Depth profiles of oceanographic parameters in spring and summer from R/V Terrapin, R/V Hugh R. Sharp multiple cruises in Chesapeake Bay, 2010-2011 (LiDZ project)

Website: https://www.bco-dmo.org/dataset/515368
Version: final
Version Date: 2014-05-20

Project
» Life in the Dead Zone: Microbial respiration, production, diversity and gene expression in seasonally anoxic estuarine waters (LiDZ)

Contributors	Affiliation	Role
Crump, Byron C	University of Maryland Center for Environmental Science (UMCES/HPL)	Chief Scientist, Principal Investigator, Contact
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Coverage

Spatial Extent: **N**:39.0414 **E**:-76.1718 **S**:37.7746 **W**:-76.446
Temporal Extent: 2010-10-18 - 2011-04-18

Dataset Description

Oceanographic data from the middle region of the Chesapeake Bay, especially water column depth profiles of seasonally anoxic bottom waters, collected in spring and summer of 2010-2011.

Water samples and sensor-based measurements were made during sixteen research cruises in 2010-2012: two 1-week cruises aboard the UNOLS vessel R/V Hugh R. Sharp, and fourteen 1-day cruises aboard the R/V Terrapin, which is a 25' Parker outboard motorboat with davit for deploying a CTD package.

Methods & Sampling

SAMPLE COLLECTION

Data Processing Description

SAMPLE ANALYSES

REFERENCES

RELATED FILES AND REFERENCES:

16S amplicon DNA sequences to the Sequence Read Archive (SRA) at the National Center for Biotechnology Information (NCBI) under Accession SAMN02863536-SAMN02863970.

Metatranscriptomic sequence data to the BioProject Archive at NCBI under Accession PRJNA222777. http://www.ncbi.nlm.nih.gov/bioproject/PRJNA222777

Lee, D. Y., M. S. Owens, B. C. Crump, and J. C. Cornwell. 2014. The Effects of Oxygen Transition on Community Respiration and Potential Chemoautotrophic Production in a Seasonally Stratified Anoxic Estuary. Estuaries and Coasts. DOI 10.1007/s12237-014-9803-8. http://link.springer.com/article/10.1007/s12237-014-9803-8

Hewson, I., E. Eggleston, M. Doherty, D. Y. Lee, M. Owens, J. P. Shipleigh, J. C. Cornwell, and B. C. Crump. 2014. Metatranscriptomic analyses of plankton communities inhabiting surface and sub-pycnocline waters of the Chesapeake Bay during oxic-anoxic-oxic transitions. Applied And Environmental Microbiology 80:328-338. http://aem.asm.org/content/early/2013/10/21/AEM.02680-13

DMO notes:
Format or vocabulary adjustments to metadata primarily involved controlling the vocabulary and adding UNOLS names for the cruises.
Date changed to date_local
Time -> time_local
Vessel -> platform
Cruise -> cruise [Inserted cruise_new to give column for UNOLS name]
Lowercase Filtered, Cast, Depth [added cast_new to separate alpha and numeric for mapper]
Abbreviated Latitude, Longiture, Conductivity, Temperature, Salinity, Fluorescence
Decoded Oxygen1 -> O2_conc and Oxygen2 -> O2_rate

In keeping with BCO-DMO best practices, ISODateTime has been added as a formatted time column. At this time it is local time.

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Data Files

File
water_samples.csv (Comma Separated Values (.csv), 43.33 KB) MD5:bc43ab9ff2fbcdcb81b968f93188882b Primary data file for dataset ID 515368

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Parameters

Parameter	Description	Units
sample_num	arbitrary	nd
date_local	Date	Eastern Daylight Time
time_local	HH:MM	24-hour clock
platform	Ship used to collect samples	nd
cruise	Internal cruise number	text

