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Epigeal and Hypogeal Macroinvertebrate Diversity in Different Microhabitats of the Yusmarg Hill Resort (Kashmir, India)

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Abstract. Soil macroinvertebrate communities are important within the soil system and contribute to a wide variety of soil processes. A soil study was conducted to assess the composition and diversity of soil macroinvertebrates in Yusmarg hill resort of Kashmir valley at four sites characterised by different types of vegetation and interferences like grazing or fencing, during the months of May, June, November and December 2010. During the study, it was observed that different sites exhibited variations in diversity of both epigeal as well as hypogeal soil macroinvertebrates. For epigeal macroinvertebrates, highest diversity was recorded in forest edge (2.089) and inner forest (2.058) and relatively low diversity in grazed (1.61) and fenced areas (1.09). For hypogeal macroinvertebrates, diversity was recorded highest for inner forest site (2.216) than forest edge (1.9) and relatively lower in fenced (1.22) and grazed (1.21) sites. The physical disturbance in the form of grazing and fencing probably reduce the diversity of the soil macro fauna as is inferred from the present study.

Key words: soil macroinvertebrates, diversity, physical disturbance, Kashmir, India.

Introduction

Soil, a still, porous medium within which temperature and moisture conditions are highly buffered were among the first terrestrial environments to be colonized because they possess environmental conditions that are intermediate between aquatic and aerial media (LAVELLE & SPAIN, 2001). Soil organisms are an integral part of terrestrial ecosystems and soil biodiversity is comprised of the organisms that spend all or a portion of their life cycles within the soil or on its immediate surface (including surface litter and decaying logs). Soil communities are among the most species-rich compartments of terrestrial ecosystems (ANDERSON, 1975; USHER *et al.*, 1979; GILLER, 1996), which carry out a range of processes that are important for soil health and fertility and thus, there are functional connections between soil biodiversity, especially soil macroinvertebrates with crop production (SUGIYARTO, 2004). The easiest and most widely used system for classifying soil organisms is to group them by size into three main groups: macro, meso and micro-fauna (SWIFT *et al.*, 1979). Micro-fauna comprises of microorganisms and the very small invertebrates (small soil mites, for example). Microorganisms are the smallest of the soil animals ranging from 20 to 200 µm in length (< 0.1 mm in diameter). The mesofauna is the next largest group and the animals range in size from 200µm to 10mm in length (0.1–2mm in diameter). These include mainly micro arthropods, such as

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Pseudoscorpiones, Protura, Diplura, Acari, small Myriapoda and others. The macro fauna contains the largest soil invertebrates. A soil macro fauna taxon (group) is an invertebrate group found within terrestrial soil samples which has more than 90 percent of its specimens (individuals) in such samples visible to the naked eye (IBOY, 2000). The Soil macro fauna consists of a large number of different animals that live on the soil surface, in the soil pores and in the soil area near tree roots. These include organisms like earthworms, millipedes, centipedes, ants, coleoptera (adults and larvae), isopoda, spiders, slugs, snails, termites, dermaptera, lepidoptera larvae and diptera larvae. Their way of living, their feeding habits, their movements into the soil, their excretions and their death have direct and indirect impacts on their habitat. Soil macro fauna is involved in – degrading organic matter and mineralizing nutrients; controlling pathogen populations; improving and maintaining soil structure; mixing organic matter through the soil. These processes are regulated by a number of abiotic and biotic factors (LAVELLE *et al.*, 1993). These comprise (1) microclimate, mainly temperature and humidity (MEENTEMEYER, 1995), (2) litter quality (WOOD, 1995; ANANTHAKRISHNAN, 1996; AERTS, 1997; HEAL *et al.*, 1997; SARIYILDIZ & ANDERSON, 2003), (3) soil nutrient content (VERHOEVEN & TOTH, 1995), and (4) the qualitative and quantitative composition of decomposer communities, including bacteria, fungi and invertebrates (SWIFT *et al.*, 1979; KNOEPP *et al.*, 2000).

This paper is intended to study: (i) the epigeal and hypogeal macroinvertebrate diversity in different microhabitats of the Yusmarg hill resort (Kashmir, India), and (ii) its influence on the soil characteristics as a living entity.

