

# Stable isotope analyses, mercury measurements, and capture data from Baltic fishes collected 2019-2021 for Project Breathless

**Website:** <https://www.bco-dmo.org/dataset/967907>

**Data Type:** Other Field Results

**Version:** 1

**Version Date:** 2025-07-11

## Project

» [Collaborative Research: Shifting the Hypoxia Paradigm – New Directions to Explore the Spread and Impacts of Ocean/Great Lakes Deoxygenation](#) (HypoxiDigm / Project Breathless)

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## Abstract

This dataset summarizes capture data and basic biological information, plus stable isotopic ratios and total mercury data collected from muscle tissue from four species of fishes investigated as part of Project Breathless. Atlantic cod, Baltic flounder, eelpout, and round goby were collected for this project to compare to fishes in our other systems within "Project Breathless." Flounder, eelpout, and round goby are all benthic species, but with different mobilities; flounder are the best swimmers and eelpout are the worst, such that eelpout likely have very small home ranges. Cod is a demersal species, which can move up and down in the water column as well as perform some migrations, to greater or lesser extent.

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## Coverage

**Location:** Baltic Sea at several locations, and North Atlantic around Iceland

**Spatial Extent:** N:60.68278 E:18.83864 S:55.18133 W:13.27433

**Temporal Extent:** 2019-10-02 - 2021-10-20

## Dataset Description

This dataset is part of Project Breathless, which brings together an interdisciplinary team of ecologists, economists and communication scholars to increase understanding of the impact of low oxygen dead zones in lakes and oceans. The project team focuses on how low oxygen conditions influence fish, their habitats and the food webs that support them, as well as ecosystem services, including fisheries production.

This dataset is one of three examining Baltic fishes using data collected during routine surveys for monitoring the status of fish stocks:

- **Dataset 967907 (this dataset of stables isotopes and mercury)** summarizes capture data as well as basic biological information; it also includes all stable isotopic ratio and total mercury data collected from muscle tissue (though not from every fish).
- Dataset 967925 (Baltic fishes otolith chemistry) contains all of the Baltic Sea fish otolith chemistry data; it also includes data from 14 Icelandic cod otoliths that were used as an out-group for part of the study
- Dataset 967934 (Baltic fishes eye lens chemistry) contains all of the eye lens chemistry data.

*(See Related Datasets section below for links)*

## Methods & Sampling

Fish were collected during routine surveys performed for monitoring the status of fish stocks, either by national fishery management agencies (Department of Aquatic Resources, Swedish University of Agricultural Sciences, Icelandic Marine and Freshwater Research Institute) or international collaborative effort (Baltic International Trawl Survey). Fish were caught by trawl or by gillnet sets, then frozen for later processing.

In the lab, fish were measured for length and weighed. Sex and spawning stage were determined where possible. Otoliths and eye lenses were removed, cleaned, and stored until workup (see Related Datasets section below). Samples of dorsal muscle tissue were collected for mercury and stable isotope analysis and were dried to constant weight.

Total mercury analyses were conducted using atomic absorption spectrophotometry on a Milestone DMA-80 tri-cell unit (Milestone Srl, Italy). Briefly, the method involves thermal decomposition of a sample, amalgamation of mercury, and absorbance of mercury using a spectrophotometer. Quality assurance and quality control was following EPA Method 7473, including daily calibration checks, the use of blanks, certified reference materials, and matrix spike/matrix spike duplicates. Sample duplicates were analyzed on a minimum of 20% of samples.

Stable isotopic ratio analyses for carbon (C), nitrogen (N), and sometimes sulfur (S) were conducted by either the Stable Isotope Facility at the University of California at Davis or at the Cornell University Isotope Laboratory. Both facilities routinely analyze solid samples, such as ours, using elemental analyzers on the front end of isotope ratio mass spectrometers (EA-IRMS). Delta values are expressed relative to Vienna Pee Dee Belemnite (for carbon), air (for nitrogen), and Vienna Canyon Diablo Troilite (for sulfur) standards. Light stable isotopes of C and N were analyzed at UC Davis with PDZ Europa ANCA-GSL elemental analyzer interfaced to a PDZ Europa 20-20 isotope ratio mass spectrometer (Sercon Ltd., Cheshire, UK). At Cornell, a Thermo Delta V isotope ratio mass spectrometer (IRMS) is interfaced to a NC2500 elemental analyzer (EA). Sulfur isotopes were analyzed separately on the same mass spectrometer at Cornell.

