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Habitat Characterization of Black Flies (Diptera: Simuliidae) in the Tafna Catchment of Western Algeria

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Abstract

Physical Habitat characterization of black flies was performed in the Tafna Basin of Algeria, based primarily on stream size, substrate, and aquatic and riparian vegetation. A total of 143 samples were taken between April and October 2009 at 11 sampling sites in the Tafna catchment. Dams exerted an effect through a slowdown of flow and sedimentation of fine particles, eliminating coarse microhabitats favorable for black flies. Stream and substrate characteristics are key parameters that determined the microhabitats of the species. Of 10 species considered, four were widely present with significant plasticity for the stream and substrate. Four other species were more closely associated with faster streams and eroded substrate. A greater rheophilic tendency was found for *Simulium bezzii* (Corti), *Simulium sergenti* Edwards, *Simulium quadrifila* Grenier, Faure and Laurent and *Simulium galloprovinciale* Giudicelli, which represents a new record for Algeria.

Keywords

Mediterranean Fauna, Aquatic Insects, Diversity, Ecology, Microhabitat, Microdistribution

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1. Introduction

Among the benthic macroinvertebrates of Algerian wadis, larvae and pupae of Diptera Simuliidae have received less attention. Apart from the first inventory [1], the early studies were devoted to the description of species but rarely to their ecology [2]-[5]. During the last three decades, the only available ecological data are scarce [6]-[8] and more recently those of Chaoui Boudghane-Bendiouis [9] and Cherairia [10].

The present study, performed 25 years after the work by Gagneur and Clergue-Gazeau [6] on Simuliidae in the Tafna catchment, aims to identify the faunal composition, to provide update simuliid geographic observations and understand the organization of the community by analysis of the micro-distribution of species within differentiated microhabitats according to the current-substrate complex. The concept of a relationship between the specific characteristics of microhabitats and the micro-distribution of macroinvertebrates has been highlighted by numerous authors [11]-[14].

2. Materials and Methods

2.1. Study Site

Wadi Tafna, which is located in northwestern Algeria, originates from the Tlemcen Mountains (Tell Atlas) and flows 170 km to the north and empties into the Mediterranean Sea. Its catchment area is about 7245 km^2 (**Figure 1**).

Tafna catchment mainly includes two geological structures: Tlemcen Mountains in the south, containing dolomitic terrains rich in carbonates of the Upper Jurassic, and the plain of Remchi in the north, consisting of clay-sandstone deposits of the Miocene. Valley bottoms are covered with alluvial Quaternary deposits [15]. The regional climate is Mediterranean with mild and wet winters; it is semi-arid over the entire catchment.

The upstream lands are highly cracked and karst-like, which gives them high permeability and a significant flow of groundwater that emerges at the surface as springs [16]. This provides the upstream wadis with some hydrological stability. In contrast, the downstream basin receives irregular and mostly seasonal rainfall, which results in a series of floods and low water periods in wadis at medium and low altitudes [17]. In the immediate vicinity of the upstream sites, the land is partly used for limited market gardening. Downstream, crop growing predominates in the plain, alternating with vegetable crops. These are irrigated by pumped water that affects the flow of streams.

2.2. Sampling Methods

Sampling was carried out at seven sites along wadi Tafna, one site in wadi Khemis, another in wadi Chouly, and two other sites in wadi Isser, the main tributary of wadi Tafna (**Figure 1**). To achieve representative sampling of the catchment, the 11 sites were randomly drawn from upstream to downstream. Three classes of sampling sites were selected (1) sites of high Tafna, from 0.5 to 11.5 km from the source and located between 1090 and 650 m altitude, (2) sites of middle Tafna, from 50 to 54.5 km, at altitudes between 303 and 220 m, and (3) sites of low Tafna at more than 75 km with an altitude between 83 and 45 m.

