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Linking classification boundaries to sources of natural variability in transitional waters: A case study of benthic macroinvertebrates

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ABSTRACT

The assessment of human impacts on aquatic ecosystems requires separate quantification of natural and anthropogenic sources of environmental variability. This statement is very challenging in some categories of water bodies such as transitional waters, because they are naturally stressed ecosystems in which natural variability occur on different spatial scales (gradients versus patchiness) and temporal scales (regular versus pulse events).

Among transitional water quality elements, benthic macroinvertebrates are the most exposed to natural variability patterns due to their life cycles and space-use behavior. In this article, we have evaluated the relevance of different potential sources of natural variability of benthic macroinvertebrate guilds on the temporal and spatial scales and we have quantified their effects on simple and multimetric descriptors of macroinvertebrate guilds; the latter included biomass and numerical densities, taxonomic diversity as well as M-AMBI and index of size spectra, ISS. The study was carried out using the TWReferenceNET database of 14 Eastern Mediterranean and Black Sea lagoons. Synoptic sampling of benthic macroinvertebrates was performed seasonally in different habitats within each lagoon in accordance with a nested design. All considered metrics showed a relatively high degree of variability among different reference stations and ecosystems, with the coefficient of variation ranging from 20% (log numerical density) to 45% (M-AMBI). The average values of every metric were significantly affected by the considered natural sources of variation: lagoon typology, seasonal period and habitat patchiness. Among components of lagoon typology, water salinity influenced the most the variation for both simple and multimetric descriptors. Seasonal period also had a strong influence, with higher values for all metrics before the summer season compared to the one after summer. Benthic habitat patchiness had a considerable influence only on the simple metrics, while continuous habitat variables significantly affected both M-AMBI and ISS. A general mixed model approach, used to quantify the relative influence of the different sources of variation on the considered metrics, allowed calculating type-specific boundaries for M-AMBI and ISS. The new boundaries significantly improved the accuracy of both multimetric indices in the classification of studied reference condition sites, with more than 75% of stations classified as good or high status. Nonetheless, results show that there is an intrinsic uncertainty in the classification of ecological status of lagoon ecosystem due to the degree of variability under reference conditions.

1. Introduction

Ecological status and ecosystem health are closely related ecosystem properties, which incorporate energy flow, organization and stability (e.g., Costanza, 1992) and vary with changes in endogenic managed pressures and exogenic unmanaged ones (Elliot, 2011), including changes in energy flows. On the other hand, the assessment of ecological status and ecosystem health is generally based on the properties of individuals, populations or communities, which are deeply dependent on the structural abiotic components of ecosystems and, consequently, vary on both spatial and temporal scales, according to the filtering effect of both abiotic and biotic ecosystem components (Zobel, 1997). Individual and population properties include functional traits (McGill et al., 2006), among which body size has a paramount importance (Brown et al., 2004; Basset and De Angelis, 2007). Therefore, decoding ecological status, as an ecosystem level property, from measurable properties of individuals and populations is a key challenge of the scientific research

