# Lake Michigan water chemistry data, including dissolved and particulate phosphorus, chlorophyll a, carbon dioxide, total dissolved inorganic carbon, and dissolved organic carbon.

**Website**: https://www.bco-dmo.org/dataset/737176

**Data Type**: Cruise Results

**Version**: 1

**Version Date**: 2018-05-18

### Project

» Collaborative Research: Regulation of plankton and nutrient dynamics by hydrodynamics and profundal filter feeders (Filter Feeders Physics and Phosphorus)

| Contributors | Affiliation | Role |
|---|---|---|
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### Abstract

Lake Michigan water chemistry data, including dissolved and particulate phosphorus, chlorophyll a, carbon dioxide, total dissolved inorganic carbon, and dissolved organic carbon.

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## Coverage

**Spatial Extent**: **N**:43.09798 **E**:-87.7187 **S**:43.09502 **W**:-87.86112

**Temporal Extent**: 2017-05-11 - 2017-11-13

## Dataset Description

Water chemistry data, including dissolved and particulate phosphorus, chlorophyll *a*, carbon dioxide, total dissolved inorganic carbon, and dissolved organic carbon from a Lake Michigan transect between Milwaukee, WI and Muskegon MI.

### Acquisition Description

**Field sampling:** Water samples were collected using 5-liter Niskin sampling bottles suspended on a 0.25" cable from a hydrographic winch. Immediately after collection, samples were transferred to 4-liter HDPE sample bottles. Sample bottles were rinsed with sample water 3 times before filling. Prior to use, sample bottles were acid washed (48 hours in 5% HCl), followed by multiple rinses with distilled, deionized water. Samples in bottles were stored in a cooler on ice until return to the laboratory. Samples were filtered immediately upon return to the laboratory (usually <8 hours after collection). Samples were filtered through pre-combusted Whatman GF/F filters. Filters were retained for particulate P,

stable isotope (particulate C and N), and chlorophyll *a* analyses. At least twice during the field season, field blanks are collected, which consist of clean bottles brought into the field where they are filled with distilled water, followed by analysis for dissolved and particulate phosphorus.

**Nutrients**: Samples were collected and analyzed as described in Mosley and Bootsma (2015). SRP was analyzed using the standard molybdate method and a 10 cm path length in the spectrophotometer. TDP and PP were digested to convert to phosphate, followed by analysis with the standard molybdate method. SRP and TDP were measured within 12 hours of sample filtration.

**Chlorophyll *a***: Samples were collected and analyzed as described in Mosley and Bootsma (2015). Chl *a* was extracted with a 68:27:5 methanol–acetone–deionized water extraction solvent for 24 hours at –28 °C and measured on a Turner Model 10 Series fluorometer, which was calibrated using a chlorophyll extract, the concentration of which was determined spectrophotometrically (Stainton et al. 1977).

**CO2** / **DIC**: Samples for CO2 and DIC analyses were collected in stoppered 120 ml glass serum bottles. Prior to sampling, bottles were flushed with nitrogen gas and then evacuated, to ensure they contained no CO2. At the time of sampling, a double-ended needle was inserted into the discharge tube of the Niskin bottle while water was flowing out, and the other end of the needle was inserted through the rubber cap of the serum sample bottle, allowing the vacuum in the bottle to draw in the sample water. The bottle was filled approximately three-quarters. CO2 and DIC analyses were carried out following the method described by Davies et al. (2003). Briefly, 50 ul subsamples are taken from the bottle headspace using a pressure-lok syringe and injected into a gas chromatograph, calibrated with CO2 standard gases. Samples are run in triplicate. Dissolved CO2 is then determined based on the temperature-dependent solubility of CO2, corrected for CO2 lost to the headspace and for the change in inorganic carbon species distribution accompanying the CO2 loss to headspace. Following CO2 analysis, samples are acidified by adding 150 ul of concentrated phosphoric acid, converting all inorganic carbon to CO2, after which the above analysis was repeated to determine total dissolved inorganic carbon concentration. In-lake CO2 concentrations are determined by correcting for any difference between in situ temperature and temperature at time of analysis, which affects the inorganic carbon partitioning coefficients. CO2 samples were measured within 24 hours of collection, and DIC samples were measured within 3 days of collection.

