Benthic dissolved oxygen and nutrient fluxes from sediment core incubations conducted aboard the R/V Oceanus and R/V Robert G. Sproul during nine cruises from 2018-2022 from the Oregon and Washington shelf

Website: https://www.bco-dmo.org/dataset/940414
Data Type: Cruise Results
Version: 1
Version Date: 2024-10-15

Project
» Benthic Biogeochemical Exchange Dynamics on the Oregon Shelf (BBEDOS)
» Environmental consequences of expanded recruitment of an ecosystem engineer on a hypoxia-influenced continental shelf (Neotrypaea COP Effects)

Contributors	Affiliation	Role
Henkel, Sarah K.	Oregon State University (OSU)	Principal Investigator
Reimers, Clare E.	Oregon State University (OSU)	Principal Investigator
Fogaren, Kristen E.	Oregon State University (OSU)	Scientist
Hughes, Anna	Oregon State University (OSU)	Student
Rauch, Shannon	Woods Hole Oceanographic Institution (WHOI BCO-DMO)	BCO-DMO Data Manager

Abstract
Continental shelf sediments are sinks for dissolved oxygen and sources of many major and minor nutrients required for oceanic surface primary production, resulting in a strong coupling between benthic and pelagic biogeochemical cycling. However, the influence and spatiotemporal variability of benthic remineralization on bottom-water chemistry and the supply of nutrients to surface waters has received minimal study on the Oregon-Washington (OR-WA) shelf. To expand knowledge of these areas, benthic flux measurements were made approximately quarter-annually at inner-shelf and mid-shelf sites on the Newport Hydrographic (NH) Line at 44.6˚N between December 2017 and July 2019, and again between 44.5˚N and 46.5˚N along the mid-shelf during July and September of 2022. The benthic fluxes were determined using a novel set-up for ex situ core incubations. The dataset described here details all benthic fluxes measured during sediment incubation experiments, conducted during the cruises from February 2018 to July 2019, at the sites on the NH Line, and during July and September of 2022. The paired bottom water dataset is located in a separate BCO-DMO dataset (dataset ID 793115). Additionally, during the 2022 cruises, community composition data were collected using box corers. These data are also located in a separate BCO-DMO dataset (dataset ID 880760).

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Coverage

Spatial Extent: **N**:46.449 **E**:-124.031 **S**:44.568 **W**:-124.529
Temporal Extent: 2018-02-27 - 2022-09-18

Methods & Sampling

Data were collected on the Oregon-Washington continental shelf (between 44.5 N,124.2 W and 46.5 N, 124.6 W) and at water depths between 30-80 meters during the following cruises and dates:

R/V Oceanus OC1802B (dates: 2018-02-26 to 2018-03-01)
R/V Oceanus OC1805B (dates: 2018-05-07 to 2018-05-11)
R/V Oceanus OC1807A (dates: 2018-07-03 to 2018-07-05)
R/V Oceanus OC1810A (dates: 2018-10-04 to 2018-10-08)

R/V Oceanus OC1901A (dates: 2019-01-11 to 2019-01-15)
R/V Oceanus OC1904A (dates: 2019-04-22 to 2019-04-26)
R/V Oceanus OC1907A (dates: 2019-07-07 to 2019-07-11)

R/V Robert Gordon Sproul SP2215 (dates: 2022-07-22 to 2022-07-25)
R/V Robert Gordon Sproul SP2219 (dates: 2022-09-14 to 2022-09-19)

