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Impact of Riparian Vegetation on The Structure and Function of Nayar River Ecosystem

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Abstract: Riparian vegetation plays a significant role in determining the structure and function of stream ecosystems. Mostly aquatic life, both invertebrates and fish are directly or indirectly dependent on inputs of terrestrial detritus to the stream for their food and microhabitat. Natural input of riparian vegetation and the biotic processing of detritus, as well as other factors, determine the kinds and abundance of aquatic invertebrates living in streams, from headwaters to large rivers. Removal of riparian vegetation will significantly affect stream organisms by decreasing detritus (food) inputs and increasing the potential for primary production. It will also cause an increase in summer water temperature and consequently there will be a Change in water quality. Also there will be a decrease in terrestrial habitat for the use of adult insects.

Keywords: Riparian vegetation • Detritus • Microhabitat • Zoobenthoss.

Introduction

The manner in which riparian systems are managed and protected is commonly related to their value as buffer strips, stream bank stabilizers, and fish and wildlife habitat. These strips of streamside vegetation may be the only habitat remaining for some wildlife species. As riparian vegetation is modified or destroyed by grazing, logging, urbanization, road construction, water development, mining, and recreation, interest in its importance is increasing. Our objective is to briefly review the role of riparian vegetation in the structure and function of stream ecosystems, especially headwater streams of Nayar valley. We also explore the possible effects of vegetation modification or destruction in headwater streams.

Headwater Streams: Headwater streams are greatly influenced by riparian vegetation since they function as processors of natural organic matter coming from the watershed (Cummins and Spengler 1978). These small streams are characteristically shaded and kept cool by overhanging riparian vegetation, which also contributes dead organic matter (detritus) to the stream. Shading not only affects water quality but influences the activities of primary producers such as algae and aquatic macrophytes. Riparian vegetation supplies organic matter in the form of dead leaves, needles, twigs, branches, logs, bud scales, fruit, droppings of terrestrial animals, and dissolved organic matter (DOM). The direct input of organic matter from riparian vegetation is substantial: annual values range from about 100 g m^{-2} to more than 1,000 g m^{-2} (Bray and Gorham 1964; Anderson and Sedell 1979), and values for standing crops can be much higher (Naiman and Sedell 1979). The addition of this organic matter is fundamentally vital to the stream biota since this is often its primary energy source, which is supplemented by lesser amounts of autochthonous production (Hynes 1963; Cummins 1974). Dead organic matter may contribute as much as 99% of the annual energy input to headwater streams covered by a dense forest canopy (Fisher and Likens 1973). Particulate detritus accounted for half of the annual energy input to western Nayar. These streams are termed "heterotrophic" because in effect they consume organic matter produced by adjacent terrestrial systems.

Although allochthonous detritus input to streams continues throughout the year, seasonal pulses do occur. Detritus is added in autumn from deciduous leaf-fall and plant die-off. In winter and spring it is washed in by water runoff (Minshall 1968; Fisher and Likens 1973; Hobbies and Likens 1973). Tree branches broken by wind and snow may drop into streams in winter. Rainstorms periodically wash in dissolved organic matter exuded from plants or collected on leaves from arboreal animals, while groundwater continuously brings in dissolved organic matter. Although the heterotrophic nature of headwater streams enclosed in forests has been well emphasized by recent research (Fisher and Likens 1973; Cummins 1974), headwater streams in unforested or sparsely-forested regions can be autotrophic, receiving most of their energy from the primary production of aquatic macrophytes and algae (Minshall 1978). Autotrophy has been documented in desert streams lacking riparian vegetation and shading (Minshall 1978; Busch and Fisher 1981) and has been suggested for high-altitude streams (Cummins and Klug 1979), especially in western mountain regions (Wiggins and Mackay 1978). Headwater streams within forests can also change seasonally from heterotrophy to autotrophy, depending upon natural variations in light intensity, nutrients, hydrologic factors, role of riparian vegetation for detritus input (Sagir and Dobriyal, 2017, 2018) and detritus input (Naiman and Sedell 1980).

