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Original article

Impact of flood deposits on earthworm communities in alder forests from a subalpine floodplain (Kandersteg, Switzerland)

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A B S T R A C T

In many ecosystems, bioindication is a tool to estimate biodiversity and quality of environment. In soils, invertebrates are generally suitable bioindicators, especially earthworms. In floodplains, young alluvial soils are exposed to sedimentation and erosion, and little is known about soil bioindication. Moreover, a reference state is now needed to evaluate river restoration projects. The aim of our study was thus to establish an “undisturbed” floodplain reference at the subalpine level based on earthworm communities and to test if they are indicators of fluvial dynamics. Seven plots were chosen along a stretch of the Kander River (BE, Switzerland). At each plot, a soil profile was described (carbonated Fluvisols) and topsoil was analysed. Earthworms were extracted in each plot using standard mustard extraction (3×1 m^2) and “hand sorting” method ($20 \times 20 \times 20$ cm). Eight species were identified, and *Lumbricus meliboeus* was found for the first time in a carbonated environment. The absence of anecics was considered, at the subalpine level, as a bioindication of the fluvial dynamics (erosion and sedimentation processes). Biomass of epigeics was positively correlated to topsoil texture and organic matter quality, and thus epigeics, sensitive to variations of topsoil composition, are bioindicators of the latest flood event at the subalpine level.

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1. Introduction

The concept of bioindicators probably first became widely used following the definition of Clements in 1920 who identified plant species as community indicators within his overall concept of plant community succession [1]. According to Markert et al. [2], a bioindicator is a living organism, even so a part of an organism or a community of organisms, which contains information on the quality of the environment. Bioindication is thus one of the organism properties, collected in the field, and giving ecological information that is used to make inferences about the quality of the environment. Such bioindication commonly refers to bioindicators which are related, directly or indirectly, to some or a complex of factors used as a barometer indicating air pressure [3]. The notion of bioindication in soils has been recently developed with the challenge of applying the expertise of soil knowledge in the assessment of contaminated soils and problems of soil degradation [4]. Therefore, bioindication has been applied mainly as a tool to estimate soil biodiversity and quality, such as the evaluation of pesticides impact or success of restoration methods (i.e. post-mining restoration [5]). Despite the fact that bioindicators for soils are still insufficiently developed, soil invertebrates were recently considered as appropriate tools in indicating the degree to which soil may be affected by human activities [5]. For instance, mesofauna groups such as Collembola and Acarina were used to evaluate the suitability of forest soils [3] as well as environmental impacts of pollutants [6]. Oligochaeta (earthworms and enchytreids) are also generally regarded as highly suitable bioindicators, because: 1) they contain key species for ecosystem functioning, 2) they are widespread and abundant and 3) they may be used at various levels of biological organisation, ranging from molecular to ecosystem levels [7]. Focusing on these organisation levels, population growth, biomass and abundance of Oligochaeta may vary according to toxicant stress [8]. At the community and ecosystem levels, Schouten et al. [9] also demonstrated that diversity and abundance of Oligochaeta were clearly discriminative between soil

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types and land-use intensities in grasslands and horticultural farms. In addition, annelid communities may also help in characterizing soil quality [7]. Earthworms, usually considered as major ecosystem engineers [10–12], may be particularly efficient for the purpose of soil bioindication because they actively contribute to organic matter recycling and soil structuring processes [13,14]. Conversely, distribution of earthworm communities is clearly influenced by soil parameters such as soil texture combined with vegetation types, soil nutrients and pH values [15–17].

Very few studies have been conducted on earthworm communities in floodplains; most of those were descriptive and focused on meadows and grasslands at very low altitude (ranging from 5 to 50 m a.s.l.), and generally on stabilized terraces [18–20]. To our best knowledge, only three studies were conducted on earthworm communities in near-natural floodplains at mountain and subalpine levels [21–23]. Moreover, in the framework of ecosystem rehabilitation, floodplain management is now questioned and river restoration projects have thus considerably increased worldwide in recent decades [24,25]. To evaluate the success of floodplain restoration, a reference state to be reached by river restoration has to be determined [26] and a value assessment could be established by using reliable indicators of restoration evaluation. The most frequently used indicators to evaluate the success of river restoration aiming to increase biodiversity are based on vegetation and aquatic fauna [27]. So far, little is known about earthworms as bioindicators of restoration success. Plum and Filser [28] demonstrated in their study carried out in Northern Germany that earthworm abundance and biomass are usually reduced by extensive flooding. Indeed, floods have a large impact on alluvial soil chemistry (especially organic matter content and quality), physics (especially texture, soil thickness) and soil stabilisation (time elapsed between flood events) through sedimentation/erosion processes and organic matter fluxes. Alluvial soils are considered as young soils resulting from the interaction between *in situ* evolution and inheritance of both organic and mineral materials [21–23]. As a consequence, a better understanding of earthworm communities as bioindicators of environment quality may therefore be helpful to evaluate the success of restoration projects in recreating the fluvial dynamics.

