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Updated checklist of mayflies from northeastern Algeria with biogeographical and ecological insights (Insecta, Ephemeroptera)

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Abstract

Mayflies (Ephemeroptera) play a crucial role in nutrient cycling and energy transfer between ecotones, making them key indicators of freshwater ecosystem health. As part of a broader study conducted between 2018 and 2022, a survey of rivers and streams across four regions in northeastern Algeria recorded 15 mayfly species, contributing to an updated regional checklist and mapping the distribution of 36 species. Notably, ten species were putatively new to science, with nine awaiting formal description. The survey also documented two rarely recorded burrowing mayfly species and one interstitial species in North Africa, whose mass emergences serve as valuable bioindicators of riverine ecological integrity. Their close association with sediment or hyporheic zones, combined with a high sensitivity to environmental stressors, makes them effective for cost-efficient, rapid assessments of contaminants in fluvial systems. This study advances knowledge of mayfly taxonomy, biogeography, and ecology in the region while providing essential data for freshwater conservation efforts.

Key Words

Aquatic insects, biodiversity, bioindicators, burrowing mayflies, freshwater conservation, Maghreb, North Africa, species distribution

Introduction

Freshwater ecosystems provide a diverse array of essential services, including drinking water supply, food resources, water purification, and flood regulation, all of which are crucial to human well-being (Dudgeon et al. 2006; Lynch et al. 2023). Beyond their ecological functions, these ecosystems hold significant cultural, educational, and scientific value (Albert et al. 2021; Pascual et al. 2024). They also support an extraordinary level of biodiversity, harbouring approximately 10% of all known animal species, including one-third of all vertebrates, making them globally recognised biodiversity hotspots (Balian et al. 2008; Strayer and Dudgeon 2010).

However, freshwater ecosystems are experiencing unprecedented declines due to multiple anthropogenic stressors, including land-use changes, flow modification, pollution, invasive species, climate change, and overexploitation (Malmquist and Rundle 2002; Geist 2011; Hafiane et al. 2016). The rapid degradation of freshwater habitats, coupled with alarming declines in both plants, invertebrate and vertebrate populations, places these ecosystems among the most threatened worldwide (Tickner et al. 2020). This crisis underscores the urgent need for sustainable management and conservation strategies to mitigate further biodiversity loss (Boulton et al. 2016).

Among the most affected organisms are freshwater insects, which play a key role in these ecosystems in terms of both abundance and diversity (Vilenica et al. 2022). A growing body of research has documented a global decline in aquatic insect populations, mirroring broader insect biodiversity losses (Hallmann et al. 2017; Leather 2018; Simmons et al. 2019; Møller 2020; Roth et al. 2020). Within this group, mayflies (Ephemeroptera) are particularly important, providing a wide range of ecosystem services and serving as critical indicators of freshwater ecosystem health (Macadam and Stockan 2015; Sartori and Brittain 2015; Jacobus et al. 2019). As an integral part of aquatic and terrestrial food webs, they serve as essential prey for predatory aquatic insects, fish, and insectivorous birds (Ormerod et al. 1987; Twining et al. 2018). Understanding the factors driving their decline is therefore crucial for the broader conservation of freshwater biodiversity.

Of the 42 recognised families, seven (Ephemeridae, Euthyplociidae, Ichthybotidae, Polymitarcyidae, Palingeniidae, Potamanthidae, and Behningiidae) are collectively known as burrowing mayflies (Ogden et al. 2009). Recent phylogenomic research suggests that Potamanthidae is a sister clade to all other burrowing families (Miller et al. 2018). With the exception of Behningiidae, burrowing mayflies are uniquely characterised by the presence of mandibular processes or tusks (McCafferty 2004).

Burrowing mayflies play a crucial role in fluvial processes, particularly nutrient cycling. They are well known for their synchronised, seasonal mass emergences (Walters et al. 2018), which, despite often being considered a nuisance due to their sheer abundance, signify functional and productive hydrosystems. These emergences contribute significantly to the transfer of nutrients and biomass across ecotones, influencing both aquatic and terrestrial ecosystems (Stepanian et al. 2020). Burrowing mayflies also include species that are particularly sensitive to pesticides, as they are exposed to contaminants through direct contact with dissolved pollutants in water and the accumulation of toxins stored in sediments. Consequently, monitoring their populations provides valuable insights into the health and stability of freshwater ecosystems, while they serve as effective bioindicators of contamination levels in fluvial systems (Winter et al. 2003).

Burrowing mayflies have undergone significant population declines in recent decades due to various environmental stressors (Stepanian et al. 2020; Schloesser et al. 2014). In Midwestern waterways of the United States, increased eutrophication from agricultural runoff, coupled with chronic hypoxia, has led to the disappearance of *Hexagenia* species, triggering cascading effects on aerial insectivores (Bartlett et al. 2018; Everall et al. 2018; Spiller and Dettmers 2019). While conservation efforts have supported partial recovery (Schloesser et al. 2000), and recolonization has been observed following catastrophic events (Britt 1955), recent studies reveal fluctuating population trends, highlighting the species' ongoing vulnerability.

