



Field experiments on colonization and movements of stream invertebrates in an Apennine river (Visone, NW Italy)

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Received 15 June 2001; accepted 31 January 2002

Key words: macroinvertebrates, lotic environments, recolonization movements

Abstract

Macroinvertebrates continuously redistribute themselves in the riverbed. A knowledge of the colonization mechanisms and movement patterns is very important for an understanding of processes of restoration of lotic environments, particularly of inland waters with severe pollution. We tested the colonization patterns of stream macroinvertebrates in the Visone River, a tributary of the highly contaminated Bormida River (NW Italy). We placed six groups of traps in the riverbed, each group consisting of three traps: the C trap allowed colonization from all directions, while the D and U traps allowed access only from downstream and upstream respectively. The C traps were the most colonized substrates, both in number of individuals and taxa. The U traps were more colonized than the D traps, demonstrating the great importance of movements directed downstream. We report data on taxonomic and seasonal differences in the colonization process.

Introduction

Benthic macroinvertebrates are a central element of lotic environments, playing an important role in the processing of allochthonous and autochthonous organic substances and in the river's self-purifying capacity (Vannote et al., 1980). Furthermore, their community structure is widely used as an indicator in environmental quality monitoring (Ghetti, 1997). It has long been known that freshwater invertebrate populations continually redistribute themselves over the stream bed. Environmental alterations can deplete or destroy a benthic biocenosis, but a recolonization process begins as soon as conditions are restored. Many studies have shown that macroinvertebrates can quickly colonize new or disturbed substrates from source areas. Recolonization studies in running water habitats have shown that animals promptly reappear in affected areas (Williams, 1980). Colonization depends on many elements, like invertebrate mobility, substrate texture (Wise et al., 1979) and associated food supplies, competition, predation, life history (Mackay, 1992) and season (Williams, 1980). Williams & Hynes (1976) showed that four main sources of animals con-

tributed to the recolonization of denuded substrates. These were vertical movements from within the substrate, aerial sources (e.g. oviposition), upstream and downstream migration (drift). Downward movement toward the hyporrheic zone plays an important role especially in the recolonization of temporary streams (Delucchi, 1989). The upstream flight of ovigerous lotic insects is also a principal component of the colonization cycle of many taxa (Bird & Hynes, 1980; Müller, 1982). Drift is the downstream transport of aquatic organisms in the current. There are different types of drift, which present seasonal and diel periodicity patterns and differ in qualitative and quantitative characteristics (Brittain & Eikeland, 1988). Upstream movement within the water has been recorded for many benthic invertebrates (Bishop & Hynes, 1969; Söderström, 1987). In permanent streams, all four sources contribute substantially, but positive rheotaxis and especially drift appear to be the primary components. Several studies have described recolonization mechanisms in North American, northern European and tropical streams, but until now there have been no similar investigations in Italian lotic environments.