cruise_new	UNOLS cruise identifier	text
filtered	indicates whether a sample was prefiltered before measuring N2_rate;O2_rate; and DIC_rate	text
cast	Depth station number for each CTD and pump cast; WC1 is near surface and WC8 is near bottom.	alphanumeric
cast_new	Depth station number for each CTD and pump cast without the alpha	numeric
depth	Sampling depth	meters
lat	Latitude	degrees
lon	Longitude	degrees
cond	Conductivity: Measured with a SBE 25 on the R/V Terrapin and SBE 911plus on R/V Hugh R. Sharp; Sea-Bird Electronics	microsiemens per centimeter
temp	Temperature: Measured with a SBE 25 on the R/V Terrapin and SBE 911plus on R/V Hugh R. Sharp; Sea-Bird Electronics	degrees celsius
sal	Salinity: Measured with a SBE 25 on the R/V Terrapin and SBE 911plus on R/V Hugh R. Sharp; Sea-Bird Electronics	salinity
O2_conc	oxygen concentration: Measured with a SBE 25 on the R/V Terrapin and SBE 911plus on R/V Hugh R. Sharp; Sea-Bird Electronics	milligrams per liter
O2_sat	oxygen saturation: Measured with a SBE 25 on the R/V Terrapin and SBE 911plus on R/V Hugh R. Sharp; Sea-Bird Electronics	percent saturation
fluor	Fluorescence: Measured with a WETStar sensor; WET Labs	milligrams per cubic meter
N2_rate	Nitrogen production rate: (TF-T0) / hr (Importantly this is the number which is multiplied by -2 to make unit of uM N2-N/h)	micromoles per liter hour
O2_rate	Oxygen consumption rate: Measured with membrane inlet mass spectrometer during short incubations in gas-tight BOD bottles	micromoles per liter hour
DIC_rate	Dissolved inorganic carbon production rate: Measured with an infrared CO2 detector during short incubations in gas-tight BOD bottles	micromoles per liter hour
NO2	Nitrite: Measured with segmented flow analysis after cadmium reduction (Lane et al. 2000)	micromolar
NO3	Nitrate: Measured with segmented flow analysis after cadmium reduction (Lane et al. 2000)	micromolar
NH4	Ammonium: Measured colorimetrically (Brewer and Spencer 1971; Parsons et al. 1984)	micromolar
SRP	Soluble reactive phosphorous: Measured colorimetrically (Brewer and Spencer 1971; Parsons et al. 1984)	micromolar
H2S	Total dissolved sulfide (DS = [S2-] + [HS-] + [H2S]): Measured colorimetrically (Brewer and Spencer 1971; Parsons et al. 1984)	micromolar
Fe	Dissolved iron (II): Measured colorimetrically (Brewer and Spencer 1971; Parsons et al. 1984)	milligrams per liter
Mn	Dissolved manganese (III and II): Measured colorimetrically (Brewer and Spencer 1971; Parsons et al. 1984)	micromolar
BP	Bacterial Production: Calculated from the rate of incorporation of tritiated L-leucine in 1-hour incubations at ambient temperature and redox conditions	micrograms carbon per liter hour
Chla	Chlorophyll a: Measured with a fluorometric method (Arar & Collins 1997)	micrograms per liter
Pheophytin_a	Phaeophytin a: Measured with a fluorometric method (Arar & Collins 1997)	micrograms per liter

Cell_Counts	flow cytometry counts of prokaryotic cells	cells per milliliter
ISO_DateTime_Local	ISO8601-compliant date/time standard	YYYY-mm-ddTHH:MM:SS.ss

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Instruments

Dataset-specific Instrument Name	Box Corer
Generic Instrument Name	Box Corer
Dataset-specific Description	Sediment cores were collected with an acrylic/PVC Soutar-design box corer to determine sediment-water fluxes.
Generic Instrument Description	General description of a box corer: A box corer is a marine geological tool that recovers undisturbed soft surface sediments. It is designed for minimum disturbance of the sediment surface by bow wave effects. Traditionally, it consists of a weighted stem fitted to a square sampling box. The corer is lowered vertically until it impacts with the seabed. At this point the instrument is triggered by a trip as the main coring stem passes through its frame. While pulling the corer out of the sediment a spade swings underneath the sample to prevent loss. When hauled back on board, the spade is under the box. (definition from the SeaVox Device Catalog) Box corers are one of the simplest and most commonly used types of sediment corers. The stainless steel sampling box can contain a surface sediment block as large as 50cm x 50cm x 75cm with negligible disturbance. Once the sediment is recovered onboard, the sediment box can be detached from the frame and taken to a laboratory for subsampling and further analysis. The core sample size is controlled by the speed at which the corer is lowered into the ocean bottom. When the bottom is firm, a higher speed is required to obtain a complete sample. A depth pinger or other depth indicator is generally used to determine when the box is completely filled with sediment. Once the core box is filled with sediment, the sample is secured by moving the spade-closing lever arm to lower the cutting edge of the spade into the sediment, until the spade completely covers the bottom of the sediment box. (definition from Woods Hole Oceanographic Institution).