In Algeria, aquatic insect populations, including mayflies, are undergoing a steep decline, with noticeable shifts in freshwater community structures (Benslimane et al. 2019; Morghad et al. 2019). Unfortunately, regional data on mayflies remain scarce, making it difficult to assess long-term trends. Thomas' seminal checklist (1998) laid the foundation for numerous mayfly studies in Algeria in the 21st century (Benhadji et al. 2018, 2019, 2020; Samraoui et al. 2021a, 2021b; Labdaoui et al. 2024). Advances in taxonomy have since led to the discovery and formal description of previously undescribed species, such as *Habrophlebia djurdjurensis* Kechemir, Sartori & Lounaci, 2020. Additionally, recent research has expanded the known mayfly fauna of Algeria, with new records including *Rhithrogena sartorii* Zrelli & Boumaiza, 2011 (Samraoui et al. 2021b). Beyond species identification, these studies have improved our understanding of species distributions and life cycles, providing valuable ecological insights that can inform freshwater management and biodiversity conservation strategies (Bouhala et al. 2020a, 2020b).

Advances in the study of Ephemeroptera in Morocco and Tunisia have, to some extent, paralleled those in Algeria, with early pioneering work culminating in the seminal checklist by Thomas (1998), which has since been refined and expanded by more recent studies (Zrelli et al. 2011, 2016; El Alami et al. 2022, 2023; Benlasri et al. 2023). Despite notable advances in the taxonomy, ecology, and conservation of Algerian mayflies, research on this order remains relatively limited. This gap is particularly concerning given the widespread decline in water quality across Algerian rivers (Abdennour et al. 2000; Belabed et al. 2017; Samraoui et al. 2024b) and the critical role of burrowing mayflies as bioindicators of water and sediment pollution. Addressing this knowledge deficit and building on recent taxonomic advancements, this study aims to: (1) investigate the phenology, abundance, and distribution of mayflies, including rare burrowing species, in northeastern Algeria; (2) update the regional checklist of mayfly species in this ecologically significant Maghrebian region; and (3) identify key conservation habitats, assess major threats, and propose measures to support mayfly populations and safeguard freshwater ecosystems.

Materials and methods

Study area

This study was conducted in four geographically and climatically diverse regions in northeastern Algeria, encompassing major watersheds along the Aurès

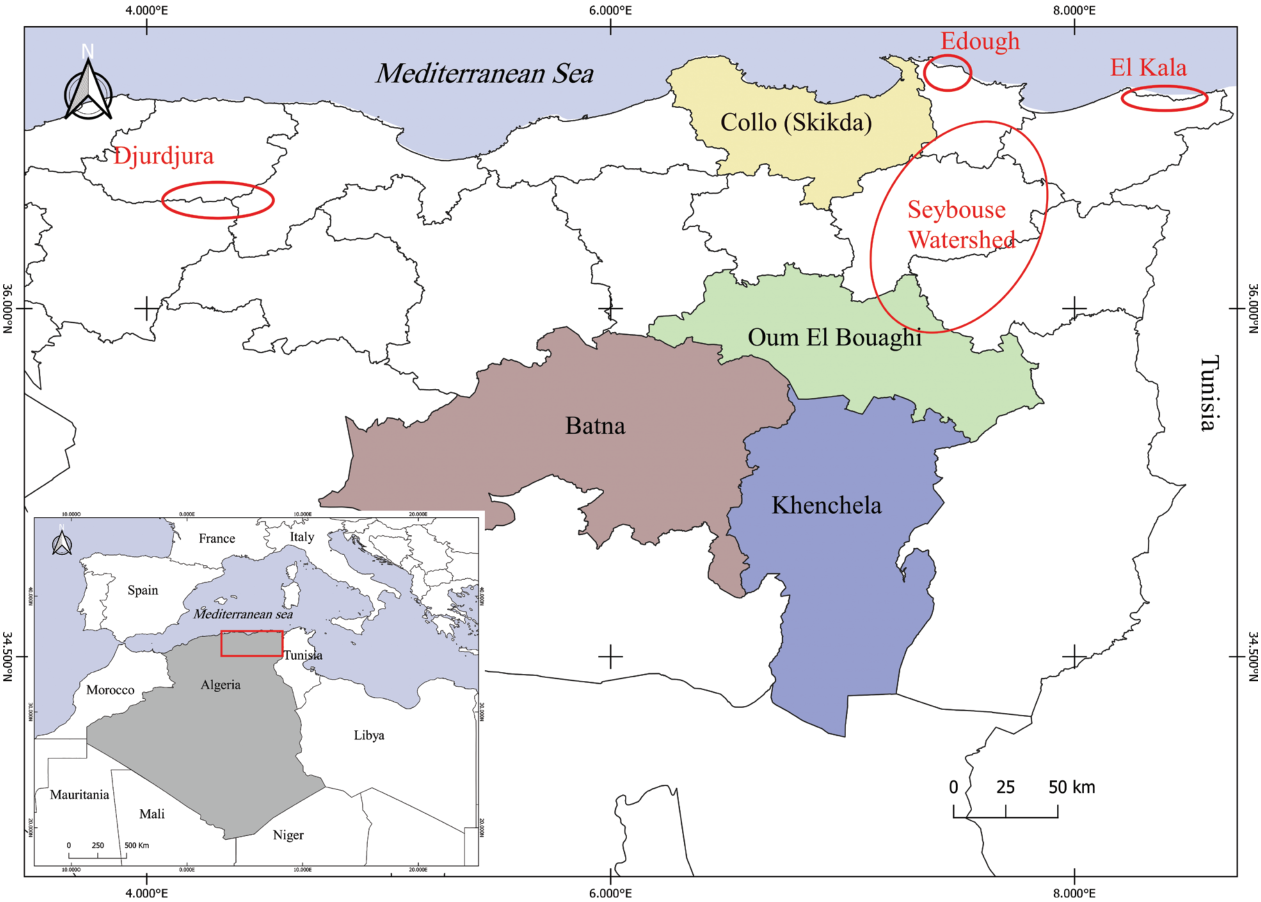

Figure 1. Map of north-eastern Algeria showing the location of the study area (coloured regions). Red ellipses highlight additional sampled regions outside the study area, as listed in Table 2.

