

Light-trapped caddisfly assemblages in two floodplain reaches of the French upper Rhone River [Trichoptera]

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Keywords: caddisfly, river, cut-off channels, lateral connectivity, biodiversity, light-trap, Rhône River, river restoration, species assemblages.

The aim of the study was to carry out a comparative approach of two floodplain reaches of the French Upper-Rhône River, on the basis of their caddisfly assemblages. Caddisflies were sampled in 2014 and 2015 in the adult stage via light-traps. A comparison with historical data in the same sector was also carried out. Our results exemplified how side-channels contribute to the maintenance of sector-scale aquatic biodiversity; especially through the lateral coexistence of species.

Assemblages de trichoptères de deux secteurs alluviaux du Haut-Rhône français à partir de piégeages lumineux [Trichoptera]

Mots clés : trichoptères, rivière, îlons, chenaux secondaires, connectivité latérale, biodiversité, pièges lumineux, programme de restauration du Rhône, assemblage d'espèces.

Le but de cette étude a été d'effectuer la comparaison de deux secteurs alluviaux du Haut-Rhône français en se basant sur les assemblages de trichoptères. Les trichoptères ont été échantillonnés en 2014 et 2015 au stade adulte via des piégeages lumineux. Une comparaison avec des données historiques du même secteur a également été réalisée. Nos résultats ont montré comment les chenaux secondaires contribuent à maintenir une biodiversité aquatique à large échelle, spécialement à travers la cohabitation latérale des espèces.

1. Introduction

Since the beginning of the industrial revolution, large European Rivers have been threatened by e.g. water pollution, containment, dams, regulation and hydroelectricity production. As a consequence, only a limited number of active or near-active floodplain sectors remain along the Rhine, the Danube and the Rhône Rivers (BRAVARD 1986). These remnants usually comprise the main river channel and few secondary channels with permanent or temporary connections. These water bodies play key roles and provide valuable functions in riverine hydrosystems. This is particularly true for the life-cycle and diversity of aquatic invertebrates (CASTELLA et al. 1984, PAILLEX et al. 2007, MÉRIGOUX et al. 2009), macrophytes (BORNETTE et al. 1998) and fish (NELVA et al. 1981,

CARREL 1986). Floodplain water bodies undergo successional changes as a consequence of their disconnection from the river and subsequent loss of connectivity. To finish, siltation occurred (if there is no sufficient sediment scouring by overflood period) and reaching a climax. These changes are reflected in their habitat condition and biotic assemblages (AMOROS & BORNETTE 2002, PAILLEX et al. 2007, BESACIER-MONBERTRAND et al. 2010).

Benthic macroinvertebrates (e.g. insects, crustaceans, molluscs...) integrate several ecosystem functions and are regarded as indicators of habitat quality on a temporal scale ranging between few months to two years (corresponding to the duration of their aquatic life cycle), and on a small spatial scale, thanks to their relatively sedentary lifestyle (VERNEAUX 1973, VANNOTE et al. 1980, CELLOT & BOURNAUD 1988, PAILLEX et al. 2007). Benthic macroinvertebrate assemblages usually provide a relative assessment of site quality in floodplain waterbodies but obtaining a full species inventory is always restricted because of identification limits. If aquatic insects make up a major part of macroinvertebrates, their imaginal stage (i.e. the winged adult stage of aquatic insects after emergence) allow an often easier and more reliable specific determination. Among benthic insects, caddisflies are recognized as valuable indicators to assess alluvial aquatic ecosystems (MALICKY 1981, CHANTARAMONGKOL 1983, WARINGER 1989, STUIJFZAND et al. 1999, BERLIN & THIELE 2002).

But, only few studies concern adult caddisflies in the Rhône River and its floodplains (EL AGBANI 1981, ROJAS-CAMOUSSEIGHT 1985, USSEGLIO-POLATERA 1985).

The positive light-tropism of adult Trichoptera is well known (SCHMERA 2003, NOWINSZKY et al. 2012). The use of light-traps allows:

- to obtain more individuals than benthic sampling and thus increase the catching probability of rare species;
- a reliable species-level identification
- to reduce the sorting time and thus to optimise sampling operations.

In the context of the Rhône River restoration program (LAMOUROUX et al. 2015), the assemblages of adult caddisflies were studied in two reaches, Belley and Miribel, to supplement the benthic investigations with species-level identifications. The objectives of the present paper were:

- to make an inventory and describe the caddisfly biodiversity in the two reaches;
- to compare it with historical data available for the French Upper-Rhône.

2. Material and method

Sampling stations

The Miribel reach is located on the Rhône River at the border between “Rhône” and “Ain” departments and the Belley reach at the border between “Savoie” and “Ain” departments (Fig. 1).

Five stations in the Miribel reach and nine in the Belley reach (Tab. I and Fig. 1) were selected to represent contrasted conditions of flow and lateral connectivity with the main channel. They correspond to stations that are monitored for their benthic assemblages within the Rhône restoration program.

The Belley reach was restored during the winter 2004-05. This entailed an increase in the discharge in the by-passed section of the river and the deepening or reconnection of some of the floodplain channels (Table 1).

The Miribel reach has not been restored yet, the floodplain channels are disconnected from the main channel (Table I).

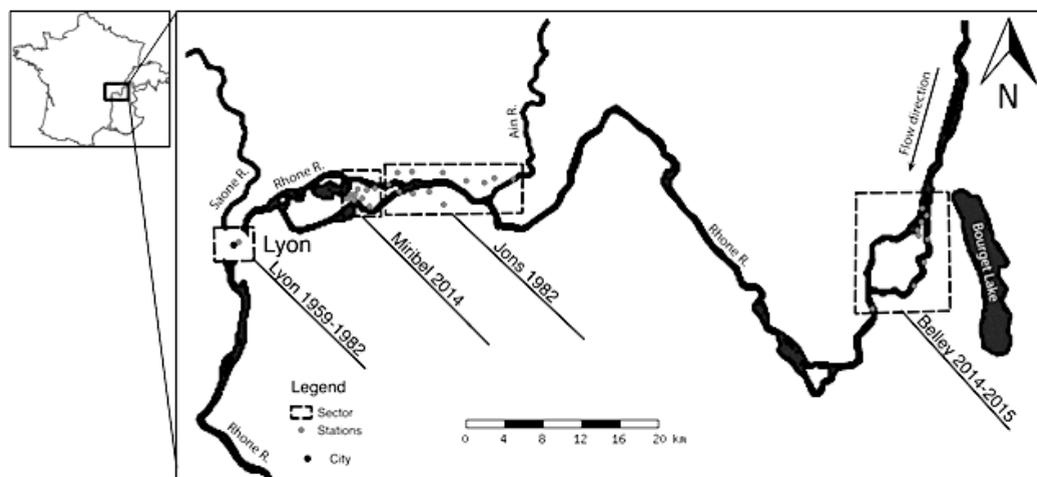


Figure 1. Map of the French Upper-Rhône showing the study sectors / reaches and stations, both for the 2014-2015 study and the historical data. Historical stations (Lyon 1959-1982: USSEGLIO-POLATERA 1985, and Jons 1982: ROJAS-CAMOUSSEIGHT 1985) were supplemented by way of comparison. Further details in § Historical data below.

