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Editors:
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UNIVERSITY OF TRENTO - Italy

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Table of contents

Preface 9

Committees 10

Keynote lectures 11

A. Lorke, J. Kreling, L.N. Wickramarathna, C. Noss, D.F. McGinnis
Vertical Transport at Biogeochemical Interfaces in Lakes 12

N. Salmaso
Scale-dependent relationships between climatic fluctuations and development of toxic cyanobacteria in large lakes 14

Extended abstracts 17

E. Bertone, R.A. Stewart, H. Zhang, K. O'Halloran
Modelling climate and storage volume influences on a subtropical reservoirs' circulation characteristics 18

B. Boehrer, L. Golmen, J. E. Løvik, K. Rahn, D. Klaveness
Thermobaric stratification in very deep Norwegian fjord lakes 20

D. Bouffard, R. Schwefel, A. Gaudard, U. Lemmin, A. Wüest
Process-based modelling of Lake Geneva 22

L. Carniello, A. D'Alpaos
Sediment dynamics in shallow micro-tidal environments 24

S. Cosoli, F. Capodici, G. Ciraolo, A. Drago, A. Maltese, M. Gacic, C. Nasello, J. Azzopardi, A. Gauci, P. Poulain, G. La Loggia
CALYPSO - an operational network of HF radars for the real-time monitoring of surface currents in the Malta-Sicily Channel 26

R. Cossu, A.L. Forrest, P. Stumpner, H. Roop, G.B. Dunbar, R.H. Levy, M.J. Vandergoes, S.G. Schladow
Observations of Turbidity Currents and Internal Waves in Lake Ohau, South Island, New Zealand 28

E. Debolskaya, G. Saminski
The analysis of turbulent structure of Ivankovskoye Reservoir (Russia) 30

C. Engelhardt, G. Kirillin
The duration of summer stratification - routine temperature measurements in two dimictic lakes of Northern Germany 32

A.L. Forrest, T.J. Mathis, M.E. Wittmann, S.G. Schladow
Critical bed shear for passive transport of a benthic bivalve 34

G. Gavrilenko, G. Zdorovennova , R. Zdorovennov, N. Palshin, S.Golosov, A. Terzhevik
Optical properties of Lake Vendyurskoe: ice-covered period and open water 36

K. Graves, A.L. Forrest, B.E. Laval, G. Kirillin
Under-ice, basin-scale circulation in an Arctic lake 38

Scale-dependent relationships between climatic fluctuations and development of toxic cyanobacteria in large lakes

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Large lakes; climatic fluctuations; teleconnection indices; toxic cyanobacteria; selective adaptation

EXTENDED ABSTRACT

Introduction

The effects of climatic fluctuations on aquatic communities are strongly dependent on the temporal scales and the ecological characteristics of species. Meteorological fluctuations at the weekly and monthly scales affect the short-term dynamics of living organisms. With long-term temporal scales, climate change causes alterations in the physics, chemistry and biology of lakes, affecting ecological processes and life cycles, with the potential of causing the disappearance of autochthonous species and the introduction of alien organisms. Further, the effects are strongly dependent on the physiographic characteristics of water bodies. The complexity of interactions and the implications of climate change and physiographic features on the lake functioning mechanisms are not always simple to recognise, requiring a wide approach, able to overcome the classical disciplinary academic barriers. In this review, we will report a few examples highlighting the strict coupling between the physical environment (climate and morphometric features) and the development of cyanobacteria (both at the population and genotypic level) in deep and large lakes. Examples will include the effects of the winter climate on the development of summer cyanobacteria in Lake Garda, and the selection of specific strains adapted to lakes of different depth (i.e. with gas-vesicles of different strength). Both processes are mediated by fluctuations in the deep mixing regimes.

Materials and methods

The experimental setup has been described in D'Alelio et al. (2011) and Salmaso et al. (2014). In the southern subalpine and Mediterranean regions the winter climate can be effectively summarized by the East Atlantic pattern measured between December and February (EA_{DJF}) (Salmaso et al., 2014). Positive values of the index are associated with warm winters, and vice versa. In this contribution, the relationships have been updated to the period from 1993/1995 to 2013. To avoid spurious correlations originating from the presence of temporal trends, before regressions the variables were linearly de-trended.

