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Research Article

First Annoted Checklist of Aquatic Diptera (Insecta) of Two Ramsar Sites (Ahançal and Aït Bouguemaz Rivers) at the Central High Atlas (Morocco): Families *Ceratopogonidae*, *Chironomidae*, *Tipulidae*, *Empididae*, and *Tabanidae*

El-Mostafa Benka,[1] **Mohamed Dakki**,[2] **Abdessamad Ouibimah**,[1] **Mohamed Mounir**,[1] **Ikram Douini**,[1] **Kawtar Kettani**,[3] **Oumnia Himmi**,[4] **and Soumaya Hammada**[1]

[1]*Laboratory of Agro-Industrial and Medical Biotechnologies, Faculty of Sciences and Technics, Sultan Moulay Slimane University, Beni Mellal, Morocco*
[2]*GREPOM, BirdLife Morocco, Lotissment Oumhani 4, route de Kénitra Salé, Salé, Morocco*
[3]*Laboratory Ecology, Systematics, and Conservation of Biodiversity (LESCB), URL-CNRST No. 18, FS, Abdelmalek Essaadi University, Tetouan, Morocco*
[4]*Geo-Biodiversity and Natural Patrimony Laboratory (GEOBIOL), Scientific Institute, Mohammed V University in Rabat, Rabat, Morocco*

Correspondence should be addressed to El-Mostafa Benka; mosben.mse@gmail.com

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This paper presents the first results of 1-year survey of aquatic *Diptera*, carried out in two Moroccan High Atlas rivers, Assif Ahançal and Assif n'Aït Bouguemaz, which are registered as Ramsar sites and drain a large part of the mountainous Geopark of Mgoun. This survey, which consists in a first study of the longitudinal distribution of these insects, occurs during the period September 2019–July 2020, at high and medium altitudes (1086–2408 m). Limited to immature stages, this study permitted to collect 561 specimens of *Diptera* from 16 river sections, mainly using a Surber-net sampler. Among the collected material, we were able to identify 38 genera and 11 species, belonging to five families. This fauna is relatively rich in new taxa for Morocco or for the High Atlas mountains. Indeed, two *Chironomidae* species, *Macropelopia notata* (Meigen, 1818) and *Psectrocladius* (*Allopsectrocladius*) *flavus* (Johannsen, 1905), and one *Tipulidae*, *Tipula (Yamatotipula) pierrei*, Tonnoir, 1921, are newly recorded in Morocco, as well as five genera: three Chironomidae (*Krenopelopia*, Fittkau; *Natarsia*, Fittkau; and *Psilometriocnemus*, Saether), one Empididae (*Chelifera*, Macquart), and one Ceratopogonidae (*Atrichopogon*, Kieffer). Two other species, *Parachironomus frequens* (Johannsen) and *Heterotrissocladius marcidus* (Walker), and seven genera are reported as new taxa in the High Atlas. The two rivers have similar richness (21 taxa each), mainly due to *Chironomidae* (94%), the most abundant and diversified family. The *Empididae* (4.8%) are relatively under-represented in the two rivers, as well as the other families (*Ceratopogonidae*, *Tipulidae*, and *Tabanidae*), which do not exceed 1% of the total dipteran abundance. The vertical distribution of the taxa revealed significant influence of the altitude on community compositions and distributions. In waiting to collect adults, immature dipteran stages prove the high abundance and diversity of the benthic entomological assemblages, which give hope that a more deep study of the dipteran fauna in the two Ramsar sites will provide remarkable novelties, in both systematic and ecological domains. It is also expected that this study will permit to assess the aquatic biodiversity of these ecosystems and its sensitivity to the increasing human disturbances.

1. Introduction

True flies (*Diptera*) constitute one of the largest orders of insects in the biosphere, with over 160,000 described species worldwide [1], as they have successfully colonized all continents and practically all inland and coastal habitat types, except inside glaciers [1]. They play a crucial role in maintaining the aquatic ecosystems functioning, as they are a major component of food webs [2, 3]. Due to their high selectivity towards ecological factors, they contain excellent indicators of water quality [1] and high rate sensitive species to anthropogenic pressures and climate change; for the same reason, they are highly rich in endemic and vulnerable species. In North Africa, these endemics are present in all ecosystem types, but particularly numerous in waters [4–15], etc.

In Morocco, considering their importance, aquatic true flies have received a large number of published notes that have been compiled by Kettani et al. [16], but these studies are still insufficient in front of the species richness of this group, the wide extension of the Moroccan hydrographic network [17], and the diversity of its aquatic habitats [18]. These insufficiencies are partly due to difficulties in identifying their aquatic phases.

Kettani et al. [16] inventoried 3057 species of *Diptera* recorded in Morocco, most of them being terrestrial, in the sense that researches on aquatic *Diptera* remain limited in terms of number [14, 15, 17, 19, 20]. These studies cover most of the families, but very unequally, and cannot provide a good idea on this fauna, both in ecological and biogeographical aspects. We mainly notice that our knowledge of the mountainous habitats needs to be increased.

This paper provides the first results of a one-year survey of *Diptera* communities in two high-altitude streams, Assif Ahançal and Assif n'Aït Bouguemaz. We present a first commented checklist of five families (*Ceratopogonidae*, *Chironomidae*, *Tipulidae*, *Empididae*, and *Tabanidae*).

It is important to remind that these streams were listed in 2019 as Wetlands of International Importance or Ramsar Sites [21, 22], while they were partly included in the Moroccan Master Plan of Protected Areas (AEFCS 1996) and in the Mgoun Geopark. This study is then also supposed to contribute to a better evaluation of these protected areas.

2. Material and Methods

2.1. Study Area. The study area corresponds to two permanent streams, Assif Ahançal and Assif n'Aït Bouguemaz, that drain the northern slopes of the central High Atlas mountains. These streams belong to one of the largest hydrographic networks, Oum-Er-Rbia Wadi, more especially to its High Atlas branch, El Abid Wadi (Figure 1). Situated between 1000 m and 2400 m a.s.l, the studied rivers have dug deep valleys, surmounted by mountains culminating between 2000 and 4000 m [21, 22].

These valleys have an oro-Mediterranean climate with a high thermal amplitude and irregular annual precipitations, ranging from 500 to 800 mm/year on average [23]. However, they have the originality of being permanent, with sustained flow and current in most of their sections, while in other regions, permanent streams and springs are becoming rare due to a high human pression on their waters.

The Ahançal River has its highest course at 2100 m high, at Taghia location, southeast of Zaouiat Ahançal village. It is supplied by karstic springs that emerge from Lias limestone cliffs [24]. Throughout its course of 250 km length, this river receives several tributaries (springs and streamlets), the largest of them (Assif Melloul and Assif n'Wabzaza) flowing into the central course, respectively, at Tamga and upstream of Bin El Ouidane reservoir [25]. On its course, this river (Figure 2) crosses three villages (Zaouiat Ahançal, Tilouguite, and Ait azigh) before flowing into Bin El Ouidane reservoir at 780 m of altitude.

The river basin is made of varied rocks [26], aging from Jurassic (limestone, sandstone, marls, conglomerates, etc.), Cretaceous (basalts), Mio-Pliocene (conglomerates, lacustrine limestone, and polygenic conglomerates), and Plio-Villafranchian (alluvium, travertine, and conglomerates).

The vegetation of this watershed consists in few types of formations that are organized in altitudinal zones: a substeppe formation of *Juniperus thurifera* at highest altitudes, a preforest formation with *Juniperus phoenicea* at medium altitudes, and *Pinus halepensis* sometimes in association with *Quercus rotundifolia* at low altitudes, which is dominating at lower parts of the basin [26, 27].

Assif n'Aït Bouguemaz is a permanent tributary of the Lakhdar Wadi located between 1800 m and 2400 m of altitude; it drains the northern slopes of the Mgoun mountain. It runs through a wide flat valley, around 25 kilometers long, which makes it different from the other adjacent valleys [23]. This particularity is due to the geology of its basin, knowing that the valley bottom is occupied by a thick layer of soft lacustrine sediments of the Quaternary, while the slopes are dominated by Mesozoic limestone and dolomite layers [26, 28].