Figure 1. Carte du Haut-Rhône français représentant les secteurs / tronçons d'études et les stations pour les années 2014 et 2015 et les données historiques. Les stations historiques (Lyon 1959-1982 : USSEGLIO-POLATERA 1985, et Jons 1982 : ROJAS-CAMOUSSEIGHT 1985) ont été ajoutées pour comparaison. Plus de détails dans le paragraphe « Historical data » ci-dessous.

Light-traps

"Leuchtfallen 12V / 220V classic" light-traps were used. Following URBANIČ (2002), black-light was used, produced by Sylvania light tubes (BLACKLIGHT F15W/BL350; 438mm ; Ø26mm). Light-traps were placed in each station a few metres away from the channel bank. Collecting jars contained 70% alcohol. A light detector caused automatic switching on and off of the light trap.

Sampling periods

Following WILLIAMS (1936), MACKAY (1972), NOWINSZKY et al. (1979, 2012) and DANTHANARAYANA & DASHPER (1986), light-trap sampling was operated during one night at each new moon phase except in case of bad weather conditions (rain, strong wind, flood risks...), in which case trapping was carried out as close as possible from the new moon optimum. Sampling was splitted in two periods: April to October for 2014 and May to October 2015 (except for September in 2015).

Adult identification

Adult caddisflies were identified to the finest taxonomic level, principally species, using MALICKY (1983). Mostly, adult females were not taken into account due to the difficulty of specific level determination but few “identifiable” individuals were determined further to build the noticeable species list. Identified material was preserved in tubes with 70% ethanol.

Individuals are housed in the Laboratory of Aquatic Biology and Ecology of University of Geneva (LEBA), other individuals are deposited in IRSTEA – UR MALY, Villeurbanne.

Sector	Station / Code	Restoration work	Sampling period	Connectivity	Current velocity	Department location			
						Savoy	Ain	Rhône	Isère
Belley	Lône de Béard upstream - BEAR_UP	Dredged	2015	--	--				
	Lône de Béard downstream - BEAR_DO	Reconnected + flow increase	2014	+	+				
	Lône de Chantemerle downstream - CHAN_DO	Unrestored	2014/2015	++	++				
	Lône d'en île downstream - ENIL_DO	Reconnected + flow increase	2015	++	+				
	Lône de Fournier downstream - FOUR_DO	Flow increase	2014/2015	+	+				
	Lône de Lucey downstream - LUCE_DO	Flow increase	2014	++	+				
	Lône des Luisettes downstream - LUIS_DO	Dredged	2014	+	+				
	Lône de Moiroud upstream - MOIR_UP	Dredged	2014/2015	-	-				
	Rhône river main channel - RHONE	Flow increase	2014		++				
	Lône du Vieux-Rhône downstream - VR_DO	Unrestored	2014	-	+				
Miribel	Miribel canal - CA_MI	Unrestored	2014	++	++				
	Lône du Plançon middle - PL_CE	Unrestored	2014	-	-				
Jons	Rizan stream downstream - RZ_DO	Unrestored	2014	--	+				
	Dragonflies pond - LIB2	Unrestored	2014	--	--				
	Miribel canal	Unrestored							
	Jonage canal	Unrestored							
	Lône de Chaume	Unrestored							
	Lône du Grand Gravier	Unrestored							
	Lône du Méant upstream	Unrestored							
	Lône du Méant : la chaussée	Unrestored							
	Lône du Puits Novet	Unrestored	1982						
	Ain's riverbank	Unrestored							
Lyon	La Négria old meander	Unrestored							
	Lône des Pêcheurs upstream	Unrestored							
	Lône des Pêcheurs downstream	Unrestored							
	Lône du Pont Henry	Unrestored							
Lyon	Rhone river main channel	Unrestored	1959-1982						

Table I. Types of restoration, sampling periods and location of the different alluvial stations in relation to the departments (Lône, in regional french, is used for designation of the entire length of the cut-off channel in floodplain).

Tableau I. Types de restauration, périodes d'échantillonnage et localisation des différentes stations par rapport aux départements (Lône, en français régional, est utilisé pour désigner le linéaire total d'un bras-mort en zone alluviale).

Data Analyses

The species accumulation curves were calculated with the specaccum function and the rarefaction method. Moreover, function specpool implemented the models to estimate the species pool size. These two functions are components of the vegan package (version 2.3-5) used in R (R DEVELOPMENT CORE TEAM 2008).

Historical data

Two sources of historical data about adult caddisfly assemblages in the Upper-Rhône were used. USSEGLIO-POLATERA (1985) studied adults trapped on the Rhône River in the center of Lyon

over a long period (1959-1982). ROJAS-CAMOUSSEIGHT (1985) studied adults trapped in the Jons sector, immediately upstream from the Miribel sector in two active channels (Miribel and Jonage canal) and some floodplain channels. These two authors identified both males and females to species level and used other trap types (high pressure mercury vapour lamp and circline lamp cool white). In the present study, these two data sets were notified "Jons 1982" and "Lyon, 1959-1982" by reference to ROJAS-CAMOUSSEIGHT (1985) and USSEGLIO-POLATERA (1985) studies, respectively. See Table I for details of the historical stations per sector.

3. Results

Main characteristics of the caddisfly assemblages

97 258 individuals were caught in total, among which 17 692 males (sex-ratio=0.18). The very low sex-ratio varied between 0.16 in Belley 2014 and 0.21 in Belley 2015 (Fig. 2). Species richness (calculated only with males) varied between 43 in Belley 2015 and 58 in Miribel 2014 (Fig. 2). Total species richness for both sectors (2014 and 2015 combined) is 79.

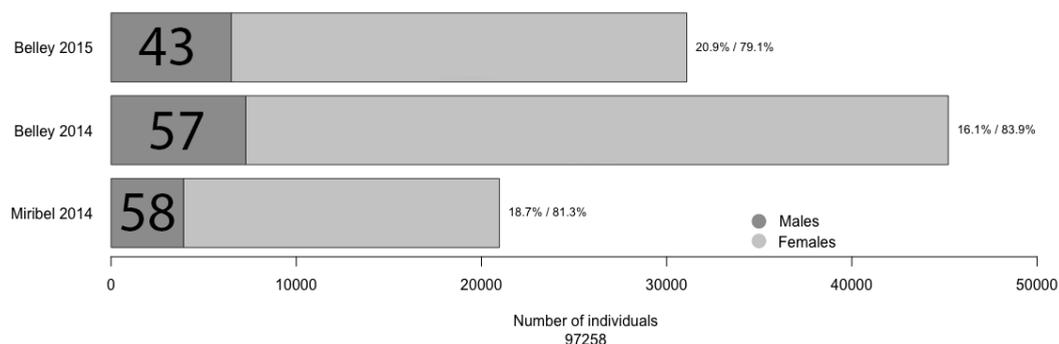


Figure 2. Variation of the adult caddisfly abundance, sex-ratio (in %) and species richness (in bold) (sampling effort differs between years and sectors).

