A georeferenced dataset of living and sedimentary diatoms in Lake Maggiore

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ABSTRACT

We publish a dataset on planktic and benthic diatom occurrence in Lake Maggiore, the second Italian lake for depth and surface. Despite their extensive use in water quality biomonitoring, and their relevance among phytoplankton groups, research on benthic diatoms in Lake Maggiore are scarce. Diatoms have been collected from surface sediments, littoral stones, macrophytes and water column, in different times and with different purposes during the last 40 years of the trophic history of the lake. Dataset includes 4124 occurrences relating to 293 taxa, 269 of which were identified at species level, 16 at subspecies level and 8 at the genus level. All occurrences are georeferenced.

INTRODUCTION

Diatoms are an abundant, diverse, and important component of algal assemblages in freshwater lakes. Because of their fast-growing season and sensitivity to changes in nutrient concentrations and ratios, they can respond rapidly to environmental variations like eutrophication and recovery (Smol and Stoermer, 2010). Within phytobenthos, diatoms are the most representative component, they are reliable indicators of the trophic and ecological status of lakes and together with macrophytes are commonly used for the evaluation of the ecological status of both lotic and lentic waterbodies (King *et al*., 2006), in order to achieve a "good ecological status" as established by the Water Framework Directive (WFD) (European Union, 2000; Foster *et al*., 2001). Diatoms are arguably the most important group of algae also for paleolimnological studies. Their paleoecology has been extensively studied, mainly because of the excellent preservation and abundance of their frustules as fossil. The fact that many species have highly predictable distribution patterns related to water chemistry characteristics (for example nutrient concentration or pH) makes them extremely useful as paleoenvironmental indicators.

Lake Maggiore is part of the Long-Term Ecological Research Network (https://deims.org/f30007c4-8a6e-4f11-ab87-569db54638fe). It is the second largest (212.5 km^2) and deepest (370 m) subalpine lake in Italy, located at 194 m asl; it is oligotrophic by nature as shown by paleolimnogical studies (Marchetto *et al*., 2004) but in the late 60s nutrient concentration, mainly phosphorus, began to rise followed by an increase in phytoplankton abundance, biovolume, and primary production. After reaching a eutrophic state in the late 1970s-early 1980s (TP concentration piked up to 35 µg L^{-1} in 1977), the lake gradually recovered to a stable oligotrophic status by the end of the 1990s (TP concentrations in the water column around 10 µg L^{-1}), thanks to the reduction of catchment P loads and the sewage treatment plants establishment (Morabito *et al*., 2012). However, both reactive and total phosphorus have slightly increased, in the deep layers, since 2010, leading to a shift in the lake trophic state towards mesotrophy (Rogora *et al*., 2021). This pattern was due to a steadily decline of mixing depth and mixed volume of water at spring overturn in Lake Maggiore, due to the increase in thermal stability of the water column resulting from the climate change.

Lake Maggiore, due to its siliceous basin, is a 'diatom lake': considering biomass, diatoms are the dominant phytoplankton group for most of the year and a valuable long record of diatom succession is available, thanks to

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the lake's monitoring programme, started at the end of the 1970's. Diatoms are known to be sensitive to environmental changes and shifts in diatom assemblage composition are frequently the first indication of ecological perturbations. Despite their extensive use in biomonitoring of river (Potapova and Charles, 2007; Rimet and Bouchez, 2012) and, in less proportion, of lakes (Bennion *et al*., 2014; Poikane *et al*., 2016) water quality, available data on diatoms in Lake Maggiore are scarce and focused on the dynamics of contemporary plankton (Morabito *et al*., 2012; Caroni *et al*., 2012) or on palaeoecological studies (Marchetto and Musazzi, 2001; Marchetto *et al*., 2004). Only in 2021 a pilot study attempted to evaluate the biodiversity of phytobenthos (Boggero *et al*., 2022).

In 1998, 14 short sediment cores (9-84 cm) were taken from 12 sites (Fig. 1) in Lake Maggiore (Marchetto *et al*., 2001), using a gravity corer 63.5 mm in diameter. Each core was cut lengthways, sliced into 1-cm sections, and dated using either ^{137}Cs or ^{210}Pb. Diatoms were cleaned following Battarbee *et al*. (2001), and mounted with Naphrax. For each sample, at least 500 valves were identified and enumerated. This study focused on environmental reconstruction, and the use of diatom assemblages to reflect nutrients pressures and establishing "reference conditions", assuming that samples, collected in profundal sediments, contain diatoms representative of all habitats within the lake and provide an integrated flora, both in time and space (King *et al*., 2006). In this paper we present data related to the surface sediment samples.

