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River Ecosystem & Macro Invertebrate: A Review

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Benthic macro invertebrates are larger aquatic animals, bottom dwelling invertebrates which can be easily visible. Macro invertebrates found in aquatic bodied like river, ponds and stream around vegetation or along with sediment in water bodies bed. Some larval forms of insects are macro invertebrates. Water quality parameters are determined by macro invertebrates in terms of pollution because they serve as a biological indicator.

Norris and Thoms (1999) have suggested that pollution in rivers and environmental deprivation affects the aquatic biota that was an important indication of aquatic ecosystem health. Biodiversity means the different animals are found in any ecosystem. That represents not only the organisms that living in a particular area but also includes the interactions between animals and environment (Barbosa et al., 1997; 1999; 3Galdean and Staicu, 1997).

There are number of biological indicators reported by Chessman et al., 1999; Harris and Silveira, 1999; 56Kingsford, 1999, amongst them the benthic macroinvertebrates are most commonly used as biological indicators. (Resh and Jackson, 1993; Kay et al., 1999; Smith et al., 1999).

With the urbanization the water quality has been adversely affected specially due to industrialization, housing and mining beside contamination from storm water (Walsh et al., 2005 a).

A consistent destruction in urban and linked water bodies have been already reported (Roy et al., 2003). Algae saprophyte invertebrates and fish all are now adversely affected (Paul and Meyer 2001). Finally there is clear reduction in biotic diversity and increase in tolerance species has been documented by (Walsh et al., 2005a). Moreover ecosystem processes and interaction were impaired (Paul & Meyer, 2001). Walsh et al in 2005 have recognized this phenomenon as “urban stream syndrome.”

The human influence on water bodies and importance of natural disturbances was recognized since long back in the pretext of ecological devastation (Whitten 1975; Macdonald et al., 1991; Naiman et al., 1992; May beck et al., 1996; and Karr & Chu 1999).

Macro-invertebrate in any water bodies clearly indicate about water quality and pollution level has been reported by (Maybeck et al., 1996). Macro invertebrates are sensitive to hydrological parameters like dissolved oxygen, pH, salinity, temperature, and turbidity documented by Water and Rivers Commission, 2001. Due to major disturbances the impact on macro-invertebrate drift was critical in downstream had not been documented widely (Minshall & Petersen 1985; Pinay et al., 1990; Hershey and Lamberti 1998). Export of nutrients in downstream was also not well documented (Polis et al., 1997 and Wipfli & Gregorish 2002).

Reisch and Winter (1954); Wilhm and Dorish (1966); Pielou (1966); Bechtel & Copeland (1970) and Cairns & Dickson (1971) have studied the benthic macro invertebrates community along with species diversity and index. Shrivastava (1962); Verma & Dalella (1975); Sarkar & Krishnamurti (1977) and Verma et al., (1978) have been studied several river system in India in relation to benthic Macro invertebrate and environmental stress in terms of pollution status that change in aquatic communities.

In past years many parameters of aquatic bodies have been investigated on the landscape level undertaken into notice VIZ ectones (Allan and Johanson, 1997; Naiman & Decamps 1990, Edwords & Huryn 1996, Nauman et al., 1998). Salmonids (Bisson et al., 1992; Willson & Halpuka 1995; Wipfli et al., 1998; Ceder holm et al., 2000; and Montgomery 2003), large woody debris (Maser & Sedell 1994, Bilby & Bisson 1998) and sediment delivery (Benda et al., 1998) have been depicted on aquatic-terrestrial level.

However the downstream export of macro invertebrate drift has received little attention and has not been incorporated into the landscape or watershed level of investigation. It was already reported that fishless steep headwater streams of mountainous region may provide large quantities of nutrient that export to downstream from macro invertebrate drift. In terms of quantity the drift may be less but in terms of quality it is superior food source with high protein content (Young & Huryn 1997).

Badri et al., 1987 and Polis et al., 1997 have concluded that the drift has rarely been examined in the context of ecological interaction or ecosystem processes in fluvial system and adjacent riparian areas. The mechanism of processing of coarse and fine particulate organic matter in downstream export has been studies by Vennote et al., 1980. Wallace et al., 1986; 1987 and Cuffney & Wallace 1989. However these studies overlooked the downstream export of macro invertebrates. Whenever this is the fact that more organism drift over a unit of stream bottom are actually present in the area as benthic community and the fact was recognized by Bishop & Hynes 1969;Townsend & Hildrew 1976; Benke et al., 1991 and Forrester, 1994a.

Several abiotic and biotic factors have been recognized as major cause to influence macro invertebrate drift in any water bodies that directly operates and affected any water bodies.

ABIOTIC FACTORS

Brittain and Eikelan, (1988) have strongly recommend the hypothesis that abiotic factors are influenced the drift. The factors may result either active drift initiated by organism or passive initiated by change in physical conditions. If physiochemical changes are the main cause of pollution then catastrophic drift may occur. In some cases biotic factors override the abiotic such as stream discharge (Lancaster 1992, Fonseca & Hart 1996), but in some case abiotic factor override biotic factor such as sediment input (Walton 1978; Ottop & Wallace 1983 and Culp et al., 1986) or dominate the biotic one (Badri et al., 1987).

Several factors have been recognized as abiotic factors influencing ecosystem of any water body Viz-

Current discharge

Several authors have established positive correlation between discharge and stream drift (Elliot, 1968; Brooker & Hems worth 1978; Clifford 1978; Dance & Hynes 1979; Ottop & Wallance, 1983 and Cuffney & wallance 1989).