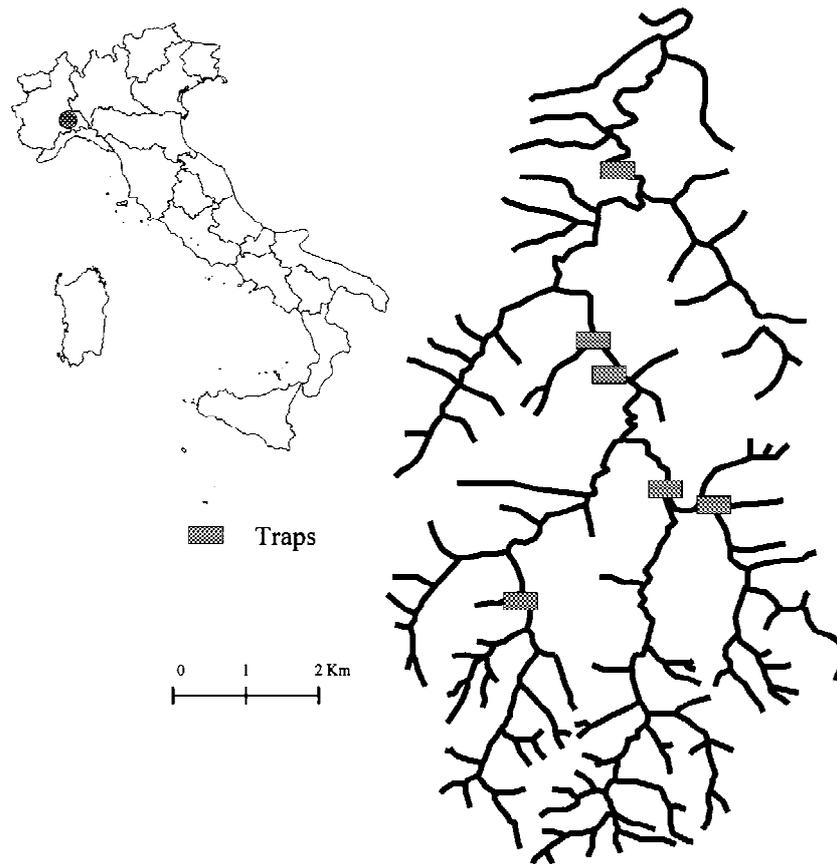


Figure 1. Location of traps in the Visone River study area.

The aim of this study was to examine quantitative and qualitative characteristics of movements upstream and downstream, by analyzing colonization patterns of lotic macroinvertebrates in denuded areas of an Apennine stream. The river investigated is a tributary of the Bormida River, a prime example of contamination in Italian inland waters.

Methods

In the period September 1999–September 2000, we placed 15 groups of artificial substrates in six sites of the Visone River, Alessandria district, NW Italy (Fig. 1). Each group comprised three traps: Control, Upstream and Downstream. The traps consisted of a basic wooden frame, measuring 50 cm long, 33 cm wide and 30 cm high. The bottom of each trap was covered by polyethylene plastic to prevent colonization vertically from the substrate.

The traps were placed in the riverbed, with a bottom made of clean sterile substrate (depth: 5 cm) reproducing an area denuded by environmental alteration. They were arranged so as to avoid interference with each other. Control traps (C) were completely open, allowing colonization from all directions. Upstream traps (U) and Downstream traps (D) were covered with a nylon net (mesh width 250 μm), allowing access exclusively from upstream or downstream, respectively. After 35 days, each trap was removed; before the trap was lifted from the streambed, a 250 μm mesh bag was slipped around it to prevent loss of organisms. We also conducted a sampling to quantify the macroinvertebrate community structure on the natural bottom of the river: we analyzed 22 Surber samples at the same stations where we placed the traps.

In the laboratory, the macroinvertebrates in each sample were classified, counted and preserved in ethyl alcohol (70°). The taxonomic level of classification

Table 1. Comparison of abundance and specific diversity in Control, Upstream and Downstream traps ($N=21\,378$ ind., from 65 taxa), and on the natural river bottom (Total $N=11\,452$ ind., from 58 taxa)

Substrates	Abundance (N ind/m ²)	Diversity (Taxa/substrate)	<i>N</i>
C Traps	3736.3±428.1	18.1±1.9	14
U Traps	2519.1±422.9	15.8±1.7	14
D Traps	2014.0±330.1	13.3±1.2	15
Surber samples	2082.2±87.6	16.8±1.8	22

was always at least the same as in the I.B.E. method (Ghetti, 1997).

Results

In the study period, we collected 22 Surber samples, as well as 14 control, 14 upstream and 15 downstream traps. We lost one U trap, obstructed by ice, and one C trap, because of lack of water in summer. In total, we collected 21 378 organisms (belonging to 65 taxa) in the traps and 11 452 organisms (58 taxa) in the Surber samples (Appendix 1).

Data for colonization density and specific richness in each trap category and in the Surber samples are given in Table 1. Comparing the U and D traps with the C traps, we detected a significant difference in the number of organisms (Fig. 2. Kruskal–Wallis test=12.35; $P<0.002$) but not in the number of taxa (Fig. 3). The C traps were the most colonized substrates, both in number of individuals (mean 678.1) and taxa (mean 18.1). The U traps (mean $N=475.2$; mean $S=15.8$) were more colonized than the D traps (mean $N=365.5$; mean $S=13.3$).