Results and discussion

The EA_{DJF} showed a strong influence on the winter climate, with significant effects on the spring lake temperatures (Fig. 1a; r^2=0.56, p<0.01). In turn, the extent of the winter cooling triggered a long chain of events which included the impact of spring water temperatures on the extent of vertical mixing (r^2=0.55, p<0.01), the impact of vertical mixing on the spring epilimnetic concentrations of total phosphorus (TP_{epiS}, r^2=0.79, p<0.01), and the effects of fertilization (TP_{epiS}) on the biovolumes of cyanobacteria in summer and autumn

(r^2=0.34, p<0.01). The key role of EA in the control and origin of the chain of causal events was exemplified by the significant relationship between EA_{DJF} and the biovolume of cyanobacteria in summer and autumn (Fig. 1b, r^2=0.29, p<0.05). Nevertheless, the effects on cyanobacteria were mediated by the autoecology of the impacted species. Whereas an increase in the early-spring replenishment of nutrients after harsh winters favoured a stronger development of summer metalimnetic Oscillatoriales (Planktothrix rubescens, the dominant species), the formation of summer surface blooms of a different minor group (Dolichospermum lemmermannii, Nostocales) was relatively unaffected by the availability of nutrients, and more strictly linked to local, weekly meteorological conditions.

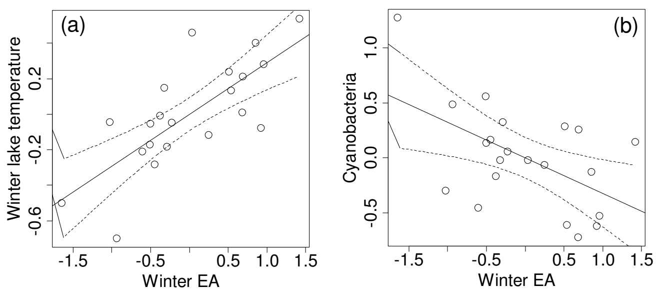

Fig. 1. Impact of the winter (Dec-Feb) East Atlantic pattern on (a) the late winter lake temperatures (February-March; 0-100 m; p < 0.01) and (b) the biomass of cyanobacteria between June and December (p = 0.01) in Lake Garda. Dotted lines are 95% confidence bands. Before the analyses, the variables were linearly de-trended.

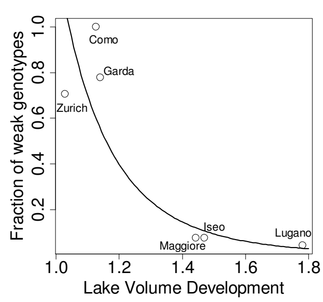

Fig. 2. Relationship between the fraction of P. rubescens genotypes synthesizing weak gas vesicles and the "Volume Development" (V_d) (p < 0.01). V_d > 1 are typical of concave lakes, i.e. characterized by a lower fraction of shallow areas. From D'Alelio et al. (2011), modified.

The morphometric features of the deep subalpine lakes and the deep mixing dynamics were proved to represent also a strong factor selecting different genotypes of P. rubescens adapted to different hydrostatic pressures. This species is able to control the vertical positioning through the synthesis of gas-vesicles, i.e. cellular structures which provide positive buoyancy. After summer metalimnetic development, in winter P. rubescens is entrained by convective mixing into the deeper water column, where gas vesicles can collapse due to increasing hydrostatic pressure, resulting in a decrease of buoyancy and population abundance. D'Alelio et al. (2012) showed that the proportion of the stronger strains (i.e. those with the genes able to synthesize stronger gas-vesicles) was greatest in deep basins with high depths and concave slopes (as exemplified by the "volume development", V_d, a parameter which estimates the departure of the shape of a lake basin from a cone, where V_d=1), i.e. in lakes where the effects of deeper penetrative mixing events were higher and extended over a greater area (Fig. 2).

The results of these recent investigations contribute to put in a new perspective the impact of the physical environment (climate and internal physical processes) on the development of algal assemblages. Physical drivers can act not only at the level of population and at different time-scales (with different time-lags), but also at the level of genotypes. Implications for the use of predictive models based on taxonomic or functional groups will be finally discussed.

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