Elloit in 1968 found that there is a positive correlation between drift of Trichoptera and stream discharge of Dartmoore stream in Great Britain. Lancaster in 1992 has been concluded that three or four times greatly increased drift of mayflies in British, Columbia in relation to stream discharge. However they found that the increase in drift rate was apparent only at sunset when the nymph was active. However the relative importance of passive and active modes of entry into drift could not be determined by the study. In another study Iverson in 1980 found that high water flow was the main cause of Trichoptera drift in a Danish low gradient woodland stream.

Borchardt in 1993 found that benthic macro invertebrates exhibit increased drift with raise stress due to heavy discharge. However woody debris on the stream bottom provided refugia from exposure to hydrological stress. It is presumed that drift rate may be lowered in stream with high complexity which created by woody debris.

Johansen in his experiment in 1990 has found that there was a positive relationship between drift rate & discharge in River Norwegian during a short drought period.

Temperatures

Williams, 1990 and Winterbottom et al., 1997 have documented that temperature is not a primary factor for change in drift of a river but it cause change in activities of insect which may increase the risk of accidental drift. Dudgeon, 1990 has reported a significant positive correlation between temperature and number of drifts group in tropical stream, however there was no significant relationship between density of drift and temperature.

Disturbances

Water, 1972 has revealed that stream substrate, sedimentation anchor ice and pollution influenced physical disturbance that could lead catastrophic drift and river system. In 1990 Lancaster has supported the hypothesis of water and stated that abiotic factor such as spates could override the influence of biotic factors such as predation. Badri et al., 1987 have been also reported a large scale catastrophic drift due to spates in Moroccan stream system. Matthaei et al., in 1997 have depicted that dramatic increase in drift density due to extensive substratum movement in Alpine river in Switzerland. Similarly Mc lay in 1968 has reported that spate in Newzealand stream resulted in heavy disturbance of the benthic community followed by severe displacement of benthic community downstream.

O'ttop and Wallace in 1983 have documented a positive relationship between macro invertebrates drift and drifting detritus and revealed that detritus act as disturbance agent. However this increase may have been more related to increase in discharge than physical disturbance of the streambed by detritus.

Photoperiod

Photoperiod is also as important factor for drift in a river system. Elliot, 1971(b), 1978, has reported that Trichoptera exhibit higher drift rate at night as compared to day time. Same result has been documented by Elliot, 1973 Elliot for leech.

Water mites (*Hydracarina*) was found to be day active group especially for search of pray (Bishop & Hynes 1969, Waringer, 1992; Johnsen, 2000). Anderson in 1966 has suggested that dial periodicity of drift rate appears to be a direct response to lowered light intensity at sunset, but the drift of Trichoptera in tropical stream at the Ivory Coast was found just contrast. Stactzner et al., in 1985 have reported that moon light did not depressed Trichoptera drift.

Ricon & Lobon Cervia has reported variation in macro invertebrates drift in Iberian system in 1997. They have documented that low drift period for macro invertebrates in January and high drift patter in July. Benson & Pearson in 1987 have also reported that nocturnal drift pattern with crepuscular peak during most of the month among macro invertebrate in tropical Australian stream.

Seasonal patterns

Continuous drift is a common feature of lotic ecosystem. A strong seasonal variation in drift of macro invertebrates in river system have been reported by various authors. Seasonal variation in drift of Trichoptera was reported by Elliot in 1968 and also supported the concept that seasonal variation is probably linked with developmental difference. Hemsworth and Brooker in 1979 have reported that generally drift occur throughout the year but with peak in summer during the time of highest productivity.

Shubina and Maytynov in 1990 have revealed that macro invertebrate drift in two ice covered Salmon streams during the month of March and April in the Northern European USSR and found to be significant macro invertebrate drift. Pennuto et al., in 1998 have reported that in winter drifting of organism was generally found low in comparison to summer.

A number of authors agree that there is a correlation between peak drift of macro invertebrates system with peak productivity of the ecosystem in terms of biomass productivity (Armitage, 1977; Clifford, 1978; Shubina & Martynov, 1990; Cellot, 1996; Moser & Minshall, 1996). Maximum drift in macro invertebrate was reported in summer and minimum in winter by Rincon & Lobon-Cervia 1997.

BIOTIC FACTORS

Several biological factors have been reported as a responsible cause for macro invertebrates drift in a river system. Willey & Kohler, (1980), have revealed that oxygen consumption is one of the major factors for drift in mayfly nymph. As oxygen content decreases the nymphs must increase their exposure and their by augment susceptibility to accidental drift.

Life stages of macro invertebrates are another important factor that recognized by Waters, (1972). He has depicted that earlier life cycle stage is generally found in maximum number during the month of October, November and December and at that time density of drift was recognized by maximum number of larval stages. Cellot, 1996 and 1989 has also confirmed seasonal variation in macro invertebrates in Rhone River.

In nocturnal streams various larval stages of shrimp shows majority of diversity based drift in macro invertebrates (Ramirez & Pringel, 1988 and Prinjal & Ramirez, 1998).

The relationship between diversity of invertebrates and fish feeding has been well established in the field as well as in laboratory by Waters 1992; Allan, 1981; 1992; Wilzbach et al., 1986 and Nakons et al., 1999. Generally benthos captured by Salmonids (Allan 1981; Hubert & Rhodes 1989; Lavoie & Hubert, 1994).

Zelinika, 1974 & Macan, 1977 have concluded that invertebrate communities were highly adopted for fish predation. Welch in 1952 has reported that small water body was more competent and quick to react with atmospheric temperature.

Pearsall, 1930 & Zafar, 1966 have reported that the pH of the water generally depends up on quantities of Calcium, Carbonates, and Bicarbonates in water body. Generally water became more Alkaline if the concentration of carbonate is found in high quantity. If the concentration of bicarbonate, Carbon dioxide & Calcium is found in less quantity then alkalinity of water body became less.