Benthic samples were taken using a Surber sampler (mesh net 300 µm), considering four main physical factors: current velocity, type of substrate, and aquatic and riparian vegetation. Measurements of the instantaneous stream velocity, using the weighted float technique [6], allowed five classes of currents velocity to be identified (VF: very fast, F: fast, M: medium, S: slow, VS: very slow). The substrate nature (**Table 1**) was determined from the erosion facies (coarse grains: rocks, stones and pebbles) or from sedimentation (fine grains: sand, silt, and mud). Three types of substrates were defined as eroded, deposited and heterogeneous (fine and coarse elements). Aquatic vegetation included all living organic materials in the form of dense herbs, submerged and emergent spermaphytes, and bryophytes and algae. The riparian vegetation was assessed through plant stratification (herbaceous, shrubby and arborous). Thus, 143 samples were collected at 11 sampling sites in 2009 (March to November). The sampling effort was the same for all sites, at the rate of two outlets per month, but the number of samples per site was linked to the specific spatial heterogeneity.

The black flies were counted and determined morphologically to species level, using the analytic key and descriptions of Simuliidae of Morocco [18].

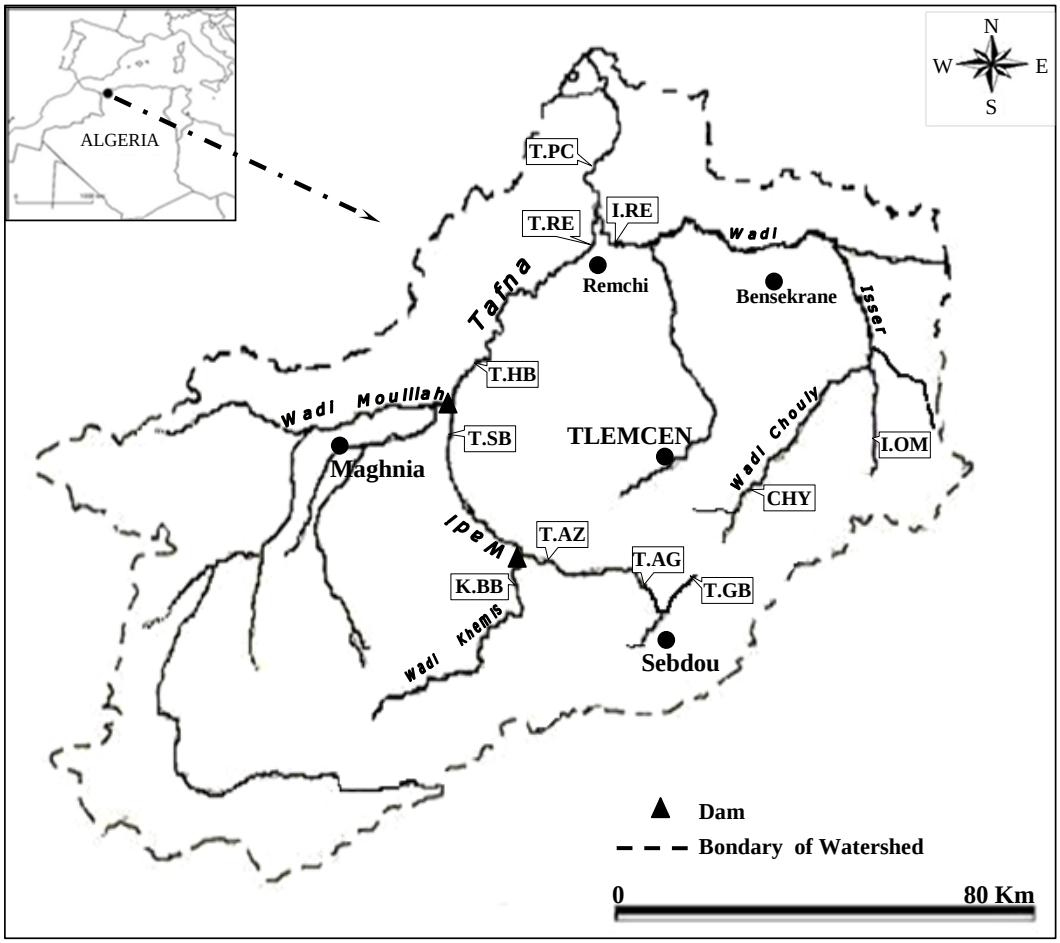

Figure 1. Map of the Tafna River Basin in western Algeria, showing locations of sampling sites for simuliids.

Table 1. Geographical and physical characteristics of sampling sites in Tafna River Basin, Algeria (March-November 2009).

