

Altitudinal distribution of lotic chironomid (Diptera) communities in the Sierra Nevada mountains (Southern Spain)

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Keywords : Diptera, Chironomidae, altitudinal distribution, streams, Sierra Nevada, Spain.

Pupae and pupal exuviae were collected by drift and hand netting from 27 sites on 10 streams in the Sierra Nevada mountains in 1986 and 1987. The sites represented an altitudinal range from 340 m to 2100 m. The pupal exuviae collections revealed a composite fauna of 143 species. *Eukiefferiella* (12 spp.) and *Tvetenia* (3 spp.) were dominant both taxonomically and numerically along most of the altitudinal profile, followed by *Cricotopus* (11 spp.), *Orthocladius* (9 spp.) and *Diamesa* (7 spp.).

The altitudinal distribution of the 99 most common species is shown and compared with those obtained in other European streams or rivers, especially in the Pyrenees. The general pattern of altitudinal zonation shows an increase in species richness from the headwaters (< 2000 m : 58 spp.) toward the middle reaches (1000-1600 m : 121 spp.). The theoretically expected highest species richness in the foothill reaches (> 1000 m : 113 spp.) was not obtained. The periods of reduced or intermittent flow, the domestic organic inputs and the narrowness of the channels in the foothill reaches appear responsible for the decrease of the species richness of the chironomid communities.

Répartition altitudinale des communautés lotiques de Chironomidés (Diptera) de la Sierra Nevada (Sud de l'Espagne)

Mots clés : Diptera, Chironomidés, répartition altitudinale, rivières, Sierra Nevada, Espagne.

Des exuvies nymphales et des nymphes de Chironomidés ont été récoltées par dérive ou dans des zones d'accumulation, dans 27 stations de 10 rivières de la Sierra Nevada, en 1986 et 1987. Les stations sont échelonnées entre 340 m et 2100 m d'altitude. 143 espèces ont été identifiées. Les *Eukiefferiella* (12 spp.) et les *Tvetenia* (3 spp.) sont les deux genres dominants, spécifiquement et numériquement, tout au long de la zone altitudinale prospectée, suivis par les *Cricotopus* (11 spp.), les *Orthocladius* (9 spp.) et les *Diamesa* (7 spp.).

La répartition altitudinale des 99 espèces les plus fréquentes est comparée avec celle d'autres rivières d'Europe, et plus spécialement des Pyrénées. Le modèle général de zonation altitudinale présente une augmentation de la richesse spécifique depuis les sources (> 2000 m : 58 spp.) jusqu'aux zones de moyenne altitude (1000-1600 m : 121 spp.). La théoriquement attendue plus forte diversité spécifique dans les zones de piémont (> 1000 m : 113 spp.) ne s'est pas vérifiée. Les périodes de réduction ou d'intermittence des débits, la pollution organique et l'étroitesse du lit des rivières du piémont semblent les causes de cette diminution de la richesse spécifique des communautés de Chironomidés.

1. Introduction

The gradient of environmental conditions that occurs as a function of altitude offers excellent opportunities to investigate factors which influence the diversity, composition and abundance of stream organisms (Ward 1986). Factors such as thermal regime, flow and characteristics of the substratum, which have primary importance in the distribution of most lotic chironomid species, are directly or indi-

rectly dependent on altitude. Altitudinal gradient is considered by Coffman (1989) as one of the major factors that influences the richness of a lotic chironomid community.

Altitudinal zonation patterns of lotic chironomids have been studied in Europe since Thienemann (1954) proposed a classification system for European rivers based on their chironomid fauna. However, some of the studies are limited in taxonomic scope, or present difficulties in the interpretation of the natural longitudinal or altitudinal distribution patterns due to disturbances (review in Laville &

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Vinçon 1991). Preliminary information on the altitudinal distribution of chironomids in the streams of the Sierra Nevada is available in Casas & Vilchez (1989). The aim of the present work is to offer some general data on the composition of the lotic chironomid communities in this massif. Furthermore, we shall examine the altitudinal distribution pattern of the most frequent species, comparing our data with other European mountains, and discussing the influence of some special features of the study area on the altitudinal pattern of species richness. In the

context of the present paper the term « community » follows the definition of « species assemblage » as stated by Giller (1984).

2. Study area

The study was carried out in 10 streams in the western part of the Sierra Nevada, Andalucía (Southern Spain). This is the most Southern European high-mountain massif, representing heights up to 3300 m (Fig. 1). The streams studied form the headwaters