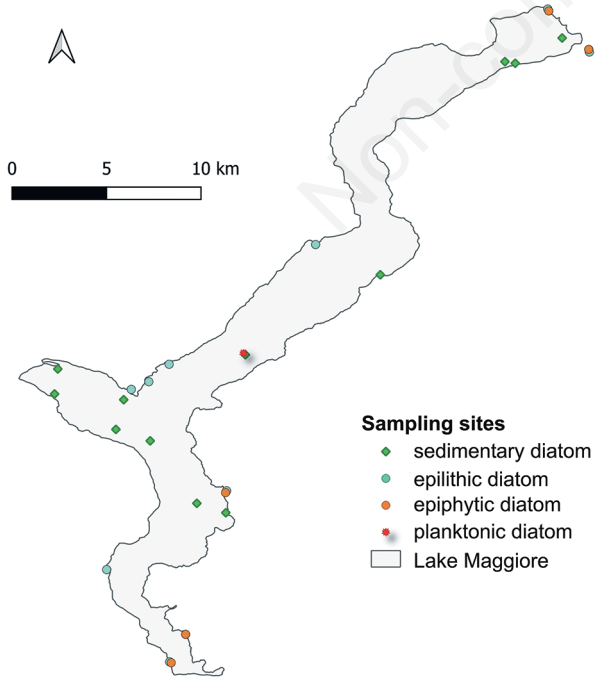

Fig. 1. Location of the sampling sites distributed along the N-S axis and differentiated by habitat.

In 2021, within the project "Search and innovation on Lake Maggiore: water quality bio-indicators along the pelagic-lake shore benthic communities continuum", aimed to monitoring contemporary phytobenthos, samples of benthic diatoms were taken by scraping five stones (usually cobbles and small boulders) and macrophytes following a European wide standardized sampling protocol (Manuals ICP WATERS, 2010). Samples were taken from the littoral zone, in 8 stations identified along the perimeter of the lake (Fig. 1) as reported in Boggero *et al*. (2022). Samples were also collected in the *Bolle di Magadino* wetland, which is in direct hydraulic connection with the lake. For each sample, at least 400 valves were identified and enumerated. This work represents the first floristic study of littoral phytobenthos in Lake Maggiore.

Benthic and sedimentary diatoms were analysed using a light microscope at 1000x magnification (Zeiss Axiolab) and identified to the lowest taxonomic level (mainly species). In 1998 Diatom taxonomy followed Krammer and Lange-Bertalot (1986-1991), integrated in 2021 with Lange-Bertalot (2001), Krammer (2000, 2002, 2003), Lange-Bertalot *et al*. (2011), Cantonati *et al*. (2017) and with the papers by Potapova and Hamilton (2007) and Van de Vijver *et a*l. (2022) concerning the *Achnanthidium minutissimum* species complex and *Fragilaria rumpens* complex respectively. Results were expressed as relative abundances.

Phytoplankton data were collected in the framework of Lake Maggiore limnological monitoring programs by the International Commission for the Protection of Swiss-Italian Waters (CIPAIS) started at the end of the 1970's and still ongoing. Annual reports are available and published at the address: https://www.cipais.org/. Samples for phytoplankton analysis were collected at the station of Ghiffa corresponding to the point of lake's maximum depth (370 m). A bottle designed to take an integrated sample in the 0-20 m water layer was used. Water samples for phytoplankton analysis were collected fortnightly from March until October, and monthly during January, February, November, and December. Diatom determinations were carried out on subsamples of integrated sample (0-20 m) preserved in acetic Lugol's solution. Algal cells were counted on a Zeiss Axiovert 10 microscope at 400X, according to CEN (2004) and Lund *et al*. (1958), until 400 cells for the most important species were counted. Biomass was estimated from density data and original measurements of cell volume (Smayda, 1978 and Hillebrand *et al*., 1999). Species were identified using the series *Süßwasserflora von Mitteleuropa* and *Das Phytoplankton des Süßwassers*.

The aim of this data paper is to gather all the available data on diatom community in Lake Maggiore in a formal

dataset to make it available for further water body studies and management guidelines.