Sites	Longitude	Latitude	Altitud (m)	Orientation	Distance from the source	Width of riverbed (m)	Dominant substrate	Turbidity	Maximum depth (cm)	Riparian vegetation	Human impact
T.GB	1˚18′42″	34˚41′3″	1090	N-S	0.56	3	P	C	60	Hb	A, Gz
T.AG	1˚22′16″	34˚41′56″	787	SE-N	8.35	3	P, G, S	C	100	Ps	A
T.AZ	1˚27′52″	34˚41′42″	664	SE-NO	11.44	5	S, M	T	60	Ps	A
T.SB	1˚39′14″	34˚49′31″	303	SE-NW	49.90	7	P, S	T	40	Sh	A
T.HB	1˚37′39″	34˚55′31″	220	SW-NE	54.43	8	S, M, Si	T	50	Sh	A
T.RE	1˚27′51″	35˚04′35″	83	SW-NE	78.40	20	M, Si	T	50	Sh	A
T.PC	1˚26′58	35˚08′37″	45	S-N	85.52	20	M, Si	T	40	Hb	A
K.BB	1˚30′20″	34˚40′57″	650	S-N	19.70	30	M, Si	T	1500	Hb	A
CH.Y	1˚9′58″	34˚50′26″	850	SE-NW	10.22	3	R, P	C	40	Sh	A
I.OM	1˚00′52″	34˚54′08″	870	SW-NE	1.15	4	P, M, Si	T	70	Ps	A
I.RE	1˚26′32″	35˚05′40″	80	S-N	66.77	5	M, Si	T	60	Ps	A

R = rocks, P = cobble, G = gravel, S = sand, Si = silt, M = mud, C = clear, T = turbid, Ps = pluristratified, Sh = shrublands, Hb = herbaceous, A = agriculture, Gz = grazing.

2.3. Data Processing

The spatio-temporal distribution of black flies was first studied using a factorial analysis (AFC) from the data matrix, taking into account species abundances only in prolific samples containing at least two individuals. An analysis of inertia was then performed to assess the proportion of variability explained by each of the five variables: five variables: station, month of sampling, stream velocity, substrate nature and class of distance from the source. A Monte Carlo Permutation Test was performed to test the significance of this variability. The dot plot was used to illustrate the distribution of species abundance for each site. These statistical analyses were performed using Minitab 16.1 statistical software.

The structure of black fly communities for each site was determined by calculating diversity indices: specific richness S, Margalef index (Dmg = S − 1/ln (N)), Shannon index ($H' = -\Sigma pilnpi$), and Piélou index ($J' = H'/H\max$). Hierarchical Cluster Analysis (HCA), performed from the matrix of samples for black flies and the studied physical characteristics, was used to measure the degree of similarity, according to the euclidean distances and aggregation, using Ward's method (moment of second order).

3. Results

3.1. Faunal Composition and Biogeographic Considerations

Ten species were recorded among more than 7208 specimens (**Table 2**). All belong to the genus *Simulium*, represented by five subgenera, namely *Eusimulium*, *Nevermannia*, *Simulium*, *Trichodagmia*, and *Wilhelmia*. The most frequent species in our samples have a wide Palaearctic distribution. These species include *S. velutinum*, *S. ornatum* (complex), *S. trifasciatum* and *S. pseudequinum. Simulium intermedium* is widespread in Europe and also in northwest Africa.

Some less abundant and less frequent species have either a Mediterranean distribution (*S. bezzii* and *S. galloprovinciale*) or an Ibero-Maghreb distribution with limited extension (*S. sergenti* and *S. quadrifila*). *Simulium ruficorne* has an Ethiopian distribution.

3.2. Spatial Distribution of Black Flies

Of all samples (143), 70% did not contain black flies; 38.5% of these were taken from areas with slow current and a deposited substrate consisting of fine sediments (sand, silt, and mud), 26.6% from fine substrate colonized by aquatic vegetation forming dense herbaceous growth, and 4.9% from a bottom covered with algae. These habitats were predominant at sites K.BB and T.SB. Although located in high and medium Tafna, these sites are upstream of dams (Beni Bahdel and Hammam Boughrara, respectively).