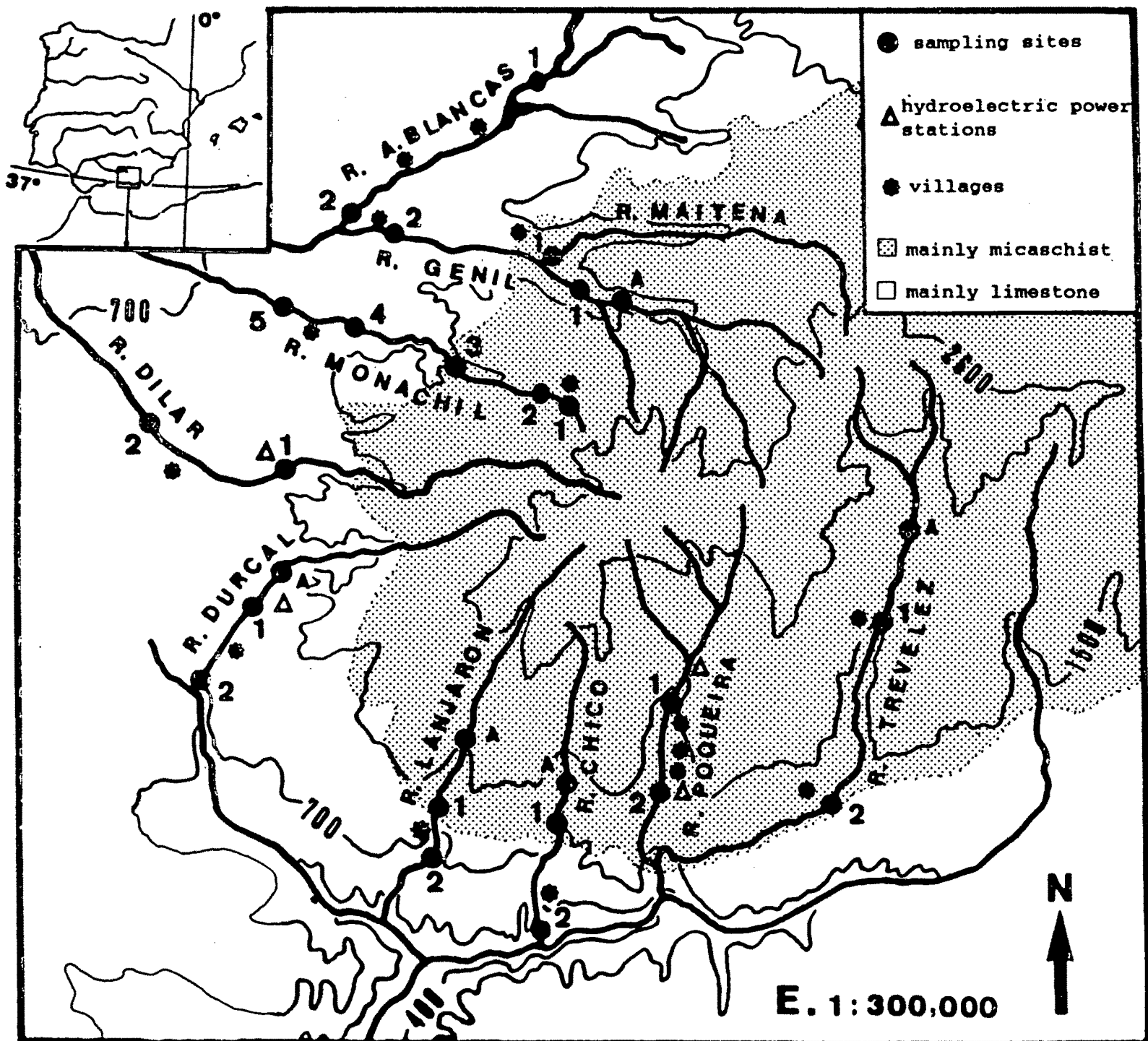


Fig. 1. Map of the Western part of the Sierra Nevada, showing the sampling sites on the streams studied.
 Fig. 1. Carte de la Sierra Nevada occidentale : localisation des 27 stations dans les 10 rivières étudiées.

of the rivers Guadalfeo, on the southern face, and Genil on the northern face. The streams have torrential flow, primarily in spring during the snow melt, but reduced flow in summer (Table 1). Twenty-seven sampling sites were studied (Fig. 1), ranging from 340 to 2100 m a.s.l.. The substratum was chiefly composed of boulders, angular rubble and gravel. In the upper reaches there is a great development of the algae *Hydrurus foetidus* during winter and spring. In the lower reaches some domestic effluents enter the streams. Impoundment of water to provide for small hydroelectric power stations and irrigation takes place mainly below 1000 m. More

detailed information concerning the physiographic and chemical characteristics of the sampling stations is provided in Table 1.

3. Material and methods

The material, pupal exuviae and pupae of Chironomidae, was collected by drift netting (875 cm² mouth, 1.1 m long, 250 µm mesh size). The nets, 1 or 2 depending on stream width, were placed in the centre of the channel. Collections were made for an hour and a half at every sampling site during four periods : May-June 1986, August 1986, November 1986, March 1987. Generally, for each stream the

Table 1. Physiographical and chemical characteristics of the sampling stations : mean values ; maximum and minimum values for flow and water temperature.

Tableau 1. Caractéristiques physico-chimiques des stations étudiées : valeurs moyennes ; valeurs maximum et minimum pour le débit et la température de l'eau.

Sampling stations	Altitude m	Km from the source	Gradient ‰	Catchement area km ²	Channel width m	Flow m ³ s ⁻¹	T °C	Alkalinity mg C l ⁻¹	Nitrates µg N l ⁻¹	Ammonia µg N l ⁻¹	Orthophosph. µg P l ⁻¹	BOD ₅ mg O ₂ l ⁻¹
TA	1700	8.5	16.9	43.1	4.4	0.59	16	12.2	46	45	0	-
T1	1460	13.0	3.5	75.5	7.1	0.20-3.09	11-19	16.9	116	25	14	1.06
T2	1000	21.5	4.4	115.1	4.0	0.37-2.23	9-19	22.3	139	45	13	1.59
P1	1300	9.2	9.5	60.5	4.5	0.04-0.30	9-17	44.7	174	50	1	0.98
P2	960	12.5	10.0	78.9	4.0	0.17-1.23	12-19	61.3	280	68	52	1.21
ChA	900	8.7	32.0	22.1	2.2	0.02	16	109.8	146	32	0	-
Ch1	740	9.5	22.5	25.9	2.3	0.00-0.59	9-14	82.0	124	59	1	0.86
Ch2	340	15.0	5.0	32.6	1.6	0.00-0.20	19-27	152.5	775	83	7	1.09
LA	1500	10.5	13.0	18.4	2.9	0.08	14	18.9	313	34	0	-
L1	720	14.7	18.3	26.4	2.4	0.01-0.55	10-16	94.1	162	39	3	1.25
L2	600	16.2	15.2	27.9	2.5	0.00-0.69	13-20	184.0	295	277	165	7.72
DA	860	13.5	8.0	45.1	2.5	0.02	19	139.1	37	23	0	-
D1	780	15.3	5.5	52.7	2.8	0.04-0.99	8-18	117.1	437	41	2	1.80
D2	680	19.7	3.0	68.4	4.1	0.18-1.32	11-18	186.5	2047	744	527	6.63
Di1	980	17.0	5.0	43.1	2.6	0.02-0.82	9-19	140.7	186	37	0	0.78
Di2	800	24.0	2.5	66.6	3.0	0.03-0.66	10-16	132.9	1000	40	0	2.03
M1	2100	2.5	20.4	5.5	2.4	0.03-0.44	4-11	21.3	268	18	6	0.45
M2	1960	3.0	60.2	6.4	1.9	0.10-0.45	4-11	25.9	450	25	12	0.99
M3	1400	7.5	11.6	27.2	4.3	0.26-1.96	7-18	58.1	342	56	36	1.78
M4	940	14.5	6.9	51.1	3.3	0.06-1.58	6-20	130.9	338	25	15	1.43
M5	780	17.5	5.0	78.0	3.9	0.27-1.36	8-21	143.3	473	63	56	2.67
GA	1220	12.2	3.2	64.7	4.3	0.75	16	39.0	33	25	34	-
G1	1060	14.5	5.5	87.7	3.2	0.06-0.72	7-22	55.2	148	42	8	1.68
G2	780	23.2	4.5	119.7	7.0	0.02-2.58	11-20	75.4	301	44	58	1.13
Ma1	1020	16.5	8.5	56.7	3.2	0.04-1.08	8-18	74.6	173	44	8	0.85
AB1	1080	5.7	3.0	45.2	3.2	0.14-0.32	9-15	271.0	399	40	7	0.69
AB2	760	16.5	1.0	135.8	4.1	0.21-0.70	12-21	227.5	712	83	87	2.05

highest station was sampled in the morning and the lowest station in the afternoon. Sampling stations marked with « A » in fig. 1 were sampled only during August 1986. Samples from Monachil stream were obtained for an hour each month during the period February-December 1987. In addition, hand-net collections were taken from the stream banks where the pupal exuviae usually accumulate, especially in low-flow conditions. Drift-net and hand-net collections were put together in a single sample.