Dataset description

Metadata: This data set includes diatom information ordered in the following 2 csv sheets, with each row containing a record of a diatom taxon from a sample from Lake Maggiore. The columns report the updated taxon name, additional taxonomic information together with origin of the data, and habitat:

i. Sedimentary and benthic diatoms, containing 26 columns headered using DwC term name (http://rs.tdwg.org/dwc/terms/): occurrenceID, organismID, basisOfRecord, scientificName, Kingdom, Phylum, Subphylum, Class, Subclass, Order, Family, Genus, specificEpithet, infraspecificEpithet, taxonRank, eventID, eventDate, samplingProtocol, decimalLatitude, decimalLongitude, geodeticDatum, countryCode, locality, references, organismQuantity, organismQuantityType.
ii. Planktic diatoms, containing 26 columns headered using DwC term name (http://rs.tdwg.org/dwc/terms/): occurrenceID, organismID, basisOfRecord, scientificName, Kingdom, Phylum, Subphylum, Class, Subclass, Order, Family, Genus, specificEpithet, infraspecificEpithet, taxonRank, eventID, eventDate, samplingProtocol, decimalLatitude, decimalLongitude, geodeticDatum, countryCode, locality, references, sampleSizeValue, sampleSizeUnit.

Licence data: Creative Commons Attribution (CC-BY) 4.0 License
Object name: Diatom occurrence in Lake Maggiore
Data set citation: Diatom occurrence Lake Maggiore
Format name: csv
Date of creation: 15 September 2022.
Date of last revision: 15 October 2022.
Date of publication: 14 November 2022.
Metadata language: English
Distribution (permanent link): GBIF, https://doi.org/10.15468/w25yy5
Licence of use: both access and use are free to any user. The authors would appreciate users providing a link to the original dataset (GBIF) and a citation the present paper, or to be included as co-author in a new paper. Stakeholders interested in additional information can contact authors via the contact information provided in the metadata.

Management details

Title: A georeferenced dataset of living and sedimentary diatoms in Lake Maggiore.
Resource (=data) contacts: Simona Musazzi (simona.musazzi@cnr.it), Martina Austoni (martina.austoni@cnr.it)
Resource creators: Simona Musazzi, Martina Austoni, Aldo Marchetto (aldo.marchetto@cnr.it).
Metadata provider: Simona Musazzi, Martina Austoni.
Metadata manager: Simona Musazzi, Martina Austoni, Lyudmila Kamburska (lyudmila.kamburska@irsa.cnr.it).

Geographic coverage

Study area: the sampling sites for sediment cores are distributed along the N-S axis, the sites for benthic diatoms are located along the shore perimeter, samples for the planktic diatoms were taken at the deepest point (Fig. 1). Data are georeferenced according to WGS 84 datum.
Bounding box: min longitude: 8.45 – max longitude: 8.95 – min latitude: 45.66 – max latitude: 46.27.
Sampling design: The general strategy was to gather all the available published data on diatom community in Lake Maggiore in a formal dataset covering different ecological niches.
Habitat type: sediment, stones, macrophytes and water column.
Biogeographic region: Continental (EEA, 2017).
Country: Italy

Taxonomic coverage

General description: the data set covers organisms of the Phylum Bacillariophyta.
Taxonomic ranks: Data from subspecies to species, genus, family, order, and class rank were included in the dataset.
Taxonomic methods: Given the continuous changes in biological nomenclature, all scientific names published were checked and updated to the currently accepted nomenclature, following the *Algaebase*: Listing of World's Algae (Guiry and Guiry, 2021).
Taxon specialists: Simona Musazzi, Martina Austoni, Aldo Marchetto.

Temporal coverage: 23/01/1984 - 10/11/2021

Sedimentary diatoms: one sampling activity during spring 1998.
Benthic diatoms: one sampling activity during autum 2021.
Planktic diatoms: monthly and fortnightly collecting activity since 1984-2007 during spring season.

Key words: Occurrence, checklist, metadata

Associated parties: CNR-IRSA (https://registry.gbif.org/institution/9443e624-7071-4d54-b05d-a69c268bfe15)

Project data

Title: GBIF dataset of freshwater diatom occurrence in Lake Maggiore (Italy).

Identifier: 2022_Diatom of Lake Maggiore.
Description funding: All these investigations have been gathered in the frame of the research program funded by the International Commission for the Protection of Swiss-Italian Waters (CIPAIS). https://www.cipais.org/
Study area description: Lake Maggiore is a large (212.5 km^2), deep (370 m), oligotrophic, subalpine lake, located in northern Italy at an altitude of 194 m asl.
Design description: Since 1974, CIPAIS has been promoting and contributing to the funding of research on the ecosystem evolution of Lakes Maggiore and Lugano, in relation to the environmental and climatic change. This activity carried out since 1978 in the face of five-year (or three-year from 2013) research programs ensured the systematicity for the acquisition of hydrological, meteorological and limnological data relating to lakes, their tributaries and hydrographic basins.
Project personnel: Simona Musazzi, Martina Austoni, Aldo Marchetto.

