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Concordance of stream macroinvertebrate assemblage classifications: How general are patterns from single-year surveys?

Heikki Mykrä[a,*], *Jani Heino*[b], *Timo Muotka*[b,c]

[a]Finnish Environment Institute, Research Programme for Integrated River Basin Management, P.O. Box 413, FIN-90014 University of Oulu, Finland
[b]Finnish Environment Institute, Research Programme for Biodiversity, P.O. Box 413, FIN-90014 University of Oulu, Finland
[c]University of Oulu, Department of Biology, P.O. Box 3000, FIN-90014 University of Oulu, Finland

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ABSTRACT

We examined how the assemblage structure and assemblage–environment relationships of stream macroinvertebrates varied over three consecutive years in a boreal drainage system. We specifically examined whether classifications produced assemblage types that were stable through time, and how these assemblages could be predicted based on local environmental variables. We also used a combination of Procrustes rotation analysis and NMDS ordinations to examine the degree of year-to-year concordance of assemblage patterns. The composition of site clusters varied among years, resulting in only moderate among-year concordance of assemblage classifications. Stream width and in-stream habitat conditions, especially macrophyte cover, were the most important variables discriminating among the cluster groups. Despite temporally variable assemblage classifications, the overall macroinvertebrate assemblage structure was concordant among years. Among-year concordance was higher in-streams with low temporal variation in the physical environment, as well as high abundance and low variability of macrophytes. Due to among-year variability in cluster composition and weakly predictable assemblage–environment relationships, a posteriori assemblage classifications may be of limited value in the conservation planning of headwater streams.

1. Introduction

Local extinction and colonization processes are among the major factors structuring biological assemblages. Extinction and colonization dynamics can also influence the responses of assemblages to environmental change, potentially leading to weakly predictable patterns of assemblage structure (e.g., Ozinga et al., 2005). Therefore, understanding the influence of temporal variation on assemblage patterns and assemblage–environment relationships is central for predicting species' distributions along environmental gradients. Yet, predictive models used in conservation planning and bioassessment typically rely on single-year surveys with the underlying assumption that these results are truly representative of local assemblages (e.g. Metzeling et al., 2002). However, in reality, the temporal dynamics of local populations and assemblages may swamp any general patterns (Wiens, 1981; Olden et al., 2006).

* Corresponding author: Tel.: +358 40 779 6663; fax: +358 8 547 2786.
E-mail addresses: heikki.mykra@ymparisto.fi (H. Mykrä), jani.heino@ymparisto.fi (J. Heino), timo.muotka@oulu.fi (T. Muotka).
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Habitat stability and biotic interactions are the main determinants of the temporal variability of assemblage structure (e.g. Oberdorff et al., 2001). In this regard, streams should be particularly interesting study systems, because they are highly variable and disturbance-prone environments (e.g. Lake, 2000). However, findings from the relatively few studies that have addressed temporal variation in stream assemblages have been controversial thus far. Some studies have shown assemblage composition to be relatively persistent, especially if environmental conditions do not vary appreciably over time (Weatherley and Ormerod, 1990; Robinson et al., 2000; Scarsbrook, 2002), while others have reported considerable temporal changes in assemblage structure (Townsend et al., 1987; Metzeling et al., 2002). Thus, there is no consensus as to whether stream assemblages are temporally stable enough for conservation planning and bioassessment programs to be based on single-year surveys.

Temporal variation of assemblage structure bears important implications for the conservation and management of lotic biodiversity. Predictive models use biological and environmental data to model assemblage–environment relationships, with the aim of predicting patterns of biodiversity in a particular area and beyond. In streams, such predictive approaches often use benthic invertebrates as their primary target group (e.g. Wright et al., 1984; Hawkins et al., 2001). These models rely on a comparison with regional reference systems ("best available condition") for the detection of an impact (Reynoldson et al., 1997). Therefore, knowing the temporal variation of benthic assemblages, and of assemblage–environment relationships, in reference sites is a critical aspect of the utility of these models. Yet, surprisingly few studies have examined the temporal variability of assemblage–environment relationships in reference streams (but see Robinson et al., 2000).

We examined how the assemblage structure and assemblage–environment relationships of stream macroinvertebrates varied over three consecutive years in a near-pristine drainage basin in northern Finland. We specifically examined whether assemblage classifications produced distinct and temporally stable assemblage types that could be predicted by environmental variables. We also examined whether assemblage patterns were (i) concordant among study years and, if so, (ii) if the assemblage concordance was related to temporal variability in environmental conditions, and (iii) which environmental variables were best related to among-year assemblage concordance.

2. Materials and methods

2.1. Study area

The study area is located in northeastern Finland (66–67°N, 28–30°E), extending across an area of ca. 2200 km^2. The bedrock of the region is highly variable, with extensive occurrences of calcareous rocks. The Kuusamo Uplands, which Koutajoki drainage basin is part of, is said to be the best preserved part of the taiga forest in Western Europe (Malmqvist et al., in press). The study streams ($n = 34$) are headwater (orders 1–3, base flow <0.6 $m^3 s^{-1}$) tributaries to the three main stems (Oulankajoki, Kitkajoki, and Kuusinkijoki) of the river Koutajoki drainage system. These are clear-water, oligotrophic streams characterized by circumneutral to slightly alkaline water and low-to-moderate nutrient concentrations (Table 1). Most of the study streams are located in Oulanka National Park and they have almost intact riparian zones. Streams located outside the park are influenced by some forestry practices, but they would still qualify as reference sites for regions with more intensive land use. The streams studied harbour fish, with brown trout (*Salmo trutta*), European minnow (*Phoxinus phoxinus*), and bullheads (*Cottus gobio* and *Cottus poecilopus*) being the dominant species. Most brown trout populations are sedentary (form *fario*), but as there are no man-made constructs in headwater streams of the river system, some streams also contain potamodromous populations (form *lacustris*).

2.2. Stream surveys

Study streams were selected randomly, with one restriction: they had to be located within a 2 km distance from the nearest road. We sampled benthic macroinvertebrates from each of the 34 streams in early September during three consecutive years (2001, 2002 and 2003). At each site, we collected a 2 min

Table 1 – Means and ranges of environmental variables in the study streams ($n = 34$) during the three-year study period

Variable	2001		2002		2003	
	Mean	Range	Mean	Range	Mean	Range
Depth (cm)	16	7–26	16	7–27	15	5–28
Current velocity (cm/s)	17	8–28	24	9–56	20	4–43
Macrophyte cover (%)	33	0–93	35	0–99	31	0–94
Substrate size[a]	6.1	3.3–7.9	6.3	2.1–8.2	6.2	3.6–8.4
Shading (%)	24	0–70	22	0–69	21	0–67
Stream width (m)	3.8	0.9–14.8	3.2	0.8–13.2	3.2	0.8–15.0
Conductivity (mS/m)	9.59	2.46–26.9	8.98	3.13–22.9	10.33	3.97–22.3
pH	7.3	6.0–8.0	7.6	7.1–8.1	7.6	7.1–8.2
$NO_2 + NO_3$ (μg/l)	19.1	4.0–142.0	14.3	5.0–140.0	17.1	2.1–88.0
Total P (μg/l)	12.0	3.0–53.0	13.4	3.6–44.0	12.0	2.6–42.0
Water colour (mg Pt/l)	62	20–205	64	10–210	48	10–170

a Substrate size was measured using a modified Wentworth scale (see text for details).