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Odonata assemblages in highland hydrosystems of northeastern Algeria, with notes on elevational patterns: application of species occupancy models

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ABSTRACT. We aim in this study to increase our knowledge of the Odonata in the Aures, an unexplored region of northeastern Algeria, using single-species occupancy model (spOccupancy R package) coupled with spatial interpolation technique (kriging ArcGis) to assess the relationships between elevation and odonatan species distribution. From time windows of about 90 days (June to August 2021), a total of 22 odonatan species belonging to 2 suborders (Anisoptera and Zygoptera) have been recorded in 15 sampling wet biotopes; among them the endangered *Calopteryx exul*. Our modelling shows that 62% of the odonatological community has a uniform probability of being present in the studied area. The probability of detecting a species is similar during each survey for 90% of the odonatological community except for the endangered *Calopteryx exul* ($p < 0.05$) and *Crocothemis erythraea* ($p < 0.05$). We also found that *Ischnura graellsii and I. saharensis* are the most common species; they are predicted to occur in more than 60% of sites, followed by *Anax imperator, Orthetrum chrysostigma,* and *Platycnemis subdilatata,* where they occur in about 50% of the wet biotopes sampled. Finally, our modelling revealed no evidence for a significant altitudinal variation (500 to 1900 meters above sea level) impact on both occupancy and detectability of the majority of the odonatan species, except for *Crocothemis erythraea* and *Sympetrum fonscolombii*. The kriging interpolation indicates that they are concentrated within the altitude range of 400 m to 1000 m.

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INTRODUCTION

It is well established that aquatic insects are considered as "Keystone" groups of arthropods, whose presence in an aquatic ecosystem, including hydro systems like rivers, streams, ponds, and wetlands, is paramount to the point that without insects, several key ecosystem processes would be vastly affected (Weisser & Siemann, 2008; Yang & Gratton, 2014; Elango et al., 2021). Because they comprise around 60% of all known animal species in the freshwater realm (Dijkstra et al., 2014), by studying these organisms,

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scientists and environmental professionals can gain insights into the health and integrity of aquatic ecosystems, and help to guide conservation and management efforts to protect and restore these vital habitats. There are several reasons why this group of animals are valuable indicators for assessing the health and quality of aquatic ecosystems: (1) they are sensitive to environmental changes; (2) they comprise diverse taxonomic groups (Hotaling et al., 2020); (3) their various life history traits offer information on specific aspects of ecosystem health and functioning (Richards et al., 1997); (4) the possibility of long-term monitoring that can indicate the effectiveness of conservation and restoration efforts (Kennen et al., 2012); and (5) straightforward sampling process and identification (Bried & Hinchliffe, 2019). Overall, the use of aquatic insects in biomonitoring and ecological assessments is a valuable and widely accepted practice.

Several groups of insects are used to serve as bioindicators to assess the quality of environmental changes such as Coleoptera, Diptera, Lepidoptera, Hymenoptera, Hemiptera, and Isoptera (Chowdhury et al., 2023; Shrivastava et al., 2018). Among them, member of the Order Odonata, which include dragonflies and damselflies, stands as one of the most valuable biological indicators in lotic and lentic habitats. The structure of their communities can be highly informative about the effects of human activity and environmental changes on the ecosystems they inhabit (Foote & Hornung, 2005). The academic study of dragonflies and damselflies (odonatology) is well-established worldwide (Bried & Samways, 2015). However, in Algeria, the biggest country in Africa, odonatological studies are unsatisfactory and disputable to the point that ecological findings in certain studied taxa are wrongly rebutting (Khelifa et al., 2018; Samraoui, 2018). Furthermore, almost all odonatological studies have not adequately proved the effects of environmental factors; instead, they all consist of checklist annotations with a cursory analysis of the issue (Khelifa et al., 2011, 2021; Chelli & Moulaï, 2019; Sellam-Bouattoura et al., 2018; Mairif et al., 2023). For the few studies in which the influence of abiotic factors on odonatan species distribution was addressed (Bouchelouche et al., 2015; Yalles Satha & Samraoui, 2017), the link was assessed only using generalized linear models or simple correlations. Although it was thought to be a suitable tool, these statistical approaches imply perfect detection of the target species which could biased parameter estimates by not incorporating non-detection error (Gomez et al., 2018). This fact underscores the need for more robust and in-depth research in odonatology, particularly by acquiring reliable models of species distribution. Indeed, in entomological studies, as in ecological research involving any taxonomic group, accounting for false absences (non-detection errors or imperfect detection) is a common challenge when predicting patterns in species richness, community composition, or species dispersion. Ignoring non-detection errors can lead to biased and misleading results. (Mourguiart et al., 2021). Recently, occupancy modelling (e.g., MacKenzie & Royle, 2005; MacKenzie et al., 2017) has become a standard application in many wildlife studies thanks to the power and flexibility of their model input (Hayes & Monfils, 2015). Occupancy modelling is a statistical approach used in ecology and conservation biology to estimate the probability of a species or ecological feature being present (occupancy) in a given area while accounting for imperfect and heterogeneous detection probabilities. It requires appropriate statistical models and can provide valuable insights into the distribution and trends of species in a cost-effective manner; only data on species presence or absence are required (Gomez et al., 2018; Nicholson & van Manen, 2009).

The study was conducted in a mountainous region of northeastern Algeria, the Aures region, it was therefore necessary to account for the effects of elevation. There is a strong consensus that this topographical variable alone may not influence the composition of aquatic invertebrate communities (Stefani-Santos et al., 2021) but, if coupled with other environmental variables, changes in community composition could be exerted (Woodward, 2001). In this research we aim to (1) increase our knowledge of the Odonata in the Aures region; an unexplored region of Algeria in terms of odonatology, located on the northeastern side of the country; (2) use a single-species occupancy model to estimate the proportion of sites occupied and detection probabilities of each inventoried species (MacKenzie et al., 2002) and (3) using the occupancy model to assess the relationships between elevation and odonatan species distribution. This study is a robust and data-driven approach that reached an altitude of 1900 meters for the first time in odonatological studies in Algeria. Additionally, it allows us to account for the complexities of imperfect detection and variations in species occurrence along elevation gradients at a unique and less-explored ecological niche, which could provide valuable insights into the distribution, behaviour, and adaptations of Odonata species in this geographical entity of the country.

MATERIAL AND METHODS

Study area and data collection. The study was conducted in the Aures region, a mountainous area in northeastern Algeria, located up to 180 km from the Mediterranean Sea (Fig. 1). Odonata were sampled by walking slowly and repeatedly at 15 locations in the Aures hydrosystems throughout an altitudinal gradient ranging from 500 m to 1900 m. Data on detection and non-detection gathered over repeated visits are necessary for occupancy models. To meet the closure assumption (MacKenzie et al. 2006), we restricted the data to time windows of about 90 days, from June to August 2021 when each site was visited three times within the year. This period is well admitted to match the flight period of all odonatan species in Algeria (Samraoui & Menaï, 1999; Mairif et al., 2023). Only the visits that were made during a time of closure within the year qualify as valid repeated visits. For the survey, a 150 m linear transect was demarcated in each study site, and adult insects were recorded when observed at a distance of up to 5 m ahead of the researcher (Batista et al., 2021; Boieiro et al., 2022; Darshetkar et al., 2023). The insects were captured with the help of a sweeping net only in case of need to confirm their species identity, being immediately released afterwards. We followed the systematics according to Dijkstra and Schröter (2020). Sampling was carried out by the same observer (Elafri A) between 10 a.m.-3 p.m. and under favourable climatic conditions.