Zafer in 1966 has reported that in water body the quantity of Carbonate is generally found very high in summer but after the monsoon in the month of July & August considerably large amount of carbonate get accumulated in the surface and the middle layer. Rao in 1972 observed that the bicarbonate is found in maximum in summer and in minimum in winter. Munawar has been reported in 1970 that high value of bicarbonate was found in the late winter and in sewage pond high content of bicarbonate was also reported by him. Moss (1973) was observed high value of bicarbonate content in the eutrophic waters.

High concentration of Chloride was generally in summer in water body when the water level was found low (Gonzalves & Joshi 1946). A direct correlation between chloride concentration & pollution level was also reported by Klen, 1956. As per finding of Zafer (1964) and Rao (1971, 1972) it was established that high chloride concentration always found in summer and low during monsoon & post monsoon in any water body.

Total hardness is also one of the important parameter which was studied by Moss in 1973 it was reported that increase in hardness in directly related to eutrophication of any aquatic body. Generally in pick summer, total hardness is found very high and during post monsoon it becomes very low.

Regarding dissolved oxygen Fritsh in 1907 stated that the oxygen content of tropical waters would be low due to the high temperature. The Periodicity of dissolved oxygen showed a definite pattern during the course of study the lowest dissolved oxygen concentration are generally found during the summer and the highest during the early winter in water bodies.

Ganapati in 1943 concluded that the nitrate nitrogen concentration declines with the increase in contamination hence chloride should also be negatively correlated with nitrate nitrogen because chlorides (Klein, 1957) are known to increase with increased contamination. But Rao, (1955) and Zafar, (1964) have been found a positive correlation between free ammonia and albuminoid ammonia.

In a study it was clearly established that bicarbonate, chloride and free ammonia increases progressively with an increase in contamination, while dissolved oxygen keeps depleting steadily as contamination increased. It was also established that the pH, magnesium, calcium, bicarbonate, albnuminoid ammonia and saline ammonia, total hardness & chloride increase with the eutrophication, while dissolved oxygen keeps on depleting. This inverse relationship between two groups of factors suggests that an adverse position in terms of the status of any water body (Zafer, 1964; Moss, 1973; Kundra et al., 1977 and Munawar, 1970).

Many studies presume that variation in water temperature of any aquatic body is depends upon atmospheric air temperature. They emphasize that maximum temperature are generally found at 3 PM and minimum at 6 AM (Hussiny, 1967, Young, 1975).

pH of water body generally increases during day time owing to photosynthetic utilization of CO_2 and decreased during nighttime due to reduced photosynthetic activity (George 1961, Reddy, 1981). Lind in 1938 also reported that fluctuation in pH follows change in sunshine and higher pH value generally attributes higher rate of productivity.

George, (1961); Verma (1967) and Reddy, (1981) have reported that dissolved oxygen of water body generally found increased in forenoon, maximum at noon and decreased in afternoon period. However, Kannan and Job (1980) have observed maximum surface water dissolved oxygen in late afternoon hours & lowest just prior to sunrise. Sumitra in 1969 has observed a gradual increase of surface dissolved oxygen between 6 AM to 9 PM in few south Indian pools and rivers while Verma, 1967 has been documented that pH and dissolved oxygen exhibit similar trend.

The presence of CO_2 in water is generally attributed to the lack of adequate phytoplankton's (Hussainy, 1967) and its absence is attributed to the high demand for this gas (Seenayya, 1971) and Zafer in 1964 found inverse relationship between carbonate and bicarbonates.

Gonzalves & Joshi (1946) & Singh (1960) have considered dissolved oxygen as a prerequisite for better growth for macro invertebrate and planktons in a water body. Munawar, (1970) and Seenayya, (1971) have reported that oxidizable organic matter favors growth of planktons and& macro invertebrate in a water body. Rao (1953); Zafar (1964) and Hosmany & Bharati (1980) have reported that there is a direct relation between dissolved oxygen and growth of planktons & macro invertebrate population in a water body.

Gonsalvies & Joshi (1946); Singh (1960); Seenayya (1971) and Bharati & Hosmani (1973) have supported the idea that high value of free cabandioxide oxidisable organic matter and chrloride are directly related to planktonic and macro invertebrate growth in a water body. Rao & Singh in 1960 specified that concentration of iron in water body is directly related to growth of Euglinoids & Trachelomonas.

Pearshall (1923); Monawar (1974); Rojer Jones (1977); Pentecost & Wood (1978); Phillp Sze (1980) have reported that there is direct relationship between silica & growth of Diatoms in a water body. Zafar in 1964 conformed that calcium is required for growth of diatoms in an aquatic body.

Several authors have concluded that increased turbidity during monsoon months causes less production of planktons and thus adversely affecting population of macro invertebrates. Welch, (1952); Roy (1955); Chakraborthy et al., (1959); and Tandon & Singh, (1972) concluded that during monsoon high turbidity value results in the death of planktons and affecting related populations.

During winter month's production of phytoplankton, zooplanktons and macro invertebrates became more due to negligible turbidity. Sahai & Sinha (1968); Vass et al., (1977); Pahwa & Mehrotra (1966); Chakraworthi et al., (1959) and Ray et al., (1966) have concluded that in any water body highest dissolved oxygen is associated with the winter maxima of planktons & macro invertebrates and low temperature of water.

The observation of Tandon and Singh, (1972) has revealed that the dissolved oxygen was likely to go up with increase in turbidity. Due to the high turbidity the oxygen content fall during monsoon months that lead the oxidation of organic materials producing the turbidity, may have been responsible for low oxygen contents.

