sand
	June	S4J	37,30	31,40	12,81	159,70	8,72	1490,00	0,60	34,50	6,00	40,00	2	3	0	
	July	S4JlI	38,90	32,50	8,96	119,00	8,50	1391,00	0,60	26,50	6,00	35,00	2	3	0	
	August	S4A	40,60	32,20	11,40	151,70	8,29	1673,00	0,60	29,90	7,00	50,00	2	3	0	
	September	S4S	36,40	30,40	10,71	146,00	8,10	1686,00	0,60	26,40	6,00	30,00	2	3	0	
	October	S4O	33,00	28,50	9,95	133,42	7,98	1661,00	0,50	24,60	6,00	25,00	2	3	0	
	S Dev		2,62	1,53	1,38	14,96	0,31	139,95	0,05	9,27	0,84	10,33				
Station 5	May	S5M	35,10	28,40	10,10	138,30	8,70	1344,00	0,40	42,50	11,00	40,00	1	3	0	Gravel, pebbles, sand+++
	June	S5J	34,30	29,60	10,45	142,80	8,86	1338,00	0,50	32,80	8,00	30,00	1	3	0	
	July	S5JlI	37,20	29,80	8,50	110,66	8,42	1312,00	0,50	22,40	6,00	20,00	1	3	0	
	August	S5A	37,80	29,50	10,91	146,80	8,23	1335,00	0,50	20,00	6,00	20,00	1	3	0	
	September	S5S	33,30	27,90	9,54	131,90	8,13	1415,00	0,50	19,60	6,00	20,00	1	3	0	
	October	S5O	31,60	27,30	8,80	118,00	7,95	1389,00	0,40	17,50	5,00	15,00	1	3	0	
	S Dev		2,35	1,03	0,94	14,32	0,35	38,51	0,05	9,80	2,19	9,17				
Station 6	May	S6M	34,60	27,00	7,50	103,42	8,73	1239,00	0,40	0,00	15,00	50,00	1	2	0	Blocks, gravel, pebbles, sand, silt+++
	June	S6J	33,60	27,50	7,30	101,66	8,84	1166,00	0,40	0,00	10,00	45,00	1	2	0	
	July	S6JlI	*	*	*	*	*	*	*	*	*	*	*	2	*	
	August	S6A	*	*	*	*	*	*	*	*	*	*	*	2	*	
	September	S6S	*	*	*	*	*	*	*	*	*	*	*	2	*	
	October	S6O	*	*	*	*	*	*	*	*	*	*	*	2	*	
	S Dev		0,71	0,35	0,14	1,24	0,08	51,62	0,00	0,00	3,54	3,54				

*: Dry state of the wadi; Aquatic and Riverine vegetation: 0 =Absent; 1 = Low; 2 = Medium; 3=Dense; Pollution: 0=absence; 1 =Presence;.+++ = dominant.

CHARACTERIZATION OF THE ODONATA COMMUNITY

We recorded 19 species of Odonata belonging to two suborders: Zygoptera and Anisoptera. A total of seven families were identified: The Libellulidae was the most diversified family with 7 taxa, i.e. 36.8 % of the overall recorded Odonata. The Lestidae ranked second with 4 taxa, i.e. 21.1 %; followed by the Aeshnidae (3 taxa; 15.8 %), the Coenagrionidae (02 taxa; 10.5 %), the Plactycnemidae, the Gomphidae, and the Calopterygidae (one taxon for each family; 5.3 %). The odonatofauna of Wadi Isser included one threatened species, the Vulnerable (VU) *Aeshna affinis* and another one evaluated as Data Deficient (DD) *Lestes numidicus*.

SUB-ORDER: ZYGOPTERA

CALOPTERYGIDAE

Calopteryx haemorrhoidalis (Vander Linden, 1825)

IUCN Red List Category (Northern Africa): LC. No change of status at the regional scale is proposed.

Comments: The only species of *Calopteryx* recorded. In North Africa, *C. haemorrhoidalis* occupies fast flowing streams and rivers from high altitudes to sea-level (Samraoui & Corbet, 2000a). Relatively uncommon, the species was sampled at stations 3 and 4.

