Hydrobiologia (2006) 562:231–246
A. Lami & A. Boggero (eds), Ecology of High Altitude Aquatic Systems in the Alps
DOI 10.1007/s10750-005-1813-x
© Springer 2006

Chironomids from Southern Alpine running waters: ecology, biogeography★

Bruno Rossaro[1,*], Valeria Lencioni[2], Angela Boggero[3] & Laura Marziali[1]
[1]*Dipartimento di Biologia, Sezione di Ecologia, Università degli Studi di Milano, Via Celoria 26, 20133 Milano, Italy*
[2]*Sezione di Zoologia degli Invertebrati e Idrobiologia, Museo Tridentino di Scienze Naturali, Via Calepina 14, 38100 Trento, Italy*
[3]*C.N.R.-Institute for Ecosystem Study (ISE), Largo Tonolli 50/52, 28922 Verbania Pallanza, Italy*
*(*Author for correspondence: E-mail: bruno.rossaro@unimi.it)*

Key words: Chironomidae, high altitude streams, ecology, biogeography, Southern Alps

Abstract

The chironomid fauna living in running waters in the Southern Alps was investigated from an ecological and biogeographical point of view: 202 species were identified (not including terrestrial species). It must be emphasised that species identification is tentative within some genera, especially those awaiting revision (e.g., *Boreoheptagyia, Chaetocladius*). Although much taxonomic work was done in the past on the chironomid Alpine fauna, there are still many unsolved problems. Most of the species found are widespread in the Palearctic Region, with no evidence of bio-geographical barriers separating different Alpine sectors. Really a relatively high number of species reported from the northern and western side (France, Switzerland, Austria) of the Alps was not captured on the southern side (Italy), whereas most species found on the southern side are also present on the northern one. Very few species are reported from southern side only. Lack of sampling, imperfect taxonomic knowledge and different environmental conditions between the northern and southern sides may be responsible of this result. A comparison of the fauna of the southern Alps with the fauna of the Apennines suggests that the differences are probably more related to ecological conditions (lack of glaciers in the Apennines) than to biogeographical barriers. Different chironomid assemblages colonise manifold habitat types: strict cold-stenothermal species tolerating high current velocity (e.g., *Diamesa latitarsis – steinboecki* group) are almost the sole inhabitants of kryal biotopes, while other cold-stenothermal species are restricted to cold springs (*Diamesa dampfi, D. incallida, Tokunagaia rectangularis, T. tonollii*), there are also species characteristic of hygropetric habitats (*Syndiamesa edwardsi, S. nigra*) or restricted to lacustrine habitats (*Corynoneura lacustris*, *Paratanytarsus austriacus*). It must be emphasised that different responses to environmental factors can be observed between species belonging to the same genus (e.g., *Diamesa*, *Eukiefferiella*, *Orthocladius*, *Paratrichocladius*), so species identification is really needed for a good ecological work. Water temperature, current velocity, substrate type are the most critical factors, sometime chironomid species appear to be rather opportunistic and their presence or absence cannot be clearly related to a well defined range of values of environmental variables: be it a lack of knowledge or a real datum will be the task of future studies. The waters of the Alps are still relatively unpolluted, but hydraulic stress due to river damming and canalization is a serious problem for macrofauna conservation, and as the glaciers retreat, the species confined to the glacial snouts are at risk of extinction, some of them possibly even before their existence be discovered.

★ The complete database with detailed taxonomical, ecological and biogeographical information can be obtained by the senior author to request (e-mail: bruno.rossaro@unimi.it). A table with species response to environmental variables is also available at the web site: http://users.unimi.it/~roma1999/rossaro.html, downloading file CHIRDB.)

Introduction

The Chironomidae are the freshwater insect family which comprises the highest number of species, both in lentic and lotic habitats (Cranston, 1995). They are well known indicators of trophic condition in lakes (Brundin, 1974), of organic pollution in running waters (Thienemann, 1953) and are considered an interesting biogeographic material (Brundin, 1966).

The numbers of species and specimens are particularly high in alpine freshwaters, making the chironomid taxocoenosis the most important in these biotopes, especially in glacier-fed streams (Ward, 2002). The high altitude lotic habitats host both euryoecious species, adapted to live in a variety of running waters (glacial streams, spring-fed brooks etc.), and truly cold-stenothermal species confined in reaches close to glacial snouts. The true cold-stenothermal species (e.g., *Diamesa steinboecki*) adapted to tolerate extremely low temperatures (generally lower than 4–6 °C) are able to face high current velocity but are vulnerable to anoxia, even if the risk of oxygen depletion is reduced in very cold, fast running waters (Thienemann, 1953). In the uppermost sector of glacier-fed streams (metakryal), where the water temperature does not exceed 2 °C, *Diamesa* species are typically the sole inhabitants. Other Diamesinae (*Pseudodiamesa*, *Pseudokiefferiella*, *Syndiamesa*), Orthocladiinae (*Tvetenia* and *Euorthocladius*) and Simuliidae, commonly *Prosimulium latimucro* (Enderlein 1925), are able to survive in the hypokryal, where maximum temperature is lower than 4 °C (Steffan, 1971; Milner & Petts, 1994; Lods-Crozet et al., 2001a; Maiolini & Lencioni, 2001).

Alpine chironomids are interesting from a biogeographical point of view (Serra-Tosio, 1973). Cold-stenothermal species should be unable to cross the geographical barriers formed by high mountains and warmer lowland waters; endemic species were reported in the past in different mountain groups, but more detailed investigations often revealed that species previously thought to live in a restricted area actually had a wider distribution (Rossaro, 1995).

Knowledge of invertebrate fauna from Alpine streams, with special reference to chironomids, is still limited, especially at species level (Lencioni et al., 2001).

Thienemann (1936) carried out the first ecological surveys on the Alpine chironomid fauna on the northern side of the Alps, in Bavaria. Serra-Tosio (1973) examined the Diamesinae of the French Alps and gave a detailed description of the morphology, ecology and geographical distribution of the species. Kownacka & Kownacki (1975) studied Diamesinae in Tyrolean glacial streams (Ötzaler Alps). Since the ‘70s chironomid species were collected in high altitude streams in the Southern Alps, focusing particularly on waters in the Ortles and Adamello groups. The chironomids (Diamesinae and Orthocladiinae above all) from these areas were described along with taxonomical and autoecological notes (Ferrarese & Rossaro, 1981; Rossaro, 1981, 1982, 1990). From 1980 to 1982 faunistic investigations were carried out on the Alpine chironomid communities of the Upper Alz (West Germany) by Caspers (1983), finding a total of 80 species. Saxl (1986) recorded 66 chironomid taxa in the Stocktalbach (Tyrol) between 2200 and 2400 m a.s.l. At the end of the ‘80s, a catalogue of chironomids from the French Alps was compiled (Serra-Tosio, 1991). French Alps include area 4 over 1000 m a.s.l. and part of area 13, under 1000 m a.s.l. in the Limnofauna Europaea (Fittkau & Reiss, 1978). Three hundred and thirty five species were recorded, about 90 from area 4 (excluding terrestrial species). Kownacki & Kownacka (1994) investigated the drift phenomenon in chironomids in high mountain streams in the Southern Tyrol (Italy). During the last ten years, Crema et al. (1996) studied springs in the southern (Trentino, Alto Adige, Veneto) and northern Alps (Bavaria), collecting respectively 61 and 71 chironomid taxa, mainly genera, larval material did not allow determination of species within some genera. Relationships between the environmental factors and the chironomid species were analysed in glacial streams in the Veny Valley (Aosta, western Italian Alps) (Rossaro & Lencioni, 2001). The chironomid communities of permanent or temporal inlets and outlets of 15 lakes in the Central Alps (Piedmont-Italy and Canton Tessin-Switzerland, Pennine-Lepontine Alps) were investigated from 1991 to 2000 within the framework of the pan-European projects Acidification of mountain Lakes: Palaeolimnology and Ecology (AL:PE), MOuntain Lake Research (MOLAR) and European Mountain lake Ecosystems: Regionalisation, diaGnostics & socio-economic Evaluation (EMERGE): 7, 23 and 300 European lakes were considered respectively in the 3 projects with the focus on their geographical, morphometrical and chemical characteristics (Fjellheim et al., 2000; Wathne & Rosseland, 2000). Inlet/outlet streams of 3 further lakes were studied in the framework of EU Inter-Reg II Programme (Marchetto et al., 2001); 4 outlets and 1 inlet were investigated in the '90s by Boggero et al. (1996) and Boggero & Nobili (1998); in all, 154 chironomid species were identified. Species identification was aided associating larval material with pupae. Since 1996 the chironomid fauna from high altitude streams in Trentino (Rhaetian Alps) have been monitored within the Arctic and Alpine Stream Ecosystem Research (AASER) and Health and integrity of high mountain streams in Trentino (HIGHEST) projects. Six streams (3 glacial, 1 non-glacial and 2 outlets) were selected in the Adamello-Presanella mountain group (Val Borzago and Val Nambrone, Adamello-Brenta Regional Park), 14 streams (5 glacial, 5 non-glacial and 4 outlets) and 5 springs in the Ortles-Cevedale mountain group (Val de la Mare, Stelvio National Park). Altogether about 130 chironomid taxa were collected, accounting for 25% of the Italian chironomid fauna (Lencioni, 2000; Lencioni et al., 2000; Lencioni & Maiolini, 2002). Some of the data on glacial systems in Trentino (Maiolini & Lencioni, 2001) were included in a special issue of Freshwater Biology (Brittain & Milner, 2001), devoted to various aspects of the ecology of glacier-fed rivers along a latitudinal gradient (46°–79° N). Many contributions to our knowledge of the European chironomid fauna were given. Among these, Lods-Crozet et al. (2001a, b) examined the physico-chemical features and benthic macroinvertebrates in glacial and non-glacial streams in the Swiss Alps, as did Füreder et al. (2001) in the Austrian Alps. Notes on the Austrian and German chironomid fauna were also provided by Orendt (2000) who investigated 30 small watercourses in Berchtesgaden National Park. Ninety four taxa were recorded (71% of specimens were determined to species) from mainly pupal exuviae.