The aim of our study is to establish an “undisturbed” floodplain reference at the subalpine level based on earthworm communities (diversity, ecological categories, abundance and biomass). The specific objective of this study is to test if earthworm communities may be used in an undisturbed subalpine floodplain as bioindicators of the fluvial dynamics. Thus, we hypothesize that earthworm communities are bioindicators of the fluvial dynamics reflected by the physical soil parameters (especially texture) and the organic matter (quantity and quality) of the topsoil layer. In a similar environment, i.e. same mesoclimate, same vegetation cover reflecting colonisation time (alder shrubs and trees), same organic input through *in situ* litter fall, same young soils regularly flooded (Fluvisols [29]) and same parental material (carbonated alluvial deposits), the topsoil layer parameters (texture, structure, thickness, organic matter content) are mostly determined by the latest flood that has led to the inheritance of mineral and organic deposits.

2. Methods

2.1. Site descriptions

The study was carried out in a Swiss subalpine floodplain site at an altitude of 1320 m a.s.l. along the Kander River (Canton of Bern) included in the alluvial zones inventory of national importance (162 ha [30]). This site originates mainly from calcareous deposits and exhibits natural hydrological dynamics where depositions and erosion processes still occur. General characteristics of this site are given in Table 1. The fluvial regime is pluvio-nival (floods in spring and summer due to rain and snow melt) and the mesoclimate is subalpine (high variation in air temperature between summer and winter).

Regarding earthworm and soil samplings, seven plots within the site of national importance were chosen along a 5 km stretch of the Kander River (Kander 1 to Kander 7 from upstream to downstream, ranging from an altitude of 1400 to 1360 m) within the same vegetation unit, forests of alder shrubs and trees, representing the dominant vegetation stage in absence of mature forests. The minimal distance between plots is 300 m and, except during floods, plots are not far from more than 20 m from the riverside. All soils correspond to the Fluvisol type according to the classification of IUSS Working Group WRB [29] and are regularly flooded at least annually. In addition, all plots have been subjected to a major flood (Q20) one year before sampling date leading to erosion or deposition of some organic and mineral materials. No data about water table-level are available for this floodplain.

2.2. Earthworm sampling

Earthworms were collected using the standard mustard extraction [31] in three replicates of 1 m^2 with a corresponding depth of about 20 cm. The “hand sorting” method (20 × 20 × 20 cm) was done to guarantee that no earthworm remained in the soil. Earthworms were directly stored in formaldehyde 4% (v/v) and identified in the laboratory at the species level [32,33], and classified according to the three main ecological categories (epigeics, endogeics and anecics [34]). Dead fixed adults and sub-adults were individually counted and weighed without gut clearing, and unidentified juveniles were allocated to species by assuming that the species ratios for adults and for juveniles were identical.

2.3. Soil sampling and analyses

In each plot, the topsoil layer, corresponding to the organo-mineral horizon, was collected according to the horizon thickness and analysed in the laboratory. Organic carbon (calculated by deducting the carbonates from the total carbon), total nitrogen

Table 1
General characteristics of the studied subalpine floodplain. Channel pattern type (according to Petts and Amoros [45]); flow ($m^3\ s^{-1}$); temperature (°C) and precipitations (mm) calculated over a period of minimum 30 years (source: MétéoSuisse, FOMC, 2010, Adelboden meteorological station; http://www.meteosuisse.admin.ch/web/fr/services/portail_des_donnees.html); flood events equivalents to a return period of at least 20 years (Q20; source: FOEN 2010, Kander-Hondrich station; http://www.hydrodaten.admin.ch/f/2469.htm), vegetation type (according to Gallandat et al. [31]).

Site characteristics	Kander River (BE)
Location	46°28′01 N, 7°39′47 E
Surface area (ha)	161.6
Channel pattern type	Braided river
Annual mean flow ($m^3\ s^{-1}$)	2.1
Max flow ($m^3\ s^{-1}$) (year)	21 (2005)
Annual min flow ($m^3\ s^{-1}$)	0.02 (winter)
Annual mean temperature (1959–2009; T in °C)	$T = 5.4$
Annual max T (1959–2009; T in °C)	$T = 14$ (July)
Annual min T (1959–2009; T in °C)	$T = -2$ (January)
Mean annual precipitations (P in mm)	$P = 1180$
Flood events (Q20 and more) from 2000 to 2010	2005
Vegetation type (main species and/or vegetation associations)	*Alnus incana* forests (*Calamagrostio-Alnetum incanae*)

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