*(For otolith chemistry and fish eye lens chemistry results, see Related Datasets section below.)*

## Data Processing Description

Results data on total mercury and C, N, and S stable isotopes were received as-is from outside labs, with no further processing.

## BCO-DMO Processing Description

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- ...

## Problem Description

Not all analytes were collected on every single fish. There were too many fish collected to allow for all of them to be assayed.

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## Related Publications

Limburg, K. E., Heimbrand, Y., & Kuliński, K. (2023). Marked recent declines in boron in Baltic Sea cod otoliths – a bellwether of incipient acidification in a vast hypoxic system? *Biogeosciences*, 20(23), 4751–4760.

<https://doi.org/10.5194/bg-20-4751-2023>

*Results*

Limburg, K. E., Heimbrand, Y., Hüssy, K., Blass, M., Thomas, J. B., Mäkinen, K., & Næraa, T. (2025). The forgotten element: Why do we ignore calcium in otolith studies? *Fisheries Research*, 283, 107297.

<https://doi.org/10.1016/j.fishres.2025.107297>

*Results*

U.S. EPA (2007) EPA Method 7473 (SW-846): Mercury in Solids and Solutions by Thermal Decomposition, Amalgamation, and Atomic Absorption Spectrophotometry. <https://www.epa.gov/sites/default/files/2015-07/documents/epa-7473.pdf>

*Methods*

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## Related Datasets

### IsRelatedTo

Limburg, K., Heimbrand, Y., Razavi, R., Miraly, H. (2025) **Eye lens chemistry of fishes in the Baltic Sea collected 2019-2021 for Project Breathless**. Biological and Chemical Oceanography Data Management Office (BCO-DMO). (Version 1) Version Date 2025-07-11 <http://lod.bco-dmo.org/id/dataset/967934> [[view at BCO-DMO](#)]

Limburg, K., Heimbrand, Y., Razavi, R., Miraly, H. (2025) **Otolith chemistry of fishes in the Baltic Sea collected 2019-2021 for Project Breathless**. Biological and Chemical Oceanography Data Management Office (BCO-DMO). (Version 1) Version Date 2025-07-11 <http://lod.bco-dmo.org/id/dataset/967925> [[view at BCO-DMO](#)]

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## Parameters

Parameter	Description	Units
Fish_ID	Unique identifier for the sample	unitless
Species	Scientific name of the fish species	unitless

Year	Year of collection	unitless
Date	Date of collection	unitless
Survey	Name of the survey (BITS = Baltic International Trawl Survey; Gävle = a site near the city of Gävle; Herrvik = site off the eastern coast of Gotland; Muskö = site in the Stockholm Archipelago)	unitless
Status	Indicates oxygen conditions of the water at the sampling site (Hypoxic or Normoxic)	unitless
Latitude	Latitude of fish capture	decimal degrees
Longitude	Longitude of fish capture	decimal degrees
Tot_Length	Fish total length	millimeters (mm)
Weight	Fish fresh weight	grams (g)
SLU_Age_years	Ages in years estimated by trained otolith readers for cod collected by Baltic International Trawl Survey	years
KL_Age_years	Ages in years determined by PI Limburg	years
Sex	Sex of the fish	unitless
d13C_VPDB	Carbon stable isotopic ratios, using Vienna Pee Dee Belemnite standard	per mille
d15N_Air	Nitrogen stable isotopic ratios, using atmospheric N as the standard	per mille
d34S_VCDT	Sulfur stable isotopic ratios, using Vienna Canyon Diablo Triolite standard	per mille
Tot_Hg_dry_weight	Total mercury, ng/g dry weight	nanograms per gram (ng/g)
Eye_Lens_Tot_Hg	Eye lens total mercury (round goby only)	nanograms per gram (ng/g)
Oto_Analyzed	Indicates whether an otolith from the individual fish was analyzed (Y=yes, blank=no or not collected)	unitless

Comments	Comments	unitless
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## Instruments

<b>Dataset-specific Instrument Name</b>	NC2500 Elemental Analyzer
<b>Generic Instrument Name</b>	Carlo Erba NC 2500 elemental analyzer
<b>Dataset-specific Description</b>	At Cornell, an isotope ratio mass spectrometer was interfaced to a NC2500 elemental analyzer (EA).
<b>Generic Instrument Description</b>	A laboratory instrument that simultaneously determines total nitrogen, total hydrogen, and total carbon in a solid sample. The sample is completely and instantaneously oxidized by flash combustion, which converts all organic and inorganic substances into combustion products. The resulting combustion gases pass through a reduction furnace and are swept into the chromatographic column by the helium carrier gas. The gases are separated in the column and quantified or they can be introduced into another instrument, such as an isotope ratio mass spectrometer, for further analysis. The instrument was originally manufactured by CE instruments (formerly Carlo Erba) and has since been replaced by Thermo Scientific (part of Thermo Fisher Scientific). This model is no longer in production.