In the present paper, the chironomid fauna of running waters from the southern Italian Alps (sites above 800–1000 m a.s.l.) will be reconsidered, with notes on biogeography and ecology of the species. Identification to species is necessary in an ecological study, it is a well-known fact that different species belonging to the same genus (*Diamesa*, *Eukiefferiella*, *Orthocladius* and *Paratrichocladius*) respond differently to the same environmental factors (Rossaro & Mietto, 1998).

All the information available about Southern Italian Alps, filed in a relational database (CHIRDB = chironomid database[1]), will be used for discussion. The response to environmental variables (water temperature, conductivity and pH) and factors (food, substrate) will be summarized for each species using all the data up to date available.

The study sites

A total of 125 study sites distributed above 800–1000 m a.s.l. were investigated in Alpine running waters (Table 1, Fig. 1). Samples were collected throughout the year with a monthly frequency in the Ortles and Adamello groups of mountains (high Camonica valley, Oglio river basin) from 1978 to 1981. In all the other areas samples were collected during summer from June to September with at least a monthly frequency. All the information available filed in CHIRDB will be considered for discussion and calculations.

The areas investigated fall within longitude 6° to 12° E (Fig. 1), and include the catchments of the major Italian lakes (Maggiore, Como, Iseo, Garda) and rivers (Po, Dora Baltea, Sesia, Toce, Ticino, Adda, Oglio, Sarca, Adige). A median zone of predominantly crystalline rocks (granite, diorite, gneiss) and two predominantly calcareous external zones in the North and the South are distinguished in the Alps. The southern external zone, belonging to the Italian Alps, is smaller in the west and more extensive in the centre and east.

Most of the study sites in protected areas, in National and Regional Parks: Val Grande (Piedmont), and Stelvio National Parks (Lombardy, Trentino and Alto Adige), Adamello-Brenta and Paneveggio Regional Parks (Trentino).

Table 1. Southern Alps: orographic division, regions (P = Piedmont, T = Canton Tessin (CH), AA = Alto Adige), main river basin, rivers, Lat = latitude North, Lg = longitude east, number of sites investigated: G = glacial streams, N = non-glacial streams, S = springs, L = lake outlets, Reference: R = Rossaro, B = Boggero, L = Lencioni, Date = sampling year/s

Sector	Alps	Region	Basin	River	Lat	Lg	G	N	S	L	Ref.	Date
Western	Graie	Aosta Valley	Veny Valley (Mt. Blanc)	Dora di Veny (Dora Baltea)	45° 45′	6° 52′	5	2	5	1	R 2000; Unpubl.	1995/1999
			Ferret Valley	Dora di Ferret (Dora Baltea)	45° 51′	7° 2′	1	1	2		Unpubl.	1995
			Valsavaranche (Gran Paradiso)	Savara (Dora Baltea)	45° 32′	7° 12′	1		1		Unpubl.	1980
Central	Pennine		Valtournenche (Matterhorn-Cervino)	Marmore (Dora Baltea)	45° 58′	7° 38′	1				Unpubl.	1980
			Gressoney Valley (Rosa)	Lys (Dora Baltea)	45° 52′	7° 48′	1				Unpubl.	1980
		P	Ossola Valley	Toce (Ticino)	46° 0′	8° 4′		9		16	B et al. 1996; Unpubl.	1991/2000
		T	Leventina Valley	Ticino	46° 10′	8° 27′		1		5	B et al. 1996; B & Nobili 1998	1991/1994
	Rhaetian	Lombardy	Malenco Valley	Mallero (Adda)	46° 18′	9° 48′			1		Unpubl.	2000
			Brembana Valley	Brembo (Adda)	46° 1′	9° 47′			2		Unpubl.	1999
			Viola Valley	Bormina (Adda)	46° 27′	10° 12′	1				Unpubl.	1980
			Valfurva	Frodolfo (Adda)	46° 21′	10° 30′	2				Unpubl.	1978/2003
			Camonica Valley (Ortles-Adamello)	Oglio and tributaries	46° 13′	10° 22′	5	5	15		R 1990; Unpubl.	1978/2000
			Paghera	Paghera (Oglio)	46° 11′	10° 23′			3		R 1990; Unpubl.	1978/1981
			Avio Valley	Coleasca (Oglio)	46° 11′	10° 26′	3		3		R 1990; Unpubl.	1978/1982
		Trentino	Sole Valley	Noce (Adige)	46° 18′	10° 42′	2				R 1990; Unpubl.	1978/1994
			Genova Valley	Sarca (Mincio)	46° 12′	10° 37′	3		1		R 1990; Unpubl.	1995
			Borzago Valley	Sarca tribu-tary (Mincio)	46° 5′	10° 35′	2	1			L et al. 2000	1996/1999
			Nambrone Valley	Sarca di Nambrone (Mincio)	46° 13′	10° 41′	1			2	L et al. 2000	1997/1999
			Val de la Mare	Noce tribu-tary (Adige)	46° 25′	10° 43′	5	5	5	4	Unpubl.	1999/2003
		AA	Martelltal	Plimabach (Adige)	46° 29′	10° 41′	1				Unpubl.	1998
	Dolomites	Trentino	Travignolo Valley	Travignolo (Avisio, Adige)	46° 18′	11° 40′		1			R 1990; Unpubl.	1990

A wide heterogeneity of habitats from large glacial streams to small spring-brooks and lake outlets was investigated. The classification of the habitat sampled included in CHIRDB follows the criteria proposed by Ward (1994, 2002) and Füreder (1999). The glacial streams (kryal) have a maximum discharge and turbidity during the icemelt period. In summer, the water velocity is generally above 2 m s^{-1}, water temperature does not exceed 4–6 °C, the channel bed is highly unstable, the higher aquatic plants are absent and the biofilm is composed only by Diatoms and blue–green algae. In this season, the zoobenthic community is dominated by Diamesinae. The non-glacial streams, fed by groundwater (krenal), snowmelt ('chial') and/or rainfall ('ombral') (Lencioni, 2000), are also included. They are less harsh and host a richer invertebrate community. The krenal streams considered originate from the underlying alluvial aquifer (alluvial springs) and from hill-slope aquifers that emerge along the edge of the river corridor (hill-slope springs). The krenal alpine streams are characterized by clear water. The temperature changes according to the origin of the ground-waters, when they originate from glacier melt it can be very low in summer, below 2 °C (Serra-Tosio, 1973), but when the ground-waters are far from glaciers and originate mainly from snow-melt or rain, the water temperature is higher (5–15 °C). The dissolved oxygen is generally under saturation and carbon dioxide concentration can be very high, favouring the development of algae, mosses and hepatiques. The zoobenthic community is co-dominated by chironomids (Diamesinae and Orthocladiinae), Plecoptera, Ephemeroptera and Trichoptera. Chial and ombral habitats are generally temporary habitats with peaks of discharge during the snowmelt or after rainfall. In CHIRDB lake outlets are also included. They represent a different stream type, with physical, hydrological and chemical features directly influenced by the upstream lake (Hieber et al., 2002). Generally outlets of high altitude lakes show higher water temperature and lower diel and annual discharge fluctuations than inlets of the same lake. Moreover, these waters are richer in food (nutrients and planktonic drifters) and faunal diversity and abundance is higher.