Table 1 list of Riparian vegetation along the Nayar stream

S.No.	Botanical Name	Family	Common Name
1	*Euphorbia royleana*	Euphorbeaceae	Sulla
2	*Sapium insigne*	Euphorbeaceae	Khinna
3	*Ficus religosa*	Moraceae	Peepal
4	*Lantana camara*	Verbenaceae	Big sage
5	*Salix*	Salicaceae	Manjar
6	*Olea glandulifera*	Oleaceae	Native olive
7	*Pinus rouxburghii*	Pinaceae	Chir
8	*Murraya koenigii*	Rutaceaea	Curry tree
9	*Acacia catechu*	Mimosaceae	Black cutch
10	*Carissa opaca*	Apocynaceae	Cudd
11	*Corchorus aestuans*	Tiliaceae	Chonch
12	*Berberis lyceum*	Berberidacea	Kingoorh
13	*Gnaphalium hypoleucum*	Asteraceae	Cudweed
14	*Cyanotis cristata*	Commelinaceae	Nabhali
15	*Jatropha curcas*	Euphorbiaceae	purging nut
16	*Solanum nigrum*	Solanaceae	Black nightshade
17	*Quercus leucotrichophora*	Fegeceae	Oak
18	*Cannabis Sativa*	Cannabaceae	Bhang
19	*Galium asparifolium*	Rubiaceae	Goosegrass
20	*Dalbergia sissoo*	Fabaceae	Biradi

21	*Phyllanthus urinaria*	Euphorbiaceae	Sulla hajarmani
22	*Oenothera rosea*	Onagraceae	Rose evening primrose
23	*Galium elegans*	Rubiaceae	Elegant goosegrass
24	*Oxalis corniculata*	Oxalidaceae	Amrul
25	*Lappacea Pupalia*	Amaranthaceae	Nagadaminee
26	*Parthenium hysterophorus*	Asteraceae	Gajar ghas
27	*Circium verutum*	Asterceae	Kandaya
28	*Geranium ocellatum*	Geraniaceae	Kaphlya
29	*Bidens pilosa*	Asteraceae	Kumur
30	*Ipomoea batatas*	Convolvulaceae	Shakarkand
31	*Rubus ellipticus*	Rosaceae	Hinssar
32	*Ricinus communis*	Euphorbiaceae	Arand
33	*Cyperus rotundus*	Cyperaceae	Motha
34	*Sonchus oleraceus*	Asteraceae	Dudiya
35	*Geranium nepalense*	Geraniaceae	Phori
36	*Woodfordia fruticosa*	Thymelaeaceae	Dhaula
37	*Trifolium ripens*	Fabaceae	Satphal
38	*Eupatorium adenophorum*	Asteraceae	Kharna
39	*Opuntia vulgaris*	Cactaceae	Cactus
40	*Lucas indica*	Lamiaceae	Guma
41	*Grewia optiva*	Tiliaceae	Bhimal
42	*Cassia fistula*	Caesalpiniaceae	Kirala
43	*Cupressus torulosa*	Cupressaceae	Surai
44	*Giardenina diversifolia*	Urticaceae	Bhainsya khandali
45	*Dutura stromonium*	Solanaceae	Kank
46	*Solanum incanum*	Solanaceae	Banbhatuja
47	*Galinsoga parviflora*	Asteraceae	Marchya
48	*Artemisia nilagirica*	Asteraceae	Kunjaa
49	*Anaphalis busua*	Asteraceae	Bugla
50	*Ziziphus mauritiana*	Rhamnaceae	Ber
51	*Malvastrum coromandelianum*	Malvaceae	Suchi
52	*Cassia tora*	Caesalpiniaceae	Chakunda
53	*Arthraxon prionodes*	Poaceae	Glum
54	*Achyrenthus aspera*	Amaranthaceae	Latjiri
55	*Conyza aegyptiaca*	Asteraceae	Mant

Data are currently lacking to classify western Nayar valley headwater streams as either heterotrophic or autotrophic. The vegetation, climate, and geology of western Nayar Mountain vary substantially from location to location. Thus headwater streams may vary widely in their heterotrophy/autotrophy balance. The extensive forests and a dense growth of shrubs and trees, on the western slope of the Nayar valley river do suggest that detritus from riparian vegetation is very important to stream energetic. We encountered fifty five plant species in the valley belonging to thirty three families (Table 1)