DIVERSITY OF ORGANISM

In 1933 Ahlstrom has documented that in low pH condition palnktonic rotifers become less but comparatively found in maximum number in alkaline water. Methew, (1975) also recorded that the number of rotifers is high in eutrophic water bodies that exceeds other zooplanktons like cladocera and copapoda. Sandhu et al., (1984) have observed that increase in rotifer number in any water body is directly related to increasing does of organic matter.

Gulati in 1978 reported that the food supply is high or increasing for stretch of time, cladocerans usually build up high number in aquatic body that dominate the any lake or river biotic population. Pillai et al., (1973) and Forsyth & Mc Callum (1980) have observed that copepode constitute most pre dominant portion of zooplankton population. Mills et al., in 1981 have recorded 80% contribution of cyclopoids copepods in the total biomass of zooplanktons in a water body. Blum, (1956) & Lakshminarayan (1965) have reported a directed relation between high pH & high

plankton production. On the other hand Das & Shrivastava (1656) and Jana (1973) & Unni, (1984) have been established that the zooplankton densities are higher at low pH.
The higher production of phytoplankton in both river & pond system has been reported by various workers (Prasad & Nair, 1963; Williams & Murdoch; 1966; Sreenivasan, 1966; Quasim et al., 1969, Khan & Siddiqui, 1971; Vijayargharan, 1971; Aduni,1975; Sharan,1980; Sharma,1983; and Bhatnaga;1984).
The direct relationship between productivity & phytoplankton biomass was also noticed by some of limnologist (Bhatnagar, 1971; Ilmavirt & Kotima 1974; Zutshi, 1976; Chaudhary et al.,1979; Awtramani, 1980 and Saran 1980).
Several factors have been recognized for fluctuation of phytoplankton productivity, such as light intensity (Marsh all Orr 1928 and Talling, 1956) change in chlorophyll content (Yentesh & Rythes 1956, Shimada, 1958) and downward migration of phytoplankton (Tilzor1973). Some authors have been reported that gross primary production community respiration rate under long exposure is always less than short exposure in a phytoplankton and macro invertebrate community of any pond or river ecosystem (Vollenwender & Nawerck, 1961, Adoni, 1975, Saran, 1980 and Singhal, 1980).
The biomass production of periphyton and macro invertebrate varies greatly in different ecological condition of both ponds and river. Odum, (1957) and Newcomb, (1950) reported 37.5 mg. m^{-2} day^{-1} of periphyton and macroinvertebrate in Silver spring of Florida. Castenholz (1960) estimated 131 mg m^{-2} day^{-1} of periphyton and macro invertebrate from a fresh water lake in Washingaton, while Sledeck & Sledeckova (1963) recorded 250 mg of Sedlice reservoir in Czeckuslavia. In India Vass et al., (1976) have reported production values of 165 mg^{-2} day^{-1} in brackish water of West Bengal.
Wetzel in 1966 was concluded that the primary productivity of aquatic environments basically depends on the photosynthetic activity of the autotrophic organism which is capable to transforms carbon dioxide into organic matter & it has been used as potential index of productivity for many divers ecosystem of the world.
It has been reported that macrophyte communities are more productive then phytoplankton community under comparable conditions unit area basis. Where as in deeper lakes, oceans, deep and turbid rivers the macrophytes are confined to the littoral zone and their by theses total production remain normally less than that of phytoplankton (Westlake, 1963). Nanoplanktons & Ultraplanktons generally assimilates mush more carbon per unit biomass then net phytoplankton like large diatoms or blue green algae and up on which population density of further tropic level including macro invertebrate of any ecosystem depends (Fingenegg,1965, Qasim et al., 1974, Khan & Zutshi,1979).
The productivity of any water body and related population density is found to increase from late winter, reaching peak in the late summer or early rains and to decline thereafter. It was emphasized by several workers that the high rate of productivity during summer was probably due to bright sunshine, high temperature, low transparency, high phytoplankton density and blooms (Prasad & Nair 1963, Sreenivasan, 1964; 1969; Williams & Murdoch 1966; Spodniewska 1969; Khan & Siddique, 1971; Adoni, 1975 and Purshothaman & Bhatnagar, 1976). They have also emphasized that the declining tendancy of productivity during rainy season could be because of the reduction in the size of productive zone due to rains, increase in water level, dilution of nutrient concentration and cloudy weather. Clear days generally resulted in relatively greater photosynthesis then the cloudy days. Low temperature and light intensity might be limiting the rate of productivity during winter season. Bimodal trend in productivity was reported by Geldman & Wetzel, 1963 and Khan & Siddique, 1971.
Several authors have tried to study community dynamics of many polluted river and ponds & found poor diversity in polluted zones (Harrell, 1966, Ewing, 1964, Dills & Rogers, 1974 and Wilhm et al., 1978). Herrel & Dorris in 1968 have been reported an increase macro invertebrate population with increasing self purification of polluted rivers.
Lacky, (1942), Bartsch (1948), Richardson, (1921), Kolwitz & Marson (1908, 1989) have concluded that analysis of the species composition and abundance of the river and streams constitute a valuable measure for evaluating their role as indicators of pollution.