Sampling methods

Study extent: the dataset contains information on 4124 occurrences for 293 taxa. The occurrences were recorded during the years 1984-2021 The study area is 212.5 km^2.
Sampling description: Sediment cores were taken using a gravity corer 63.5 mm in diameter. Each core was cut lengthways, sliced into 1-cm sections, and dated using either 137Cs or 210Pb. Diatoms were cleaned following Battarbee *et al*. (2001) and mounted with Naphrax. For each sample, at least 500 valves were identified and enumerated. Benthic diatoms were taken by scraping five stones (usually cobbles and small boulders) and macrophytes following a European wide standardized sampling protocol (Manuals ICP WATERS, 2010). Samples were taken from the littoral zone, in 8 stations identified along the perimeter of the lake and in the Bolle di Magadino wetland, an area which is in direct hydraulic connection with the lake as reported in Boggero *et al*. (2022). Digestion followed standard procedures. For each sample, at least 400 valves were identified and enumerated. Samples for phytoplankton were all collected at a central sampling site, corresponding to the point of lake's maximum depth (370 m). Samples were always collected with an integrating bottle in the 0-20-m water layer, corresponding to the euphotic layer in Lake Maggiore. Counting followed CEN (2004) and Lund *et al*. (1958).
Quality control: Quality control for geographic data: coordinates were collected by GPS during sampling and verified on topographic maps.
Quality control for taxonomic data: before publication of the data set, algal taxon spelling and authorship were verified and updated using Algaebase: Listing of World's Algae (Guiry and Guiry, 2021).

CONCLUSIONS

The present dataset offers a holistic perspective about the distribution of diatom taxa in Lake Maggiore. We agree to publish the present form in order to share knowledge acquired, for a better understanding of ecology and population dynamics of this algal group related to the environmental and climatic changes.

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REFERENCES

Battarbee RW, Jones VJ, Flower RJ, Cameron NG, Bennion H, Carvalho L, Juggins S, 2001. Diatoms. In: Smol J, Birks HJ, Last W (eds), Tracking environmental change using lake sediments. Volume 3: Terrestrial, algal, and siliceous indicators. Kluwer Academic Publishers, Dordrecht: p. 155-202.

Bennion H, Kelly MG, Juggins S, Yallop ML, Burgess A, Jamieson BJ, Krokowski J, 2014. Assessment of ecological status in UK lakes using benthic diatoms. Freshw. Sci. 33:639-654.

Boggero A, Zaupa S, Borgomaneiro G, Eckert E, Gariboldi L, Marchetto A, Musazzi S, Sabatino R, Paganelli D, Fontaneto D, 2022. Ricerca ed innovazione sul Lago Maggiore: indicatori di qualità nel continuum acqua - rive. Rapporto finale 2019-2021. Commissione Internazionale per la Protezione delle Acque Italo-Svizzere: 156 pp.

Cantonati M, Kelly MG, Lange-Bertalot H, 2017. Freshwater benthic diatoms of central Europe: over 800 common species used in ecological assessment. Koeltz Botanical Book, Oberreifenberg: 942 pp.

Caroni R, Free G, Visconti A, Manca M, 2012. Phytoplankton functional traits and seston stable isotopes signature: A functional-based approach in a deep, subalpine lake, Lake Maggiore (N. Italy). J. Limnol. 71:84-94.

CEN (2004). Water quality – Guidance standard for the routine analysis of phytoplankton abundance and composition using inverted microscopy (Utermöhl technique) CEN TC 230/WG 2/TG 3/N83, May 2004.

Foster D, Wood A, Griffiths M, 2001. The EC Water Framework Directive and its implications for the Environment Agency.

Available from: https://core.ac.uk/download/pdf/11020129.pdf

Guiry MD, Guiry GM, 2021. AlgaeBase. World-wide electronic publication, National University ofIreland, Galway. Accessed: 24 February 2021. Available from: https://www.algaebase.org

Hillebrand H, Dürselen CD, Kirschtel D, Pollingher D, Zohary T, 1999. Biovolume calculation for pelagic and benthic microalgae. J. Phycol. 35:403-424.

ICP Waters Programme Centre 2010. ICP Waters Programme Manual 2010. NIVA SNO 6074-2010. ICP Waters report 105/2010.

King L, Clarke G, Bennion H, Kelly M, Yallop M, 2006. Recommendations for sampling littoral diatoms in lakes for ecological status assessments. J. Appl. Phycol. 18:15-25.

Krammer K, 2000. The genus *Pinnularia*. Diatoms of Europe: Diatoms of the European Inland Waters and Comparable Habitats. Volume 1. Gantner Verlag, Ruggell: 703 pp.