**Continuous CO2**: The components of the continuous CO2 monitoring system include a peristaltic pump that forces water through an air-water equilibrator (Membrana mini-module membrane contactor). Reverse-flow air from the equilibrator is pumped through desiccant, after which it flows through an infrared gas analyzer (Li-Cor Li-820) which measures the partial pressure of CO2 normalized to 1 atmosphere. The system also includes a

temperature sensor and a WETLabs flow-through fluorometer. The system is controlled by a Campbell CR1000 Controller / Datalogger. Input from a GPS on the ship's upper deck allows all data to be geo-referenced. The system is mounted in the engine room of the Lake Express high-speed ferry, where it draws water from a sea chest that has a residence time of several seconds.

**Stable isotopes**: Samples for stable isotope (13C:12C and 15N:14N ratios) analyses were collected by filtering lake water samples through GF/F glass fiber filters (nominal pore size = 0.7 – 0.8 um). Following filtration, filters were doused with 5% HCl for ~ 3 minutes to remove any inorganic carbon, followed by rinsing with distilled, deionized water. Filters were then freeze dried and packed in tin foil disks. Samples were then analyzed on an isotope ratio mass spectrometer, following the methods as described in Turschak et al. (2014). After every 12th sample, an acetanilide control was run to ensure instrument calibration.

**Dissolved organic carbon**: 25 ml of filtered water was transferred to an amber glass ampule and acidified to a pH of less than 2 by adding 2-3 drops of 1 N hydrochloric acid (HCl), converting all inorganic carbon to CO2, which was then purged from the sample bubbling with carbon-free gas prior to OC analysis. DOC was then measured using the combustion catalytic oxidation method on a total organic carbon analyzer (Shimadzu TOC-L analyzer equipped with an ASI-5000 auto sampler). The analyzer was calibrated with a dilution series of reagent grade potassium hydrogen phthalate in 0.3 molar hydrochloric acid.

## Processing Description

All nutrient data are stored in a common database. Following analyses, nutrient standard curves are examined to ensure that calibration coefficients are within the range of variability of a long-term (5-year) dataset (±3%). Fluorometer measurements are entered into a spreadsheet containing the fluorometer calibration coefficients, which are used to calculate chlorophyll *a* and phaeophytin concentrations. The fluorometer is calibrated annually against extracted chlorophyll *a* standards. CO2 and DIC gas chromatograph measurements are entered into a spreadsheet program that calculates all inorganic carbon species concentrations, as well as pH and carbonate alkalinity. Concentrations are then corrected for any temperature difference between in situ and time of analysis. Stable isotope measurements are stored in a stable isotope database, while DOC measurement data are stored along with nutrient, chlorophyll and inorganic carbon measurements in a chemistry database.

**BCO-DMO Processing:**
- modified parameter names to conform with BCO-DMO naming conventions;
- re-formatted date to ISO format;
- replaced missing data with nd ("no data").

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## Related Publications

Davies, J.-M. (2003). PCO2 method for measuring photosynthesis and respiration in freshwater lakes. Journal of Plankton Research, 25(4), 385–395. doi:10.1093/plankt/25.4.385

Mosley, C., & Bootsma, H. (2015). Phosphorus recycling by profunda quagga mussels (Dreissena rostriformis bugensis) in Lake Michigan. Journal of Great Lakes Research, 41, 38–48. doi:10.1016/j.jglr.2015.07.007

Stainton, M.P., M.J. Capel, and F.A.J. Armstrong. (1977). The chemical analysis of fresh water, 2nd ed. Fish. Mar. Serv. Misc. Spec. Publ. 25:166 p. http://www.dfo-mpo.gc.ca/Library/110147.pdf