Organic Matter Processing: The importance of organic matter contributions from riparian vegetation to stream ecosystems has been fully appreciated for about 10 years (Cummins 1974). The manner in which aquatic organisms utilize and process organic matter at different seasons and locations along streams is a current research topic (Cummins 1973, 1975; Cummins and Klug 1979; Anderson and Sedell 1979; Hawkins and Sedell 1981). We briefly summarize here the role of aquatic organisms in continually processing and transforming organic matter from the time it enters the stream. Coarse particulate organic matter (CPOM: > 1 mm. diameter), such as leaves, starts leaching DOM once it enters the water. Up to 30% of dry weight may be leached in the first day; deciduous leaves leach faster than coniferous needles (Cummins 1974; Hynes et al. 1974). Fungi and bacteria rapidly colonize the leaves undergoing leaching. Although most of these microbes can metabolize cellulose, only some can use lignin (Cummins and Spengler 1978). Certain aquatic insects such as some stonefly nymphs, cranefly larvae, and caddisfly larvae shred or break down leaves (CPOM) during feeding and are called "shredders" (Cummins 1973). The microorganisms that colonize the leaves are an essential source of shredder nutrition.

Shredder and microorganism feeding eventually break down CPOM into fine particulate organic matter (FPOM: < 1 mm. diameter). However, this process is only one source of FPOM which may result from: 1- shredder and microorganism feeding on CPOM; 2- physical abrasion of CPOM by stream turbulence; 3- fine particles eroded from streambed algae; 4- excellent material washed or blown in from the surrounding watershed, and 5- conversion from DOM by chemical and microbial activity (Cummins 1974). Dissolved organic matter leached from CPOM, plus DOM entering from the watershed, aquatic plants, and microbial excretions, can be partially converted into FPOM. This conversion is accomplished by physical flocculation and microbial assimilation processes dependent on water turbulence, temperature, pH, and various ionic concentrations (Lush and Hynes 1973). FPOM is the food for aquatic organisms known as "collectors". These animals obtain FPOM either by gathering it from stream substrate deposits or by filtering it from the flowing water. Deposit feeders include certain larvae and mayfly nymphs. Filter feeders have diverse ways of capturing FPOM from the passing water (Wallace and Merritt 1980). Blackfly larvae possess fan-shaped structures on their heads for filtering FPOM and transferring it to their mouths. Some caddisfly larvae construct detailed silk nets capable of sieving out FPOM. The net is often held between small twigs or stones exposed to the current, and the larva hides in a tube just behind. The collected FPOM contains bacteria on its surfaces, which increases the quality of the food for the collector. Particle size is significant to collectors since their mouthparts and sieving devices have specific shapes and openings for obtaining and handling FPOM.

A thin film of algae covers most stream substrates and contributes to in-stream primary production, especially when light intensity and nutrient concentrations are high. Microscopic diatoms are often the most abundant algal group, but larger filamentous green and blue-green algae are also familiar. Aquatic organisms are known as "scrapers" have well-adapted mouthparts for scraping up and consuming this algal film, which also includes some FPOM and microscopic animals. Scrapers in Nayar streams include many mayfly nymphs, water penny beetles, riffle beetles, and some midge larvae.

Some aquatic invertebrates and vertebrates prey on shredders, collectors, scrapers, and each other; they are known as "predators". Predators in Nayar streams include many stonefly nymphs, dragonfly nymphs, some midge larvae, alderfly larvae, and dobsonfly larvae. Most aquatic insects in streams, even those that are predatory, are potential prey for many carni-omnivore fishes..

The amount, kind, and timing of riparian vegetation additions to the stream and the shading provided by streamside plants will determine which feeding groups (shredders, collectors, scrapers, predators) prosper at any site. Thus, the population abundance of stream animals and community composition of the stream ecosystem are dependent on riparian vegetation.

The River Continuum Concept: The structure and function of aquatic communities along a river system have recently been organized into the River Continuum Concept (Cummins 1975; Vannote et al 1980). This concept involves several stream factors—temperature, substrate, water velocity, stream morphology, and energy inputs from allochthonous and autochthonous sources—which interact to influence the availability of food for stream animals. These factors should vary in a predictable fashion from headwaters to downstream locations and should produce predictable distributions of the four feeding groups along the continuum. Since headwater streams (orders 1-3) are often heavily shaded and receive large amounts of organic matter from riparian vegetation, these streams are heterotrophic. Their ratio of gross photosynthesis (P) to respiration (R) will be less than one. Coarse substrates predominate since stream gradients and erosive powers are high. Shredders reach maximum abundance in these upper stream sections because of the abundant CPOM. FPOM and DOM are used and exported downstream. Because western Nayar stream originate within coniferous forests, they may differ from typical headwater streams originating within deciduous forests of the other Himalayan headwater streams in detrital input and lighting conditions.