Figure 2. Variation d'abondance, sex-ratio (en %) et richesse spécifique (en gras) des trichoptères adultes (l'effort d'échantillonnage diffère entre les années et les secteurs).

64, 41 and 25 species were collected for Ain, Savoy and Rhone departments respectively. Among the seventy-nine species collected (see faunal list in annex), some of them can be grouped under the following categories of noticeable species.

We highlighted some as "noticeable" on the basis of the following criteria:

- Species known to be associated with groundwater supply (category 1)
- Species rarely recorded in France and Switzerland (category 2);
- Species rarely recorded in the French upper Rhône (category 3);
- Species endemic for the Jura and/or the Alps (category 4);
- Species for which the French upper Rhône River is the northern or southern limit of their known distribution range (category 5).

Noticeable species only recorded by female adult trapped (no males captured) are preceded by “^a”. In an effort to provide reliable data, these “^a” species do not appear in faunal table presented in annex, where only adult males trapped were mentioned (for Miribel and Belley sector only).

Family Psychomyiidae

Genus *Paduniella* Ulmer, 1913

^a*Paduniella vandeli* Decamps, 1965 (categories 2, 3, 5)

PL_CE 26/06/2014 I♀

P. vandeli mainly occurs in rivers from Languedoc, Roussillon, Bas-Rhône and its tributaries from Massif Central and the Vienne river (COPPA et al. 2009). The Miribel sector can be regarded as the northernmost area of its distribution range. This rare species is currently known only from twelve stations in France.

Family Hydroptilidae

Genus *Hydroptila* Dalman, 1819

Hydroptila tineoides Dalman, 1819 (1)

CA_MI 26/06/2014 I♀ ; CA_MI 24/07/2014 I♀ ; LIB2 26/06/2014 I♀♂ ; LIB2 24/07/2014 I♀♂ ; LIB2 25/08/2014 I♀ ; LIB2 22/09/2014 I♀ ; PL_CE 26/06/2014 I♀♂ ; PL_CE 24/07/2014 I♀♂ ; PL_CE 25/08/2014 I♀ ; RZ_DO 02/06/2014 I♀ ; RZ_DO 26/06/2014 I♀♂ ; RZ_DO 24/07/2014 I♀ ; RZ_DO 25/08/2014 I♀ ; RZ_DO 22/09/2014 I♀♂ ; VR_DO 02/06/2014 I♀♂ ; VR_DO 26/06/2014 I♀♂ ; VR_DO 24/07/2014 I♀♂ ; VR_DO 25/08/2014 I♀♂ ; VR_DO 22/09/2014 I♀♂ ; VR_DO 22/10/2014 I♀♂

H. tineoides is generally associated with cold limestone rivers. Its occurrence in the Vieux Rhône cut-off channel of Miribel seems to be directly linked with the supply of groundwater from the river hyporheos. Its water temperature is buffered between 11 and 20°C.

Genus *Oxyethira* Eaton, 1873

^a*Oxyethira tristella* Klapálek, 1895 (2, 3)

VR_DO T5 I♀

The single reference of *O. tristella* originates from the Rhone department in ROJAS-CAMOUSSEIGHT (1985). Its occurrence in the French upper Rhone River is not yet confirmed with an adult male capture.

Family Leptoceridae

Genus *Ceraclea* Stephens, 1829

Ceraclea aurea Pictet, 1834 (2, 3)

FOUR_DO 27/06/2014 I♂ ; FOUR_DO 15/07/2015 I♂ ; CHAN_DO 27/06/2014 I♂ ; CHAN_DO 24/07/2014 I♂ ; CHAN_DO 15/07/2015 I♂ ; LUIS_DO 24/07/2014 I♂ ; RHONE 27/06/2014 I♂ ; RHONE 24/07/2014 I♂ ; RHONE 25/08/2014 I♂ ; LUCE_UP 27/06/2014 I♂ ; MOIR_UP 27/06/2014 I♂ ; MOIR_UP 15/07/2015 I♂ ; ENIL_DO 15/07/2015 I♂ ; BEAR_UP 15/07/2015 I♂

C. aurea is currently a rare species (OPIE 2016); it has been considered to be extinct from Germany (MARTEN 2002). Our data confirm its known occurrence in Ain department (BERLY 1981, OPIE 2016).

Ceraclea riparia Albarda, 1874 (2, 3)

PL_CE 26/06/2014 I♀ ; VR_DO 26/06/2014 I♀♂

Our data confirm the occurrence of the species in the Rhône department, as mentioned by USSEGLIO-POLATERA (1985). The species is common in water bodies of the Loire and Seine watershed. However, in many countries, especially of Western Europe, it is included in Red lists as “endangered” or “probably extinct” (LUBINI et al. 2012, NEU 2013). The species microhabitat (large cobbles and macrolithal) is scarce and scattered in European floodplain rivers (WARINGER et al. 2005B).

Genus *Leptocerus* Leach, 1815

^a*Leptocerus lusitanicus* MacLachlan, 1884 (2, 3)

CA_MI 24/06/2014 I♀

This species was trapped along the Rhône in 1959 and 1960 (USSEGLIO-POLATERA & BOURNAUD 1989), the Rhine in 1991 near Kehl (SCHÖLL 1992) then in 2004 near Basel (LUBINI et al. 2012). Its distribution ranges southern and central Europe, few individuals were sampled in southern United Kingdom too (SCHÖLL 1992). Its occurrence in the French upper Rhône is not yet confirmed with an adult male capture.

Family Limnephilidae

Genus *Limnephilus* Leach, 1815

Limnephilus flavospinosus Stein, 1874 (2, 3, 5)

BEAR_DO 27/09/2014 I♂

Belonging to the French rare species, known occurrences are restricted to the Ain river downstream, the Rhone river near Bregnier-Cordon and Jons sector (CASTELLA 1987) and in the Bouches-du-Rhône department (OPIE 2016). *L. flavospinosus* was also mentioned in the Ukrainian Danube Delta (POLISHCHUKV 1974) and in Lake Chiuse (Italy) where individuals were found between leaves of *Ceratophyllum demersum* (MORETTI & GIOVANNI 1982).

Limnephilus decipiens Kolenati, 1848 (2, 3, 5)

LIB2 20/10/2014 I♂ ; PL_CE 20/10/2014 I♂

Also considered as a rare French species (occurrence only in Ain, Isère and Ardennes departments; OPIE 2016), *L. decipiens* is rather low abundant in western Europe but is abundant in several sites in northeastern Europe : United Kingdom (HICKIN 1967), Norway (BREKKE 1946), Hungary (UHERKOVICH & NOGRADI 1997). The species mainly occurs in lakes and large rivers.