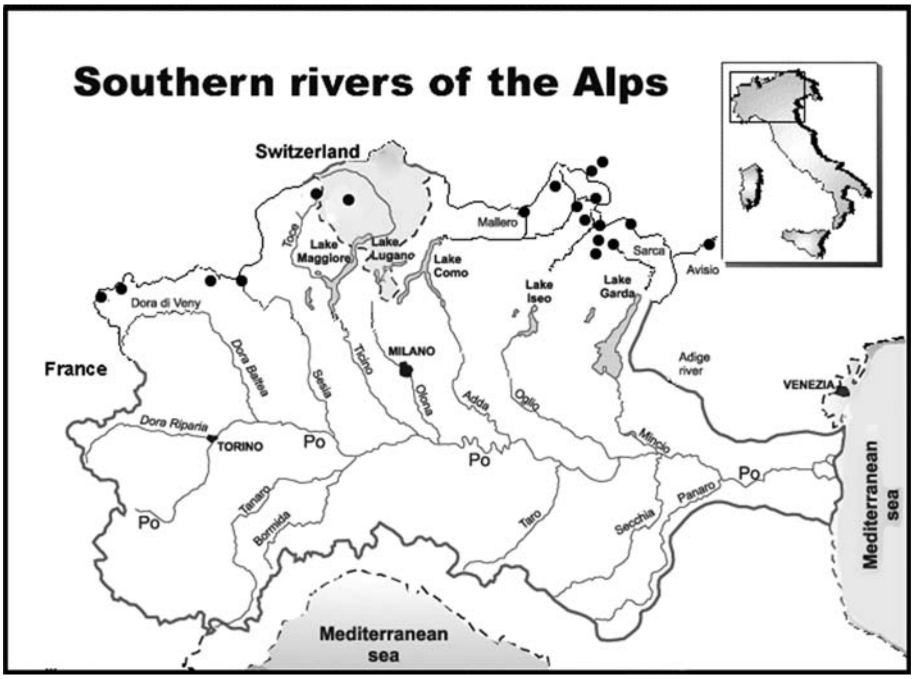

Figure 1. The study area: the most important rivers investigated in the Italian Alps (Po and Adige basins).

Methods

Environmental factors

Point records of water temperature, dissolved oxygen, pH and conductivity were recorded with a field multiprobe in all sampling sites, with the exception of the outlets of the small alpine lakes where 1 l of water was taken from each site using a polyethylene bottle and analysed in the laboratory (Tartari & Mosello, 1997). Nutrients (nitrogen, phosphorous, silica), the main cations and anions were recorded in all sites investigated in the AL:PE, EMERGE, AASER and HIGHEST projects. The last two projects also required the measurement of suspended sediments and temperature to be performed continuously throughout the year (from June to August with a monthly frequency), as well as geo-morphological (e.g., channel stability) and hydrological (current velocity, depth, discharge) factors. More details are in Maiolini & Lencioni (2001).

Chironomid fauna

In each sampling site, larvae and immature pupae were collected from different microhabitats (e.g., stones, mosses and algal mats) with a pond net (225–300 μm mesh sizes) (Thienemann, 1936), while mature pupae and pupal exuviae were taken with a drift net (300 μm mesh size) (Brundin, 1966). When qualitative samples were collected, at least 30 (generally more, 100–200) specimens were examined per sample and mounted on permanent slides for identification. In the AASER and HIGHEST sampling sites quantitative kick samples were taken (in each 15 m-long station, 5–10 replicates were taken, each of them from an area of 0.1 m^2). Lake outlets were sampled near the lake source and 50–100 m downstream.

For rearing single larvae and pupae were transported alive to the laboratory, with moss-stems or leaf pieces. Some specimens were kept in Petri dishes (1 cm high, 5 cm diameter) at low temperature (1–6 °C) till the adults emergence. Strictly cold-stenothermal species (e.g., *Diamesa latitarsis* and *steinboecki* group) required water temperature below 4 °C for rearing. Larvae successfully reared in Petri dishes become mature pupae, but mature pupae often did not moult to live imagos under these conditions. Imagos were successfully obtained from larvae and pupae reared in larger boxes (30×30×30 cm) aerated with an aquarium air pump. Under these conditions, emerging adult mortality was low, but an association of single larval and pupal exuviae with adults was not possible. Adults were also collected occasionally in the field using sweep nets, light and emergence traps.

Genera were identified using Wiederholm (1983, 1986, 1989) keys for Holarctic fauna, species using the miscellaneous specialised literature available.

Only species whose identification was based on well preserved material mounted on permanent slides, stored in the collection of the Department of Biology of the University of Milan (Italy), the Natural Science Museum of Trento (Italy) and the Institute for Ecosystem Study in Pallanza (Italy) were included in the checklist (see Appendix).

Data analysis

All the data available from the southern Alps summarized in Table 1 were filed in a relational database (CHIRDB = chironomids database) using Microsoft ACCESS (MS) (Rossaro et al., 2002). Means of environmental variables weighted by species abundances were calculated. Values obtained with fixed count sub-samples, generally 100 specimens, were used as species abundances (King & Richardson, 2002). Means of water temperature, conductivity, and pH (and other variables when available) were calculated, using the formula

$$\overline{z}_{jk} = \frac{\sum_{i=1}^{n} y_{ik} z_{ij}}{\sum_{i=1}^{n} y_{ik}},$$

where z_{ij} is the value of the environmental variable j measured in a locality i, y_{ik} is the abundance of the species k in the same locality i and $\overline{z}_{jk}$ is the weighted mean value calculated for species j and variable k. Weighted standard deviations, minimum and maximum values were also filed in the database. Sites above 900 m a.s.l. were selected for calculations. Species for which at least 10 records were available for each environmental variable were included in Tables 2–4.

Table 2. *x* = mean water temperature weighted by species abundance, *s* = standard deviation, *n* = number of records

Species	*x*	*s*	*n*
Tanypodinae			
Arctopelopia griseipennis	12.13	3.04	14
Macropelopia nebulosa	10.32	5.31	29
Zavrelimyia hirtimana	6.40	4.30	12
Zavrelimyia punctatissima	8.16	2.15	17
Diamesinae			
Diamesa aberrata	4.39	3.26	20
Diamesa bertrami	3.48	1.29	119
Diamesa cinerella	3.64	1.83	111
Diamesa dampfi	3.83	1.45	38
Diamesa goetghebueri	3.83	3.63	37
Diamesa incallida	5.35	0.94	13
Diamesa latitarsis	2.76	1.96	240
Diamesa steinboecki	2.68	1.61	208
Diamesa tonsa	7.15	2.57	34
Diamesa zernyi	3.39	2.11	298
Pseudodiamesa branickii	4.90	1.88	112
Pseudodiamesa nivosa	4.45	4.42	11
Pseudokiefferiella parva	3.66	2.06	128
Prodiamesinae			
Prodiamesa olivacea	4.04	3.90	12
Orthocladiinae			
Brillia bifida	7.10	2.03	22
Chaetocladius sp.	5.72	2.37	128
Corynoneura edwardsi	5.50	1.71	77
Cricotopus sp.	10.26	4.86	12
Cricotopus fuscus	9.24	4.24	17
Eudactylocladius fuscimanus	3.80	1.48	63
Eukiefferiella brevicalcar	4.24	1.48	204
Eukiefferiella claripennis	5.45	1.46	23
Eukiefferiella fuldensis	4.81	2.28	105
Eukiefferiella minor	4.90	2.41	166
Euorthocladius rivicola	3.81	1.61	205
Euorthocladius thienemanni	3.30	3.18	11
Heleniella serra-tosioi	5.35	2.08	91
Heterotrissocladius marcidus	7.28	2.34	26
Krenosmittia camptophleps	6.94	1.80	82
Metriocnemus hygropetricus	5.73	1.93	32
Orthocladius frigidus	4.35	1.98	292
Parametriocnemus stylatus	7.31	1.90	93
Paratrichocladius nivalis	6.41	4.13	60
Paratrichocladius rufiventris	5.97	3.03	28
Paratrichocladius skirwithensis	4.60	2.11	254
Parorthocladius nudipennis	4.00	1.32	58
Rheocricotopus effusus	6.37	2.56	31
Rheocricotopus fuscipes	10.77	4.42	17
Thienemanniella partita	5.01	1.52	67
Tokunagaia tonollii	4.47	1.76	19
Tvetenia calvescens	4.80	1.91	267
Chironominae			
Tanytarsini			
Micropsectra atrofasciata	5.10	3.04	260
Paratanytarsus austriacus	5.34	1.04	16
Tanytarsus gracilentus	4.11	1.31	13
Chironomini			
Microtendipes pedellus	8.91	2.90	16
Paratendipes nudisquama	3.83	2.84	35

Results

In all, 202 species were captured on the Italian side of the Alps (Appendix 1).

Taxonomy

The present research confirms the importance of identifying species (Rossaro & Mietto, 1998), in fact different species within a genus often have a divergent ecological niche.