MACROINVERTEBRAETE: AN INDICATOR OF WATER QUALITY

Mac Neil et al., 2002 have recognized the concept that macro invertebrate families are very diverse, sensitive, population to pollution of a water body and may be suitable for assessment of severity of contamination of water pollution. Able (1966) and Ziglio et al., (2006) have concluded that the macro invertebrate groups is well diverse, so some members are very responsive to pollution and some members allowing the observation of temporal changes in communities and the pollution to which they are responding. Some important macro invertebrate sensible to pollution may be recorded as mentioned below-

1. Stone flies (***Placoptera***): This is considered as high sensitive to pollution and requires large quantity of oxygen (Mason, 2002, Sterry, 1977.)
2. May flies (***Ephemeroptera***): This is considered as sensitive to environmental stress although family is reported in poor environmental condition in abundance (Hall et al., 2006). Kosnicki & Buria in 2004 have reported emergence of Mayflies in summer.
3. Caddis flies (***Trichoptera***): This is specially known for susceptible to environmental stress but some other members of the family are less susceptible to environmental stress (Hall et al., 2006) Normally the adult members emerged out in May to July (Sterry, 1997) as per study of Berenzon et al., (2001) the member of Limnephidae one ten time less sensitive to ammonia then the members of Gammeridae.
4. Gammeridae ***(Amphipoda):*** Pulex has been reported that among *Amphipoda Gammarus* much sensitive to organic pollution whereas, Asellus, Juveniles has been recognized as sensitive to less polluted water (Bloor and Banks, 2006)
5. ***Asellidea*** (*Isopoda*): According to Matby (1995) *Asellue* is a member capabale to tolerate inordinate pollution but can tolerate hypoxia (5 times) & ammonia (2 times) in comparison to *Gammurus.*
6. ***Chironomidae*** (*Deptera*): Member of Chironomidae is generally considered highly tolerant to organic pollution. Stuijfzand et al., 2000 proposed the idea those members of Chironomidae more competently utilizing organic food. Meson in 2002 has advocated that reproduction rate of Chironomidae group is very high in organic pollution. But Raunio et al., 2007 advanced the concept that still several members of Chironomidae are quite intolerant to organic pollution.
7. *Aquatic worm* (***Oligocheata****):* Mason in 2002 reported that family tubificidae is extremely tolerant to organic pollution & are capable to survive even in anoxic condition.

REFERENCES

1. Allan, J.D. (1981) Determinants of diet of brook trout (*Salvelinus fontinalis*) in a mountain stream. Canadian Journal of Fisheries and Aquatic Sciences 38(2):184-192.
2. Allan, J.D. (1982) The effects of reduction in trout density on the invertebrate community of a mountain stream. Ecology 63(5):1444-1445.
3. Allan, J.D. & Russek, E. (1985) The quantification of stream drift. Canadian Journal of Fisheries and Aquatic Sciences 42: 210-215.
4. Anderson, N.H., (1966) Depressant effect of moonlight on activity of aquatic insects. Nature 209(5020):319-320.
5. Armitage, P.D., (1977) Invertebrate drift in the regulated River Tees, and an unregulated tributary Maize Beck, below Cow Green dam. Freshwater Biology 7:167-183.
6. Badri, A., Giudicelli, J. & Prévot,G.(1987) Effects d'une eruesur la communauté d'invertébrés benthiques d'une rivière méditerranéenne, Le Rdat (Maroc). Acta Oecologica; Oecologia Generalis 8(4):481-500. (In French)
7. Barbosa, F.A.R., Souza, E.M.M., Vieira, F., Renault, G.P.C.P., Rocha, L.A., Maia-Barbosa, P.M., Oberdá, S.M.G., Mingoti,S.A., (1997) Impactos Antrópicos e biodiversidade aquática.In: J.A. Paula, (Ed.), Biodiversidade, população e economia.PADCT-CIAMB, UFMG, CEDEPLAR, ECMVS, Belo Horizonte, Brazil. Rona Editora, pp. 455- 468.
8. Barbosa, F.A.R., Maia-Barbosa, Rocha, P.M., Marques,L.A., Callisto,M.M., (1999) Human impacts and freshwater biodiversity in the Rio Doce, southeast Brazil: the watershed as the study unit. Proc. Of the 8th. Internat. Symp. On Conservation and Management of Lakes, ILEC, Copenhagen. , pp. 575-577.
9. Benda, L.E., Miller,D.J., Dunne,T., . Reeves,G.H., & . Agee,J.K.,(1998) Dynamic landscape systems. Pages 261-288 in R.J. Naiman and R.E. Bilby, eds. River ecology and management; lessons from the Pacific coastal ecoregion. Springer, New York, NY.
10. Benke, A.C., Parsons,K.A., & Dhar, S.M., (1991) Population and community patterns of invertebrate drift in an unregulated coastal plain river. Canadian Journal of Fisheries and Aquatic Sciences 48:811-823.
11. Benson, L.J., & Pearson,R.G., (1987) Drift and upstream movement in Yuccabine Creek, an Autralian tropical stream. Hydrobiologia 153:225-239.