Turschak, B. A., Bunnell, D., Czesny, S., Höök, T. O., Janssen, J., Warner, D., & Bootsma, H. A. (2014). Nearshore energy subsidies support Lake Michigan fishes and invertebrates following major changes in food web structure. Ecology, 95(5), 1243–1252. doi:10.1890/13-0329.1

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## Parameters

| Parameter | Description | Units |
|---|---|---|
| Year | Year | unitless |
| ISO_DateTime_UTC | UTC Data and time. Local time + 5 hours between March 12, 2:00 a.m. and November 5, 2:00 a.m. Local time + 6 hours between November 5, 2:00 a.m. and March 12, 2:00 a.m. | MM/DD/YY HH:MM, 24-hour format. |
| Site | Station name / number | unitless |
| Lat | Latitude. Locations south of equator are negative. | Decimal degrees |
| Long | Longitude. Locations west of prime meridian are negative. | Decimal degrees |
| DepthSite | Lake bottom depth at sampling location | Meters |
| DepthSmp | Depth below surface from which sample was collected | Meters |
| Ht | Height above lake bottom | centimeters (cm) |
| SRP | Soluble Reactive Phosphorus; resolution = 0.01; accuracy = ±5%; detection limit = 0.5 | micrograms per liter (ug/L) |
| TDP | Total Dissolved Phosphorus; resolution = 0.01; accuracy = ±5%; detection limit = 1 | micrograms per liter (ug/L) |
| PP | Particulate Phosphorus; resolution = 0.01; accuracy = ±5%; detection limit = 0.5 | micrograms per liter (ug/L) |
| Chl | Chlorophyll a; resolution = 0.01; accuracy = 0.1; detection limit = 0.5 | micrograms per liter (ug/L) |
| PC | Particulate Carbon; resolution = 0.1; accuracy = 1; detection limit = 0.5 | micrograms per liter (ug/L) |

| | | |
|---|---|---|
| PN | Particulate Nitrogen; resolution = 0.01; accuracy = 0.1; detection limit = 0.1 | micrograms per liter (ug/L) |
| d13C | Delta 13C, representing the ratio of 13C to 12C of suspended particulate material, calculated as d13C = ((Rsmp/Rstd)-1) X 1000, where R = 13C/12C, smp = sample, std = PDB carbonate standard. resolution = 0.01; accuracy = 0.05 ‰ | per mil (‰) |
| d15N | Delta 15N, representing the ratio of 15N to 14N of suspended particulate material, calculated as d15N = ((Rsmp/Rstd)-1) X 1000, where R = 15C/14C, smp = sample, std = air. resolution = 0.01; accuracy = 0.1 ‰ | per mil (‰) |
| CO2 | Carbon dioxide; resolution = 0.1 umol/L; accuracy = ±3% | micromoles per liter (umol/L) |
| DIC | Dissolved Inorganic Carbon (carbon dioxide + carbonic acid + bicarbonate + carbonate); resolution = 1 umol/L; accuracy = ±3% | micromoles per liter (umol/L) |
| DOC | Dissolved organic carbon; resolution = 0.1; accuracy = 5; detection limit=5 | micromoles per liter (umol/L) |

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## Instruments

| | |
|---|---|
| **Dataset-specific Instrument Name** | Niskin sampling bottle |
| **Generic Instrument Name** | Niskin bottle |
| **Generic Instrument Description** | A Niskin bottle (a next generation water sampler based on the Nansen bottle) is a cylindrical, non-metallic water collection device with stoppers at both ends. The bottles can be attached individually on a hydrowire or deployed in 12, 24 or 36 bottle Rosette systems mounted on a frame and combined with a CTD. Niskin bottles are used to collect discrete water samples for a range of measurements including pigments, nutrients, plankton, etc. |

| | |
|---|---|
| **Dataset-specific Instrument Name** | Turner Designs benchtop fluorometer model 10-000 |
| **Generic Instrument Name** | Turner Designs Fluorometer -10 |
| **Generic Instrument Description** | The Turner Designs Model 10 fluorometer (manufactured by Turner Designs, turnerdesigns.com, Sunnyvale, CA, USA) is used to measure Chlorophyll fluorescence. No information could be found for this specific model. |

| | |
|---|---|
| **Dataset-specific Instrument Name** | Finnigan MAT delta S stable isotope ratio mass spectrometer with elemental analyzer |
| **Generic Instrument Name** | Isotope-ratio Mass Spectrometer |
| **Dataset-specific Description** | Finnigan MAT delta S stable isotope ratio mass spectrometer with elemental analyzer front end and ConFlo II interface; Thermo Fisher Scientific, Waltham, MA, USA. |
| **Generic Instrument Description** | The Isotope-ratio Mass Spectrometer is a particular type of mass spectrometer used to measure the relative abundance of isotopes in a given sample (e.g. VG Prism II Isotope Ratio Mass-Spectrometer). |

| | |
|---|---|
| **Dataset-specific Instrument Name** | Varian Cary 50 UV-Vis spectrophotometer |
| **Generic Instrument Name** | Spectrophotomer-Varian Cary 50UV |
| **Generic Instrument Description** | The Varian Cary 50 UV-Visible Spectrophotometer has a xenon flash lamp and a 1.5nm slit width for measurement of total particulate absorption spectra. |

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|---|---|
| **Dataset-specific Instrument Name** | SRI 8610C Gas chromatograph |
| **Generic Instrument Name** | Gas Chromatograph |
| **Generic Instrument Description** | Instrument separating gases, volatile substances, or substances dissolved in a volatile solvent by transporting an inert gas through a column packed with a sorbent to a detector for assay. (from SeaDataNet, BODC) |

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|---|---|
| **Dataset-specific Instrument Name** | Li-Cor Li-820 |
| **Generic Instrument Name** | CO2 Analyzer |
| **Generic Instrument Description** | Measures atmospheric carbon dioxide (CO2) concentration. |

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|---|---|
| **Dataset-specific Instrument Name** | Shimadzu TOC-L total organic carbon analyzer |
| **Generic Instrument Name** | Shimadzu TOC-L Analyzer |
| **Generic Instrument Description** | A Shimadzu TOC-L Analyzer measures DOC by high temperature combustion method. Developed by Shimadzu, the 680 degree C combustion catalytic oxidation method is now used worldwide. One of its most important features is the capacity to efficiently oxidize hard-to-decompose organic compounds, including insoluble and macromolecular organic compounds. The 680 degree C combustion catalytic oxidation method has been adopted for the TOC-L series. http://www.shimadzu.com/an/toc/lab/toc-l2.html |

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## Deployments

**Neeskay_Cruise_1**

| | |
|---|---|
| **Website** | https://www.bco-dmo.org/deployment/730830 |
| **Platform** | R/V Neeskay |
| **Start Date** | 2017-08-01 |
| **End Date** | 2017-08-16 |
| **Description** | Multiple deployments of the research vessel, R/V Neeskay, in Lake Michigan, Depth = 55 m, approximately 12 km northeast of Milwaukee Harbor. Ship returned to port at end of each day. Dates: August 1, 2017 to August 16, 2017. |

**Osprey_Lake_Michigan_2017**

| | |
|---|---|
| **Website** | https://www.bco-dmo.org/deployment/737338 |
| **Platform** | R/V Osprey |
| **Start Date** | 2017-05-11 |
| **End Date** | 2017-11-13 |
| **Description** | Multiple deployments of the small research vessel, R/V Osprey, in Lake Michigan at three locations northeast of Milwaukee Harbor, with bottom depths of 15 m (43.09577 N, 87.8611 W), 45 m (43.097983 N, 87.784033 W), and 75 m (43.097917 N, 87.7187 W). The vessel returned to port at end of each day. 2017 Dates: May 11, 26, June 1, 8, 13, 23, 30, July 11, 18, 25, Aug. 1, 2, 9, 10, 16, 29, Sep. 12, Oct. 5, 9, 23, Nov. 13. |