Krammer K, 2002. *Cymbella*. Diatoms of Europe. Diatoms of Europe: Diatoms of the European Inland Waters and Comparable Habitats. Volume 1. Gantner Verlag, Ruggell: 583 pp.

Krammer K, 2003. *Cymbopleura*, *Delicata*, *Navicymbula*, *Gomphocymbellopsis*, *Afrocymbella* Supplements to cymbelloid taxa. Diatoms of Europe: Diatoms of the European Inland Waters and Comparable Habitats. Volume 4. Gantner Verlag, Ruggell: 530 pp.

Krammer K, Lange-Bertalot H, 1986-1991. Süßwasserflora von Mitteleuropa. In: E.H.J. Gerloff, H. Heynig and D. Mollenhauer (eds.), 2/1Bacillariophyceae, Naviculaceae; 2/2Bacillariaceae, Epithemiaceae, Surirellaceae, Centrales, 2/3 Fragilariaceae, Eunotiaceae, 2/4 Achnanthaceae. Gustav Fischer Verlag, Stuttgart: 876 pp.

Lange-Bertalot H, 2001. *Navicula* sensu stricto. 10 Genera separated from *Navicula* sensu lato. *Frustulia*. In Lange-Bertalot, H. (ed.), Diatoms of Europe, 2. Gantner Verlag, Ruggell: 526 pp.

Lange-Bertalot H, Witkowski A, Bąk M, 2011. *Eunotia* and some related genera. In: H. Lange-Bertalot (ed.), Diatoms of Europe 6. Gantner Verlag, Ruggell: 780 pp.

Lund JWG, Kipling C, Le Cren ED, 1958. The inverted microscope method of estimating algal number and the statistical basis of estimations by counting. Hydrobiologia 11:143-170.

Marchetto A, Musazzi S, 2001. Comparison between sedimentary and living diatoms in Lago Maggiore (N. Italy): implications of using transfer functions. J. Limnol. 60:19-26.

Marchetto A, Lami A, Musazzi S, Massaferro J, Langone L, Guilizzoni P, 2004. Lake Maggiore (N. Italy) trophic history: fossil diatom, plant pigments, and chironomids, and comparison with long-term limnological data. Quaternary Int. 13:97-110.

Morabito G, Oggioni A, Austoni M, 2012. Resource ratio and human impact: how diatom assemblages in Lake Maggiore responded to oligotrophication and climatic variability. Hydrobiologia 698:47–60.

Poikane S, Kelly M, Cantonati M, 2016. Benthic algal assessment of ecological status in European lakes and rivers: Challenges and opportunities. Sci. Total Environ. 568:603-613.

Potapova MG, Charles DF, 2007. Diatom metrics for monitoring eutrophication in rivers of the United States. Ecol. Indic. 7:48–70.

Potapova MG, Hamilton PB, 2007. Morphological and ecological variation within the *Achnanthidium minutissimum* (Bacillariophyceae) species complex. J. Phycol. 43:561-575.

Rimet F, Bouchez A, 2012. Life-forms, cell-sizes and ecological guilds of diatoms in European rivers. Knowl. Managt. Aquatic Ecosyst. 406:1-12.

Rogora M, Austoni M, Caroni R, Giacomotti P, Kamburska L, Marchetto A, Mosello R, Orru'A, Tartari G, Dresti C, 2021. Temporal changes in nutrients in a deep oligomictic lake: the role of external loads *versus* climate change. J. Limnol. 80:2051.

Ruggiu D, Morabito G, Panzani P, Pugnetti A, 1998. Trends and relations among basic phytoplankton characteristics in the course of the long-term oligotrophication of Lake Maggiore (Italy). Hydrobiologia 369:243-257.

Smayda TJ, 1978. From phytoplankters to biomass. In: A. Sournia (ed.), Phytoplankton Manual. UNESCO: p. 273-279.

Smol JP, Stoermer EF, 2010. The diatoms. Applications for the environmental and earth sciences. Cambridge University Press: 686 pp.

Utermöhl H, 1958. Zur Vervollkommung der quantitative Phytoplankton-Methodik. Mitt. Int. Ver. Limnol. 9:1-38.

Van de Vijver B, Williams DM, Schuster TM, Kusber WH, Cantonati M, Wetzel CE, Ector L, 2022. Analysis of the *Fragilaria rumpens* complex (Fragilariaceae, Bacillariophyta) with the description of two new species. Fottea 22:93-121.

Wieczorek J, Bloom D, Guralnick R, Blum S, Döring M, Giovanni R, Robertson T, Vieglais D. 2012. Darwin core: An evolving community-developed biodiversity data standard. PLoS One 7:e29715.