

## Review

# Macroinvertebrates in streams: A review of some ecological factors

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**Macroinvertebrates are an important component of stream ecosystems and are a link in the transfer of material and energy from producers to top level consumers and also act as excellent bioindicators of stream health. This review discusses some of the factors which regulate the occurrence and distribution of stream macroinvertebrates namely water current, temperature, substrate, drainage basin land use/land cover, vegetation, pH of water, drought, flood, food, shade and stream geomorphology.**

**Key words:** Macroinvertebrates, bioindicator, current speed, substratum, temperature, vegetation, flood.

## INTRODUCTION

Macroinvertebrates are a diverse array of animals without backbones operationally defined as those that are retained by a sieve or mesh with pore size of 0.2 to 0.5 mm, as used most frequently in stream sampling devices. Stream macroinvertebrates include various groups of worms (flatworms, eelworms and segmented roundworms), molluscs (snails and bivalves), crustaceans (shrimps, crayfish and other shrimp-like groups), mites, and above all insects (Winterbourn, 1999).

Most invertebrates are important components of stream ecosystems. They graze periphyton (and may prevent blooms in some areas), assist in the breakdown of organic matter and cycling of nutrients and, in turn, may become food for predators (e.g., fish) (Hynes, 1970; Jimoh et al., 2011; Uwem et al., 2011). Macroinvertebrates are the organisms most commonly used for biological monitoring of freshwater ecosystems worldwide. This is because they are found in most habitats, have generally limited mobility, are quite easy to collect by way of well established sampling techniques, and there is a diversity of forms that ensures a wide range of sensitivities to changes in both water quality (of

virtually any nature) and habitats (Hellawell, 1986; Abel, 1989).

The invertebrates, which live on, in, or near the substratum of running water, include representatives of almost every taxonomical group that occurs in freshwater. There are indeed remarkably few freshwater groups which are not regularly represented in rivers. In contrast, there are several groups which occur only in running water, and many which reach their maximum development and diversity there. This is undoubted by the permanence of streams as compared with lakes and ponds. Many river systems have been in continuous existence from far back into the geological time, whereas lakes persist for relatively short periods and give little opportunity for the development of purely lacustrine fauna. Although rivers may change and evolve, they rarely disappear, so they are not evolutionary traps (Hynes, 1970). One of the most striking features of the faunas of stony streams is their remarkable similarity all over the world. This uniformity is much less evolved in the faunas of the softer substrata in the larger rivers (Hynes, 1970; Allan, 1995).

Many factors regulate the occurrence and detailed distribution of stream dwelling invertebrates. The most important of these are current speed (Hynes, 1970; Grubaugh et al., 1996; Younes-Baraille et al., 2005; Donohue et al., 2006; Hussain, 2011), temperature

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(Hynes, 1970; Bass, 1995; Castella et al., 2001; Li et al., 2001; Sullivan et al., 2004), including the effects of altitude and season (Hynes, 1970; Dutta and Malhotra, 1986; Engblom and Lingdell, 1999; Ometo et al., 2000; Miserendino and Pizzolon, 2003; Waite et al., 2004; Sporka et al., 2006; Joshi et al., 2007), the substratum (Hynes, 1970; Tumwesigye et al., 2000; Munoz, 2003; Yousuf et al., 2006; Silveira et al., 2006; Pandit et al., 2007; LeCraw and Mackreth, 2010), vegetation (Hynes, 1970; Subramanian and Sivaramakrishnan, 2005), and dissolved substances (Hynes, 1970; Lods-Crozet et al., 2001; Azrina et al., 2006; LeCraw and Mackreth, 2010; Hussain, 2011). Other important factors are liability to drought and floods (Negishi et al., 2002), food (Hynes, 1970), competition between species (Bass, 1995), shade (Hynes, 1970), and of course, zoogeography (Hynes, 1970).

## FACTORS REGULATING STREAM MACROINVERTEBRATES

### Water current

Current is the most significant characteristic of running water, and it is in their adaptation to constantly flowing water that many stream animals differ from their still water relatives. Steinmann (1907, 1908) in his studies of the animals of mountain streams was the first to codify a number of anatomical characteristics (dorsoventrally flattened body shape, adhesive organs, or specialized claw) which he considered to be adaptations to life in rapid waters. Many workers have found that within even fairly uniform groups of animals, e.g., *Simulium* (Hynes, 1970); different species have different current preferences (Wesenberg-Lund 1943; Hynes, 1970). Flow variability and predictability have been hypothesized to be major components of the habitat templet for lotic macroinvertebrate communities by dictating the kinds, numbers, and life history strategies of organisms present (Minshall, 1985). Consequently, patterns of colonization differ among streams that differ in flow regime because of inherent differences in benthic community structure (Poff and Ward, 1989).

