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Diversity and distribution of backswimmer assemblages in northeastern Algeria (Heteroptera: Nepomorpha)

Meriem Taferghoust[1,2] Farrah Samraoui[1,2], Hayat Boucenna[1,2] Abdellatif Satour[1,2] Wissem Hezil[1,2] Zineb Bouhala[1,2] and Boudjéma Samraoui[1,3]*

[1]*Wetland Conservation Laboratory. University 8 May 1945 Guelma, Algeria*

[2]*Department of Ecology. University 8 May 1945 Guelma, Algeria*

[3]*Department of Biology. University Badji Mokhtar, Annaba. Algeria*

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***Corresponding author:** Boudjéma Samraoui, Laboratoire de Conservation des Zones humides. Université 8 Mai 1945 Guelma and Department of Biology. University Badji Mokhtar, Annaba. Algeria.

Abstract

Predators play a central role in shaping food web structures, and the backswimmers (Notonectidae), active predators of aquatic invertebrates, is a key component of freshwater trophic systems. This study investigates the diversity and distribution of backswimmers in four regions of northeastern Algeria and emphasizes their value as an indicator of ecological integrity and habitat diversity. Five species were identified during the field surveys: Notonecta glauca, N. maculata, N. meridionalis, N. viridis, and Anisops sardeus. The distribution patterns of these species have been mapped, with environmental factors such as longitude, altitude, water depth, substrate, and, to a lesser extent, helophytes influencing these patterns. In addition, the life history and conservation status of backswimmers and their habitats are discussed, with particular emphasis on the impact of global environmental change on freshwater biodiversity in the region.

Keywords: Aquatic bugs, freshwater biodiversity, ecological indicators, species distribution, life history, North Africa

Introduction

Anthropogenic stressors are threatening aquatic ecosystems worldwide thus imperiling freshwater biodiversity [1-3]. Processes driving responses to global changes like overpopulation, pollution, climate change, habitat loss, invasive species, and biodiversity erosion are complex and multi-faceted [4,5]. One of the leading reasons for habitat destruction is human encroachment which is a leading cause of species loss in various parts of the world [6-8]: As cities expand, natural wetlands and rivers are often channeled, drained or diverted to make way for infrastructure development such as real estate et recreational areas [9]. This loss of habitat is exacerbated by agricultural activities that not only reduce available habitat, but also introduce pollutants into freshwater systems via runoff. Pesticides, fertilizers used in agriculture and other chemicals that find their way in wastewater can lead to eutrophication, which reduces oxygen levels in the water and affects aquatic life [10,11].

The over-abstraction of water resources for agricultural and industrial use further worsens the problem with climate change adding to the complexity of these challenges. Rising temperatures and changing precipitation patterns can alter the hydrology of freshwater systems, making them more vulnerable to droughts and floods. These changes can have a profound impact on species that are adapted to certain environmental conditions. In addition, climate change can facilitate the spread of invasive species and increase the frequency and severity of extreme weather events, further stressing freshwater ecosystems. In view of these mounting threats, efforts to mitigate these impacts must focus on sustainable management practices that strike a balance between human needs and biodiversity conservation.

The freshwater ecosystems of North Africa are exposed to significant anthropogenic pressures that threaten their biodiversity and ecological integrity. These pressures include habitat destruction, pollution, overexploitation of water resources, the introduction of invasive species and climate change [12]. Together, these factors have led to the decline of many native species and the degradation of freshwater habitats [13]. Many freshwater systems in North Africa are being depleted faster than they can be replenished, resulting in reduced water availability for both wildlife and humans. This over-abstraction of water can also alter the natural flow of rivers and disrupt the life cycles of many aquatic species. The introduction of invasive species is another major threat to the biodiversity of North African freshwaters. Non-native species can displace and deplete native species or introduce diseases, leading to decline or extinction [14,15]. For example, the introduction of predatory fish species into several North African waters has been shown to have devastating effects on native fish populations and macroinvertebrates [16]. Addressing these challenges requires coordinated efforts to implement sustainable practices and strategies to protect and restore these vital ecosystems.

