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Promoting a functional macroinvertebrate approach in the biomonitoring of Italian lotic systems

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ABSTRACT

Over fifty years of research on freshwater macroinvertebrates has been driven largely by the state of the taxonomy of these organisms. Significant advances have been and continue to be made in developing ever more refined keys to macroinvertebrate groups. When advances in macroinvertebrate ecological research are restricted by the level of detail in identifications, then analysis by function is a viable alternative. The focus on function, namely adaptations of macroinvertebrates to habitats and the utilization of food resources, has facilitated ecological evaluation of freshwater ecosystems. This classification is based not on what insects eat, but how they obtain their food. These categories are called "functional feeding groups", as the name implies, denoting their functional role when describing how and where they feed. This is the basis for the functional feeding group (FFG) method that was initially developed in the early 1960s. Taxonomy is applied only to the level of detail that allows assignment to one of five functional feeding group categories: detrital shredders, scrapers, filtering collectors, gatherers, and predators. The aim of this short communication, originating from the presentation of R.W. Merritt at the Biomonitoring Symposium in Rome, 2015, is to promote the use of a functional approach in biomonitoring, especially in Italian and European lotic systems. Here, we present two case studies and we discuss the advantages of the method, especially considering the great availability of quantitative data on macroinvertebrates after the implementation of the WFD 2000/60. We are confident that the increase of functional assessment of ecosystem attributes could have important and direct repercussions in the understanding and management of running waters.

Key word: Functional Feeding Groups; ecological traits; biological traits; living stream.

INTRODUCTION

In the last 30-40 years, enormous advances have been made in the knowledge of lotic systems (Davies and Walker, 2013). Stream ecology is at present a solid discipline, with a good theoretical basis and a wide number of promising lines of research. In particular, a conceptual seed, which was a constitutive element of the River Continuum Concept (Vannote *et al.,* 1980) and previous works (Cummins, 1973, 1974), blossomed, becoming a stimulating area of investigation, with numerous applied aspects. This idea is related to the fact that, for a better understanding of lotic systems, it is important to consider not only structural elements, such as community composition and abundance, but also functional traits. In general, the importance of a functional approach has grown exponentially throughout ecological studies (Mouillot *et al.*, 2013), so that the term 'functional diversity' is at present widely used to indicate a component of biodiversity that generally concerns the range of things that organisms do in communities and ecosystems. In this context, feeding strategies are important and typical traits reflecting the adaptation of species to environmental conditions (Merritt and Cummins, 1996).

In lotic food webs, much of the energetic support originates from non-living sources of terrestrial organic matter origin, so that heterotrophic pathways are of greatest importance, and detritus rather than living plant material is the basis of most invertebrate food chains (*e.g.*, Cummins and Klug, 1979; Cummins *et al*., 1989). Aquatic invertebrates generally have great genetic feeding plasticity and, at least in their early instars, almost all aquatic insects can be considered omnivores (Clifford and Hamilton, 1987; Merritt *et al*., 2008). For this reason, the Functional Feeding Group approach (Cummins, 1974; Merritt and Cummins, 1996), based not on what aquatic organisms eat, but how they obtain their food, has increased the understanding of trophic dynamics in streams and rivers by simplifying the benthic community into trophic guilds. Functional Feeding Groups (FFG), based on morphological and behavioral mechanisms associated with food acquisition, are basically five: shredders, chewing or mining coarse particulate organic matter, primarily dead leaves and associated microbiota; scrapers or grazers, that scrape periphyton and generally biofilm; collectors-gatherers, that collect deposited organic fine sediments; collectors-filterers, that collect fine particulate organic matter from the water column; and predators. Appreciable differences

can occur among these categories, depending on possible variations in food availability or ontogenetic shifts in diet (Malmqvist *et al.*, 1991, Fenoglio *et al.*, 2010), but the relative importance of these functional feeding groups within benthic communities can be considered to obtain useful ecological information.

The use of functional traits to investigate different ecosystem attributes has already been introduced (Merritt *et al*., 1996), and for example adopted to give practical recommendations about river oxbow and river-riparian marsh restoration in Florida (Merritt *et al*., 1999, 2002). The functional group analysis can be used as surrogates for ecosystem attribute studies (Cummins *et al*., 2005): for example, using the relationship among FFG it is possible to provide useful information about ecosystem stability, energy flow and trophic webs. The aim of this short communication, developed within the *Biomonitoring Symposium* held in Rome in September 2015 in the frame of the European Ecological Federation (EEF), is to encourage the use of the functional approach in European and especially Italian lotic environments. As an example of the potential applications of this approach, we are presenting two case studies, carried out in Alpine environments and characterized by hydrological and morphological alterations.