LESTIDAE

LESTINAE

Lestes barbarus (Fabricius, 1798)

IUCN Red List Category (Northern Africa): Least Concern (LC). No change of status at the regional scale is proposed.

Comments: The species is known to breed in lentic, often temporary, habitats (Utzeri *et al*., 1984). It aestivates as immature adults in wet forests at sea-level and in mountain forests (Samraoui, 2009). The species was locally abundant at Wadi Isser and only sampled at station 3.

Lestes numidicus Samraoui, Weekers & Dumont, 2003

IUCN Red List Category (Northern Africa): DD. In the light of the new findings, we propose that the species be assessed as Near Threatened (NT) on the basis that its habitats in North Africa (temporary wetlands and mountain forests) are under severe anthropogenic pressures with a steep decline of known populations.

Comments: Locally abundant but the species was only captured at station 3. This species is known to aestivate at high altitudes before moving to lowlands in autumn to breed (Samraoui, 2009). It is endemic to Algeria and is assessed as Data Deficient (DD) by IUCN (Riservato *et al*., 2009; Samraoui *et al*., 2010).

Chalcolestes viridis (Vander Linden, 1825)

IUCN Red List Category (Northern Africa): LC. No change of status at the regional scale is proposed.

Comments: The species breeds in both lotic and lentic habitats (Grand & Boudot, 2007) and it also aestivates in the adult stage in cool, moist habitats (Agüero-Pelegrin *et al*., 1999; Samraoui, 2009). The species was moderately abundant at all stations 3, 4 and 5.

SYMPECMATINAE

Sympecma fusca (Vander Linden, 1820)

IUCN Red List Category (Northern Africa): LC. No change of status at the regional scale is proposed.

Comments: Uncommon and limited to station 3. Another lestid that aestivates and hibernates at the adult stage (Samraoui, 2009).

PLATYCNEMIDAE

Platycnemis subdilatata Sélys, 1849

IUCN Red List Category (Northern Africa): LC. No change of status at the regional scale is proposed.

Comments: A Maghrebian endemic, locally abundant, and recorded at stations 3, 4, and 5.

COENAGRIONIDAE

COENAGRIONINAE

Coenagrion caerulescens (Fonscolombe, 1838)

IUCN Red List Category (Northern Africa): LC. No change of status at the regional scale is proposed.

Comments: Recorded in low numbers at stations 3 and 4.

Ischnurinae

Ischnura graellsii (Rambur, 1842)

IUCN Red List Category (Northern Africa): LC. No change of status at the regional scale is proposed.

Comments: A multivoltine species that colonizes both running and stagnant waters. Locally abundant, it was recorded at stations 4 and 6.

Sub-Order: Anisoptera

Gomphidae

Onychogomphus forcipatus (Linné, 1758)

IUCN Red List Category (Northern Africa): LC. No change of status at the regional scale is proposed.

Comments: The only gomphid recorded. Locally abundant and relatively well distributed in the catchment area. The species was observed at stations1, 2, 3 and 5.

Aeshnidae

Aeshninae

Aeshna affinis (Vander Linden, 1820)

IUCN Red List Category (Northern Africa): VU. No change of status at the regional scale is proposed.

Comments: In North Africa, the species is mainly known to breed in marshes and other mainly stagnant waters (Samraoui & Corbet, 2000a). One record from a mountain stream is known (Korbaa *et al*., 2014). Uncommon at Wadi Isser, *A. affinis* was recorded at station 3.

Anax imperator Leach, 1815

IUCN Red List Category (Northern Africa): LC. No change of status at the regional scale is proposed.

Comments: Uncommon and recorded only at station 6. This is however a widespread species across the northern fringe of North Africa breeding in both running and stagnant waters.

Anax parthenope (Selys, 1839)

IUCN Red List Category (Northern Africa): LC. No change of status at the regional scale is proposed.

Comments: This species which is abundant in arid regions (Samraoui & Menai, 1999) was much less common than *A. imperator*. Its distribution at Wadi Isser is unlikely to be limited to only station 6.

Libellulidae

Libellulinae

Orthetrum coerulescens anceps (Schneider, 1845).