Aquatic bugs (Heteroptera: Nepomorpha) play a crucial role in freshwater ecosystems, and their sensitivity to water quality has made them valuable indicators for the classification of freshwater lakes [17,18]. In addition to their biomonitoring importance, they also serve as prey for a variety of predators, including fish [19,20] waterfowl [21], and other insects. Especially in fishless ponds, notonectids act as apex predators and exert a strong influence on the structure of the food web of freshwater communities. Aquatic bugs also contribute to the dispersal of cladoceran resting eggs [22]. However, despite their important ecological and economic role [23], research on the distribution and ecology of this group in Algeria has lagged behind that of many other taxa. There are only a few recent studies [24-26], which emphasise the need for further research.

The aims of this study is to: (1) identify the backswimmers (Hemiptera: Notonectidae) assemblages and map their distribution across four distinct regions of north-east Algeria; (2) identify the environmental factors structuring these assemblages.

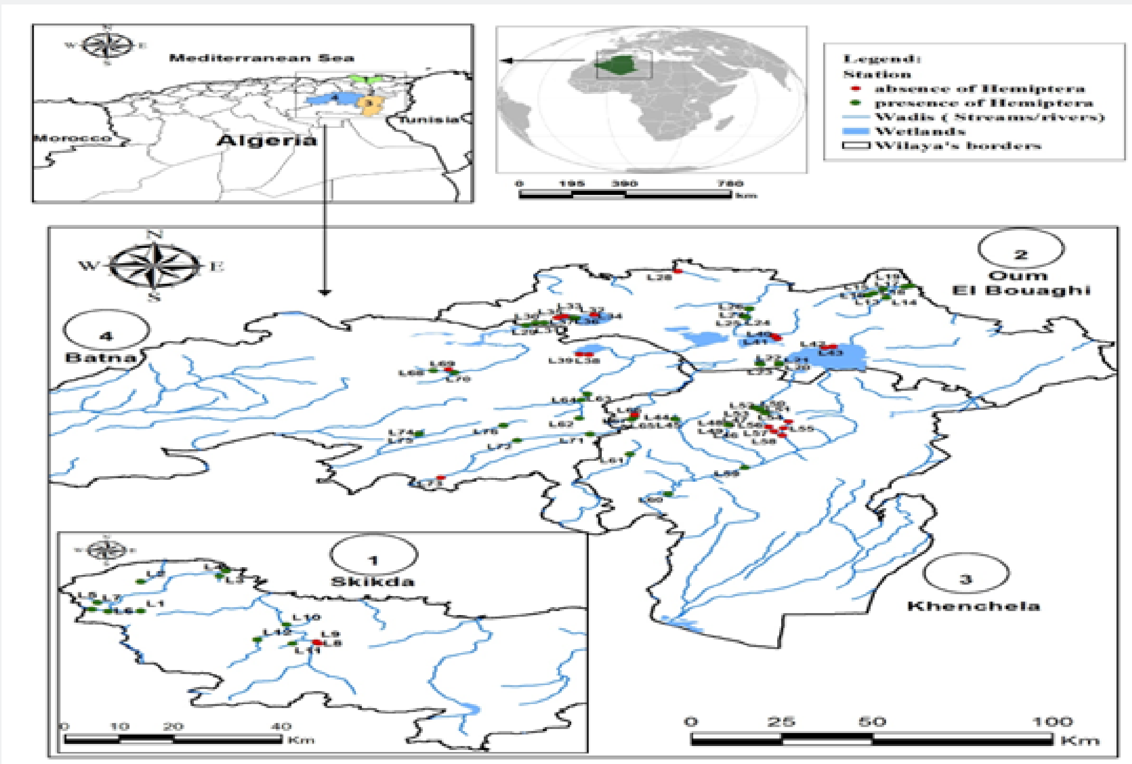

Figure 1: Map of north-eastern Algeria with location of sampling sites.