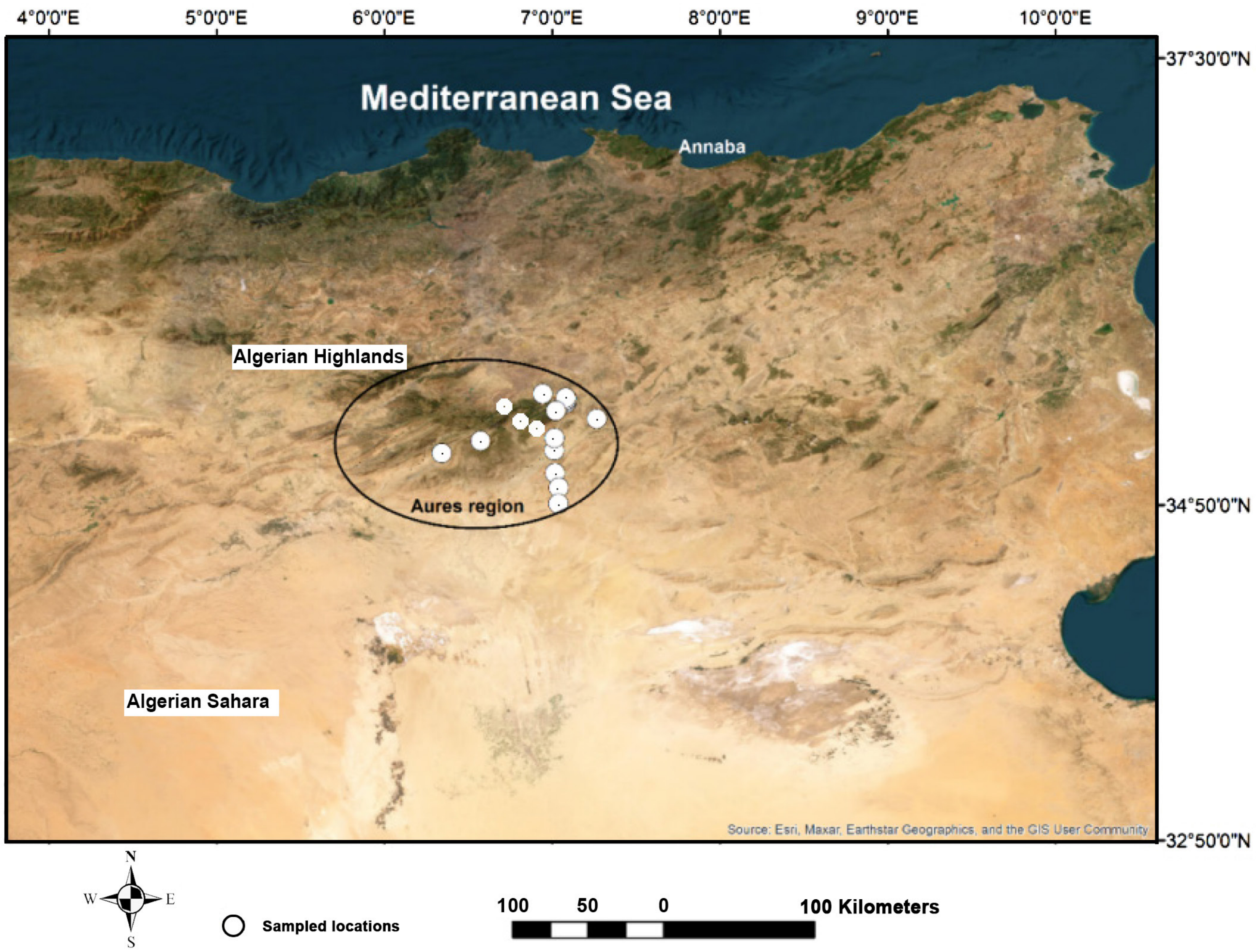

Figure 1. Map showing sampled locations, the Aures region, the Algerian highlands and the Sahara.

Statistical analysis. We applied a single-species occupancy model, which followed the material by MacKenzie et al. (2002). The occupancy model consists of two hierarchically coupled sub-models, one for occupancy and one for detection probability, the latter being conditional on the occupancy sub-model (Donovan & Hines, 2007). Occupancy models were developed to address the issues arising from imperfect detectability, where species detection is not always perfect, leading to both detected and non-detected records of a species during surveys at each site (MacKenzie et al., 2002). These models account for detection probabilities to estimate true occupancy and are typically defined by the following equations:

$$Occupancy\ Probability\ (\psi){:}\ Z_i \sim Bernoulli\ (\psi_i)$$

Where Z_i is a latent variable arising from a Bernoulli process representing whether site i is occupied (Z_i=*1*) or unoccupied (Z_i=*0*), and ψ is the probability that site '*i*' is occupied.

$$Detection\ Probability\ (p){:}\ Y_{ij} \sim Bernoulli\ (Z_i * p_i)$$

Where Y_{ij} is the detection/non-detection data for site *i* during survey '*j*', and 'p_i' is the probability of detecting the species at site '*i*' during survey '*j*' given it is present (p_i: probability arising from a Bernoulli process conditional on the true latent occurrence process).

The details of this and other variations on occupancy estimation are described in a series of journal articles (see MacKenzie & Royle, 2005; Doser et al., 2022). For each inventoried taxon we calculated occupancy using an intercept-only model to test two null hypotheses that are 1) $H_{(0)Occupancy}$ assumes that the probability of being present is the same at each surveyed site, and 2) $H_{(0)detection}$ assumes that the probability of detecting a species is consistently the same during each survey. In order to assess the impact of elevation on species occupancy and detection we added the site altitude as an occupancy covariate for each model. For the modelling process, we used R Core Team (2021) with the unmarked R package (Doser et al., 2022; Kellner et al., 2023). The occupancy models provide predicted values at the locations where we had data or observations. In order to estimate values at locations where we did not have observations, and to create smooth and continuous maps of our predicted values we have used the kriging method (Hengl et al., 2009; Hortal & Lobo, 2011). Species for which this spatial interpolation technique was performed were those whose occupancy modelling was significantly influenced by elevation. For mapping, we used ArcGIS 10.8 (ESRI, 2011).

RESULTS

Species distribution models. As a result of field surveys, we collected 945 detection/non-detection data in the 15 sampling wet biotopes, belonging to 22 Odonata species (Table 1), among them the endangered *Calopteryx exul* (Fig. 2). By analyzing the single-season occupancy models (an intercept-only model) we found that the probability of being present is the same at each surveyed site ($H_{(0)Occupancy}$) for 62% of the odonatological community (13 species, $p > 0.05$). Significant differences in occupancy probabilities among sites are found for the remaining species (9 species, $p < 0.05$), these particular species exhibit distinct habitat preferences and their presence is limited at a few numbers of sites (Table 1). We also found that the probability of detecting a species is consistently the same during each survey ($H_{(0)Detection}$) for almost all of the observed Odonata (90% of the odonatological community) except for *Calopteryx exul* ($p < 0.05$) and *Crocothemis erytharaea* ($p < 0.05$) where their likelihood of being detected at the site when they present varied significantly among the survey period. The negative estimate ($\beta = -2.64$) in the occupancy model for the first species indicates a decreasing trend in detection probability when the breeding season progresses, and the positive estimate ($\beta = 1.34$) for the second one indicates an increasing trend in detection probability as the breeding season progress (Table 1).

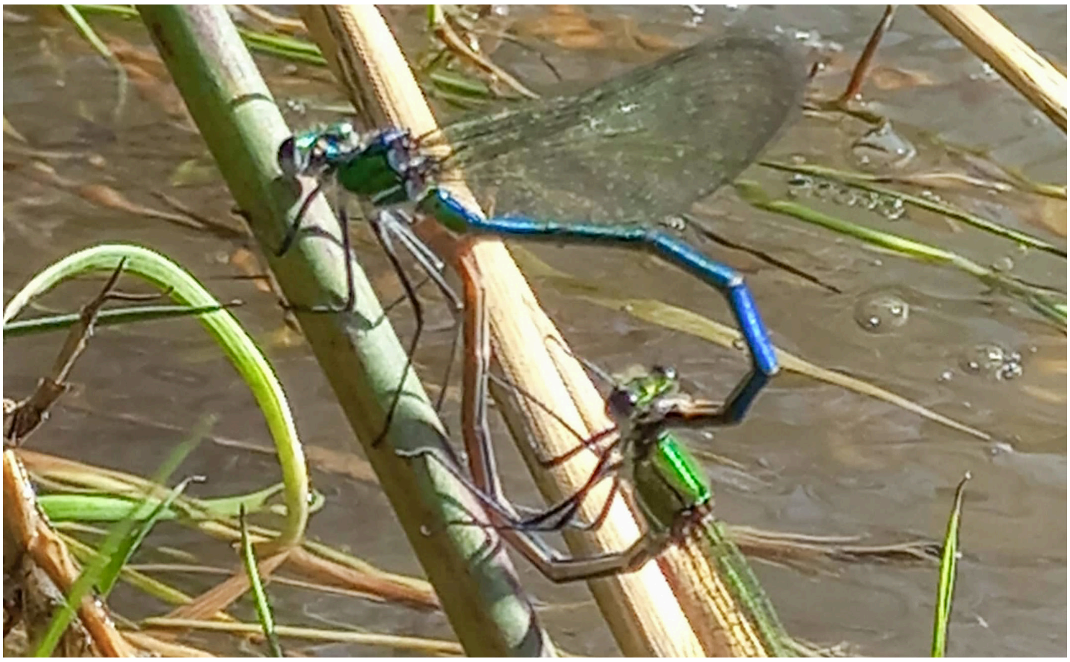

Figure 2. The endangered species, *Calopteryx exul* Selys, 1853 (Elhamm, Khenchela, Algeria, 07°5'15.81"E, 35°27'56.39"N).

