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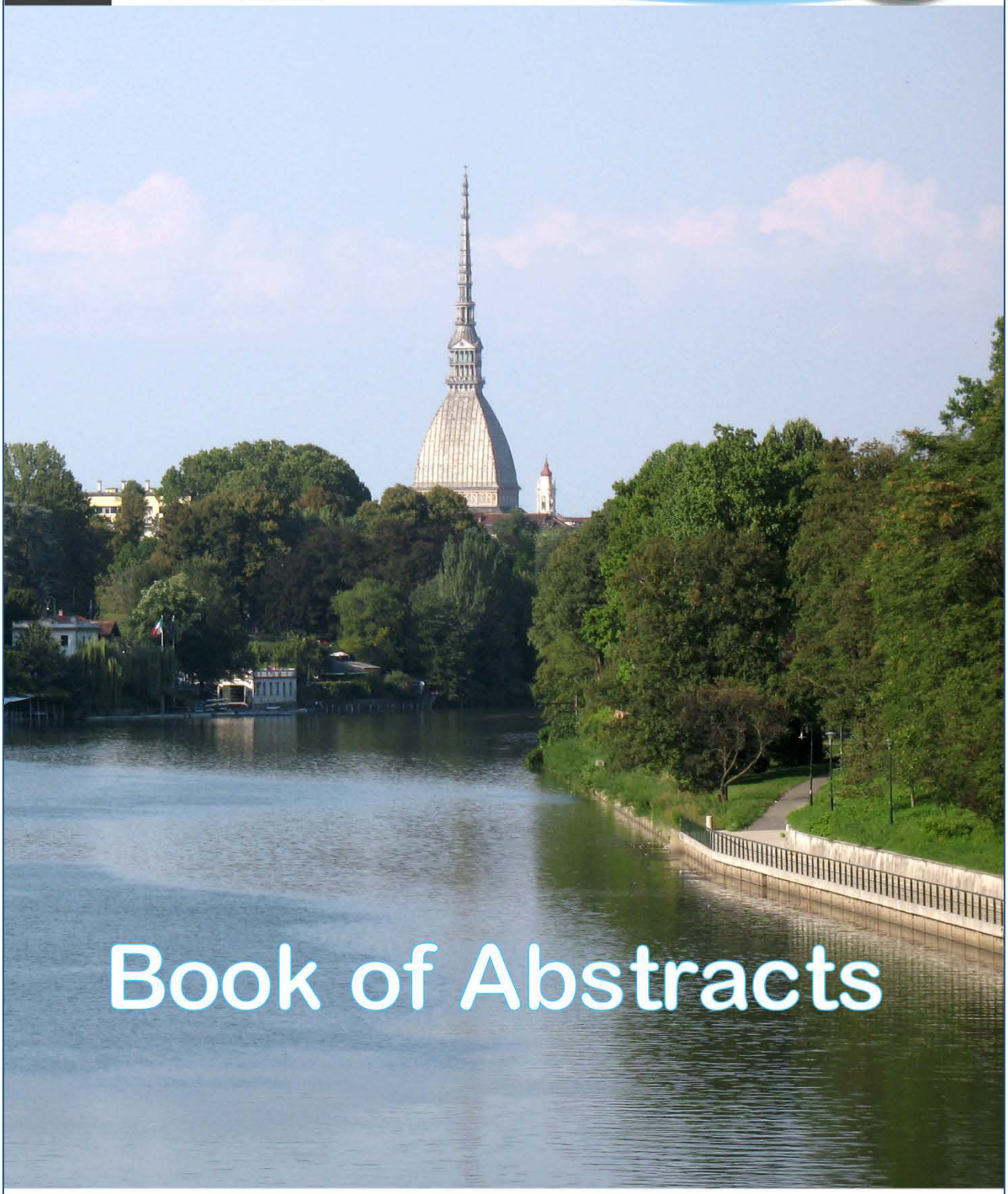