Massif and the Collo region. These four regions encompass a broad environmental gradient, ranging from the humid coastal environment of Collo (Skikda) to the semi-arid landscapes of Oum El Bouaghi, Batna, and Khenchela (Fig. 1). The coastal climate is typically Mediterranean, with a rainy season extending from November to April and a dry season from May to October. Rainfall decreases along a north-south gradient, from approximately 800 mm/year in the northern areas to 350 mm/year in the southern regions, reflecting increasing aridity. However, this gradient is further modulated by altitude, creating diverse ecological conditions that offer a valuable framework for assessing mayfly diversity across northeastern Algeria.

Batna is part of the western Aurès Massif, which belongs to the Saharan Atlas. This mountainous region is bordered by the Constantine Hauts Plateaux to the north and the Saharan depression to the south. Elevations in the Aurès Mountains vary significantly, ranging from 87 m at the oasis of Biskra to 2,136 m at Belezma. The region experiences a diverse climate: winters on the northern slopes are cold, with temperatures dropping below 4 °C, while the southern areas have milder winters, averaging 13 °C. Summers are typically hot and dry, with temperatures ranging from 30 °C to 39 °C.

The Khenchela region, located at the northernmost tip of the eastern Aurès Massif, lies approximately 120 km southeast of Constantine. It features highly variable elevations, ranging from 40 m below sea level at Chott Melghir to 2,328 m at Djebel Chelia.

Oum El Bouaghi, a wetland complex in the eastern Hauts Plateaux (35.26°–36.11°N, 6.9°–7.5°E), serves as a natural transition zone between the Mediterranean and the Sahara. Bordered by the Guelma Mountains to the north and the Aurès range to the south, the region comprises diverse landscapes, including mountains, valleys, and plateaux. It has a semi-arid climate, with an average annual temperature of 17.5 °C and less than 350 mm of precipitation. The steppe vegetation is interspersed with temporary salt lakes, known as chotts, garaas, or sebkhas.

The Collo region, a coastal area 71 km northeast of Skikda (36.61°–37.06°N, 6.28°–6.73°E), is part of the Tell Atlas, which extends from northwestern Tunisia to northeastern Morocco. The region experiences a Mediterranean climate, characterized by hot, dry summers and cool, rainy winters. Annual temperatures range from 2.9 °C to 6.6 °C (minimum) and 25 °C to 28 °C (maximum), with average annual precipitation between 800 and 1,400 mm.

The updated checklist of Ephemeroptera in northeast Algeria was compiled based on this study, along with sampling conducted between 2018 and 2022 at the Seybouse River (Samraoui et al. 2021a), El Kala (Samraoui et al. 2021b), Djurdjura (Labdaoui et al. 2024), and the Edough Mountains (B.S. unpublished) (Fig. 2).

Sampling

Mayflies were sampled monthly from June 2019 to May 2022 across 75 sites distributed among the four hydrological regions (Table 1). At each site, specimens were collected using a dip net (30 cm diameter, 500 µm mesh) to ensure comprehensive sampling across different microhabitats. The collected specimens were preserved in 80% ethanol, and transported to the laboratory for sorting, identification, and classification. Larval identification was carried out using various taxonomic keys and descriptions (Müller-Liebenau 1969; Bauernfeind and Soldán 2012; Gattolliat et al. 2023).

In situ measurements were taken to assess key habitat parameters, including water depth, bed width, and current velocity. Additional data collected at each site included GPS coordinates, altitude, land use, substrate composition, percentage cover of helophytes and hydrophytes, and hydroperiod characteristics.

Results

Fifteen mayfly species were recorded across the four study regions (Table 2), contributing to a total of 36 species documented in northeastern Algeria between 2018 and 2022(Table 3). Among these, ten species were new to science, awaiting formal description. The newly discovered species included seven putative new *Habrophlebia* species, one baetid species (*Procloeon* sp. A), and two heptageniid species: *Ecdyonurus* sp. Co and *Rhithrogena* sp. EK. The list also includes a recently described baetid *Centroptilum samraouii* Kaltenbach, Vuataz & Gattolliat, 2022.

In addition, two species of burrowing mayflies were identified: *Ephemera glaucops* Pictet, 1845 (family Ephemeridae) and *Ephoron virgo* (Olivier, 1791) (family Polymitarcyidae). These two species are adapted to soft substrates, where their larvae excavate burrows in sediment. Alongside these, an interstitial mayfly species, *Potamanthus luteus* (Linné, 1758) (family Potamanthidae), was also recorded. In contrast to the burrowing mayflies, this species does not burrow but inhabits interstitial spaces using the gaps between sand or sediment particles for shelter and foraging (Bae and McCafferty 1991).

The following section provides an overview of the known distribution and phenology of burrowing and interstitial mayflies in Algeria:

Figure 2. Three views of sampled localities. **a.** Oued Arab, Khenchela (L60); **b.** Oued Dahman, Oum El Bouaghi (L16); **c.** O. Agab, Edough Mountain.