Material and methods

Study area

The study was conducted at Yusmarg (Fig. 1), a cluster of meadows bounded by magnificent trees in the lap of Pir Panjal mountain range, which is approximately 47 km from the Srinagar and lies in the district Budgam of Kashmir valley (Indian O). The study sites selected had relatively different vegetation and anthropogenic impacts. Site-1 represented the fenced area with geographical coordinates of N33°50′0.665″, E74°40′1.653″, and an elevation of 2418±6m. The site, dominated by herbaceous vegetation, was fenced by 6 ft wire mesh and as such was free of grazing and other anthropogenic activities. Site-2 (N33°50′1.768″, E74°39′57.555″; Elevation 2411±6m) was also dominated by herbaceous vegetation but witnessed grazing and anthropogenic activities. The third site (N33°50′0.034″, E74°39′57.506″; Elevation 2446±6m) was located in between the grazing area and the forest, having vegetation of conifers (*Picea smithiana* Wall. Boiss, *Pinus wallichiana* A.B. Jacks, and *Abies pindrow* Royle ex.D.Don), with an understory of shrubs (chiefly *Viburnum* sp.) and herbaceous vegetation (as *Fragaria nubicola*, *Cynodon dactylon,* etc.). Few marks of human interference in the form of lopped burnt stumps and logged wood were visible at this site. Site-4 (N33°49′55.747″, E74°39′56.262″ E; Elevation 2451±6m) comprised the forested area, with a dense cover of conifers dominated by *Abies* sp., interspersed with *Picea smithiana* and *Pinus wallichiana* trees.

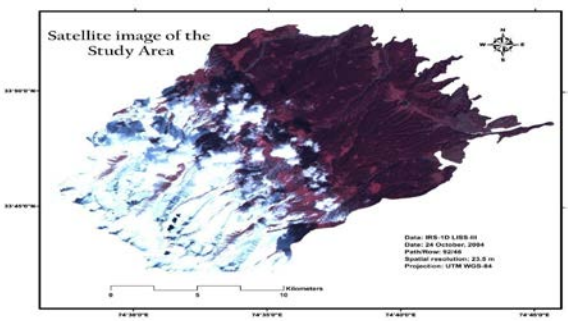

Fig. 1. Satellite image of the study area – Yusmarg.

Methods

The sampling methods used for the epigeal and hypogeal macroinvertebrates followed the recommended methods by the Tropical Biology and Soil Fertility Program (TSBF) (ANDERSON & INGRAM, 1993;

LAVELLE & PASHANASI, 1989) with fewer modifications. At each site, five samplings were performed for duration of 50 minutes on each sampling occasion. For sampling of epigeal macroinvertebrates, quadrat sizes of 25cmx25cm were used, with hand picking of the organisms using entomological forceps. Soil samples of the dimensions of 25cmx25cmx30cm were taken, after removing litter layer, for the collection of hypogeal macroinvertebrates. The soil sample obtained was then carefully hand-sorted on a large white cloth. The macroinvertebrates were collected, killed in a bottle containing cotton balls saturated with 40% formaldehyde at the bottom and a covering of filter paper above, and counted. The samples were preserved in 75% alcohol.

Due to the continuous unrest and prolonged curfew imposed by the Indian Security Forces stationed in Kashmir, the study could not be carried out during July to October 2010.

Data analysis

No single index encompasses all characteristics of an ideal index, i.e., high discriminate ability, low sensitivity to a sample size, and ease in calculation (MARGURAN, 1988). Therefore an observation of the different indices reflecting species evenness, dominance and diversity heterogeneity provide some valid viewpoints. Shannon's index of diversity (PRICE, 1997) reflects both evenness and richness (COLWELL & HUSTON, 1991) and is commonly used in diversity studies (KREBS, 1989). It is calculated as $H = -\Sigma P_i \ln P_i$; i =1–n; where n is the number of species and P_i is the proportion of the i^{th} species in the total. Index of dominance is calculated as $\Sigma(ni/N)^2$ where *ni* is the number of individuals of a species and *N* is the total number of individuals of all species. Evenness indicates the degree of homogeneity in abundance between species and is based on the Shannon index of diversity. Shannon evenness [$E = H/H_{max} = H/\ln S$; where H is the Shannon diversity index and S the number of species in the community] ranges from 0 to 1.