Materials and methods

Study area

Our study area is located in north-east Algeria and stretches from the coastal strip along the Mediterranean Sea to the Saharan Atlas, which borders the northern Sahara. The area comprises four regions: Batna, Khenchela, Oum El Bouaghi and Collo (Skikda) (Figure 1). These regions represent a large geographical area with a rich diversity of landscapes, topography, climate, flora and fauna. Compared to the rest of Algeria, the study area can be divided into

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two different climatic zones. The Collo region has a Mediterranean climate characterised by hot, dry summers and mild, humid winters. The average annual rainfall is between 800 and 1,400 mm and the average annual temperature is around 20.2 °C [27]. The other three regions are characterised by a semi-arid climate, with an average annual rainfall of 350 mm in Oum El Bouaghi, located in the Hauts Plateaux, and an average annual temperature of 17.51 °C. This area is mainly characterised by temporary salt lakes, locally known as "chotts", "garaas" or "sebkhas" [28]. The average rainfall is 496.8 mm in Khenchela and 563.33 mm in Batna. The altitude ranges from 14 to 1,550 metres and is the lowest in the Collo region.

Sampling methods

For a whole year, we conducted monthly sampling at 76 stations covering the main streams and their tributaries in 20 major river basins throughout the study area (Figure 2). The sampling included five rivers or streams in Collo, nine in Khenchela, four in Batna and two in Oum El Bouaghi. Some of these rivers and streams were intermittent, while others were permanent. The sampling also included lentic habitats, such as the four wetlands in Oum El Bouaghi, two of which were artificially created (Table 1). Despite its high ecological importance, this area has only been covered by a handful of studies [29,30].

Figure 2: Four views of sampled localities (a) O. Kfaoun (L5); (b) O. Dahmen 2 (L16); (c) O. Ibikan 1 (L50); (d) O. Lakhal 2 (L66). The abbreviation "O." stands for Oued (stream or river).

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Table 1: List of the sampled localities in the study area.

