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Functional trait composition of aquatic plants can serve to disentangle multiple interacting stressors in lowland streams

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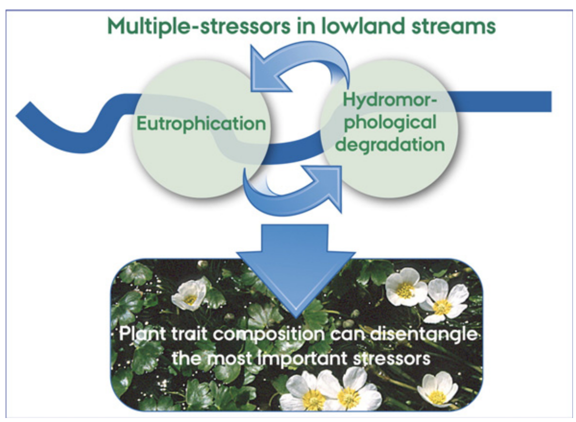
HIGHLIGHTS

- Functional trait composition of aquatic plants can distinguish hydromorphological degradation from eutrophication in streams
- A conceptual framework on how eutrophication and hydromorphological degradation interact on functional trait composition
- Weed cutting can set aside light as a factor controlling trait-abundance pattern in eutrophic lowland streams.

GRAPHICAL ABSTRACT



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ABSTRACT

Historically, close attention has been paid to negative impacts associated with nutrient loads to streams and rivers, but today hydromorphological alterations are considered increasingly implicated when lowland streams do not achieve good ecological status. Here, we explore if trait-abundance patterns of aquatic plants change along gradients in hydromorphological degradation and eutrophication in lowland stream sites located in Denmark. Specifically, we hypothesised that: i) changes in trait-abundance patterns occur along gradients in hydromorphological degradation and ii) trait-abundance patterns can serve to disentangle effects of eutrophication and hydromorphological degradation in lowland streams reflecting that the mechanisms behind changes differ. We used monitoring data from a total of 147 stream reaches with combined data on aquatic plant species abundance, catchment land use, hydromorphological alterations (i.e. planform, cross section, weed cutting) and water chemistry parameters. Traits related to life form, dispersal, reproduction and survival together with ecological preference values for nutrients and light (Ellenberg N and L) were allocated to 41 species representing 79% of the total species pool. We found clear evidence that habitat degradation (hydromorphological alterations and eutrophication) mediated selective changes in the trait-abundance patterns of the plant community. Specific traits could distinguish hydromorphological degradation (free-floating, surface; anchored floating leaves; anchored heterophylly) from eutrophication (free-floating, submerged; leaf area). We provide a conceptual framework for interpretation of how eutrophication and hydromorphological degradation interact and how this is reflected

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in trait-abundance patterns in aquatic plant communities in lowland streams. Our findings support the merit of trait-based approaches in biomonitoring as they shed light on mechanisms controlling structural changes under environmental stress. The ability to disentangle several stressors is particularly important in lowland stream environments where several stressors act in concert since the impact of the most important stressor can be targeted first, which is essential to improve the ecological status.

1. Introduction

Today, anthropogenic pressures related to agriculture are one of the main drivers of ecological deterioration of stream and river ecosystems, primarily through emissions of nitrogen and phosphorous, increased sediment load and hydromorphological alterations (Vörösmarty et al., 2010). Historically, close attention has been paid to negative impacts associated with nutrient loads to streams and rivers, but today hydromorphological alterations are considered increasingly implicated when lowland streams do not achieve good ecological status (EEA, 2012). Even though the importance of hydromorphological degradation is accepted as a major stressor, the ability to assess the level of hydromorphological impact on the biological communities is limited (e.g. Vaughan et al., 2009; Feld et al., 2014), and there is a clear need for improving our conceptual understanding of the underlying response mechanisms. One reason for the current limited knowledge could be that the high level of spatial and temporal variability characterising stream and river habitats makes it difficult to assess the hydromorphological impact at a scale relevant for the biological communities. At the reach scale, the biota responds to local hydromorphological features (i.e. the interaction between the flow of water and the channel form), but, additionally, disturbances occurring at larger spatial scales (stream network) (Poff, 1997) and even historical disturbances (Harding et al., 1998) can mask the effect of local factors on species composition (Poff, 1997; Kail and Wolter, 2013).