Analyzing the macroinvertebrate abundance in the natural river bottom, we detected no significant difference between the Surber samples and the D traps (Mann–Whitney test, $U=137$; $P=n.s.$) nor between the Surber samples and the U traps ($U=150$; $P=n.s.$). However, there was a significant difference between the Surber samples and the artificial substrate of the C traps ($U=247$; $P<0.005$). Analyzing the macroinvertebrate taxon richness, we detected no differences between the natural river bottom and traps C, D and U (respectively, $U=176$; $P=n.s.$; $U=137$; $P=n.s.$; $U=152.5$; $P=n.s.$).

The faunal composition differed among the three traps and there were also differences between the traps

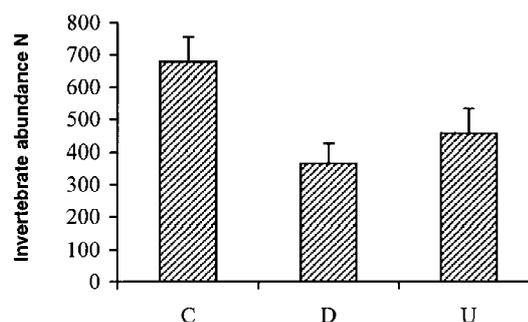


Figure 2. Abundance of macroinvertebrates (mean±se) after a 35-day colonization period in the Control (C), Downstream (D) and Upstream (U) traps.

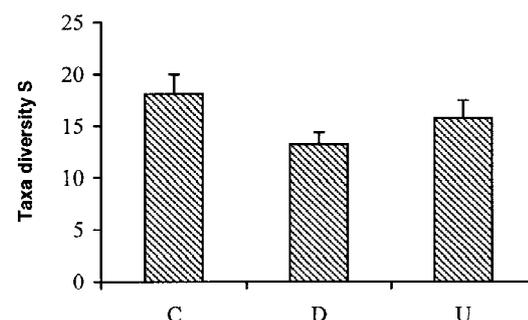


Figure 3. Diversity of macroinvertebrates (mean±se) after a 35-day colonization period in the Control (C), Downstream (D) and Upstream (U) traps.

and the natural river bottom (details in Appendix 1). However, Chironomidae were the most abundant organisms in all substrates: they represented 51, 51.3 and 57.4% of the total number of macroinvertebrates in the C, U and D traps, respectively, and 55.4% of those in the natural substrate. There were seasonal differences in the recolonization patterns of some groups. The most important seasonal patterns were observed in the mussel *Ancylus fluviatilis*, found in the traps only in summer, and in the stoneflies *Brachyptera* sp. and *Capnia* sp., which colonized the substrates only in winter (Fig. 4).

Discussion

The C traps, open in all directions, were colonized by a higher number of individuals than the U and D traps. For the two traps that allowed access only from one direction, invertebrate abundance was higher in the U traps than in the D traps. This confirms the considerable importance of downstream movement as a primary source of colonization of new areas (Town-