Fed by great and permanent springs, emerging at 2357 m of altitude, this river benefits from an appreciable aquifer, mainly fed by the Izourar landslide lake [29]. However, most of the river water is diverted to the agriculture fields or to domestic use. Indeed, the lower slopes of Aït Bouguemaz valley are densely occupied by rural population.

The slopes of this valley hold a presteppe with a sparse formation of *Juniperus thurifera* and *Quercus rotundifolia*. The bottom of the valley and some adjacent lower slopes are invaded by irrigated agriculture, varied but dominated by vegetable crops [26, 27].

2.2. Study Sites. A total of 16 sampling sites were prospected (Figure 1) along the two rivers, distributed in eight stations per river. These sampling sites were chosen in a way to represent all the dominant types of running water ecosystems (springs, fresh streamlets and streams, and rivers of low and high mountains). The main location data and abiotic characteristics of the prospected sites are summarized in Table 1.

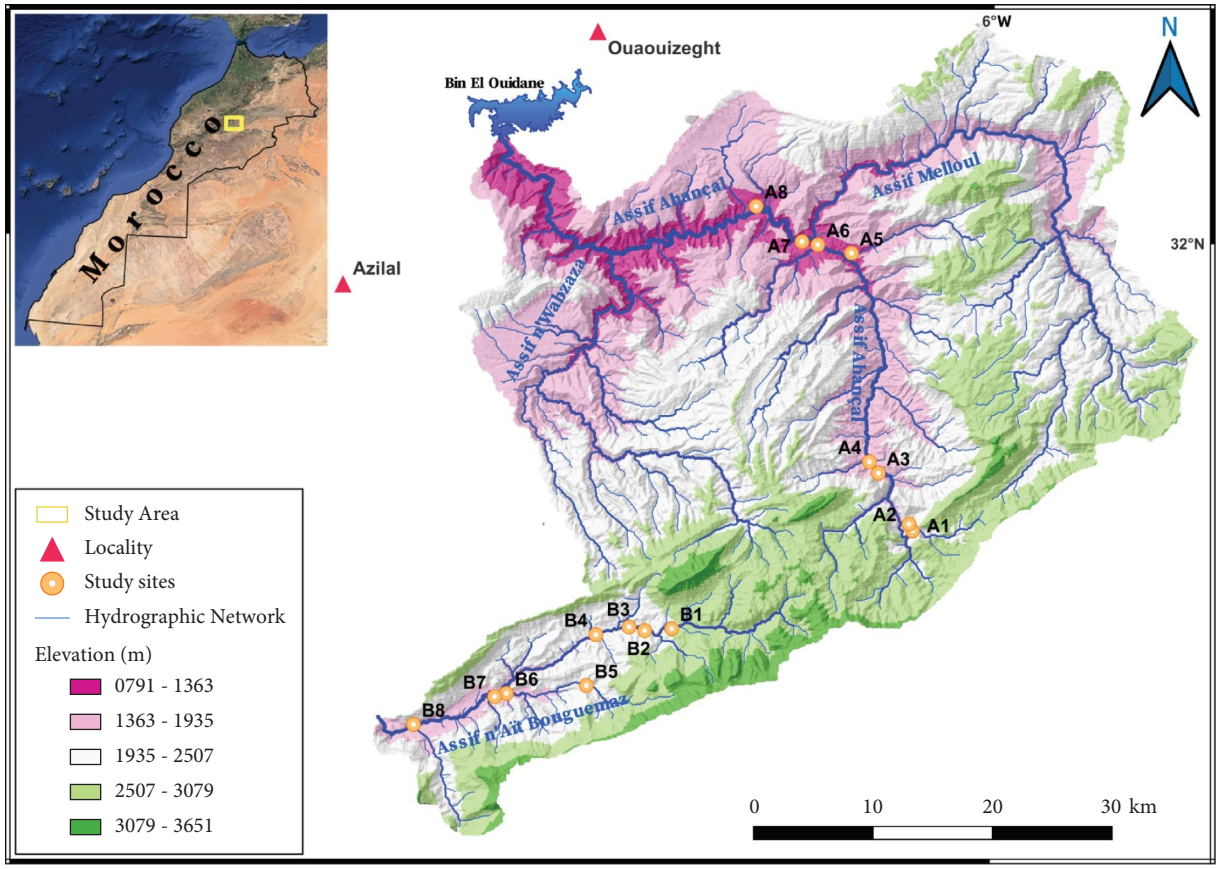

Figure 1: Sampling sites in Assif Ahançal and Assif n'Aït Bouguemaz (Oum-Er-Rbia watershed).

2.3. Sampling Method. This research was conceived in order to assess the aquatic biodiversity of the two studied rivers, as Ramsar sites, at least during one year. A standard sampling tool has been chosen, the Surber type net [30], but with a surface area of 250 cm^2 and a net mesh of 0.5 mm. As this surface is relatively low, we increased the number of samples to six per campaign and per station. To ensure that the sample is representative of the population, the six samples were distributed according to the occurrence of the different habitat types that make up the station [14]. Each site was allocated a sampling duration of 1 hour.

In addition to the quantitative sampling, we undertook a qualitative prospecting of the different substrate components, in order to collect the maximum of species. Two qualitative methods were used: (1) manual sampling (using flexible forceps) of insect larvae and pupae attached to the substrate (big rocks, clump of moss, wood, etc.), (2) collecting insects living in the interstices of hard substrate in a net, by stirring this latter with foot. Certainly, because of shortness of the field campaigns, we were unable to cover all microhabitats as we expected.

The field work, planned in a way to cover two campaigns per season during two years, was partly performed (between September 2019 and July 2020), knowing that the field visits were interrupted due to the COVID-19 crisis, as human movements have been severely restricted starting from March 2020. However, we were unable to accomplish a quick flied visit during July 2020.

The collected samples were preserved in 70° ethanol both for its transport and to the laboratory and conservation. Each specimen was cleared in a 10% KOH solution and mounted on permanent slides in Canada balm. In most cases, identification was carried out only at the genus level due to the difficulties of reaching the specific level for larval and pupae forms. Identification of larvae of *Chironomidae* was performed following the keys of [31–35].

3. Results

3.1. A Global Overview of the Community Composition. In this first phase, we studied only five families (*Ceratopogonidae*, *Chironomidae*, *Tipulidae*, *Empididae*, and *Tabanidae*), which reveal 43 taxa (Table 2). Among these taxa, and due to the difficulties to identify species on the basis of larvae, we were able to identify only 11 species. Table 2 indicates the cumulative number of individuals collected in the four seasonal campaigns for each species in each site. We should note that some species that were absent in quantitative samples are indicated in this table with low numbers.

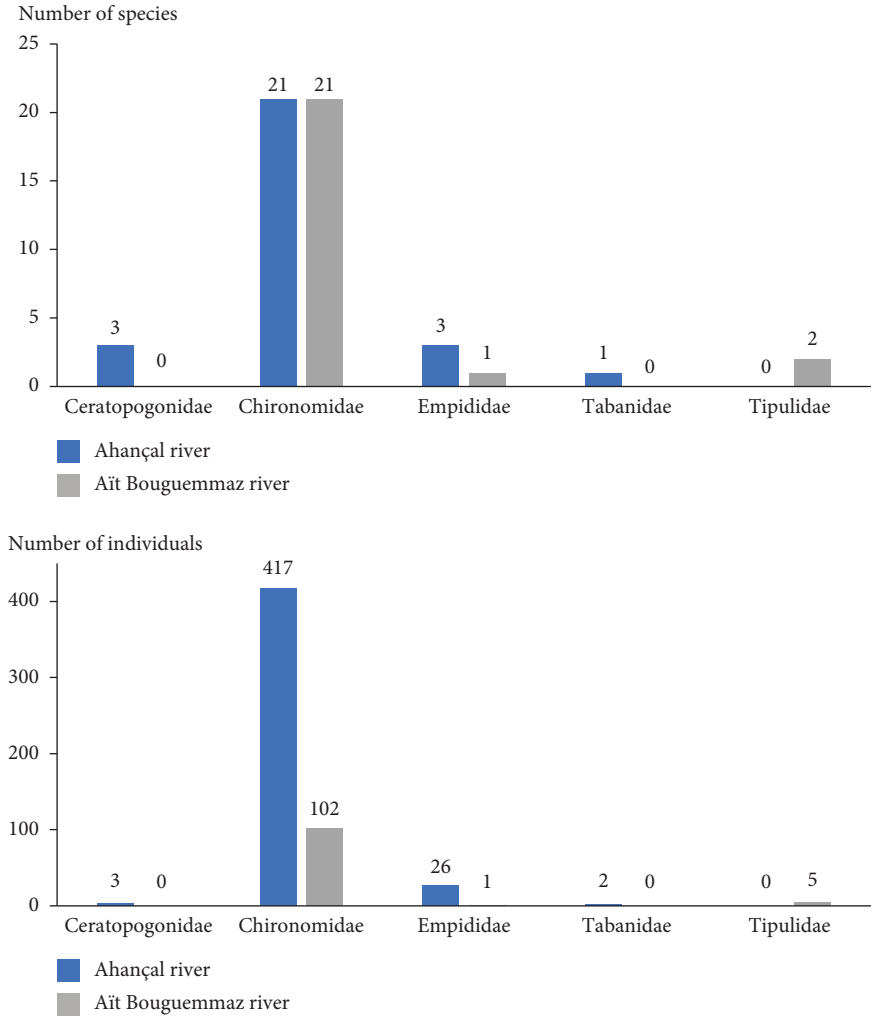

Figure 2: Comparison between the *Diptera* communities in the two studied rivers.

Among the five studied families, only *Tipulidae* are not recorded in the Ahançal river, while two families (*Ceratopogonidae* and *Tabanidae*) are absent in Aït Bouguemaz (Table 3, Figure 2).

Chironomidae constitutes the most diversified family, as we identified 21 taxa in each river. It is also the most abundant family, representing 94% of the individuals in each river (Table 3). Three of these taxa/genera (*Cricotopus, Krenopelopia*, and *Orthocladius*) are the most abundant in Aït Bouguemaz, representing, respectively, 15.74%, 12.04, and 10.2% of the total number of the collected individuals (Table 2); they are followed by the genera *Natarsia* (9.26%), *Parakiefferiella*, and *Macropelopia* (7.41% each). In Assif Ahançal, the *Diptera* community is dominated by three genera *Orthocladius* (18.30%), *Eukiefferiella* (18.08%), and *Cricotopus* (16.74%), followed by the genera *Parakiefferiella* (13.84%) and *Rheotanytarsus* (8.93%). The relative abundance of each of the other genera does not exceed 6% in each river.

Among this fauna, we could identify only seven species, five in Aït Bouguemaz (*Heterotrissocladius marcidus, Macropelopia notata*, *Macropelopia nebulosa*, *Rheopelopia maculipennis*, and *Parachironomus frequens*) and three in Ahançal (*Ablabesmyia monilis*, *Telopelopia fascigera*, and *Psectrocladius flavus*).

The family *Ceratopogonidae*, absent in Aït Bouguemaz river, is represented in Ahançal by two genera, *Culicoides* and *Atrichopogon*, cumulating only 0.45% of the collected individuals.

The family Empididae showed in Aït Bouguemaz is solely one genus, *Hemerodromia*, that cumulates only 1% of the fauna collected. However, in Ahançal river, three genera

Table 1: Sampling stations of *Diptera* in Assif Ahançal and Assif n'Aït Bouguemaz: location and main characteristics.

Rivers	Site name	Site code	Habitat type	Latitude	Longitude	Altitude (m)	Depth (cm)*	Flow (m/s)*	Substrate	Vegetation
Assif Ahançal	Ighboula n'Taghia	A1	S	31.7823361	−6.0673500	2043	15	1.15	Boulders, cobbles, and gravel	Ferns, Mosses, Grasses, Asteraceae, and Brassicaceae
	Taghia	A2	MS	31.7838972	−6.0676889	1967	20	1.20	Gravel	*Mentha* sp., *Salix* sp., *Buxus* sp., and Algae
	Ighboula n'Zaouit	A3	S	31.8256250	−6.0977556	1641	35	0.90	Gravel and sand	*Buxus* sp. and *Salix* sp.
	Agodim	A4	MS	31.8342306	−6.1058278	1607	48	1.70	Boulders and cobbles	*Mentha* sp. and Algae
	Ouakhoudan	A5	MS	31.9914722	−6.1227806	1229	40	1.56	Gravel	*Quercus ilex*, *Nerium*, *Pistacia lentiscus*, and *Buxus* sp.
	Almou n'Ofarsig	A6	MR	31.9976472	−6.1527083	1131	35	1.30	Cobbles and gravel	*Equisetum* sp., *Populus nigra*, *Mentha* sp., *Dittrichia* sp., and *Nerium oleander*
	Tanokrit	A7	MR	31.9999417	−6.1667917	1128	49	1.26	Boulders and cobbles	Cupressaceae, *Nerium*, *Populus nigra*, and *Quercus ilex*
	Bouatass	A8	MR	32.0263833	−6.2076222	1086	52	1.20	Gravel and cobbles	Cupressaceae, *Nerium*, *Spirogyra* sp., *Vaucheria* sp., *Cladophora* sp., and *Chara* sp.
Assif n'Aït Bouguemaz	Aghbalou n'Taghfist	B1	S	31.7070944	−6.2793917	2408	10	7.16	Gravel	Mosses, Ferns, and Algae
	Ait Ouham	B2	MS	31.7055028	−6.3031361	2140	40	0.88	Cobble and gravel	Grasses and Algae
	Taghbalout n'Iglouan	B3	S	31.7082056	−6.3170361	2075	35	1.25	Gravel, sand	Grasses and *Mentha* sp
	Aghbalou n'Aït Megdoul	B4	S	31.7021472	−6.3462778	2006	38	0.78	Cobbles and boulders	*Populus nigra*, Grasses, Equisetaceae, and *Mentha* sp
	Aghbalou n'Tawaya	B5	S	31.6636722	−6.3543389	1978	50	0.75	Sand and cobbles	*Salix* sp., *Rumex* sp., Mosses, Grasses, *Juncus* sp., Asteraceae, and *Mentha* sp.
	Tabant	B6	MS	31.6571694	−6.4247750	1849	10	8.14	Gravel	*Mentha* sp., *Juncus* sp., *Veronica* sp., *Nasturtium* sp., and Algae
	Aghbalou n'Aguerd n'Ouzrou	B7	S	31.6546611	−6.4351833	1836	18	9.20	Gravel and fine sol	Grasses, *Juncus* sp., *Mentha* sp., *Cyperus* sp., *Equisetum* sp., and Algae
	Agouti	B8	MR	31.6330583	−6.5064778	1766	30	0.91	Cobbles and gravel	Algae (filamentous), *Salix* sp., *Dittrichia* sp., *Mentha* sp., and Grasses

Habitat types: S = spring, MS = mountainous stream, and MR = mountainous river. *Depth and flow were measured in summer.

Table 2: True flies (*Diptera*) collected in the Ahançal and Aït Bouguemaz rivers.