Results

Taxonomical diversity

Epigeal macroinvertebrate fauna of the study area was found to be comprising of 25 genera (2 classes), and was represented by six orders –Araneida (6 genera), Orthoptera (2 genera), Hemiptera (5 genera), Coleoptera (8 genera), Hymenoptera (3 genera) and Diptera (1 genera) (Table 1). Hypogeal macroinvertebrate fauna was found to be comprised of 15 genera (four classes), representing six orders – Opisthopora (1), Scorpionida (1), Araneida (2), Scolopendromorpha (3), Coleoptera (5), and Hymenoptera (3 genera) (Table 2).

The inner forest and the forest edge exhibited nearly similar species diversity of epigeal macroinvertebrates with forest edge showing slightly higher richness (Table 3). The grazing site showed comparatively lower species diversity compared to the forest and the transition zone. However, the species richness was found to be significantly lower at the fenced site. Accordingly, higher uniform dominance was found to be exercised by the less diverse species at the fenced site (Table 3). The dominance was scattered among the more diverse species at the forest edge followed by the forest, and thus exhibited less dominance. Similarly, the dominance was higher at the grazing site compared to the forest edge and the forest; however, it was lesser than that at the fenced site (Fig. 2).

In case of hypogeal macroinvertebrates, the inner forest site showed higher diversity than the forest edge, while it was lower at the grazing and the fenced site (Table 4). Similarly the dominance was found to be high among the taxa at the grazing site followed by the fenced site. However, the dominance was scattered among the more taxa at the forest edge, and still much higher scatter or low dominance was found at the inner forest site (Table 4, Fig. 3).

Table 1. Epigeal macroinvertebrate fauna encountered at the different sites of the study area.

Taxa	Month (Year 2010)				Average	Relative Abundance
	May	June	Nov.	Dec.		
Site-1						
Elymana sp.	4	8	5	21	9.50	20.28
Harpalus sp.	3	1	0	0	1.00	11.39
Araneus sp.	0	1	2	0	0.75	8.54
Pyrrhocorris sp.	2	0	0	0	0.50	17.08
Lycosa sp.	0	1	0	0	0.25	8.54
Pardosa sp.	1	0	0	0	0.25	8.54
Endomychus sp.	0	0	1	0	0.25	8.54
Geotrupes sp.	1	0	0	0	0.25	8.54
Phytodecta sp.	0	0	1	0	0.25	8.54
Total	11	11	9	21	13.00	100.00
Site-2						
Elymana sp.	2	18	2	5	6.75	1.41
Messor sp.	2	3	2	0	1.75	4.23
Araneus sp.	1	2	1	0	1.00	4.23
Harpalus sp.	3	1	0	0	1.00	5.63
Pyrrhocorris sp.	3	0	0	0	0.75	8.45
Amphimallus sp.	1	1	0	0	0.50	8.45
Satacid sp.	0	1	0	0	0.25	16.90
Xysticus sp.	0	1	0	0	0.25	16.90
Onthophagus sp.	0	1	0	0	0.25	16.90
Unidentified beetle	0	1	0	0	0.25	16.90
Total	12	29	5	5	12.75	100.00
Site-3						
Araneus sp.	1	0	1	1	0.75	8.00
Elymana sp.	0	2	0	1	0.75	12.00
Messor sp.	0	0	3	0	0.75	24.00
Pholcus sp.	0	0	1	1	0.50	8.00
Lasius sp.	0	2	0	0	0.50	16.00
Harpalus sp.	1	0	0	0	0.25	8.00
Magdalis sp.	0	0	0	1	0.25	8.00
Asilius sp.	0	0	0	1	0.25	8.00
Vespa vulgaris	0	0	1	0	0.25	8.00
Total	2	4	6	5	4.25	100.00
Site -4						
Messor sp.	0	0	4	1	1.25	14.71
Cicada sp.	0	3	0	0	0.75	17.65
Lasius sp.	0	0	3	0	0.75	17.65
Leva sp.	0	0	3	0	0.75	8.82
Eurydema oleraceum	0	2	0	0	0.50	11.76
Empicoris sp.	0	0	0	2	0.50	11.76
Araneus sp.	0	0	0	1	0.25	5.88
Pardosa sp.	1	0	0	0	0.25	5.88
Aulachobothrus sp.	0	0	0	1	0.25	5.88
Total	1	5	10	5	5.25	100.00

Table 2. Hypogeal macroinvertebrate fauna encountered at the different sites of the study area.