Our knowledge of Holarctic genera is well-consolidated (Wiederholm, 1983, 1986, 1989), whereas there are still many unsolved taxonomic problems at the species level. Many genera require revision, e.g., *Boreoheptagyia* and *Chaetocladius*. Species identities must be checked accurately in *Diamesa latitarsis* and *steinboecki* groups to avoid misidentifications, and there are many open taxonomic questions in other genera; recent revisions (*Orthocladius* s. str., see Langton & Cranston, 1991; Rossaro et al., 2003) have emphasised the existence of incorrect synonymies.

Biogeography

Information about the distribution and ecology of chironomids in the Alps is still fragmentary, despite the large number of studies carried out in the past (see Introduction). Many high altitude stream ecosystems in the Southern Alps are still unexplored or very little known, such as those in the

Table 3. x = mean pH weighted by species abundance, s = standard deviation, n = number of records

Species	x	s	n
Tanypodinae			
Zavrelimyia hirtimana	8.02	0.31	12
Zavrelimyia punctatissima	6.67	0.45	15
Diamesinae			
Diamesa bertrami	6.11	0.44	93
Diamesa cinerella	6.08	1.06	88
Diamesa dampfi	8.67	0.56	11
Diamesa goetghebueri	6.60	1.16	28
Diamesa latitarsis	7.68	1.38	177
Diamesa steinboecki	5.77	0.62	183
Diamesa tonsa	7.89	0.38	14
Diamesa zernyi	7.39	1.53	232
Pseudodiamesa branickii	6.82	1.09	77
Pseudokiefferiella parva	5.91	0.92	103
Orthocladiinae			
Chaetocladius sp.	6.34	0.56	94
Corynoneura edwardsi	6.46	0.37	68
Eudactylocladius fuscimanus	6.48	0.70	40
Eukiefferiella brevicalcar	6.54	0.68	176
Eukiefferiella claripennis	6.61	0.57	13
Eukiefferiella fuldensis	6.24	0.31	96
Eukiefferiella minor	6.52	0.98	121
Euorthocladius rivicola	6.35	0.98	164
Heleniella serra-tosioi	6.43	0.75	69
Heterotrissocladius marcidus	7.23	1.09	14
Krenosmittia camptophleps	6.21	0.42	77
Metriocnemus hygropetricus	7.45	1.25	18
Orthocladius frigidus	6.43	0.70	226
Parametriocnemus stylatus	6.20	0.59	63
Paratrichocladius rufiventris	7.14	1.37	22
Paratrichocladius skirwithensis	8.45	0.91	69
Parorthocladius nudipennis	6.54	0.64	40
Rheocricotopus effusus	7.05	0.60	22
Smittia	7.86	1.17	30
Thienemanniella partita	6.33	0.29	57
Tokunagaia tonollii	8.79	0.44	11
Tvetenia calvescens	6.44	0.65	208
Chironominae			
Micropsectra atrofasciata	6.26	0.47	195
Paratendipes nudisquama	8.40	0.71	20

Table 4. x = mean conductivity weighted by species abundance, s = standard deviation, n = number of records

Species	x	s	N
Tanypodinae			
Macropelopia nebulosa	77.49	51.22	13
Zavrelimyia punctatissima	21.83	8.12	14
Diamesinae			
Diamesa aberrata	176.17	39.07	11
Diamesa bertrami	11.86	27.12	102
Diamesa cinerella	42.61	61.65	94
Diamesa dampfi	274.13	177.13	26
Diamesa goetghebueri	31.80	92.58	28
Diamesa latitarsis	84.17	122.21	194
Diamesa steinboecki	15.89	41.98	187
Diamesa tonsa	101.20	59.00	16
Diamesa zernyi	88.26	140.27	247
Pseudodiamesa branickii	76.03	133.07	91
Pseudokiefferiella parva	20.05	53.21	108
Orthocladiinae			
Brillia bifida	49.58	39.26	12
Chaetocladius sp.	20.94	44.64	110
Corynoneura edwardsi	11.29	7.55	61
Eudactylocladius fuscimanus	22.21	40.92	46
Eukiefferiella brevicalcar	24.14	51.69	186
Eukiefferiella claripennis	35.60	36.81	15
Eukiefferiella fuldensis	11.42	9.57	103
Eukiefferiella minor	33.88	61.11	137
Euorthocladius rivicola	26.19	55.61	180
Heleniella serra-tosioi	24.68	48.09	76
Heterotrissocladius marcidus	99.95	151.41	18
Krenosmittia camptophleps	9.51	2.11	78
Metriocnemus hygropetricus	92.96	107.90	20
Orthocladius frigidus	27.61	45.98	238
Parametriocnemus stylatus	15.07	25.83	66
Paratrichocladius rufiventris	100.12	133.46	23
Paratrichocladius skirwithensis	344.08	186.82	86
Parorthocladius nudipennis	33.19	31.75	53
Rheocricotopus effusus	34.23	20.17	21
Thienemanniella partita	11.15	8.59	65
Tokunagaia tonollii	227.23	122.36	14
Tvetenia bavarica	48.44	12.03	11
Tvetenia calvescens	24.56	39.25	230
Chironominae			
Micropsectra atrofasciata	14.28	25.38	208
Paratanytarsus austriacus	63.92	46.52	16
Paratendipes nudisquama	151.68	110.29	19
Tanytarsus gracilentus	90.54	9.59	11

Matterhorn (Cervino), Gran Paradiso, Dolomites and Carnia mountains.

Most species are widespread in the Palaearctic Region, with some exceptions: for example *Diamesa longipes* and *Stilocladius montanus* showed a distribution restricted to very few locations. A comparison of checklists from different countries can be misleading due to dissimilarities in the taxonomic accuracy applied by specialists in species identification. Different sampling efforts and devices, and differences in the characteristics of the areas investigated also advice caution.

A comparison between the list of species from the northern and southern side of the Alps emphasises that a geographical barrier separating chironomid species is not apparent. Reiss (1968) draw the same conclusion in comparing the fauna of lakes in the Prealps. The fact that a high number of species names is reported from only one side of the Alps seems to contradict the absence of barriers; within the well investigated Diamesinae *Protanypus* spp., *Diamesa wuelkeri* (Serra-Tosio 1964), *D. martae* (Kownacki & Kownacka 1980), *D. novikiana* (Kownacki & Kownacka 1975), *D. hamaticornis* (Kieffer 1909) were reported from the western and northern side only, and *Syndiamesa nigra* from the southern side only; among the Orthocladiinae, there are many species reported from the northern side only, but the presence of *Heterotanytarsus* sp. A from the southern side only must be noted. The example of *Boreoheptagyia* is also instructive: four species belonging to the genus *Boreoheptagyia* were reported from the French Alps (Serra-Tosio, 1991), three species from the Italian Alps, but only *B. legeri* and *B. rugosa* are common to both; *B. alpicola* (Serra-Tosio, 1989); *B. dasyops* (Serra-Tosio, 1989) are endemic to the French Alps, *B. monticola* (Serra-Tosio 1964) is reported from the French Alps, Switzerland, and Macedonia, and there is one still not described species from the Italian Alps. At least three species are known as pupae and larvae only (Serra-Tosio, 1989) as a demonstration of incomplete knowledge of the genus. On the other hand it must be emphasised that there are also species collected in few localities on both sides of the Alps (*Diamesa longipes* and *Stilocladius montanus* for example); rare species such as *Protanypus* spp., *D. wuelkeri* and *D. starmachi* are also probably present in both sides, but the determinations on the southern side must be confirmed.

To sum up incomplete knowledge can be always an explanation of conflicting evidence.

An intriguing puzzle is the case of *Diamesa insignipes:* it was never captured on the southern side of the Alps, which is rather surprising because the species is widespread in Europe, common in the French, Bavarian and Austrian Alps; in Italy it is also present and common in the northern Apennines, even though its emergence is restricted in this area to a short period in January. In the central Apennines adults have been captured only in one occasion (a spring near Opi, Sangro river, May 1978); the species was not captured again after that date, despite the intensive sampling in the area between 1990 and 1993. In the southern Alps larvae with a yellow head attributable to this species (Ferrarese & Rossaro, 1981) were rarely captured, so the presence of the species cannot be excluded, but adults were never collected. It must be emphasised that reports from different localities based on larval collection only are not enough to confirm the presence of a species.

Ecology

The relatively high species richness observed can be explained by the high heterogeneity of the habitats investigated. Most species are typical of mountain streams but there are taxa which are also common in lowland rivers (*Rheocricotopus fuscipes*, *Synorthocladius semivirens*, *Micropsectra atrofasciata*, *Tanytarsus* spp., *Polypedilum* spp., *Chironomus* spp.).

Correlation coefficients between environmental variables and the most common species are in Table 5. Altitude, source distance and water temperature were significantly correlated with many taxa, but total phosphorous and ammonia emphasized also significant (often inverse) correlations, Among the species living at high altitude, some appeared to be strictly cold-stenothermal, others eurithermal, most with a range below 12 °C (Table 2), and/or able to tolerate acidic pH (up to 4.5 units) (Table 3). Species records occurred in a wide water conductivity range (2–700 μS cm^{-1} (Table 4).