IUCN Red List Category (Northern Africa): LC. No change of status at the regional scale is proposed.

Comments: A libellulid that breeds in running waters from high altitude sites to sea-level. Uncommon at Wadi Isser and noted only at station 1.

Orthetrum chrysostigma (Burmeister, 1839).

IUCN Red List Category (Northern Africa): LC. No change of status at the regional scale is proposed.

Comments: Locally abundant and fairly well distributed in the Isser watershed. It was recorded at stations 1, 3, 4, 5, and 6. This libellulid is known to be abundant at low altitudes in all types of flowing water and even in swamps where water is constantly renewed (Jacquemin & Boudot, 1999).

Sympetrinae

Sympetrum fonscolombi (Sélys, 1840)

IUCN Red List Category (Northern Africa): LC. No change of status at the regional scale is proposed.

Comments: Locally abundant and relatively common. The species was captured at stations1, 3 and 5.

Sympetrum meridionale (Selys, 1841)

IUCN Red List Category (Northern Africa): LC. No change of status at the regional scale is proposed.

Comments: Uncommon, the species was noted at station 3. *S. meridionale* is however a common species that breeds in stagnant waters. It aestivates as adults in high altitude mountain forests before moving back to lowland wetlands to breed in the autumn (Samraoui *et al*., 1998).

Sympetrum striolatum (Charpentier, 1840)

IUCN Red List Category (Northern Africa): LC. No change of status at the regional scale is proposed.

Comments: Uncommon and recorded only at station 4. This is also a common species with a life history strategy similar to that of *S. meridionale* (Samraoui *et al*., 1998). Breeding in running waters is relatively uncommon.

Crocothemis erythraea (Brullé, 1832)

IUCN Red List Category (Northern Africa): LC. No change of status at the regional scale is proposed.

Comments: Uncommon at Wadi Isser and noted only at station 4, this species is more abundant in stagnant waters.

TRITHEMISTINAE

Trithemis arteriosa (Burmeister, 1839)

IUCN Red List Category (Northern Africa): LC. No change of status at the regional scale is proposed.

Comments: Uncommon at Wadi Isser and recorded only at station 3. One of three species in the genus, *T. arteriosa* is relatively uncommon in the Tell (northern Algeria). In contrast, it is more abundant in the Sahara (Samraoui & Menaï, 1999).

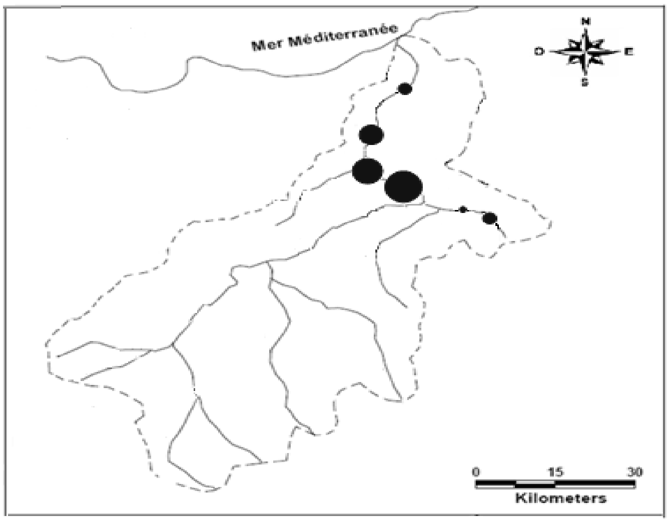

Figure 2— Mapped species richness recorded at Wadi Isser.

The variation of the species richness along Wadi Isser is illustrated by Figure 2. The number of Odonata per site varied from 1 to 14. However, the variation of species richness along the river was irregular. Station 3, the richest station, hosted 14 different species of Odonata and was characterized by a relatively large bed width which includes a multitude of microhabitats represented by a very heterogeneous substratum, dense riverine and aquatic vegetation, and a low to moderate flow. During the summer, station 3 dried up but small residual pools persisted.