Limnephilus helveticus Schmid, 1965 (1, 2, 3)

CA_MI 02/06/2014 I♂ ; CA_MI 20/10/2014 I♂ ; LIB2 31/03/2014 I♂ ; LIB2 02/06/2014 I♂ ; LIB2 26/06/2014 I♂ ; LIB2 24/07/2014 I♂ ; LIB2 22/09/2014 I♀♂ ; LIB2 20/10/2014 I♀♂ ; PL_CE 20/10/2014 I♀♂ ; RZ_DO 31/03/2014 I♀♂ ; RZ_DO 02/06/2014 I♂ ; RZ_DO 26/06/2014 I♀ ; RZ_DO 22/09/2014 I♀♂ ; RZ_DO 20/10/2014 I♀♂ ; VR_DO 31/03/2014 I♀♂ ; VR_DO 28/04/2014 I♂ ; VR_DO 02/06/2014 I♀ ; VR_DO 26/06/2014 I♂ ; VR_DO 22/09/2014 I♀ ; VR_DO 20/10/2014 I♀♂

According to BOTOSANEANU & MALICKY (1978), the biogeographic distribution of *L. helveticus* includes the Alps, the Balkans, and the Massif Central in France. This species inhabits lotic

and crenal habitats and is occasionally found in spring waters overgrown with hydrophytes (*Berula*, *Veronica*, *Lemna*, *Nastursium*, *Potamogeton*; MORETTI & BATTÀ 1983). Adults have no fixed period of emergence: in the French upper Rhone, they emerged from April to November.

Genus *Mesophylax* MacLachlan, 1882

Mesophylax impunctatus MacLachlan, 1884 (1, 2, 3)

BEAR_DO 30/04/2014 I♂ ; FOUR_DO 25/03/2014 I♂ ; FOUR_DO 03/04/2014 I♂ ; FOUR_DO 30/04/2014 I♂ ; FOUR_DO 28/05/2014 I♂ ; FOUR_DO 27/09/2014 I♂ ; FOUR_DO 20/10/2014 I♂ ; FOUR_DO 17/05/2015 I♂ ; FOUR_DO 15/06/2015 I♂ ; FOUR_DO 13/10/2015 I♂ ; LUIS_DO 30/04/2014 I♂ ; LUCE_UP 20/10/2014 I♂ ; MOIR_UP 20/10/2014 I♂

Phytophilous and sometimes cavernicolous (BOURNAUD & BOUVET 1969), *M. impunctatus* is rather unfrequent in Europe (Great Britain, Austria etc.) and belongs to the rare French species (Savoy, Isère and Ardennes departments). Its distribution ranges southwards to the Northeast Iberian peninsula (BOIX et al. 2001). As for *H. tineoides*, its occurrence may be directly associated with groundwater supply from the river hyporheos.

Family Sericostomatidae

Genus *Sericostoma* Latreille 1825

Sericostoma galeatum Rambur, 1842 (2, 3, 5)

BEAR_DO 27/06/2014 I♂ ; CHAN_DO 27/06/2014 I♂ ; CHAN_DO 15/06/2015 I♂ ; MOIR_UP 27/06/2014 I♂

S. galeatum is a southern eurytopic species associated with the metarhithral/hyporhithral zones. It is usually found in alluvial brooks, small streams and channels of the upper Rhône and Ain River (ROUX & CASTELLA, 1987). It was reported in the Argens River (France ; GIUDICELLI et al. 1981), the middle Durance river in France (PRÉVOT 1984) and in northern Italy (MORETTI & CIANFICCONI 1977).

Family Goeridae

Genus *Silo* Curtis, 1833

Silo nigricornis Pictet, 1834 (1)

BEAR_DO 03/04/2014 I♂ ; BEAR_DO 28/05/2014 I♂ ; BEAR_DO 27/06/2014 I♂ ; BEAR_DO 25/08/2014 I♂ ; FOUR_DO 28/05/2014 I♂ ; FOUR_DO 17/05/2015 I♂ ; FOUR_DO 15/06/2015 I♂ ; CHAN_DO 30/04/2014 I♂ ; CHAN_DO 15/06/2015 I♂ ; LUIS_DO 03/04/2014 I♂ ; LUIS_DO 28/05/2014 I♂ ; RHONE 30/04/2014 I♂ ; RHONE 27/06/2014 I♂ ; RHONE 25/08/2014 I♂ ; ENIL DO 17/05/2015 I♂ ; ENIL DO 15/06/2015 I♂

S. nigricornis is a widely distributed species, being present in Central and Southern Europe, with an altitudinal range of 200-1300 m (MORETTI 1983). Its habitat refers to hydrologically dynamic water bodies, connected with the main channel usually at both ends at mean water discharge. High water velocity and sand/gravel substrate are dominating (WARINGER et al. 2005A; MARLE 2015; CASTELLA et al. 2016).

The occurrence of hypocreanal/epirhithral species as *Silo nigricornis*, *Agapetus ochripes*, *Hydropsyche siltalai*, *Sericostoma galeatum* and *Mesophylax impunctatus* in connected side-channels represent a pool of small stream species in a potamic reach of a large river floodplain (VERNEAUX

1973; SCHMEDITJE & COLLING 1996). Some of the floodplain active side-channels exhibit morphological and physical features (e.g. small wetted section, high hydraulic stress, lotic conditions, buffered temperature variations and higher dissolved oxygen than in isolated cut-off channels) characteristics of upper stream stretches in the longitudinal typology (VERNEAUX 1973).

Regional, historical and inter-annual comparisons

Degree of pool overlap is approximately comparable between regional comparison (between 34 and 41 common species) and historical comparison (between 33 and 41 common species; Fig. 3). About historical comparison, caddisfly Miribel 2014 and Belley 2014-2015 assemblages appear to be more similar to Jons 1982 assemblage (nearest sector with 41 and 40 common species respectively) than to Lyon 1959-1982 assemblage (36 and 33 common species respectively; Fig. 3). On Belley sector, comparison between 2014 and 2015 show a pool of 38 common species. Most of the 19 remaining species not sampled in 2015 were autumnal species as *Glyphotaelius pellucidus*, *Halesus radiatus*, *Anabolia nervosa*, few *Limnephilus* sp. etc. (due lack of sampling for September and probably too cold night during October sampling in 2015), the 5 remaining species not sampled in 2014 represent rarely trapped and less widespread species like *Plectrocnemia conspersa*.