Water temperature is confirmed as the variable which best accounts for species distribution (Brittain & Milner, 2001; Castella et al., 2001; Maiolini & Lencioni, 2001). Low temperature is associated to high oxygen concentration. Many species are

Table 5. Correlation coefficients between environmental variables and the most frequent species groups and their probability of significance

	D. latitarsis	*Tvetenia*	*D. zernyi*	*Micropsectra*	*Orthocladius frigidus*	*E. claripennis*
Altitude	0.337	−0.008	0.108	−0.068	0.099	0.081
Source distance	−0.059	−0.086	−0.016	−0.093	−0.047	−0.094
Alkalinity	0.074	0.025	−0.032	−0.036	0.054	0.035
Conductivity	−0.118	−0.006	−0.001	−0.056	−0.129	−0.113
N-NH_4	−0.034	−0.022	0.033	−0.132	−0.160	−0.127
N-NO_3	−0.124	−0.010	−0.082	−0.145	−0.161	−0.142
O_2	0.025	−0.081	−0.041	−0.103	−0.117	−0.109
pH	−0.128	0.067	−0.001	−0.057	−0.073	−0.017
Total-*P*	0.082	−0.206	0.111	−0.261	−0.293	−0.334
Water temperature	−0.399	0.045	−0.168	0.121	−0.082	−0.049
Altitude	0.00	0.86	0.00	0.20	0.00	0.00
Source distance	0.00	0.01	0.78	0.02	0.29	0.00
Alkalinity	0.04	0.49	0.36	0.30	0.13	0.32
Conductivity	0.00	0.48	0.77	0.00	0.00	0.00
N-NH_4	0.17	0.00	0.09	0.00	0.00	0.00
N-NO_3	0.00	0.35	0.04	0.00	0.00	0.00
O_2	0.29	0.01	0.28	0.00	0.00	0.00
pH	0.00	0.03	0.85	0.16	0.08	0.82
Total-*P*	0.48	0.00	0.00	0.00	0.00	0.00
Water temperature	0.00	0.00	0.00	0.00	0.76	0.28

steno-oxybiontic and have an optimum at low temperatures (Table 2). Brittain & Milner (2001) added channel stability and turbidity to the variables that mainly influence the zoobenthic communities in high altitude streams. pH (Table 3), water conductivity (Table 4), current velocity and food availability can also be responsible of different species patterns, but none does seem to be very limiting. Very low pH values were never observed in the localities examined and no species is apparently excluded by pH. Conductivity also is not a limiting factor within the observed ranges. Hydraulic stress due to river damming and canalization alter the hydrological and thermal pattern: at present this is probably a serious problem for freshwater macrofauna conservation in the Alps, but a quantification of its influence on species response is not easy: there is evidence indeed that there are species able to sustain high current velocity (more than 2 m s^{-1}): *Boreoheptagyia* spp., *D.* gr. *latitarsis, Tvetenia calvescens*, *Eukiefferiella brevicalcar, E. minor, Eudactylocladius fuscimanus, Euorthocladius rivicola, E. frigidus, Krenosmittia camptophleps, Heleniella serra-tosioi, Micropsectra atrofasciata*: many of them have a wide distribution range and do not seem to be restricted to fast flowing streams. The species tolerance to high current velocity requires further study. Correlation coefficients emphasized that water temperature is the variable most frequently correlated with species abundance, followed by conductivity and pH (Table 5). Water velocity was also probably very important but few measures are available and the importance of nutrients must be emphasised.

Chironomids in alpine streams feed largely on Diatoms, which live epiphyte on different substrates (rocks, *Hydrurus foetidus*, mosses). Biofilm chlorophyll *a* concentration and the total number of chironomids are significantly positively correlated ($r = 0.38$, $p < 0.01$, data from CHIRDB) suggesting that food may be a limiting factor.

Waters in the Alps are still relatively unpolluted, organic pollution and sewage discharge was observed only locally in the Alps, organic pollution does not appear to be a serious problem for the chironomid fauna; many species can actually be favoured by moderate organic enrichment.

Conclusion

At present the objective of relating species to environmental factors in alpine inland waters is reached only in part, species groups or genera and not species were generally used in multivariate analysis carried out to emphasise the species response to environment (Ruse & Davison, 2000; Ruse et al., 2000; Milner et al., 2001); the reason is that species identification is a very laborious task and rarely it is matched by the estimation of species abundances and measurement of environmental variables. CHIRDB allowed the calculation of correlations between environmental variables with species, but the number of samples available was low for many species resulting in high standard deviations (see Tables 2–4).

CHIRDB mainly refers to Alpine samples collected in summer. Winter samples are available for a limited number of sites (Camonica, Malenco valley, see Table 1). Recent findings (e.g., Burgherr, 2002; Uehlinger et al., 2002) highlighted that in some habitats, such as glacial streams, the winter community is generally richer than that of the summer, both in species numbers and abundances, because in winter environmental stress is reduced (lower discharge, higher channel stability and higher transparency, abundant algae (mostly Diatoms) growing on mats of *H. foetidus*, etc.). For a better understanding of the relationships between fauna and environment, the winter season should be taken into account in future ecological research (Füreder et al., 2001).

Long term studies should be encouraged, especially on habitats characterised by strong seasonality like high altitude streams (Kaufmann, 2002): the reference period of CHIRDB is rather long (25 years from 1978 to 2005), but long term studies are restricted to few localities (Camonica valley). In some localities (i.e. Conca, Niscli, Cornisello, de la Mare and Careser stream systems, all in Trentino) series of data with a robust sampling design are available (2–5 years of records for the same streams with a 15 days frequency in summer). In any case the available data do not highlight trends in species composition. Reductions in chironomid abundance were emphasised in the last years in some glacial streams in the southern Alps. High discharges were observed for the entire summer, due to unusually high air temperatures (in summer 2003 above 30 °C during the day and above 0 °C during all the night above 2500 m of altitude). This climatic situation maintained very high discharge with high turbidity and channel instability for many consecutive months, hindering the development of a biofilm. The strict cold-stenothermal species, such as those belonging to the *Diamesa latitarsis – steinboecki* group, confined to glacial snouts, are at risk of extinction as the glaciers retreat. This has probably already happened in the Apennines, where the recent disappearing of small glaciers ('the Calderone' in the Gran Sasso group, Abruzzo) reduced the *Diamesa latitarsis* group to only one species, *Diamesa bertrami* (Edwards 1935). It was captured only in the upper stretch of the River Mavone on 4/12/92 and 20/3/93, never elsewhere. *Diamesa aberrata* was also very rarely captured (Tasso stream, National Park in Abruzzo, 20/5/78, Aso stream, 29/1/79). The absence of records of *D. insignipes* in the Central Apennines after 1978 despite a conspicuous sampling effort also deserves attention.

Spatial and temporal changes of chironomid fauna in terms of number of individuals and/or species can be explained through the effects of short term and long term climate change. Inter-annual variations can be explained by exceptional climatic conditions such as an extremely warm summer or cold winter; they modify physical variables (e. g. an higher discharge, a shorter or longer snow cover) promoting a global community response with inter-species competition. These causal events can be complicated by stochastic factors such as the chance that an adult female deposits eggs. There is enough evidence that the glaciated areas in the Alps, and cold water habitats in the Mediterranean region in general, are at serious risk in relation with the global climatic change.

Acknowledgements

Part of this research was supported by: a grant from Italian MURST n. 2002058154_002 within the project 'An analysis of spatio-temporal distribution of species and populations belonging to critical groups living in inland waters, with morphological and molecular characterization'. The studies carried out in the Adamello-Brenta Regional Park and in the Stelvio National

Park (Trentino sector) were partly supported by the European Union Environment and Climate Programme (AASER project, Arctic and Alpine Stream Ecosystem Research, n. ENV4-CT95-0164, 1996–1999) and partly were co-funded by the Natural Science Museum of Trento and the Trento Provincial Council (1999–2003). Researches conducted on inlets and outlets of lakes in the Toce and Ticino rivers basins were partly funded by the European Commission Environment Programmes AL:PE (CNR-CEE STEP-CT90-0079-(SMA) and CNR-CEE EV5V-CT92-0205), MOLAR (ENV4-CT95-0007) and EMERGE projects (CE/CNR EVK1-CT-1999-00032) and by the Val Grande National Park, in the framework of the EU Inter-Reg II Programme 'Concetto di paesaggio transfrontaliero quale sostegno per la creazione di una rete di aree protette tra il Parco Nazionale Val Grande (Italia) e l'area Centovalli-Collina di Maia-Lago Verbano (Confederazione Elvetica)'. We are grateful to Dr J.S. Olafsson for providing *Diamesa lindrothi* from Iceland and to prof. U. Ferrarese for the identification of pupae and pupal exuviae from inlets and outlets of lakes studied within the EMERGE project.