Rivers	Assif n'Aït Bouguemaz									Assif Ahançal								
Taxa sites	B1	B2	B3	B4	B5	B6	B7	B8	Total	A1	A2	A3	A4	A5	A6	A7	A8	Total
Ceratopogonidae																		
Atrichopogon spp. (M)										1								1
Culicoides sp.														1				1
Chironomidae																		
Ablabesmyia (Ablabesmyia) monilis															1			1
Ablabesmyia spp.														19	2			21
Brilla sp.								1	1									
Cardiocladius spp. (H)	1								1	3								3
Conchapelopia sp.															1			1
Cricotopus spp.				3		11		3	17	6	12	5		20			32	75
Diamesa sp.		1							1									
Eukiefferiella spp.														5			76	81
Heterotrissocladius spp. (H)										2							2	4
Heterotrissocladius marcidus (H)						1			1									
Hydrobaenus sp. (H)											1							1
Krenopelopia spp. (A)								13	13									
Macropelopia nebulosa						8			8									
Macropelopia notata (M)							1		1									
Metriocnemus spp.								6	6									
Nanocladius spp.						3			3									
Natarsia sp. (M)								10	10				1	2				3
Orthocladius (Euorthocladius) spp.					2				2									
Orthocladius spp.	1						3	7	11	18	2			16		7	39	82
Parachironomus frequens (H)						1			1									
Parakiefferiella spp.							3	5	8	12				13	9		28	62
Parametriocnemus spp. (H)					2	3			5	4			1		4			9
Paratanytarsus spp.							1	3	4					7				7
Polypedilum sp															1			1
Psectrocladius (*Allopsectrocladius*) *flavus* (M)															6			6
Psilometriocnemus sp. (M)												1						1
Rheopelopia maculipennis						2			2									
Rheotanytarsus spp.							4		4		3			33	4			40
Tanytarsus spp.														3				3
Telopelopia fascigera																	2	2
Thienemanniella spp. (H)										2								2
Thienemannimyia spp.						2			2									
Tvetenia spp.														12				12
Zalutschia sp. (H)			1						1									
Zavrelimyia sp.																	1	1
Empididae																		
Chelifera spp. (M)												1		1				2
Hemerodromia spp.						1			1	10				12	1			23
Wiedemannia sp.														1				1
Tabanidae																		
Chrysops viduatus (A)												1		1				2
Tipulidae																		
Tipula (*Yamatotipula*) *barbarensis*								1	1									
Tipula (*Yamatotipula*) *pierrei* (M)						4			4									
Total number of individuals	2	1	1	3	4	36	12	49	108	58	18	8	2	146	29	7	180	448

Ahançal sites: A1: *Taghia Spring*, A2: *Taghia*, A3: *Zaouiat Ahançal Spring*, A4: *Agodim*, A5: *Tamga Gorge*, A6: *Almou n'Ofarsig*, A7: *Tanokkrit*, A8: *Bouatass*, Aït Bouguemaz sites: B1: *Agouti*, B2: *Aguerd N'Ouzrou Spring*, B3: *Tabant*, B4: *Tawaya Spring*, B5: *Aït Megdoul Spring*, B6: *Iglouan Spring*, B7: *Ait Ouham*, and B8: *Taghfiste Spring*. New records are indicated between brackets following the taxa name: M: new for Morocco, H: new for the High Atlas, and A: new for the studied rivers.

Table 3: Comparison between the *Diptera* communities in the two studied rivers.

Rivers =>	Aït Bouguemaz			Ahançal			Total			Common species	
Families	Sp	Ind	%	Sp	Ind	%	Sp	Ind	%	Sp	%
Ceratopogonidae	0	0	0.00	3	3	0.67	3	3	0.54	0	0.000
Chironomidae	21	102	94.44	21	417	93.71	34	519	93.85	8	0.190
Empididae	1	1	0.93	3	26	5.84	3	27	4.88	1	0.250
Tabanidae	0	0	0.00	1	2	0.45	1	2	0.36	0	0.000
Tipulidae	2	5	4.63	0	0	0.00	2	5	0.90	0	0.000
Total Nb indiv	24	108		28	445		43	553		9	0.173

Species: Sp = number of species, Ind = number of individuals, and % = family number of individuals/total individuals of Diptera.

were identified (*Wiedemannia*, *Chelifera*, and *Hemerodromia*); they are relatively frequent and abundant (6% of the collected fauna).

The family *Tipulidae*, absent in Ahançal River, is represented by one genus, *Tipula*, that contains two species: *Tipula barbarensis* and *Tipula pierrei*. These taxa cumulate 5% of the fauna collected in Aït Bouguemaz.

3.2. Checklist of Aquatic Diptera

3.2.1. F. Ceratopogonidae

(1) Genus Culicoides Latreille, 180

Culicoides sp.

This genus, with 1,347 species worldwide [36, 37], is represented in Morocco by 56 species, 30 of which are listed in the High Atlas [16]. The *Culicoides* species are usually present in humid habitats, rich in organic matter, and are frequent on the edges of both lacustrine and riverine ecosystems [38], including highly alkaline and saline waters. Some species can also be found in animal manure and even in rotting fallen fruits [39, 40].

Given its preferences, this genus is certainly undersampled in our study, as it was found only in Assif Ahançal at 1229 m of altitude (A5-Tamga Gorge), during summer (July 04, 2020).

(2) Genus Atrichopogon Kieffer, 1906

Atrichopogon sp.

This genus is newly cited in Morocco; we collected one larva on July 07, 2020, from a high-altitude permanent spring, Ighboula n'Taghia (A1), with shallow, rapid, and fresh waters.

With a worldwide distribution, this genus is common in wet terrestrial habitats [41], frequently in decaying organic matter, but it can be found also on the banks of streams, ponds, lakes, and on partially submerged substrate, as stones, algae or mosses, including inland and coastal saline habitats [42, 43].

3.2.2. F. Chironomidae

(1) Genus Macropelopia Thienemann, 1916

Macropelopia *nebulosa* (Meigen, 1804).

In Morocco, this Palearctic species is known in the High Atlas and the Rif mountains [16] and in the Oriental region [44]. It inhabits fine sediments in both lotic and lentic habitats [44–46]. In our study area, we collected 8 larvae during summer (July 08, 2020) in a shallow sector of Aït Bouguemaz at Tabant (B6, 1836 m of altitude).

Macropelopia *notata* (Meigen, 1818).

This species, newly cited in Morocco, is widely distributed in Europe [35], where it inhabits springs and rivers [47], with preference of cold spring waters [48], more especially rheo-hygropetric [49] or moss-rich [50, 51]. It was also cited from lakes and peat ponds [52, 53], sometimes as a dominant species [54]. In our study area, we collected one larva of *M. notata* in a summer sample (July 09, 2020), in a permanent spring of Aït Bouguemaz basin, Aghbalou n'Aguerd N'Ouzrou (B7), at 1836 m of altitude.

(2) Ablabesmyia Johannsen, 1905

Ablabesmyia (*Ablabesmyia*) *monilis* (Linnaeus, 1758).

This is a Holarctic species [55] that is already known in Morocco, in the Rif, Middle Atlas, and High Atlas Mountains [16]. It occurs in rivers [56, 57], as well as in stagnant waters [58], and the larvae prefer silty grounds [57]. We collected one larva in summer sample (November 29, 2019), in the lowest course of Assif Ahançal, at Almou n'Ofarsig (A6, 1131 m of altitude).

Ablabesmyia spp.

Unidentified larvae of this genus were found in Assif Ahançal river, at Ouakhoudan (A5, 19 larvae on November 30, 2019 and July 03, 2020) and Almou n'Ofarsig (A6, 2 larvae collected on November 29, 2019), respectively, at the altitudes of 1131 m and 1229 m.

(3) Genus Conchapelopia Fittkau, 1957

Conchapelopia sp.

This genus has a worldwide distribution [59] and occupies both running and stagnant waters [58, 60] and even lagoons [61]. The genus is already known in Morocco, from the Rif and the High Atlas mountains with three species, *C. melanops*, *C. pallidula*, and *C. viator* [16]. During our study, we collected one larva during summer (July 30, 2020), in Assif Ahançal, at Almou n'Ofarsig (A6, 1131 m of altitude).

(4) Genus Krenopelopia Fittkau, 1962

Krenopelopia spp.

This Holarctic genus [62] is newly cited in Morocco: 13 larvae were collected on July 08, 2020, in the lowest sector of Aït Bouguemaz (Agouti, 1766 m of altitude).

