Doctoral Thesis

Individual-level trait diversity in photosynthetic organisms and its implications for ecosystem functioning

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INDIVIDUAL-LEVEL TRAIT DIVERSITY IN PHOTOSYNTHETIC ORGANISMS
AND ITS IMPLICATIONS FOR ECOSYSTEM FUNCTIONING

A thesis submitted to attain the degree of

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presented by

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SUMMARY

It is increasingly recognised that traits, rather than species identities, should be considered as the fundamental feature of communities when it comes to understanding their responses to environmental change, their dynamics and influence on ecosystem processes. As a consequence, in the last years trait-based approaches have become more and more popular, and many trait diversity metrics have been proposed to study community assembly and dynamics. Traits are ideally defined by phenotypic features of individual organisms, still almost all trait diversity metrics have been designed for the use of species mean traits. However, as phenotypic traits determine the fitness of individuals and intraspecific trait differences have consequences that propagate to higher biological organisation levels, the lack of consideration of individual-level variation has no apparent justification other than the technical difficulty of measuring it.

Phytoplankton are a common model system in community ecology, since the traits that define their ecological interactions are well studied, and they are a key component (primary producers) in pelagic aquatic ecosystems. Recent developments in the application of scanning flow-cytometry permit highfrequency monitoring of phytoplankton communities, focal functional traits at the individual level and fluctuating aquatic small-scale environments, and thus fit the temporal and spatial scales that are relevant for their dynamics (Chapter 1). Given these premises, the time is ripe for a major step forward represented by the extension of trait-based ecology towards individual-level dynamics.

Defining individuals as the fundamental unit of investigation imposes a careful consideration of the unique features of individual-level trait data, which affect both the calculation and interpretation of trait diversity metrics. Chapter 1 offers a review of published metrics, which were evaluated based on methodological and ecological criteria to assess their suitability for application in an individual-based context. In Chapter 2, the best candidate metrics were tested through manipulation of both artificial and real phytoplankton data, and a set of indices covering the three independent components of trait diversity (richness, evenness and divergence) was validated, including two indices developed during this thesis. In Chapter 3, the above set of individual-based trait diversity indices was compared next to species richness and evenness for their ability to explain changes in phytoplankton biomass and resource use efficiency in several European lakes. Even spacing of individuals along multiple trait axes defined by shape, structure and fluorescence profile (obtained by scanning flow-cytometry) was the strongest predictor of the measured ecosystem properties. The negative relationship between even trait spacing and biomass suggested that the concept of limiting similarity might apply also to individual organisms, which could tend to maximize their phenotypic differences to reduce competition due to resource limitation. In Chapter 4, we found strong experimental evidence for the validity of this hypothesis in light-limited phytoplankton laboratory populations.

This thesis demonstrated that individual-level trait variation is an important component of the biodiversity of natural communities of phytoplankton, that can advance our comprehension of community interactions and ecosystem processes, and should be carefully considered in future research aimed at understanding and predicting the dynamics of plankton (and possibly other natural systems). This conclusion was supported in this study by a combination of theoretical work, surveys of the natural environment and experimental hypothesis testing.
questa tesi di dottorato, è stato validato. Nel Capitolo 3, il soprammenzionato gruppo di indici di diversità dei tratti individuali, il numero di specie e l'equitabilità sono stati confrontati sulla base della loro abilità nello spiegare cambiamenti nella biomassa di fitoplancton e nella sua efficienza di utilizzazione delle risorse in diversi laghi europei. La regolarità dello spaziamento tra individui lungo assi multipli definiti da forma, struttura e profilo di fluorescenza (ottenuti tramite citofluorimetria a flusso) si è dimostrata la più importante variabile esplicativa delle proprietà dell'ecosistema misurate. La relazione negativa tra la regolarità dello spaziamento nei tratti fenotipici e la biomassa ha suggerito che il concetto di “limiting similarity” possa essere applicato anche a singoli organismi, che potrebbero tendere a massimizzare le loro differenze fenotipiche per ridurre la competizione, a causa di una limitazione delle risorse disponibili. Nel Capitolo 4 abbiamo ottenuto una solida evidenza sperimentale della validità di questa ipotesi in popolazioni di fitoplancton cresciute in laboratorio in condizioni di limitazione della luce.

Questa tesi ha dimostrato che la variazione dei tratti fenotipici a livello individuale è un'importante componente della biodiversità delle comunità naturali di fitoplancton, che può far progredire la nostra comprensione delle interazioni nelle comunità e dei processi degli ecosistemi, e dovrebbe essere considerata con attenzione nella futura ricerca tesa alla comprensione e previsione delle dinamiche del fitoplancton e (possibilmente di altri sistemi naturali). Questa conclusione è stata supportata in questo studio da una combinazione di lavoro teorico, rilevamenti dell'ambiente naturale e verifica sperimentale di ipotesi.