Taxa	Month				Average	Relative Abundance
	May	June	Nov.	Dec.		
Site-1 (Fenced area)						
Eutypheous sp.	3	2	0	0	1.25	25.00
June bug larva	1	1	0	0	0.5	25.00
Unidentified larva	0	0	1	1	0.5	25.00
Amphimallus sp.	1	0	0	0	0.25	25.00
Total	5	3	1	1	2.5	100.00
Site-2 (Grazing area)						
Messor sp.	23	1	0	2	6.5	53.28
Eutyphoeus sp.	3	5	0	0	2	9.84
June bug larva	2	1	0	0	0.75	6.15
Lasius sp.	2	0	0	0	0.5	12.30
Amphimallus sp.	1	0	0	0	0.25	6.15
Unidentified larva	0	0	1	0	0.25	6.15
Unidentified moth	0	0	0	1	0.25	6.15
Total	31	7	1	3	10.5	100.00
Site-3 (Forest edge)						
Lasius sp.	2	13	0	0	3.75	33.04
Eutyphoeus sp.	2	3	1	0	1.5	5.29
Scolopendra sp.	2	2	1	0	1.25	4.41
Messor sp.	0	0	5	0	1.25	22.03
Monomorium sp.	0	2	0	0	0.5	8.81
Scolopendra morsitans	0	1	0	0	0.25	4.41
Amphimallus sp.	1	0	0	0	0.25	4.41
Harpalus sp.	1	0	0	0	0.25	4.41
Lympyrus sp.	1	0	0	0	0.25	4.41
Vespa vulgaris	0	0	0	1	0.25	4.41
June bug larva	1	0	0	0	0.25	4.41
Total	10	21	7	1	9.75	100.00
Site -4 (Inner Forest)						
Messor sp.	0	0	2	10	3	20.76
Unidentified weevils	0	0	8	0	2	27.68
Scolopendra sp.	2	3	2	0	1.75	4.84
Lasius sp.	0	0	6	0	1.5	10.38
Eutyphoeus sp.	0	1	2	0	0.75	3.46
Scorpiops sp.	0	2	1	0	0.75	3.46
Scolopendra morsitans	3	0	0	0	0.75	5.19
Archaeolithobius sp.	0	0	0	2	0.5	6.92
Araneus sp.	1	0	0	0	0.25	3.46
Lycosa sp.	0	0	1	0	0.25	3.46
Lamycetes sp.	0	1	0	0	0.25	3.46
Lympyrus sp.	1	0	0	0	0.25	3.46
Elm bark beetle	0	0	0	1	0.25	3.46
Total	7	7	22	13	12.25	100.00

Table 3. Diversity, dominance and evenness of epigeal macro invertebrates at different study sites.

Selected Sites	Shannon Diversity Index	Simpson's Index	Shannon Evenness Index
Site-1 (Fenced area)	1.096	0.547	0.50
Site-2 (Grazing area)	1.61	0.318	0.70
Site-3 (Forest edge)	2.089	0.134	0.95
Site-4 (Inner forest)	2.058	0.143	0.94

Table 4. Diversity, dominance and evenness of hypogeal macro invertebrates at the four different study sites.

Selected Sites	Shannon Diversity Index	Simpson's Index	Shannon Evenness Index
Site-1 (Fenced area)	1.22	0.34	0.90
Site-2 (Grazing area)	1.21	0.43	0.52
Site-3 (Forest edge)	1.9	0.21	0.80
Site-4 (Inner forest)	2.21	0.14	0.90