<b>Dataset-specific Instrument Name</b>	Milestone DMA-80 tri-cell unit atomic absorption spectrophotometer
<b>Generic Instrument Name</b>	Milestone Direct Mercury Analyzer
<b>Dataset-specific Description</b>	Mercury analyses of tissues were made with a Milestone DMA-80 tri-cell unit atomic absorption spectrophotometer.
<b>Generic Instrument Description</b>	The Milestone DMA-80 is a mercury analyzer used to determine mercury concentrations in liquid and solid samples. The DMA-80 is based on the principles of sample thermal decomposition, mercury amalgamation, and atomic absorption detection. See more: <a href="https://milestonesci.com/direct-mercury-analyzer/">https://milestonesci.com/direct-mercury-analyzer/</a>

<b>Dataset-specific Instrument Name</b>	PDZ Europa 20-20 isotope ratio mass spectrometer
<b>Generic Instrument Name</b>	PDZ Europa 20-20 isotope ratio mass spectrometer
<b>Dataset-specific Description</b>	Light stable isotopes of C and N were analyzed at UC Davis with elemental analyzer interfaced to a PDZ Europa 20-20 isotope ratio mass spectrometer (Sercon Ltd., Cheshire, UK).
<b>Generic Instrument Description</b>	The PDZ Europa 20-20 is a dedicated continuous flow isotope ratio mass spectrometer for hyphenated stable isotope analyses able to measure $^{15}\text{N}$ , $^{13}\text{C}$ , $^{18}\text{O}$ , and $^{34}\text{S}$ in a host of applications. The analyzer has been purposely designed to measure $^2\text{H}$ by continuous flow methodology and is also suitable to analyze the light stable isotopes in all the commonly measured gases: $\text{H}_2$ , $\text{N}_2$ , $\text{NO}$ , $\text{N}_2\text{O}$ , $\text{O}_2$ , $\text{CO}$ , $\text{CO}_2$ , $\text{SO}$ , and $\text{SO}_2$ .

<b>Dataset-specific Instrument Name</b>	PDZ Europa ANCA-GSL elemental analyzer
<b>Generic Instrument Name</b>	PDZ Europa ANCA-GSL elemental analyzer
<b>Dataset-specific Description</b>	Light stable isotopes of C and N were analyzed at UC Davis with PDZ Europa ANCA-GSL elemental analyzer interfaced to an isotope ratio mass spectrometer.
<b>Generic Instrument Description</b>	The ANCA-GSL module allows samples such as soil, viscous liquids, plant material, and organic compounds, to be analyzed directly by using Dumas combustion for $^{15}\text{N}$ , $^{13}\text{C}$ , and $^{34}\text{S}$ or pyrolysis for $^{18}\text{O}$ and D. It also allows isotope analysis of abundant gases from septum sealed containers. During combustion mode, a capsule containing the sample falls into the combustion tube and is converted in the presence of oxygen to $\text{CO}_2$ , $\text{N}_2$ , $\text{NO}_x$ , and $\text{H}_2\text{O}$ . An elemental copper stage reduces $\text{NO}_x$ , a $\text{MgClO}_4$ trap removes water vapor, a switchable Carbosorb trap can be used to remove $\text{CO}_2$ (for $^{15}\text{N}$ only analyses) and a GC column separates $\text{CO}_2$ from $\text{N}_2$ (allowing dual isotope analysis). Modified packings, a Nafion dryer and different GC column allow $^{34}\text{S}$ analysis. The sample preparation unit consists of a 66-place autosampler for unattended operation (larger options are available), 2 furnaces able to operate to $1100^\circ\text{C}$ , and an on-board microprocessor. The analyzer is capable of dual isotope analysis of $^{15}\text{N}$ and $^{13}\text{C}$ . For $\text{CO}$ ( $^{18}\text{O}$ ), $\text{H}_2$ ( $^2\text{H}$ ), $\text{N}_2$ ( $^{15}\text{N}$ ), $\text{CO}_2$ ( $^{13}\text{C}$ ), $\text{CO}_2$ ( $^{18}\text{O}$ ), and $\text{SO}_2$ ( $^{34}\text{S}$ ) with precisions between 0.1 and 3 dependent on the element.