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## Project Information

**Collaborative Research: Regulation of plankton and nutrient dynamics by hydrodynamics and profundal filter feeders (Filter Feeders Physics and Phosphorus)**

**Coverage**: Lake Michigan

Overview: While benthic filter feeders are known to influence plankton and nutrient dynamics in shallow marine and freshwater systems, their role is generally considered to be minor in large, deep systems. However, recent evidence indicates that profundal quagga mussels (Dreissena rostriformis bugensis) have dramatically altered energy flow and nutrient cycling in the Laurentian Great Lakes and other larges aquatic systems, so that conventional nutrient-plankton paradigms no longer apply. Observed rates of phosphorus grazing by profundal quagga mussels in Lake Michigan exceed the passive settling rates by nearly an order of magnitude, even under stably stratified conditions. We hypothesize that the apparently enhanced particle deliver rate to the lake bottom results from high filtration capacity combined with vertical mixing processes that advect phytoplankton from the euphotic zone to the near-bottom layer. However, the role of hydrodynamics is unclear, because these processes are poorly characterized both within the hypolimnion as a whole and within the near-bottom layer. In addition, the implications for phytoplankton and nutrient dynamics are unclear, as mussels are also important nutrient recyclers. In the proposed interdisciplinary research project, state-of-the-art instruments and analytical tools will be deployed in Lake Michigan to quantify these critical dynamic processes, including boundary layer turbulence, mussel grazing, excretion and egestion, and benthic fluxes of carbon and phosphorus. Empirical data will be used to calibrate a 3D hydrodynamic-biogeochemical model to test our hypotheses. Intellectual Merit: This collaborative biophysical project is structured around two primary questions: 1) What role do profundal dreissenid mussels play in large lake carbon and nutrient cycles? 2) How are mussel grazing and the fate of nutrients recycled by mussels modulated by hydrodynamics at scales ranging from mm (benthic boundary layer) to meters (entire water column)? The project will improve the ability to model nutrient and carbon dynamics in coastal and lacustrine waters where benthic filter-feeders are a significant portion of the biota. By so doing, it will address the overarching question of how plankton and nutrient dynamics in large, deep lakes with abundant profundal filter feeders differ from the conventional paradigm described by previous models. Additionally, the project will quantify and characterize boundary layer turbulence for benthic boundary layers in large, deep lakes, including near-bed turbulence produced by benthic filter feeders. Broader Impacts: The project will provide new insight into the impacts of invasive dreissenid mussels, which are now threatening many large lakes and reservoirs across the United States. Dreissenid mussels appear to be responsible for a number of major changes that have occurred in the Great Lakes, including declines of pelagic plankton populations, declines in fish populations, and, ironically, nuisance algal blooms in the nearshore zone. As a result, conventional management models no longer apply, and managers are uncertain about appropriate nutrient loading targets and fish stocking levels. The data and models resulting from this project will help to guide those decisions. Additionally, the project will provide insight to bottom boundary layer physics, with applicability to other large lakes, atidal coastal seas, and the deep ocean. The project will leverage the collaboration and promote interdisciplinary education for undergraduate and

graduate students from two universities (UW-Milwaukee and Purdue). The project will support 3 Ph.D. students and provide structured research experiences to undergraduates through a summer research program. The project will also promote education of future aquatic scientists by hosting a Biophysical Coupling Workshop for graduate students who participate in the annual IAGLR conferences, and the workshop lectures will be published for general access through ASLO e-Lectures and on an open-access project website. Background publications are available at:http://onlinelibrary.wiley.com/doi/10.1002/2014JC010506/fullhttp://link.... Note: This is an NSF Collaborative Research Project.

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## Funding


| Funding Source | Award |
| --- | --- |
| NSF Division of Ocean Sciences (NSF OCE) | OCE-1658390 |


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