Site selection for ecosystem metrics: Linking river metabolism to biological indicators

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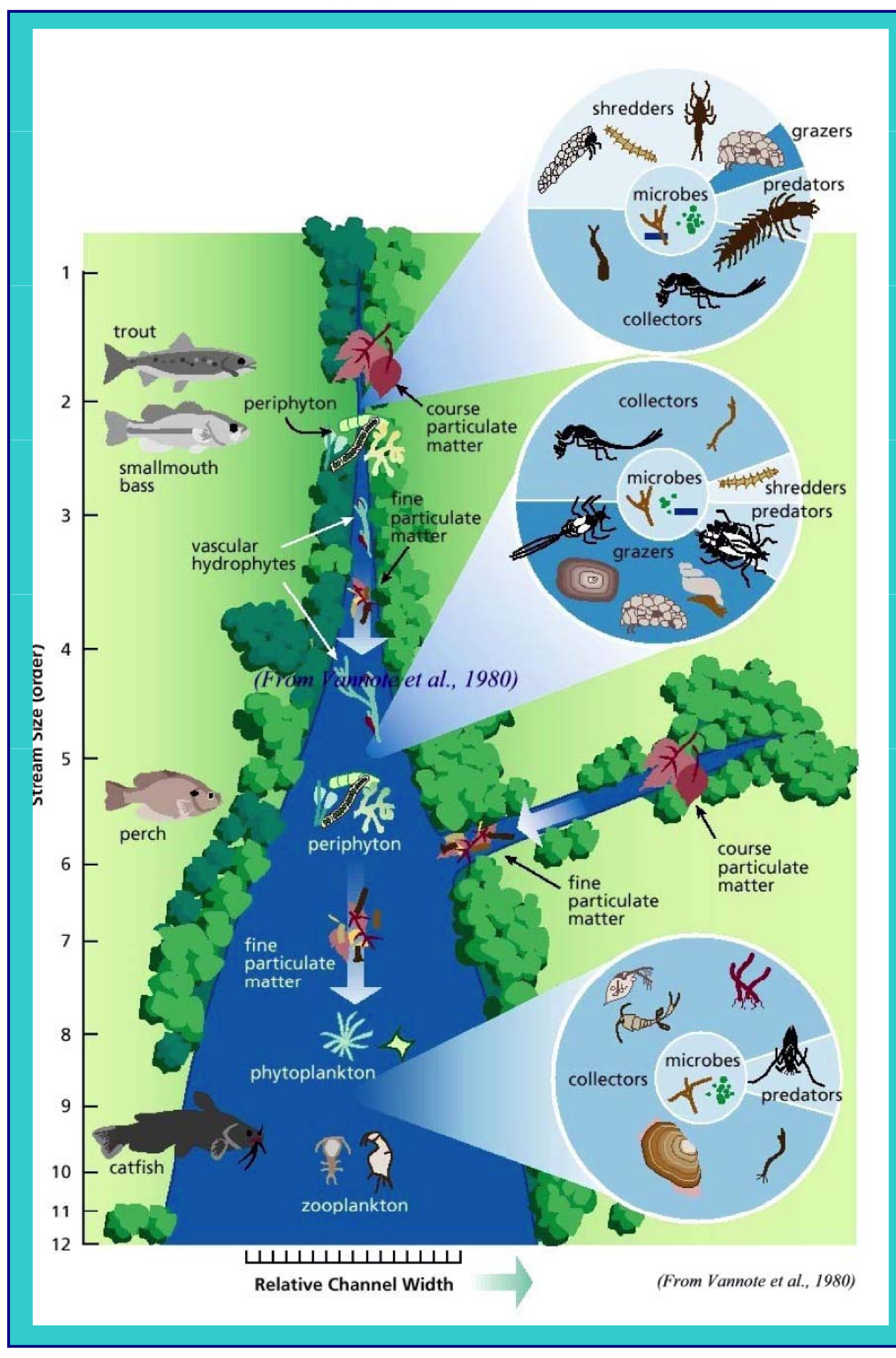

Introduction

The Water Framework Directive (WFD) requires the protection and restoration of aquatic ecosystems to at least a good status. The assessment of the status is traditionally done by physico-chemical and hydro-morphological factors supplemented by the taxonomic composition of pollution-sensitive aquatic organisms (namely invertebrates and algae).

Both, chemical and biological monitoring are instantaneous, parallel snapshots with rather high work effort and little connection to dynamic modelling tools. This approach disregards functional properties of the ecosystem processes such as gross primary productivity (GPP) and ecosystem respiration (ER). These metrics are essential indicators of river metabolism and thus ecosystem health / ecological status.