Dataset-specific Instrument Name	oxycline sampling device
Generic Instrument Name	Discrete water sampler
Dataset-specific Description	Samples were collected at 7 depths across the oxycline using a syringe-sampling device that simultaneously fills a total of 28 syringes (4 syringes every 20cm vertically) using a mechanical feature that gradually pulls the water into the syringes when triggered. In 2012, a new “oxycline sampling device” was developed that uses a multi-channel peristaltic pump to draw water from 8 depths across a 3m range.
Generic Instrument Description	A device that collects an in-situ discrete water sample from any depth and returns it to the surface without contamination by the waters through which it passes, such as a water bottle.

Dataset-specific Instrument Name	Flow Cytometer
Generic Instrument Name	Flow Cytometer
Dataset-specific Description	Enumeration was performed using a FACSCalibur flow cytometer (Becton Dickinson) using green fluorescence as an incident trigger, with a target range for sample event rates at 100-1000 particles s-1 to prevent incident coincidence. (http://www.bdbiosciences.com/instruments/facscalibur/features/index.jsp)
Generic Instrument Description	Flow cytometers (FC or FCM) are automated instruments that quantitate properties of single cells, one cell at a time. They can measure cell size, cell granularity, the amounts of cell components such as total DNA, newly synthesized DNA, gene expression as the amount messenger RNA for a particular gene, amounts of specific surface receptors, amounts of intracellular proteins, or transient signalling events in living cells. (from: http://www.bio.umass.edu/micro/immunology/facs542/facswhat.htm)

Dataset-specific Instrument Name	Apollo SciTech infrared-based analyzer
Generic Instrument Name	Inorganic Carbon Analyzer
Dataset-specific Description	Dissolved inorganic carbon (DIC = [H2CO3] + [HCO3-] + [CO32-]) was measured with an infrared-based analyzer (Apollo SciTech) http://www.apolloscitech.com/DIC.htm
Generic Instrument Description	Instruments measuring carbonate in sediments and inorganic carbon (including DIC) in the water column.

Dataset-specific Instrument Name	Liquid Scintillation Analyzer
Generic Instrument Name	Liquid Scintillation Counter
Dataset-specific Description	Radioactivity, expressed as disintegration per minute (DPM), was counted in a liquid scintillation analyzer (Tri-Carb 3100TR, Packard). The Tri-Carb® 3100TR is a computer-controlled benchtop liquid scintillation analyzer for detecting small amounts of alpha, beta and gamma radioactivity. (http://shop.perkinelmer.com/Content/relatedmaterials/specificationsheets...)
Generic Instrument Description	Liquid scintillation counting is an analytical technique which is defined by the incorporation of the radiolabeled analyte into uniform distribution with a liquid chemical medium capable of converting the kinetic energy of nuclear emissions into light energy. Although the liquid scintillation counter is a sophisticated laboratory counting system used the quantify the activity of particulate emitting (ß and a) radioactive samples, it can also detect the auger electrons emitted from 51Cr and 125I samples.

Dataset-specific Instrument Name	membrane inlet mass spectrometer
Generic Instrument Name	Mass Spectrometer
Dataset-specific Description	"A membrane inlet mass spectrometer was modified to perform rapid, high-precision measurements of dissolved 02, and Ar in water. The instrument pumps water at < 1 mL per min through semipermeable microbore silicone; tubing positioned inside an inlet vacuum line of a quadrupole mass spectrometer. Precise pumping and temperature control of the water sample contribute to high signal stability and reproducibility. Dissolved gas concentrations are determined from intensities of the mass spectrometer signals in the multiple ion detection mode. Precision (coefficient of variation) is
Generic Instrument Description	General term for instruments used to measure the mass-to-charge ratio of ions; generally used to find the composition of a sample by generating a mass spectrum representing the masses of sample components.