### Temperature

Temperature being one of the most important ecological factors is intimately related to latitude, altitude, season, and in spring fed or lake fed streams to the distance from the source. The benthic macroinvertebrates have evolved to live within a specific temperature range, which limits their distribution and affects the community structure (Hynes, 1960; Biggs et al., 1990). Temperature affects their emergence patterns, growth rates (Sweeney and Schnack, 1977), metabolism (Angelier, 2003),

reproduction (Vannote and Sweeney, 1980), and body size (Sweeney and Schnack, 1977). Species vary in their tolerance to temperature ranges, but few are able to tolerate temperatures beyond their upper tolerance limit (Coutant, 1962; Angelier, 2003).

### Substrate

Bed material characteristics are an important aspect of physical habitat in riverine ecosystems. For example, bed sediments are the primary component of the substrate upon which benthic macroinvertebrates move, rest, shelter, and feed; through their role in defining channel slope and roughness, bed sediments affect the hydraulic stresses that benthic fauna utilize and must tolerate. The effects of mineral substrate on macroinvertebrate communities are therefore profound (Cummins and Lauff, 1969; Minshall, 1984).

Spatial variations in bed material character (size, shape, and sorting) have been seen to produce macroinvertebrate responses in different ways. The grain characteristics determine the inertial, hiding, and, to some extent, structural properties (packing, pivot angles, arrangement) that control particle entrainment and define substrate stability (Buffington and Montgomery, 1997; Downes et al., 1997). Relatively coarse and strongly structured, stable substrates are attractive to benthic fauna because they represent sites of minimal disturbance during floods and help to define refugia from where recolonization can occur following floods (Lancaster and Hildrew, 1993; Rempel et al., 1999). Substrate stability is therefore associated with community persistence (Death and Winterbourn, 1994) and high levels of species diversity and abundance (Hynes, 1970; Scarsbrook and Townsend, 1993; Death and Winterbourn, 1995). Unstable areas tend to host assemblages that have particular morphological and behavioral traits, while stable patches exhibit more variable communities (Hynes, 1970; Death, 1995; Townsend et al., 1997). Second, grain roughness defines the near-bed hydraulic conditions (turbulence intensity, shear stress and flow separation) that are important to organisms living on and around bed particles, affecting their ability to maintain position, move, and feed effectively (Statzner et al., 1988). In turn, strong associations between substrate characteristics, microhydraulic characteristics, and the abundance, diversity, and species traits of benthic fauna have been widely reported (Hynes, 1970; Orth and Maughan, 1983; Wetmore et al., 1990; Quinn and Hickey, 1994; Allan, 1995; Bouckaert and Davis, 1998; Rempel et al., 2000; Tumwesigye et al., 2000; Munoz, 2003; Yousuf et al., 2006; Silveira et al., 2006; Pandit et al., 2007; LeCraw and Mackreth, 2010; Hussain, 2011). The result of all the factors associated with differences in substrate type is that, in general, the

fauna of clean stony runs is richer than that of silty reaches and pools both in number of species and in total biomass (Hynes, 1970). The type of substratum controls the types of invertebrates which occur there, and that the effect is numerical as well as specific. This has been confirmed statistically by Gaufin et al. (1956), who showed that even where a common organism occurs on various substrata, it tends to cluster in particular micro-habitats. Many studies have shown that in the same stream, the numbers and weights per unit area vary with the type of substratum. For example, Pennak and Van Gerpen (1947) found that for a mountain stream in Colorado, the average numbers (and wet weight in grams) per square meter in summertime were: on rubble, 610 (2.5); on bedrock, 551 (1.7); on coarse gravel, 575 (1.3); and on coarse sand, 202 (0.6). Generally, it has been seen that sand is the poorest habitat. It is also clear that islands of solid material, such as rock or rubble, and doubtless also trees and stick debris, on sandy areas are concentration points for the fauna (Mikulski, 1961). Third, substrate characteristics, including particle surface roughness, are an important control on periphyton growth and the retention of organic detritus (McAuliffe, 1983; Ward, 1992) that, in turn, affect food availability for herbivorous insects and thence higher trophic levels. Fourth, bed material characteristics influence the extent, connectivity, and stability of the interstitial spaces that constitute the in-channel hyporheic environment. In particular, they moderate hyporheic fluxes of water and nutrients (Claret et al., 1997) and the degree to which substrata can be utilized as refugia (Dole-Olivier et al., 1997).