Code	Name	Region	Latitude (N)	Longitude (E)	Altitude (m)	Hydroperiod	Land_use
L5	O. Kfayoun	Collo	36°56'16.20"	6°18'7.31"	194	Temporary	Forest
L11	O. Gratam	Collo	36°47'37.41"	6°37'35.95"	108	Temporary	Semi-urban
L12	O. Di El Habal	Collo	36°48'25.29"	6°34'4.60"	73	Temporary	Semi-urban
L13	O. Dhimine	Oum_El_Bouaghi	35°59'49.16"	7°16'46.99"	803.2	Temporary	Agriculture
L14	O. Dahmen_0	Oum_El_Bouaghi	36° 0'31.28"	7°14'1.33"	817.7	Permanent	Agriculture
L15	O. Dahmen_1	Oum_El_Bouaghi	36° 1'13.20"	7°14'55.50"	799.3	Permanent	Agriculture
L16	O. Dahmen_2	Oum_El_Bouaghi	36° 2'26.44"	7°16'23.63"	779	Permanent	Agriculture
L17	O. Dahmen_3	Oum_El_Bouaghi	36° 3'12.09"	7°19'33.95"	754.5	Permanent	Agriculture
L18	O. Dahmen_4	Oum_El_Bouaghi	36° 3'29.21"	7°20'24.68"	746.9	Permanent	Agriculture
L19	Timerganine_1	Oum_El_Bouaghi	35°38'55.15"	6°57'52.84"	836	Temporary	Agriculture
L20	Timerganine_2	Oum_El_Bouaghi	35°38'48.91"	6°57'53.24"	835.3	Temporary	Agriculture
L21	Timerganine_3	Oum_El_Bouaghi	35°38'42.00"	6°57'56.93"	836.1	Temporary	Agriculture
L22	Jemott_1	Oum_El_Bouaghi	35°38'44.04"	7° 0'45.17"	832.7	Temporary	Grazing
L23	Jemott_2	Oum_El_Bouaghi	35°39'3.85"	7° 0'42.63"	829.2	Temporary	Grazing
L24	Ourkis Dam_1	Oum_El_Bouaghi	35°53'48.86"	6°55'38.87"	946.5	Permanent	Grazing
L26	Touzline_1	Oum_El_Bouaghi	35°56'15.37"	6°56'14.47"	994.8	Permanent	Agriculture
L27	Touzline_2	Oum_El_Bouaghi	35°56'18.03"	6°56'19.85"	996.6	Permanent	Agriculture
L29	O. Zerhaib_0	Oum_El_Bouaghi	35°51'3.96"	6°22'56.44"	798.4	Temporary	Agriculture
L37	L.Ezzemoul_1	Oum_El_Bouaghi	35°53'20.43"	6°30'22.24"	791.2	Temporary	Agriculture
L44	O. Lazrag_1	Khenchela	35°21'32.63"	6°45'9.91"	1214	Permanent	Agriculture
L49	O. Noghis_4	Khenchela	35°19'42.17"	6°53'7.75"	1492	Permanent	Forest
L50	O. Ibikan_1	Khenchela	35°23'26.61"	6°58'42.29"	1280	Permanent	Forest
L52	O. Ibikan_3	Khenchela	35°24'43.16"	6°57'51.11"	1071	Permanent	agriculture
L61	O. Assoul	Batna	35°10'28.33"	6°38'26.01"	1310	Temporary	Forest
L63	O. Rbaa_S2	Batna	35°27'28.99"	6°31'7.28"	1040	Permanent	Grazing
L64	O. Rbaa_S3	Batna	35°29'23.58"	6°32'7.62"	1011	Permanent	Semi-urban
L65	O. Lakhal_S1	Batna	35°21'17.70"	6°38'37.20"	1341	Permanent	Agriculture
L67	O. Lakhal_S3	Batna	35°22'50.76"	6°39'1.50"	1246	Temporary	Semi-urban
L69	O. Bouilef_S2	Batna	35°37'7.06"	6°11'11.35"	1068	Temporary	Forest
L70	O. Bouilef_S3	Batna	35°36'8.70"	6°12'12.68"	1000	Temporary	Agriculture
L76	O. Abdi_S1	Batna	35°19'29.42"	6°19'30.81"	1608	Temporary	Agriculture

Sampling of Notonectidae fauna was carried out using a dip net with a diameter of 30 cm and a mesh size of 500 µm. Notonectid larvae and adults were collected using kick sampling kick-sampling in all microhabitats. The collected specimens were preserved in 80% ethanol. Simultaneously, we classified the land use based on the predominant human activities and the substrate, which was categorised as clay, sand or silt depending on the predominant soil structure. We also measured several environmental variables in situ, such as hydrophyte cover (%), flow velocity (using a cork float and stopwatch), water depth, bed width and duration of flow (hydroperiod). The altitude and geographical coordinates of the sampling sites were recorded using a Garmin GPS.

Statistical analysis

An exploratory data analysis was performed to evaluate the dataset and identify possible violations of the underlying assumptions for the statistical methods used [31]. A Kruskal-Wallis test was performed to assess the differences in median species richness between the study regions. Following a significant result, a post-hoc Dunn test with p-value adjustment was performed to allow pairwise comparisons between groups. Principal Component Analysis (PCA) was performed using a matrix of 32 sites by 5 notonectid species. A Hellinger transformation was applied to the relative abundances of the species to standardise the data. Vector

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fitting was performed using the functions envfit and ordisurf to identify environmental factors that correlate significantly with the ordinationAll statistical analyses were performed with the FactoMineR package and the vegan package [32] in R [33].

Results

We have identified five species of notonectids: Notonecta glauca, N. maculata, N. meridionalis, N. viridis, and Anisops sardeus (Table 2). By far the most abundant species was N. maculata, which did not occur in the Collo region. This region harboured the least abundant species, N. glauca and N. meridionalis (Figure. 3a). The sites in the Hauts Plateaux (Oum El Bouaghi) were the most species-rich, with one site (L15) harbouring four species (Figure. 3b). The Kruskal-Wallis test indicated that species richness was significantly different between the study regions (Kruskal-Wallis chi-squared = 20.964, df = 3, p-value = 0.0001).