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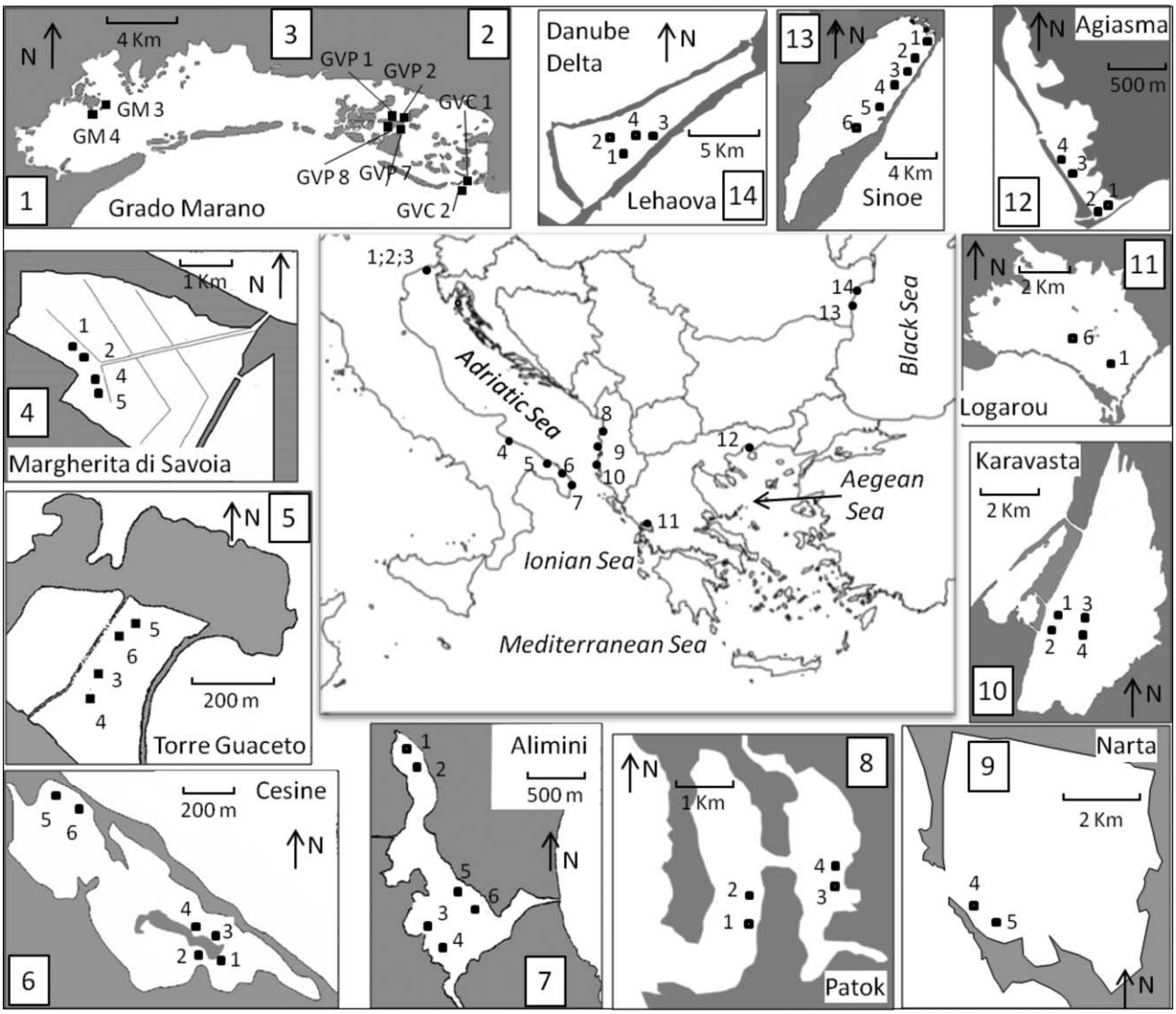

Fig. 1. Geographical distribution of the fourteen transitional waters ecosystems, listed as in Table 1 from 1 to 14.

(Basset, 2010) and requires accounting for the natural variability of low hierarchy ecosystem components (Neto et al., 2010).

In Europe, the concepts of Typology and type-specific Reference Conditions specifically consider the natural variability of individual, population and community properties, following the European legislation, which addresses the conservation and recovery of good ecological status of all aquatic ecosystems in Europe [Water Framework Directive (WFD), European Commission 2000/60, 2000].

In this study we focus on Eastern Mediterranean and Black Sea lagoons, which are one geo-morphologically defined type within the Transitional Water category in the frame of WFD. Lagoons are defined as 'shallow coastal water bodies separated from the ocean by a barrier, connected at least intermittently to the ocean by one or more restricted inlets, and usually oriented shore-parallel' (Kjerfve, 1994). They are characteristic of coastal areas with low tidal excursion (generally micro- tidal or non-tidal, *sensu* Basset et al., 2006) and receive little direct freshwater discharge.

Benthic macroinvertebrate taxa are known to be sensitive to different sources of abiotic heterogeneity in lagoon ecosystems, such as water salinity (Guelorget and Perthuisot, 1983; Cognetti and Maltagliati, 2000), sediment granulometry and composition (Teske and Wooldridge, 2003; Reizopoulou and Nicolaidou, 2004) and type of vegetation (Diehl and Kornijòw, 1998; Arocena, 2007). Lagoon surface area (Sabetta et al., 2007) and lagoon hydrology (Barbone and Basset, 2010) also influence species richness and diversity in lagoon ecosystems. Similarly, individual body size in benthic macroinvertebrates is known to be affected by different sources of lagoon heterogeneity, such as salinity (Barbone et al., 2007), sediment composition (Basset et al., 2008), and lagoon surface area (Sabetta et al., 2007), even though body size spectra have a higher degree of invariance than taxonomic composition (Basset et al., 2004). Nevertheless, few attempts have been made to quantify the natural variability of benthic macroinvertebrate guilds (Irvine, 2004; Neto et al., 2010), particularly in lagoon ecosystems.

Current knowledge of the natural variability of both taxonomically based and non-taxonomically based (mainly rely on individual phenotypic traits such as body size) macroinvertebrate indices (Mouillot et al., 2006) for the classification of lagoon ecological status is also scarce.

In this study, we perform a quantitative analysis of the natural variability of benthic macroinvertebrate guilds in lagoon ecosystems. Macroinvertebrate guilds are described with reference to simple metrics (numerical density, biomass density and the Shannon diversity index), and multimetric indices [M-AMBI (taxonomically based) and ISS (non-taxonomically based)]. The paper has two main aims: