

Limnology in the 21st century: the importance of freshwater ecosystems as model systems in ecology and evolution

Angela BOGGERO, Diego FONTANETO, Giuseppe MORABITO, Pietro VOLTA

CNR Institute of Ecosystem Study (ISE), Largo Tonolli 50, 28922 Verbania Pallanza, Italy

ABSTRACT

In 1990, in order to celebrate the 50th anniversary of the former Italian Institute of Hydrobiology, now Institute of Ecosystem Study, a special issue summarising the advances in limnology was published by Memorie dell'Istituto Italiano di Idrobiologia, now Journal of Limnology. After 25 years, it is time again for a synthesis of what limnology did in the past, but mostly for suggestions on widening the horizon of the discipline, by including new tools and techniques. We hope that limnology will live long, and we celebrate the 75th anniversary of the Institute with this special issue, containing manuscripts on the advances in the field and introducing recent and new lines of research in lentic waters studies.

Key words: aquatic ecology, freshwater, review.

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INTRODUCTION

Advancements in science operate in a complex way, with sudden paradigm shifts more than as a linear accumulation of knowledge and wisdom. Thus, the aim of this volume is twofold: on one hand we want to work on the linear accumulations, by reviewing of the state of the art and points of view to summarise the foundations of what has been done in the different aspects of limnology; on the other hand, we want to help directing the future shifts in limnology, with scientists from other disciplines providing their external advice to describe how new tools, methods, technologies and paradigms may change the way limnologists work.

The rationale for the existence of the volume, celebrating the 75th anniversary of the Institute of Ecosystem Study (former known as Italian Institute of Hydrobiology) located in Verbania Pallanza, is that limnology has been important in the development of several ecological aspects, and still has many suggestions to offer. Limnology is the study of inland waters, but given that historically the Institute focused on lentic systems such as lakes and ponds, this celebratory volume will focus mostly on such habitats. Once a fundamental part of ecological studies, limnology has experienced a failure to keep up with the moving scientific trends. Limnologists were among the leading names in ecology (*e.g.*, Margalef, Edmonson, Hutchinson): most of their studies on plankton and eutrophication lead to the developments of current ecological sciences and tracked the ways towards new visions and approaches (*e.g.*, Reynolds, Peters, Harris). Nowadays, lakes and ponds may still be exploited to advance science. They could be used as model systems, for bio-manipulation experiments, for their high local biological

diversity and, thanks to the availability of many long-term data series, for their response to environmental changes, and for everything we learned from polluting and recovering them. The rationale of this volume is to deal with these problems, in order to give limnology its important place in science again.

Other reviews and special volumes on limnology exist: *e.g.*, in 2000 a new journal, *Limnology*, started with three reviews on limnology, its state and the future directions: <http://www.springerlink.com/content/1439-8621/1/1/>. In 2008, *International Review of Hydrobiology*, published a celebratory volume focusing mostly on paradigm shifts in freshwater ecology: <http://onlinelibrary.wiley.com/doi/10.1002/iroh.v93:4/5/issuetoc>. The novelty of the current special issue is in the interaction between limnology and other disciplines. Our hope is that, by doing so, we will be able to show how limnology can help the general advancement of science, by building on previous experiences and by going a step further.

THE SPECIAL ISSUE

The structure of the special issue mirrors the rationale explained above. There are three main parts. The first one can be seen as a general introduction to the second one dealing with relevant cross-cutting themes in relation with other disciplines. The last one is devoted to the contribution that other disciplines can provide to the advancement of limnology.

The first part, introducing the topic, is composed of three papers. The current paper provides the structure; the second one (Manca and Bertoni, 2014) highlights the importance of the Institute in the field of limnology, span-

ning through the many topics characterising the research efforts since the Institute's foundation and showing the leading role of the former Istituto Italiano di Idrobiologia in developing the limnological science since its early stages. The third paper (Jenkins, 2014) provides a provocative view on the failures of limnology and the attitude of limnologists by reviewing literature, by performing meta-analyses, and by highlighting idiosyncrasies on how limnology is taught during university courses and is practised as a research field.

The second part deals with a series of 10 papers reviewing what the study of lakes and ponds achieved in the advancement of the scientific understanding of our changing world. Within this idea, two main groups of manuscripts are present: those showing how the results of studies on lentic waters are directly connected to broader fields, and those focusing on freshwaters to fully understand these systems.

The first group of manuscripts in the second part spans different fields such as evolution (Merilä, 2014), macroecology and biogeography (Hortal *et al.*, 2014), community ecology from the point of view of neutral theory (Gravel *et al.*, 2014) and of niche partitioning (Salcher, 2014). As regards evolution, Merilä (2014) discusses parallel phenotypic evolution through parallel or convergent genetic changes focusing particularly on freshwater fish populations. For macroecology and biogeography, Hortal *et al.* (2014) points out that terrestrial environments are much more studied, although freshwater systems could be equally if not even better suited for research on these topics, and discuss the interactions between limnology and macroecology. Gravel *et al.* (2014), using empirical data and simulations in the framework of the neutral theory, provide convincing arguments that limnologists, and ecologists in general, need to integrate more realistic scenarios, when analysing community assembly. A different focus on communities is provided by Salcher (2014), where lacustrine species assemblages of prokaryotes are used as a model to disentangle the contribution of limiting resources (bottom-up control) and mortality factors (top-down control).

The second group of papers addresses several topics that represent threats or are important for lakes and ponds, including climate change (Jeppesen, *et al.* 2014), biological invasions (Drake *et al.* 2014), habitat conservation (Winfield, 2014), sustainable fishing (Kolding and van Zwieten, 2014), and paleolimnology (Whitmore and Riedinger-Whitmore, 2014). Climate change may have profound impacts on freshwater systems, and Jeppesen *et al.* (2014) address this issue reviewing the strengths and weaknesses of the multi-faceted approaches that are presently available for elucidating the effects of climate change in lakes. Biological invasions are another threat to the biological integrity of aquatic ecosystems, and Drake *et al.* (2014) suggest to test for the effect of propagule and colonization pressure, determining the underlying statistical species abundance distribution for zooplankton assemblages transported between freshwater ecosystems.

Threats to biological conservation are not limited to these two aspects, and Winfield (2014), in reviewing such issue, provides a positive view for the future, especially because conservation priorities enter the political agenda of nearly all governments. In line with a more widespread public awareness of biological problems, Kolding and van Zwieten (2014) provide a positive feedback on the future sustainable use of fisheries, focusing on the concept and examples of balanced harvest. Studies and forecasts on biological conservation are based on previous knowledge, mostly based on paleoecological reconstructions and on analyses of long-term data series, whereas Whitmore and Riedinger-Whitmore (2014) discuss the integration of paleolimnology and ecology for a more comprehensive overview.

The third part, considering the new tools that could be used to get new insides into limnological research, is composed of five papers. The first one highlights a series of advances in the available statistical toolboxes that would be of great help to limnologists (Beckerman, 2014). Boukal (2014) convincingly demonstrates the usefulness of the analyses of species functional traits, on a more specific topic, such as the study of biotic interactions in aquatic communities; Vamosi (2014) introduces the application of phylogenetic information to study the mechanisms maintaining long-term co-occurrence of plankton; De Meester and Pantel (2014) review the recent development of the paradigm of eco-evolutionary dynamics in freshwater systems, highlighting achievements and pointing to remaining challenges. As a final paper, Giardino *et al.* (2014) provide a review of optical satellite remote sensing as an opportunity to integrate traditional methods for assessing water quality of lakes.

THE CHALLENGE

Limnology is a multidisciplinary science, and the broad research themes covered by this special volume clearly show that limnology is not a dead-end in ecological research. Our hope is that the different approaches gathered in this volume will be beneficial to our readers, and that at least some of them will find new insights and will improve the way they work, thanks to what they found in these pages. Of course, we also hope that the next special issue for the Centenary of the Institute of Ecosystem Study will find a strong starting point in this volume, as we did find it in the previous special issue for the 50th anniversary.

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