Sediment cores were collected from sites along the Newport Hydrographic Line on the Oregon shelf during the the February, May, July, and October 2018, January, April, and July 2019 cruises, and from 8 different sites, along the Oregon-Washington mid-shelf during the July and September 2022 cruises. Sediment cores were incubated using a unique method designed around the core tube itself. The method is described in Hughes et al. (2024). Briefly, sediment cores were collected in acrylic tubes with a radius of 5.3 centimeters (cm) and length of 94 cm using a hydraulically dampened Gravity Corer (Reimers et al., 2012). Once onboard, cores were immediately transported to a cold van, pre-set to the approximate in situ bottom water temperature. The core's overlying water was siphoned down to ~10 cm above the sediment surface and the core was sealed with a custom-made black Delrin puck. The pucks included two side grooves, two through-wells threaded at each end, two eye screws, and top and bottom axially aligned cavities. The two grooves each held an X-ring seal to ensure a seal with the core tube sides. One of the wells was fitted with a barbed connector joined to Tygon tubing (inner diameter of 3 millimeters (mm) and ranging in length from 0.66 meters (m) to 0.88 m) to enable overlying water sampling. The other well was plugged into the waterside. The top cavity was fitted with a 4-inch long threaded, clear PVC pipe (McMaster-Carr, part no. 4677T33) which contained an externally powered 6-volt DC mini electric motor. The output shaft of the motor ended in a small Delrin disk, fitted with four rare earth magnets (McMaster-Carr, part no. 5862K108). The bottom cavity held a second Delrin disk, with its top side fitted with four rare-earth magnets as well. The stir bar was set to rotate at 30 rpm at the top of the overlying water column. The resealed core was placed in a temperature-equilibrated, water-filled, incubation chamber with a lid to ensure the core remained at bottom water temperature and under low light conditions inside the cold van.

Incubations ran between 24 and 36 hours, with three to six time-point measurements conducted per core (about every 4 to 12 hours) before oxygen saturation dropped below 10%. For each measurement, the stirring motor of the core was stopped, and a custom device was used to slowly depress the black puck caps against the overlying water, expelling small, carefully measured volumes through the open sampling tube into a 10-milliliter (mL) gas-tight glass syringe with a luer-lock fitting. Following a flush of the sample tube, the sample water was directed to the flow-through cell of a PreSens Microx T3 micro-fiber optic oxygen sensor via a three-way valve at the end of the tubing, and its dissolved oxygen (DO) was recorded as percent air-saturation. The luer-lock fitting of the gas-tight glass syringe was attached to the exit side of the flow-through cell to collect timepoint water samples. These samples included 7 mL for shore-based dissolved inorganic carbon (DIC) analysis that were transferred to 8 mL borosilicate scintillation vials with polyethylene screw caps with poly-seal cone liners, pre-poisoned with 50 microliters (µL) of mercuric chloride to halt any biological activity. Another 10 mL was stored in a Nalgene™ HDPE bottle, and frozen (-20 degrees Celsius) for shore-based nutrient analysis. The second sample enabled a repeat oxygen measurement through the flow cell; however, the initial oxygen measurement was used for the flux calculation. After samples were collected, the stirring motor for the core was turned back on for the core to continue to incubate.

Nutrient samples from sediment core incubation experiments were analyzed onshore using standard auto-analyzer colorimetric methods at Oregon State University (Gordon et al., 1993). For DIC samples collected during the 2018 and 2019 cruises, samples were analyzed using a UIC Coulometer with a 1 mL sample loop, however, the results were not found to be reliable and therefore these data are not reported. For the DIC samples collected during the 2022 core incubations, samples were processed for DIC with a Finnigan

GasBench-II headspace sampler online with a Finnigan DELTAplusXL gas-source isotope-ratio mass spectrometer, with reported precision between 0.5 and 1%, using a procedure outlined in Torres et al. (2005). Additional details on core collection, incubations, and sample analyses can be found in Hughes et al. (2024).

Data Processing Description

The oxygen concentration of the overlying water at each timepoint of individual core incubations was calculated using oxygen solubility and percent air-saturation measured with the micro-fiber optic sensor. Oxygen solubility was calculated with inputs of sample temperature (obtained during each timepoint sampling), the latitude of the core collection, and bottom water salinity from the nearest CTD deployment using http://ocean.ices.dk/Tools/Calculator.aspx. Oxygen, nutrients, and DIC water sample concentration data were then used to calculate fluxes for each component using a linear fit to the time-varying inventory of the solute (in millimoles (mmol)) in the initial overlying water volume of the core, normalized to area. Inventory calculations were made by multiplying measured concentrations times volumes at each time point and adding back amounts contained in water volumes removed during preceding sample collections, over the time of the incubation. These results were also used to calculate stoichiometric ratios of component fluxes.

BCO-DMO Processing Description

- Imported original file "AllBenthicFluxes_BCODMO.csv" into the BCO-DMO system.
- Renamed fields to comply with BCO-DMO naming conventions.
- Converted the "Date_UTC" column to ISO 8601 format and renamed "ISO_DateTime_UTC".
- Converted "Date_Local" column to ISO 8601 format and renamed "ISO_DateTime_Local".
- Submitter rounded fields and provided as file "940414_v1_benthic_do_and_nutrient_fluxes.xlsx".
- Imported file "940414_v1_benthic_do_and_nutrient_fluxes.xlsx" into the BCO-DMO system.
- Saved final file as "940414_v1_benthic_do_and_nutrient_fluxes.csv".