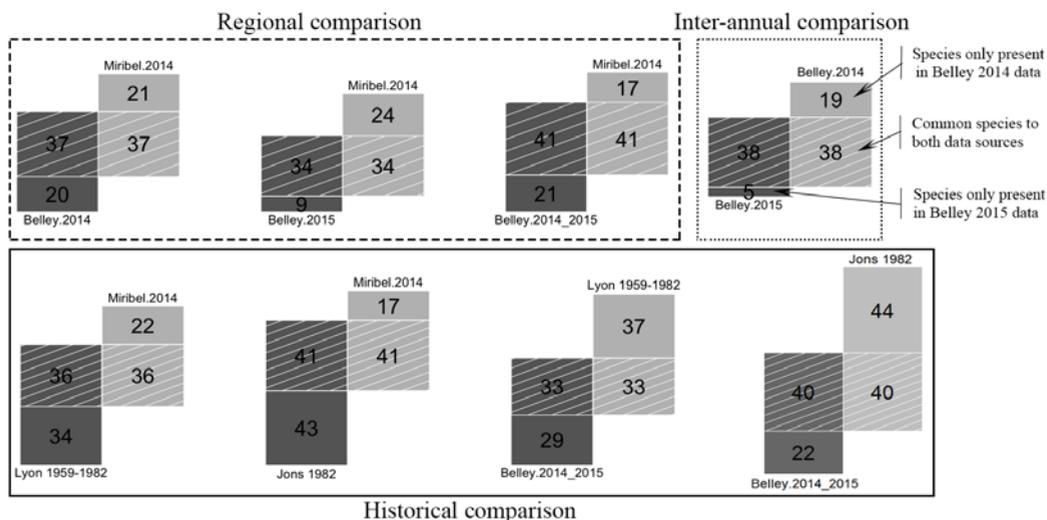


Figure 3. Historical, regional and inter-annual comparisons of caddisfly species inventories showing the number of common and distinctive species.

Figure 3. Comparaison historique, régionale et inter-annuelle des inventaires d'espèces de trichoptères montrant le nombre d'espèces communes et distinctives.

At a regional scale, distinctive species concern lotic and/or rheophilic species (inhabiting main channel or connected channels) as *Agapetus ochripes*, *Ceraclea aurea* and *Mystacides longicornis* (on Belley sector), *Ecnomus tenellus*, *Cheumatopsyche lepida*, *Hydropsyche angustipennis*, *Hydroptila tineoides*, *Setodes argipunctellus* (on Miribel sector) etc. as well as lentic species (inhabit cut-off channels or lentic zone) like *Phryganea grandis*, *Allogamus alpenis*, *A. kefes* (on Belley sector), *Limnephilus helveticus*, *Orthotrichia tragetti* (on Miribel sector) etc.

The historical shift which can be observed from 1959-1982 (Jons & Lyon data sets) to 2014-2015 (Belley & Miribel data sets) is characterised by an impoverishment of local trichoptera assemblages (between 34 and 44 lost species). The main affected families are: Leptoceridae with a loss over 10 species whose *Ceraclea annulicornis*, *C. fulva*, *C. nigronevosa*, *C. senilis*, *Erotesis baltica*, *Homilia leucophaea*, *Leptocerus lusitanicus*, *Mystacides niger*, *Oecetis ochracea*, *O. tripunctata*, *Triaenodes bicolor* etc.; Hydroptilidae with 9 lost species : *Allotrichia pallicornis*, *Hydroptila martini*, *H. occulta*, *H. pulchricornis*, *Ithytrichia lamellaris*, *Oxyethira frici*, *O. simplex*, *O. tristella* and *Stactobiella risi*. Other families are less affected : Limnephilidae (e.g. *Limnephilus borealis*, *L. germanus*, *Micropterna nycterobia* etc.), Brachycentridae (*Brachycentrus maculatus* and *B. subnubilus*), Glossosomatidae (e.g. *Agapetus delicatulus*, *A. fuscipes*, *A. laniger* and *Glossosoma conforme*), Philopotamidae (e.g. *Chimarra marginata*, *Tinodes dives* and *T. maculicornis*), Polycentropodidae (e.g. *Cyrnus cintranus*, *C. flavidus*, *Holocentropus dubius*, *H. stagnalis* and *Polycentropus irroratus*), Hydropsychidae (*Hydropsyche ornatula*) etc.

However, the loss of biodiversity was partially replaced in 2014-2015 by species whose *Agapetus ochripes* (Glossosomatidae), *Agrypnia varia* and *Trichostegia minor* (Phryganeidae), *Allogamus alpenis*, *A. kefes*, *Anabolia nervosa*, *Glyphotaelius pellucidus*, *Grammotaulius nigropunctatus*, *Halesus tessellatus*, *Limnephilus affinis*, *L. bipunctatus*, *Mesophylax impunctatus* and *Potamophylax latipennis* (Limnephilidae), *Hydropsyche incognita* (Hydropsychidae), *Rhyacophila fasciata* (Rhyacophilidae), *Sericostoma galeatum* (Sericostomatidae) and *Synagapetus dubitans* (Glossosomatidae) etc. Mostly, belonging to lentic floodplain related environments as temporary pools, low connected cut-off channels submitted to the terrestrialisation processes and/or with a significant coverage of open water areas by macrophytes.

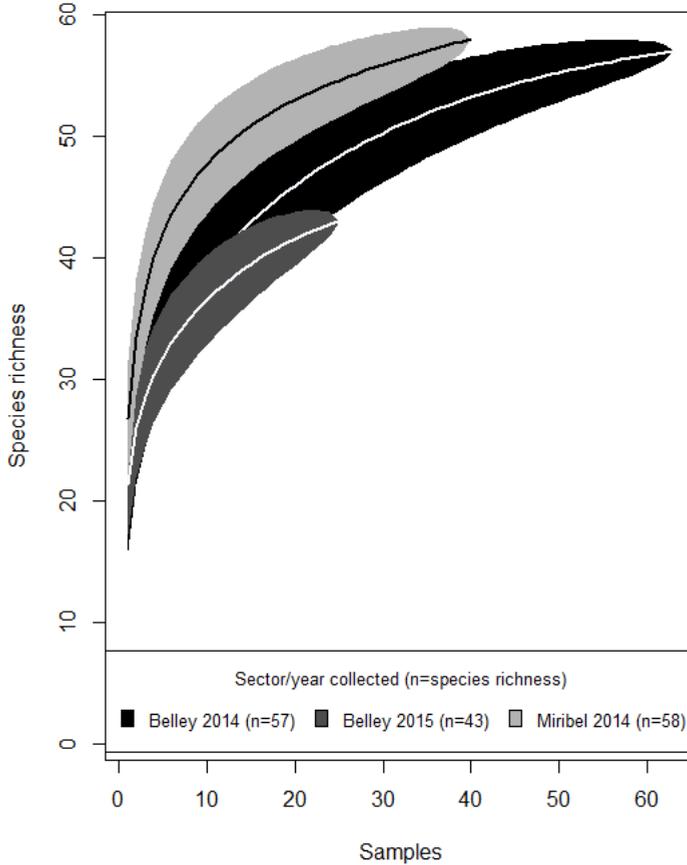
Agaylea sexmaculata, *Athripsodes albifrons*, *Ceraclea albimacula*, *C. dissimilis*, *Cyrnus trimaculatus*, *Lepidostoma hirtum*, *Leptocerus tineiformis*, *Lype phaeopa*, *Micropterna testacea*, *Mystacides azureus*, *Orthotrichia costalis*, *Oxyethira flavicornis*, *Polycentropus flavomaculatus*, *Psychomyia pusilla*, *Rhyacophila dorsalis*, *Tinodes waeneri* and few species of *Hydropsyche* and *Hydroptila* genera composed the pool of common species to all data sets (see faunal list in annex). Many of these species are representative of lotic conditions present in main river channel.