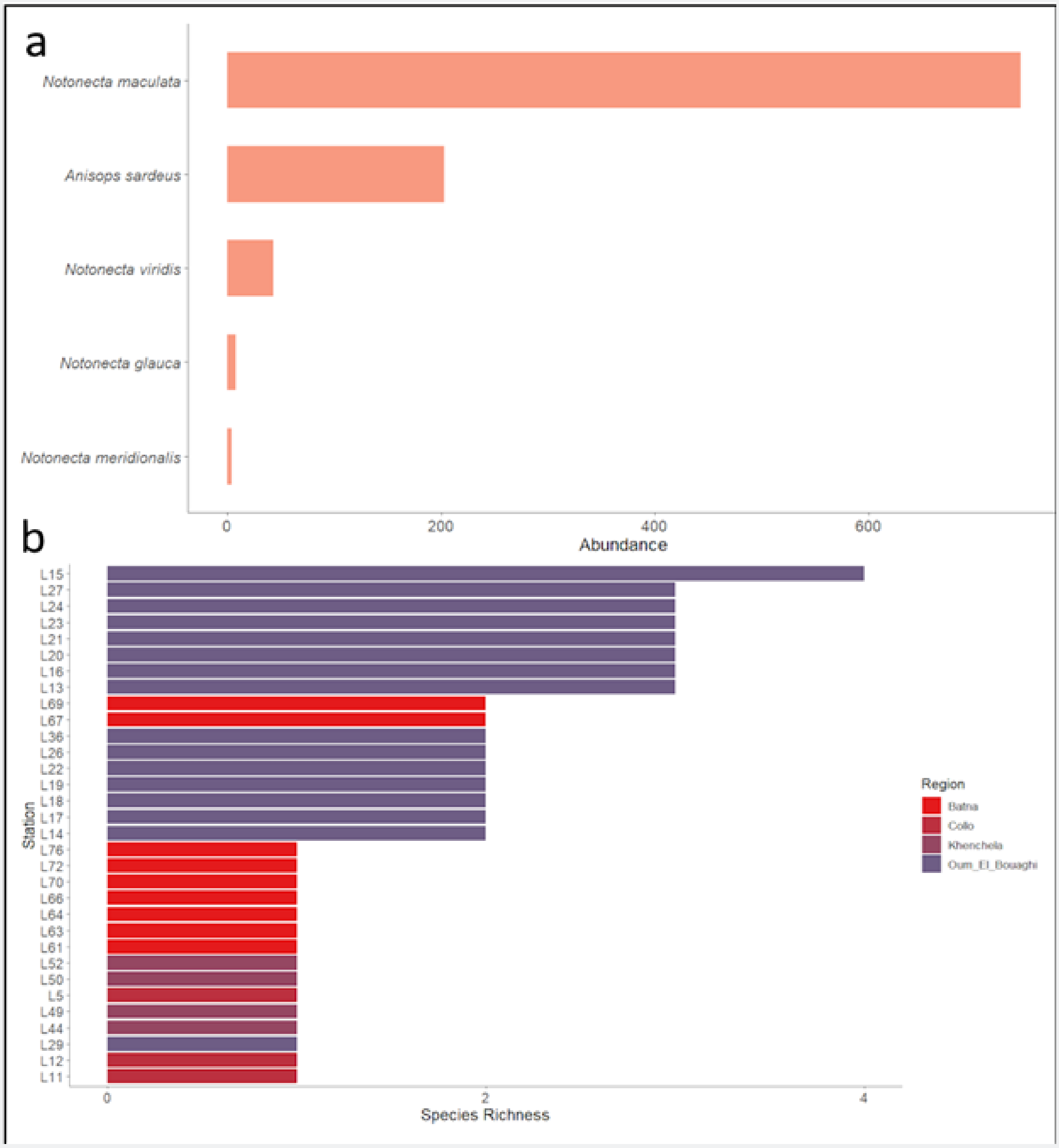

Figure 3: (a) Abundance of notonectids recorded in the study area. (b) Species richness of notonectids/site.