Organic matter input and shading are less critical in medium-sized rivers because of the greater widths and more open canopy. Increased primary production shifts these streams from heterotrophy into autotrophy, and a P: R ratio higher than one. Increased algal production allows scrapers to be abundant. Collectors are also familiar, and a few shredders are still present. FPOM and DOM are again used and exported downstream. Riparian vegetation has little direct influence on large rivers since the wide channels are open to sunlight, and the input of terrestrial detritus relative to water volume is small. However, FPOM from upstream sources is very important, and for this reason, collectors are the predominant aquatic organisms of large rivers. Although these rivers are open to sunlight, increased turbidity restricts both light penetration and primary production by algae on the excellent river substrates. Instead, phytoplankton may be critical primary producers in the upper water layers, although turbidity may restrict the depth of their production. Therefore, large rivers are thought to be heterotrophic and have a P: R ratio less than one. Shredders and scrapers are essentially absent because their food resource and coarse substrate are lacking.

Streams on the western slope of Nayar valley typically pass through several plant communities—subalpine forests (conifers), mixed conifer forests, oak woodlands, and grasslands—each of which contributes different organic matter inputs and shading effects. Also, alpine, mountain meadows, may be locally significant. It is not known if all aspects of the river continuum concept apply to Nayar streams. It is possible to summarize predictions of the river continuum concept (Vannote et al .1980), especially as they are thought to be true for many streams in forested regions. Exceptions are known to occur for desert streams (Minshall 1978), and possibly for western montane streams (Wiggins and Mackay 1978). Some of these predictions have recently been tested in four Oregon streams and shown to support the river continuum concept (Naiman and Sedell 1980; Hawkins and Sedell 1981). Width, depth, and discharge increase as stream order increases. Substrate size changes from coarse to fine going from headwaters to large rivers. CPOM and riparian vegetation shading decrease in importance downstream, and FPOM increases in importance. This causes the CPOM: FPOM ratio to decrease as stream order increases. The particle size of detritus decreases downstream. DOM diversity decreases downstream as labile components are used by microorganisms, causing refractory components to accumulate.

P: R ratio < 1 for stream orders 1–3—heterotropic condition.

P: R ratio > 1 for stream orders 4–6—autotrophic condition.

P:R ratio < 1 for stream orders > 6—heterotrophic condition.

Shredders decrease downstream as CPOM becomes less abundant. Collectors increase downstream as FPOM becomes more critical.

Scrapers increase to a maximum abundance in medium-sized rivers (orders 4–6) as the canopy opens and admits light to the substrate, but then decrease in larger rivers (orders > 6) because of turbid water shades algae on the stream substrate. Predators maintain approximately constant abundance along the continuum. Biotic diversity is low in the headwaters, increases to a maximum in medium stream orders (3–5), and decreases in larger rivers.

Effects of Riparian Vegetation Removal: Effects of riparian vegetation removal on stream invertebrates of disruptions to five of these inputs will be discussed: 1) decrease of detrital inputs; 2) loss of shade as it affects primary production; 3) loss of shade as it affects stream temperature; 4) water quality and quantity alterations, and 5) loss of terrestrial habitat. The intensity of these effects is related to the degree of modification of the vegetation.

The decrease of Detrital Inputs: Riparian vegetation often supplies large amounts of organic matter (energy) to the stream, forming a dependable food base for stream invertebrates year after year. Many of these animals have complex structures, behaviors, and life cycle events which are specially adapted for using different kinds and sizes of detritus as food. The decrease of detritus will cause decreased populations of these species, although in-stream production may still maintain some at lower densities.