Table 1. Sampling localities in Collo, Oum El Bouaghi, Khenchela, and Batna, northeast Algeria.

Code	Name	Region	Coordinates	Altitude (m)	Code	Name	Region	Coordinates	Altitude (m)
L1	O. Beni Zid	Collo	36°54'25.88"N, 6°28'32.30"E	79	L42	Tarf_1	Oum El Bouaghi	35°44'19.17"N, 7°8'46.06"E	829
L2	O. Tizagbane	Collo	37°0'39.41"N, 6°22'29.57"E	492	L43	Tarf_2	Oum El Bouaghi	35°44'0.89"N, 7°7'33.32"E	829
L3	O. Tamanart_S1	Collo	37°1'49.90"N, 6°30'19.58"E	47	L44	O. Lazrag_1	Khenchela	35°21'32.63"N, 6°45'9.91"E	1214
L4	O. Tamanart_S2	Collo	37°2'56.04"N, 6°30'52.95"E	14	L45	O. Lazrag_2	Khenchela	35°21'28.59"N, 6°45'13.15"E	1201
L5	O. Kfayoun	Collo	36°56'16.20"N, 6°18'7.31"E	194	L46	O. Noghis_1	Khenchela	35°19'38.07"N, 6°53'18.18"E	1551
L6	O. Zhor_S1	Collo	36°54'25.32"N, 6°19'10.68"E	28	L47	O. Noghis_2	Khenchela	35°19'36.87"N, 6°53'15.87"E	1546
L7	O. Zhor_S2	Collo	36°54'51.34"N, 6°17'29.29"E	18	L48	O. Noghis_3	Khenchela	35°19'39.25"N, 6°53'12.76"E	1529
L8	O. El Meraya	Collo	36°47'36.87"N, 6°40'8.27"E	58	L49	O. Noghis_4	Khenchela	35°19'42.17"N, 6°53'7.75"E	1492
L9	O. Guebli_S1	Collo	36°48'2.88"N, 6°39'54.49"E	61	L50	O. Ibikan_1	Khenchela	35°23'26.61"N, 6°58'42.29"E	1280
L10	O. Guebli_S2	Collo	36°51'36.26"N, 6°36'54.46"E	31	L51	O. Ibikan_2	Khenchela	35°24'20.40"N, 6°57'58.38"E	1110
L11	O. Gratam	Collo	36°47'37.41"N, 6°37'35.95"E	108	L52	O. Ibikan_3	Khenchela	35°24'43.16"N, 6°57'51.11"E	1071
L12	O. Di El Habal	Collo	36°48'25.29"N, 6°34'4.60"E	73	L53	O. Ibikan_4	Khenchela	35°25'6.57"N, 6°57'0.97"E	1038
L13	O. Dhimine	Oum El Bouaghi	35°59'49.16"N, 7°16'46.99"E	803	L54	O. Djemri_1	Khenchela	35°20'42.13"N, 7°2'4.16"E	1248
L14	O. Dahmen_0	Oum El Bouaghi	36°0'31.28"N, 7°14'1.33"E	818	L55	O. Djemri_2	Khenchela	35°18'39.97"N, 7°1'20.49"E	1176
L15	O. Dahmen_1	Oum El Bouaghi	36°1'13.20"N, 7°14'55.50"E	799	L57	O. Chindgouma_2	Khenchela	35°17'36.67"N, 6°59'54.47"E	1145
L16	O. Dahmen_2	Oum El Bouaghi	36°2'26.44"N, 7°16'23.63"E	779	L58	Confluence	Khenchela	35°16'22.30"N, 7°1'10.42	1080
L17	O. Dahmen_3	Oum El Bouaghi	36°3'12.09"N, 7°19'33.95"E	755	L59	O. Arab_S1	Khenchela	35°6'12.38"N, 6°55'39.03"E	835
L18	O. Dahmen_4	Oum El Bouaghi	36°3'29.21"N, 7°20'24.68"E	747	L60	O. Arab_S2	Khenchela	34°57'57.16"N, 6°44'13.00"E	480
L19	Timerganine_1	Oum El Bouaghi	35°38'55.15"N, 6°57'52.84"E	836	L61	O. Assoul	Batna	35°10'28.33"N, 6°38'26.01"E	1310
L20	Timerganine_2	Oum El Bouaghi	35°38'48.91"N, 6°57'53.24"E	835	L62	O. Rbaa_S1	Batna	35°21'46.91"N, 6°30'52.78"E	1449
L21	Timerganine_3	Oum El Bouaghi	35°38'42.00"N, 6°57'56.93"E	836	L63	O. Rbaa_S2	Batna	35°27'28.99"N, 6°31'7.28"E	1040
L22	Jemott_1	Oum El Bouaghi	35°38'44.04"N, 7°0'45.17"E	833	L64	O. Rbaa_S3	Batna	35°29'23.58"N, 6°32'7.62"E	1011
L23	Jemott_2	Oum El Bouaghi	35°39'3.85"N, 7°0'42.63"E	829	L65	O. Lakhal_S1	Batna	35°21'17.70"N, 6°38'37.20"E	1341
L24	Ourkis Dam_1	Oum El Bouaghi	35°53'48.86"N, 6°55'38.87"E	947	L66	O. Lakhal_S2	Batna	35°22'7.22"N, 6°39'3.04"E	1303
L25	Ourkis Dam_2	Oum El Bouaghi	35°53'34.80"N, 6°55'48.24"E	947	L67	O. Lakhal_S3	Batna	35°22'50.76"N, 6°39'1.50"E	1246
L26	Touzline_1	Oum El Bouaghi	35°56'15.37"N, 6°56'14.47"E	995	L68	O. Bouilef_S1	Batna	35°36'44.15"N, 6°9'1.97"E	1033
L27	Touzline_2	Oum El Bouaghi	35°56'18.03"N, 6°56'19.85"E	997	L69	O. Bouilef_S2	Batna	35°37'7.06"N, 6°11'11.35"E	1068
L28	O. Sigus	Oum El Bouaghi	36°9'0.08"N, 6°44'1.13"E	720	L70	O. Bouilef_S3	Batna	35°36'8.70"N, 6°12'12.68"E	1000
L30	O. Zerhaib_1	Oum El Bouaghi	35°51'53.83"N, 6°24'22.55"E	798	L71	O. Labiod_S1	Batna	35°16'43.25"N, 6°32'28.47"E	1259
L32	Tinsilt_1	Oum El Bouaghi	35°53'27.96"N, 6°29'56.55"E	787	L72	O. Labiod_S2	Batna	35°14'42.79"N, 6°21'38.26"E	610
L33	Tinsilt_2	Oum El Bouaghi	35°53'57.23"N, 6°28'36.68"E	787	L73	O. Labiod_S3	Batna	35°3'2.38"N, 6°10'6.61"E	1226
L34	Tinsilt_3	Oum El Bouaghi	35°53'28.38"N, 6°27'31.48"E	799	L74	O. Bouzina_S1	Batna	35°16'53.12"N, 6°6'56.45"E	1318
L35	Ezzemoul_0	Oum El Bouaghi	35°53'18.41"N, 6°30'20.86"E	791	L75	O. Bouzina_S2	Batna	35°16'44.54"N, 6°6'50.21"E	1299
L37	Ezzemoul_1	Oum El Bouaghi	35°53'20.43"N, 6°30'22.24"E	791					