Problem Description

For DIC samples collected during the 2018 and 2019 cruises, samples were analyzed using a UIC Coulometer with a 1 mL sample loop, however, the results were not found to be reliable and therefore these data are not reported. In the data file, these entries are represented by "NaN".

For the cruises conducted in 2022, two replicate cores were collected for all 8 sites visited. However, a few cores leaked during the course of the incubation. The data for these cores was not used for subsequent analyses and is not reported here.

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Data Files

File
940414_v1_benthic_do_and_nutrient_fluxes.csv (Comma Separated Values (.csv), 6.40 KB) MD5:4ac87e536be38b9a7666972f1ca2779c Primary data file for dataset ID 940414, version 1

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Related Publications

Gordon, L.I., J.C. Jennings, Jr., A.A. Ross, and J.M. Krest (1993) A Suggested Protocol For Continuous Flow Automated Analysis of Seawater Nutrients, in WOCE Operation Manual, WHP Office Report 90-1, WOCE Report 77 No. 68/91, 1-52. https://cchdo.github.io/hdo-assets/documentation/manuals/pdf/91_1/gordnut.pdf
Methods

Hughes, A. (2023). Spatiotemporal Variability in Benthic-Pelagic Coupling on the Oregon-Washington Shelf: An Investigation of Bottom Water and Benthic Flux Data. Oregon State University. https://ir.library.oregonstate.edu/concern/graduate_thesis_or_dissertations/xg94hz674
Results

Reimers, C. E., Özkan-Haller, H. T., Berg, P., Devol, A., McCann-Grosvenor, K., & Sanders, R. D. (2012). Benthic oxygen consumption rates during hypoxic conditions on the Oregon continental shelf: Evaluation of the eddy correlation method. Journal of Geophysical Research: Oceans, 117(C2). Portico. https://doi.org/10.1029/2011jc007564
Methods

Torres, M. E., Mix, A. C., & Rugh, W. D. (2005). Precise δ13C analysis of dissolved inorganic carbon in natural waters using automated headspace sampling and continuous-flow mass spectrometry. Limnology and Oceanography: Methods, 3(8), 349–360. Portico. https://doi.org/10.4319/lom.2005.3.349
Methods

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Related Datasets

IsRelatedTo

Henkel, S. K., Reimers, C. E. (2024) **Sample stations for the Neotrypaea COP (Community, Oxygen, & Productivity) Effects ground-truth cruises in 2021 and 2022.** Biological and Chemical Oceanography Data Management Office (BCO-DMO). (Version 2) Version Date 2023-12-14 doi:10.26008/1912/bco-dmo.880760.2 [view at BCO-DMO]

Reimers, C. E. (2020) **Seawater properties and biogeochemical parameters of bottom boundary layer samples collected aboard the R/V Oceanus during ten cruises from 2017-2019 from the Oregon shelf and slope.** Biological and Chemical Oceanography Data Management Office (BCO-DMO). (Version 1) Version Date 2020-10-20 doi:10.26008/1912/bco-dmo.793115.1 [view at BCO-DMO]

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Parameters

Parameter	Description	Units
Cruise_ID	Cruise designation	unitless
Core_number	Cores were numbered in order of collected at each site	unitless
Site_name	The name of the site where the cores were collected, which corresponds with sites in Hughes et al. (2024)	unitless
ISO_DateTime_UTC	Date and time (UTC) in ISO 8601 format	unitless
ISO_DateTime_PST	Date and time (PST) in ISO 8601 format	unitless
Julian_day	Julian day of the year	unitless
Lat	Latitude of core collection	decimal degrees North