Table 1. Species (scientific name) recorded in the 15 wet biotopes of the Aures region Northeastern Algeria during biodiversity surveys from Jun to August 2021. With the standardized beta coefficients, standard error, *z-value*, and *p-value* (bold data shows significant models) of the single-season occupancy models (an intercept-only model).

Scientific name	Occupancy				Detection			
	β	*SE*	*z*	*P values*	*β*	*SE*	*z*	*P values*
Enallagma deserti	-0.69	0.54	-1.27	0.20	11.70	90.1	0.13	0.89
Orthetrum chrysostigma	-0.13	0.51	-0.25	0.79	10.30	38.3	0.27	0.78
Platycnemis subdilatata	-0.13	0.51	-0.25	0.79	10.03	38.3	0.27	0.18
Calopteryx haemorrhoidalis	-1.01	0.58	-1.87	0.09	9.85	39.7	0.24	0.8
Trithemis kirbyi	-0.98	0.58	-1.79	0.10	1.03	0.7	1.45	0.14
Sympetrum meridionale	-0.94	0.6	-1.56	0.11	0.54	0.68	0.80	0.42
Ischnura saharensis	0.56	0.76	0.73	0.46	-0.18	0.52	-0.36	0.71
Ischnura graellsii	0.56	0.76	0.73	0.46	-0.18	0.52	-0.36	0.71
Anax imperator	-0.05	0.92	-0.05	0.95	-0.75	0.77	-0.97	0.32
Calopteryx exul	-2.58	1.05	-2.45	**0.01**	-2.64	0.6	-4.36	**0.00**
Crocothemis erythraea	-0.68	0.55	-1.23	0.21	1.34	0.55	2	**0.04**
Onychogomphus forcipatus unguiculatus	-0.63	0.78	-0.79	0.42	-0.48	0.79	-0.78	0.54
Chalcolestes viridis	-1.01	0.58	-1.73	0.08	9.85	39.7	0.24	0.8
Sympetrum sinaiticum	-1.39	0.64	-2.15	**0.03**	10.3	58.6	0.17	0.86
Orthetrum cancellatum	-2.64	1.04	-2.55	**0.01**	8.4	38.5	0.21	0.8
Orthetrum trinacria	-2.59	1.05	-2.46	**0.01**	0.54	1.05	0.4	0.68
Orthetrum nitidinerve	-2.59	1.05	-2.46	**0.01**	0.54	1.05	0.4	0.68
Coenagrion caerulescens	-1.55	0.9	-1.67	0.09	-0.41	1.12	-0.48	0.66
Sympecma fusca	-2.59	1.05	-2.46	**0.01**	0.54	1.05	0.4	0.68
Orthetrum coerulescens anceps	-2.59	1.05	-2.46	**0.01**	0.54	1.05	0.4	0.68
Sympetrum fonscolombii	-2.59	1.05	-2.46	**0.01**	0.54	1.05	0.4	0.68
Paragomphus genei	-2.59	1.05	-2.45	**0.01**	0.54	1.05	0.4	0.68

By extracting the real parameters predicting occupancy probability and detection probability from our occupancy models we found that *Ischnura graellsii and I. saharensis* are the most common species, that are predicted to occur in more than 60% of sites, followed by *Anax imperator, Orthetrum chrysostigma,* and *Platycnemis subdilatata* where that are occurred in about 50% of the wet biotopes sampled (Fig. 3). On the other hand, eight species among them the endangered *Calopteryx exul* were predicted to have a very low occupancy probability throughout the study region (less than 8%, *p-value* = *0.01*).

The monitoring data revealed that mean detections varied considerably among species, ranging from 0.02 ($CI_{95\%}$=*0.01–0.17*) to 0.99 ($CI_{95\%}$=*0.94–1*) (Fig. 3). We also found that the majority of the species had a higher probability of being detected (> 63%), followed by a small group (four species) with a relatively moderate detection probability (31% to 45%), and finally, five species with a much lower chance of being detected because they are more difficult to find (< 6%) (Fig. 3).

Altitudinal profile. Our monitoring data allowed us to generate occupancy models for the occupancy probability of 20 species and for the detection probability of 14 species. The main reason why some species were excluded from the modelling process was the inadequate validity of their models due to the complete separation of data (Table 2). In our case, this statistical phenomenon is occurring due to insufficient data collection, it highlights a data limitation rather than a statistical issue per se. That's why we preferred to exclude these species instead of going through complicated statistical strategies.

The examination of the obtained models revealed no evidence for a significant altitudinal variation impact on both occupancy and detectability of the majority of the odonatan species except for *Crocothemis erythraea* where elevation seems to have a significant impact on their occupancy probability (*p = 0.04*) (Table 2). This species was predicted to colonize wet biotopes at lower elevations more than high areas (β = *-0.0055*) (Fig. 4). They typically resided in areas where the height ranged from 420 m to 1000 m (Fig. 5). For the second species, *Sympetrum fonscolombii*, detection probability varied significantly with altitudinal variation (*p = 0.01*). Their likelihood of being detected at sites where they present decreased with the increase of elevation (β = *-0.03*) (Fig. 4), and their detection was higher within the altitude range of 400 to 1000 m (Fig. 6).

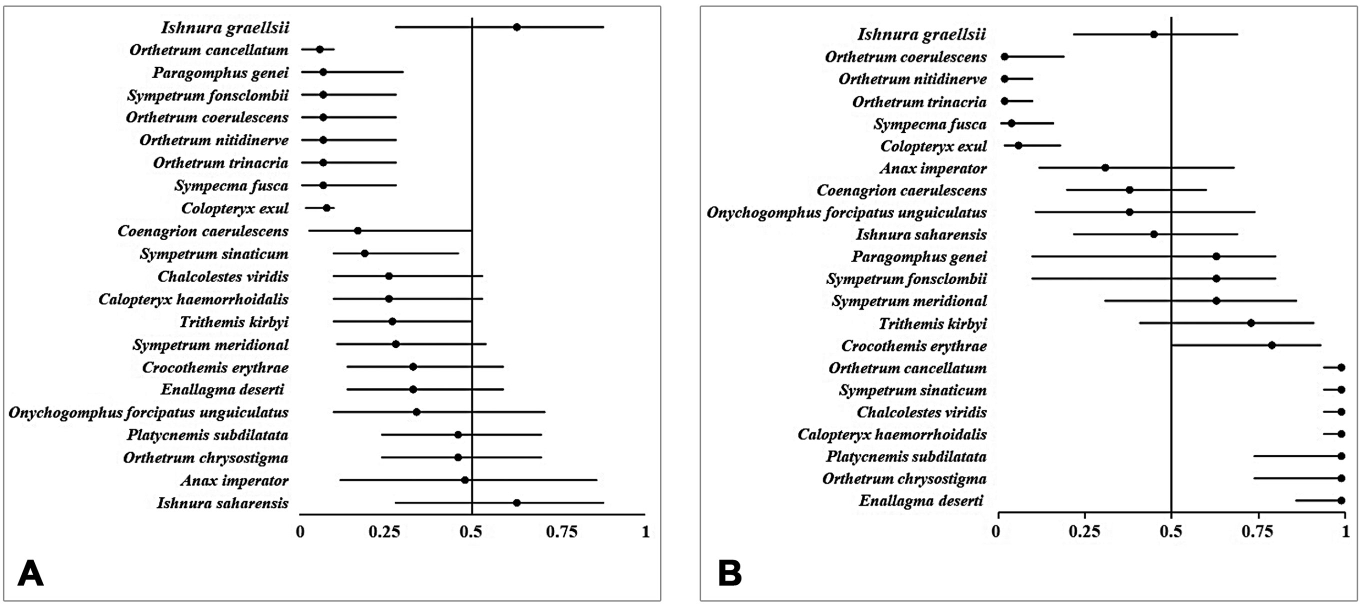

Figure 3. Caterpillar plots highlight the probability estimates. **A.** Occupancy; **B.** Detection, as well as the 95% confidence intervals for the single-season occupancy models.