The presence of these dams results in slow flow, homogenization of facies, and sedimentation of fine elements, eliminating coarse microhabitats favorable for black flies. Inertia analysis showed that the highest inertia percentage concerns the variable station (68.8%) with a significant difference, according to the Permutation Test

Table 2. Total numbers of 10 species of *Simulium* collected in the Tafna River Basin, Algeria.

Subgenus	Group	Species	Numbers
Eusimulium		*S. velutinum* (Santos Abreu) (complex)	1353
Nevermannia	*S.* (*N.*) *ruficorne*	*S. ruficorne* Macquart	1
Simulium	*S.* (*S.*) *bezzii*	*S. bezzii* (Corti)	385
	S. (*S.*) *ornatum*	*S. intermedium* Roubaud	898
		S. ornatum Meigen (complex)	1489
		S. trifasciatum Curtis	2149
Trichodagmia		*S. galloprovinciale* Giudicelli	12
Wilhelmia	*S.* (*W.*) *equinum*	*S. pseudequinum* Séguy	897
		S. quadrifila Grenier, Faure and Laurent	6
		S. sergenti Edwards	18

(p = 0.019), revealing that distributions would primarily be determined by the factor station; p remained insignificant for the other four variables analyzed.

At all the sites, the Margalef index values were less than 2 and the index *H'* fluctuated between 1.97 and 0.97, indicating low diversity. However, the values of the index *J'*, always greater than 0.5, indicated the presence of regular and balanced communities (**Table 3**).

The communities of upper Tafna sites (T.GB, T.AG, T.AZ, and CH.Y) displayed the greatest specific richness due to certain typical species. *Simulium galloprovinciale* was collected exclusively in wadi Chouly (CH.Y) and *S. quadrifila* at site T.AG (**Figure 2**). Upstream of Beni Bahdel dam, the two sites T.AG and T.AZ have *S. sergenti*. However, *S. bezzii* is abundant in samples from three upstream sites (T.GB, T.AG and CH.Y). Moreover, the lowland sites have mostly species such as *S. velutinum*, *S. trifasciatum*, and *S. pseudequinum*. These species, the most abundant and ubiquitous taxa, are constant over the entire Tafna catchment (**Figure 2**).

3.3. Microhabitats

The 42 prolific samples tested with respect to the main physical characteristics are shown in a dendrogram, resulting from hierarchical cluster analysis (HCA) (**Figure 3**). Twelve groups were found, each corresponding to a

Table 3. Diversity index of simuliid communities at sampling sites in the Tafna Basin, Algeria.

Sites	DS	N	S	D.mg	*H'*	*J'*
T.GB	1	307	4	1.75	1.79	0.89
T.AG	1	2313	8	1.96	1.97	0.65
T.AZ	1	146	5	1.85	1.94	0.83
T.HB	2	22	4	1.11	1.36	0.68
T.RE	3	666	3	1.27	1.28	0.81
T.PC	3	242	3	0.95	0.97	0.61
CHY	1	3157	6	1.81	1.82	0.70
I.OM	1	20	2	0.5	1	1
I.RE	3	335	5	1.18	1.22	0.52

DS = class of distance from the source, N = sample size, S = specific richness, D.mg = Margalef index, *H'* = Shannon index, *J'* = eveness.