Dataset-specific Instrument Name	Diaphragm Pump
Generic Instrument Name	Pump
Dataset-specific Description	Water samples for chemistry and biological rate measurements were collected with a diaphragm pump with a 2.54 cm diameter hose attached to the CTD frame and ended with a conical PVC manifold distributing water to 16 tubings to fill sample vials.
Generic Instrument Description	A pump is a device that moves fluids (liquids or gases), or sometimes slurries, by mechanical action. Pumps can be classified into three major groups according to the method they use to move the fluid: direct lift, displacement, and gravity pumps

Dataset-specific Instrument Name	Submersible Well Pump
Generic Instrument Name	Pump
Dataset-specific Description	Water samples for DNA and RNA were collected with a submersible well pump (Tornado Pump, Groundwater Essentials) attached to the CTD Frame (R/V Sharp) or deployed by hand separately from the CTD (R/V Terrapin). http://www.groundwateressentials.com/pumps/plastic-pumps-standard/tornad...
Generic Instrument Description	A pump is a device that moves fluids (liquids or gases), or sometimes slurries, by mechanical action. Pumps can be classified into three major groups according to the method they use to move the fluid: direct lift, displacement, and gravity pumps

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Deployments

LDZ1

Website	https://www.bco-dmo.org/deployment/515278
Platform	R/V Terrapin
Start Date	2010-05-17
End Date	2010-05-17
Description	One of 14 one-day cruises on a 25' Parker outboard motorboat with a davit for deploying a CTD package. **Methods & Sampling** Vertical profiles at sampling stations were conducted from surface to near bottom depth with a Sea-Bird conductivity-temperature-depth (CTD) system with dissolved oxygen (SBE 25 on the R/V Terrapin); Sea-Bird Electronics and fluorescence (WETStar, WET Labs) sensors.

LDZ2

Website	https://www.bco-dmo.org/deployment/515281
Platform	R/V Terrapin
Start Date	2010-06-07
End Date	2010-06-07
Description	One of 14 one-day cruises on a 25' Parker outboard motorboat with a davit for deploying a CTD package. **Methods & Sampling** Vertical profiles at sampling stations were conducted from surface to near bottom depth with a Sea-Bird conductivity-temperature-depth (CTD) system with dissolved oxygen (SBE 25 on the R/V Terrapin; Sea-Bird Electronics) and fluorescence (WETStar, WET Labs) sensors.

LDZ3

Website	https://www.bco-dmo.org/deployment/515284
Platform	R/V Terrapin
Start Date	2010-06-16
End Date	2010-06-16
Description	One of 14 one-day cruises on a 25' Parker outboard motorboat with a davit for deploying a CTD package. **Methods & Sampling** Vertical profiles at sampling stations were conducted from surface to near bottom depth with a Sea-Bird conductivity-temperature-depth (CTD) system with dissolved oxygen (SBE 25 on the R/V Terrapin; Sea-Bird Electronics) and fluorescence (WETStar, WET Labs) sensors.

HRS100709BC

Website	https://www.bco-dmo.org/deployment/514970
Platform	R/V Hugh R. Sharp
Start Date	2010-07-09
End Date	2010-07-16
Description	**Methods & Sampling** Vertical profiles at sampling stations were conducted from surface to near bottom depth with a Sea-Bird conductivity-temperature-depth (CTD) system with dissolved oxygen (SBE 911plus on R/V Hugh R. Sharp; Sea-Bird Electronics) and fluorescence (WETStar, WET Labs) sensors.

LDZ5

Website	https://www.bco-dmo.org/deployment/515323
Platform	R/V Terrapin
Start Date	2010-08-05
End Date	2010-08-05
Description	One of 14 one-day cruises on a 25' Parker outboard motorboat with a davit for deploying a CTD package. The deployment synonym (in the same place and time) called "*_filt" is labeled a deployment although it was really a different treatment of the samples -- filtered or unfiltered. **Methods & Sampling** Vertical profiles at sampling stations were conducted from surface to near bottom depth with a Sea-Bird conductivity-temperature-depth (CTD) system with dissolved oxygen (SBE 25 on the R/V Terrapin); Sea-Bird Electronics and fluorescence (WETStar, WET Labs) sensors.

LDZ6

Website	https://www.bco-dmo.org/deployment/515326
Platform	R/V Terrapin
Start Date	2010-08-31
End Date	2010-08-31
Description	One of 14 one-day cruises on a 25' Parker outboard motorboat with a davit for deploying a CTD package. The deployment synonym (in the same place and time) called "*_filt" is labeled a deployment although it was really a different treatment of the samples -- filtered or unfiltered. [DMO- I have removed this synonym. Not necessary.] **Methods & Sampling** Vertical profiles at sampling stations were conducted from surface to near bottom depth with a Sea-Bird conductivity-temperature-depth (CTD) system with dissolved oxygen (SBE 25 on the R/V Terrapin; Sea-Bird Electronics) and fluorescence (WETStar, WET Labs) sensors.