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Table 2: Checklist of the recorded notonectids with their distribution

Species	Sites
Notonecta glauca Linnaeus, 1758	L5, L11, L12
Notonecta maculata Fabricius, 1794	L13-24, L26, L27, L29, L36, L44, L49, L50, L52, L61, L63, L64, L66, L67, L69, L70, L72, L76
Notonecta meridionalis Poisson, 1926	L15, L67, L69
Notonecta viridis Delcourt, 1909	L13-17, L20, L21, L23, L24, L26, L27
Anisops sardeus Herrich-Schäffer, 1849	L13, L15, L16, L18-24, L27, L36

Dunn's test confirmed that Oum El Bouaghi had a significantly higher richness of notonectids compared to Khenchela (p = 0.009), Collo (p = 0.028), and Batna (0.002).

The preliminary analysis of the data revealed strong correlations between altitude and latitude (Y), current velocity and bed width, as well as hydrophytes and helophytes. Due to these highly significant correlations, latitude, bed width, and hydrophytes were excluded from further analysis to avoid redundancy. The first principal component of PCA of the species data, accounting for 28% of the variance, separated the sites in Batna, characterised by N. maculata and N. meridionalis, from the others. The second component (25.5 %) distinguished the sites in Collo (L5, L11 and L12) from those in Oum El Bouaghi (L13 to L27), which were characterised by N. viridis and A. sardeus (Figure. 4a). The notonectid assemblages could be clearly distinguished between the study regions, except in Khenchela (Figure. 4b). In addition, the lotic (L14–L16) and lentic (L19–L27) habitats in Oum El Bouaghi were also separable.

Figure 4: (a) Biplot of PCA ordination of notonectid assemblages in the study area. (b) Distribution of regions in the first two components.

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Before modelling, we calculated the VIF values (variance inflation factor) for the environmental variables. All values were below 10, indicating that there was no significant multicollinearity. Vector fitting of the measured environmental variables with the envfit function revealed that four variables—substrate (R^2 = 0.27, p = 0.008), altitude (R^2 = 0.69, p = 0.001), water depth (R^2 = 0.58, p = 0.001), and longitude (R^2 = 0.60, p = 0.001)—were significantly correlated with the ordination of the notonectids (Figure. 5). Helophytes (R^2 = 0.24, p = 0.062) showed only a marginal influence. Furthermore, the ordisurf function was used to test for non-linearity effect, but neither flow velocity (F = 0.22, p = 0.15) nor helophytes (F = 0.48, p = 0.06) had a statistically significant effect at the 5% threshold.