Station 4 was also rich, with 8 species. This station did not dry up during the study period and was characterized by a moderate to high flow during spring and low flow during summer. The width changed from 6 to 8 m and water depth varied from 25 to 50 cm. Station 4 had a very heterogeneous substratum and hosted a dense riverine vegetation. Station 5 hosted 5 species and was characterized by dense riverine vegetation and a permanent flow during all the study period. Station 1 and 6 presented a similar number of species (respectively 4 and 3 species). Station 2 was the poorest and the only recorded species there was *O. forcipatus* during May and June before being deserted after it dried up during the other months.

VARIATION OF THE SPECIES RICHNESS WITH ENVIRONMENTAL FACTORS

Analyses were hindered by the limited sample of study stations but results suggest that the variation of species richness along Wadi Isser was associated with some environmental factors. Thus, species richness was positively and significantly correlated with the riverine vegetation density (ρ = 0.88, p = 0.03). It was negatively associated with pollution but the test was not significant (ρ = -0.65, p = 0.17), probably due to the limited sample size. Results also suggest that there may exist a weak relationship between species richness and the water mineralisation (ρ = 0.60, p = 0.24) and air temperature (ρ = 0.77, p = 0.10).

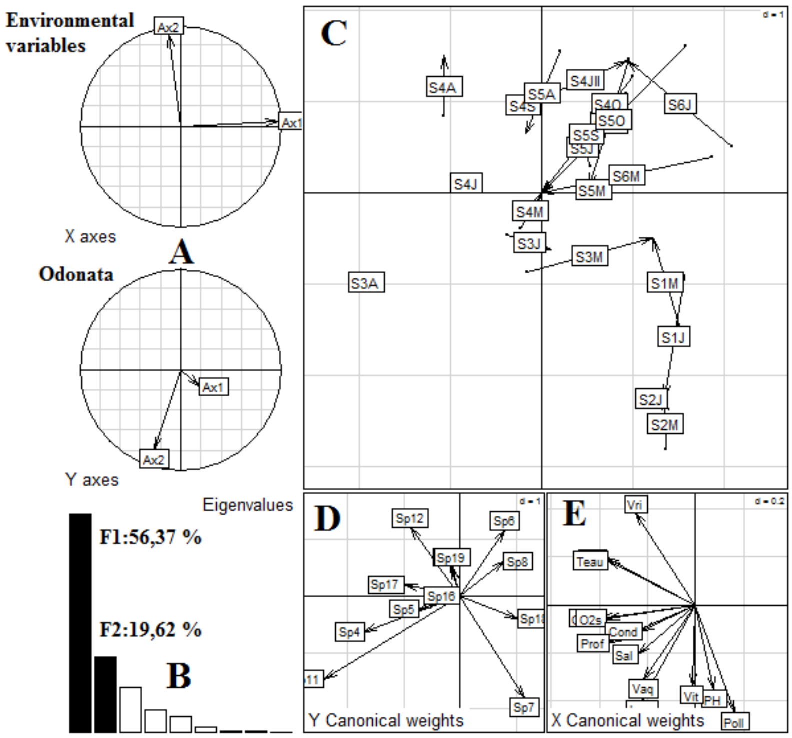

Figure 3.— Results of the co-inertia analysis (CIA) performed between recorded Odonata (coded as presence/absence) and measured environmental variables. A) Components of the standardized principal component analysis of the environmental data set projected on to the co-inertia axes (top) and components of the centred principal component analysis of the odonatological data set projected on to the co-inertia axes (bottom). B) Distribution of eigenvalues of CIA. C) F1xF2 factorial plane of CIA with arrows linking stations according to physico-chemical variables (base of arrows) and Odonata (end of arrows). D) Distribution of species on the F1x F2 factorial plan of CIA. E) Distribution of environmental descriptors on the F1xF2 factorial plan of CIA.

ANALYSIS OF CO-INERTIA OF BOTH FAUNA AND ENVIRONMENTAL DESCRIPTORS

A co-inertia analysis of both «species» and «environmental descriptors» tables was performed (Fig. 3). This co-structure is described by the first two axes of co-inertia representing respectively 56.4 % and 19.6% of inertia. These axes reveal a good correspondence between the provided structures by each of the tables (environment and fauna) and the one provided by the co-inertia. The coefficient of vectorial correlation « RV » of co-inertia analysis highlights the relationship between the species and the sampled environmental descriptors. The RV is significant (RV = 0.51), thus indicating the existence of a significant co-structure between the environmental setting and the odonatological community at Wadi Isser.