References

Boggero, A. & M. Nobili, 1998. Macrobenthic community and chemical characteristics of four Alpine lakes in Canton Ticino. Bollettino Società Ticinese Scienze Naturali 86: 17–23.

Boggero A., A. M. Nocentini, M. Nobili & M. Gianatti, 1996. Ricerche sulla fauna macrobentonica litorale in laghi d'alta quota nel bacino imbrifero del Lago Maggiore. Atti VII Congr. Naz. S.It.E. Napoli, 11-14 Settembre 1996, 83–86.

Brittain, E. J. & A. M. Milner, 2001. Ecology of glacier-fed rivers: current status and concepts. Freshwater Biology 46: 1571–1578.

Brundin, L., 1966. Transantarctic relationships and their significance, as evidenced by chironomid midges, with a monograph of the Subfamilies Podonominae and Aphroteniinae and the austral Heptagyiae. Kungliga Svenska Vetenskapsakademiens Handlingar 11: 1–472.

Brundin, L., 1974. Fifty years' limnic zoogeography. Mitteilungen International Vereinigung Limnologie 20: 287–300.

Burgherr, P., 2002. Biodiversity of Zoobenthos in Alpine streams: the Val Roseg. EAWAG News 54: 22–23.

Caspers, N., 1983. Die Chironomiden der Oberen Alz (Diptera, Nematocera). Nachrichtenblatt der Bayerischen Entomologen 32: 97–108.

Castella, E., H. Adalsteinsson, J. E. Brittain, G. M. Gislason, A. Lehmann, V. Lencioni, B. Lods-Crozet, B. Maiolini, A. M. Milner, J. S. Olafsson, S. J. Saltveit & D. L. Snook, 2001. Macrobenthic invertebrate richness and composition along a latitudinal gradient of European glacier-fed streams. Freshwater Biology 46(12): 1811–1831.

Cranston, P. S., 1995. Introduction. In Armitage, P., P. S. Cranston & L. C. V. Pinder (eds), The Chironomidae. The biology and ecology of non-biting midges. Chapmann & Hall, London, UK, 1–7.

Crema, S., U. Ferrarese, D. Golo, P. Modena, B. Sambugar & R. Gerecke, 1996. A research on benthic and interstitial fauna in alpine and pre-alpine springs. Centro di Ecologia Alpina 8: 1–104.

Ferrarese, U. & B. Rossaro, 1981. Chironomidi 1 (Diptera Chironomidae: Generalità, Diamesinae, Prodiamesinae). Guide per il riconoscimento delle specie animali delle acque interne italiane, vol. 12. Consiglio Nazionale delle Ricerche, Verona, 97 pp.

Fittkau, E. J. & F. Reiss, 1978. Chironomidae. In Illies, J. (ed), Limnofauna Europea. Gustav Fischer Verlag, Stuttgart, 404–440.

Fjellheim A., A. Boggero, G. A. Halvorsen, A. M. Nocentini, M. Rieradevall, G. G. Raddum & O. A. Schnell, 2000 Distribution of benthic invertebrates in relation to environmental factors. A study of European remote alpine lake ecosystems International Association of Theoretical and Applied Limnology/Stuttgart 27th Congress in Dublin 1998. Proceedings. no. 1: 484–488.

Füreder, L. 1999. High alpine streams: cold habitats for insect larvae. In Margesin, R. & F. Schinner (eds), Cold adapted Organisms. Ecology, Physiology, Enzymology and Molecular Biology. Springer Verlag; Berlin (Germany), 181–196, 416 pp.

Füreder, L., C. Schütz, M. Wallinger & R. Burger, 2001. Physico-chemistry and aquatic insects of a glacier-fed and a spring-fed alpine stream. Freshwater Biology 46: 1673–1690.

Hieber, M., C. T. Robinson, U. Uehlinger & J. V. Ward, 2002. Are alpine lake outlets less harsh than other alpine streams?. Archiv Fur Hydrobiologie 154: 199–223.

Kaufmann, R., 2002. Glacier foreland colonisation: distinguishing between short-term and long-term effects of climate change. Oecologia 130: 470–475.

King, R. S. & C. J. Richardson, 2002. Evaluating subsampling approaches and macroinvertebrate taxonomic resolution for wetland bioassessment. Journal of the North American Bentological Society 21: 150–171.

Kownacka, M. & A. Kownacki, 1975. Gletscherbach-Zuckmücken der Ötztaler Alpen in Tirol (Diptera: Chironomidae: Diamesinae). Entomologica Germanica 2: 35–43.

Kownacki, A. & M. Kownacka, 1994. Diurnal periodicity in the drift of high mountain stream invertebrates (South Tyrol, Italy). Journal Freshwater Ecology 25: 1768–1772.

Langton, P. H. & P. S. Cranston, 1991. Pupae in nomenclature and identification: West Palaearctic *Orthocladius* s. str. (Diptera: Chironomidae) revised. Systematic Entomology 16: 239–252.

Lencioni V., 2000. Chironomid (Diptera: Chironomidae) assemblages in three Alpine glacial systems. Ph.D. Thesis, University of Innsbruck (Austria), 202 pp.

Lencioni, V., A. Boscaini, A. Franceschini & B. Maiolini, 2001. Distribuzione di macroinvertebrati bentonici in torrenti d'alta quota sulle alpi italiane: stato delle conoscenze e recenti risultati. Proceedings of the XI Congress of the Società Italiana di Ecologia (S.It.E.), Sabaudia (LT), 12–14 settembre 2001. *S.It.E. Atti*, 25 (CD-ROM, paper n.42).

Lencioni, V., B. Maiolini (eds), 2002. L'ecologia di un ecosistema acquatico alpino (Val de la Mare, Parco Nazionale dello Stelvio). Natura alpina, 54(4): 96 pp.

Lencioni, V., B. Maiolini & B. Rossaro, 2000. The kryal and rhithral chironomid community in the Carè Alto system (Italian central-eastern Alps). Verh. Internat. Verein. Limnol. 27(2): 711–715.

Lods-Crozet, B., E. Castella, D. Cambin, C. Ilg, S. Knispel & H. Mayor-Siméant, 2001a. Macroinvertebrate community structure in relation to environmental variables in a Swiss glacial stream. Freshwater Biology 46(12): 1641–1661.

Lods-Crozet, B., V. Lencioni, J. S. Olafsson, D. L. Snook, G. Velle, J. E. Brittain, E. Castella & B. Rossaro, 2001b. Chironomid (Diptera: Chironomidae) communities in six European glacier-fed streams. Freshwater Biology 46(12): 1791–1809.

Maiolini, B. & V. Lencioni, 2001. Longitudinal distribution of macroinvertebrate assemblages in a glacially influenced stream systems in the Italian Alps. Freshwater Biology 46(12): 1625–1639.

Marchetto A., A. Boggero & M. Manca, 2001. Aspetti ecologici delle piccole zone umide e delle sorgenti di quota In Copiatti, F. & C. Movalli (eds), Aree di cresta e zone umide. Risultati delle ricerche. Ente Parco Nazionale Val Grande, Griggi, Baveno, 110 pp.

Milner, A. M., J. E. Brittain, E. Castella & G. E. Petts, 2001. Trends of macro-invertebrate community structure in glacier-fed rivers in relation to environmental conditions: a synthesis. Freshwater Biology 46(12): 1833–1847.

Milner, A. M. & G. E. Petts, 1994. Glacial rivers: physical habitat and ecology. Freshwater Biology 32: 295–307.

Orendt, C., 2000. Chironomids of small Alpine water bodies (springs, spring brooks, pools, small lakes) of the northern Calcareous Alps (Insecta, Diptera, Chironomidae). Spixiana 2: 121–128.

Reiss, F., 1968. Verbreitung Lakustrischer Chironomiden (Diptera) des Alpengebietes. Annales Zoologica Fennici 5: 119–121.

Rossaro, B., 1981. Analisi delle larve delle Diamesinae europee, con descrizione di alcune specie (Diptera Chironomidae). Bollettino del Museo Civico di Storia Naturale di Verona 8: 29–43.

Rossaro B., 1982. Chironomidi 2 (Diptera, Chironomidae: Orthocladiinae). Guide per il riconoscimento delle specie animali delle acque interne italiane, Vol. 16. Consiglio Nazionale delle Ricerche, Verona, 80 pp.

Rossaro, B., 1990. Chironomids collected in the Western and Central Alps (Diptera, Chironomidae). Studi Trentini di Scienze Naturali 67: 181–195.

Rossaro, B., 1995. The distribution of Palaearctic Diamesinae. Spixiana 18: 177–186.

