NYSG Completion Report Instructions & Required Format

Please include the following information for your project. The text of this report should be at least 5-8 pages and be composed for an audience of your peers. Other formats, or reports with incomplete sections, will not be accepted. The expectation is that information or material will be provided under each section.

Report Written By: Robinson W. Fulweiler and Claudia Mazur **Date:** July 3, 2019

Project Number and Title: Quantifying Benthic-Pelagic Coupling in Long Island Sound (####)

Project Personnel: List the Co- and Associate Investigators, and any other project personnel including NYSG Scholars.

1. Alia Al-Haj — Research Technician
2. Claudia Mazur — Graduate Student
3. Isabel Sanchez-Viruet — Research Technician

A. Project Results: Complete the following sub-sections to discuss your results as they relate to the project's objectives:

C1. Meeting the Objectives:

The goal of this proposal was to quantify benthic-pelagic coupling in LIS as a mechanism to better understand the current state of organic matter decomposition and internal nutrient recycling in LIS.

Objective 1: Quantify the downward flux of organic matter from the euphotic zone at five stations in LIS.

Overview of methods: For this study, five sampling stations were selected in Long Island Sound (LIS) along a west to east transect to capture a range of environmental conditions within the estuary. The stations were variable in salinity, dissolved inorganic nitrogen (DIN) concentrations, chlorophyll- a concentrations as well as sediment characteristics. From each of the four incubations we subcored triplicate sediment cores at 0.5 cm increments to 2 cm depth and then from 2 to 5 cm at 1 cm intervals. Sediment samples were frozen and stored in a −80 °C freezer until further analysis. C:N sample preparation: Subsamples from cores were ground with a Wiggle Bug, placed in a labeled bottles, and put in the drying oven at 60 ºC for at least 24 hours. Bottles were capped tightly and kept in a dessicator. Using a Mettler MT5 microbalance, sediment material was weighed out to 4-5 mg and packed in duplicate tin capsules. Analysis of C:N in capsules was conducted at Boston University using an Elemental Combustion System 4010 made by Costech Analtical Technologies (Valencia, CIA). We also measured %C and chlorophyll-a concentrations in the sediments.

Summary of results: We anticipated that stations in western LIS with their higher nitrogen loading and productivity would have the greatest sediment organic matter content as shown in Table 1. %C decreased as you moved from eastern to western LIS. Both C:N and Chlorophyll-a were more variable.

Table 1. Sediment characteristics at the five sites sampled in this study. Note that %C and C:N both decline as you move from western Long Island Sound (EXR) to eastern Long Island Sound (ELIS).

Station	Density (mg L^{-1})	Porosity	% C	C:N	Chl-a (mg m^{-2})
EXR	1.10 (±0.03)	0.64 (±0.09)	3.22 (±0.03)	12.49 (±0.49)	16.66 (± 2.05)
WLIS	1.09 (±0.02)	0.64 (±0.09)	2.59 (±0.07)	10.91 (±0.18)	23.52 (±3.17)
ARTG	1.07 (±0.04)	0.67 (±0.09)	2.46 (±0.05)	10.02 (±0.13)	26.26 (±4.24)
CLIS	1.54 (±0.07)	0.41 (±0.02)	0.61 (±0.11)	12.73 (±0.02)	12.89 (±4.54)
ELIS	1.78 (±0.03)	0.40 (±0.05)	0.58 (±0.12)	n.m.	3.88 (±0.72)

Objective 2: Quantify benthic metabolism at five sites in LIS. Specifically, we will measure seasonal rates of sediment oxygen demand (SOD), benthic inorganic nutrient (nitrogen, phosphorus) fluxes, and directly measured net denitrification rates.

Objective 2 methods:

Sediment Coring and Field Measurements: Sediment cores were collected on four occasions to quantify benthic metabolism at five sites in Long Island Sound along a gradient of anthropogenic nutrient loading. At each site, rates of sediment oxygen demand (SOD), fluxes of DIN (ammonium (NH_4^+), nitrate (NO_3^-), nitrite (NO_2^-)), dissolved inorganic phosphorus (DIP), net N_2 fluxes, and GHG fluxes (CH_4 and N_2O). Cores were collected during two summer seasons (summer 2016 and 2017) and one winter season to capture seasonal variability. Each station was sampled two to four times during this period, except for CLIS, which was only sampled during the winter. Triplicate, intact sediment cores were collected at each site using a multi-core, to keep the delicate surface layer intact as well as the upright structure of the sediment cores (Fulweiler *et al.*, 2008). Core tube dimensions varied because of sediment type. Longer cores were used for muddy sediments found at EXR, WLIS and ARTG (60 cm in height and 5 cm in diameter) and shorter cores were used at CLIS and ELIS which had sandier sediments (30 cm in height and 5 cm in diameter).