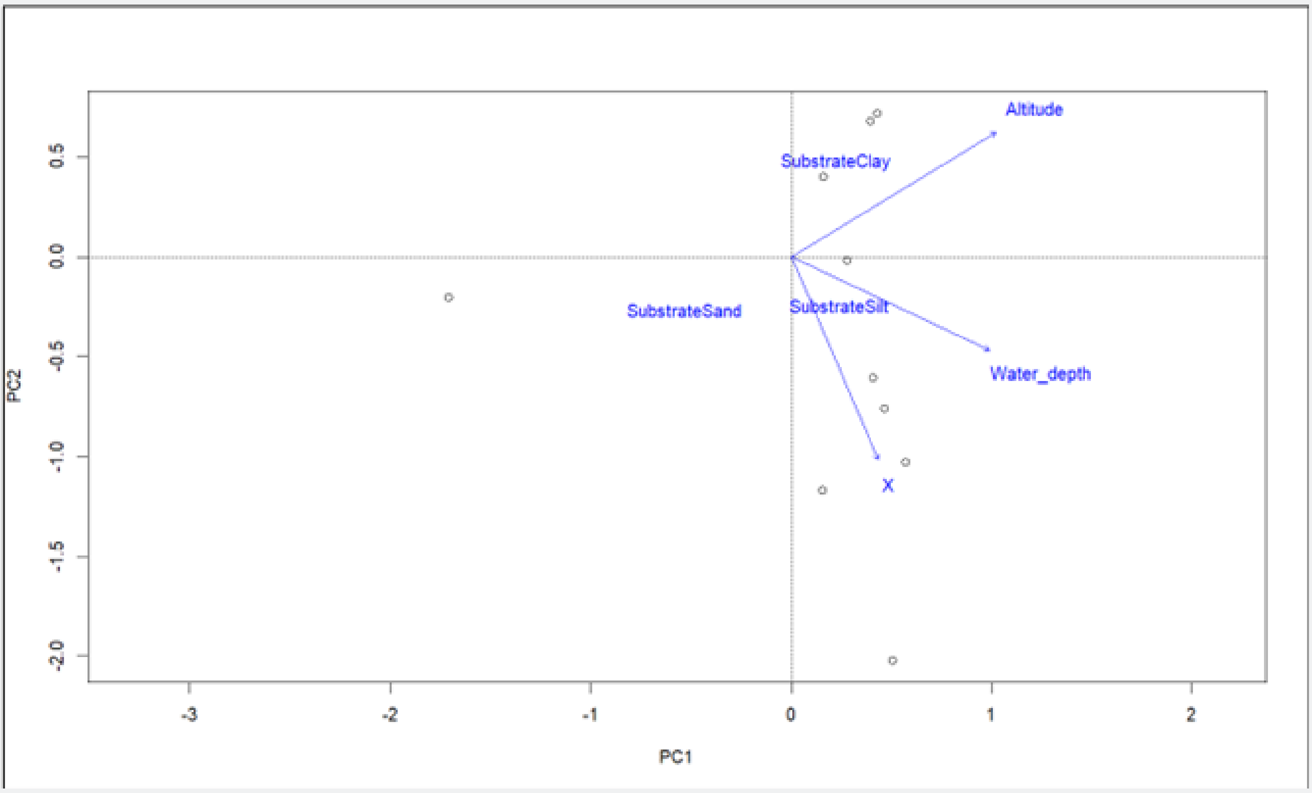

Figure 5: Relationship between notonectid assemblages and environmental variables: substrate; longitude (X), altitude, and water depth.

Discussion

Distribution and abundance of backswimmers

The distribution of the five recorded notonectid species varies geographically, with Notonecta maculata and N. glauca occupying distinct ranges. Notonecta maculata is found in the Hauts Plateaux and the Saharan Atlas, and its abundance reflects the preponderance of sites from those regions. In contrast, N. glauca inhabits the coastal regions and is absent from the semi-arid regions. Although N. meridionalis was not observed in the Collo region during this study, it is noteworthy that the species is abundant and widespread in the coastal wetlands of northeastern Algeria N. meridionalis is syntopic with N. glauca and occupies temporary ponds, residual pools, marshes, and residual pools within intermittent streams. Similarly, N. viridis and A. sardeus are found in coastal wetlands, and their absence in the Collo region is likely due to the lack of lentic habitats sampled in Collo. It is important to note, however, that N. viridis is significantly less common in the northern region compared to N. glauca and N. meridionalis. These findings align with previous research, which indicate a lack of geographical overlap in the ranges of aquatic Hemiptera, with N. maculata confined to the Hauts Plateaux, while species such as Hydrocyrius columbiae, Ranatra linearis, Hesperocorixa

linnaei, and Micronecta scholtzi are restricted to the northern littoral.

Environmental factors driving backswimmer assembles

The presence of three or four species of notonectids raises the question of how these species can coexist. An issue raised by [34] when contemplating the coexistence of three species of Corixa in a small artificial pond in Monte Pelligrino, Sicily. Although the trophic position of most notonectids and corixids is poorly sketched [35], notonectids are known as active predators of zooplankton and other aquatic organisms [36]. They may achieve niche partitioning through differences in body size, which probably affect prey size

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[37], and through the selective utilization of microhabitats, such as varying water depths and vegetation densities [38].