In this context, we suggest that the metrics employed within the scope of the WFD suffer from poor coherence regarding nutrient status and ecological indicators.

During a 2 year period, one focus within Action 3 “Monitoring design and implementation” of the M3-project is to bridge this gap, analysing (1) river metabolism measures (GPP, ER), (2) related physical and hydraulic properties, connected to (3) a community structures evaluation based on trophic relationships of macroinvertebrates structured by the functional feeding group (FFG; cf. tab. 1) approach.

The basic idea of overall approach follows the river continuum concept (Fig. 1), whose theory is based on the concept of a natural dynamic equilibrium of (1)-(3), with respect to stream size / order.

Fig. 1: The river continuum concept recapitulates longitudinal changes in carbon inputs and consumption from a first order stream to a large river. A low P/R ratio indicates that the majority of the energy supplied to the food web derives from autochthenous organic matter and microbial activity. A P/R ratio approaching 1 indicates that much more energy of the food web is supplied by primary production within the stream channel.

Hypothesis and methods

GPP and ER correlate well to water quality, namely nutrients. Our hypothesis is that we can relate nutrient loads, reflected in GPP and ER profiles, to specific community structures reflecting the ecological state characterized by the basic food resources available.

Upstream to downstream invertebrate food categories in river ecosystems are (a) CPOM, (b) FPOM, (c) periphyton and (d) prey to which the community structure is efficiently adapted through their morphology and behaviour. Roughly, shredders feed on (a) i.e. gammarids, different may- & stonefly larvae, collectors feed on (b) i.e. black flies, chironomids, nematodes and grazers (i.e. snails) feed on (c), predators ingest prey (cf. tab.1).

Following this approach, we might, for example, encounter a shift of typical headwater guilds (shredders and collectors) to typical lowland guilds (grazers) in a first order stream with increased nutrient levels.

The FFG approach categorizes the different morphological-behavioural adaptations to the available food and thus directly links geomorphic and associated biological changes with alterations due to human impact.

Tab. 1: General classification system for aquatic insect trophic relationships (mod. From Merritt and Cummins 1996 in: Howard and Lambert 2007)

Functional Group (based on feeding mechanism)	Subdivision of functional group: Dominant food	Subdivision of functional group: Feeding mechanism	Examples of taxa	Particle size range of food (mm)
Shredders	Live hydrophyte plant tissue	Herbivores - chewers and miners of live macrophyres		>1
	Decomposing vascular plant tissue and wood - coarse particulate organic matter (CPOM)	Detritivores - chewers, wood borers, and gougers	Plecoptera (stoneflies): Menouridae, Peltoperlidae Diptera (flies); Tipulidae Trichoptera (caddisflies): Limnephilidae, Lepidostomidae Amphipoda	>1
Collectors	Decomposing fine particulate organic matter (FPOM)			<1
Filtering collectors		Detritivores - filterers or suspension feeders	Trichoptera: Hydropsychidae Diptera: Simuliidae	<1
Gathering collectors		Detritivores - gatherers or deposit (sediment and surface films) feeders	Ephemoptera (mayflies): Ephemeridae Diptera: Chironomidae	<1
Scrapers	Periphyton - attached algae and associated material	Herbivores - grazing scrapers of mineral and organic surfaces	Trichoptera: Glossosomatidae Coloeptera (beetles):Psephenidae Ephemoptera: Heptageniidae	<1
Piercers - Herbivores		Herbivores - suck contents of algal cells	Trichoptera: Hydroptilidae	<1
Predators	Living animal tissue	Carnivores - attack prey, pierce tissue and cells, and suck fluids		>1
	Living animal tissue	Carnivores - ingest whole or part of animals	Odonata, Plecoptera: Perlidae Megaloptera: Corydalidae Sialidae	>1

GPP and ER are derived from diel O_2-concentration curves. The instrumental set-up consists of two continuously measuring oxygen probes which are exposed at a stream stretch distance of 100-300 m. The balance is made by difference. In addition, newly developed continuous probes for photometric measurement will allow for the observation of NH_4, NO_3 and PO_4 concentrations in the same time interval.

Site selection

The selection for river metabolism monitoring is done by statistical analysis of macroinvertebrate counts for which water quality data are available. Cluster analysis resulted in six clear groupings of organism assemblages (Fig. 3) which have been characterized by linking water quality, land use and geology. Fig. 3 maps the six clusters derived from averaged macroinvertebrate counts over several years (left) in comparison with averaged IGBN (French “Indice Biologique Global Normalisé”), an abundance and sensitivity weighted macroinvertebrate community index principally based on family level (right), which is applied in Luxemburg.