4. Results and discussion

4.1. General characteristics of lotic chironomid fauna of the Sierra Nevada

A total of 81483 pupal exuviae and pupae was sampled and sorted, and 143 chironomid species were identified. Orthocladiinae (78 species, 54.2 %) tended to dominate, this situation being characteristic of headwaters (Thienemann 1954). Tanytarsini (22 species, 15.5 %) and Chironomini (16 species, 11.3 %) were represented by intermediate frequencies, Tanypodinae (13 species, 9.1 %) and Dia-

mesinae (12 species, 8.6 %) showed similar diversities. Prodiamesinae were represented by 2 species (1.4 %).

The altitudinal changes in the relative abundance of the main chironomid taxa from Monachil stream is represented in fig. 2. Along the reach sampled, Orthocladiinae dominate numerically. Diamesinae, constituting approximately 35 % in the headwaters, fell to less than 2 % at M5. On the other hand, Chironomini, almost absent at M1 and M2, increased downstream to 8.5 % at M5, this increase coinciding with sewage input at this site (see BOD₅, Table 1).

The most abundant genera and species from all the 10 streams studied are listed in Table 2. *Eukiefferiella* and *Tvetenia* were the dominant genera both specifically and numerically. Most species of these genera live in fast-flowing and well-oxygenated waters (Lehmann 1972). *Orthocladus* and *Cricotopus* were also well represented. *Rheocricotopus* was represented by 7 species, although it was numerically a scarce genus. Species of this genus are usually

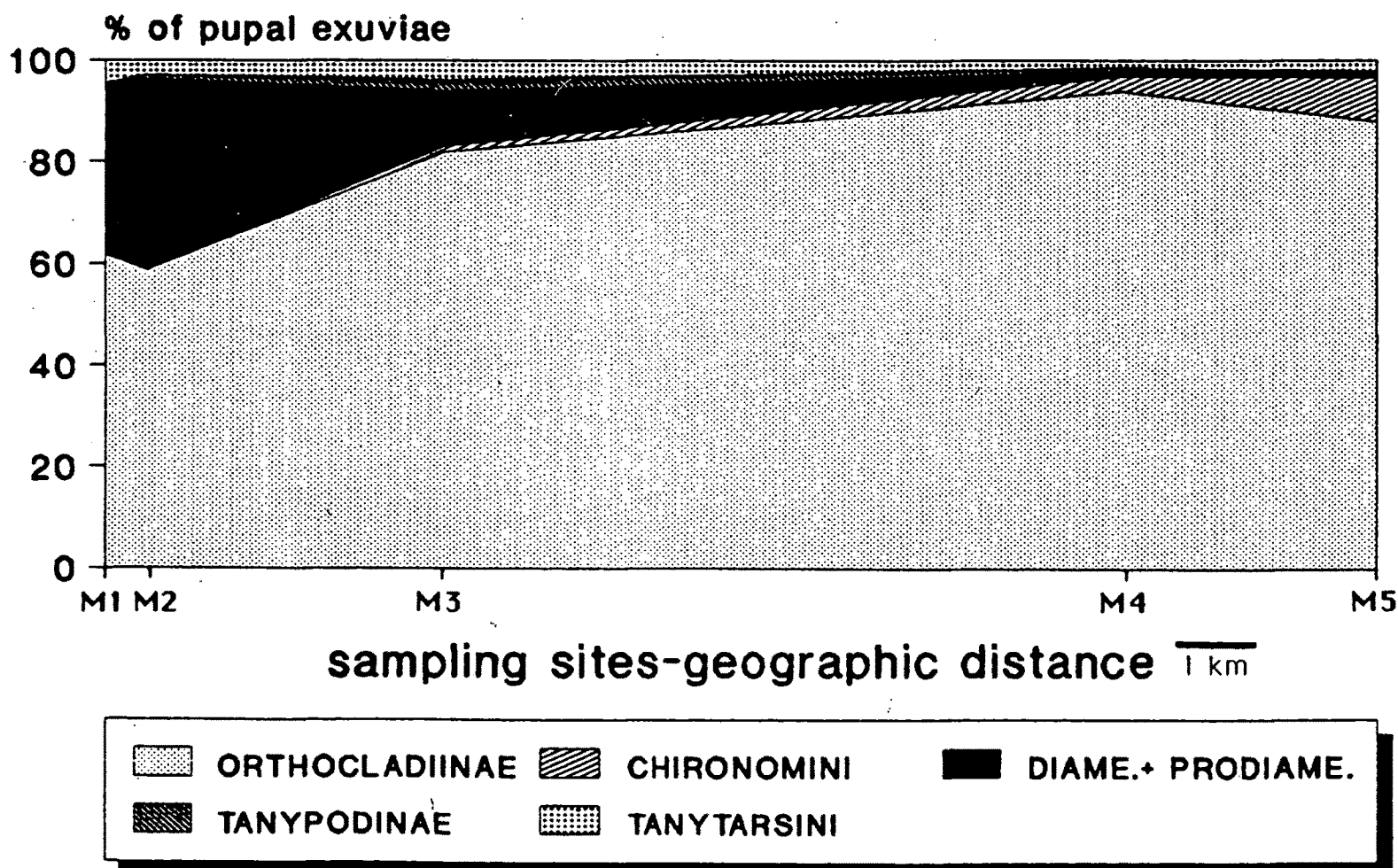


Fig 2. Altitudinal changes of the frequency of the chironomid subfamilies or tribes along the Monachil stream.

Fig. 2. Evolution altitudinale de la fréquence des sous-familles ou tribus de Chironomidés.

Table 2. Number of species for the main chironomid genera and percentages of the main genera and species present in the streams from the Sierra Nevada.

Tableau 2. Nombres d'espèces des principaux genres et pourcentages des principaux genres et espèces de Chironomidés des rivières de la Sierra Nevada.

GENERA	N species	%	SPECIES	%
<i>Eukiefferiella</i>				
+	15	30.1		
<i>Tvetenia</i>			<i>O. ashei</i>	9.5
<i>Cricotopus</i>	11	9.4	<i>E. cyanea</i>	9.1
<i>Orthocladus</i>	9	14.2	<i>Cricotopus</i> ssp.	7.1
<i>Rheocricotopus</i>	7	1.2	<i>P. rufiventris</i>	6.9
<i>Diamesa</i>	6	1.6	<i>E. devonica</i>	6.5
<i>Polypedilum</i>	5	2.3	<i>E. claripennis</i>	6.3
<i>Micropsectra</i>	4	4.2	<i>P. stylatus</i>	5.1

recorded from reaches with abundant submerged macrophytes (Lindgaard-Petersen 1972, Cranston et al. 1983, Bass 1986), these being unusual in fast-flowing streams.

The most abundant species (> 5 %, Table 2) were 7 Orthoclaadiinae species or taxa (*Cricotopus* spp.) which together constituted 50.4 % of the total. Most of these, widely distributed in the Palaearctic region, are rheophilic and prefer the headwaters (Lehmann 1971, Laville & Lavandier 1977, Verneaux & Vergon 1974, Ringe 1974, Wilson 1977, Laville 1981).

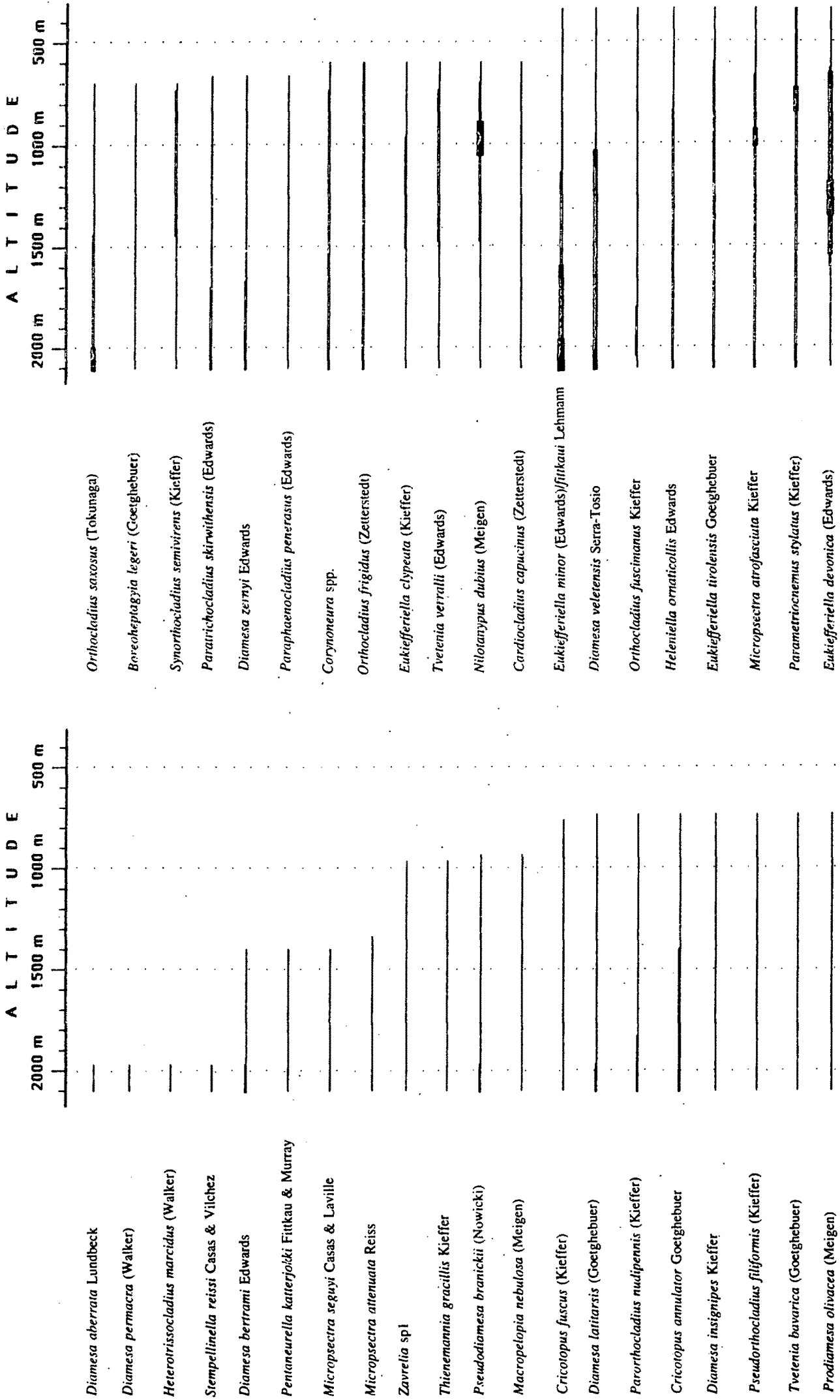
4.2. Altitudinal distribution of the species