The Odonata community of Wadi Isser.

The first axis opposes species like *C. haemorrhoidalis* and *C. caerulescens* that are associated with well oxygenated and perennial waters to species like *S. fonscolombi* which generally breeds in all types of stagnant waters. *S. fusca*, *S. striolatum* and *S. meridionale* are aestivating species associated with good vegetation cover. The second axis separates *C. erythraea* and *I. graellsii* which prefer to dwell close to dense riverine vegetation to species like *O. forcipatus* which may inhabit fast streams devoid of riverine vegetation.

Description of the environmental descriptors

The first axis is dominated by several descriptors (dissolved oxygen, depth, conductivity, etc.) and it indicates strong colinearity between these factors. The second axis opposes riverine vegetation to pollution with denser aquatic vegetation, higher current and pH.

Description of the sampling stations

The plan 1-2 indicates an overall upstream-downstream gradient with the first axis separating the middle course stations (St. 3 and St. 4) to the rest which had a lesser diversified Odonate assemblages. The second axis divides the upstream stations from the downstream stations.

DISCUSSION

The study aims at gaining a better knowledge of the odonatofauna of Wadi Isser, located in a previously uncharted region of Algeria. The study area has a semi-arid, Mediterranean climate with dry and summers and relatively cold winters. A total of 19 species of Odonata spread over seven families (Calopterygidae, Lestidae, Plactycnemidae, Coenagrionidae, Gomphidae, Aeshnidae, Libellulidae) was recorded. Among the 19 species, *L. numidicus* and *P. subdilatata* are two Maghrebian endemics (Riservato *et al*., 2009). Concerning the species richness, station 3 was the richest and it hosted 14 species while the other stations hosted between 1 and 5 species. The flying period of the observed species of Wadi Isser was spread from the beginning of May to the end of November, which is synchronized with the dry season (May-November) during which the climate and topographic conditions are suitable for the emergence and breeding of local species (Ferreras-Romero, 1994; Samraoui *et al*., 2000b).

In line with previous expectations (Samraoui *et al*., 2003), our study extends considerably the range of *L. numidicus*, a cryptic member of the *L. virens* complex. This species is listed by IUCN as "Data deficient" and is, until now, known only from eastern Algeria (Boudot, 2010). *L. numidicus* cannot be differentiated from *L. virens* morphologically but is genetically and ecologically (breeding phenology) distinct (Samraoui, 2009). Noticeable is the clear absence of *Calopteryx exul*, another Maghrebian endemic, listed as Endangered (EN) by IUCN (Riservato *et al*., 2009; Samraoui *et al*., 2010). The same comment applies to another Maghrebian endemic

Gomphus lucasii. More sampling efforts are however needed, especially at high altitudes sites, before the absence of *C. exul* and *G. lucasii* from Wadi Isser can be duly acknowledged.

The distribution of Odonata is determined by physical factors (sunshine exposition, precipitations), and by biological factors (availability of nutritious needs, competition, and predation) (Corbet, 1999). It is the case of station 3 where 14 species were sampled. Many studies emphasize that among the main factors in forming Odonata assemblages are water and outflow permanent availability (Schindler *et al*., 2003; Boudot *et al*., 2009). Therefore, water outflow constancy, or at least permanence of surface water is needed for the survival of species with a protracted larval development. In the Mediterranean region where wetlands may dry in the summer period, species have adapted to the seasonal nature of their habitats (Samraoui *et al*., 1998; Agüero-Pellegrin *et al*., 1999; Samraoui, 2009) and semi-voltine and partivoltine species can only be found in perennial streams (Ferreras-Romero & Corbet, 1995).