Lon	Longitude of core collection	decimal degrees East
Depth	Water depth at core collection site	meters (m)
Temp_mean	Average temperature of overlying water during the incubation	degrees Celsius
Temp_std	Standard deviation of the average temperature of overlying water during the incubation	degrees Celsius
DO	The measured dissolved oxygen benthic flux of the incubated core	millimoles per square meters per day (mmol/(m^2 day))
DIC	The measured dissolved inorganic carbon benthic flux of the incubated core; NaN in cases where data not reported	millimoles per square meters per day (mmol/(m^2 day))
NOx	The measured nitrate benthic flux of the incubated core	millimoles per square meters per day (mmol/(m^2 day))
NO2	The measured nitrite benthic flux of the incubated core	millimoles per square meters per day (mmol/(m^2 day))
NH4	The measured ammonium benthic flux of the incubated core	millimoles per square meters per day (mmol/(m^2 day))
PO4	The measured phosphate benthic flux of the incubated core	millimoles per square meters per day (mmol/(m^2 day))
Si	The measured silicate benthic flux of the incubated core	millimoles per square meters per day (mmol/(m^2 day))
TDN	The measured total dissolved nitrogen benthic flux of the incubated core	millimoles per square meters per day (mmol/(m^2 day))
Notes	Notes about any invertebrates found in the incubated core	unitless

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Instruments

Dataset-specific Instrument Name	UIC Coulometer
Generic Instrument Name	CO2 Coulometer
Generic Instrument Description	A CO2 coulometer semi-automatically controls the sample handling and extraction of CO2 from seawater samples. Samples are acidified and the CO2 gas is bubbled into a titration cell where CO2 is converted to hydroxyethylcarbonic acid which is then automatically titrated with a coulometrically-generated base to a colorimetric endpoint.

Dataset-specific Instrument Name	hydraulically dampened Gravity Corer
Generic Instrument Name	Gravity Corer
Generic Instrument Description	The gravity corer allows researchers to sample sediment layers at the bottom of lakes or oceans. The coring device is deployed from the ship and gravity carries it to the seafloor. (http://www.whoi.edu/instruments/viewInstrument.do?id=1079).

Dataset-specific Instrument Name	Finnigan DELTAplusXL gas-source isotope-ratio mass spectrometer
Generic Instrument Name	Isotope-ratio Mass Spectrometer
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	PreSens Microx T3 micro-fiber optic oxygen sensor
Generic Instrument Name	Oxygen Sensor
Generic Instrument Description	An electronic device that measures the proportion of oxygen (O2) in the gas or liquid being analyzed

Dataset-specific Instrument Name	Finnigan GasBench-II headspace sampler
Generic Instrument Name	Thermo-Fisher Scientific Gas Bench II
Generic Instrument Description	An on-line gas preparation and introduction system for isotope ratio mass spectrometry that is designed for high precision isotope and molecular ratio determination of headspace samples, including water equilibration, carbonates and atmospheric gases. The instrument allows for the use of a dual viscous flow inlet system of repetitive measurements of sample and standard gas on a continuous flow isotope ratio mass spectrometer (CF-IRMS) system. The sample volume is the sample vial (instead of a metal bellows), and the reference gas volume is a pressurized gas tank. The instrument consists of a user programmable autosampler, a gas sampling system, a maintenance-free water removal system, a loop injection system, an isothermal gas chromatograph (GC), an active open split interface, a reference gas injection system with three reference ports, and one or two optional LN2 traps for cryofocusing. The gas sampling system includes a two port needle which adds a gentle flow of He into the sample vial, diluting and displacing sample gas. Water is removed from the sample gas through diffusion traps. The loop injector aliquots the sample gas onto the GC column, which separates the molecular species. The reference gas injection system allows accurate referencing of each sample aliquot to isotopic standards. The system can be used with several options including a carbonate reaction kit that allows injection of anhydrous phospohric acid into sample vials. Note "Finnigan GasBench-II" is the previous brand name of this instrument.

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Deployments

OC1802B

Website	https://www.bco-dmo.org/deployment/793218
Platform	R/V Oceanus
Start Date	2018-02-26
End Date	2018-03-01
Description	More information is available at R2R: https://www.rvdata.us/search/cruise/OC1802A

OC1805B

Website	https://www.bco-dmo.org/deployment/793242
Platform	R/V Oceanus
Start Date	2018-05-07
End Date	2018-05-11
Description	More information is available at R2R: https://www.rvdata.us/search/cruise/OC1805A

OC1807A

Website	https://www.bco-dmo.org/deployment/793307
Platform	R/V Oceanus
Start Date	2018-07-03
End Date	2018-07-05
Description	More information is available at R2R: https://www.rvdata.us/search/cruise/OC1807A