Loss of Shade Effect on Primary Production: Riparian vegetation is a significant control on light intensities reaching algae and macrophytes in headwater streams, and therefore on the level of primary production that can occur. Shade removal has been demonstrated to increase primary production and cause algal mats in small streams, both in the field (Brown and Krygier 1970; Likens et al. 1970; Granoth 1979) and the laboratory (Brocksen et al . 1968). For example, vegetation removal along a small stream in Kansas changed it from heterotrophy to autotrophy (Gelroth and Marzolf 1978). Also, in laboratory streams exposed to two different light levels, the stream receiving twice as much light had twice the gross plant production (Brocksen et al . 1968). If nutrients or other factors are not limiting, increased illumination due to shade removal will increase primary production and the food resources used by scrapers.

Loss of Shade Effect on Stream Temperature: Shade from riparian vegetation moderates streams temperatures, often preventing excessive summer temperatures that may be lethal to stream biota. Field studies have demonstrated significant increase in summer water temperatures and decrease in winter temperatures when the shade is removed from small streams.

Relationships between riparian vegetation and stream components: Studies on clear-cut watersheds show that when riparian buffer strips are used, stream temperatures remain mostly the same as in undisturbed watersheds (Brown and Krygier 1970; Swift and Messer 1971; Graynoth 1979), and stream macro-invertebrate diversities remain high (Erman et al . 1977). Water temperature affects numerous essential stream functions, such as processing rates of organic matter, chemical reactions and concentrations, metabolic rates of stream invertebrates, and cues for lifecycle events. Because of these complex interactions, it is challenging to assess the ultimate effects of shade removal and water temperature changes on stream animals. Stream invertebrates have different tolerances for water temperature variations, but most species in headwater streams are narrowly adapted for cold temperatures and may use dormant strategies to survive natural warm periods (Hynes 1970).

Water Quality and Quantity Alterations: Riparian vegetation affects water quality not only by moderating water temperature and influencing chemical reactions but also by contributing DOM and nutrients to the stream. Riparian vegetation also protects stream banks from excessive erosion, minimizing the input of fine sediments which can fill the numerous cracks, crevices, narrow channels, and openings that ramify through the upper substrate layers that form the invertebrate habitat of standard headwater streams. Removal of riparian vegetation may increase the annual amount of stream runoff, increase peak discharges after rainstorms, and change the timing of peak flows. Change in runoff quantity will cause the stream channel to readjust its velocity patterns, channel dimensions, the frequency of pools and riffles, and substrate composition, all of which are important for the amount and quality of invertebrate habitat. Since invertebrate species vary in their habitat requirements, some species may be benefitted while others are harmed. Nonetheless, disturbances that add fine sediment to streams decrease the species diversity.

Loss of Terrestrial Habitat: Most aquatic insects, including those in Nayar streams, emerge into terrestrial ecosystems as adults with wings for dispersing and searching for mates. Riparian vegetation is a critical habitat used by these adult insects for feeding, resting, and hiding. Some insect adults lay eggs on riparian vegetation overhanging the stream so that upon hatching the young larvae will drop back into the stream for the aquatic life stages. The flies use this method of egg lying in Nayar streams. Stoneflies signal and find mates by drumming with their abdomens on stream side vegetation.

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References

Anderson, N.H., Sedell, J.R., (1979). Detritus processing by macroinvertebrates in stream ecosystems. *Ann. Rev. Entomol.* 24:351–377.

Aubertin, G.M., Patric, J.H., (1974). Water quality after clearcutting a small watershed in Western Virginia. *J. Environ. Qual*. 3:243–249.

Bray, J.R., Gorham, E., (1964). Litter production in forests of the world. p. 101–157. *In: J.B. Cragg (ed.). Advances in ecological research*, Vol. 2. 264 p. Academic Press, New York, N.Y.

Brocksen, R.W., Davis, G.E., Warren, C.E., (1968). Competition, food consumption, and production of sculpins and trout in laboratory stream communities. *J. Wildl. Mgmt*. 32:51–75.

Brown, G.W., Krygier J.T., (1970). Effects of clear-cutting on stream temperature. *Water Resources Res.* 6:1133–1139.

Busch, D.E., Fisher, S.G., (1981). Metabolism of a desert stream. *Freshwat. Biol.* 11:301–307.

Cummins, K.W., (1973). Trophic relations of aquatic insects. *Ann Rev. Entomol.* 18:183–206.

Cummins, K.W., (1974). Structure and function of stream ecosystems. *Biosci.* 24:631–641.