Table 2. Checklist of Ephemeroptera recorded during this study in Collo, Oum El Bouaghi, Khenchela, and Batna, northeast Algeria.

Family and Species	Distribution
Leptophlebiidae	
***Habrophlebia* sp. 12**	L8, L12 (Collo)
***Choroterpes atlas* Soldán & Thomas, 1983**	L3 (Collo), L59, L60 (Khenchela), L69-70 (Batna)
Potamanthidae	
***Potamanthus luteus* (Linné, 1758)**	L3-4 (Collo)
Ephemeridae	
***Ephemera glaucops* Pictet, 1845**	L59 (Khenchela)
Caenidae	
***Caenis luctuosa* (Burmeister, 1839)**	L2-4, L6-7, L8-12 (Collo), L13-15, L18-21, L24-25, L42-43 (Oum El Bouaghi), L44-45, L51, L53, L59-60 (Khenchela), L62-64, L66-70, L3 (Batna)
Baetidae	
***Baetis atlanticus* Soldán & Godunko, 2006**	L2-4, L6-8, L12 (Collo), L44-49, L50-54, L57 (Khenchela), L61-67, L69, L71, L74-75 (Batna)
***Baetis pavidus* Grandi, 1949**	L3-4, L6-7, L9 (Collo), L14-18 (Oum El Bouaghi), L44-45, L53, L59-60 (Khenchela), L62-64, L66-73 (Batna)
Baetis* gr. *alpinus	L2-3, L6, L8, L10, L12 (Collo)
***Baetis dihyae* Benhadji, Dambri & Godunko, 2023**	L44, L47, L49, L51, L54 (Khenchela), L65, L71 (Batna)
***Acentrella sinaica* (Bogoescu, 1931)**	L28 (Oum El Bouaghi), L62-64, L66-69, L72-73 (Batna)
Cloeon* gr. *dipterum	L8 (Collo), L14-18, L20-21, L24-25, L27, L30, L33, L37, L42-43 (Oum El Bouaghi), L60 (Khenchela), L61, L63-65, L67-68 (Batna)
Heptageniidae	
***Ecdyonurus rothschildi* Navás, 1929**	L14 (Oum El Bouaghi)
***Ecdyonurus* sp. Co**	L2, L6-7 (Collo)
***Ecdyonurus aurasius* Dambri, Benhadji & Sartori, 2022**	L44-46, L50-54, L57, L59-60 (Khenchela), L62, L64-68, L70-71, L73, L75 (Batna)
***Rhithrogena* sp. EK**	L2 (Collo)

Table 3. Updated checklist of Ephemeroptera recorded between 2018 and 2022 in northeast Algeria. O.E.B. stands for Oum El Bouaghi.