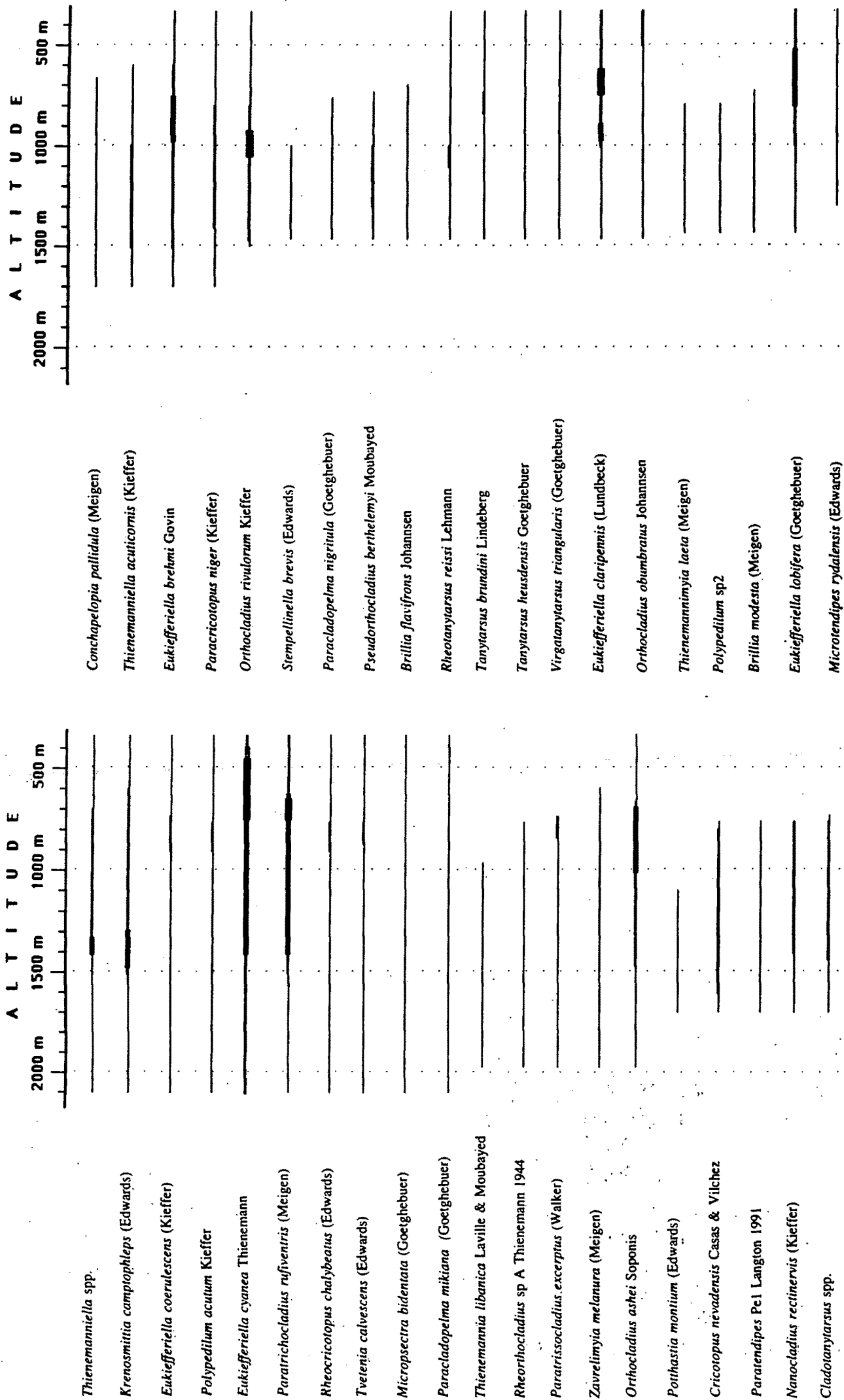
In Table 3 we have represented the relative abundance, according to altitude, of the 99 most frequent chironomid species. The lines represent the altitudinal distribution of each species, even if absent at intermediate sampling stations. We used lines instead of dots for graphic clarity. In no case we did join two very distant points of distribution in the altitudinal gradient without another point between them.

Most Tanypodinae species were poorly represented at all sampling stations. *Macropelopia nebulosa*, considered by Wilson (1980) as a potamal species, was nevertheless recorded from 940 m to 2100 m, in accord with its eurythermal and eurytopic character proposed by Caspers & Reiss (1987). The distribution of this species seems mostly determined by the presence of a soft organic substratum (Buisson 1986).

Diamesinae species were arranged by Serra-Tosio (1973) into 3 groups according to their altitudinal distribution and water-temperature margins in the French Alps and the Massif Central. Only *Pseudodiamesa nivosa*, which occurs in some high-altitude lagoons (> 2600 m) in the Sierra Nevada (Laville & Vilchez 1986), was recorded from Serra-Tosio's first group (high-altitude and cold-stenotherm species). For the second group, low-altitude species inhabiting less cold waters, we recorded 3 species in the Sierra Nevada: *Sympotthastia zavreli*, *Potthastia montium* and *Potthastia gaedii*. These species occurred at higher altitudes than in the Alps and the Massif Central, although over a medium-low altitudinal range (740-1700 m) with respect to the rest of Diamesinae in the Sierra Nevada. The remaining species are included in a group of intermediate species which live mainly in the mid-altitude range. In general, the distribution range of the Diamesinae was noticeably higher in the Sierra Nevada than in the French Alps and the Massif Central. This may be due to the latitudinal difference—the lower latitude of the Sierra Nevada may raise the altitude of the thermal threshold for species which require temperatures lower than 15° C (Serra-Tosio 1973). Moreover, the presence of *Hydrurus foetidus* algae might influence the distribution of the Diamesinae, as some species such as *Diamesa zernyi* prefer to inhabit this algae (Serra-Tosio 1973, Kownacki 1971), which grows only with ample light and low temperatures, between 2 and 12° C according to Bursa (1934). In addition, the impoundment of water mainly below 1000 m might indirectly affect this distribution pattern, by modifying the thermal regime and current speed conditions.

Among Orthoclaadiinae, 15 species or taxa were distributed all along the altitudinal profile, and 16 other species were distributed from 600 m/700 m to the highest sampling station at 2100 m. Some taxa are indicated in Table 3 as a group of species because of the difficulty of distinguishing in their pupal stage. However, some species identifications of imagines ♂ were possible. For example, most of the recorded imagines ♂ of *Corynoneura* belonged to *C. lobata* Edwards, at medium-high altitudes (940-2100 m); two *Thienemanniella* species were identified as *T. cf. morosa* (Edwards) and *T. cf. vittata* (Edwards). *Parorthocladus nudipennis* and *Paratrithocladus skirwithensis*, despite their wide distribution, are more abundant in the upper reaches,