12. Berenzen, N; Schulz, R; Liess, M. (2001).Effects of chronic ammonium contamination on the macroinvertebrate community in running water microcosms. Water Research, 35, 3478 – 3482.
13. Bilby, R.E. & Bisson,P.A., (1998) Function and distribution of large woody debris. Pages 324-346 in R.J. Naiman and R.E. Bilby, eds. River ecology and management; lessons from the Pacific coastal ecoregion. Springer, New York, NY.
14. Bishop, J.E., & Hynes, H.B.N., (1969) Downstream drift of the invertebrate fauna in a stream ecosystem. Archiv für Hydrobiologie 66(1):56-90.
15. Bisson, P.A., Quinn,T.P., Reeves,G.H., & Gregory,S.V., (1992) Best management practices, cumulative effects, and long-term trends in fish abundance in Pacific Northwest river systems. Pages 189-232 in R.J. Naiman, ed. Watershed management; balancing sustainability and environmental change. Springer-Verlag, New York, NY.
16. Bloor, M. C; Banks, C. J. (2006). An evaluation of mixed species in-situ and ex-situ feeding assays: The altered response of Asellus aquaticus and Gammarus pulex. Environment International, 32, 22 – 27.
17. Borchardt, D., (1993) Effects of flow and refugia on drift loss of benthic macroinvertebrates: implications for habitat restoration in lowland streams. Freshwater Biology 29:221-227.
18. Brittain, J.E., & Eikeland,T.J., (1988) Invertebrate drift - a review. Hydrobiologia 166:77-93.
19. Brooker, M.P., & Hemsworth,R.J., (1978) The effect of the release of an artificial discharge of water on invertebrate drift in the River Wye, wales. Hydrobiologia 59(3):155-163.
20. Chessman, B., Growns, I., Currey, J., Plunkett-Cole, N., (1999) Predicting diatom communities at the genus level for the rapid biological assessment of rivers. Freshwat. Biol. 41 (2), 317-332.
21. Corkum, L.D., (1989) Hall, L.W; Author, Reprint Author Hall Lenwood, W. J. (2006). Characterization of benthic communities and physical habitat in the Stanislaus, Tuolumne, and Merced Rivers, California. Environmental Monitoring and Assessment, 115, 223 – 264.
22. Cederholm, C.J., Johnson,D.H., Bilby,R.E., Dominguez,L.G., Garrett,A.M., Graeber,W.H., Greda,E.L., Kunze,M.D., Marcot,B.G., Palmisano,J.F., Plotnikoff,R.W., Pearcy,W.G., 58 Siemenstad,C.A., & Trotter,P.C., (2000) Pacific salmon and wildlife - Ecological contexts, relationships, and implications for management. Special Edition Technical Report, Prepared for D.H. Johnson and T.A. O'Neil (Managing Directors), Wildlife-habitat relationships in Oregon and Washington. Washington department of Fish and Wildlife, Olympia, WA. 136p.
23. Cellot, B., (1989a) Macroinvertebrate movements in a large European river. Freshwater Biology 22:45-55.
24. Cellot, B., (1996) Influence of side-arms on aquatic macroinvertebrate drift in the main channel of a large river. Freshwater Biology 35:149-164.
25. Clifford, H.F., (1978) Descriptive phenology and seasonality of a Canadian brown-water stream. Hydrobiologia 58(3):213-231.
26. Cuffney, T.F., & Wallace,J.B., (1989) Discharge-export relationships in headwater streams: the influence of invertebrate manipulations and drought. Journal of North American Benthological Society 8(4):331-341.
27. Culp, J.M., Wrona,F.J., & Davies,R.W., (1986) Response of stream benthos and drift to fine sediment deposition versus transport. Canadian Journal of Zoology 64:1345-1351.
28. Dance, K.W., & Hynes,H.B.N., (1979) A continuous study of drift in adjacent intermittent and permanent streams. Archiv für Hydrobiologie 87(3):253-261.
29. Dudgeon, D., (1990) Seasonal dynamics of invertebrate drift in a Hong Kong stream. Journal of Zoology (London) 222:187-196.
30. Edwards, E.D., & Huryn.A.D., (1996) Effect of riparian land use on contributions of terrestrial invertebrates to streams. Hydrobiologia 337:151-159.
31. Elliott, J.M. (1968) The life histories and drifting of Trichoptera in a Dartmoor stream. Journal of Animal Ecology 37:615-625.
32. Elliott, J.M,. (1971a) The distances travelled by drifting invertebrates in a lake district stream. Oecologia (Berlin) 6:350-379.
33. Elliott, J.M., (1971b) Life histories and drifting of three species of Limnephilidae (Trichoptera). Oikos 22:56-61.
34. Fonseca, D.M., & Hart,D.D., (1996) Density-dependent dispersal of black fly neonates is mediated by flow. Oikos 75:49-58.
35. Forrester, G.E., (1994a) Influences of predatory fish on the drift dispersal and local density of stream insects. Ecology 75(5):1208-1218.
36. Galdean, N., Staicu, G., (1997) The carrying capacity assessment of the lotic system Crisul Repede (Tisa Area Catchment, Romania), based on faunistical analysis. Trav. Mus. natl.Hist. nat. 'Grigore Antipa' 37, 237-254.
37. Harris, J.H., Silveira, R., (1999) Large-scale assessments of river health using an index of biotic integrity with low-diversity fish communities. Freshwat. Biol. 41 (2), 235-252.
38. Hemsworth, R.J., & Brooker,M.P., (1979) The rate of downstream displacement of macroinvertebrates in the upper Wye, Wales. Holarctic Ecology 2:130-136.
39. Hershey, A.E., & Lamberti,G.A., (1998) Stream macroinvertebrate communities. Pages 169-199 in R.J. Naiman & BilbyR.E. eds. River ecology and management: lessons from the Pacific coastal ecoregion. Springer, New York, NY.
40. Hubert, W.A., & Rhodes,H.A., (1989) Food selection by brook trout in a subalpine stream. Hydrobiologia 178:225-231.
41. Iversen, T.M., (1980) Densities and energetics of two streamliving larval populations of Sericostoma personatum (Trichoptera). Holarctic Ecology 3:65-73.
42. Johansen, O.T.,(1990) En ny drivfelle for bruk i rennende vann presentert sammen med endel innsamlingsresultater fra Hoenselva i Buskerud. Fauna 43:123-128. (In Norwegian)
43. Johansen, M., Elliot,J.M., & Klemetsen,A., (2000) Diel fluctuations in invertebrate drift in a Norwegian stream north of the Arctic circle. Norwegian Journal of Entomology 47(2):101-112.