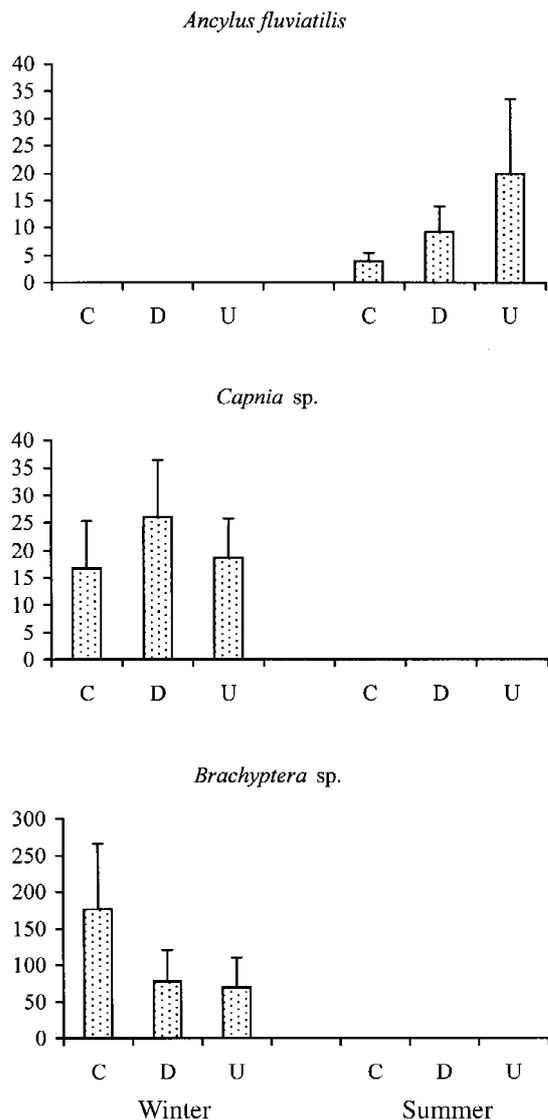


Figure 4. Abundance of the three macroinvertebrate taxa showing the most important seasonal variations (mean and s.e.).

send & Hildrew, 1976; Bird & Hynes, 1981; Allan, 1997), occurring through a combination of drift and downstream movement along the substrate.

The presence of strong positive rheotaxis (many taxa with a considerable number of individuals) is very interesting. Unlike drift, upstream movements are always active; hence they are always non-accidental and have an adaptive value (Allan, 1997). We detected preferential directions of migration for different groups of organisms. Some groups were particularly abundant in the riverbed and were represented by many organisms in all three traps: the taxa most in-

involved were Ephemeroptera Leptophlebiidae, *Leuctra* sp. and *Baetis* sp., all of them well known as precocious colonizers (Shaw & Minshall, 1980). Although Plecoptera normally constitute an important component of drift (Mendel & Muller, 1978), we detected strong positive rheotaxis in *Brachyptera* sp. and *Capnia* sp. We can explain this phenomenon by trophic competition in species with precocious emergence, in agreement with previous studies on taxa with similar autoecology (Bishop & Hynes, 1969). In contrast, *Bezzia* sp. and other Eieini were recovered only in U traps, underlining the importance in this group of downstream movement for the colonization of new areas. Chironomidae exhibited an intense rate of colonization in the different trap typologies, confirming the high mobility already noticed in other studies (Mackay, 1992). Comparison of the structural composition of the communities that colonized the artificial substrates in the study period revealed an evident seasonal pattern in some groups. In particular, some species (*Brachyptera* sp. and *Capnia* sp.) moved into the traps only in winter, while another (*Ancyclus fluviatilis*) occupied the substrates only in summer. This pattern is likely due to life cycle characteristics in the former case and higher trophic availability in the latter case.

The abundance of macroinvertebrates in natural stream bottoms can show remarkable geographic differences, depending on climate and other factors, such as substrate texture, water current, physical-chemical and biotic parameters. The density on the natural bottom of the Visone River (mean 2082 ind./m²) was in the range reported elsewhere in similar environments (Grubaugh & Wallace, 1995; Clarke & Scruton, 1997). In the Visone River, the abundance of macroinvertebrates in the natural bottom was lower than that in the artificial substrate of the C traps. Indeed the artificial bottom represents a good environment for macroinvertebrates, so the density can quickly reach a high value.

Conclusions

The Visone River is an interesting subject of research, since it is one element of a complex environmental mosaic: it is an important tributary of the Bormida River, which has become a national example of serious environmental pollution (Badino et al., 1992). After 90 years of pollution, the chemical manufacturing activity in Cengio ceased and the biological quality

of the Bormida River has been slowly but constantly improving in recent years. Thanks to the decrease of pollutants, a lot of macroinvertebrate taxa are recolonizing this river (Regional Agency for the Environment, 1990–2001 unpubl. data, A. Morisi & S. Ferrari, pers. comm.). Small tributaries with a well structured and diversified macrobenthic fauna have probably played a significant role in this colonization process. The peripheral basins are sources of organisms, i.e. areas from which a part of the benthic community constantly drifts downstream to colonise new substrates. When these aquatic invertebrates meet a critical situation (e.g. a highly polluted area), they disappear; however, as soon as the environmental conditions improve, intensive recolonization from this source can begin. This process subsequently involves the entire river network in the two directions: upstream and downstream. Recolonization from tributaries was very likely the cause of the recent reappearance of a rich and diversified benthic fauna in the Bormida River.

Our data on the recolonization patterns underline the great resilience and revitalization capacities of aquatic biocenoses and lotic systems and the importance of small unpolluted basins for the maintenance and recovery of high environmental quality in a hydrographic network.

Acknowledgements

We thank Giorgio Malacarne for their comments on the manuscript. The study was supported by 40-60 MURST grants.

References

- Allan, J. D., 1997. Stream ecology. Structure and function of running waters. Chapman & Hall, London: 388 pp.
- Badino G., G. Forneris & E. Lodi, 1992. Carta Ittica relativa al territorio della regione piemontese. University of Turin, Turin: 186 pp.
- Bird G. A. & H. B. N. Hynes, 1980. Movements of adult aquatic insects near stream in Southern Ontario. *Hydrobiologia* 77: 65–69.
- Bird G. A. & H. B. N. Hynes, 1981. Movement of immature aquatic insects in a lotic habitat. *Hydrobiologia* 77: 103–112.
- Bishop J. E. & H. B. N. Hynes, 1969. Upstream movements of the benthic invertebrates in the Speed River, Ontario. *J. Fish. Res. Bd Can.* 26: 279–298.
- Brittain J. E. & T. J. Eikeland, 1988. Invertebrate drift – A review. *Hydrobiologia* 166: 77–93.
- Clarke K. D. & D. A. Scruton, 1997. The benthic community of stream riffles in Newfoundland, Canada and its relationship to selected physical and chemical parameters. *J. Anim. Ecol.* 12: 113–121.
- Delucchi, C. M., 1989. Movement patterns of invertebrates in temporary and permanent streams. *Oecologia* 78: 199–207.
- Ghetti, P. F., 1997. Manuale di applicazione Indice Biotico Esteso (I.B.E.). Provincia Autonoma di Trento, Trento: 222 pp.
- Grubbaugh, J. W. & J. B. Wallace, 1995. Functional structure and production of the benthic community in a Piedmont river: 1956–1957 and 1991–1992. *Limnol. Oceanogr.* 40: 490–501.
- Mackay, R. J., 1992. Colonization by lotic macroinvertebrates: a review of processes and patterns. *Can. J. Fish. aquat. Sci.* 49: 617–628.
- Mendel, H. & K. Müller, 1978. The colonization cycle of *Ampinemura sulcicollis* Ris (Ins. Plecoptera) in the Abisko area. *Hydrobiologia* 60: 109–111.
- Müller, K., 1982. The colonization cycle of freshwater insects. *Oecologia* 52: 202–207.
- Shaw, D. W. & G. W. Minshall, 1980. Colonization of an introduced substrate by stream invertebrates. *Oikos* 34: 259–271.
- Söderström, O., 1987. Upstream movements of invertebrates in running waters – a review. *Arch. Hydrobiol.* 111: 197–208.
- Townsend, C. R. & A. G. Hildrew, 1976. Field experiments on the drifting, colonization and continuous redistribution of stream benthos. *J. anim. Ecol.* 45: 759–772.
- Vannote, R. L., G. W. Minshall, K. W. Cummins, J. R. Sedell & C. E. Cushing, 1980. The river continuum concept. *Can. J. Fish. aquat. Sci.* 37: 130–137.
- Williams, D. D. & H. B. N. Hynes, 1976. The recolonization mechanisms of stream benthos. *Oikos* 27: 265–272.
- Williams, D. D., 1980. Temporal patterns in recolonization of stream benthos. *Arch. Hydrobiol.* 90: 56–74.
- Wise, D. H. & M. C. Molles Jr., 1979. Colonization of artificial substrates by stream insects: influence of substrate size and diversity. *Hydrobiologia* 65: 69–74.