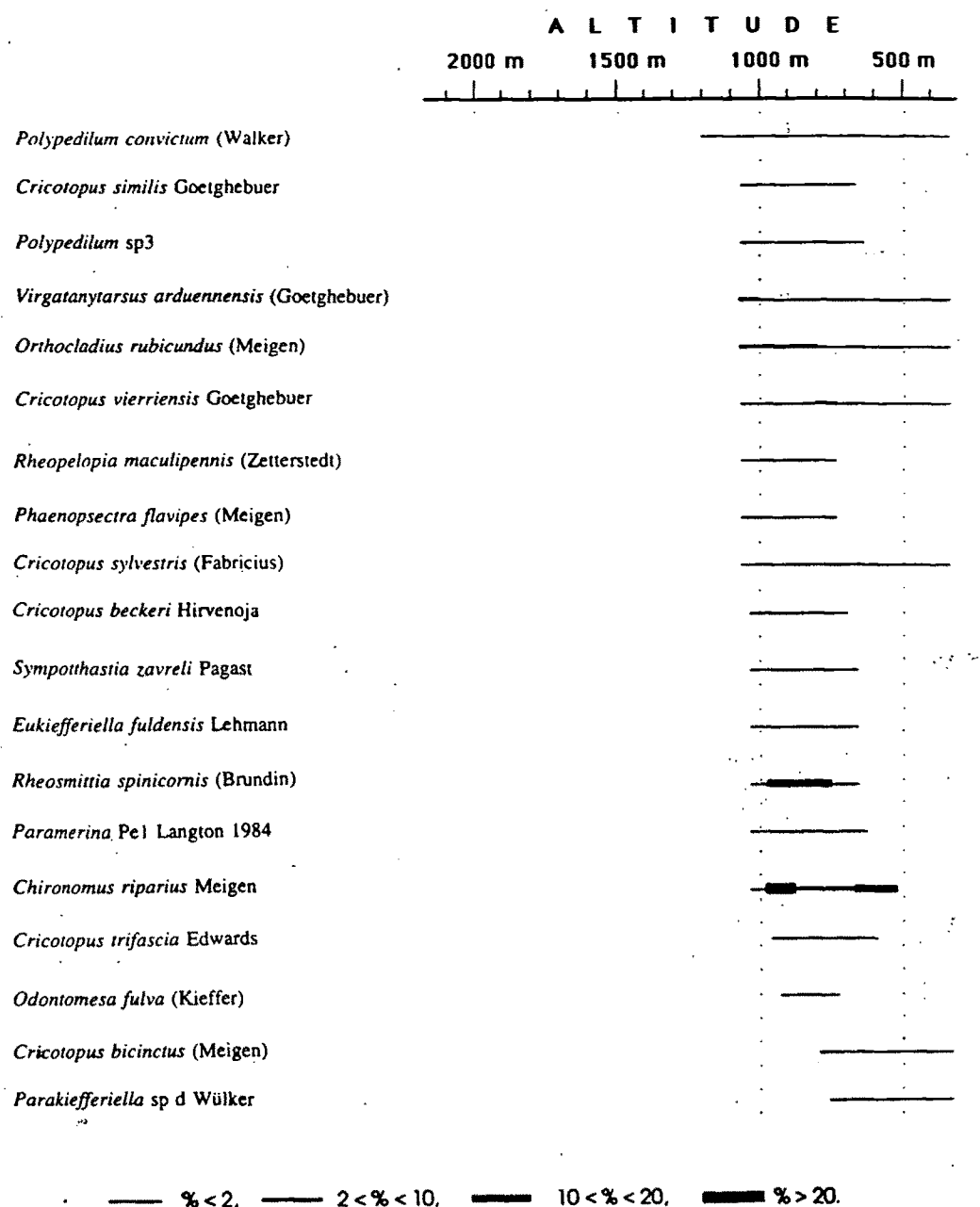


Table 3. Altitudinal distribution of the 99 most common chironomid species in the Sierra Nevada. Relative abundance of the species in respect to the other chironomid species at the stream reach considered.

Tableau 3. Répartition altitudinale des 99 espèces de Chironomidés les plus fréquents dans la Sierra Nevada. Abondance relative de chaque espèce par rapport aux autres Chironomidés dans la station considérée.

and are considered to be cold-stenothermal (Caspers & Reiss 1987). The first species was recorded mainly from the upper reaches in some southern European rivers (Prat et al. 1984, Rossaro 1991) : the second species is a typical Krenal species, extending to the Rhitral during low-flow periods (Rossaro 1982), and was also signalized as the most abundant species in a low-gradient alpine-tundra stream (Aagaard et al. 1987). These results are consistent with our observation : we recorded *P. skirwithensis* with higher frequency from adjacent sources with low flow at the station M2.

Most of the *Cricotopus* species were distributed at lower altitudes. *C. sylvestris* and *C. bicinctus* are usually considered as eurythermal and euryecious species (Caspers 1983). The presence of *C. bicinctus* is probably related to the organic input at some low sampling stations (D2, M5). These two species tend to replace other species under conditions of environmental stress (Simpson & Bode 1980). *C. annulator* and *C. nevadensis* were distributed at the highest altitudes, the latter species at present known only from the Sierra Nevada.

Most of the *Eukiefferiella* species were widely distributed all along the altitudinal gradient, although with notable differences in abundance according to the altitude. *Eukiefferiella minor/fittkai* is more frequent from 1400 to 2100 m. We recorded a single imago ♂ of *E. fittkai* at 2100 m, and the remaining imagines belonging to *E. minor* were collected from 750 m to 2100 m. This distribution agrees with the altitudinal division of both species observed in other rivers or streams (Lehmann 1971, Laville & Lavandier 1977). *E. cyanea*, *E. clypeata*, *E. devonica* and *E. claripennis* are recorded at widely different altitudes in some European rivers (Lehmann 1971, Ringe 1974, Laville & Lavandier 1977, Laville 1981). The same is true of four *Orthocladius* species : *O. fuscimanus*, *O. ashei*, *O. frigidus* and *O. saxosus*.

Only two species of Chironomini, *Paracladopelma mikiana* and *Polypedilum acutum*, were recorded along the entire profile ; nevertheless in the headwaters and upper reaches only one specimen was recorded from the summer sampling. The autoecology of these species is almost unknown. The remaining Chironomini species are distributed mainly in the lower parts of the streams where they often occur in low abundance. *Chironomus riparius* is more abundant at low sites with sewage input, as is usually recorded (Mc Gill et al. 1979, Hawkes 1978).

Among Tanytarsini, *Micropsectra atrofasciata* and *Micropsectra bidentata* had the widest distribution ; both are widely distributed in European rivers. *Stempellinella reissi*, *Micropsectra seguyi* and *Zavrelia* sp1, at present are recorded only from the Sierra Nevada, and although rare, these species seem to prefer the headwaters and upper reaches. The taxa noted in Table 3 as *Cladotanytarsus* spp., represent at least two species identified using imago ♂ as *C. atridorsum* Kieffer and *C. vanderwulpi* (Edwards).

4.3. Comparison with the chironomid zonation of the Pyrenean streams

The comparison of the altitudinal zonation of the chironomid communities of the Sierra Nevada with those of other European mountain ranges, seems useful only in the case of the Pyrenees (Laville & Vinçon 1991). Other studies on altitudinal distribution are limited in several aspects, as mentioned

above, and present altitudinal gradients hardly comparable with that considered in the present work.