Book of Abstracts

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bodies in Europe. Classification of water bodies into ecological quality status has been a key issue for implementation of that framework. In France, the assessment of the ecological quality of lakes is based on four measurements per year, vertically integrated over the euphotic zone at the deepest point of the lake. However, in large lakes, ecological parameters used for water quality assessment (e.g. chlorophyll-a concentration and Secchi depth) exhibit strong spatial heterogeneities. Consequently, the representativeness of those data might be questionable and needs to be verified. Moreover, understanding their spatial distribution and temporal dynamics, and to what extent they alter the water quality assessment, is essential prerequisites for objectively evaluating, protecting and restoring freshwater ecosystems. We analysed spatial variability of phytoplankton abundance in Lake Geneva (France/Switzerland) using the MEdium Resolution Imaging Spectrometer (MERIS) sensor and used outputs of a coupled three-dimensional (3D) hydrodynamic model Delft3D-FLOW to an ecological model (Delft3D-WAQ) in order to explain mechanisms responsible for the occurrence of hot-spot of phytoplankton abundance. While remote sensing provides horizontal instantaneous observation of integrated parameters, 3D modelling provides supplementary information on the vertical distribution and temporal variability. Results indicate temporal changes in the intensity of Chlorophyll-a horizontal heterogeneity. In spring, chlorophyll-a horizontal heterogeneity occurs because of an earlier onset of phytoplankton growth in some littoral area. Spatial differences in the timing of phytoplankton growth can be explained by spatial variability in thermal stratification dynamics and nutrient inputs from river. In summer, spatial heterogeneity presents transient dynamics and is characterized by local higher phytoplankton abundances in relation to the impact of basin-scale upwellings. Using the 3D model, we highlighted the influence of hydrodynamics on the phenology and abundance of phytoplankton and aim at providing information that could be used to improve sampling strategies for the water quality monitoring of large lakes such as Lake Geneva.

39-O Responses of phytoplankton size structure to oligotrophication and climate variability.

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The size of phytoplankton species is considered a key trait as many physiological rates such as maximal nutrient uptake and light absorbance, as well as sedimentation rates and edibility are affected by the size of phytoplankton cells. Hence, phytoplankton size is expected to change as a consequence of environmental changes such as eutrophication, oligotrophication and/or climate change. Here we analyse the response of phytoplankton size to environmental changes in deep and large Lake Constance. As many other lakes Lake Constance went through a history of strong eutrophication and subsequent oligotrophication during the last century with increases and subsequent decreases of total phosphorus (TP) exceeding one order of magnitude. On average warming has increased epilimnetic temperatures by approximately 0.7 °C and has reduced the frequency of winter mixing. The response of phytoplankton to these changes has been investigated utilizing data from a fortnightly sampling programme covering the time period from 1965 to 2007. Analyses of these long-term data showed that annual average biomass of phytoplankton was rather stable at both, TP concentration above 35 µg/L (range: 35 – 87 µg/L) and below 35 µg/L (range 7 – 30 µg/L). At a threshold TP concentration of approximately 30-35 µg/L biomass dropped within a few years by 50 % suggesting a regime shift of phytoplankton biomass. The size structure of phytoplankton, e.g. mean, variance and the slope of the abundance-size distributions showed large seasonal and interannual variability. With oligotrophication mean phytoplankton size as well as the slope if the abundance-size relationship increased. The strongest change roughly coincided with the timing of the biomass regime shift.

39-O Lake Garda as a paradigmatic case study of ongoing ecological changes in the large lakes south of the Alps.

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The largest (62-368 km^2) and deepest (251-410 m) lakes south of the Alps (Garda, Maggiore, Como and Iseo) are one of the most important lake districts in Europe. In the last decades, these lakes underwent important changes, which include the warming of the water column; the tendency to oligotrophication or stabilization of the concentrations of total