By comparing the 6 clusters, cluster 1 and 6 are the least impacted sites with low BOD_5, high dissolved oxygen, low nutrients, low turbidity and temperature, both predominantly located in the Oesling, in the north of Luxemburg. Clusters 4 and 5 are characterized by relatively high BOD_5, low dissolved oxygen, high ortho-phosphate and ammonium, all exclusively located in the mid and southern part of the country. Clusters 2 and 3 are “moderately impacted” sites in comparison to the previous ones and are distributed in the mid and northern part of the country. 12 sites distributed in the six clusters will be selected to investigate our hypothesis.

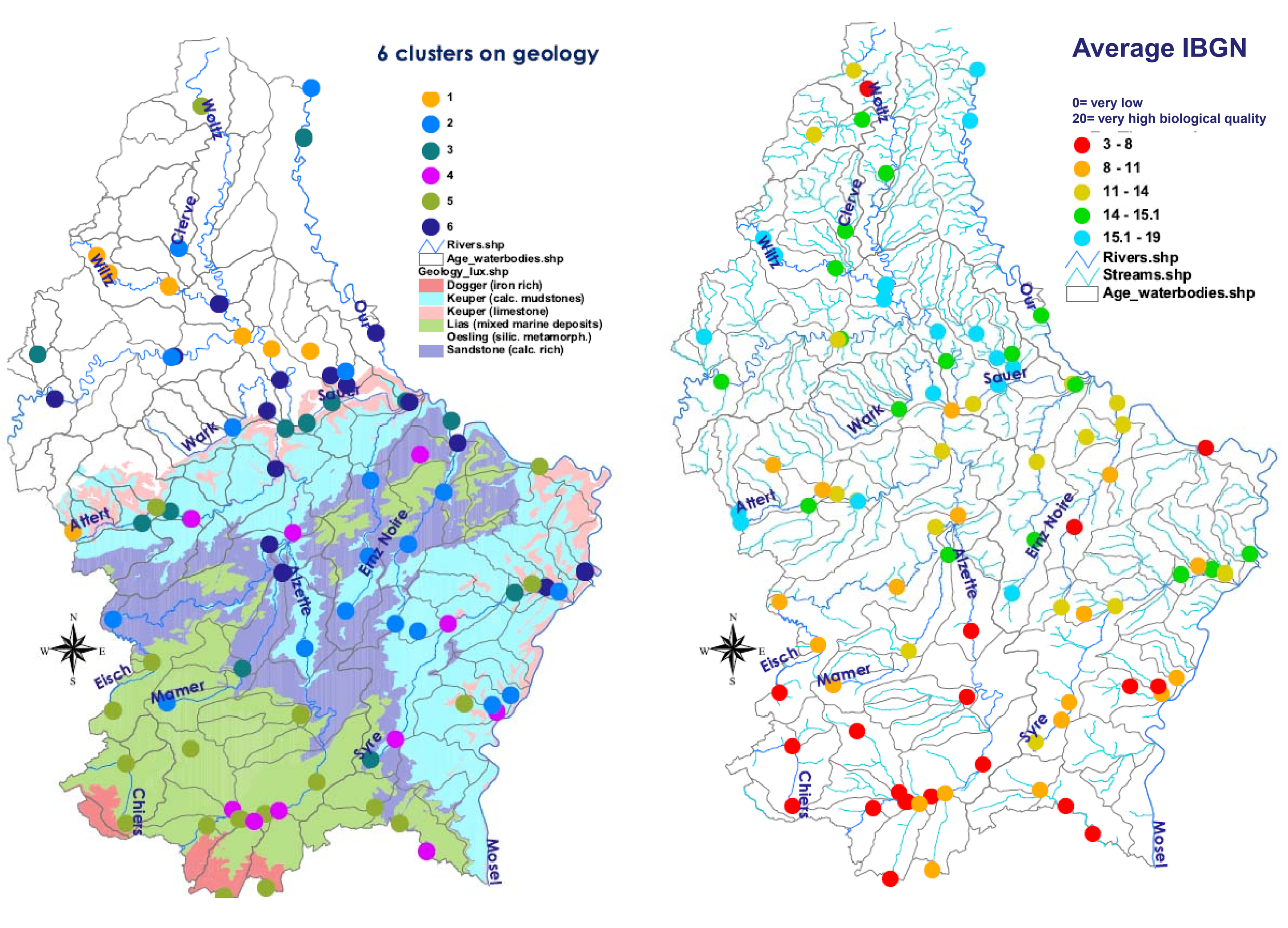

Fig. 3: 6 macroinvertebrate cluster groupings mapped on geology for Luxembourg, and average IBGN scores for the same data.

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