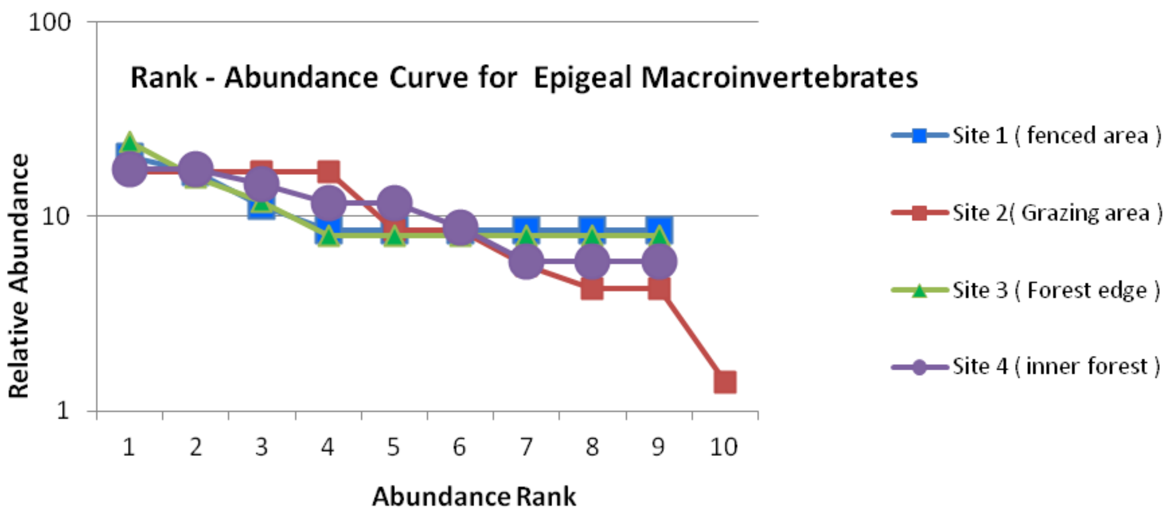

Fig. 2. Rank abundance curve for epigeal macroinvertebrates at the respective sites.

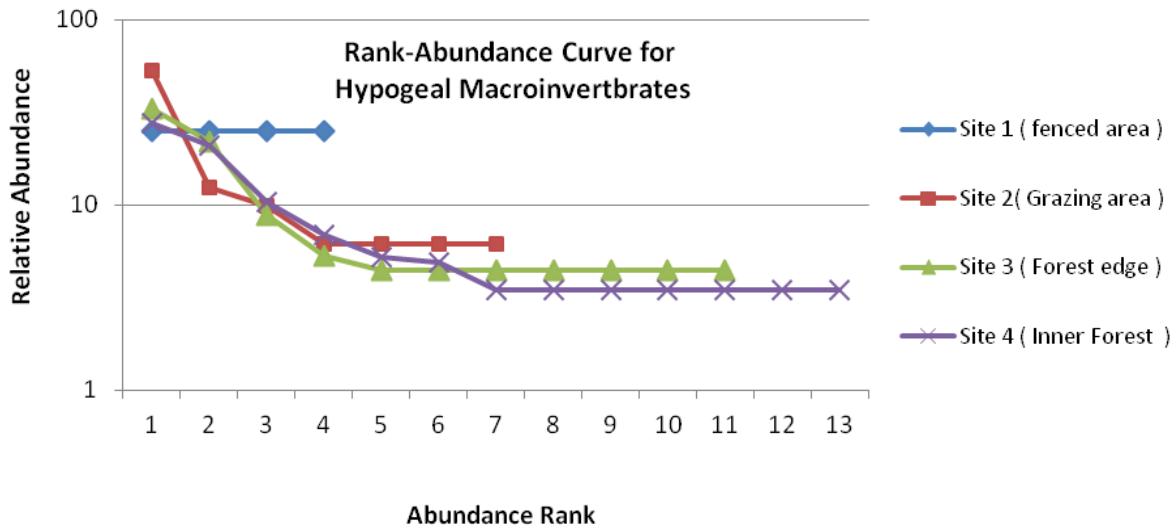

Fig. 3. Rank abundance curve for the hypogeal macroinvertebrates at the respective sites.