Table 2. Summary statistics of the single-season occupancy models (Altitude as a covariate) of the odonatological fauna at the Aures region of Northeastern Algeria. (NaN: Complete separation of data points detected and the validity of the model fit is questionable). The bold data shows significant models.

	Occupancy				Detection			
Scientific name	*β*	*SE*	*z*	*P values*	*β*	*SE*	*z*	*P values*
Anax imperator	0.00202	0.003	0.51	0.60	NaN	NaN	NaN	NaN
Calopteryx exul	-0.00258	0.003	-0.75	0.45	0.54	1.38	0.397	0.69
Calopteryx haemorrhoidalis	-0.00406	0.002	-1.61	0.10	0.959	0.649	1.48	0.13
Sympetrum sinaiticum	-0.00731	0.004	-1.52	0.12	5.6	5.51	1.02	0.30
Coenagrionca coerulescens	-0.01	0.02	-0.64	0.51	-0.20	1.03	-0.19	0.84
Chalcolestes viridis	0.003	0.002	1.27	0.20	NaN	NaN	NaN	NaN
Platycnemis subdilatata	-0.78	0.67	-1.17	0.24	NaN	NaN	NaN	NaN
Orthetrum cancellatum	0.0004	0.005	0.08	0.92	NaN	NaN	NaN	NaN
Crocothemis erythraea	-0.0055	0.002	-2.01	**0.04**	-0.0007	0.003	-0.21	0.83
Trithemis kirbyi	-0.00101	0.002	-0.39	0.69	0.006	0.004	1.69	0.09
Sympetrum meridionale	-0.00101	0.002	-0.39	0.69	NaN	NaN	NaN	NaN
Sympetrum fonscolombii	-0.0041	0.003	-1.07	0.28	-0.03	0.01	-2.55	**0.01**
Paragomphus genei	-0.0032	0.003	-0.88	0.37	-0.008	0.019	-0.44	0.66
Ishnura saharensis	0.00039	0.002	0.15	0.87	0.0002	0.003	0.06	0.94
Ischnura graellsii	0.00039	0.002	0.15	0.87	0.0002	0.003	0.06	0.94
Onychogomphus forcipatus unguiculatus	0.00514	0.004	1.1	0.27	NaN	NaN	NaN	NaN
Enallagma deserti	0.000238	0.001	0.12	0.90	0.479	205	0.002	0.99
Sympecma fusca	-0.000636	0.01	-0.03	0.96	-0.002	0.007	-0.31	0.75
Orthetrum trinacria	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
Orthetrum nitidinerve	-0.0024	0.05	-0.04	0.96	-0.003	0.007	-0.51	0.604
Orthetrum coerulescens anceps	-0.0029	0.003	-0.86	0.38	NaN	NaN	NaN	NaN
Orthetrum chrysostigma	0.838	0.60	1.38	0.16	-0.0029	0.002	-0.98	0.324

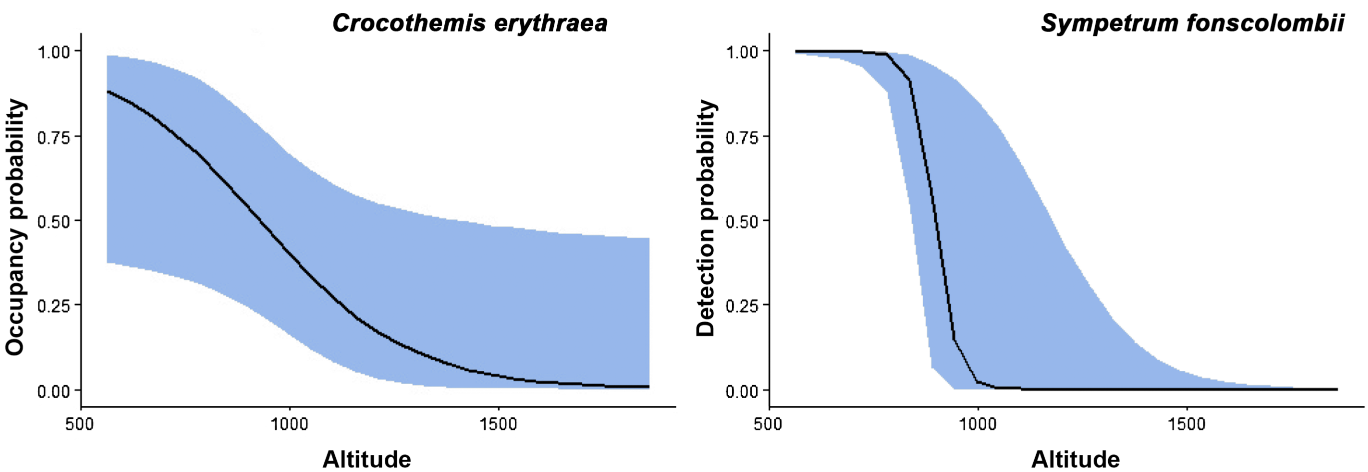

Figure 4. Significant altitudinal occupancy/detection probability (±95% confidence interval) of the odonatological fauna at the Aures region Northeastern Algeria during a period of closure from Juan to August 2021.

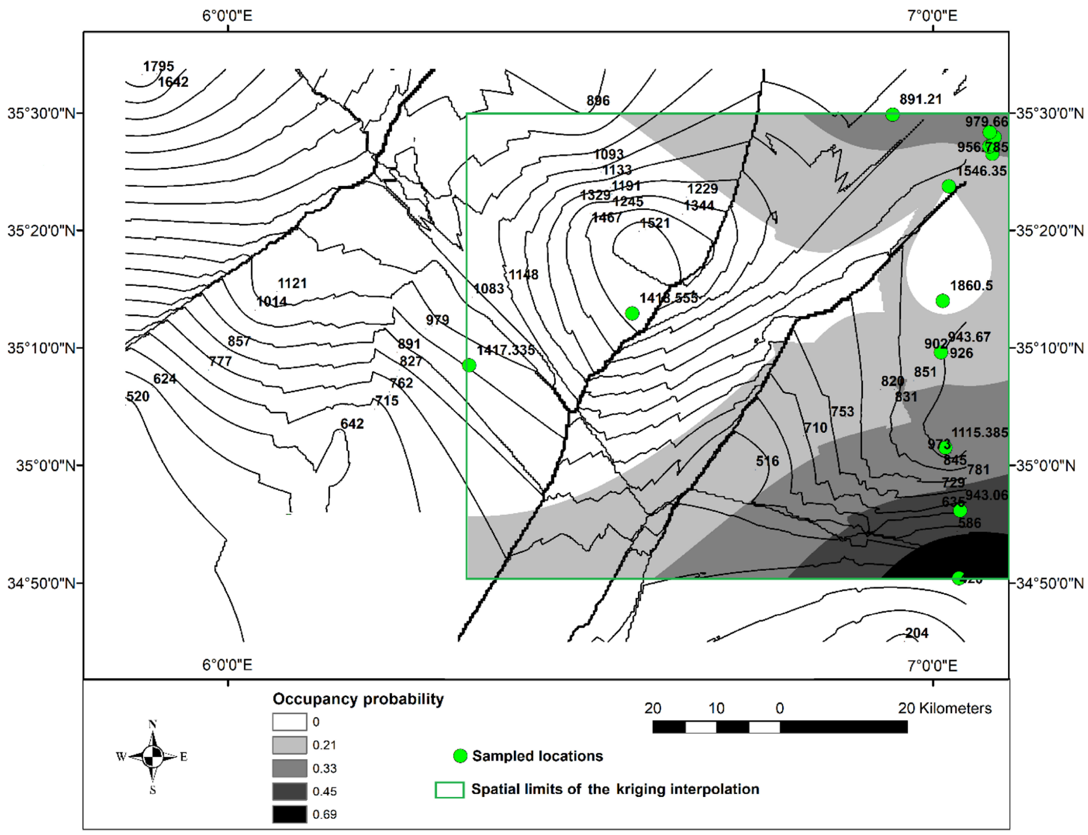

Figure 5. Maps of predicted occupancy probabilities of *Crocothemis erythraea* in the Aures region of northeastern Algerian highlands (Altitude as a covariate).