In the Pyrenees, the altitudinal zonation was based mainly on the chironomid communities of two natural lotic basins, little altered by human activity. This study covered an altitudinal range of 2000 m (400-2400 m), similar to that considered in the Sierra Nevada. Table 4 lists the characteristic or most frequent species in the altitudinal reaches differentiated in the Pyrenees (for detailed information concerning zonation see Laville & Vinçon (1991). For comparing we have included in Table 4 the most common chironomid species collected in the Sierra Nevada at these reaches (recorded in Table 3). The headwaters are considered by Laville & Vinçon (1991) to be upstream of 2100 m ; however, this is the highest sampling altitude in the Sierra Nevada. Nevertheless, species such as *Diamesa aberrata*, *D. permacra*, *Heterotrissocladius marcidus* and *Stempellinella reissi* are probably more frequent, or at least characteristic, up to 2100 m.


From Table 4 we can draw four generalities :

- The relative low number of common species living in the same reach ;
- The relative high number of species with a different altitudinal distribution pattern, mainly in the middle and foothill reaches ;
- The absence from the Sierra Nevada of a great number of cold-stenothermal Pyrenean species, frequent in the headwaters and upper reaches. At the present time, four characteristic or common elements in the Sierra Nevada, are not recorded in the Pyrenees.
- The relative high number of species with altitudinal distribution patterns which shift toward the upper reaches in the Sierra Nevada with respect to the Pyrenees.

The last two aspects are possibly related to the different latitudinal situations of the two mountain massifs. Additional differences in historical, geographical and physiographical characteristics of the basins (climate, flow regime, gradient, pattern of branching) may also contribute to the differences in altitudinal distribution patterns of species. Furthermore, we should bear in mind that the study carried out in the Pyrenees took place in two basins scarcely altered by human activity, a point well contrasting with our study area.

Table 4. Characteristic or common chironomid species at different altitudinal reaches in the Pyrenees and in the Sierra Nevada.
 Tableau 4. Espèces caractéristiques ou communes dans les différentes sections altitudinales des Pyrénées et de la Sierra Nevada.

	PYRENEES Laville & Vinçon (1991)	SIERRA NEVADA
HEADWATER REACHES	<i>Diamesa aberrata</i>	
>2000 m	<i>Pseudodiamesa nivosa</i> <i>Diamesa steinboeckii</i> <i>Diamesa laticauda</i> <i>Diamesa wuelkeri</i> <i>Parakiefferiella parva</i>	<i>Diamesa permacra</i> <i>Hetero. marcidus</i> <i>Stempellinella reissi</i>
UPPER REACHES	<i>Diamesa bertrami, Pseudodiamesa branickii, Euk. fitkaui</i>	
1600-2000 m	<i>Eukiefferiella tirolensis</i> <i>Micropsectra bidentata</i> <i>Diamesa incallida.</i> <i>Diamesa tonsa</i> <i>Diamesa lavillei</i> <i>Diamesa thomasi</i> <i>Krenosmittia boreoalpina</i> <i>Krenopsectra fallax</i>	<i>Cricotopus annulator</i> <i>Diamesa latitarsis</i> <i>Paror. nudipennis</i> <i>Orthocladius saxosus</i> <i>Parat. skirwithensis</i> <i>Diamesa zernyi</i> <i>Diamesa veletensis</i>
MIDDLE REACHES	<i>Nilo. dubius, Hel. ornatocollis, Kren. camptophleps, Orth. rivulorum</i>	
1000-1600 m	<i>Eukiefferiella fuldensis</i> <i>Corynoneura lobata</i> <i>Tvetenia bavarica</i> <i>Paracladopelma mikiana</i> <i>Polypedilum albicorne</i> <i>Micropsectra lindrothi</i>	<i>Syn. semivirens</i> <i>Tvetenia verralli</i> <i>Eukiefferiella devonica</i> <i>Pseud. berthelemyi</i> <i>Rheotanytarsus reissi</i>
	<i>Diamesa latitarsis</i> <i>Diamesa zernyi</i> <i>Orthocladius saxosus</i> <i>Parat. skirwithensis</i> <i>Paror. nudipennis</i>	<i>Eukiefferiella clypeata</i> <i>Nanocladus rectinervis</i> <i>Paracricotopus niger</i>
	<i>Rheocricotopus nigricauda</i>	<i>Cricotopus nevadensis</i>
FOOTHILL REACHES	<i>Euk. cyànea, Euk. lobifera, Orth. ashei, Rheo. spinicornis</i>	
< 1000 m	<i>Conchapelopia pallidula</i> <i>Macropelopia nebulosa</i> <i>Pothastia gaedii</i> <i>Brillia flavifrons</i> <i>Cardiocladius capucinus</i> <i>Cricotopus curtus</i> <i>Cricotopus similis</i> <i>Orthocladius fuscimanus</i> <i>Polypedilum convictum</i>	<i>Orthocladius obumbratus</i> <i>Orthocladius rubicundus</i> <i>Cricotopus vierriensis</i> <i>Tanytarsus brundini</i>
	<i>Eukiefferiella clypeata</i> <i>Nanocladus rectinervis</i> <i>Paracricotopus niger</i>	
	<i>Cr. tremulus, Nano. parvulus</i> <i>Poly.laetum, Neoz.fuldensis</i> <i>Rheotanytarsus pentapoda</i>	<i>Euk. brehmi</i>

Species out of the boxes, not in common; species in common; species with divergence or rare;
 species in common in the next upper or lower reach respectively

The most useful comparison of altitudinal profiles between these two distantly separate mountain areas, would be on the basis of patterns of community diversity. In the Pyrenees, the species richness increases from the headwaters toward the foothill reaches, where the maximum average richness occurs. According to Laville & Vinçon (1991), the decrease in slope and the increase in flow favour the colonization of a community richer in potamophilic Tanyptodinae and Chironominae species. In the Sierra Nevada, an increase in the species richness took place down-stream as well, from the headwaters (58 species), through the upper reaches (72 species), to the maximum in the middle reaches (121 species). But a somewhat lower species richness appeared in the foothill reaches (113 species). Thienemann (1954) observed the most diversified chironomid communities in the foothill reaches, where the greatest biotope diversity occurs. Ward (1986) found a similar pattern in the species richness of macroinvertebrates of a Rocky Mountain river : the higher species richness at the foothill sites was related to a faunistic discontinuity produced by the tran-

sition from the Rhithral to the Potamal conditions. Such foothill reaches coincide mostly with 3rd and/or 4th order streams, that in the northern temperate regions have the greatest chironomid richness, according to Coffman (1989) ; many factors operate in this increase, mainly related to the greater ecological heterogeneity of the streams with intermediate width and altitude.