<b>Dataset-specific Instrument Name</b>	Thermo Delta V isotope ratio mass spectrometer (IRMS)
<b>Generic Instrument Name</b>	Thermo Fisher Scientific DELTA V Advantage isotope ratio mass spectrometer
<b>Dataset-specific Description</b>	At Cornell, a Thermo Delta V isotope ratio mass spectrometer (IRMS) is interfaced to an elemental analyzer.
<b>Generic Instrument Description</b>	The Thermo Scientific DELTA V Advantage is an isotope ratio mass spectrometer designed to measure isotopic, elemental, and molecular ratios of organic and inorganic compounds. The DELTA V Advantage is the standard model of the DELTA V series of isotope ratio mass spectrometers, which can be upgraded to the DELTA V Plus. The DELTA V Advantage can be operated in Continuous Flow or Dual Inlet mode. The standard collector configuration is the Universal Triple Collector. H <sub>2</sub> collectors with online hydrogen capability are optional. The DELTA V Advantage is controlled by an automated, integrated Isodat software suite. A magnet, whose pole faces determine the free flight space for the ions, eliminates the traditional flight tube. The magnet is designed for fast mass switching which is further supported by a fast jump control between consecutive measurements of multiple gases within one run. The sample gas is introduced at ground potential, eliminating the need for insulation of the flow path, ensuring 100 percent transfer into the ion source. The amplifiers register ion beams up to 50 V. The DELTA V Advantage has a sensitivity of 1200 molecules per ion (M/I) in Dual Inlet mode and 1500 M/I in Continuous Flow mode. It has a system stability of < 10 ppm and an effective magnetic detection radius of 191 nm. It has a mass range of 1 - 80 Dalton at 3 kV.

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## Project Information

### Collaborative Research: Shifting the Hypoxia Paradigm - New Directions to Explore the Spread and Impacts of Ocean/Great Lakes Deoxygenation (HypoxiDigm / Project Breathless)

**Coverage:** Central Baltic Sea; Lake Erie; and Lavaca Bay, Texas

#### *NSF Award Abstract:*

Ocean oxygen loss (deoxygenation) is increasing due to climate warming. This warming, together with nutrient loading, is causing many marine and freshwater systems to experience increasing episodes of hypoxia (low oxygen) of greater duration and intensity. Impacts on fish and fisheries have been difficult to quantify; direct observation has been challenged by a lack of long-term exposure indicators. This team has successfully refined the use of fish chemical biomarkers in fish otoliths (earstones) to directly assess lifetime hypoxia exposure in fishes. This project will those findings to look for additional biomarkers and models, to expand our understanding of how hypoxia affects fish and their food webs, contaminant transfers, and ecosystem services including economic impacts. The project includes a unique way of training students in science communication, posing the question: What forms of media and "messaging strategies" about deoxygenation are most effective at raising public awareness and understanding? Students are developing entries for PlanetForward's Storyfest, which is a contest to tell compelling stories to foster environmental understanding and solutions. Students from historically underrepresented, economically disadvantaged backgrounds are particularly sought out to participate. The investigators will engage with regional, national, and international management agencies and other relevant stakeholder groups to share information.

This project encompasses a novel, linked set of interdisciplinary studies of food webs, and ecosystem services assessment. The thematic questions explored in this project are: 1. How does hypoxia alter habitat use for fishes? 2. How does hypoxia-altered habitat use and habitat productivity change food webs? 3. How does hypoxia affect/enhance trophic transfer of methylmercury? 4. How do hypoxia-induced changes in food webs affect aquatic ecosystem services? The set of linked studies will employ chemical analyses of otoliths and eye lenses, combined with chemical analyses of muscle tissues (Questions 1 and 3), physiologically-structured

food web modeling informed by monitoring time-series (Questions 2 and 4), and a scoping workshop to address ecosystem services (Question 4). The investigators are using a "trans-basin" comparative approach to system-specific responses, studying fishes in Lake Erie, the Baltic Sea, and a Gulf of Mexico estuary. They study three species from each system that represent different degrees of benthic reliance, to discern differential responses to the increasingly hypoxic environment. This research provides novel insight about variable biotic responses to oxygen loss and the impacts on ecosystem functioning.

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## Funding

Funding Source	Award
<a href="#">NSF Division of Ocean Sciences (NSF OCE)</a>	<a href="#">OCE-1923965</a>

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