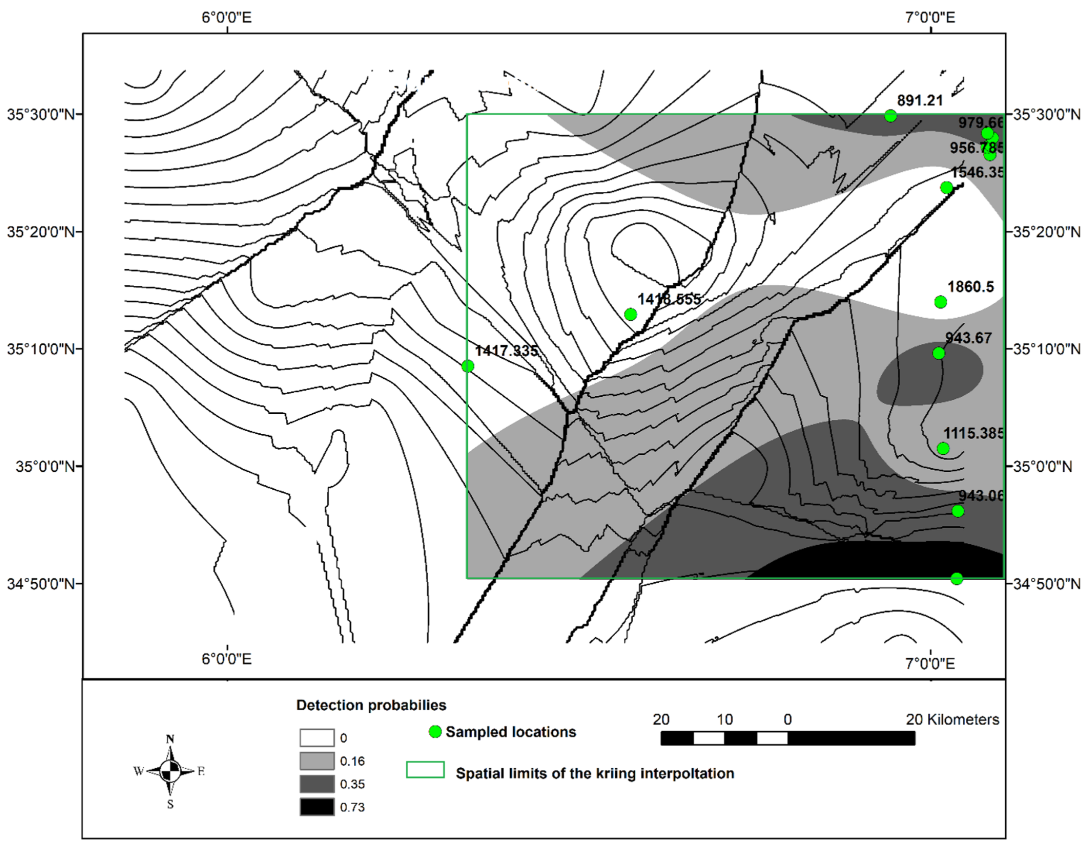

Figure 6. Maps of predicted detection probabilities of *Sympetrum fonscolombii* in the Aures region of northeastern Algerian highlands (Altitude as a covariate).

DISCUSSION

Our dataset contains 22 recorded odonatan species from 15 locations in highlands hydrosystems of northeastern Algeria (The Aures region). Among them, four species (*Calopteryx exul, Platycnemis subdilatata, Ischnura saharensis,* and *Enallagma deserti)* are a North African (commonly named Maghrebian) endemic species (Khelifa et al., 2011). The presence of endemic species indicates that the region likely has unique ecosystems and an evolutionary history worth protecting and studying. Such interesting findings are crucial for ecological studies since systematic conservation planning the establishment of protected areas and conservation prioritization are fundamentally based on the status of rare and endemic species (Harrison & Noss, 2017; Margules & Pressey, 2000). Species of semi-arid and Saharan habitats comprise *Sympetrum sinaiticum*, *Coenagrion caerulescens, Enallagma deserti,* and *Orthetrum nitidinerve*. The observation of these Saharan species in the Aures region confirms the range expansion of these species beyond their historically documented boundaries in Algeria as reported previously (Boudot et al., 2009; Khelifa et al., 2011). The rapid colonization and expansion of Saharan species into new areas, including Southern Europe has also been confirmed (Boudot, 2010; Boudot et al., 2009; Corso et al., 2012).

Our finding (in terms of species of semi-arid and Saharan habitat) is far from what was previously achieved by Samraoui & Menaï (1999), who reported the presence of 11 semi-arid and Saharan species in Algeria. Indeed, this number of species is not as fruitful as we had expected, given that the studied region is situated at the edge of the Algerian Sahara, and experienced a semi-arid climate. We hope that this discrepancy is primarily a result of differences in data collection and methodology rather than habitat degradation or climate change. Further, the recorded insects are a widespread species with ranges spanning both the Sahara and the Tell or the coastal wetlands (Boudot et al., 2009) which could indeed explain this discrepancy. In contrast, the remaining Saharan species (*lschnura fountaineae*, *Orthetrum ransonneti*, *0. sabina*, and *Selysiothemis nigra*) (Samraoui & Menaï, 1999) not confirmed during our odonatological survey are rare and elusive, they need much more sampling effort to be detected. Rarity was also revealed for some species (Occupancy probabilities under 10%, Fig. 2) assessed in contrast as Least Concern in the IUCN North African Red List and the IUCN Mediterranean Red List (Yalles Satha & Samraoui, 2017).

Although we are so far from the national records of 64 odonatan species (Khelifa et al., 2021) or from the Odonata fauna (35 species) of the closest region, the Seybouse river catchment (Khelifa et al., 2011), we believe that the presence of 21 odonatan species in a region facing adverse climatic conditions and extensive water resource use (Elafri, 2022) is a noteworthy finding and raises several important ecological and environmental considerations: (1) underscores the resilience of biodiversity; (2) provide opportunities for further scientific research mainly the adaptations strategies of these species in response to the local environment; and (3) raising awareness among local communities about the ecological importance of odonatans and the need to conserve their habitats can foster community engagement in conservation efforts. Using the data from our survey, we were able to predict the occupancy probabilities of 22 odonatan species in this particular area of Algeria, while accounting for imperfect detection through a single-species occupancy model. The occupancy probabilities obtained through our modelling show a uniform pattern of distribution in 59% (13 species) of the odonatological community. In other words, there is no reason why any species found in one of these sites might not be expected in the others as well. This is for example the case of *Orthetrum coerulescens*, despite its lower probability of detection it has the same chance of occurrence in any sites from the 15 surveyed ones. When we have such information about species' occurrence, we will be able to enhance our biodiversity results by increasing our sampling efforts at each site since we have statistically confirmed that these species have the same likelihood of being present across the study area. This is one of the most valuable accomplishments of occupancy modelling in ecological research. It highlights areas where species may be present but have lower detection probabilities, indicating the need for improved survey methods or increased monitoring efforts rather than ignored localities, where species have a lower detection rate from our inventory schemes. On the other hand, significant differences in occupancy probabilities among sites are revealed for 9 species. These particular species exhibit distinct habitat preferences and their presence is limited at a few numbers of sites. This allows for a more detailed understanding of the ecological requirements of these species and the factors influencing their presence. Finally, we have found that the probability of detecting of presence of each species remains consistent during each survey visit within the year (period of closure) for a significant portion of the Odonata community (90% of the observed Odonata). It is well-admitted that occupancy modelling is a valuable tool in ecological research, but it relies on certain assumptions, including the period of closure assumption (Kendall et al., 2013; Mourguiart et al., 2021). This assumption implies that during the defined period of closure, the site or habitat is considered either occupied or unoccupied by the species of interest, but it is not abandoned or colonized during that time frame (van Strien et al., 2013). In our study, we are confident that this assumption holds true for the majority (90%) of the Odonata community we observed, which strengthens the robustness of our occupancy modelling approach for this particular group of insects in our study context.

Altitudinal patterns of distribution. The examination of the occupancy models did not show any significant impact of altitudinal variation on both the occupancy and detectability of almost all the odonatan species along the elevational gradient of northeastern Algerian highlands hydrosystems (the Aures region). This suggests that, for most Odonata species in our study, their presence and the likelihood of detecting them did not vary significantly with changes in altitude. However, there were two exceptions to this general pattern. For the species *Crocothemis erythraea* and *Sympetrum fonscolombii*, there was evidence of significant altitudinal variation. This means that these two Anisopteran species exhibited distinct patterns in their occupancy and detectability along the altitudinal gradient. The fact that most species did not show significant altitudinal variation suggests that factors other than altitude may be more influential in determining their presence and detectability. To the best of our knowledge, this is the first study in Algerian odonatological studies that reached an altitude of 1900 m. The national histories range from 1 to 550 m (Sellam-Bouattoura et al., 2018), 1 m to 1572 m (Chelli & Moulaï, 2019), 1287 m to 1524 m (Mairif et al., 2023), 31 m to 789 m (Khelifa et al., 2011), an average of 2 m (Benchalel & Samraoui, 2012) and 1 m to 346.5 m (Yalles Satha & Samraoui, 2017). These odonatological studies have not adequately proved the effects of altitudinal variation; instead, they all consist of checklist annotations with a cursory analysis of the issue. Therefore, we have resorted to odonatological studies conducted abroad. In corroborating with our results, no clear distribution pattern was found for Odonata along the elevational gradient in Java Island, Indonesia (Leksono et al., 2017), in the Atlantic Forest of southeastern Brazil (Stefani-Santos et al., 2021) and in eastern Colombia (Palacino-Rodríguez et al., 2021). On the other side negative relationships between Odonata species richness and altitude were observed in Ecuador (Jacobsen, 2004), Switzerland (Oertli et al., 2002), and Mexico (Novelo-Gutiérrez & Gómez-Anaya, 2009). The debate about the impact of elevation on odonates (dragonflies and damselflies) is a complex and multifaceted one, as altitude can have varying effects on these insects depending on the species, geographical region, and specific environmental conditions. In conclusion, there is almost consensus that the altitude alone may not affect the composition of aquatic invertebrate communities (Stefani-Santos et al., 2021) but, if associated with other environmental variables such as the area conservation degree, the vegetation cover or the physicochemical characteristics of the water, changes on community composition could be exerted (Woodward, 2001). Reaching an altitude of 1900 meters in odonatological studies in Algeria represents a significant milestone and achievement in the field of dragonfly and damselfly research within the country. This elevation likely corresponds to a unique and less-explored ecological niche, and conducting studies at this altitude can provide valuable insights into the distribution, behaviour, and adaptations of Odonata species in high-altitude environments.

Our dataset, which includes records of 22 odonatan species especially North African endemic ones (four species, among them the endangered *Calopteryx exul*) in the highland hydrosystems of northeastern Algeria (specifically, the Aures region), provides a foundation for studying the odonatan diversity and ecology in this unique geographical entity of the country. It can serve as a valuable resource for scientific research, conservation efforts, and environmental education, ultimately contributing to the understanding and protection of these unique ecosystems and their inhabitants. Obtaining a uniform pattern of distribution in 59% (13 species) of the odonatological community through our occupancy modelling is an interesting finding. Understanding which species exhibit such distribution patterns can shed light on their ecological roles within the ecosystem. Some species may serve as important prey items for predators or play other key roles in the food web. Throughout our occupancy models, we confirm the rare status of certain species in contrast to what was previously known. Such a finding underscores the importance of continually updating and verifying species status through scientific investigation. Previous knowledge may have been based on limited data or outdated information, and our work helps to refine our understanding. Despite their clear impact in shaping the distribution and behaviour of odonates, we confirm that the impact of elevation is species-dependent and influenced by a range of environmental factors.

AUTHOR'S CONTRIBUTION

The authors confirm their contribution to the paper as follows: Conceptualization: Elafri Ali; Methodology: Elafri Ali, Aoues Abdelah, Ghomrassi Hanin; Formal analysis and investigation: Elafri Ali, Halassi; Writing - original draft preparation: [Elafri Ali, Halassi Ismahan]; Writing - review and editing: [Elafri Ali]. The authors read and approved the final version of the manuscript.

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AVAILABILITY OF DATA AND MATERIAL

Not applicable.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

This study only included arthropod material, and all required ethical guidelines for the treatment and use of animals were strictly adhered to in accordance with international, national, and institutional regulations. No human participants were involved in any studies conducted by the authors for this article.

CONSENT FOR PUBLICATION

Not applicable.

CONFLICT OF INTERESTS

The authors declare that there is no conflict of interest regarding the publication of this paper.

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REFERENCES

Benchalel. W. & Samraoui, B. (2012) 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) [Ecological and biological characteristics of odonate fauna at two mediterranean streams: El-Kebir and Bouaroug rivers]. *Méditerranée*, 118, 19–27. https://doi.org/10.4000/mediterranee.6182

Batista, J.D., Ferreira, V.R.S., Cabette, H.S.R., de Castro, L.A., De Marco, P. & Juen, L. (2021) Sampling efficiency of a protocol to measure Odonata diversity in tropical streams. *PLoS One,* 16 (3), e0248216. https://doi.org/10.1371/journal.pone.0248216

Boieiro, M., Antunes, S., Figueiredo, H., Soares, A., Lopes, A., Monteiro, E., Pereira, P.G., Rego, C., Conde, J., Borges, P.A.V. & Serrano, A.R.M. (2022) Standardized sampling of odonates (Odonata) in Serra da Estrela (Portugal)-2013 and 2014. Available from https://hdl.handle.net/10400.3/6532 [Accessed July, 18, 2024]

Bouchelouche, D., Kherbouche-Abrous, O., Mebarki, M.. Arab, A. & Samraoui, B. (2015) The Odonata of Wadi Isser (Kabylia, Algeria): status and environmental determinants of their distribution. *Revue d'Écologie (La Terre et La Vie)*, 70 (3), 248–260. https://doi.org/10.3406/revec.2015.1787

Boudot, J.P. (2010) Spécificités du peuplement en Odonates du nord de l'Afrique et observations récentes d'espèces remarquables (Insecta: Odonata) [Specificity of the Dragonfly fauna from Northern Africa and recent noteworthy records (Insecta : Odonata]. *Martinia*, 26 (3/4), 109–122.

Boudot, J.P., Kalkman, V.J., Azpilicueta Amorín, M., Bogdanović, T., Cordero Rivera, A., Degabriele, G., Dommanget, J-L., Ferreira, S., Garrigós, B., Jović, M., Kotarac, M., Lopau, W., Marinov, M., Mihoković, N., Riservato, E., Samraoui, B. & Schneider, W. (2009) Atlas of the Odonata of the Mediterranean and North Africa. *Libellula*, 9 (Suppl.), 1–256.

Bried, J.T. & Hinchliffe, R.P. (2019) Improving taxonomic resolution in large-scale freshwater biodiversity monitoring: an example using wetlands and Odonata. *Insect Conservation and Diversity*, 12 (1), 9–17. https://doi.org/10.1111/icad.12323

Bried, J.T. & Samways, M.J. (2015) A review of odonatology in freshwater applied ecology and conservation science. *Freshwater Science,* 34 (3), 1023–1031. https://doi.org/10.1086/682174

Chelli, A. & Moulaï, R. (2019) Ecological characterization of the odonatofauna in lotic and lentic waters of northeast Algeria. *Annales de La Societe Entomologique de France*, 55 (5), 430–445. https://doi.org/10.1080/00379271.2019.1660215

Chowdhury, S., Dubey, V.K., Choudhury, S., Das, A., Jeengar, D., Sujatha, B., Kumar, A., Kumar, N., Semwal, A. & Kumar, V. (2023) Insects as bioindicator: A hidden gem for environmental monitoring. *Frontiers in Environmental Science*, 11, 1146052. https://doi.org/10.3389/fenvs.2023.1146052

Corso, A., Janni, O., Pavesi, M., Sammut, M., Sciberras, A. & Vigan M (2012) Annotated checklist of the dragonflies (Insecta Odonata) of the islands of the Sicilian Channel, including the first records of *Sympetrum sinaiticum* Dumont, 1977 and *Pantala flavescens* (Fabricius, 1798) for Italy. *Biodiversity Journal*, 3 (4), 459–478.