44. Karr, J.R. & Chu,E.W., (1999) Restoring life in running waters;better biological monitoring. Island Press, Washington, D.C. 206p.
45. Kingsford, R.T., (1999) Aerial survey of waterbirds on wetlands as a measure of river and floodplain health. Freshwat. Biol. 41(2), 425- 438.
46. Kay, W.R., Smith, M.J., Pinder, A.M., Rae,M.C., Davis,J.M., Halse, S.A., (1999) Patterns of distribution of macroinvertebrate families in rivers of northwestern Australia. Freshwat. Biol. 41(2), 299-316.
47. Kosnicki, E; Buria, S. (2004). Life history aspects of the mayfly Siphlonurus typicus (Ephemeroptera:Siphlonuridae) with a new application for measuring nymphal development and growth. Hydrobiologia,1-3, 131 – 146.
48. Lancaster, J., (1990) Predation and drift of lotic macroinvertebrates during colonization. Oecologia (Berlin) 85:48-56.
49. Lancaster, J., (1992) Diel variations in the effect of spates on mayflies (Ephemeroptera: Baetis). Canadian Journal of Zoology 70:1696-1700.
50. LaVoie IV, W.J., & Hubert,W.A.,(1994) Use of drifting invertebrates by young-of-year brown trout in stream-margin habitat. Journal of Freshwater Biology 9(1):37-43.
51. Macan, T.T. (1977) The influence of predation on the composition of fresh-water animal communities. Biological Reviews 52:45-70.
52. MacNeil, C; Dick J.T. A; Bigsby, E; Elwood, R. W; Montgomery WI; Gibbins CN; Kelly D.W. (2002). The validity of the Gammarus: Asellus ratio as an index of organic pollution: abiotic and biotic influences. Water Research, 36, 75 – 84.
53. Maltby, L. (1995). Sensitivity of the crustaceans Gammarus pulex (L.) and Asellus aquaticus (L.) to short-term exposure hypoxia and unionised ammonia observations and possible mechanisms. Water Research, 29, 781 – 787.
54. Mason, C.F. (2002). Biology of Freshwater Pollution, Fourth Edition. Prentice Hall, London.
55. MacDonald, L.H., Smart,A.W., & Wissmar,R.C.,(1991) Monitoring guidelines to evaluate effects of forestry activities on streams in the Pacific Northwest and Alaska. Center for Streamside Studies, College of Forest Resources, University of washington, Seattle, WA for Region 10 US EPA. EPA 910/9-91-001. 166p.
56. Maser, C. & Sedell,J.R.,(1994) From the forest to the sea: the ecology of wood in streams, rivers, estuaries, and oceans. St. Lucie Press, Delray Beach, FL. 200p.
57. Matthaei, C.D., Uehlinger,U., & Frutiger,A., (1997) Response of benthic invertebrates to natural versus experimental disturbance in a Swiss prealpine river. Freshwater Biology 37:61-77. 67
58. Maybeck, M., Friedrich,G., Thomas,R., & Chapman,D., (1996) Rivers. Pages 243-320 in D. Chapman, ed. Water quality assessment: a guide to the use of biota, sediments and water in environmental monitoring. Second edition. UNESCO, WHO, UNEP, and Spon, London.
59. McLay, C.L., (1968) A study of drift in the Kakanui River, New Zealand. Australian Journal of Marine and Freshwater Research 19:139-149.
60. Minshall, G.W., & Petersen,R.J. Jr., (1985) Towards a theory of macroinvertebrate community structure in stream ecosystems. Archiv für Hydrobiologie 104(1):49-76. 68
61. Montgomery, D.R., (2003) King of fish; the thousand year run of salmon. Westview Press, Boulder, CO. 290p.
62. Moser, D.C., & Minshall,G.W., (1996) Effects of localized disturbance on macroinvertebrate community structure in relation to mode of colonization and season. American Midland Naturalist 135:92-101.
63. Naiman, R.J., & Décamps,H., Eds., (1990) The ecology and management of aquatic-terrestrial ecotones. UNESCO. Paris. 316p.
64. Naiman, R.J., Beechie,T.J., Benda,L.E., Berg,D.R., Bisson,P.A., MacDonald,L.H., O'Connor,M.D., Olson,P.A., & Steel,E.A., (1992) Fundamental elements of ecologically healthy watersheds in the Pacific Northwest Coastal Ecoregion. Pages 127-188 in R.J. Naiman, ed. Watershed management; balancing sustainability and environmental change. Springer-Verlag, New York, NY.
65. Naiman, R.J., . Fetherston,K.L., McKay,S.J., & Chen,J., (1998) Riparian forests. Pages 289-323 in R.J. Naiman and R.E. Bilby, eds. River ecology and management; lessons from the Pacific coastal ecoregion. Springer, New York, NY.
66. Nakano, S., Fausch,K.D., & Kitano,K., (1999) Flexible niche partitioning via a foraging mode shift: a proposed mechanism for coexistence in stream-dwelling charrs. Journal of Animal Ecology 68(6):1079-1092.
67. Norris, R.H., Thoms, M.C., (1999) What is river health? Freshwat. Biol. 41, 197-209.
68. Oliveira, L.G., Froehlich, C.G., 1996. Natural history.
69. O'Hop, J., & Wallace,J.B., (1983) Invertebrate drift, discharge, and sediment relations in a southern Appalachian headwater stream. Hydrobiologia 98:72-84.
70. Paul, M.J; Meyer,JL, (2001). Streams in the Urban Landscape. Annual Review of Ecological Systems, 32, 333 – 365.
71. Pinay, G., Décamps,H., Chauvet,E., & Fustec,E., (1990) Functions of ecotones in fluvial systems. Pages 141-169 in Naiman, R.J., and H. Décamps (eds.). The ecology and management of aquatic-terrestrial ecotones., UNESCO, Paris.
72. Polis, G.A., Anderson,W.B., & Holt,R.D., (1997) Toward an integration of landscape and food web ecology: dynamics of spatially subsidized food webs. Annual Review of Ecology and Systematics 28:289-316.
73. Pringle, C., & Ramirez,A., (1998) Use of both benthic and drift sampling techniques to assess tropical stream invertebrate communities along an altitudinal gradient, Costa Rica. Freshwater Biology 39:359-375.
74. Ramirez, A., & Pringle.C.M., (1988) Invertebrate drift and benthic community dynamics in a lowland tropical stream, Costa Rica. Hydrobiologia 386:19-26.
75. Raunio, J; Paavola R; Muotka,T. (2007). Effects of emergence phenology, taxa tolerance and taxonomic resolution on the use of the Chironimid Pupal Exuvial Technique in river biomonitoring. Freshwater Biology, 52, 165 – 176.
76. Roy, A. H; Rosemond, A.D; Paul, M.J; Leigh, D.S; Wallace, J.B (2003). Stream macroinvertebrate response to catchment urbanisation. Freshwater Biology, 48, 329 – 346.