The general tendency throughout the Sierra Nevada, can be observed as well in the particular case of the Monachil stream (Fig. 3), where the collecting effort was greatest, and therefore the probability of bias lesser. This decreasing diversity seems to be caused by two kinds of factors, natural and human, which coincide mainly in the foothill reaches of the Sierra Nevada streams. The natural factors refer to the geologic composition and structure of this mountain massif. It has a core of crystalline materials and a border of limestone which is mainly exposed in the foothill sites. The channels are relatively wide in the crystalline region, above the foothill, but begin to become narrow, and in

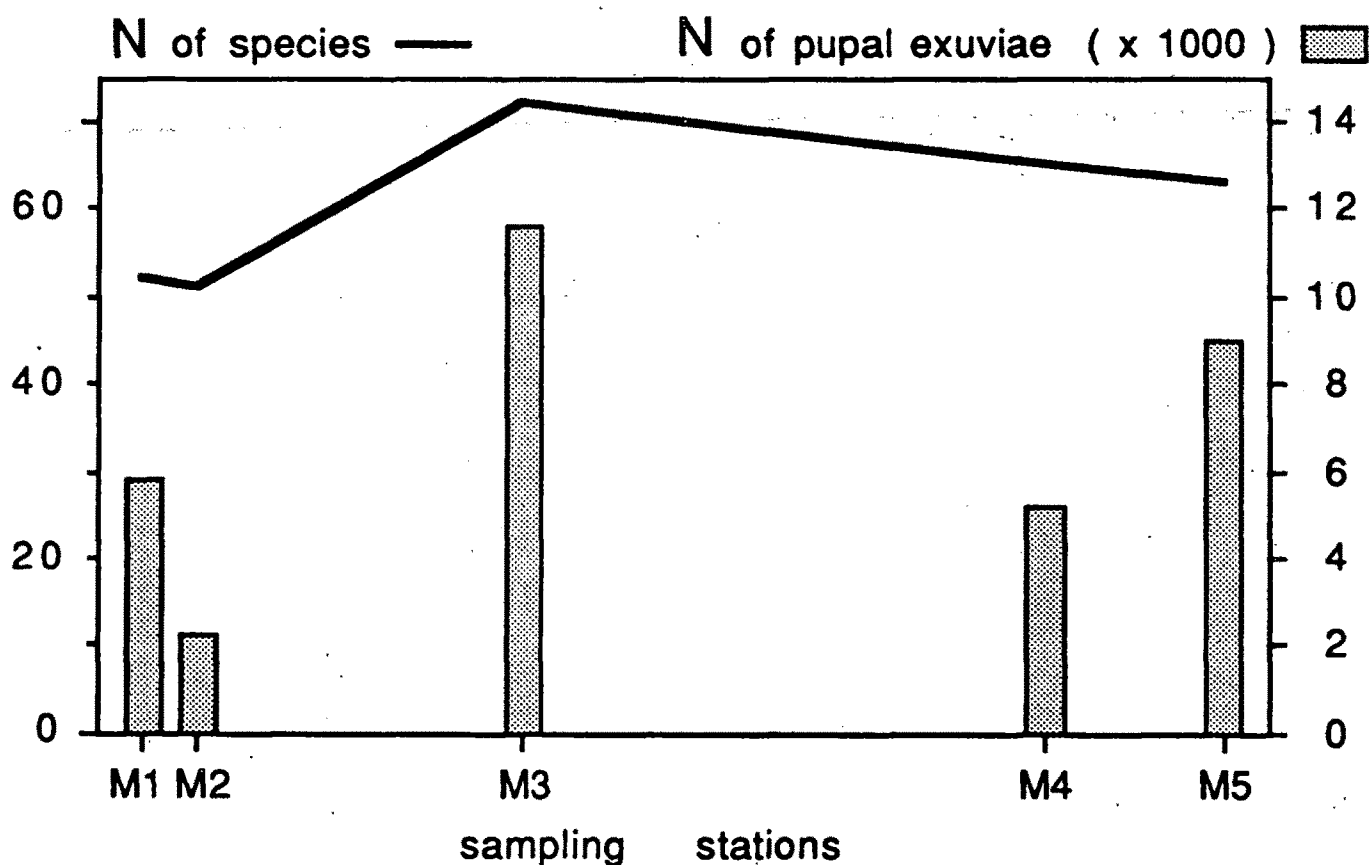


Fig. 3. Altitudinal changes in chironomid species richness and total number of pupal exuviae collected at each sampling station in the Monachil stream.

Fig. 3. Evolution altitudinale de la richesse spécifique et du nombre total d'exuvies nymphales récoltées dans chaque station de la rivière Monachil.

many cases strongly shaded because of the very close riparian canopy. Both narrowness and shade may be responsible, at least in part, for the decrease in chironomid species richness (Hawkins et al. 1982, Lenat 1983, Coffman 1989). On the other hand, two human activities are particularly intense below 1000 m : sewage input and water impoundment. Sewage input, considerable in certain sampling stations (see BOD₅, Table 1), limits habitat heterogeneity excluding a large number of species in favour of a few, such as *Eukiefferiella claripennis*, *Chironomus riparius*, *Micropsectra atrofasciata* and *Paratrichocladius rufiventris* (Table 3). Furthermore, the impoundment of water may cause important changes in lotic communities : flow reduction, according to Ward (1976), brings about certain physical changes that decrease the number of species. Water diversion for agriculture and small power stations results in long periods of reduced and intermittent flow in certain stations of the lower reaches (Table 1).

Conclusions

The altitudinal distribution of some chironomid species in the Sierra Nevada streams, coincides with that of other European water courses. Nevertheless, in many cases, as in the Diamesinae species, the range of distribution in the Sierra Nevada was noticeably higher in altitude than in the French Alps and the Massif Central. The same tendency can be found in comparison with the Pyrenean zonation. In addition, there was an absence in the Sierra Nevada of a great number of cold-stenothermal Pyrenean species. Both tendencies may be connected with the different latitudinal situation of these two mountain massifs. Furthermore, there was a relatively high number of species with a different altitudinal distribution pattern, which can be attributable to many historical, geographical and physiographical differences between the two massifs.

The theoretically expected highest species richness in the foothill sites was not obtained. Periods of reduced or intermittent flow, the sewage input and the narrowness of the channels in the foothill sites appear to decrease the species richness of the chironomid communities. It remains to be seen to what extent human activity and natural factors, separately, influence chironomid species richness.

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