Case studies

Hydrological alterations – droughts

This first case study is focused on the effect of droughts in previously known perennial rivers. In particular, we re-analyzed here, through a functional approach, data from a study observed in Italian pre-Alpine environments. Droughts constitute a growing problem in Southern Europe, with dramatic ecological consequences and underestimated economic and social repercussions (Filipe *et al.*, 2013). Over-exploitation of water resources, land use transformations and particularly global climate change are among the main causes of hydrological alteration increase (Vicente-Serrano *et al.*, 2014).

In recent years, a significant part of Northern Italy lotic systems changed from naturally 'permanent', with continuous presence of running water, to 'intermittent', with extreme water scarcity or lack in some periods, mostly during summer. The study was conducted in the upper section of the Po River, the largest Italian river and tenth largest in Europe. We selected as case study at an 11-km reach, with altered flow regimes in the lowest part, where in the last few decades drought has become a regular event. From January 2004 to September 2005, we collected samples in four stations that are close to each other (<10 km from Site 1 to 4) but with different drought lengths. In the study period, superficial flowing waters were permanent in Site 1, while disappeared for 150 days in Station 2, 240 days in Station 3, and 330 days in Station 4. Discussion and conclusions about biodiversity, taxonomic richness, and invertebrate densities are reported in Fenoglio *et al.* (2007). Here, we focus on the relative importance of invertebrate functional groups as analogs of ecosystem attributes. Functional composition of benthic assemblages varied dramatically among stations, with an evident increase of collectors-gatherers and a marked reduction of shredders and scrapers in the most impacted sites. First, according to Merritt *et al.* (1996), we investigated the importance of instream primary production, and consequently the autotrophy to heterotrophy ratio, by calculating the importance of scrapers (plus live vascular hydrophyte shredders) as a proportion of shredders plus total collectors. Results are reported in Fig. 1. Moreover, we analyzed the ecological importance of allochthonous energetic inputs, markedly CPOM, in the different stations through the importance of shredders as a proportion of total collectors. In this case, we utilized only fall/winter samples, because of the seasonality of this input in the study area. Interestingly, sites that are very close in the same river reach evidenced decreasing values with the increase of drought length (Fig. 2).

These results indicate that the progressive diminution of permanent water flow profoundly alters energy fluxes and food webs of the river biota. The metabolism of instream primary producers is highly sensitive to alterations in hydrological and thermal conditions (Uehlinger, 2006). So, while in the first site the constant water permanence permits the establishment of stable periphytic biofilms, in the other stations, we can evidence a progressive reduction of autotrophy at the ecosystem level, the entity of which is inversely proportional to drought length. Furthermore, the absence of permanent water probably inhibits the microbial breakdown of allochthonous inputs (*i.e.*, the conditioning by aquatic hyphomycetes and bacteria), that is essential to make this resource available for

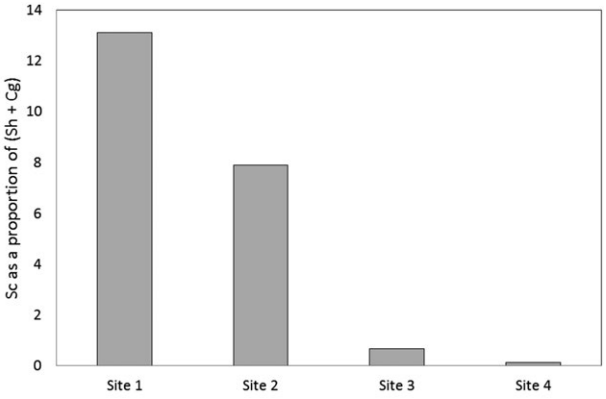

Fig. 1. Scrapers as a proportion of Shredders and Collectors in the four sites of the Po River.

macroinvertebrates and the rest of the trophic web. We can hypothesize that droughts in these naturally perennial systems cause a dramatic functional alteration, drastically reducing the importance of internal productivity and allochthonous coarse organic detritus processing. With the progressive increase of drought persistence, benthic communities became simplified and more functionally generalist, relying mainly on fine organic sediments.