77. Resh, V. H., Jackson, J. K., (1993) Rapid assessment approaches to biomonitoring using benthic macroinvertebrates. In: D.M.Rosenberg, V.H. Resh (Eds.), Freshwater Biomonitoring and Benthic Macroinvertebrates, pp. 195-233. Chapman andHall, New York.
78. Rincón, P.A., & Lobón-Cerviá,J., (1997) Temporal patterns in macroinvertebrate drift in a northern Spanish stream. Marine and Freshwater Research 48:455-464.
79. Shubina, V.N. & Martynov,V.G., (1990) Drift of benthic invertebrates in salmon streams of the northern European USSR during the period of ice cover. Gidrobiologicheskiy Zhurnal 26(6):27-31.
80. Smith, M.J., Kay, W.R., Edward, D.H.D., Papas, P.J., Richardson, K. St J., Simpson, J.C., Pinder, A.M., Cale, D.J., Horwitz, P.H.J., Davis, J.A., Yung, F.H., Norris, R.H., Halse, S.A., (1999). AusRivAS: Using macroinvertebrates to assess ecological condition of rivers in Western Australia. Freshwater Biology, 41(2), 269-283.
81. Statzner, B., & Mogel,R., (1985) An example showing that drift net catches of stream mayflies (Baetis spp. Ephemeroptera, Insecta) do not increase during periods of higher substrate surface densities of the larvae. Verhandlungen der Internationalen Vereinigung für Theorethische Angewamnologie 22:3238-3243.
82. Townsend, C.R., & Hildew,A.G.,(1976) Field experiments on the drifting, colonization, and continuous redistribution of stream benthos. Journal of Animal Ecology 45:759-772.
83. Vannote, R.L., Minshall,G.W., Cummins,K.W., Sedell,J.R., & Cushing,C.E., (1980) The river continuum concept. Canadian Journal of Fisheries and Aquatic Sciences 37:130-137.
84. Wallace, J.B., Cuffney,T.F., Lay,C.C., & Vogel,D., (1987) The influence of an ecosystem-level manipulation on prey consumption of a lotic dragonfly. Canadian Journal of Zoology 65:35-40.
85. Wallace, J.B., Vogel,D., & Cuffney,T.F., (1986) Recovery of a headwater stream from an insecticide-induced community disturbance. Journal of North American Benthological Society 5:115-126.
86. Walsh, C.J; Roy, A.H; Feminella, J.W; Cottingham, P.D; Groffman, P.M; Morgan, R.P. (2005a). The urban stream syndrome: current knowledge and the search for a cure. Journal of the North American Benthological Society, 24, 706 – 723.
87. Walton, O.E., (1978) Substrate attachment by drifting aquatic insect larvae. Ecology 59(5):1023-1030.
88. Waringer, J.A., (1992) The drifting of invertebrates and particulate organic matter in an Austrian mountain brook. Freshwater Biology 27:367-378
89. Waters, T.F., (1972) The drift of stream insects. Animal Review of Entomology 17:253-267.
90. "Water Facts: Water Quality and Macroinvertebrates." *Water and Rivers Commission 2ndEdition*. 2001. Web. 07 Apr. 2011.
91. Whitton, B.A., (1975) River Ecology. Studies in Ecology. Blackwell Scientific Publications, Oxford, England. 725p.
92. Wiley, M.J., & Kohler, S.L., (1980) Positioning changes of mayfly nymphs due to behavioral regulation for oxygen consumption. Canadian Journal of Zoology 58:618-622.
93. Winterbottom, J.H., Orton,S. E., & Hildrew,A.G., (1997) Field experiments on the mobility of benthic invertebrates in a southern English stream. Freshwater Biology 38:37-47.
94. Wipfli, M.S.. Hudson,J., & Caouette,J.,(1998) Influence of salmon carcasses on stream productivity: response of biofilm and benthic macroinvertebrate in southeastern Alaska, U.S.A. Canadian Journal of Fisheries and Aquatic Sciences 55:1503-1511
95. Wipfli, M.S., & Gregovich,D.P., (2002) Export of invertebrates and detritus from fishless streams in southeastern Alaska: implications for downstream salmonid production. Freshwater Biology 47(5):957-969.
96. Young, R.G., & Huryn,A.D., (1997) Longitudinal patterns of organic matter transport and turnover along a New Zealand grassland river. Freshwater Biology 38(1):93-107.
97. Zelinka, M., 1974. Die Eintagsfliegen (Ephemeroptera) in Forellenbachen der Beskiden. III. Der Einfluss des verschiedenen Fishbestandes. Vestnik Ceskoslovenske Spolecnesti Zoologicje 38:76-80. (In German) 78.
98. Ziglio, G; Siligardi, M; Flaim, G. (2006) Biological Monitoring of Rivers. John Wiley and Sons Ltd, West Sussex.