It is often difficult to identify the relative importance of these various factors. Thus, positive relations between substrate heterogeneity and taxa diversity have been reported from both experimental manipulations of in-stream substrate (Allan, 1975; Williams, 1980) and examinations of natural substrates (Hynes, 1970; Dudgeon, 1982; Scarsbrook and Townsend, 1993; Quinn and Hickey, 1994), but the relative influences of particle stability, hydraulic complexity, and food availability have proven difficult to isolate (Erman and Erman, 1984).

### **Drainage basin land use/land cover**

Viewing stream communities in the holistic context of drainage systems has been a major research approach in stream ecology, and it has led to the generation of many influential hypotheses about the organization of stream communities. The river continuum concept (RCC) (Vannote et al., 1980; Minshall et al., 1985) in particular has attained a central position in stream ecology, although its global applicability has also been questioned (Winterbourn et al., 1981; Statzner and Higler, 1985). The RCC predicts, for example, that the functional feeding group composition of macroinvertebrate assemblages

should shift from the shredder-dominated headwaters via scraper dominated middle reaches to the collector-dominated lower reaches of large rivers (Vannote et al., 1980; Minshall et al., 1983). Furthermore, species richness should peak in the middle reaches of large rivers, where high environmental heterogeneity enables the co-occurrence of species with widely differing niche requirements (Minshall et al., 1985; Grubaugh et al., 1996; Vinson and Hawkins, 1998). While the RCC mainly relates biotic changes to paralleling variation in the productivity base, other conceptual approaches associate such changes to stream hydraulics (Statzner and Borhardt, 1994), or stress the effects of stream position in terms of downstream confluences on biotic patterns along the river continuum (Osborne and Wiley, 1992).

Many descriptive studies of biological communities in small streams (Hynes, 1970; Minshall, 1981) and more holistic concepts recognized that stream biota are influenced by the surrounding landscape (Vannote et al., 1980; Allan et al., 1997). Grubaugh et al. (1996) studied richness and mean annual abundance and biomass of benthic taxa in prevalent habitats along a first- through seventh -order stream continuum in the southern Appalachian Mountains (United States). Richness was greatest in mid-order reaches attributed to the localized patterns of stream geomorphology on taxonomic composition (Statzner and Higler, 1985, 1986) and edge effect thus accounting for higher biotic diversity, and benthic densities were highest in cobble habitats, followed by bedrock, pebble-gravel, and depositional areas explained to be because of particle-size heterogeneity of cobble relative to sand, gravel, or bedrock (Minshall, 1984). Abundance-based estimates of functional feeding-group composition were dominated by collector-gatherers and changed little with habitat as these were the most abundant throughout. As these taxa, however, account for relatively little of total benthic biomass. Subsequently, biomass-based estimates differed greatly among habitats: collector-filterers generally dominated cobble and bedrock areas; collector-gatherers, in pebble-gravel; and shredders and collector-gatherers, in depositional habitats. When functional-group biomass estimates were weighted for relative habitat availability along the continuum, patterns of benthic community composition generally matched predictions of the river continuum concept, although localized changes in stream geomorphology also influenced community structure. Similarly, Omoto et al. (2000) compared the variability of chemical composition and macroinvertebrates in the streams of two catchments, Pisca and Cabras in south east Brazil, which belong to the same ecoregion but have different land use. In the Cabras catchment among other parameters, dissolved inorganic carbon and invertebrate richness was found to be strongly correlated with the land use index, but the correlation was not significant. In another study, Miserendino and Pizzolon (2003) studied

the longitudinal and seasonal changes in physical and chemical variables, and macroinvertebrate community structure and function in the Azul-Quemquemtreu river system in the subantarctic forest of Patagonia, Argentina. Species richness and Ephemeroptera, Plecoptera, and Trichoptera richness decreased from upstream sites to the mouth of the river system and were affected by land use. Hussain (2011) in his study of the Doodhganga stream in Kashmir Himalaya found that the changing land use/land cover in the drainage basin is aptly represented by the changing community structure of the macroinvertebrate complex in the stream. He further found that there was a close and highly significant correlation ( $P < 0.05$ ) between macroinvertebrate indices and metrics namely Total Number of Taxa, Number EPT, Number Ephemeroptera, Percent EPT, Percent Scrapers, Family Biotic Index considered without Chironomidae and Oligochaeta, BMWP score, ASPT score and Fisher's Alpha and the land use/land cover in the drainage basin and suggested that these macroinvertebrate indices and metrics can be used as robust bioindicators for assessing watershed management practices in the spirit that 'in every respect the stream reflects the valley'.