Rossaro, B., C. Casalegno & V. Lencioni, 2003. Revision of West Palaearctic species belonging to *Orthocladius* s. str. van der Wulp, 1874 (Diptera: Chironomidae: Orthocladiinae), with a new key to species. Studi Trentini di Scienze Naturali – Acta Biologica 79(2002): 213–241.

Rossaro, B. & V. Lencioni, 2001. Analysis of relationships between chironomid species (Diptera, Chironomidae) and environmental factors in an Alpine glacial stream system using a general linear model. Studi Trentini di Scienze Naturali – Acta Biologica. 76(1999): 17–27.

Rossaro, B., V. Lencioni & C. Casalegno, 2002. Relazioni tra specie di Ditteri Chironomidi e fattori ambientali in ambienti di alta quota esaminate con un data base relazionale. In Lencioni, V. & Maiolini B. (eds), Atti del XV Convegno Gadio, Trento, 5-7 maggio 2001, Studi Trentini di Scienze Naturali – Acta Biologica, 78/1 (2001), 201–206.

Rossaro, B., S. Mietto, 1998. Multivariate analysis using chironomid species. River Bottom IV. 27–30/8/1996. In Advances in River Bottom Ecology Backhuys Publ. The Netherlands, 191–205.

Ruse, L. & M. Davison, 2000. Long-term data assessment of chironomid taxa structure and function in the River Thames. Regulated Rivers: Research and Management 16: 113–126.

Ruse, L., S. J. Herrmann & J. E. Sublette, 2000. Chironomidae (Diptera) species distribution related to environmental characteristics of the metal-polluted Arkansas River, Colorado. Western North American Naturalist 60: 34–56.

Saxl R., 1986. Die Chironomiden des Stocktalbaches. Dissertation, Institut für Zoologie und Limnologie Universität Innsbruck, Innsbruck, Austria. 22: 1–183.

Serra-Tosio, B., 1973. Ecologie et biogéographie des Diamesini d'Europa (Diptera: Chironomidae). Travaux du Laboratoire d'Hydrobiologie et de Pisciculture de Grenoble 63: 5–175.

Serra-Tosio, B., 1989. Révision des espèces ouest-paléarctiques et néarctiques de *Boreoheptagyia* (Diptera,Chironomidae), avec des clés pour les larves, les nymphes, et les imagos. Spixiana 11: 133–173.

Serra-Tosio, B., 1991. Liste annotée des Dipteres Chironomidés de France continentale et de Corse. Annales de limnologie 27: 37–74.

Steffan, A. W., 1971. Chironomid (Diptera) biocoenoses in Scandinavian glacier brooks. The Canadian Entomologist 103: 477–486.

Tartari, G. A. & R. Mosello, 1997. Metodologie analitiche e controlli di qualità nel laboratorio chimico dell'Istituto Italiano di Idrobiologia del Consiglio Nazionale delle Ricerche60 Documenta Ist, ital Idrobiol, 160 pp.

Thienemann, A., 1936. Alpine Chironomiden (Ergebnisse von Untersuchungen in der Gegend von Garmisch-Partenkirchen, Oberbayern). Archiv für Hydrobiologie 30: 167–262.

Thienemann A., 1953. *Chironomus* Leben Verbreitung und wirtschaftliche Bedeutung der Chironomiden. Die Binnengewässer, Bd. 20, Schweizerbart'sche Verlagsbuchhandlung, Stuttgart, 834 pp.

Uehlinger, U., F. Malard & K. Tockner, 2002. Val Roseg: a glacial flood plain in the Swiss Alps. EAWAG News 54: 12–13.

Ward, J. V., 1994. Ecology of alpine streams. Freshwater Biology 32: 277–294.

Ward, J. V., 2002. The Ecology of Alpine streams. EAWAG News 54: 3–5.

Wathne, B. M. & B. O. Rosseland, 2000. Measuring and modelling the dynamic response of remote mountain lake ecosystems to environmental change: a programme of MOuntain LAke Research. NIVA Report, 96061-1: 201 pp.

Wiederholm, T. (ed.), 1983. Chironomidae of the Holartic region. Keys and Diagnoses. Part I: Larvae. Entomologica Scandinavica Supplement 19: 1–457.

Wiederholm, T. (ed.), 1986. Chironomidae of the Holartic region. Keys and Diagnoses. Part II: Pupae. Entomologica Scandinavica Supplement 28: 1–482.

Wiederholm, T. (ed.), 1989. Chironomidae of the Holartic region. Keys and Diagnoses. Part III: Adult males. Entomologica Scandinavica Supplement 34: 1–532.

Appendix

Chironomid species collected in streams above 900 m a.s.l. in the Italian Alps with the number of sites where a species was collected

TANYPODINAE	
Arctopelopia griseipennis (van der Wulp, 1858)	16
Conchapelopia pallidula (Meigen, 1818)	42
Krenopelopia binotata (Wiedemann, 1817)	2
Macropelopia fittkaui Ferrarese & Ceretti, 1987	3
Macropelopia nebulosa (Meigen, 1818)	70
Nilotanypus dubius (Meigen, 1804)	1
Paramerina cingulata (Walker, 1856)	51
Procladius choreus (Meigen, 1804)	14
Rheopelopia ornata (Meigen, 1838)	1
Telmatopelopia nemorum (Goetghebuer, 1921)	1
Telopelopia fascigera Verneaux, 1970	2
Thienemannimyia carnea (Fabricius, 1805)	5
Thienemannimyia woodi (Edwards, 1929)	4
Trissopelopia longimana (Staeger, 1839)	1
Xenopelopia falcigera (Kieffer, 1912)	3
Zavrelimyia barbatipes (Kieffer, 1911)	8
Zavrelimyia hirtimana (Kieffer, 1918)	2
Zavrelimyia melanura (Meigen, 1804)	5
Zavrelimyia nubila (Meigen, 1818)	5
Zavrelimyia punctatissima (Goetghebuer, 1934)	1
DIAMESINAE	
(°) Boreoheptagyia legeri (Goetghebuer, 1933)	61
(°) Boreoheptagyia rugosa (Saunders, 1930)	1
Boreoheptagyia sp.	3
Diamesa aberrata Lundbeck, 1889	56
Diamesa bertrami Edwards, 1935	176
Diamesa cinerella Meigen in Gistl, 1835	128
Diamesa dampfi (Kieffer, 1924)	72

Appendix (Continued)

Diamesa goetghebueri Pagast, 1947	45
Diamesa incallida (Walker, 1856)	35
Diamesa laticauda SerraTosioSerra-Tosio, 1964	3
Diamesa latitarsis (Goetghebuer, 1921)	30
Diamesa lindrothi Goetghebuer, 1931	5
Diamesa longipes Goetghebuer, 1941	1
Diamesa permacra (Walker, 1856)	12
Diamesa steinboecki Goetghebuer, 1933	218
Diamesa tonsa (Walker, 1856)	161
Diamesa vaillanti SerraTosioSerra-Tosio, 1972	25
Diamesa zernyi Edwards, 1933	384
(°°*) Pagastia partica (Roback, 1957)	2
Potthastia gaedii (Meigen, 1838)	6
Potthastia longimanus (Kieffer, 1922)	2
Pseudodiamesa branickii (Nowicki, 1873)	200
Pseudodiamesa nivosa (Goetghebuer, 1928)	19
Pseudokiefferiella parva (Edwards, 1932)	158
Sympotthastia spinifera SerraTosioSerra-Tosio, 1968	3
(°) Syndiamesa edwardsi (Pagast, 1947)	2
Syndiamesa nigra Rossaro, 1980	34
PRODIAMESINAE	
Prodiamesa olivacea (Meigen, 1818)	46
ORTHOCLADIINAE	
Allopsectrocladius obvius (Walker, 1856)	2
Brillia bifida (Meigen, 1830)	65
Brillia longifurca Kieffer, 1921	21
Cardiocladius capucinus (Zetterstedt, 1850)	12
Cardiocladius fuscus Kieffer, 1924	33
(°*) Chaetocladius acuticornis (Kieffer in Potthast, 1915)	2
(°*) Chaetocladius dentiforceps (Edwards, 1929)	4
Chaetocladius dissipatus (Edwards, 1929)	2
Chaetocladius gelidus Brundin, 1956	2
Chaetocladius laminatus Brundin, 1947	11
(°*) Chaetocladius maeaeri Brundin, 1947	3
(°*) Chaetocladius melaleucus (Meigen, 1830)	4
Chaetocladius perennis (Meigen, 1830)	4
Chaetocladius suecicus (Kieffer in Thienemann e Kieffer, 1916)	3
(°*) *Chaetocladius vitellinus* (Kieffer in Kieffer & Thienemann, 1908)	2
Corynoneura edwardsi Brundin, 1949	79
Corynoneura fittkaui Schlee, 1968	1
Corynoneura lacustris Edwards, 1924	18
Corynoneura lobata Edwards, 1924	42
Corynoneura scutellata Winnertz, 1846	7
Cricotopus algarum (Kieffer, 1911)	2