As dragonflies are a warm-adapted group, water temperature represents an abiotic factor of the utmost importance in the developing and growth of larvae. Water temperature is a factor that influences the emergence pattern, and particularly its onset. Each species possesses "a limit" beyond it the emergence is triggered. Farkas *et al*. (2012) have shown that for the same species, the beginning of the emergence may vary from site to site or from one year to another because of the differences in temperature fluctuations during spring. The influence that water temperature has on the distribution of Odonata is principally emphasized by many authors (Corbet, 1999; Schütte & Schrimpf, 2002; Grand & Boudot, 2007) and, probably, the larval stage is the most effective way to obtain information about population dynamics (Carle, 1979) and population regulation (Corbet & Brooks, 2008).

As expected, the polluted site (station 2) had the lowest number of dragonfly species. The origin of the pollution found at this station was related to its location downstream of an agglomeration that is known for its numerous oil mills. Discharges of these mills and domestic waste water were directly dumped to this station. A single species (*O. forcipatus*) was recorded suggesting that pollution may constitute a limiting factor to the distribution of numerous species of Odonata. This result needs confirmation but is in line with findings of Ferreras-Romero *et al*. (2009) who showed that urban and agricultural pollutions may negatively affect Odonata communities.

Station of larger surfaces (stations 3, 4, and 5) contain higher habitat diversity and greater odonatological diversity. These stations are characterized by a relatively large bed which promotes the presence of a multitude of micro-habitats. A very heterogeneous substratum, a dense riverine and aquatic vegetation, and a weak to moderate flow may contribute to the diversification of this station. Thus, this large bed surface may allow the coexistence of a larger number of species like in station 3. This result also confirms those of other studies on other types of habitats (Oertli *et al*., 2002; Carchini *et al*., 2003) which have also demonstrated significant associations between specific richness in Odonata and the surface area of ponds. The reduced set of stations did not allow us to identify potential drivers of the Odonata distribution. Species with weak dispersion capacities tend to be present in the largest and richest sites whereas species with strong dispersion capacities tend to be present in the majority of sites.

The aquatic vegetation of Wadi Isser presents a gradient passing from sparse vegetation to an extensive one. Our results indicate that species richness is higher in stations where the aquatic vegetation is dense, mainly at station 3. Dense stands of plant cover may be provide of a high diversity of habitats (Oertli *et al*., 2002).

The riverine vegetation and the forested zones are particularly important to Odonata because they offer protected areas for dispersal and numerous refuge sites for adults that feed, breed and defend their territory among this vegetation (Samways & Taylor, 2004). This is the case for stations 3, 4 and 5. The majority of the sampled species were captured in the riverine vegetation. This is especially true for the Zygoptera (Lestidae, Platycnemidae and Coenagrionidae). Some species like *O. coerulescens* are associated with abundant vegetation, either in the bed or on the banks while others like *O. brunneum*, prefer streams and banks devoid of vegetation (Aguilar & Dommanget, 1998; Dijkstra & Lewington, 2006).

Co-inertia suggested that the co-structure between the environmental variables and the Odonata is linked to aquatic vegetation, mainly riverine vegetation, width of the wadi bed, and water mineralisation. These results are of preliminary nature and they involve a limited subset of environmental factors, some of which were collinear with each other. The performed analysis and interpretation are also based on a reduced sample size but they may offer a baseline and a first step in the search of environmental factors driving the structure of the Odonata community at Wadi Isser and other North African wadis.

CONCLUSION

The survey of the odonatofauna of Wadi Isser is an important component and a first step in the local and regional efforts leading to an effective biodiversity conservation, particularly that of wadis. As "guardians of the watershed" (Clausnitzer & Jödicke, 2004), Odonata could be efficient indicators of the stability, health and integrity of freshwater habitats. A total of 19 species of dragonflies and damselflies was recorded during the study period. The spatial distribution of the recorded Odonata appears to be related to environmental factors like riverine vegetation, pollution and dissolved oxygen. Our preliminary study could be extended to include a greater sampling size which should include stations from mountain streams to sea-level. It should also benefit from a longer sampling effort spanning several years. Because dragonflies are attractive and easily recognizable, they may represent a first-rate biological model to monitor freshwater biodiversity in arid regions where aquatic ecosystems are highly vulnerable to anthropogenic changes.

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