OC1810A

Website	https://www.bco-dmo.org/deployment/793260
Platform	R/V Oceanus
Start Date	2018-10-04
End Date	2018-10-08
Description	More information is available at R2R: https://www.rvdata.us/search/cruise/OC1810A

OC1901A

Website	https://www.bco-dmo.org/deployment/827118
Platform	R/V Oceanus
Start Date	2019-01-11
End Date	2019-01-15
Description	More information is available at R2R: https://www.rvdata.us/search/cruise/OC1901A

OC1904A

Website	https://www.bco-dmo.org/deployment/827167
Platform	R/V Oceanus
Start Date	2019-04-22
End Date	2019-04-26
Description	More information is available at R2R: https://www.rvdata.us/search/cruise/OC1904A

OC1907A

Website	https://www.bco-dmo.org/deployment/827213
Platform	R/V Oceanus
Start Date	2019-07-07
End Date	2019-07-11
Description	More information is available at R2R: https://www.rvdata.us/search/cruise/OC1907A

SP2215

Website	https://www.bco-dmo.org/deployment/916941
Platform	R/V Robert Gordon Sproul
Start Date	2022-07-22
End Date	2022-07-25
Description	More information is available at R2R: https://www.rvdata.us/search/cruise/SP2215

SP2219

Website	https://www.bco-dmo.org/deployment/916944
Platform	R/V Robert Gordon Sproul
Start Date	2022-09-14
End Date	2022-09-19
Description	More information is available at R2R: https://www.rvdata.us/search/cruise/SP2219

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Project Information

Benthic Biogeochemical Exchange Dynamics on the Oregon Shelf (BBEDOS)

Coverage: Oregon Shelf 44.6N 124 W

NSF Award Abstract:
The longstanding theory regarding the formation of low oxygen zones in coastal shelf regions at the eastern boundaries of the oceans has pointed to the upwelling of oxygen-depleted waters from off of the shelf. In other words, dense water from beyond the shelf break that is depleted in dissolved oxygen is drawn along the seafloor upwards onto the shelf, mixing with the oxygenated water there, and creating low oxygen (hypoxic) zones. This is a paradigm that the researcher in this project seeks to shift by analyzing the added effects of respiration in shelf sediments. The investigator hypothesizes that changes in the biological activity of sediments due to seasonal changes in organic matter input from overlying waters are a major factor in the changes in dissolved oxygen content of deep shelf water, perhaps being the leading variable in the creation of hypoxic zones. Though the field analysis will be confined to the Oregon margin, there is a great deal of applicability for this research in other coastal regions where hypoxic zones form. In addition to the potential for unraveling complex local feedbacks between physical and biogeochemical processes, the researcher plans to work with a small business called Analytical Instrument Systems to build a new oxygen sensor, called a rotating disc microelectrode (RDME), that does not intrude on the environment it is testing and that can be deployed for much longer periods of time than currently popular sensors, micro-optodes. Her RDME will be deployed with micro-optodes for comparison and to validate the necessity for the RDME in the study of coastal ecosystems. This project will provide a unique experience for a postdoctoral researcher as well as a graduate and three undergraduate students. A public database will be created which will greatly help with accessibility and archiving of data for anyone who is interested in similar research. The database will be connected with a variety of other ocean observing data products, which will allow the research community and the public to make connections outside of this particular field of study. This investigator has a strong track record of including Research Experiences for Undergraduates (REU) students in her research, and she will continue to do so in this project.

The researcher aims to challenge the paradigm that hypoxic zones on the Oregon shelf are created by upwelling of offshelf oxygen-depleted water and that most of the local primary productivity is exported off the shelf during downwelling periods. Preliminary data suggests the possibility that seasonal benthic respiration may be a major factor in hypoxic water formation on the shelf. With the use of eddy covariance measurements, sediment core incubations, and near seabed particulate organic matter (POM) collections, the biogeochemical fluxes of the Oregon margin will be characterized for every season. This work is ambitious on its own, but the investigator also plans to incorporate the development of a new oxygen sensor called a rotating disc microelectrode (RDME) that will be compared to currently popular micro-optodes when making eddy covariance measurements. The RDME will be small enough as not to interfere with the physical properties being measured in situ; it will be insensitive to flow and deployable for longer periods of time. Not only does this project contain the possibility of completely overturning the current best theory of hypoxic zone formation on shelf margins, but the use of eddy covariance is new to the study of dynamic coastal ecosystems and will yield great insights into the biogeochemical processes of shelf benthos.