Continued on p. 245

Appendix (Continued)

Cricotopus annulator Goetghebuer, 1927	19
Cricotopus bicinctus (Meigen, 1818)	4
Cricotopus curtus Hirvenoja, 1973	15
Cricotopus fuscus (Kieffer, 1924)	41
Cricotopus pulchripes Verral, 1912	3
Cricotopus tibialis (Meigen, 1804)	31
Cricotopus tremulus (Linnaeus, 1756)	75
Cricotopus triannulatus Edwards, 1922	13
Cricotopus trifascia Edwards, 1929	10
Cricotopus tristis Hirvenoja, 1973	1
Diplocladius cultriger Kieffer, 1908	12
Epoicocladius flavens (Malloch, 1915)	1
Eudactylocladius fuscimanus (Kieffer in Kieffer & Thienemann, 1908)	122
Eudactylocladius gelidus Kieffer, 1922	2
Eudactylocladius olivaceus (Kieffer, 1911)	9
Eukiefferiella brevicalcar (Kieffer, 1911)	255
Eukiefferiella claripennis (Lundbeck, 1890)	65
Eukiefferiella clypeata (Kieffer, 1923)	8
Eukiefferiella coerulescens (Kieffer in Zavrel, 1926)	26
Eukiefferiella cyanea Thienemann & Harnisch, 1936	18
Eukiefferiella devonica (Edwards, 1929)	34
Eukiefferiella dittmari Lehmann, 1972	1
Eukiefferiella fittkaui Lehmann, 1972	10
Eukiefferiella fuldensis Fittkau, 1954	129
Eukiefferiella gracei (Edwards, 1929)	1
Eukiefferiella ilkleyensis (Edwards, 1929)	16
Eukiefferiella lobifera Goetghebuer, 1934	16
Eukiefferiella minor (Edwards, 1929)	249
Eukiefferiella pseudomontana Goetghebuer, 1935	4
Eukiefferiella tirolensis Goetghebuer, 1938	26
Euorthocladius ashei Soponis, 1990	4
Euorthocladius luteipes Goetghebuer, 1938	13
Euorthocladius rivicola Kieffer, 1921	295
Euorthocladius rivulorum Kieffer, 1909	35
Euorthocladius saxosus (Tokunaga, 1939)	13
Euorthocladius thienemanni (Kieffer in Kieffer & Thienemann, 1906)	36
Eurthocladius frigidus (Zetterstedt, 1838)	427
Heleniella serratosioSerra-tosioi Ringe, 1976	2
Heterotanytarsus apicalis (Kieffer, 1921)	4
Heterotrissocladius marcidus (Walker, 1856)	78
Hydrobaenus distylus (Kieffer, 1915)	16
Isocladius glacialis (Stäger, 1839)	1
Isocladius intersectus (Stäger, 1839)	2
Isocladius sylvestris (Fabricius, 1974)	26

Appendix (Continued)

Krenosmittia boreoalpina (Goetghebuer, 1944)	18
Krenosmittia camptophleps (Edwards, 1929)	97
Krenosmittia sp A cfr *hispanica* Wülker, 1957	5
Metriocnemus hirticollis (Stäger, 1839)	3
Metriocnemus hygropetricus Kieffer, 1912	68
Nanocladius bicolor (Zetterstedt, 1838)	5
Nanocladius rectinervis (Kieffer, 1911)	7
Orthocladius excavatus Brundin, 1947	6
Orthocladius oblidens (Walker, 1856)	2
Orthocladius rhyacobius Kieffer, 1911	47
Orthocladius rubicundus (Meigen, 1818)	43
Orthocladius ruffoi Rossaro & Prato, 1991	11
Orthocladius vaillanti Cranston & Langton, 1991	4
Orthocladius wetterensis Brundin, 1956	11
Parachaetocladius abnobaenus Wülker, 1959	2
Paracladius alpicola (Zetterstedt, 1850)	2
Paracladius conversus (Walker, 1856)	5
Paracricotopus niger (Kieffer, 1913)	12
Parakiefferiella bathophila (Kieffer, 1912)	14
Parakiefferiella gracillima (Kieffer, 1924)	4
Parametriocnemus boreoalpinus Gouin in Gouin & Thienemann, 1942	5
Parametriocnemus stylatus (Kieffer, 1924)	157
Paratrichocladius nivalis (Goetghebuer, 1938)	60
Paratrichocladius rufiventris (Meigen, 1830)	67
Paratrichocladius skirwithensis (Edwards, 1929)	200
Parorthocladius nudipennis (Kieffer in Kieffer & Thienemann, 1908)	87
Psectrocladius limbatellus (Holmgren, 1869)	5
Psectrocladius octomaculatus Wülker, 1956	5
Psectrocladius psilopterus (Kieffer, 1906)	2
Psectrocladius schlienzi Wülker, 1956	3
Psectrocladius sordidellus (Zetterstedt, 1838)	7
Rheocricotopus atripes (Kieffer, 1913)	2
Rheocricotopus chalybeatus (Edwards, 1929)	7
Rheocricotopus effusus (Walker, 1856)	71
Rheocricotopus fuscipes Kieffer, 1909	51
Rheocricotopus gallicus Lehmann, 1969	2
Rheocricotopus glabricollis (Meigen, 1830)	2
Stilocladius montanus Rossaro, 1979	21
Symposiocladius lignicola (Kieffer in Potthast, 1915)	4
Synorthocladius semivirens (Kieffer, 1909)	8
Thienemaniella morosa (Edwards, 1924)	1
Thienemaniella partita Shlee, 1968	79
Thienemaniella clavicornis (Kieffer, 1911)	1
Tokunagaia rectangularis (Goetghebuer, 1940)	13
Tokunagaia tonollii Rossaro, 1983	21

Continued on p. 246

Appendix (Continued)

Tvetenia bavarica (Goetghebuer, 1934)	48
Tvetenia calvescens (Edwards, 1929)	356
Tvetenia discoloripes (Goetghebuer in Thienemann, 1936)	3
Tvetenia verralli (Edwards, 1929)	2
Heterotanytarsus sp. A	10
Zalutschia tatrica (Pagast in Zavrel e & Pagast, 1935)	3
CHIRONOMINAE	
TANYTARSINI	
Cladotanytarsus atridorsum Kieffer, 1924	4
Krenopsectra fallax Reiss, 1969	2
Micropsectra atrofasciata (Kieffer, 1911)	380
Micropsectra attenuata Reiss, 1969	15
Micropsectra bidentata (Goetghebuer, 1921)	9
Micropsectra contracta Reiss, 1965	4
Micropsectra lindrothi Goetghebuer in Goetghebuer & Lindroth, 1931	1
Micropsectra notescens (Walker, 1856)	20
Micropsectra radialis Goetghebuer, 1939	10
Neozavrelia fuldensis Fittkau, 1954	5
Parapsectra nana (Meigen, 1818)	2
Paratanytarsus austriacus (Kieffer in Albrecht, 1924)	46
Paratanytarsus natvigi (Goetghebuer, 1933)	7
Rheotanytarsus photophilus (Goetghebuer, 1921)	5
Tanytarsus bathophilus Kieffer, 1911	6
Tanytarsus fimbriatus Reiss & Fittkau, 1971	7
Tanytarsus lestagei Goetghebuer, 1922	2

Appendix (Continued)

Tanytarsus lugens (Kieffer in Thienemann e Kieffer, 1916)	1
Tanytarsus nemorosus Edwards, 1929	2
CHIRONOMINI	2
Chironomus plumosus Linnaeus, 1758	4
Chironomus riparius Meigen, 1804	4
Cladopelma edwardsi (Kruseman, 1933)	16
Cryptochironomus albofasciatus (Stäger, 1839)	2
Dicrotendipes lobiger (Kieffer, 1921)	1
Einfeldia longipes (Staeger, 1839)	2
Harnischia fuscimana (Kieffer, 1921)	1
Microchironomus tener (Kieffer, 1818)	1
Microtendipes chloris (Meigen, 1818)	1
Microtendipes pedellus (de Geer, 1776)	10
Paracladopelma camptolabis (Kieffer, 1913)	28
(°) Paratendipes nudisquama Edwards, 1929	1
Phaenopsectra flavipes (Meigen, 1818)	49
Polypedilum albicorne (Meigen, 1838)	7
Polypedilum convictum (Walker, 1856)	5
Polypedilum laetum (Meigen, 1818)	1
Polypedilum nubeculosum (Meigen, 1804)	17
Tribelos dispar (Meigen, 1830)	39
Tripodura scalaenum (Schrank, 1803)	1

(°)New for Italian fauna.
(°°*)New for West-Palaearctic Region (young larvae, determinations need confirmation).
(°*)New for Italian fauna, but the genus *Chaetocladius* must be revised.