	Family and Species	Distribution
Leptophlebiidae		
1	***Habrophlebia djurdjurensis* Kechemir, Sartori & Lounaci, 2020**	Djurdjura
2	***Habrophlebia* sp. 7**	El Kala
3	***Habrophlebia* sp. 8**	Djurdjura
4	***Habrophlebia* sp. 9**	Edough
5	***Habrophlebia* sp. 11**	El Kala
6	***Habrophlebia* sp. 12**	Seybouse River; Collo
7	***Habrophlebia* sp. 13**	Djurdjura
8	***Habrophlebia* sp. 17**	Edough; Djurdjura
9	***Choroterpes* (*Euthraulus*) *lindrothi* (Peters, 1980)**	Djurdjura
10	***Choroterpes atlas* Soldán & Thomas, 1983**	El Kala; Seybouse River; Collo; Khenchela; Batna; Djurdjura
Potamanthidae		
11	***Potamanthus luteus* (Linné, 1758)**	El Kala; Seybouse River; Collo
Polymitarcyidae		
12	***Ephoron virgo* (Olivier, 1791)**	Seybouse River
Ephemeridae		
13	***Ephemera glaucops* Pictet, 1845**	El Kala; Seybouse River; Khenchela
Caenidae		
14	***Caenis luctuosa* (Burmeister, 1839)**	El Kala; Seybouse River; Edough; Collo, O.E.B., Khenchela, Batna, Djurdjura
15	***Caenis pusilla* Navás, 1913**	Seybouse River; Djurdjura
Baetidae		
16	***Baetis atlanticus* Soldán & Godunko, 2006**	El Kala; Seybouse River; Edough; Collo; Khenchela; Batna; Djurdjura
17	***Baetis pavidus* Grandi, 1949**	El Kala; Seybouse River; Collo; O.E.B.; Khenchela; Batna; Djurdjura
18	***Baetis* gr. *alpinus***	El Kala; Seybouse River; Edough; Collo
19	***Baetis dihyae* Benhadji, Dambri & Godunko, 2023**	Khenchela; Batna
20	***Baetis maurus* Kimmins, 1938**	El Kala; Seybouse River
21	***Acentrella sinaica* (Bogoescu, 1931)**	El Kala; O.E.B.; Batna; Djurdjura
22	***Alainites sadati* Thomas, 1994**	El Kala; Seybouse River; Djurdjura
23	***Cloeon* gr. *dipterum***	El Kala; Seybouse River; Edough; Collo; O.E.B.; Khenchela; Batna; Djurdjura
24	***Centroptilum samraouii* Kaltenbach, Vuataz & Gattolliat, 2022**	El Kala; Djurdjura
25	***Procloeon stagnicola* Soldán & Thomas, 1983**	El Kala; Seybouse River; Djurdjura
26	***Procloeon* sp. A**	Seybouse River
27	***Cheleocloeon dimorphicum* (Soldán & Thomas, 1985)**	El Kala
28	***Similicloeon simile* (Eaton, 1870)**	Djurdjura
29	***Labiobaetis neglectus* (Navás, 1913)**	El Kala; Seybouse River
30	***Nigrobaetis rhithralis* (Soldán & Thomas, 1983)**	El Kala; Djurdjura
Oligoneuriidae		
31	***Oligoneuriopsis skhounate* Dakki & Guidicelli, 1980**	Seybouse River
Heptageniidae		
32	***Ecdyonurus rothschildi* Navás, 1929**	El Kala; Seybouse River; O.E.B.
33	***Ecdyonurus aurasius* Dambri, Benhadji & Sartori, 2022**	Khenchela; Batna
34	***Ecdyonurus* sp. Co**	Seybouse River; Collo; Djurdjura
35	***Rhithrogena sartorii* Zrelli & Boumaiza, 2011**	El Kala; Djurdjura
36	***Rhithrogena* sp. EK**	El Kala; Collo; Djurdjura

Potamanthidae

***Potamanthus luteus* (Linné, 1758)**
Fig. 3c

Past distribution. Constantine (Eaton 1899); Alger (Lestage 1915); Tafna (Gagneur and Thomas 1988).

This study. O. Bougous, El Kala (Samraoui et al. 2021b); O. Cherf, a tributary of O. Seybouse (Samraoui et al. 2021a).

Larval growth and development. November-April/May.

Emergence. No data.

Ephemeridae

***Ephemera glaucops* Pictet, 1845**
Fig. 3a, b

Past distribution. No mention of locality (Eaton 1883); Mascara, Hammam Righa (Lestage 1925); O. Bouhamdane, a tributary of O. Seybouse (Navás 1929); O. Tafna (Gagneur and Thomas 1988).

This study. O. Seybouse, including its tributary, O. Cherf (Samraoui et al. 2021a); O. Bougous, El Kala (Samraoui et al. 2021b); O. Tafna (B.S. unpublished.).

Larval growth and development. January - May.

Emergence. May

Polymitarcyidae

***Ephoron virgo* (Olivier, 1791)**
Figs 3c, 4a, b

Past distribution. O. Tafna (Gagneur and Thomas 1988)

This study. O. Seybouse, including its tributary, O. Cherf (Samraoui et al. 2021a)

Larval growth and development. May - July.

Emergence. End June-end August.

Three additional species have been recorded in Algeria; however, these records are likely erroneous or require confirmation:

***Eatonica schoutedeni* (Navás, 1911)**

Past distribution. Bahr-el-Ghazal, Algeria (Navás 1928). As noted by Thomas (1998), no such locality exists in Algeria, whereas this Afrotropical species may occur in southern Sudan (Demoulin 1969; Elouard 1986; Hwang et al. 2008).

***Ephemera danica* Müller, 1764**

Past distribution. Boghari (Navás 1928). Although this species is found in southern Spain, it has never been recorded in the Maghreb.

***Ephemera glaucops* var. *barbarus* Navás, 1922**

Past distribution. Hammam Righa (Navás 1922).