Trapping efficiency

The three “richness accumulation curves” constructed from the 63 light-trap samples (Belley 2014 adult data), the 20 light-trap samples (Belley 2015 adult data) and the 40 light-trap samples (Miribel 2014 adult data) appeared close from reaching a plateau at 57, 43 and 58 species, respectively (Fig. 4).

The extrapolated total richness ranged between 63 (bootstrap) and 71 (2nd order jackknife) for Belley 2014, 45 (Chao) and 49 (1st order jackknife) for Belley 2015 and 62 (bootstrap) and 71 (2nd order jackknife) for Miribel 2014. In this way, distance between observed and lowest extrapolated richness differs for 2 points (species richness of Belley 2015 compared with Chao extrapolated richness) to 4 points (species richness of Belley 2014 and Miribel 2014 compared with bootstrap extrapolated richness) and for 6 (species richness of Belley 2014 with bootstrap and Belley 2015 with 1st order jackknife) to 14 (species richness of Belley 2014 with 2nd order jackknife) between observed richness and highest extrapolated richness (Fig. 4). Standard error ranged between 2 to 7, the lowest (2 to 3) concern bootstrap and the highest (2 to 7) concern Chao model (Fig. 4). Overall, the lower number of samples, the lower distance between observed and extrapolated richness, the lower standard error, and vice versa.

According extrapolated richness, between 80 and 95% of total species were inventoried during the 2014 and 2015 sampling. The lower difference between extrapolated and observed species richness and the overall accumulation curve approach (reaching a plateau) show a relatively satisfactory sampling.



	Species richness	Chao	Standard error	1st order Jackknife	Standard error	2nd order Jackknife	Bootstrap	Standard error
Belley 2014	57	65	6	69	5	71	63	3
Belley 2015	43	45	2	49	2	46	47	2
Miribel 2014	58	66	7	67	4	71	62	2

Figure 4. Accumulation curve for each sector: 2014 and 2015 for Belley sector and 2014 for Miribel sector (permutations; function specaccum; method: rarefaction), estimation of pool size implemented by the four models presented in table (function specpool).

Figure 4. Courbe d'accumulation pour chaque secteur : Belley 2014 et 2015 et Miribel 2014 (permutations ; fonction specaccum ; méthode : raréfaction), estimation du pool d'espèces calculée par les quatre modèles présentés dans le tableau (fonction specpool).

4. Discussion

The contribution of the present inventory in relation to the alluvial biodiversity has highlighted that floodplain ecosystems should be considered as habitats in which many caddisfly species with different ecological needs coexist and assemblages vary over time to adapt more closely to environmental conditions changing.

Regional and historical comparison

There is a low degree of overlap between current and past assemblages as between sectors (Fig. 3). Two hypotheses may explain these patterns:

- methodology (e. g. type of light-trap, sampling period, males and/or females adult identification etc.) differs greatly between these two periods of inventory and can therefore influence trapping and determination procedure;
- embankments, hydro-power production implementation, pollution, river restoration and successional changes occurred between these two inventory periods, affected floodplain waterbodies and their caddisfly assemblages. A possible mixture of these two hypotheses should go some way to answer this problematic. Reuse historical methodology (ROJAS-CAMOUSSEIGHT 1985, USSEGLIO-POLATERA 1985) and that of the present study, on the same sector, then compare faunal data, could confirm or reject the first hypothesis.

Loss or shift of biodiversity between these two periods could be characterised by habitat destruction and the increasing uniformity of the biotope due to embankments, riverbed incisions, overdrying of temporary waterbodies, flow regulation and flush-outs of the upstream reservoir (USSEGLIO-POLATERA & BOURNAUD 1989). This has led to reduce the diversity of substratum (e.g. wood litter used by Limnephilidae and few Leptoceridae larvae case construction) and food sources (e.g. disappearance of filamentous algae, one of usual source of food for *Hydroptila sp.* larvae ; SCHMEDITJE & COLLING 1996). Consequently, the development of diversity is not always well-rounded and representative of alluvial ecosystem. On the French upper Rhône river, USSEGLIO-POLATERA & BOURNAUD (1989) defined five “successive” faunal group according to the increasing uniformity of the alluvial biotope: stenoecic species seem to disappear and a small number whose ecological requirements are less demanding subsist. In the present study, the two *Brachycentrus* species (*B. maculatus* and *B. subnubilus*) trapped in the period of 1959-1982 and most demanding species were not sampled again in 2014 and 2015. However, Brachycentridae larvae are best indicator for larger and less impacted streams in France: according IBGN grid, its sensitivity pollution index is 9/10 (AFNOR 2004). These observations confirm that habitat modification and physico-chemical pollution might be the principal factors affecting the distribution of most demanding species.

Completeness of the inventory and trapping efficiency

The light-trap sampling operations considered here took place over thirteen months (end of March to October 2014 and May to October 2015) and allowed almost a full caddisfly species inventory in the two reaches (Fig. 4). The species sampled can be regarded as representing an hyporhithral/epipotamal assemblage (SCHMEDITJE & COLLING 1996). It is worth underlining that less than twenty-five trichoptera species were recorded using benthic sampling (local and macro-habitat scale) on seven floodplain stations on Belley sector in 2015 (CASTELLA et al. 2016). Whereas adult light-trapping (regional scale) seems to provide a broad picture of caddisfly assem-

blages at the scale of an entire floodplain sector and allowed to record a minimum of fourty caddisflies species each year (Fig. 4). However, light-trap attractiveness and meteorological conditions entail abundance variations in the catches.

Many species of the stagnant water were sampled but some rarities such as *Holocentropus dubius* and *H. stagnalis* already recorded in Ain department (OPIE 2016) were not yet trapped. These species inhabit pond and temporary water bodies and are typical lentic water species reported in several locations in Europe whose Rhone River (ROJAS-CAMOUSSEIGHT 1985, NICOLET et al. 2004, BOIX et al. 2012). In 2015, most of caddisfly larvae captured in a small lentic area like unconnected channels (MOIR UP, BEAR UP etc.) are part of the family Limnephilidae (*Limnephilus*, *Glyphotaelius*, *Mesophylax*, *Anabolia* genera etc.). The low larvae density often belongs to Leptoceridae (e.g. *Athripsodes aterrimus* not exceed 6 ind.m²; MARLE 2015) and contrasts with the high Limnephilidae density observed (e.g. *Limnephilus flavicornis* and *L. lunatus* exceed 25 ind.m² ; MARLE 2015). Larvae of Polycentropodidae (like *Holocentropus stagnalis* & *H. dubius*) and Leptoceridae (like *Athripsodes* and *Oecetis* genera) are not as frequent as Limnephilidae in unconnected channels, but several species may be found in these habitats (WIGGINS 1973). Also, it is relevant to comment that high densities of Limnephilidae larvae in limited space show more propensity to aggression, predation and even cannibalism (WISSINGER et al. 1996, 2004) and may cause the loss of lowest abundant taxa (e.g. Polycentropodidae and Leptoceridae).

Sweep-net samples could represent a trapping method complementary to light-traps. Indeed, some species might be less efficiently attracted by light. In Belley 2015 samples, 3 individuals of *Silo nigricornis* (Pictet, 1834) and *Goera pilosa* (Fabricius, 1775) were caught by sweep-net on the 18th May while only one individual of each species was captured by light-trap, while densities exceed 70 ind.m² on ENIL DO for these taxa (MARLE 2015). We can hypothesize that these two species are either weakly attracted by the light type used or their emergence occurs mostly during daytime when the light-trap was not operating. Consequently, unseen species might be partly represented by species with a negative light tropism, such as *Tricholeiochiton fagesii* characterized by a diurnal activity and therefore rarely captured by light-trap (G. COPPA, pers. comm.). This species is mentioned in stagnant water overgrown by macrophytes particularity in Indre and Hérault departments, in the Netherlands and the Volga delta (COPPA & JOLIVET 2008).

Future research

On the one hand, our observations suggest considering their high diversity of life strategies or feeding modes. For this reason, it would be worth investigating the possibility of using caddisflies for a functional analysis as surrogate of the entire macrobenthic community.

On the other hand, historical data (USSEGLIO-POLATERA 1985, USSEGLIO-POLATERA & BOURNAUD 1989) show that species like *Leptocerus lusitanicus* (MacLachlan, 1884), *Oecetis tripunctata* (Fabricius, 1793), *Sericostoma personatum* (Kirby & Spence, 1826), *Homilia leucophea* (Rambur, 1842), *Oecetis lacustris* (Pictet, 1834) and *Hydroptila pulchricornis* (Pictet, 1834) were exceptionally trapped on the Upper Rhône. They could be regarded as still potentially present and represent target for future trapping along the river. Other species such as *Platyphylax frauenfeldi* (Brauer, 1857), a European-level rarity that was found in the Danube, Mur, Enns, Rhone, Aare and Inn rivers (UHERKOVICH & NOGRADI 1997) could also be regarded as potential for the less impacted stretches of the Rhône.

Despite a historical collection to more than 50 years ago, caddisfly inventories in the French upper Rhône River should be regularly updated to better reflect the highly fluctuating in large environmental perturbations (e. g. Lyon sector).

Acknowledgements

We thank all research team involved in the ecological restoration for availability of data, the Syndicat du Haut-Rhône for providing financial support and fruitful collaboration during the Rhone river restoration programme. Our thanks must also be extended to Adrien Auzeil from National Office for Insects and their Environment (Opie) and Audrey Bolard from UMR Chrono-environnement of Besançon for adult identification checking, David Mc Crae and Hélène Mayor from Laboratory of Aquatic Ecology and Biology – University of Geneva for providing larval data.

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Appendix

P.57:

Figure 5. Pictures of few Belley stations

Figure 5. Photographies de quelques stations de Belley

Pp. 58-59:

Table II. Faunal list with data at sampling sites.

Tableau II. Liste faunistique et présence des espèces aux stations de collectes.



SECTOR - PERIOD	Jons 1982 ♀♂		Lyon 1959-1982 ♀♂	Miribel, 2014 ♂	Belley 2014-2015 ♂	
NUMBER OF STATIONS	12		1	5	9	
COLLECTED SPECIES	COLLECTOR		F. Rojas-Camousseight	P. Usseglio-Polatera	V. Rosset, S. Maréchal & M.-C. Roger	P. Marle & S. Rabarivelo
Type of environment / water bodies	Mir/Jon canal	Cut-off ch.	Main channel in urban zone	Floodplain	Floodplain	
<i>Agapetus delicatulus</i> MacLachlan, 1884		+				
<i>Agapetus fuscipes</i> Curtis, 1834		+				
<i>Agapetus laniger</i> Pictet, 1834		+	+			
<i>Agapetus ochripes</i> Curtis, 1834					+	
<i>Agraylea multipunctata</i> Curtis, 1834	+	+			+	
<i>Agraylea sexmaculata</i> Curtis, 1834	+	+	+	+	+	
<i>Agrypnia pagerana</i> Curtis, 1834		+				
<i>Agrypnia varia</i> Fabricius, 1793				+	+	
<i>Allogamus alpinensis</i> Oláh, Lodovici & Valle, 2014					+	
<i>Allogamus kefes</i> Coppa & Oláh, 2014					+	
<i>Allotrichia pallicornis</i> Eaton, 1873		+	+			
<i>Anabolia nervosa</i> Curtis, 1834				+	+	
<i>Athripsodes albifrons</i> Linnaeus, 1758	+	+	+	+	+	
<i>Athripsodes aterrimus</i> Stephens, 1836		+		+	+	
<i>Athripsodes cinereus</i> Curtis, 1834	+	+	+	+	+	
<i>Brachycentrus maculatus</i> Fourcroy, 1785			+			
<i>Brachycentrus subnubilus</i> Curtis, 1834			+			
<i>Ceraclea albimacula</i> Rambur, 1842	+	+	+	+	+	
<i>Ceraclea annulicornis</i> Stephens, 1836			+			
<i>Ceraclea aurea</i> Pictet, 1836			+		+	
<i>Ceraclea dissimilis</i> Stephens, 1836	+	+	+	+	+	
<i>Ceraclea fulva</i> Rambur, 1842			+			
<i>Ceraclea nigronervosa</i> Retzius, 1783			+			
<i>Ceraclea riparia</i> Albarda, 1874	+		+	+		
<i>Ceraclea senilis</i> Burmeister, 1839		+	+			
<i>Cheumatopsyche lepida</i> Pictet, 1834	+	+	+	+		
<i>Chimarra marginata</i> Linné, 1767			+			
<i>Crunoecia irrorata</i> Curtis, 1834		+				
<i>Cyrnus cintranus</i> MacLachlan, 1884		+				
<i>Cyrnus crenaticornis</i> Kolenati, 1859	+	+		+	+	
<i>Cyrnus flavidus</i> MacLachlan, 1864	+	+	+			
<i>Cyrnus trimaculatus</i> Curtis, 1834	+	+	+	+	+	
<i>Ecnomus deceptor</i> MacLachlan, 1884		+				
<i>Ecnomus tenellus</i> Rambur, 1842	+	+	+	+		
<i>Erotesis baltica</i> MacLachlan, 1877		+				
<i>Goera pilosa</i> Fabricius, 1775			+	+	+	
<i>Glossosoma boltoni</i> Curtis, 1834			+	+	+	
<i>Glossosoma conforme</i> Neboiss, 1963			+			
<i>Glyptotaelius pellucidus</i> Retzius, 1783				+	+	
<i>Grammotaulius nigropunctatus</i> Retzius, 1783					+	
<i>Halesus radiatus</i> Curtis, 1834	+	+		+	+	
<i>Halesus tessellatus</i> Rambur, 1842					+	
<i>Holocentropus dubius</i> Rambur, 1842	+	+				
<i>Holocentropus picicornis</i> Stephens 1836	+					
<i>Holocentropus stagnalis</i> Albarda, 1874		+				
<i>Homilia leucophaea</i> Rambur, 1842			+			
<i>Hydropsyche angustipennis</i> Curtis, 1834	+	+	+	+		
<i>Hydropsyche contubernalis</i> MacLachlan, 1865	+	+	+	+	+	
<i>Hydropsyche excollata</i> Dufour, 1841	+	+	+	+	+	
<i>Hydropsyche incognita</i> Pitsch, 1993					+	
<i>Hydropsyche modesta</i> Navás, 1925	+	+	+	+	+	
<i>Hydropsyche ornata</i> MacLachlan, 1878	+	+	+			
<i>Hydropsyche pellucidula</i> Curtis, 1834	+	+	+	+	+	
<i>Hydropsyche siltalai</i> Siltalai, 1963	+	+	+	+	+	
<i>Hydroptila angulata</i> Mosely, 1922			+	+	+	
<i>Hydroptila forcipata</i> Eaton, 1873	+	+	+	+	+	
<i>Hydroptila lotensis</i> Mosely, 1930		+	+	+		
<i>Hydroptila martini</i> Marshall, 1977		+				
<i>Hydroptila occulta</i> Eaton, 1873		+	+			
<i>Hydroptila pulchricornis</i> Pictet, 1834		+	+			
<i>Hydroptila simulans</i> Mosely, 1920			+	+		
<i>Hydroptila sparsa</i> Curtis, 1834	+	+	+	+	+	
<i>Hydroptila tineoides</i> Dalman, 1819	+	+	+	+		
<i>Hydroptila vectis</i> Curtis, 1834		+	+	+	+	