This genus seems cold-stenothermic, inhabiting then springs, running water banks [62], and cold lake banks [63, 64]. In our study area, its habitats have cold waters in winter but slightly hot in summer.

(5) Genus Rheopelopia Fittkau, 1962

Rheopelopia maculipennis (Zetterstedt, 1838).

This species was cited in the Rif, Middle Atlas, and High Atlas chains [16]. The genus *Rheopelopia* is almost Holarctic, with four West-Palearctic species [65], including *R. maculipennis* [66, 67]. Aquatic stages of this species are usually found in running waters [66, 68, 69].

In the High Atlas, we collected *R. maculipennis* only in Aït Bouguemaz stream: two larvae at Tabant (B6, 1849 m of altitude, on July 08, 2020). This stream section is slightly polluted by organic matters.

(6) Genus Telopelopia Roback, 1971

Telopelopia fascigera (Verneaux, 1970).

This species has a Western Palearctic distribution [66]; in Morocco; it has been reported from the High and Middle Atlas Mountains and in the Atlantic Plains [16]. The *Telopelopia* larvae apparently prefer rivers [70], but they also occur in lentic habitats [2, 71]. *T. fascigera* seems eurythermic, preferring large rivers [33, 66]. In our study, we found it in the lowest section of Ahançal: two larvae on July 05, 2020, at Bouatass (A8, 1086 m of altitude), where we recorded high variations of seasonal flow and temperature.

(7) Genus Thienemannimyia Fittkau, 1957

Thienemannimyia spp.

This genus has a very large distribution throughout the world [72]. In Morocco, it contains seven species, known in the mountains (Rif, Middle Atlas, and High Atlas) and the Eastern Plateaus [16]. The *Thienemannimyia* larvae live in both lotic and lentic waters [48]; they are polyoxybiontic and rheophilic and sometimes found in the profundal zone of oligotrophic or montane lakes [72] and running waters [73]. The larvae of this genus prefer 'sandy-muddy' sediments in streams [74]. In our study area, we collected 2 larvae during summer (July 08, 2020) in a shallow sector of Aït Bouguemaz at Tabant (B6, 1836 m of altitude).

(8) Genus Zavrelimyia Fittkau, 1962

Zavrelimyia sp.

This worldwide genus [75] has been recorded in Morocco, with five species, from three mountainous regions in the Rif, Middle Atlas, and High Atlas [16]. It is frequent in running waters [76, 77] and springs [2, 78], as well as in standing waters [79, 80], generally of good quality [81]. In our study, we found it only in the lowest section of Ahançal river at Bouatass location (A8, 1086 m of altitude): one larva on July 05, 2020.

(9) Genus Natarsia Fittkau, 1962

Natarsia spp.

Our study provides the first citation of the *Natarsia* genus in Morocco; composed of six species, it has a worldwide distribution: Palearctic [82, 83], Nearctic [64], and Oriental [84]. It occupies lake and river banks [84], and low flowing streamlets [63, 64] and streams [83]. In our mountainous study area, the larvae, that can belong to different species, were collected in permanent small rivers with medium flow speed, more precisely at Agouti (B8, 1766 m of altitude) in the lower part of Aït Bouguemaz stream (10 larvae collected on July 08, 2020) and Agodim-Ouakhoudan sector (A4-A5, 1229–1607 m) of Ahançal (respectively, two and one larva on July 03 and 06, 2020).

(10) Genus Diamesa Meigen, 1835

Diamesa sp.

Ten species of this genus are known in Morocco, in the Rif and High Atlas Mountains [16].

The *Diamesa* species are known for their preference for cold waters, even freezing or glacial habitats, poor in food resources [85, 86]; this explains their distribution in arctic and alpine headwaters [86, 87], in both Holarctic and Afrotropical regions [88].

In our study area, we collected one larva on July 10, 2020, in a high section of Aït Bouguemaz Ait Ouham (B2, 2140 m of altitude).

(11) Genus Brilla Kieffer, 1913

Brilla sp.

This genus was reported in Moroccan mountain chains: Rif, High Atlas, and Middle Atlas with three species, *B.* bifida, *B. flavifrons*, and *B. longifurca* [16]. Known in the Holarctic and Oriental regions [89], this genus inhabits a wide range of freshwater habitats: springs, streams and rivers [90], lake banks [2], and ponds [91, 92]. In our study, we found one larva on July 08, 2020, in Agouti (B8, 1766 m of altitude), representing the lowest section of Aït Bouguemaz stream.

(12) Genus Cardiocladius Kieffer, 1912

Cardiocladius spp.

This genus is already known in the Rif and Middle Atlas Mountains, where two species, *C. capucinus* and *C. fuscus*, were reported [16]; our study extends its distribution to the High Atlas. Its larvae occur in rivers [93, 94], including fast-flowing ones [95]. In Ahançal-Aït Bouguemaz streams, we found larvae in the highest rheocrene springs: three individuals on July 07, 2020, in Ighboula n'Taghia (A1, 2043 m of altitude) and one individual on July 11, 2020, in Aghbalou n'Taghfist (B1, 2408 m of altitude).

(13) Genus Cricotopus van der Wulp, 1874

Cricotopus spp.

This genus is composed of at least 218 species, widely distributed across the world [96]. In Morocco, 23 species were reported in the mountains (High Atlas, Middle Atlas, and Rif) and the Atlantic Plains [16]. Their larvae inhabit a wide range of running and standing waters and springs [97, 98], where they can use floating leaves or submerged plants as supports [99]. In our study area, the larvae were collected from both rivers, in their major courses, ranging between 1086 m and 2043 m of altitude (A1, A2, A3, A5, A8, B4, B6, and B8). Three of these locations (A1, A3, and B4) are springs.

The collected material, belonging quite certainly to different species, is as follows:

(i) Assif Ahançal: 6 larvae in Ighboula n'Taghia, on July 07, 2020; 12 larvae in Taghia, on July 07, 2020; 5 larvae in Ighboula n'Zaouit, on July 06, 2020; 20 larvae in Ouakhoudan, 13 on July 03, 2020, 4 on November 23, 2019, and 6 on November 30, 2019; and 32 larvae in Bouatass, on July 05, 2020;

(ii) Assif n'Aït Bouguemaz: 3 larvae in Aghbalou n'Aït Megdoul, September 15, 2019; 11 larvae in Tabant, on December 01, 2019; and 3 larvae in Agouti, on July 08, 2020.

(14) Genus Eukiefferiella Thienemann, 1926

Eukiefferiella spp.

This genus, with a very wide world distribution, is represented in Morocco by a minimum of 20 species, which were recorded in different regions, mostly in the Rif, Middle Atlas, and High Atlas [16]. The larvae inhabit almost exclusively running waters of all types, some species being in eurythermal streams, while others are restricted to cold montane waters [100, 101]. Our material was collected in two sections of Ahançal river, at the altitudes of 1229 m (A5-Ouakhoudan, 5 larvae on July 03, 2020) and 1086 m (A8-Bouatass, 76 larvae on July 05, 2020).

(15) Genus Heterotrissocladius Spärck, 1923

Heterotrissocladius marcidus (Walker, 1856).

This species is previously cited in the Middle Atlas [16], and it is newly reported in the High Atlas. It has a Holarctic distribution [102, 103] and inhabits different running and standing waters: lakes [104, 105], streams and rivers [46, 106, 107], springs [106, 107], peat bogs [106], and ponds [108, 109].

We collected one larva of this species in a summer sample (on July 08, 2020), made in the mountain river of Aït Bouguemaz (B6-Tabant) at 1849 m of altitude.

Heterotrissocladius spp.

We identified four larvae, two of them were found on July 07, 2020, in the highest spring of Ahançal (A1-Ighboula n'Taghia, 2043 m of altitude) and the others were sampled on July 05, 2020, in the lowest section of this stream (A8-Bouatass, 1086 m of altitude). It is useful to reminder that this genus contains up to 15 species and has a worldwide distribution [102].