Discussion

The recent systematic survey of various regions in northeastern Algeria (Samraoui et al. 2021a, 2021b; Labdaoui et al. 2024), from the Djurdjura Mountains to the Tunisian border and from the Mediterranean coast to the Saharan Atlas, combined with advances in mayfly taxonomy (Zrelli et al. 2011; Kaltenbach et al. 2022; Dambri et al. 2023; Gattolliat et al. 2023), has significantly improved our understanding of the distribution of Algerian mayflies. This region, recognised as a freshwater biodiversity hotspot, harbours numerous Maghrebian endemics and Afrotropical freshwater relicts (Samraoui et al. 1993, 1998). Despite their ecological significance, mayflies have remained largely understudied, having not been sampled since Eaton's exploration in the late nineteenth century. Consequently, recent research in these areas has important implications for both mayfly taxonomy, biogeography, and freshwater conservation.

Between 2018 and 2022, a total of 36 mayfly species were documented in northeastern Algeria, including ten putative species new to science. Additionally, *Centroptilum samraouii* and three microendemic species (*Habrophlebia djurdjurensis*, *Ecdyonurus aurasius* Dambri, Benhadji & Sartori, 2022, and *Baetis dihaye* Benhadji, Dambri & Godunko, 2022 were described from the same region in recent years (Kechemir et al. 2020; Kaltenbach et al. 2022; Dambri et al. 2022, 2023). Furthermore, the survey contributed to the addition of *Rhithrogena sartorii*, described from Northwest Tunisia, to the Algerian checklist (Samraoui et al. 2021b).

The remarkable number of newly identified species is best exemplified by the genus *Habrophlebia* Eaton, 1881 which has undergone an explosive radiation in the Maghreb, with no fewer than seven possible yet-undescribed species recorded in northeastern Algeria. These undescribed species are restricted to hilly or mountainous habitats but are widely distributed across an extensive area, spanning from the Tunisian border to the Djurdjura Mountains. Their discovery further reinforces the emerging pattern of Maghrebian endemism, exemplified by Moroccan endemics such as *H. vaillantorum* Thomas, 1996 and *H. dakkii* El Alami, Sartori & Vuataz, 2023, as well as the two Algerian species *H. hassainae* Benhadji & Sartori, 2018 and *H. djurdjurensis*. These findings also call into question previous records of European species in the region. Notably, reports of *H. fusca* (Curtis, 1834) and *H. consiglioi* Biancheri, 1959 are likely misidentifications, highlighting the need for taxonomic reassessment and further investigation of Maghrebian *Habrophlebia* diversity (Thomas 1998; Zrelli et al. 2011).

Several factors may have contributed to the remarkable diversity of *Habrophlebia* in the Maghreb, including its specialized ecological niche, limited

Figure 3. a. *Ephemera glaucops* larva; **b.** *Ephemera glaucops* adult; **c.** *Ephoron virgo* adult, d) *Potamanthus luteus* larva.

dispersal ability, and the region's function as a refugium during glaciation periods. Additionally, parts of the Maghreb likely served as biogeographical islands during marine transgressions, further promoting speciation. Alternatively, *Habrophlebia* may have originated in the Maghreb, with the region acting as a center of radiation, subsequently facilitating its spread across the Mediterranean basin. This high endemicity in Maghrebian mayflies is also reflected in other freshwater taxa, such as odonates (Samraoui et al. 2010), stoneflies (Yasri-Cheboubi et al. 2013; Lamine et al. 2022), and caddisflies (Samraoui et al. 2024a).

Figure 4. Larvae of *Ephoron virgo* (**a** and **b**).

One of the unresolved issues in this study is the taxonomic status of the cold-stenothermic taxon *Baetis* gr. *alpinus*, sometimes classified as a subgenus of *Baetis* Leach, 1815 under the name *Patites* Thomas & Dia, 1999 (Gattolliat et al. 2023; Dambri et al. 2023). This taxon is well-defined by several characteristics, primarily related to its rheophilic habitat and feeding behaviour, which involves scraping diatoms from the surface of stones (Bauernfeind and Soldán 2012). A set of diagnostic traits has been proposed to delimit species in the Western Palaearctic (Godunko et al. 2017; Dambri et al. 2023).

In the Maghreb, four species have been described within this group: *B. berberus* Thomas, 1986, likely endemic to Morocco; *B.* (*Baetis*) *dihyae*, endemic to the Aurès Mountains, northeastern Algeria; *B. maurus* Kimmins, 1938, recorded from the Tafna and Seybouse river basins; and *B. punicus* Thomas, Boumaïza & Soldán, 1983, which is widely distributed across the Maghreb. In addition to these described species, several populations across Algeria and Morocco are attributed to this species group without specific assignment (Samraoui et al. 2021a, 2021b; El Alami et al. 2022). In northeastern Algeria, *B.* gr. *alpinus* is widespread at high altitudes in mountain streams along the coastal region but becomes increasingly rare further south. A comprehensive revision of the *B.* gr. *alpinus* species complex is needed to clarify species delimitations, distribution patterns, and ecological adaptations.

A similar taxonomic ambiguity affects the *Cloeon* gr. *dipterum* species complex, which encompass *C. peregrinator* Gattolliat & Sartori, 2008, recently reported from western Algeria (Benhadji et al. 2020), along with other potentially undescribed or unreported taxa. A thorough taxonomic reassessment of this group is necessary to delineate species boundaries and improve our understanding of their ecology and biogeography.