### Vegetation

The presence of vegetation greatly affects the fauna. To understand this, a number of studies have compared the ability of different species of macrophytes to support varying densities of invertebrate communities (Percival and Whitehead, 1929; Berg, 1949; McGaha, 1952; Krull, 1970; Soszka, 1975; Gerrish and Bristow, 1979; Chilton, 1990). These studies showed that the abundance and distribution of invertebrates varies greatly over time and that some plants support greater numbers, higher diversity, and greater biomass of organisms than others (McGaha, 1952; Krull, 1970; Chilton, 1990). The surface area of the plant and the leaf morphology may have an important effect on a plant's ability to support macroinvertebrates (McGaha, 1952) and chemicals secreted by the plants may also be a factor influencing the total possible number of invertebrates present (Krull, 1970). Krull (1970) noted that those communities with higher plant surface area tended to support larger invertebrate populations. Many insects are dependent on the litter deposited as vegetation dies and sinks to the bottom and this may also play a role in determining which plants support the greatest numbers of macroinvertebrates (Nelson et al., 1990).

Not only the vegetation within the stream channels but also the riparian vegetation also greatly affects the structure and function of macroinvertebrates (Barton et al., 1985). It has been recorded that streams with forests in their riparian corridors are about two and half times wider than streams whose riparian zones have been

deforested and have more benthic surface area in the form of inorganic (sand, gravel, cobble) and organic (tree roots, leaf litter, wood, etc.) substrates for macroinvertebrate colonization. The streamside forests have been shown to affect the food quality and quantity for macroinvertebrates directly through inputs of particulate food (leaf litter, soils, wood, etc.) and indirectly by affecting the structure and productivity of microbial (algae, bacteria) food web through shading and modifying the levels of dissolved organic carbon and nutrients (Behmer and Hawkins, 1986; Cummins et al., 1989; Bilby and Ward, 1991). The deforestation of riparian zones of streams removes shading and can result in a 2 to 5°C warming of small streams which has been found to greatly affect the life history characteristics of macroinvertebrates including their growth rate, survivorship, adult size and fecundity, and time of reproduction (Bilby and Ward, 1991).

### pH of water

pH being one of the most important water quality parameters has been found to have profound effects on the ecology of macroinvertebrates in aquatic systems. Although, benthic macroinvertebrate sensitivities to pH vary (Yuan, 2004), values below 5.0 and greater than 9.0 are considered harmful. Low pH values are associated with lower diversity of benthic macroinvertebrates (Thomsen and Friberg, 2002), and cause decreased emergence rates in them (Hall et al., 1980). In macroinvertebrates, low pH has also been associated with egg failure (Willoughby and Mappin, 1988) and physiological problems because it is difficult for benthic macroinvertebrates to regulate ions within their bodies and to absorb the calcium needed for exoskeletons (Hall et al., 1980). A decrease in the pH of stream water can trigger the release of heavy metals, which are toxic to benthic macroinvertebrates (Ramsey and Brannon, 1988; Clements, 1994; Peiffer et al., 1997). Amphipods, isopods, crayfish, snails, and bivalves are more common in hard than in soft waters, as has been reported by several workers (Shoup, 1943; Slack, 1955; Reynoldson, 1961; Hynes, 1970; Allan, 1995).

### Drought

Droughts are very common features in temporary lotic systems. Williams (1987) defined these systems as natural watercourses that experience recurrent dry phases of variable duration. The biota in these systems is exposed to a suite of adverse environmental conditions and alterations in the biotic interactions during the dry period. Drought conditions frequently lead to intolerable thermal stress and/or low dissolved oxygen levels for