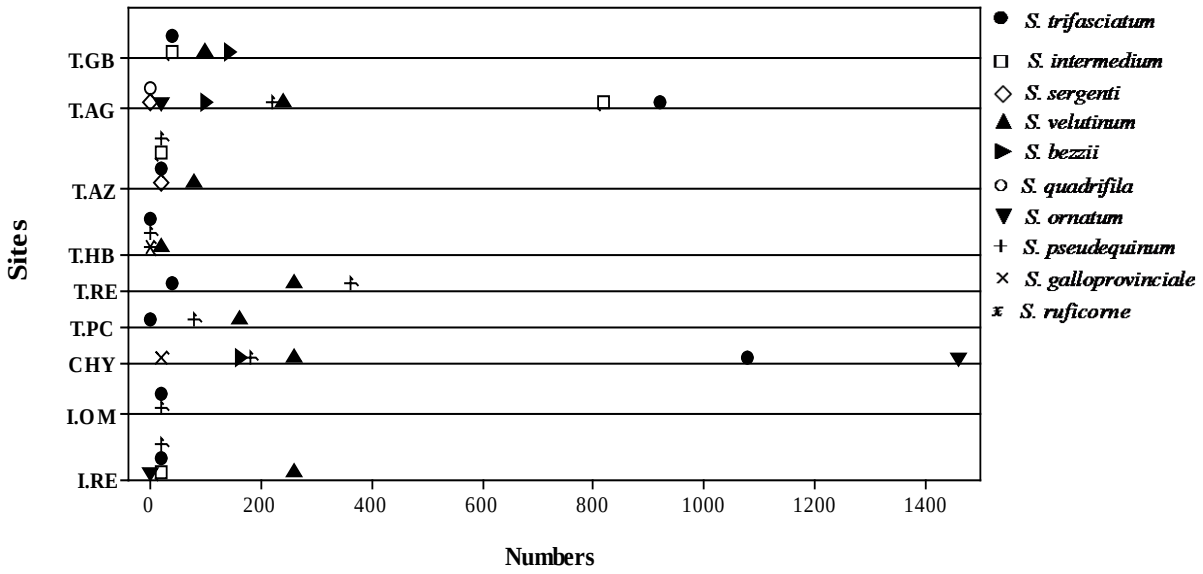

Figure 2. Dot plot showing the spatial distribution of the total number of specimens per species of Simuliidae in the Tafna Basin of Algeria (March-November 2009).

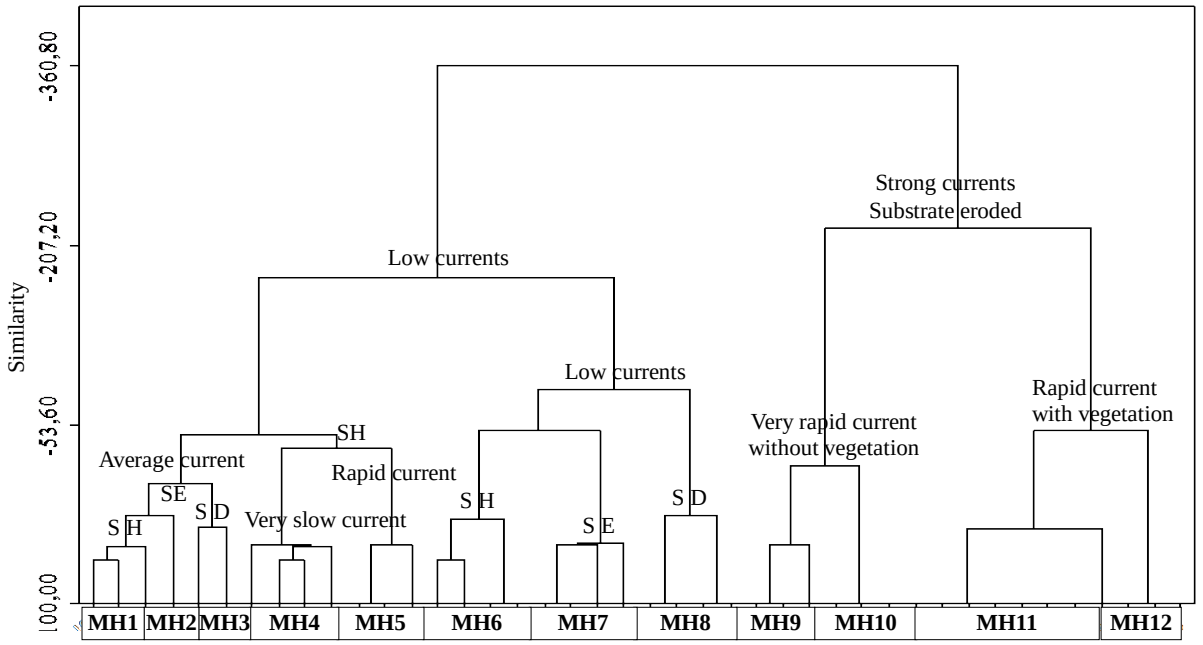

Figure 3. Dendrogram resulting from the physical characteristics of HCA microhabitats in the Tafna Basin of Algeria, defined by the current-substrate complex (SE = substrate eroded; SH = heterogeneous substrate; SD = substrate deposited).