The survey also documented another alticolous species, *Rhithrogena* sp. EK, which appears to have a broad distribution similar to that of *R. sartorii*. With the exception of *R. sartorii*, which is endemic to Tunisia and Algeria, five other *Rhithrogena* species (*R. ayadi* Dakki & Thomas, 1986, *R. giudicelliorum* Thomas & Bouzidi, 1987, *R. maria* Vitte, 1991, *R. ourika* Thomas & Mohati, 1985, and *R. ryszardi* Thomas, Vitte & Soldán, 1987) are all Moroccan endemics, primarily restricted to mountainous streams. With *R. sartorii*, the newly discovered species is allotopic, occupying distinct streams, yet it inhabits riffles in adjacent mountain streams and rivers. However, *R. sartorii* seems to exhibit a broader ecological valence. Species of this genus are highly sensitive to environmental change and have been experiencing declines across their range (Lubini and Sartori 1994; Jacobus et al. 2019; Burian 2024).

Another heptageniid identified during the survey, *Ecdyonurus* sp. Co, represents a new addition to the fauna of the Maghreb, where only three species have been previously documented: *E. rothschildi* Navás, 1929, *E. ifranensis* Vitte & Thomas, 1988, and the recently described *E. aurasius*. Two additional taxa, *Ecdyonurus venosus* var. *constantinicus* Lestage, 1925, and *Ecdyonurus venosus* (Fabricius, 1793), have never been confirmed in the region and are likely misidentifications. The newly recorded heptageniid was found to be relatively less common than its counterpart, *E. rothschildi* Navás, 1929, yet it occupies a relatively extensive range. Similar to *Rhithrogena* species, both *Ecdyonurus* species are allotopic, inhabiting distinct streams within the same river system. However, preliminary data suggest that *E.* sp. Co may be confined to hilly and mountainous streams, whereas *E. rothschildi* has a wider ecological valence.

The study also revealed the highly restricted distribution of certain species within the region, which appear to be confined to specific watersheds. Among these, the undescribed *Procloeon* sp. A, *Oligoneuropsis skhounate* Dakki & Giudicelli, 1980, and the burrowing mayfly *Ephoron virgo* are all localized in the Seybouse River. Notably, *E. virgo* has also been recorded in large, warm-water rivers elsewhere in the Maghreb (El Agbani et al. 1992). The localised distribution of the burrowing mayflies *Ephemera virgo*, *Ephemera glaucops*, and the interstitial *Potamanthus luteus* indicates that their presence may depend on particular hydrological regimes and the physical characteristics of the substratum. Phenological data from both larval and adult stages indicate that all three species are likely univoltine. Additionally, *Choroterpes lindrothi* (Peters, 1980) and *Similicloeon simile* (Eaton, 1870) appear to be restricted to the Djurdjura Mountains, while *Cheleocloeon dimorphicum* (Soldán &

Thomas, 1985) has only been recorded in the El Kala region. These findings underscore the role of local environmental factors in shaping species distributions and highlight the need for further research into their ecological requirements. A deeper understanding of these species' ecology is essential for the development of targeted conservation strategies aimed at preserving their habitats and ensuring their long-term survival.

Biogeographical and conservation implications

Due to its location and a unique combination of geological, topographic, and climatic features, the Maghreb serves as a natural laboratory for studying evolution, offering insights into how species respond to geographic barriers and climatic fluctuations (Brown et al. 2002; Harris et al. 2002; Migliore et al. 2012). Within the Maghreb, northeastern Algeria stands out as a major hotspot of freshwater biodiversity in the Mediterranean region, hosting numerous Maghrebian endemics, many of which are micro-endemics. The region is particularly notable for its mayfly diversity (Samraoui et al. 2021a, 2021b) and a rich assemblage of other aquatic insect taxa, including stoneflies (Yasri-Cheboubi et al. 2013), caddisflies (Malicky and Lounaci 1987; Samraoui et al. 2024a), and dragonflies (Samraoui and Menaï 1999). Beyond its invertebrate endemics and relict species, northeastern Algeria is also home to endemic amphibians and fish, such as the newts *Pleurodeles poireti* (Gervais, 1835) and *Pleurodeles nebulosus* (Guichenot, 1850), the tree frog *Hyla carthaginiensis* Dufresnes et al. 2019, and the Maghreb bleak, *Tropidophoxinellus callensis* (Guichenot, 1850).

Furthermore, the region serves as a well-documented refugium for Afrotropical relict taxa, including Copepoda (Samraoui et al. 1998), Odonata (Samraoui et al. 1993), aquatic Hemiptera, and Coleoptera (Annani et al. 2012), which likely migrated across the hyperarid Saharan desert during a humid Holocene period (Samraoui et al. 1993).

A significant proportion of freshwater species in North Africa (over 47%) are threatened with extinction (García et al. 2010). Many belong to species complexes (Samraoui et al. 2003; Adler et al. 2015) or have been misidentified, as was the case with the *Habrophlebia* taxa until recently. The region faces increasing anthropogenic pressures driven by population growth, compounded by global challenges such as climate change. Addressing this biodiversity crisis requires urgent, integrative conservation strategies, including ecosystem-based management, habitat restoration, and policy interventions. Equally important is a deeper understanding of these species' genetic diversity and ecology, which are critical for developing targeted conservation efforts and ensuring their long-term survival.

Sustainable management approaches must balance conservation priorities with human needs to safeguard the persistence of freshwater biodiversity and the essential ecosystem services these habitats provide (Boulton et al. 2016). Strengthened conservation planning, adaptive management strategies, and improved governance are essential to reversing biodiversity declines and maintaining the ecological integrity of North African freshwater biodiversity (Erős et al. 2023).

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