Cummins, K.W., (1975). The ecology of running waters: theory and practice. p. 277–293. *In: Proceedings of Sandusky River Basin Symposium. Int. Joint Commission of the Great Lakes. Heidelberg College, Tiffin Ohio.*

Cummins, K.W., Spengler, G.L., (1978). Stream Ecosystems. Water Spectrum 10:1–9.

Cummins, K.W., Klug, M.J., (1979). Feeding ecology of stream invertebrates. Ann. Rev. Ecol. Syst. 10:147–172.

Erman, D.C., Newbold, J.D., Roby, K.B., (1977). Evaluation of streamside buffer strips for protection aquatic organisms. Water Resources Center Contract No. 165. 48 p. University of California, Davis.

Fisher, S.G., Likens, G.E., (1973). Energy flow in Bear Brook, New Hampshire: an integrative approach to stream ecosystem metabolism. *Ecol. Monog.* 43:421–439.

Gelroth, J.V., Marzolf, G.R., (1978). Primary production and leaf-litter decomposition in natural and channelized portions of a Kansas stream. *Am. Midl. Nat.* 99:238–243.

Graynoth, E., (1979). Effects of logging on stream environments and faunas in Nelson. *New Zealand J. Mar. Freshwat. Res*. 13:79–109.

Greene, G.E., (1950). Land use and trout streams. *J. Soil Wat. Cons.* 5:125–126.

Hawkins, C.P., Sedell, J.R., (1981). Longitudinal and seasonal changes in the functional organization of macroinvertebrate communities in four Oregon streams. Ecology 62:387–397.

Hobbie, J.E., and G.E. Likens. 1973. The output of phosphorus, dissolved organic carbon, and fine particulate carbon from Hubbard Brook watersheds. *Limnol. Oceanogr*. 18:734–742.

Hynes, H.B.N., (1963). Imported organic matter and secondary productivity in streams.

Knight, A.W., Bottorff, R.L., (1984). The importance of riparian vegetation to stream ecosystems. California riparian systems:

ecology, conservation, and productive management. University of California Press, Berkeley, CA, USA, 160-167.

Likens, G.E., Bormann, F.H., Johnson, N.M., Fisher, D.W., Pierce, R.S., (1970). Effects of forest cutting and herbicide treatment on nutrient budgets in the Hubbard Brook watershed-ecosystem. *Ecological monographs*, *40*(1), 23-47.

Lush, D.L., Hynes, H.B.N., (1973). The formation of particles in freshwater leachates of dead leaves 1. *Limnol. Oceano. 18*(6), 968-977.

Minshall, G.W., (1978). Autotrophy in stream ecosystems. *BioSci. 28*(12), 767-771.

Naiman, R.J., Sedell, J.R., (1979). Characterization of particulate organic matter transported by some Cascade Mountain streams. *J. Fis. Board Canada*, *36*(1), 17-31.

Naiman, R.J., Sedell, J.R., (1980). Relationships between metabolic parameters and stream order in Oregon. *Canadian J. Fis. Aqu. Sci. 37*(5), 834-847

Sagir, M., Dobriyal, A.K., (2017). Diversity of riparian vegetation in Western Nayar valley on selected experimental spots. *J. Mountain Res.12*: 115-118.

Sagir, M. Dobriyal, A.K., (2018). Influence of riparian vegetation on detritus standing stock of western Nayar valley Uttarakhand. *Int. Res. Anal. Rev.* 5(04) 1051-1064.

Swift Jr, L.W., Messer, J.B., (1971). Forest cuttings raise temperatures of small streams in the southern Appalachians. *J. Soil Wat Cons*., 26(3), 111-116.

Vannote, R.L., Minshall, G.W., Cummins, K.W., Sedell, J.R., Cushing, C.E., (1980). The river continuum concept. *Canadian J. Fis. Aqu. Sci*. 37(1), 130-137.

Wallace, J.B., Merritt, R.W., (1980). Filter-feeding ecology of aquatic insects. *Ann. Rev. Ento.* 25(1), 103-132.

Wiggins, G.B., Mackay, R.J., (1978). Some relationships between systematics and trophic ecology in nearctic aquatic insects, with special reference to Trichoptera. *Ecology*, 59(6), 1211-1220.

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