Morphological alterations - siltation

In the last decades, anthropogenic pressures have increasingly altered the sediment transport-deposition cycle in many rivers. In particular, siltation, that is the deposition of unnatural amounts of fine sediments, has become a key ecological problem (Owens *et al*., 2005), especially in mountain areas that are naturally characterized by coarse substrata. Here, fine sediment accumulations can dramatically alter the environmental characteristics of streambeds, combining physical (*i.e*., clogging interstices, reducing micro- and meso-habitat heterogeneity – Bo *et al*., 2007), chemical (*i.e.*, lowering substrata permeability to oxygen and other dissolved gases, nutrients and metabolites – Pretty *et al*., 2006), and biological (*i.e.*, causing burial, constraining or preventing movement and survival of lotic organisms – Jones *et al*., 2012) effects. Siltation can cause significant changes in many aspects of stream biota, the most frequently documented being structural, such as abundance diminution and taxonomic transformation in lotic communities (Allan and Castillo, 2007). Here, we utilized the functional approach to evaluate if stream reaches impacted by anthropogenic fine sediments have similar ecosystem attributes (based on the FFG proportion). We reanalyzed data from a study conducted in two third order streams in the Cottian Alps (Piemonte, NW Italy), the Luserna and the Comba Liussa streams. These streams are very close (<7 kilometers away from each other), share the same climatic conditions, but show a great difference in fine sediment amounts, because the first drains one of the most important mining areas of Western Alps while the second is almost pristine. We performed quantitative samplings on stream macroinvertebrate communities in both streams (see details in Bona *et al*., 2015). Here we present results from the application of a functional approach. Firstly, we considered the ratio between scrapers as a proportion of shredders plus total collectors. Considering quantitative data from the two lotic systems, mean values were 4.15 (±1.45 SE, standard error) in the clogged stream and 10.12 (±3.47) in the unaltered stream. Furthermore, we calculated the ratio between total shredders and total collectors: values were 5.62 (±1.69) for the Luserna and 22.7 (±4.27) for the Comba Liussa. In addition, if no threshold levels (Merritt *et al*., 2002) have been utilized here because of the novelty of this approach in Alpine and pre-Alpine Italian lotic systems, these values underline important changes in ecosystem attributes. In particular, we can hypothesize that anthropogenic siltation severely altered energetic inputs in the Luserna stream. The elevated amounts of fine sediments in the streambed resulted in a lower instream primary production, because of the reduced survival possibilities for periphyton, and in a lower CPOM availability, due to the increased homogenization of the substrate and the consequent reduction of the coarse allochthonous detritus retention. These important functional changes were well evidenced by the different FFG ratio we reported.

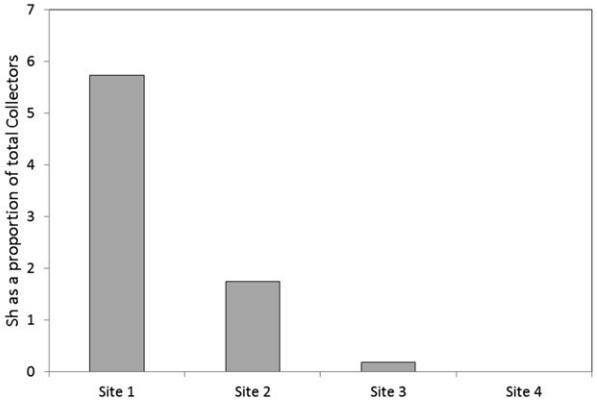

Fig. 2. Shredders as a proportion of total Collectors in the four sites of the Po River.

DISCUSSION AND CONCLUSIONS

This manuscript originates from the interesting oral communication of R. W. Merritt at the EEF 2015 Congress (Rome, September 2015) and successive conversations. The main purpose of this work is to encourage the evaluation of ecosystem attributes through the use of functional macroinvertebrate traits, in particular FFG ratios. At present, this functional approach has been rarely used in Europe and especially in Italy. This work aims to promote the use of this method, which has many advantageous applications.

Firstly, the functional group approach can be used to investigate ecosystem attributes in natural and in different kind of impacted systems. Applications can be made in the field of morpho-hydrological alterations, as shown here, or to assess ecological conditions of polluted rivers (Canobbio *et al*., 2010). This method can be applied to a wide range of river environments, across a broad geographic range. Moreover, this method provides information about ecosystem conditions that are often difficult or even quite impossible to measure directly. Finally, the dif-

fusion of quantitative surveys of benthic macroinvertebrate communities in Italy (and in the rest of Europe) after the compliance of the Water Framework Directive 2000/60 provides the availability of a vast amount of data, which can be easily analyzed through a ''functional lens", with the assignment of organisms to the different FFGs. In fact, as shown here, starting from macroinvertebrate quantitative data, appropriate functional traits can be assigned to each *taxon* and used, without problems, to evaluate ecosystem attributes.

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