phosphorus (TP); the introduction of new cyanobacteria, i.e. the establishment of the water-bloom forming *Dolichospermum lemmermannii* since the 1990s, and the very last discovery of *Tychonema bourrellyi*, a species producing anatoxin-a (ATX, a neurotoxin). These changes will be critically described considering in detail the results obtained in the Long-Term Ecological Research station of Lake Garda.
From 1991 to 2015, the long-term increase of the mean annual water temperatures in the mixolimnion (0-50 m) showed a positive and significant trend (>0.025 °C yr^{-1}). The warming was confirmed also considering the satellite measurements of temperature of the surface waters since the 1980s. The deep hypolimnion (< 200 m) showed periods of warming caused by a downward transport of heat by turbulent diffusion during stratification, interrupted by irregular cooling and overturn during harsh winters. Overall, the frequency of mixing episodes decreased. The last circulation was observed in 2006; since then, the waters below 200 m showed a continuous warming reaching, in 2015, unprecedent temperature values, between 8.5 and 8.7 °C. These changes were paralleled by a continuous increase of TP in the whole water column until 2002 (ca. > 20 µg P/L), followed by a decrease (17-18 µg P/L). These changes concurred to affect the ecological features of the lake.
The first surface blooms of *D. lemmermannii* in Lake Garda were recorded in the 1990s. The introduction (in the 1960s) and expansion of this species was linked to the incipient eutrophication and to the lake warming, which is a general positive factor for the development of gas-vacuolated cyanobacteria. Nevertheless, while the impact of *Dolichospermum* was limited to the development of summer surface "oligotrophic" blooms, recent investigations showed that *Tychonema* was able to develop with biomasses as high as those of *P. rubescens*. These findings induce to change an important paradigm in the phytoplankton ecology of the southern perialpine lakes. In fact, until now, *Planktothrix* was the dominant cyanobacterium, and the only producer of microcystins (MCs, hepatotoxins). Conversely, many strains of *Tychonema* isolated in Lake Garda and in the other large perialpine lakes tested positive for the presence of the genes encoding ATX, and for the production of ATX. Since 2009, the increasing role of *Tychonema* was confirmed by the increase of ATX and the decrease of MCs. The causes will be discussed considering in particular the interactions between changes in the trophic level and lake warming.

39-O A multi-proxy sediment study to assess long-term effects of nutrients and climate variability on the ecological dynamics of the largest Italian lake (Lake Garda).

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The study of lake sediments allows to place limnological investigations within a secular temporal perspective, providing a longer time-span compared to monitoring data. A multi-site and multi-proxy paleoecological approach was applied to Lake Garda, the largest Italian lake, in order to disentangle the effects of local anthropogenic forcings, such as nutrients, and climate variability on the lake ecosystem during the last few centuries.Short sediment cores were collected from the deepest point of the two lake basins: Brenzone (350 m depth) and Bardolino (81 m depth). Biological indicators(diatoms and Cladocera) were used to reconstruct changes in the aquatic food web and to define the lake reference conditions, while sediment geochemistry, analyzed by wavelength-dispersive X-ray fluorescence spectroscopy (WD-XRF), was investigated to obtain information on different physical or chemical processes affecting the lake and its catchment.
The selected biological proxies suggested stable oligotrophic conditions of Lake Garda until the 1960s, while the following lake nutrient enrichmentled to a drastic change in the phytoplankton community. The major climatic anomalies,i.e. the Medieval Climatic Anomaly and the Little Ice Age, did not apparently affect planktonic diatom taxonomic composition, while Cladocera showed changes in total abundance and speciescompositions. On the other hand, diatoms showed an indirect response to climate variabilitysince the beginning of the nutrient enrichment phase in the 1960s, while Cladocera revealed a weaker climate-response during this nutrient-driven period. This different response to nutrients and climate was put in relation with the thermal dynamics of large and deep lakes. In fact, climate variability regulates magnitude and frequency of thermal circulationin large and deep lakes, which in its turn controlthe degree of nutrient fertilization of the entire water column and the related phytoplankton growth.
Geochemical data showed a pronounced change in elemental composition since the middle of the 20th century, when major elements and lithogenic tracers started to decrease, while elements related to redox conditions and contamination (trace elements) increased. The general trends agreed with the biological records. However, some differences recorded in the two different basins of Lake Garda reflected the effects of local hydrological and sedimentation patterns.