LDZ7

Website	https://www.bco-dmo.org/deployment/515329
Platform	R/V Terrapin
Start Date	2010-10-18
End Date	2010-10-18
Description	One of 14 one-day cruises on a 25' Parker outboard motorboat with a davit for deploying a CTD package. **Methods & Sampling** Vertical profiles at sampling stations were conducted from surface to near bottom depth with a Sea-Bird conductivity-temperature-depth (CTD) system with dissolved oxygen (SBE 25 on the R/V Terrapin); Sea-Bird Electronics and fluorescence (WETStar, WET Labs) sensors.

LDZ8

Website	https://www.bco-dmo.org/deployment/515332
Platform	R/V Terrapin
Start Date	2011-04-18
End Date	2011-04-18
Description	One of 14 one-day cruises on a 25' Parker outboard motorboat with a davit for deploying a CTD package. **Methods & Sampling** Vertical profiles at sampling stations were conducted from surface to near bottom depth with a Sea-Bird conductivity-temperature-depth (CTD) system with dissolved oxygen (SBE 25 on the R/V Terrapin); Sea-Bird Electronics and fluorescence (WETStar, WET Labs) sensors.

LDZ9

Website	https://www.bco-dmo.org/deployment/515334
Platform	R/V Terrapin
Start Date	2011-05-24
End Date	2011-05-24
Description	One of 14 one-day cruises on a 25' Parker outboard motorboat with a davit for deploying a CTD package. **Methods & Sampling** Vertical profiles at sampling stations were conducted from surface to near bottom depth with a Sea-Bird conductivity-temperature-depth (CTD) system with dissolved oxygen (SBE 25 on the R/V Terrapin); Sea-Bird Electronics and fluorescence (WETStar, WET Labs) sensors.

LDZ10

Website	https://www.bco-dmo.org/deployment/515337
Platform	R/V Terrapin
Start Date	2011-06-14
End Date	2011-06-14
Description	One of 14 one-day cruises on a 25' Parker outboard motorboat with a davit for deploying a CTD package. **Methods & Sampling** Vertical profiles at sampling stations were conducted from surface to near bottom depth with a Sea-Bird conductivity-temperature-depth (CTD) system with dissolved oxygen (SBE 25 on the R/V Terrapin); Sea-Bird Electronics and fluorescence (WETStar, WET Labs) sensors.

HRS110705BC

Website	https://www.bco-dmo.org/deployment/515146
Platform	R/V Hugh R. Sharp
Start Date	2011-07-05
End Date	2011-07-13
Description	**Methods & Sampling** Vertical profiles at sampling stations were conducted from surface to near bottom depth with a Sea-Bird conductivity-temperature-depth (CTD) system with dissolved oxygen (SBE 911plus on R/V Hugh R. Sharp; Sea-Bird Electronics) and fluorescence (WETStar, WET Labs) sensors.

LDZ12

Website	https://www.bco-dmo.org/deployment/515340
Platform	R/V Terrapin
Start Date	2011-08-08
End Date	2011-08-08
Description	One of 14 one-day cruises on a 25' Parker outboard motorboat with a davit for deploying a CTD package. **Methods & Sampling** Vertical profiles at sampling stations were conducted from surface to near bottom depth with a Sea-Bird conductivity-temperature-depth (CTD) system with dissolved oxygen (SBE 25 on the R/V Terrapin); Sea-Bird Electronics and fluorescence (WETStar, WET Labs) sensors.

LDZ13

Website	https://www.bco-dmo.org/deployment/515343
Platform	R/V Terrapin
Start Date	2011-08-30
End Date	2011-08-30
Description	One of 14 one-day cruises on a 25' Parker outboard motorboat with a davit for deploying a CTD package. **Methods & Sampling** Vertical profiles at sampling stations were conducted from surface to near bottom depth with a Sea-Bird conductivity-temperature-depth (CTD) system with dissolved oxygen (SBE 25 on the R/V Terrapin); Sea-Bird Electronics and fluorescence (WETStar, WET Labs) sensors.