(16) Genus Hydrobaenus Fries, 1830

Hydrobaenus sp.

In Morocco, one species of this genus, *H. conformis*, was discovered for the first time in the Rif mountains by Kettani and Moubayed-Breil [110]. Our work expands its distribution to the Central High Atlas.

The genus *Hydrobaenus* is Holarctic [111] and contains at least 51 species [112], inhabiting diverse habitats [113], including saline and brackish waters and lagoons [110]. Some species are cold-stenothermal, preferring oligotrophic conditions [113]. We collected one larva of this genus on July 07, 2020, in the highest section of Ahançal stream (A2-Taghia, 1967 m of altitude).

(17) Genus Metriocnemus van der Wulp, 1874

Metriocnemus spp.

This genus is represented in Morocco by five species, reported from the Rif and the High Atlas Mountains [16]. The genus has a worldwide distribution and presently includes 67 species [114]. It inhabits mosses and phytotelmata, springs, streams, and occasionally lakes and pools [115, 116]. In our study area, we identified this genus through 6 larvae found in a summer sample (July 08, 2020), in Aït Bouguemaz stream (B8-Agouti, 1766 m of altitude).

(18) Genus Nanocladius Kieffer, 1913

Nanocladius spp.

This genus has a worldwide distribution and comprises 34 species [117], while only four of them are known in Morocco, from the Rif and Middle Atlas Mountains [16]. The *Nanocladius* larvae are found in lotic and lentic habitats [118], some species (i.e., *N.*

plecopteracoluthus) have been found living symphoretically on the larvae of other insects, as Plecoptera, Megaloptera and Ephemeroptera [119, 120]. The material we collected (3 larvae) was found in a summer sample (July 08, 2020) at Tabant (B6), in Aït Bouguemaz river, at 1849 m of altitude.

(19) Genus Orthocladius van der Wulp, 1874

Orthocladius spp.

This genus is represented in Morocco by 12 species, cited in the Rif, Middle Atlas, and the High Atlas Mountains [16]. It has a very worldwide distribution [121], and includes at present 142 species, 104 among them being in the Palearctic region [122, 123]. The larvae are found in high variety of inland waters and moist soils [97, 121].

In our study, an abundant material (95 larvae) was collected between 1086 and 2408 m of altitude, mostly from Ahançal river: Ighboula n'Taghia (1 larva on March 07, 2020, and 17 others on July 07, 2020); Taghia (2 larvae on July 07, 2020); Ouakhoudan (10 larvae on July 03, 2020, 6 others on July 04, 2020); Tanokkrit (7 larvae on July 04, 2020); Bouatass (39 larvae on July 05, 2020). In Aït Bouguemaz river, we found it in three sites: Agouti (7 larvae on July 08, 2020); Aghbalou n'Taghfist (1 larva on September 14, 2019); Aghbalou n'Aguerd N'Ouzrou (3 larvae on September 15, 2019). Some of these sites are cold or fresh springs.

Among all this material, two larvae, collected on July 09, 2020, in Aït Bouguemaz stream (Aghbalou n'Tawaya), are attributed to the subgenus *Euorthocladius*.

(20) Genus Parakiefferiella Thienemann, 1936

Parakiefferiella spp.

Two species (*P. coronata* and *P. wuelkeri*) were recorded in Morocco, in the Rif and High Atlas Mountains [16]. This cosmopolitan genus [124] contains 44 species, 33 of them being Palearctic [125]; it inhabits both standing and running waters [124] and is often found in mosses of high mountain brooks [51]. In our study area, we collected this genus from 6 different habitats; 4 of them are in Ahançal stream: 12 larvae on July 07, 2020, in Ighboula n'Taghia (A1); 5 larvae on July 03, 2020, and 8 larvae on November 30, 2019, in Ouakhoudan (A5); 9 larvae on July 03, 2020, in Almou n'Ofarsig (A6); and 28 larvae on July 05, 2020, in Bouatass (A8). In Aït Bouguemaz stream, we found 3 larvae on July 09, 2020, in Aghbalou n'Aguerd N'Ouzrou (B7) and 5 larvae on July 08, 2020, in Agouti (B8).

(21) Genus Parametriocnemus Goetghebuer, 1932

Parametriocnemus spp.

The genus is represented in Morocco in the Rif and the Middle Atlas, by four species [16] and we found it in the central High Atlas. It is a worldwide genus, composed of 35 species [122], which are found in aquatic habitats but sometimes on their banks [126, 127]. Most of these species are cold-stenothermic [127] in the sense that they prefer cold streams [107, 128].

We found larvae of this genus in the two rivers; in Ahançal, 4 larvae on July 07, 2020, in Ighboula n'Taghia (A1); 1 larva on July 06, 2020, in Agodim (A4); and 4 larvae on November 29, 2019, in Almou n'Ofarsig (A6). In Aït Bouguemaz, 2 larvae on July 09, 2020, in Aghbalou n'Tawaya (B5) and 3 larvae on July 08, 2020, in Tabant (B6).

(22) Genus Psecrocladius Kieffer, 1906

Psectrocladius (*Allopsectrocladius*) *flavus* (Johannsen, 1905).

We discovered this species for the first time in Morocco: 6 larvae collected on July 03, 2020, in Ahançal river, at Almou n'Ofarsig (A6, 1131 m of altitude). This genus has a Holarctic distribution [129, 130] and can be found in both different lentic and lotic ecosystems [129, 131], but it seems preferring acidic waters [2]. In our study area, we found it in a large section of the river Ahançal, with slightly fluctuant temperatures.

(23) Genus Psilometriocnemus Saether, 1969

Psilometriocnemus sp.

We discovered this genus for the first time in Morocco; it seems having a large worldwide distribution [31, 132] but composed only of two species. Its larvae occur in damp soils, springs, seeps in streams [133], peatlands [134], and lakes [135]. We collected one larva on July 06, 2020, in the spring of Ighboula n'Zaouit (Ahançal stream, A3, 1641 m of altitude).

(24) Genus Thienemanniella Kieffer, 1911

Thienemanniella spp.

This genus has a worldwide distribution [136–138]; in Morocco, it is represented at least by six species, all of them being recorded in the Rif mountains, and *T. acuticornis* exists also in the Middle Atlas [16]. Our material (two larvae) collected on March 07, 2020 in the Ahançal spring, Ighboula n'Taghia (A1), extends the presence of this genus to the central High Atlas. The genus prefers fast mountain streams [139, 140], as the case of Ighboula n'Taghia spring, but some species were found in other permanent water bodies [115], including lakes [141].

(25) Genus Tvetenia Kieffer, 1922

Tvetenia spp.

This genus has a wide distribution in the Palearctic region [142]; in Morocco, it shows four species that occur in three mountainous regions High Atlas, Middle Atlas, and the Rif [16]. The larvae of this genus are found in springs [58, 143] and in different running waters [19, 65, 144]. During our study, we collected 12 larvae on November 30, 2019, in Ahançal river at Ouakhoudan (A5, 1229 m of altitude).

(26) Genus Zalutschia Lipina, 1939

Zalutschia sp.

In Morocco, this genus is known through one species (*Z. humphriesiae*), reported in the Rif region [16]. Our study highlights the presence of the genus in the Atlas Mountains.

This Holarctic genus [57] occurs in lakes [145, 146], shallow marshes [10], and ponds [147], but its larvae were also found in the upper courses of rivers. During our research, we collected one larva on July 10, 2020, in Aït Bouguemaz basin, especially in the intermittent spring of Taghbalout n'Iglouan (B3, 2075 m of altitude).

(27) Genus Parachironomus Lenz, 1921

Parachironomus frequens (Johannsen, 1905).

This species was previously reported in the Rif region [16], and our research highlights its presence in Atlas Mountains. Indeed, we identified one larva in a winter sample (December 01, 2019), from Aït Bouguemaz river, at Tabant (B6, 1849 m of altitude). This Holarctic species [148, 149] is widely spread in the Mediterranean region [20]. *P. frequens* occurs in rivers, lakes, coastal ponds, and brackish marshes [20, 150, 151].

