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Review

The use of multiple biological traits in marine community ecology and its potential in ecological indicator development

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ABSTRACT

Biological traits offer valuable approaches to understand species distributions and underlying mechanisms. Their use has received a growing interest in marine community ecology, for both fundamental and applied purposes. The need of ecological indicators as part of marine directives and conservation programmes has promoted the use of multiple traits for indicator development, but in a questionable context regarding the state of fundamental developments. Biological Trait Analysis (BTA) is a complex research field, characterised by flexible concepts and applications. In order to enhance the development of relevant marine ecological indicators, this review provides baselines for better theoretical and applied BTA. A compilation of the existing literature reveals that specific topics have dominated the use of multiple traits in marine ecology unlike in freshwater and terrestrial ecology where tests of theories and uses of evolutionary concepts consistently preceded BTA applications. Availability of data sets and analytical techniques seemed to have driven the growing use of marine BTA rather than fundamental questions regarding life history theories in marine ecosystem components and the functional nature of traits. It is therefore suggested that greater focus on life history ecology and on the links between marine species traits and ecosystem functioning are still needed to support trait-based indicator development. Life history strategy understanding is put forward as a theoretically-sound basis and fundamental pre-requisite for trait-based marine indicator development.

Contents

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1. Introduction

Biological traits are characteristics of species life history and are generally used to understand the structure and dynamics of ecological communities (Dray et al., 2014). Until fifteen years ago, ecologists were still debating the fundamental and applied research potentialities of community ecology (Lawton, 1999; Simberloff, 2004). The complexity of biotic interactions and biology among species in communities were thought to be major obstacles to generate ecological laws. Although analytical techniques were sufficiently sophisticated to detect multiple gradients in ecosystems (Dolédec and Chessel, 1991; Gauch, 1982), correlations between species distributions and habitat characteristics had limited potential for mechanistic understanding of ecological patterns since analyses based on taxonomic grounds alone do not provide confirmation of assembly rules independent of species biology (Fleishman et al., 2006; Statzner et al., 1994). Species assemblage distributions are only patterns, and patterns are phenomena arising from unknown mechanisms, a mechanism being a comprehensive interplays between variables (Rosenzweig and Ziv, 1999). Biological traits can be used to understand why different taxonomic entities (e.g. species, genera) occur in similar habitats (Dolédec et al., 1996; Dray and Legendre, 2008; Keddy, 1992; Legendre et al., 1997), as organism performances result from common adaptations to environmental forces (Greenslade, 1983; Southwood, 1988). Hence, the use of multiple traits, as variables describing species performances, enable to generate laws, patterns with mechanisms, and consequently can support the development of theoretically-sound applications.

Incorporation of biological traits in community ecology gained momentum in terrestrial and freshwater research (Bonada et al., 2006; Statzner and Bêche, 2010). Increased biological knowledge and better computational tools have since triggered the development of trait-based frameworks that were used both in theoretical studies (Statzner et al., 1994) and for practical monitoring requirements (WFD, 2000; Bonada et al., 2006; Furse et al., 2006; Dolédec and Statzner, 2008). The growing success of Biological Trait Analysis (hereafter "BTA") has given a new impetus to community ecology, and it has even been suggested to rebuild the discipline based on BTA when studying large sets of species (McGill et al., 2006). Currently, the use of biological traits to understand natural community assembly patterns has become standard practice, as well as to support management tools in ecosystems undergoing adverse effects of human impacts (de Bello et al., 2010; Resh and Rosenberg, 2010; Statzner and Bêche, 2010).

More recently, traits have been used in the development of functional diversity indices, enabling the description of the dynamics of ecological niches (Mason et al., 2005). Although such indices have been shown to be a potentially promising tool to identify ecological impacts of disturbances (Mouillot et al., 2013b), their use will not be discussed in this review as traits are not directly expressed in the procedure, which rather uses traits to indirectly separate the different facets of ecological niches. For a complete review on this topic, see Mason et al. (2005), Villéger et al. (2008), Mouchet et al. (2010), and Mouillot et al. (2013b).

These last years, the use of biological traits has received a growing interest in marine ecology as a means to improve the understanding of marine ecosystem functioning, which is still relatively limited relative to that in terrestrial ecosystems (Heip, 2003). In parallel, multiple human pressures are exerted on the marine environment so that growing demands from marine directives and conservation programmes are enhancing the need of ecosystem understanding and reliable indicators of environmental health (Bremner, 2008). To this end, the use of multiple traits in the marine environment has been claimed to have many application potentials (Bolam, 2013; Bremner, 2008; King and McFarlain, 2003; Rijnsdorp et al., 2016; Tillin et al., 2006), but a theoretically-sound basis for this needs further development (Kershner et al., 2011). Using biological traits to this end requires firstly an understanding of life history in marine habitats. In other words, this means that empirical models validated in given areas can be generalized to other areas if the identified mechanistic relationships between environmental conditions and subsequent species adaptations are conserved (i.e. absence of biogeographic contingencies). The debate in terrestrial and freshwater ecology has significantly advanced as has the understanding of habitat-species and community relationships in a way able to guide environmental management (de Bello et al., 2010; Menezes et al., 2010; Resh and Rosenberg, 2010). In the marine environment, greater challenges to sampling, observation and manipulation of natural assemblages' means, from first principles, that our stride has been shorter, and the present understanding of the mechanisms driving marine habitat-community relationships, as derived from biological traits, lags behind.

Monitoring environmental health is constrained by ecosystem complexity (e.g. several tens of species), whereas only a reduced set of variables can be technically handled for assessment. Ecological indicators, by relaying and/or summarising complex fluxes of information, aim to provide a more practical and economical way to track the state of the environment. Though they have been more frequently explored in the academic community, there is at present almost no concrete multivariate application of biological traits to support environmental policies. In this domain, most uses are limited to individual (Bolam et al., 2014; Greenstreet et al., 2012), or few traits, such as feeding and bioturbation (Rijnsdorp et al., 2016; Jennings et al., 1999). Though these are important traits mediating specific ecosystem processes (e.g. benthic-pelagic coupling, trophic linkage), we have a limited understanding of underlying pressure impact and recovery mechanisms on the biota. As traits represent the link between life-history and habitat, there is clearly potential to explore multiple trait approaches in support of marine management and policies aimed at curbing human impact on the marine environment.

The literature in marine ecology has been largely enriched with BTA these last years; synthesis is presently lacking, both assessing the present state of the art and to guide future research. The aims of this review are (1) to provide an explicit description of the nature of biological species traits to support the conceptualisation of fundamental and applied uses; (2) to list key developments to assess current knowledge gaps among the different ecosystem components; (3) to review the technical uses in order to (4) provide a framework toward the development of sound, multiple trait-based marine indicators.