microhabitat identified by the stream-substrate complex. The number of samples per microhabitat ranged from 1 to 7. Two large sets could be distinguished: (1) four microhabitats (MH 9-10-11-12) with strong currents on eroded substrate, including 17 samples (40.5%), (2) eight microhabitats, including 22 samples (52.4%) with low current and heterogeneous or deposited substrates, and three samples (7.1%) with fast currents and heterogeneous substrates. **Table 4** summarizes the characteristics of the 12 microhabitats, their occurrence (%) and their location per station. The microhabitat MH11, with fast current and eroded substrate without vegetation, was distinguished by a higher importance (16.7%). Microhabitats MH2 and MH3 were the least representative; they were characterized by an average current and eroded or deposited substrates. The nine remaining microhabitats had a similar number of samples (3 or 4). The distribution of these microhabitats per site (**Table 4**) indicated a clear between-station effect. Therefore, microhabitat MH11 was found at four sites, and remained fairly representative. The other microhabitats were found at 2 or 3 sites in upper (T.GB, T.AG, T.AZ) and middle (T.HB, T.RE, T.PC) Tafna and rarely in its tributaries (CH.Y, I.RE, I.OM). Microhabitat MH2, with an average current and eroded substrate, was represented by a single sample taken at station T.GB, downstream of the source of wadi Tafna.

3.4. Microdistribution

Analysis of simuliid distributions in the 12 defined microhabitats (**Table 5**) revealed that species richness, as well as abundance, varied from one microhabitat to another. On an eroded substrate and fast current (MH11), the maximum richness (eight species) was found, with high abundances, exceeding 1450 individuals for the *S. ornatum* (complex) and 900 individuals for *S. trifasciatum*. With the same specific richness, abundance was substantially lower for microhabitat MH6, which had heterogeneous substrate and slow current. However, the abundance decreased slightly (up to 78 individuals for *S. pseudequinum*) on eroded substrates covered with aquatic vegetation with a fast current (MH10). In contrast, microhabitats with deposited substrate had few individuals, especially microhabitat MH8 where the current was slow.

The most common species *S. velutinum* had less than 20 individuals. Intermediate values of species richness were observed in the other microhabitats, displaying abundances higher than 100 individuals for *S. intermedium* and *S. trifasciatum* in microhabitats MH4 and MH6 with heterogeneous substrates.

Species abundance differed according to the microhabitats (**Table 5**). *Simulium velutinum* was the most plastic and widespread, occuppying all types of microhabitats. It was followed by *S. pseudequinum*, *S. trifasciatum*

Table 4. Characterization of microhabitats in the Tafna Basin of Algeria, determined by HCA according to the current-substrate couple and spatial distribution by microhabitat.

				Sampling sites								
Microhabitat	Code	p	F (%) (p = 42)	T.GB	T.AG	T.AZ	T.HB	T.PC	T.RE	I.OM	I.RE	CHY
Mean current heterogeneous substrate	MH 1	3	7.14	X			X	X				
Mean current substrate eroded	MH 2	1	2.38	X								
Mean current substrate deposited	MH 3	2	4.76	X		X						
Very slow current heterogeneous substrate	MH 4	4	9.52		X							X
Rapid current heterogeneous substrate	MH 5	3	7.14	X				X				
Slow current heterogeneous substrate	MH 6	4	9.52		X							X
Slow current substrate eroded	MH 7	4	9.52		X				X		X	
Slow current substrate deposited	MH 8	4	9.52			X	X		X			
Very fast current substrate eroded	MH 9	3	7.14			X					X	
Very fast current substrate eroded with vegetation	MH 10	4	9.52		X					X		
Fast current substrate eroded	MH 11	7	16.66		X	X		X				X
Fast current substrate eroded with vegetation	MH 12	3	7.14	X				X	X			

Table 5. Total number of specimens in 12 microhabitats of the Tafna Catchment, Algeria (March-November 2009).

Species	**MH1**	**MH2**	**MH3**	**MH4**	**MH5**	**MH6**	**MH7**	**MH8**	**MH9**	**MH10**	**MH11**	**MH12**
S. quadrifila	0	0	0	0	0	4	0	0	0	2	0	0
S. galloprovinciale	0	0	0	0	0	0	0	0	0	6	6	0
S. sergenti	0	0	1	0	0	4	0	0	0	0	13	0
S. bezzii	0	0	0	6	0	11	0	0	0	0	230	138
S. pseudequinum	3	0	1	1	25	23	1	0	364	92	304	84
S. intermedium	0	0	1	187	6	29	18	1	6	51	551	46
S. velutinum	51	4	62	61	49	11	161	17	269	42	434	193
S. ornatum complex	0	0	0	0	0	28	6	0	0	0	1455	0
S. trifasciatum	2	0	0	151	8	122	24	2	51	82	1657	50
Species richness	**3**	**1**	**4**	**5**	**4**	**8**	**5**	**3**	**4**	**6**	**8**	**5**
Abundance	**56**	**4**	**65**	**406**	**88**	**232**	**210**	**20**	**690**	**275**	**4650**	**511**

and *S. intermedium*, which were encountered in up to 10 microhabitats. These four species colonized habitats with fast and slow currents and different substrates.

Simulium bezzii was found in four microhabitats, with a significantly higher defined by the current-substrate complex. (SE = substrate eroded; SH = heterogeneous substrate; SD = substrate deposited) were characterized by fast current and eroded substrate, with or without vegetation.

The *S. ornatum* complex was found in three microhabitats; its presence in microhabitat MH11 was represented by more than 1450 individuals. *Simulium sergenti* accounted for only 18 individuals, of which 13 were in microhabitat MH11. A similar but smaller number of *S. galloprovinciale* was noted in microhabitats MH10 and MH11, each with a strong current and eroded substrate. The lowest abundance was found for *S. qua-*

drifila with only eight individuals distributed among microhabitats MH6 and MH10.

4. Discussion

Of the 10 species in our samples, seven previously have been reported in Tafna catchment by Gagneur and Clergue-Gazeau [6]: *S. velutinum*, *S. ruficorne*, *S. bezzii*, *S. intermedium*, *S. ornatum* (complex), *S. pseudequinum*, and *S. sergenti*. They have also found in wadis of the Djurdjura Mountains in northern Algeria [8] and in the Seybouse River Basin in northeastern Algeria [10]. *Simulium trifasciatum* and *S. quadrifila* were reported recently in the checklist of Simuliidae of Algeria [9], and *S. galloprovinciale* was recorded for the first time in this work. *Simulium quadrifila* is a rare species, initially described as a subspecies of *S. sergenti* [19], then raised to species level by Crosskey [20]. This species has been reported in various localities in Spain [21] [22] and northern Morocco [23] [24].

The composition of the simuliid communities is similar between Tafna catchment and neighboring countries. With lower species richness (10 species), the recorded species in Tafna are among the 27 species known in Algeria [9], the 42 species in Morocco [25], and the 50 species in Spain [26]. In the eastern Mediterranean, 12 species were reported in Lebanon [27], with three species in common with ours, namely *S. bezzii*, *S. ornatum* complex, and *S. peudequinum*, and 63 species are known in Turkey [28] with six species in common with ours. Five species are also in common with the Tunisian fauna, which includes 18 species [29]. The number of simuliid species collected is relatively low compared to other catchment in Maghreb. Lounaci [8] identified 19 species in Sebaou Basin, Belqat [30] reported 14 species in Laou Basin, and Guidicelli [31] found 24 species in the High Atlas. Eight nominal species and species complexes in three genera were identified in the Seybouse River Basin in northeastern Algeria [10]. *Simulium bezzi* and *S.* (*S.*) *ornatum* were also found in Pyrenean rivers [32]-[35]. The low diversity of black flies in two catchments in southern Spain was noted by Gallardo-Mayenco and Toja [36] who reported values of H' less than 1.

The presence of larvae and pupae of black flies in Tafna catchment is linked to the availability of favorable habitats, especially with high current and eroded substrate. These restricted habitats (30%) limit the simuliids, which are known for their rheophily and preference for hard, coarse substrates (rocks, stones, pebbles) [7] [31]. This probably explains their absence in 70% of samples characterized by deposited substrates (fine elements) and bottoms colonized by aquatic vegetation.

Simuliid distributions in the Tafna catchment were determined, in part, by the station effect. This spatial variability has been demonstrated in several studies in which altitude played an important role [37]-[40]. Studies [31] [41] revealed that simuliid distributions depend on two main physical factors: water temperature and altitude. However, in our study, the effect of distance from the source, which is related to altitude, is not significant. Current and substrate are key parameters determining microhabitats in sites of the Tafna catchment. The four most abundant species in Tafna basin are *S. velutinum*, *S. trifasciatum*, *S. intermedium* and *S. pseudequinum*, compared with three (*S. velutinum*, *S. intermedium* and *S. pseudequinum*) in Sebaou basin where *S. trifasciatum* is absent. Larvae and pupae of these species are abundant in shallow waters, rich in organic material and filamentous algae [8]. The ability of these species to inhabit a large range of ecological factors was reported by several authors [6] [7] [21] [31] [36]. Larvae of *S. velutinum* are found at moderate velocities, but also can be found in slow currents [24]. *Simulium intermedium* colonizes temporary, semi-permanent and permanent habitats with variable substrates and low to average velocities [24]. It can develop in waters heavily loaded with organic material [24] [42]. In Europe, *S. trifasciatum* is confined to small streams with stony substrates and slow current and abundant vegetation [21], and in highly oxygenated waters [22]. In Morocco, this species appears to be a strictly montane form that colonizes substrates in moderate to fast currents [30] [41] [43]. In Turkey, it is associated with calcareous waters of the sources [44]. *Simulium pseudequinum* is collected in large numbers in microhabitats with eroded substrate and fast currents, with or without vegetation, but rarely in slow currents. This Palaearctic species, widely represented in England [45], is common in Morocco [30] and Tunisia [46] in all habitats, especially those with rocky substrates. *Simulium bezzii* is limited to three sites in the upper Tafna basin and colonizes microhabitats with eroded bottoms swept by fast current. In the northern Mediterranean, it is associated with mountain and piedmont streams with fast flow and rocky bottoms [32]-[34] [38]. In Morocco, *S. bezzii* is found on muddy bottoms with stones and slow to fast currents [24].

Belqat [24] considered sympatry of *S. intermedium* and *S. ornatum* (complex) to be typical in Morocco. However, this sympatry is rather rare in Portugal and Spain [47] [48]. These observations are comparable with

ours; the two species coexist only in three microhabitats out of 12. The *S. ornatum* (complex) is abundant in fast currents with eroded bottoms near the source of wadi Chouly (tributary of wadi Tafna), whereas it is scarce in slow currents with heterogeneous or eroded substrate. Gagneur [8] reported this species in the crenal of Tafna catchment, and Guidicelli [31] considered it more rithrophilic in the High Atlas. In the extreme north of Tunisia, larvae and pupae of the *S. ornatum* complex were found in low abundance in rapid and highly oxygenated streams with abundant vegetation [46]. This species complex usually inhabits Pyrenean streams with slow current and aquatic vegetation rich in macrophytes [33] [34].

The less abundant species (*S. quadrifila* and *S. sergenti*) in our samples have been found in slow and fast currents with heterogeneous substrate. Their habitats in Europe and Morocco are similar [19] [21] [23] [24].

Equally rare in our samples, *S. galloprovinciale* is restricted to microhabitats with rocky substrates eroded by strong currents. This species, known in southwestern Europe, has been described as rheophilic [49]. It was collected in streams of the Rif Mountains in Morocco, but always confined to fast currents. Pupal cocoons from wadi Chouly in upper Tafna, were covered with calcareous concretions [24].

The ecological features associated with the wadis of the Tafna catchment demonstrated the diversity of habitats available to black flies. The low altitudinal variation (<1090 m) partly explains the degree of absence of simuliids in the Tafna catchment. Future studies of other environments (e.g., springs and coastal wadis), with analysis of their distributions according to environmental factors, such as temperature, altitude, and chemical analyses of waters (e.g., dissolved oxygen, orthophosphates, nitrites and nitrates) would improve the understanding of the ecological requirements of the black flies in Algeria.

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