SECTOR - PERIOD	Jons 1982 ♀♂		Lyon 1959-1982 ♀♂	Miribel, 2014 ♂	Belley 2014-2015 ♂
NUMBER OF STATIONS	12		1	5	9
COLLECTOR	F. Rojas-Camousseight		P. Usseglio-Polatera	V. Rosset, S. Maréchal & M.-C. Roger	P. Marle & S. Rabarivelo
COLLECTED SPECIES	Mir/Jon canal	Cut-off ch.	Main channel in urban zone	Floodplain	Floodplain
Type of environment / water bodies					
<i>Ithytrichia lamellaris</i> Eaton, 1873		+	+		
<i>Lepidostoma hirtum</i> Fabricius, 1775		+	+	+	+
<i>Leptocerus lusitanicus</i> MacLachlan, 1884			+		
<i>Leptocerus tineiformis</i> Curtis, 1834		+	+	+	+
<i>Linnephilus affinis</i> Curtis, 1834					+
<i>Linnephilus auricula</i> Curtis, 1834			+	+	
<i>Linnephilus bipunctatus</i> Curtis, 1834				+	
<i>Linnephilus borealis</i> Zetterstedt, 1840		+			
<i>Linnephilus decipiens</i> Kolenati, 1848		+		+	
<i>Linnephilus flavicornis</i> Fabricius, 1787		+		+	+
<i>Linnephilus flavospinosus</i> Stein, 1874		+			+
<i>Linnephilus germanus</i> MacLachlan, 1875					
<i>Linnephilus helveticus</i> Schmid, 1965		+		+	
<i>Linnephilus lunatus</i> Curtis, 1834		+		+	+
<i>Linnephilus rhombicus</i> Linnaeus, 1758		+			+
<i>Linnephilus vittatus</i> Fabricius, 1798			+	+	
<i>Lype phaeopa</i> Stephens, 1836		+	+	+	+
<i>Lype reducta</i> Hagen, 1868		+			
<i>Mesophylax impunctatus</i> MacLachlan, 1884					+
<i>Metalyse fragilis</i> Pictet, 1834			+		
<i>Micropterna nycterobia</i> MacLachlan, 1875			+		
<i>Micropterna testacea</i> Gmelin, 1789		+	+	+	+
<i>Mystacides azureus</i> Linnaeus, 1761		+	+	+	+
<i>Mystacides longicornis</i> Linnaeus, 1758	+	+	+		+
<i>Mystacides niger</i> Linnaeus, 1758		+	+		
<i>Neureclipsis bimaculata</i> Linnaeus, 1758	+	+	+		
<i>Oecetis furva</i> Rambur, 1842	+	+		+	
<i>Oecetis lacustris</i> Pictet, 1834	+	+	+		+
<i>Oecetis notata</i> Rambur, 1842			+	+	+
<i>Oecetis ochracea</i> Curtis, 1825		+			
<i>Oecetis testacea</i> Curtis, 1834		+		+	
<i>Oecetis tripunctata</i> Fabricius, 1793	+		+		
<i>Orthotrichia angustella</i> MacLachlan, 1865		+	+		
<i>Orthotrichia costalis</i> Curtis, 1834	+	+	+	+	+
<i>Orthotrichia tragetti</i> Mosely, 1930		+		+	
<i>Oxyethira flavicornis</i> Pictet, 1834		+	+	+	+
<i>Oxyethira friei</i> Klapálek, 1891	+	+			
<i>Oxyethira simplex</i> Ris, 1897	+	+			
<i>Oxyethira tristella</i> Klapálek, 1895		+			
<i>Phryganea bipunctata</i> Retzius, 1783		+			+
<i>Phryganea grandis</i> Linnaeus, 1758		+			+
<i>Plectrocnemia conspersa</i> Curtis, 1834		+			+
<i>Polycentropus flavomaculatus</i> Pictet, 1834	+	+	+	+	+
<i>Polycentropus irroratus</i> Curtis, 1835	+				
<i>Potamophylax latipennis</i> Curtis, 1834					+
<i>Psychomyia pusilla</i> Fabricius, 1781	+	+	+	+	+
<i>Rhyacophila dorsalis</i> Curtis, 1834	+	+	+	+	+
<i>Rhyacophila fasciata</i> Hagen, 1859				+	+
<i>Rhyacophila pascoei</i> MacLachlan, 1879			+		
<i>Sericostoma galeatum</i> Rambur, 1842					+
<i>Sericostoma personatum</i> Kirby & Spence, 1826		+	+		
<i>Setodes argentipunctellus</i> MacLachlan, 1877			+	+	
<i>Setodes punctatus</i> Fabricius, 1793	+		+		+
<i>Silo nigricornis</i> Pictet, 1834		+		+	+
<i>Stactobiella risi</i> Felber, 1908			+		
<i>Stenophylax permistus</i> MacLachlan, 1895				+	+
<i>Synagapetus dubitanus</i> MacLachlan, 1879				+	
<i>Tinodes dives</i> Pictet, 1834					
<i>Tinodes maculicornis</i> Pictet, 1834		+			
<i>Tinodes waeneri</i> Linnaeus, 1758		+	+	+	+
<i>Trienodes bicolor</i> Curtis, 1834		+			
<i>Trichostegia minor</i> Curtis, 1834				+	+
SPECIES RICHNESS	38	79	70	56	59
	84				