Darshetkar, A., Patwardhan, A. & Koparde, P. (2023) A comparison of four sampling techniques for assessing species richness of adult odonates at riverbanks. *Journal of Threatened Taxa*, 15 (1), 22471–22478

Dijkstra, K.D.B., Monaghan, M.T. & Pauls, S.U. (2014) Freshwater biodiversity and aquatic insect diversification. *Annual Review of Entomology*, 59, 143–163. https://doi.org/10.1146/annurev-ento-011613-161958

Dijkastra, K.D.B. & Schroter, A. (2000) *Field Guide to the Dragonflies of Britain and Europe*. 2nd Edition. Bloomsbury Publishing, London. 336 p.

Donovan, T.M. & Hines, J.E. (2007) Exercises in occupancy modeling and estimation. Chapter 16. Available from: https://www.uvm.edu/rsenr/vtcfwru/spreadsheets/?Page=occupancy/occupancy.htm/[Accessed July 10, 2024]

Doser, J.W., Finley, A.O., Kéry, M. & Zipkin, E.F. (2022) spOccupancy: An R package for single-species, multi-species, and integrated spatial occupancy models. *Methods in Ecology and Evolution*, 13, 1670–1678. https://doi.org/10.1111/2041-210X.13897.

Elafri, A. (2022) New records of the endangered *Calopteryx exul* in a semi-arid territory of north-eastern Algeria (Odonata: Calopterygidae). *Notulae Odonatologicae*, 9 (9), 451–454. https://doi.org/10.60024/nodo.v9i9.a8

Elango. K., Vijayalakshmi, G., Arunkumar, P., Sobhana, E.& Sujithra, P. (2021) Aquatic insect's biodiversity: Importance and their conservation. *Biological Diversity: Current Status and Conservation Policies*, 1, 289–303. https://doi.org/10.26832/aesa-2021-bdcp-019

ESRI, (2011) ArcGIS Desktop: Release 10. Redlands, CA: Environmental Systems Research Institute.

Foote, A.L. & Hornung, C.L.R. (2005) Odonates as biological indicators of grazing effects on Canadian prairie wetlands. *Ecological Entomology*, 30, 273–283. https://doi.org/10.1111/j.0307-6946.2005.00701.x

Gomez, M.D., Goijman, A.P., Coda, J., Serafini, V. & Priotto, J. (2018) Small mammal responses to farming practices in central Argentinian agroecosystems: The use of hierarchical occupancy models. *Austral Ecology*, 43 (7), 828-838. https://doi.org/10.1111/aec.12625

Harrison, S. & Noss, R. (2017) Endemism hotspots are linked to stable climatic refugia. *Annals of Botany,* 119 (2), 207–214. https://doi.org/10.1093/aob/mcw248

Hayes, D.B., Monfils, M.J. (2015) Occupancy modeling of bird point counts: Implications of mobile animals. *Journal of Wildlife Management*, 79 (8), 1361–1368. https://doi.org/10.1002/jwmg.943

Hengl, T., Sierdsema, H., Radović, A. & Dilo, A. (2009) Spatial prediction of species' distributions from occurrence-only records: combining point pattern analysis, ENFA and regression-kriging. *Ecological Modelling*, 220 (24), 3499–3511. https://doi.org/10.1016/j.ecolmodel.2009.06.038

Hortal, J. & Lobo, J.M. (2011) Can species richness patterns be interpolated from a limited number of well-known areas? Mapping diversity using GLM and kriging. *Natureza a Conservacao*, 9 (2), 200–207. https://doi.org/10.4322/natcon.2011.026

Hotaling, S., Kelley, J.L. & Frandsen, P.B. (2020) Aquatic insects are dramatically underrepresented in genomic research. *Insects*, 11 (9), 1–7. https://doi.org/10.3390/insects11090601

Jacobsen, D. (2004) Contrasting patterns in local and zonal family richness of stream invertebrates along an Andean altitudinal gradient. *Freshwater Biology*, 49 (10), 1293–1305. https://doi.org/10.1111/j.1365-2427.2004.01274.x

Kellner, K.F., Smith, A.D., Royle, J.A., Kéry, M., Belant, J.L. & Chandler, R.B. (2023) The unmarked R package: Twelve years of advances in occurrence and abundance modelling in ecology. *Methods in Ecology and Evolution*, 14 (6), 1408–1415. https://doi.org/10.1111/2041-210X.14123

Kendall, W.L., Hines, J.E., Nichols, J.D. & Grant, E.H.C. (2013) Relaxing the closure assumption in occupancy models: Staggered arrival and departure times. *Ecology*, 94 (3), 610–617. https://doi.org/10.1890/12-1720.1

Kennen, J.G., Sullivan, D.J., May, J.T., Bell, A.H., Beaulieu, K.M. & Rice, D.E. (2012) Temporal changes in aquatic-invertebrate and fish assemblages in streams of the north-central and northeastern US. *Ecological Indicators*, 18, 312–329. https://doi.org/10.1016/j.ecolind.2011.11.022

Khelifa, R., Youcefi, A., Kahlerras, A., Alfarhan, A., Al-Rasheid, K.A.S.& Samraoui, B. (2011) L'Odonatofaune (insecta: odonata) du bassin de la seybouse en Algérie: intérêt pour la biodiversité du maghreb. *Revue d'Ecologie (La Terre et La Vie)*, 66 (1), 55–66. https://doi.org/10.3406/revec.2011.1557

Khelifa, R., Zebsa, R., Amari, H., Mellal, M.K., Zouaimia, A., Bensouilah, S., Laouar, A. & Houhamdi, M. (2018) The hand of man first then Santa Rosalia's blessing: a critical examination of the supposed criticism by Samraoui (2017) *Journal of Insect Conservation*, 22 (2), 351–361. https://doi.org/10.1007/s10841-018-0045-0

Khelifa, R., Deacon, C., Mahdjoub, H., Suhling, F., Simaika, J.P. & Samways, M.J. (2021) Dragonfly conservation in the increasingly stressed African Mediterranean-type ecosystems. *Frontiers in Environmental Science*, 9, 660163. https://doi.org/10.3389/fenvs.2021.660163

Leksono, A.S., Feriwibisono, B., Arifianto, T. & Pratama, A.F. (2017) The abundance and diversity of Odonata along an altitudinal gradient in East Java, Indonesia. *Entomological Research*, 47 (4), 248–255. https://doi.org/10.1111/1748-5967.12216

MacKenzie, D.I., Nichols, J.D., Lachman, G.B., Droege, S., Royle, A.A. & Langtimm, C.A. (2002) Estimating site occupancy rates when detection probabilities are less than one. *Ecology*, 83 (8), 2248–2255. https://doi.org/10.1890/0012-9658(2002)083[2248:ESORWD]2.0.CO;2

MacKenzie, D.I. & Royle, A.J. (2005) Designing occupancy studies general advice and allocating survey effort. *Journal of Applied Ecology,* 42, 1105–1114. https://doi.org/10.1111/j.1365-2664.2005.01098.x

MacKenzie, D.I., Nichols, J.D., Royle, J.A., Pollock, K.H., Hines, J.E. & Bailey, L.L. (2006) *Occupancy Estimation and Modeling: Inferring Patterns and Dynamics of Species Occurrence*. Academic Press, USA. 324 p.