Four environmental factors were found to influence notonectid assemblages in the study region: Longitude, altitude, water depth, and substrate. Longitude may simply reflect sampling bias in the Oum El Bouaghi region, which is rich in lentic habitats, many of which are salt lakes. Altitude, an important factor influencing other environmental conditions such as climate and land use, is difficult to separate from latitude in our study. It may be surprising that we found that helophytes play only a minor role in structuring notonectid assemblages, although aquatic vegetation is known to play a key role in notonectid ecology [39]. For example, N. glauca is associated with both helophytes and hydrophytes [40]. In contrast, the effect of water depth is not surprising, as deeper ponds and rivers can provide larger areas of open water, a niche favoured by some notonectids [41]. Substrate is another key factor, and our finding that N. maculata and N. meridionalis occupy clay is consistent with results showing that N. maculata favours small habitats with clay substrate [42]

Life history of backswimmers

In response to fluctuating environmental conditions, especially drought, many aquatic species have developed survival strategies [43]. Life-history adaptations include changes in behaviour such as rheotaxis [44] or in trade-off between growth and development when organisms face habitat dessication (De Block & Stoks, 2005). In addition, many aquatic insects exhibit life histories that allow them as adults to survive the hot and dry Mediterranean summer by undergoing prolonged maturation over several months, typically in high-altitude refuges [45], in cooler, low-altitude habitats such as alder forests [46,47], or in artificial reservoirs that can provide suitable refuges during droughts [48]. These insects typically follow a univoltine life cycle in which they reproduce at low altitudes in autumn and emerge in spring. They then migrate to summer refuges, where they aestivate. When it rains again in autumn, they go back to their breeding grounds to restart a new life cycle.

This life history, which is adopted by numerous Odonata species such as Lestes barbarus, Chalcolestes viridis, Aeshna mixta, Sympetrum meridionale, and Sympetrum striolatum, is particularly well suited to temporary wetlands. The caddisfly Mesophylax asperus, which breeds in intermittent streams, also seeks refuge in caves as adults when the streams dry up [49]. A similar life history has also been observed in Notonecta lactitans in South Africa [50] and in Notonecta glauca and Notonecta meridionalis in Algeria. These species inhabit two types of habitats: they breed during winter in temporary lentic habitats and aestivate as adults in residual stream pools at high altitudes. A distinct strategy is adopted by N. maculata which was found to occur in permanent ponds where it achieves a bivoltine life cycle [51]. Environmental gradients such as hydrological stress can place differential ecological pressure on aquatic organisms triggering divergent evolutionary responses across a species' range [52-54].

Backswimmer conservation

Temporary ponds, intermittent streams, and rivers are distinctive features of the North African landscape. However, conservation efforts in Algeria have mainly focused on protecting the few permanent freshwater lakes and salt lakes that serve as important habitats for wintering and breeding waterbirds [55]. This narrow focus needs to be broadened to take a more holistic approach to freshwater biodiversity conservation. For example, the region's mountain streams harbour numerous endemic species, many of which are threatened with extinction due to various human-induced impacts such as habitat encroachment, climate change, and the introduction of alien fish such as Gambusia holbrooki [56].

Northeast Algeria in particular is a biodiversity hotspot that is at risk of rapid decline if immediate and proactive measures are not taken. This should include the establishment of Red Lists, continuous monitoring, and strict enforcement of environmental regulations [57]. To prevent further erosion of freshwater biodiversity, which could disrupt ecosystem functioning and lead to the loss of vital ecosystem services, active management strategies need to be adopted. These should emphasize more efficient water use, habitat restoration, pollution control, and the monitoring and management of invasive species. In addition, the integration of climate change adaptation into freshwater management plans is essential to ensuring the resilience and sustainability of these vulnerable ecosystems.

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