macroinvertebrates before the entire stream dries up (Griswold et al., 1982; Collier, 1995; Velasco and Millán, 1998). When the disturbance is strong enough, habitats can be restricted to isolated pools where interactions can be enhanced. As a consequence, species richness decreases before the total drying up of the channel (Boulton et al., 1992; Maltchik and Silva-Filho, 2000). Drying of stream channels normally occurs gradually, allowing time for behavioural adaptations. In this type of stressed stream, many macroinvertebrates have evolved life history or behavioural characteristics that enhance their survival or recovery. Among these, most successful adaptations are those related to life cycle (e.g., diapause states or resisting forms), to the ability to seek refuge from dryness in the hyporheic zone and to the dispersion capacity (Williams, 1987, 1996; Boulton, 1989). Dispersion capacity is linked to re-colonization strategies employed by the macroinvertebrates which include drift, upstream migration, aerial migration or oviposition and upward movements from the substrate or hyporheic zone (Williams, 1977; Cushing and Gaines, 1989; Yount and Niemi, 1990; Mackay, 1992; Ilg et al., 2001). The contribution of each pathway to the re-colonization process depends on the magnitude of the disturbance, the season in which this occurs, and the distance to undisturbed zones (Gore, 1982; Cushing and Gaines, 1989).

Natural disturbance (or discreet events that damage abiotic properties of an environment) plays a pervasive role in structuring most ecological communities and particularly stream benthic communities (Resh et al., 1988; Lake, 2000). Assemblages from frequently disturbed environments are more resilient than assemblages that experience disturbance infrequently (Reice et al., 1990; Death, 1996) because unstable environments are likely to be dominated by taxa with traits (e.g., short life cycles, dormancy) that allow them to persist in fluctuating environments (Townsend and Hildrew, 1994). Many studies have indicated that macroinvertebrate assemblages in intermittent streams are resistant to the drying phase (Scott, 1958; Extence, 1981; Stanley et al., 1994; Miller and Golladay, 1996). Hynes (1970) while concluding on the response of macroinvertebrates to stress of drying of streams maintained that species which are in an active state during the dry period are killed. The exceptions is that those invertebrates which can endure drought even in an active state, include at least some flat worms, oligochaetes, harpacticoid copepods, Elminthidae and their larvae, some chironomid larvae, and *Hydrocarina* presumably creep down into the habitat and there they find sufficient moisture, or even water, to allow them to survive.

## Flood

The ecological importance of floods is far greater than a

simple exchange of organic matter between the main channel and the floodplain system (Benke et al., 1999). Floods provide a temporary habitat for fishes and other aquatic organisms several times larger than the area of the river channel (Ross and Baker, 1983). The flood-pulse concept (Junk et al., 1989) identifies the floods as the principal agent controlling the adaptations of most of the biota in river-floodplain systems. The different attributes of floods such as, for example, frequency, duration and predictability can influence the life stories of aquatic organisms (Angradi, 1997; Benke, 2001; Fritz and Dodds, 2004; Tronstad et al., 2005). According to Poff and Ward (1989), the predictability of flow regimes determines whether the biotic or the abiotic factors are the ones that control the structure of communities. Very variable and/or unpredictable flow regimes generate a physical environment in which abiotic processes determine community organization, while a more predictable regime encourages interactions among the biota, such as competition or predation, factors which will control the community structure (Gasith and Resh, 1999). Variations in the flow of water are frequently related with changes in the community structure of fluvial organisms (Gasith and Resh, 1999). Studies of the biota in the Matarranya stream north east Spain demonstrated that certain species had adapted their life cycle to avoid floods, for example the bivoltine cycle of *Perla marginata*, *Hydroptila insubrica* and *Hydropsyche instabilis* (Argerich et al., 2004). In general terms, it has been observed that passage from the typical summer community in this river to that of autumn-winter is marked by the beginning of the autumn floods.

It has often been observed that periods of high water reduce the invertebrate fauna in streams. An early study of Moffett (1936) showed that because of a cloud burst and subsequent flood in South Willow Creek, the fauna was completely wiped out, but recovery started soon after. Similar disastrous effects of spates are reported from all over the world (Hynes, 1970; Allan, 1995; Hussain, 2011). The reduction may not be, and probably usually is not, uniform. One result of these phenomena is that streams which are more liable to spates have less abundant and less varied fauna than others. This has been established by studies in different countries and it is doubtless a universal phenomenon (Hynes, 1970; Grubaugh et al., 1996; Negishi et al., 2002; Younes-Baraille et al., 2005; Donohue et al., 2006; Hussain, 2011). A further effect of flooding is that in areas where spates are seasonally regular there tends to be a corresponding seasonal change in the density of fauna. Many researchers (Gaufin, 1959; Hussain, 2011) have found that in the mountain streams with spring runoff of melt water, there are always fewest animals in the period April to June. Some of this reduction is attributed to the difficulties of sampling during high water and some to the emergence of early species of *Plecoptera*, but much is

because of losses caused by wash-out. The macroinvertebrates of communities subjected to fluctuating flows show a high degree of resistance to moderate flooding (Resh et al., 1988; Puig et al., 1991), and need little time to recover. An example of such resilience was observed in the Ter basin, where recovery took six to nine months, depending on the station in question (Argerich et al., 2004).

Populations of macroinvertebrates are severely depressed after extreme flooding, but typically recover very quickly (Elwood and Waters, 1969; Hilsenhoff, 1996). Populations of macroinvertebrates in large low-gradient rivers generally experience an increase in population during flooding events. The expanding water surface initiates an influx of food while increasing the amount of habitat available to these creatures (Allen, 1993). Theiling et al. (1994) found that the densities of invertebrates near the expanding shoreline more than doubled those in permanent aquatic habitats despite the significant increase in total available habitat on the Illinois River during the 1993 Mississippi River basin flood.

### Food

The availability of food is an obvious factor controlling the occurrence and abundance of species. Generally speaking species occur, or are common, only where food is readily available, but it should not be forgotten that few running water invertebrates are very specialized in their diets (Hynes, 1970; Allan, 1995). For instance, many insects can eat either algae scraped from stones, or detritus, and diets may change with season according to the availability of algae (Chapman and Demory, 1963). In the River Polenz, a tributary of the Elbe, Albrecht and Bursche (1957) found that the number of algae decreased downstream over a reach of 6 km, although the lower reaches were better lighted, and so presumably should have produced more growth. However, at the same time the population of invertebrates increased and it is likely that the effect had been produced by increased grazing. Occasionally this effect may work the other way, and larger developments of algae may overtake the fauna and eliminate much of it. Harker (1953) reported that during her study of the mayflies in a small English stream a sudden growth of Cyanophyta eliminated several species. Similar effects of diatoms on *Simulium* larvae have been noticed and it has been reported that they grow over and smother the larvae (Sommerman et al., 1955).

### Shade

Shade may directly or indirectly influence the distribution and abundance of macroinvertebrates. Thorup (1966)

made a careful study of a spring stream in Denmark, the Rold Kilde, and he found that *Baetis rhodani* was more abundant in unshaded areas than under trees, and that the same seemed to apply to *Agapetus*, *Ecclisopteryx*, *Helodes* and *Ancylus*, all of which fed, to a large extent upon attached algae. The net-spinning caddis-worm *Wormaldia* showed, however, an opposite correlation. Shade affects the temperature regime in streams and influences the life history patterns of macroinvertebrates and also the availability of food from the periphytic and planktonic algae (Hynes, 1970; Bilby and Ward, 1991; Allan, 1995; Hussain, 2011).

### Stream geomorphology

Scientists have long assumed that the physical structure and condition of stream and river channels have pervasive effects on biological communities and processes, but specific tests are few (Hynes, 1970; Allan, 1995). To investigate the influence of the stream-reach geomorphic state on in-stream habitat and aquatic macroinvertebrate communities, Sullivan et al. (2004) compared measures of habitat conditions and macroinvertebrate community composition in Lewis Creek and White River watersheds in Vermont, USA between stable and unstable stream reaches in a paired-study design. They also explored potential associations between these ecological measures and individual geomorphic characteristics and channel adjustment processes (degradation, aggradation, overwidening, and change in planform). They found that habitat quality and heterogeneity were closely tied to stream stability, with geomorphically stable reaches supporting better habitat than unstable reaches. Geomorphic and habitat assessment scores were highly correlated ( $r = 0.624$ ,  $P < 0.006$ ,  $n = 18$ ). Stable reaches were found not to support significantly greater macroinvertebrate densities than unstable reaches ( $t = 0.415$ ,  $P > 0.689$ ,  $df = 8$ ). However, the percent of the macroinvertebrate community in the Ephemeroptera, Plecoptera and Trichoptera (EPT) taxa was significantly correlated with the overall habitat assessment scores as well as with individual measures of geomorphic condition and habitat quality.

### CONCLUSION

From the preceding review, it is evident that the composition and distribution of macroinvertebrates in streams is governed by numerous physical, chemical and biological factors which need to be taken into consideration in any study of stream macroinvertebrates. In addition, it may be said that the composition and distribution of stream macroinvertebrates is a reflection of the stream health and thus can be used as robust

bioindicators.

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