The majority of studies investigating the effects of hydromorphological degradation on biological communities have focused on species richness and/or multivariate descriptors of species composition (e.g. Hering et al., 2006; Dahm et al., 2013, but see also Feld et al., 2014, Elosegi and Sabater, 2013, and references therein). However, the taxonomic composition may differ between regions due to spatial constraints on community assemblies, making compositional approaches vulnerable to scale-dependent processes. Functional community characteristics have been suggested as an alternative or complement to compositional characteristics. Because the same traits (responding to similar environmental conditions) can be applied to most species in the world, functional composition is thought to be less vulnerable to scale-dependent processes (e.g. Dolédec et al., 2006; Friberg et al., 2011) than taxonomic composition. Additionally, traits provide a means to gain insight into the mechanisms mediating the response to natural and anthropogenic drivers of change (Diaz et al., 2007; Moretti and Legg, 2009).

Functional trait composition has recently proven useful to assess effects of eutrophication on aquatic plant communities in European lowland streams (Baattrup-Pedersen et al., in press). Clear indications exist that eutrophication promotes species that efficiently capture light by concentrating their photosynthetic active biomass near the water surface and species that utilise light efficiently. The mechanism behind these changes was suggested to be intensified competition due to enhanced aquatic plant growth, biofilm development and more turbid waters under nutrient-rich conditions. Here, we explore whether functional trait composition of the aquatic plant community can be used as a means to assess hydromorphological degradation as well. Currently, there is no comprehensive theory on how aquatic vegetation responds to hydromorphological degradation, but from ecological niche theory we expect that significant changes occur (Southwood, 1988). As aquatic vegetation is known to exhibit preference for and adaptation to substrates, current velocities and depths (Dawson et al., 1999; Baattrup-Pedersen and Riis, 1999; Gurnell et al., 2010; Puijalon et al., 2011), we expect that channelisation (e.g. deepened, widened and straightened; Brookes and Gregory, 1983; Brookes, 1987; Mattingly et al., 1993; Verdonschot and Nijboer, 2002; Landwehr and Rhoads, 2003) will restrict the niches available for aquatic plants. In particular loss of pool–riffle sequences in channelised streams implies that the habitats that predominate are generally deeper and flow velocities higher and, at the same time, flow patterns, substrate conditions and depth characteristics get more uniform (Baattrup-Pedersen and Riis, 1999; Rambaud et al., 2009). Consequently, channelisation likely affects the presence and distribution of different plant life forms. For example, the abundance of submerged species is likely to be higher in channelised streams because these species may bend, thereby mitigating the increase in drag at higher velocities compared to emergent species (Brewer and Parker, 1990; Schutten and Davy, 2000). Furthermore, species that have their biomass distributed evenly in the water column experience lower drag than species that have their biomass in high-velocity areas near the surface (Bal et al., 2011).

Active maintenance of the channelised stream profile by dredging and mechanical removal of the vegetation by cutting, as performed regularly in many lowland streams today (for instance Fox and Murphy, 1990; Kaenel and Uehlinger, 1999; Vereecken et al., 2006; Baattrup-Pedersen et al., 2009; Wiegleb et al., 2014), may also affect the functional traits composition of the aquatic plant community. Dredging is a very dramatic form of disturbance that can remove all vegetation and reset the community (Wade and Edwards, 1980; Wade, 1993). In cases where the channel bed is only superficially scrapped, overwintering propagules may be left in place, whereas a more profound removal of the bottom sediments may affect also the overwintering organs. In regularly dredged streams we may therefore expect that traits related to species dispersal and establishment may be of overriding importance for community composition. Effects of weed cutting has particularly been studied in cases where single species have been implicated in blocking channels (Dawson, 1989; Dawson, 1976; Pitlo and Dawson, 1990; Kern Hansen and Dawson, 1978), whereas studies on the effects of cutting on community composition are scarce and geographically restricted (Baattrup-Pedersen et al., 2002; Baattrup-Pedersen et al., 2003; Baattrup-Pedersen and Riis, 2004). However, weed cutting can be compared to grazing and expectedly has a similar selective pressure favouring species that recover fast, i.e. those with intact growth meristems following cutting (Baattrup-Pedersen et al., 2002; Wood et al., 2012).

To investigate how hydromorphological degradation and eutrophication affect plant trait composition we have examined how traits related to morphology, dispersal, survival and the ecological preferences of the species vary along gradients in the impact of these stressors in lowland streams in Denmark. Specifically, we hypothesised that: i) changes in trait-abundance patterns occur along gradients in hydromorphological degradation and ii) trait-abundance patterns can be used to identify the main stressor in lowland streams, for instance high abundance of species that efficiently capture or utilise light indicates that the main stressor is related to eutrophication (see Baattrup-Pedersen et al., in press), whereas these traits will be subordinate in streams where the main stressor is related to hydromorphological degradation, reflecting that weed cutting improves light availability and therefore the light climate in eutrophic streams.