This project is affiliated with the Coastal Endurance Array of the Ocean Observatories Initiative (OOI): https://www.bco-dmo.org/program/661079

Environmental consequences of expanded recruitment of an ecosystem engineer on a hypoxia-influenced continental shelf (Neotrypaea COP Effects)

Coverage: NE Pacific continental shelf

NSF Award Abstract:
Highly productive US West Coast fishery species and marine mammals rely on benthic invertebrate communities for food. However, these communities are changing. This project addresses the potential ecological consequences of a new member to these benthic communities, the ghost shrimp Neotrypaea. In estuaries, Neotrypaea continuously rework the sediment via their burrowing activities. The combination of high shrimp abundances and the effects of burrowing mitigate the impacts of nutrient run-off (natural and human-induced) that can exacerbate low oxygen conditions. However, Neotrypaea are also considered threats to the oyster industry because of their sediment-excavating activities. An expansion of their distribution beyond estuaries may have additional unforeseen consequences for the Dungeness crab fishery (regionally valued at $33-74M/y) as Neotrypaea are both competitors with juveniles and prey for larger Dungeness crab. Thus, new data are needed to determine how offshore benthic communities are being altered by the recruitment of Neotrypaea into new habitats. This study is comparing communities with high and low shrimp abundances to understand their impact on offshore benthic communities. The shrimp's contributions to oxygen and carbon cycling are being estimated through field measurements. Benthic community assessments are quantifying changes to food resources on the seafloor caused by the presence of these relatively large shrimp. The coastal waters along the Oregon-Washington shelf are commercially valuable, yet they are also subject to growing human-related impacts. Sustainable management requires optimizing extractive, cultural, and recreational activities. The broader impacts of this research include key data for managers, commercial fisheries' stakeholders and oyster growers that inform decisions regarding ocean-use planning and management of burrowing shrimp. This project is providing research training for three graduate students and two summer undergraduate students. Curriculum development for elementary school students is focused on the ecology of soft-bottom benthos. The ocean sandy/muddy benthos are often unknown to K-12 students on the West Coast who are usually more familiar with intertidal and kelp forest systems.

Changing environmental conditions in shelf waters along the Oregon and Washington coasts and elsewhere have included increasingly frequent and severe hypoxia events, ocean acidification, and warming. These changes have affected biological communities and altered species distributions. An abundant mid-shelf population of the burrowing ghost shrimp, Neotrypaea sp. was documented in shelf waters following the Marine Heat Wave of 2015. Neotrypaea are ecosystem engineers that were previously known to be abundant in intertidal estuary mudflats with an insignificant presence in the open ocean. In estuaries Neotrypaea continuously rework the sediment via their burrowing activities. The shrimp can increase oxygen cycling due to burrow irrigation and reduce impacts of nutrient loading such as low-oxygen conditions. However, enhanced benthic oxygen consumption linked to Neotrypaea sp. beds could have the opposite effect on the shelf by intensifying regional hypoxia. This study is characterizing the environmental conditions associated with the expanded distribution of Neotrypaea using a habitat-suitability modeling approach. Model predictions are being validated through extensive field sampling via box coring and video lander observations. In addition, the benthic samples are documenting changes in the benthic invertebrate communities within the Neotrypaea beds and how this is potentially affecting biological interactions. Analyses of aquatic eddy covariance and of core incubations in shelf areas with and without abundant shrimp are providing estimates of the shrimp's contribution to benthic oxygen fluxes and organic carbon cycling. These data are being used to quantify the shrimp's and their burrows' effects on the overall productivity of the mid-shelf benthos relative to reference areas. How Neotrypaea alter seafloor structure and biogeochemistry need to be characterized to predict the impact of these ecosystem engineers on the food supply for higher trophic levels and fisheries.

This award reflects NSF's statutory mission and has been deemed worthy of support through evaluation using the Foundation's intellectual merit and broader impacts review criteria.

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Funding

Funding Source	Award
NSF Division of Ocean Sciences (NSF OCE)	OCE-1634319
NSF Division of Ocean Sciences (NSF OCE)	OCE-2126112

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