Discussion

The main groups of soil macrofauna in terms of their abundance and the importance of their activities in soil are earthworms, termites, ants, myriapoda, diptera and coleoptera (LAVELLE & SPAIN, 2001). The epigeal and hypogeal macroinvertebrate community of the study area was found to be more diverse in terms of genera belonging to order coleoptera (epigeal macroinvertebrates – 25 genera: Araneida {6}, Orthoptera {2}, Hemiptera {5}, Coleoptera {8}, Hymenoptera {3}, and Diptera {1}; hypogeal macroinvertebrates– 15 genera: Opisthopora {1}, Scorpionida {1}, Araneida {2}, Scolopendromorpha {3}, Coleoptera {5}, and Hymenoptera {3}). To better understand the comparatively higher diversity of beetles, several explanations have been forwarded by various workers. One of the important factors for explanation of the overall establishment of the Coleoptera order was proposed to be the development of the forewings into sclerotized elytra (LAWRENCE & BRITTON, 1994) which cover the membranous flight wings and the abdomen. In this way, the elytra are thought to protect beetles against environmental stresses and predation (HAMMOND, 1979). With more than 350,000 species and approximately 40% of all described insects, Coleoptera has a high diversity of food habits (LAWRENCE & BRITTON, 1991). The effect of photoperiod, temperature and relation to the quality and availability of host-plants or possibly the asymmetric competition (LINZMEIER & RIBEIRO-COSTA, 2008), seasonality (WERNER & RAFFA, 2003; RINTOUL *et al.*, 2005), niche partitioning on the basis of habitat, or other factors such as soil type, grassland topography or landuse practices (RINTOUL *et al.*, 2005) have been documented as the factors for the relatively higher diversity of the Coleoptera.Forest edge (Site-3) exhibited highest diversity of epigeal macro-invertebrates. The most common explanation for this trend is that there is a mixing of distinct fragment and matrix faunas at habitat edges, giving rise to a zone of overlap with greater overall species richness (INGHAM & SAMWAYS, 1996; MAGURA, 2002). The transition zones offer the habitat features which are representative of both the transient habitats and as such species of both the habitats are found in this zone to a varying degree and thus an overall greater diversity of species in this zone, the so called “edge effect”.

The Grazing area (Site-2) showed a relatively higher species richness of the epigeal macroinvertebrates compared to the fenced area (Site-1). The reason for this richness might be the return of the nutrients by the natural manuring of the grazing animals. Return of nutrients, defoliation and trampling appears to be the major components of grazing that could affect soil organisms. Return of nutrients in dung and urine can also influence the abundance and activity of decomposers (GRIFFITHS *et al.*, 1992). Defoliation of plants is known to affect soil organisms by changing the quality and quantity of carbon that enters the soil (PATERSON & SIM, 2000; SIROTNAK & HUNTLY, 2000; PATERSON *et al.*, 2003; HAMILTON *et al.*, 2008).

At Site-1 (fenced area), epigeal macroinvertebrates showed less diversity. This decline could be ascribed to habitat isolation as isolation disrupts species distribution patterns because species differ in their willingness to disperse through matrix environments (LAURANCE & YENSEN, 1991; COLLINGE, 2000), and forces dispersing individuals to traverse a matrix habitat that separates suitable habitat fragments from each other. An extreme example of this was highlighted by BHATTACHARYA *et al.* (2003), who found that two species of Bombus bumblebees would rarely cross roads or railways despite the presence of suitable habitat that was within easy flying range.

In case of hypogeal macroinvertebrates, Site-4 (inner forest) was showing relatively higher species richness, followed by forest edge site and grazing area. Soil and litter of forests generally contain highly diverse communities with a large number of organisms (DE RUITER *et al.*, 2002; SETALA, 2005; FITTER *et al.*, 2005) as higher habitat diversity, may in turn increase species diversity (LAVELLE & SPAIN, 2001). Since plant diversity has often been found to affect structural and biotic properties of ecosystems (e.g. GARTNER & CARDON, 2004; HOOPER *et al.*, 2005; SCHERER-LORENZEN *et al.*, 2005, UNSICKER *et al.*, 2006), it might also positively or negatively influence macroinvertebrate communities either directly or indirectly by modifying important habitat features for forest floor species (e.g. spatial and temporal changes in litter structure and microclimate). The high diversity of hypogeal macroinvertebrates at Site 4 (forest) compared to all other three sites, could possibly be attributed to the reason that hypogeal macroinvertebrates apparently avoid light and open space. SUGIYARTO *et al.* (2007) showed that most of soil macroinvertebrates tend to avoid risk of open space or high light intensity. Another possible reason could be the less compact soils and availability of comparatively more moisture and more decaying organic matter on the forest floor. Trampling seems to reduce the abundance and diversity of hypogeal macroinvertebrates. These negative effects have been ascribed to soil compaction and reduction of pore spaces (DREWRY *et al.*, 2001).

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