MacKenzie, D.I., Nichols, J.D., Royle, J.A., Pollock, K.H., Bailey, L.L. & Hines, J.E. (2017) *Occupancy Estimation and Modeling: Inferring Patterns and Dynamics of Species Occurrence*. 2nd Edition. Academic Press, USA. 648 p. https://doi.org/10.1016/C2012-0-01164-7

Mairif, M., Bendifallah, L. & Doumandji, S. (2023) Diversity of Odonates (Odonata, Anisoptera and Zygoptera) in the Theniet El Had National Park-North West of Algeria. *Journal of Insect Biodiversity and Systematics*, 9 (1), 155–182. https://doi.org/10.52547/jibs.9.1.155

Margules, C.R. & Pressey, R.L. (2000) Systematic conservation planning. *Nature*, 405 (6783), 243–253. https://doi.org/10.1038/35012251

Mourguiart, B., Couturier, T., Braud, Y., Mansons, J., Combrisson, D. & Besnard, A. (2021) Multi-species occupancy models: an effective and flexible framework for studies of insect communities. *Ecological Entomology*, 46 (2), 163–174. https://doi.org/10.1111/een.12991

Nicholson, J.M. & van Manen, F.T. (2009) Using occupancy models to determine mammalian responses to landscape changes. *Integrative Zoology,* 4 (2), 232–239. https://doi.org/10.1111/j.1749-4877.2009.00159.x

Novelo-Gutiérrez, R. & Gómez-Anaya, J.A. (2009) A comparative study of Odonata (Insecta) assemblages along an altitudinal gradient in the Sierra de Coalcomán Mountains, Michoacán, Mexico. *Biodiversity and Conservation,* 18 (3), 679–698. https://doi.org/10.1007/s10531-008-9533-y

Oertli, B., Joye, D.A., Castella, E., Juge, R., Cambin, D. & Lachavanne, J.B. (2002) Does size matter? The relationship between pond area and biodiversity. *Biological Conservation*, 104 (1), 59–70. https://doi.org/10.1016/S0006-3207(01)00154-9

Palacino-Rodríguez, F., da Silva Brito, J., Calvão, L.B., Gonzalez, A.S. & Juen, L. (2020) In Neotropical savannas, altitude affects the diversity of the Anisoptera but not the Zygoptera (Insecta: Odonata). *Marine and Freshwater Research*, 72 (6), 766–773. https://doi.org/10.1071/MF20182

R Core Team (2021) *R: A Language and Environment for Statistical Computing* [Computer software manual]. Vienna, Austria. URL https://www.r-project.org

Richards, C., Haro, R.J., Johnson, L.B. & Host, G.E. (1997) Catchment and reach-scale properties as indicators of macroinvertebrate species traits. *Freshwater Biology*, 37 (1), 219–230. https://doi.org/10.1046/j.1365-2427.1997.d01-540.x

Samraoui, B. (2018) The hand of man or Santa Rosalia's blessing? A rebuttal of the paper "on the restoration of the relict population of a dragonfly *Urothemis edwardsii* Selys (Libellulidae: Odonata) in the Mediterranean". *Journal of Insect Conservation*, 22 (2), 345–350. https://doi.org/10.1007/s10841-017-9966-2

Samraoui, B. & Menaï, R. (1999) A contribution to the study of Algerian odonata. *International Journal of Odonatology*, 2 (2), 145–165. https://doi.org/10.1080/13887890.1999.9748126

Sellam-Bouattoura, N., Attou, F., Arab, A. & Samraoui, B. (2018) Odonata of the Mazafran hydrosystem: Distribution and community structure. *Revue d'Ecologie (La Terre et La Vie)*, 73 (4), 537–549. https://doi.org/10.3406/revec.2018.1956

Shrivastava, S.K., Prakash, A. & Rao, J. (2018) Insect As Bioindicator: an Untapped Treasure. *Journal of Applied Zoological Researches, ,* 29 (2), 128–154.

Stefani-Santos, G., Ávila, W.F., Clemente, M.A., Henriques, N.R., Souza, A.S.B., Vilela, D.S. & Souza, M.M. (2021) Odonata (Insecta) communities along an elevational gradient in the Atlantic forest of southeastern brazil, with the description of the female of heteragrion mantiqueirae Machado. *International Journal of Odonatology*, 24, 178–196. https://doi.org/10.23797/2159-6719_24_14

van Strien, A.J., Termaat, T., Kalkman, V., Prins, M., De Knijf, G., Gourmand, A.L., Houard, X., Nelson, B., Plate, C., Prentice, S., Regan, E., Smallshire, D., Vanappelghem, C. & Vanreusel, W. (2013) Occupancy modelling as a new approach to assess supranational trends using opportunistic data: a pilot study for the damselfly *Calopteryx splendens*. *Biodiversity and Conservation*, 22, 673–686. https://doi.org/10.1007/s10531-013-0436-1

Weisser, W.W. & Siemann, E. (2008) The Various Effects of Insects on Ecosystem Functioning. In: Weisser, W.W., Siemann, E. (eds) *Insects and Ecosystem Function. Ecological Studies,* Springer, Berlin, Heidelberg, pp. 3–24. https://doi.org/10.1007/978-3-540-74004-9_1

Woodward, G. (2001) Dragonflies: Behaviour and Ecology of Odonata. *Freshwater Biology,* 46, 141–143. https://doi.org/10.1111/j.1365-2427.2001.00664.x

Yalles Satha, A. & Samraoui, B. (2017) Environmental factors influencing odonata communities of three Mediterranean rivers: Kebir-east, Seybouse, and Rhumel Wadis, Northeastern Algeria. *Revue d'Ecologie (La Terre et La Vie)*, 72 (3), 314–329. https://doi.org/10.3406/revec.2017.1894

Yang, L.H. & Gratton, C. (2014) Insects as drivers of ecosystem processes. *Current Opinion in Insect Science*, 2, 26–32. https://doi.org/10.1016/j.cois.2014.06.004

ترکیب طیاره‌مانندها در منابع آب ارتفاعات شمال شرقی الجزایر، با نکاتی از الگوهای مبتنی بر ارتفاع: کاربرد مدل‌های سکونت گونه‌ها

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چکیـــده: هدف ما در این تحقیق، ارتقای دانش و اطلاعات در مورد طیاره‌مانندها در أوْرَاس، یک منطقه ناشناخته در شمال شرقی الجزایر می‌باشد. ما از مدل سکونت تک‌گونه‌ای (بسته نرم‌افزاری spOccupancy R) همراه با تکنیک درون‌یابی فضایی (کریگینگ ArcGis) استفاده کردیم تا روابط بین ارتفاع و توزیع گونه‌های طیاره‌مانند را ارزیابی کنیم. در بازه زمانی حدود ۹۰ روزه (ژوئن تا اوت ۲۰۲۱)، مجموعاً ۲۲ گونه از سنجاقک‌ها و آسیابک‌ها (زیرراستهٔ Anisoptera و Zygoptera در ۱۵ بیوتوپ مرطوب نمونه‌برداری شده شامل گونه در معرض خطر *Calopteryx exul* ثبت شدند. مدل‌سازی نشان داد که ۶۲٪ از جمعیت طیاره‌مانندها دارای شانس برابر برای حضور در منطقه مورد مطالعه دارند. احتمال یافت شدن هر یک از گونه‌ها به استثنای گونه‌های در معرض خطر *Calopteryx exul* ($p < 0.05$) و *Crocothemis erythraea* ($p < 0.05$) در هر بررسی برای ۹۰٪ از جمعیت طیاره‌مانندها یکسان بود. همچنین مشخص شد که *Ischnura graellsii* و *I. saharensis* رایج‌ترین گونه‌ها هستند؛ پیش‌بینی می‌شود که آنها در بیش از ۶۰٪ مناطق یافت شوند و پس از آنها *Anax imperator*، *Orthetrum chrysostigma* و *Platycnemis subdilatata* که در حدود ۵۰٪ از بیوتوپ‌های مرطوب نمونه‌برداری شده دیده شدند، قرار می‌گیرند. در نهایت، مدل‌سازی ما هیچ شواهدی برای تأثیر معنی‌دار تغییرات ارتفاع (۵۰۰ تا ۱۹۰۰ متر بالاتر از سطح دریا) بر سکونت و قابلیت تفکیک زیستگاه طیاره‌مانندها، به جز برای *Crocothemis erythraea* و *Sympetrum fonscolombii* را نشان نداد. تخمین کریگینگ نشان می‌دهد که آنها در محدوده ارتفاعی ۴۰۰ متر تا ۱۰۰۰ متر متمرکز هستند.

واژگـان کلیدی: ارتفاع، آسیابک‌ها، سنجاقک‌ها، محلی، کریگینگ، spOccupancy