(28) Genus Polypedilum Kieffer, 1912

Polypedilum sp.

With more than 520 known species worldwide [152], this genus is almost cosmopolitan [153]. It provides 20 species in Morocco, making its distribution widespread in the Atlas and Rif Mountains, and the Atlantic Plains [16]. The larvae occur in all kinds of standing and flowing waters [153], some species living on Trichoptera [115]. During our study, we collected one larva on July 30, 2020, in Ahançal river, at Almou n'Ofarsig (A6; 1131 m of altitude).

(29) Genus Paratanytarsus Thienemann and Bause, 1913

Paratanytarsus spp.

With about 45 valid species, this genus is known in the Holarctic region [154], where it was found in outflows of lakes, coastal rivers, and temporary pools [154]. In Morocco, 7 species represent the genus [16]; they are found in the Atlantic plain and the montane regions (Rif, Middle Atlas, and High Atlas). In our prospections, we found larvae in the Ahançal river, at Ouakhoudan (A5, 1229 m of altitude), where we collected 2 larvae on July 03, 2020, and 5 larvae on November 30, 2019, and in Aït Bouguemaz river, we collected 3 larvae at Agouti (B8, 1766 m of altitude), on July 08, 2020, and 1 larva at spring, Aghbalou n'Aguerd N'Ouzrou (B7, 1836 m of altitude), on July 09, 2020.

(30) Genus Rheotanytarsus Thienemann and Bause, 1913

Rheotanytarsus spp.

The genus is almost cosmopolitan [154, 155] and inhabits running waters [126, 155] and rough waters in lake shores [108, 156]. In Morocco, 13 species belong to this genus, which has a wide distribution Rif, Middle Atlas, High Atlas, Anti Atlas, and Atlantic Plains [16]. Our study was permitted to collect larvae of this genus from Ahançal river: 2 larvae on July 03, 2020, and 31 larvae on November 30, 2019, at Ouakhoudan (A5); 3 larvae on July 07, 2020, at Taghia (A2); and 4 larvae on November 29, 2019, at Almou n'Ofarsig (A6). In Aït Bouguemaz river, we collected 2 larvae on July 09, 2020, and 2 larvae on September 15, 2019, at Aghbalou n'Aguerd N'Ouzrou.

(31) Genus Tanytarsus van der Wulp, 1874

Tanytarsus spp.

This genus has a Holarctic-Neotropical distribution [157–159], where it occurs in almost all types of freshwater [159], and even in coastal marine habitats [115] and some terrestrial environments [160]. It occurs in almost all the regions of Morocco (Atlantic Plains, Rif, High Atlas, Anti-Atlas, and Eastern Plateaus), where it is represented by 19 species [16]. Our investigations reveal only 3 larvae, collected on July 03, 2020, in Ahançal river, at Ouakhoudan (A5).

3.2.3. F. Tipulidae

(1) Genus Tipula Linnaeus, 1758

Tipula (*Yamatotipula*) *barbarensis* Theowald and Oosterbroek, 1980.

This West palearctic species has been cited in different region of Morocco, as the Atlantic Plains, Middle Atlas, High Atlas, and the Rif [16, 161]. Its male seems anthropophilic [162], but in Morocco, it was collected in rivers at different altitudes [161]. In our study, we found one larva in Aït Bouguemaz river, at Agouti (B8, 1766 m of altitude), on July 08, 2020.

Tipula (*Yamatotipula*) *pierrei* Tonnoir, 1921.

This species is widely distributed throughout the Palearctic Region [163, 164], but it was unknown in Morocco before our study. Its larvae are usually found on the grazing edges of ponds and lakes [165–167] or rivers [168, 169]. In Aït Bouguemaz river, we found four larvae on July 08, 2020, at Tabant (B6, 1849 m of altitude), in a shallow habitat.

3.2.4. F. Empididae

(1) Clinocerinae

Genus *Wiedemannia* Zetterstedt, 1838.

Wiedemannia sp.

This genus has a worldwide distribution, but its greatest richness is in the Western Palearctic, more especially in the Mediterranean region [170], where it is common in streams and small rivers [171, 172], generally clear and

fresh [173, 174]. In Morocco, the genus has six species that are already known in the High Atlas mountains [16] and we found it in Assif Ahançal: one larva collected on July 03, 2020, at Ouakhoudan (A5, 1229 m of altitude).

Genus *Chelifera* Macquart, 1823.

Chelifera spp.

This genus is newly cited in North Africa, even if it is distributed nearly worldwide, except in the Afrotropical region [175–177]. Its larvae can be found in lakes but more especially in streams, predominantly in mountains, including seepages and trees, leaves, and bushes [177, 178]. We found it in Assif Ahançal: one larva at Ouakhoudan (A5), on November 30, 2019, and one larva at Ighboula n'Zaouit, on July 06, 2020.

Genus *Hemerodromia* Meigen, 1822.

Hemerodromia spp.

This genus has a worldwide distribution and occurs predominantly in well-oxygenated lotic habitats, but some species may occasionally be found in lentic waters [179, 180]. In Morocco, five species are known, in the High and Middle Atlas Mountains [16], and we collected several larvae in both studied rivers. In Assif Ahançal, we collected larvae at Almou n'Ofarsig (one larva on November 29, 2019), at Ouakhoudan (5 larvae on November 30, 2019, and 7 larvae on July 03, 2020), and at Ighboula n'Taghia (10 larvae on July 07, 2020); in Assif n'Aït Bouguemaz, we found one larva at Tabant, on July 08, 2020.

3.2.5. F. Tabanidae

(1) Genus Chrysops (Meigen, 1803)

Chrysops viduatus (Fabricius, 1794).

This is a Eurosiberian species that spreads to some Mediterranean islands [181, 182] and Morocco [183]. Its larvae are detritophagous, developing mostly in swampy parts of shores, in piles of roots and mosses of black-alder marshes [184, 185], river [186], and even in springs.

In Morocco, this species was initially found at Setti Fatma, in the High Atlas piedmont south of Marrakech [183]; where it is collected from a spring [183]. We found it only in Assif Ahançal, at a spring, Ighboula n'Zaouit (1 larva on July 06, 2020), and in a stream, Ouakhoudan (1 larva on July 03, 2020).

3.3. Overview of the Influence of Altitude on Communities. This preliminary study allowed a first illustration of the *Diptera* distribution according to altitudes (Table 4), which reveals three groups of taxa, preferring respectively high, medium, and low mountains; a fourth group, composed of taxa with large altitudinal distribution, overlaps the previous groups.

Another synthesis of these results is made by representing the altitudinal variation of richness and cumulated abundances (Figure 3) of the *Diptera* assemblages; this figure shows that the high mountain communities are generally poor (in terms of both richness and abundance), in comparison with low mountain communities. This pattern has already been highlighted in North Africa [14], as well as in other regions [126, 187] at least relating the richness.

However, in the present study, we record remarkable exceptions to this pattern, as the high richness in the high mountainous spring A1 (2043 m) and the very low richness at low mountain waters of A7 (1128 m). In A1, this richness can be related to the regular flow of the spring, which contributes to habitat diversification. In the site A7, the water depth and speed are high and the riverbed is dominated by big boulders; these conditions make it difficult to sample benthic invertebrates.

This means that only a more deep study of the *Diptera* of these rivers can provide reliable information on the ecological preferences of the species towards both elevation and habitats.

4. Discussion

The recent published catalog of Moroccan *Diptera* [16] contains 3057 species, distributed into 949 genera and 93 families; our research in the central High Atlas Mountains contributes to the knowledge of only five families among this fauna, which families comprised until now a total of 622 species in Morocco, shared by 128 genera [16]. This research, even limited to larvae, adds a minimum of eight species to this catalog. Indeed, we identified three species and five genera (probably corresponding to more than five species) that were unknown in Morocco before this study.