Appendix 1. Occurrence of macroinvertebrate taxa in Control, Upstream and Downstream traps, and on the natural river bottom

Taxa	C	U	D	Surber
Odonata (Anisoptera)				
<i>Boyeria</i> sp.	x		x	
<i>Cordulegaster boltonii</i>		x	x	x
<i>Onychogomphus</i> sp.	x		x	x
<i>Orthetrum</i> sp.				x
Odonata (Zygoptera)				
<i>Calopteryx splendens</i>	x	x	x	x
<i>Calopteryx virgo</i>				x
<i>Pyrhosoma nymphula</i>				x
Coleoptera				
Dytiscidae gen. (larvae & adults)	x	x	x	x
Elminthidae gen. (larvae & adults)	x	x	x	x
Gyrinidae gen.	x	x	x	
Helodidae gen.	x			x
<i>Hydraena</i> sp.		x	x	x
Hydrophilidae gen.	x	x		
<i>Pomatinus substriatus</i> (larvae & adults)	x	x	x	x
Crustacea				
<i>Austropotamobius p.italicus</i>	x			
Diptera				
<i>Anthomyia</i>		x		
<i>Atherix Ibisia marginata</i> sp.	x	x	x	x
<i>Atrichops crassipes</i>				x
<i>Beris</i> sp.	x	x	x	x
Chironomidae gen.	x	x	x	x
Eleini gen.		x		x
Empididae gen.	x	x	x	
Psychodidae gen.	x	x	x	x
Simuliidae gen.	x	x	x	x
Tanypodinae gen.	x	x	x	x
<i>Tipula</i> sp.	x	x		x
Culicidae				x
Limoniidae				x
Tabanidae				x
Ephemeroptera				
<i>Baetis</i> sp.	x	x	x	x
<i>Caenis</i> sp.	x	x	x	x
<i>Choroterpes</i> sp.	x	x	x	
<i>Ecdyonurus</i> sp.	x	x	x	x
<i>Electrogena</i> sp.	x	x	x	
<i>Ephemera danica</i>	x	x	x	x
<i>Ephemerella ignita</i>	x	x	x	x
<i>Habroleptoides</i> sp.	x	x	x	x
<i>Habrophlebia</i> sp.	x	x	x	x
<i>Paraleptophlebia</i> sp.				x
<i>Torleya</i> sp.				x

Appendix 1. Continued

Taxa	C	U	D	Surber
Nematomorpha				
<i>Gordius</i> sp.	x			
Heteroptera				
<i>Gerride</i> sp.	x		x	
<i>Micronecta</i> sp.	x	x	x	x
<i>Nepa cinerea</i>		x		
<i>Notonecta</i> sp.		x		x
<i>Velia</i> sp.	x	x	x	x
Hymenoptera				
<i>Agriotypus armatus</i>	x	x	x	x
Megaloptera				
<i>Sialis</i> sp.	x	x	x	x
Oligochaeta				
<i>Eiseniella tetraedra</i>	x		x	x
Lumbriculidae gen.	x	x	x	x
Neuroptera (Planipennia)				
<i>Osmylus fulvicephalus</i>		x		x
Plecoptera				
<i>Amphinemura</i> sp.	x		x	
<i>Brachyptera monilicornis</i>	x	x	x	x
<i>Capnia</i> sp.	x	x	x	x
<i>Isoperla grammatica</i>	x	x	x	
<i>Leuctra</i> sp.	x	x	x	x
<i>Nemoura</i> sp.	x		x	
Pulmonata				
<i>Ancylus fluviatilis</i>	x	x	x	x
<i>Lymnaea peregra</i>	x	x	x	x
<i>Planorbis</i> sp.	x	x		
Trichoptera				
Beraeidae gen.		x		x
Glossosomatidae gen.	x	x		x
<i>Hydropsyche</i> sp.	x		x	x
Hydroptilidae	x			
Lepidostomatidae gen.	x	x		x
Leptoceridae gen.	x	x	x	x
Limnephilidae gen.	x	x	x	x
<i>Polycentropus</i> sp.	x	x	x	x
<i>Potamophylax cingulatus</i>	x	x		x
<i>Rhyacophila</i> sp.	x		x	x
<i>Sericostoma pedemontanum</i>	x	x	x	
<i>Sericostoma</i> sp.				x
<i>Silo</i> sp.	x	x	x	x
<i>Wormaldia</i> sp.		x	x	x
Tricladida				
<i>Dugesia</i> sp.	x	x	x	x