LDZ14

Website	https://www.bco-dmo.org/deployment/515346
Platform	R/V Terrapin
Start Date	2011-09-21
End Date	2011-09-21
Description	One of 14 one-day cruises on a 25' Parker outboard motorboat with a davit for deploying a CTD package. **Methods & Sampling** Vertical profiles at sampling stations were conducted from surface to near bottom depth with a Sea-Bird conductivity-temperature-depth (CTD) system with dissolved oxygen (SBE 25 on the R/V Terrapin); Sea-Bird Electronics and fluorescence (WETStar, WET Labs) sensors.

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Project Information

Life in the Dead Zone: Microbial respiration, production, diversity and gene expression in seasonally anoxic estuarine waters (LiDZ)

Coverage: Chesapeake Bay

Every summer in many estuaries and coastal margins, eutrophication-elevated phytoplankton production drives rapid bacterial respiration creating hypoxic and anoxic bottom waters. These so-called “dead zones” exclude fish, kill benthic organisms, and eliminate habitat. Despite their popular name, anoxic/hypoxic zones are not really dead, but rather are populated with living and very active microbial communities. In fact, bacterial production in anoxic waters can exceed that in overlying oxic waters due, in part, to reduced grazing and increased cell size and abundance. Once oxygen is depleted, microbial respiration undergoes a succession of redox reactions with decreasing energy yield as terminal electron acceptors are depleted (e.g., O2, NO3-, Mn(IV), Fe(III), and SO42-). This combination of high production and reduced growth efficiency creates a condition in which respiration may be very high, making anoxic zones significant sinks for organic matter and key sites for nutrient cycling.

Previous research documented respiratory succession in Chesapeake Bay bottom waters based on redox chemistry measurements. Heterotrophic bacterial production was very high at some stages of this succession, suggesting elevated respiration. Also, the phylogenetic composition of bacterioplankton communities in anoxic waters was similar to oxic surface waters for nearly half the summer, only changing after the appearance of H2S. This suggests that typical aerobic estuarine bacteria are able to shift to anaerobic metabolisms and continue to dominate.

Most of what is known about microbial respiration and community composition in anoxic water comes from studies of permanently anoxic systems like the Black Sea and Cariaco Basin. By comparison, very little is known about what is a much more common and more dynamic marine environment – seasonally anoxic estuarine waters. This proposal describes a 3-year integrated study to advance the quantitative and mechanistic understanding of biogeochemical cycling in one of the largest seasonal estuarine anoxic zones in the USA. It hypothesize that:

• Dominant sub-pycnocline respiratory processes undergo a succession from aerobic respiration to nitrate respiration and metal reduction to sulfate reduction.
• Bacterial growth efficiency decreases with this respiratory succession, but bacterial production remains high, resulting in very high carbon respiration rates.
• Bacterial community composition changes little during respiratory succession until sulfate respiration dominates (i.e., the sulfide threshold), but gene expression closely tracks changes in redox conditions in order to support the most energetic respiratory processes.

These hypotheses will be addressed by quantifying carbon respiration rates using several techniques including delta CO2; quantifying bacterial production, biomass and growth efficiency; and characterizing succession in the composition and respiratory gene expression patterns of microbial communities in water column and sediments during each stage of respiratory succession. This project will integrate biogeochemical, biological, and genomic data to explain how biogeochemistry influences, and is influenced by, microbial respiration, production, diversity, and gene expression.

The proposed research will provide (1) reliable measurements of production and respiration in anoxic/hypoxic waters, (2) techniques applicable to other ecosystems, and (3) ecological insight for predicting future changes with ongoing restoration efforts in anoxia-impacted estuaries. These measurements will be useful for calibrating biogeochemical models and for estimating carbon budgets. This research will train two graduate students and one postdoctoral scientist in several state-of-the-art geochemical and molecular biology techniques. Applications will be submitted to the NSF Research Experiences for Teachers program to engage two teachers to work on this project and to participate in the seven-week Environmental Science Education Partnership (ESEP) Teacher Research Fellowship Program (www.esep.umces.edu) at UMCES Horn Point Laboratory. New discoveries will be incorporated into graduate-level courses entitled Aquatic Microbial Ecology, Biological Oceanography, and Environmental Geochemistry. Nucleic acid sequences will be deposited in online repositories including GenBank.

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Funding

Funding Source	Award
NSF Division of Ocean Sciences (NSF OCE)	OCE-0961920

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