In addition to these novelties, our investigations extended the Moroccan distribution of eight taxa to the High Atlas Mountains. This means that our knowledge of some families of Aquatic Diptera is still very poor in Morocco. The difficulties in identifying them at immature stages constitute probably the major obstacle to their use in the quantitative ecology studies carried out in Morocco. However, this is not the case of the groups that are important in medicine, veterinary, or agriculture, as *Culicidae* [188] and *Simuliidae* [189], and all *Diptera* of the Rif Mountains, which have been well studied, due to their proximity to the University of Tetouan, where there is a great team of Dipterologists.

In both studied rivers, Chironomidae are the most diversified (31 genera, within which 8 species were identified) and abundant (94% of the total abundance). Its highest abundances are in the lower sector of Assif Ahançal, where they cumulate 60% of their total abundance in two sites (A5 and A8). This family is also relatively abundant in three fresh springs: B1-Aghbalou n'Taghfist and B3-Taghbalout n'Iglouan in Aït Bouguemaz and A1-Ighboula n'Taghia in Ahançal.

Unlike the Chironomids, we note poor results about the other families, both in their relative abundance (4.8% for *Empididae* and less than 1% for the others) and richness (1–3

Table 4: Altitudinal distribution of the collected *Diptera* in the two studied rivers.

Taxa\sites (in elevation order) =>	B1	B2	B3	A1	B4	B5	A2	B6	B7	B8	A3	A4	A5	A6	A7	A8	
Altitudes =>	2408	2140	2075	2043	2006	1978	1967	1849	1836	1766	1641	1607	1229	1131	1128	1086	Distribution patterns
Habitats types =>	S	MS	S	S	S	S	MS	MS	S	MR	S	MS	MS	MR	MR	MR	
Number of species =>	2	1	1	9	1	2	4	10	5	9	4	2	15	9	1	7	
Total numbers of individuals =>	2	1	1	58	3	4	18	36	12	49	8	2	146	29	7	180	
Cardiocladius spp.	◦			•													
Diamesa sp.		◦															
Zalutschia sp.			◦														Alticolous taxa
Thienemanniella spp.				◦													
Atrichopogon sp.				◦													
Heterotrissocladius spp.				◦												◦	
Hemerodromia spp.				•				◦					●	◦			
Parametriocnemus spp.				•		◦		•				◦		•			
Orthocladius spp.	◦			●			◦		•	•			●		•	●	
Parakiefferiella spp.				●					•	•			●	•		●	Taxa with large altitudinal range
Cricotopus spp.				•	•		●	●		•	•		●			●	
Orthocladius (Euorthocladius) sp.						◦											
Rheotanytarsus spp.							•		•				●	•			
Hydrobaenus sp.							◦										
Macropelopia nebulosa								•									
Tipula (*Yamatotipula*) *pierrei*								•									
Nanocladius spp.								•									
Rheopelopia maculipennis								◦									
Thienemannimyia spp.								◦									
Heterotrissocladius marcidus								◦									
Parachironomus frequens								◦									
Macropelopia notata									◦								
Paratanytarsus spp.									◦	•			•				Taxa preferring medium mountain waters
Krenopelopia spp.										●							
Natarsia spp.										•		◦	◦				
Metriocnemus spp.										•							
Brilla sp.										◦							
Tipula (*Y/*) *barbarensis*										◦							
Psilometriocnemus sp.											◦						
Chelifera spp.											◦		◦				
Chrysops viduatus											◦		◦				

Table 4: Continued.

Taxa\sites (in elevation order) =>	B1	B2	B3	A1	B4	B5	A2	B6	B7	B8	A3	A4	A5	A6	A7	A8	
Altitudes =>	2408	2140	2075	2043	2006	1978	1967	1849	1836	1766	1641	1607	1229	1131	1128	1086	Distribution patterns
Habitats types =>	S	MS	S	S	S	S	MS	MS	S	MR	S	MS	MS	MR	MR	MR	
Number of species =>	2	1	1	9	1	2	4	10	5	9	4	2	15	9	1	7	
Total numbers of individuals =>	2	1	1	58	3	4	18	36	12	49	8	2	146	29	7	180	
Ablabesmyia sp.													●	◦			
Tvetenia spp.													●				
Tanytarsus spp.													•				
Culicoides sp.													◦				
Wiedemannia sp.													◦				
Ablabesmyia (A.) monilis														◦			Taxa preferring low mountain rivers
Conchapelopia sp.														◦			
Polypedilum sp.														◦			
Psectrocladius (*A.*) *flavus*														•			
Eukiefferiella spp.													•			●	
Telopelopia fascigera																◦	
Zavrelimyia sp.																◦	

Habitat types: S = spring; MS = mountainous stream; MR = mountainous river. Abundance: 1-2 (◦), 3–10 (•), 11–20 (●), and >20 (●).

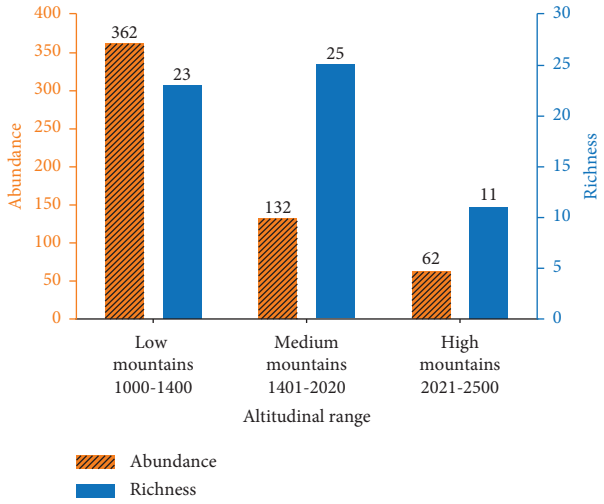

Figure 3: Altitudinal variation of richness and abundance of *Diptera* communities.

genera). This poverty is partly due to the sampling protocol used in this first investigation phase; indeed, the field survey was interrupted during the spring season (April to June), in relation with the COVID-19 restrictions; in addition, the Surber-net sampler do not cover habitats specific to the highly selective species, particularly preferring seepage or moss microhabitats or inhabiting running water edges rich in organic matter, etc. This is particularly true for *Tipulidae* and *Empididae*, which are very poor in our samples, while they contain, respectively, 39 and 40 species in Morocco.

The two rivers have similar richness (21 and 21 taxa), even if their fauna composition and their altitudes are different (see Table 2).

Despite some weakness of our sampling plan, the results of this study confirm a significant influence of the altitude on the distribution pattern of the *Diptera* communities; this gives hope that a continuation of this study will provide very significant results on the ecology of *Diptera*. In addition, as we know that the springs are rich in endemic taxa [14, 190], this gives hope that a sampling of adult material will permit to discover additional new species for Morocco.

5. Conclusion

This study, even though based on immature stages, allowed us to produce a first inventory of five aquatic dipteran families of the two studied rivers. This inventory, limited for most taxa to the genus level, provides interesting biogeographical novelties, as it contains four new genera for the country, nine genera for the High Atlas, and three new species for Morocco. The collected dipteran material provided some ecological information, mainly linked to the altitudinal distribution of the studied families; however, its interpretation needs more investigation about the other families, and more especially a great effort in adult harvesting.

Our future objective is to use diverse qualitative sampling methods, mainly applicable to dipteran adults, in a way to push the taxonomic identification to the species level and complete the inventory of the whole dipteran fauna of the two studied rivers. As the aquatic habitats of the central High Atlas are somehow original due to their elevation range, their diversity, and their relatively wild state, in the sense that they are less disturbed than in other regions.

We planned to continue our research on the High Atlas running waters, with the hope of discovering more novelties for the country and probably for science. Another major result expected consists in improving the biodiversity assessment of the Ahançal and Lakhdar rivers, as Ramsar sites, knowing that this type of ecosystems is under-represented in the Ramsar list of wetland of international importance.

Data Availability

The datasets used and/or analysed during the current study are available from the corresponding author on request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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