In the field, we measured surface and bottom dissolved O_2 concentrations, salinity and temperature (Hach HQd using LD101, CDC401 probes). We also collected surface and bottom water samples for DIN, DIP, GHG concentrations of CH_4 and N_2O, N_2 gas, and chlorophyll-*a*. Duplicate DIN and DIP samples were immediately filtered into 30 mL acid washed and deionized (DI) water leached polyethylene bottles using 60 mL acid washed polypropylene syringes and glass fiber filters (Whatman GF/F, 0.70 µm pore size). The vials were frozen on dry ice immediately and stored in a freezer (at approximately -15 °C) until analysis for inorganic nutrients was conducted. We collected duplicate water samples for N_2-N, N_2O, and CH_4 concentrations in 12 mL Labco Limited Exetainer® vials with gas tight septa and preserved these samples with 25 µl of saturated zinc chloride solution (Fulweiler and Nixon, 2009; Foster and Fulweiler, 2014). Upon arrival to the lab, gas samples were stored in a refrigerator (4 °C) until processing. At each station 120 ml of water was collected for chlorophyll-*a* analysis, which was filtered through glass fiber filters using 60 ml polypropylene syringes rinsed with DI water. Filters were carefully removed using tweezers, frozen and placed in aluminum foil packets to keep them in the dark.

Benthic Inorganic Nutrient Fluxes: We also quantified fluxes of dissolved inorganic nutrients (NO_3^- + NO_2^-, NH_4^+, DIP) across the sediment-water interface. Water samples were collected from the water overlying the core at two time points (initial and final) and filtered through glass fiber filters (Whatman GF/F) using an acid washed polypropylene syringe. The filtrate was collected and stored in 30 ml acid washed and deionized water leached polyethylene bottles and stored at -15 ºC until analysis. All nutrient samples were analyzed with a continuous segmented flow analyzer (SEAL AA3) using standard colorimetric techniques.

Net N_2-N Fluxes: The net N_2 fluxes were collected from the overlying water at least five times during each incubation from specially designed in situ chambers. The water samples (12 ml) were immediately killed with a saturated ZnCl solution and held in gas tight exetainers for later measurement using membrane inlet mass spectrometry (MIMS). The change in N_2 concentration over time is calculated from the N_2/Ar ratio, which assumes that Ar remains constant (Heip 1995; Rideout et al. 2010). Oxygen was measured concurrently using an oxygen electrode (Hach LDO probe). Incubations were concluded before the oxygen concentration droped to 75-50% saturation.

Not sure how specific you want to be in this report, but since we include GHG data, should we discuss how we measured our GHG fluxes on the GC?

Summary of results

Sediment Oxygen Uptake: Sediment O_2 uptake from incubations ranged from 101 (±26) to 1140 (±265) µmol O_2 m^{-2} h^{-1} with a mean of 445 (±77) µmol O_2 m^{-2} h^{-1}. Oxygen uptake values were not significantly different between sites. However EXR, WLIS and ARTG had greater O_2 uptake rates than CLIS and ELIS. Oxygen uptake was significantly higher between summer and winter ($p < 0.0001$). These data also exhibit a positive correlation with temperature ($R^2 = 0.44$, $p = 0.0001$, temperature range 6.7-27.2 °C).

Measurement of Sediment N_2-N Flux: Fluxes of N_2-N varied among the stations, with three stations (EXR, WLIS, and ELIS) exhibiting positive (net denitrification) fluxes and one station (ARTG) exhibiting negative (net N-fixation) fluxes. Fluxes of N_2 were not significantly different between stations or between the summer and winter seasons (p = 0.403). The mean net N_2-N flux across all stations and sampling dates was 10 (±8) µmol N_2-N m^{-2} h^{-1} and did not have a significant relationship with temperature (R^2 = 0.021, p = 0.350) or O_2 uptake (R^2 = 0.026, p = 0.304). Mean net denitrification (positive fluxes only) was 52 (±12) µmol N_2-N m^{-2} h^{-1} and net N fixation (negative values only) was -65 (±32) µmol N_2-N m^{-2} h^{-1}. The highest rate of net denitrification (185 µmol N_2-N m^{-2} h^{-1}) was in a core collected on 27-Jun-2016 at the EXR station. Overall, the N_2-N fluxes from EXR had the highest mean N_2-N flux rates (23 (±20) µmol N_2-N m^{-2} h^{-1}). The highest rate of net N-fixation (-184 N_2-N m^{-2} h^{-1}) was measured in a sediment core collected from ARTG on 7-Dec-2016. ARTG exhibited N-fixation in 3 out of the 12 cores collected, however, it also exhibited a zero flux in 5 out of the 12 cores. On 13-Jun-2017, ARTG was dominated by denitrification (29 (±2) µmol N_2-N m^{-2} h^{-1}), however on 8-Aug-2017, there was no denitrification or N-fixation occurring (i.e. zero flux).

Benthic Dissolved Inorganic Nutrient Fluxes: The mean (± standard error) NH_4^+ flux rates across all sampling dates and stations was 18 (±22) µmol NH_4^+ m-^{2} h^{-1} with a range of -13 (EXR, 7-Dec-2016) to 134 (EXR, 8-Aug-2017) µmol NH_4^+ m-^{2} h^{-1}. Ammonium fluxes were not significantly different between the summer and winter seasons (p = 0.064), However, NH_4^+ fluxes were significantly different between ARTG and EXR (p =0.048). Ammonium flux rates were positively correlated with temperature (R^2 = 0.328, p = 0.000), but showed no relationship with O_2 uptake (R^2 = 0.023, p = 0.372).

In general, we observed very low sediment NO_2^- fluxes. Overall, all stations were sinks for NO_2^-, except for ARTG , which was a source of NO_2^- (0.04 (± 0.08) µmol NO_2^- m^{-2} h^{-1}). The highest NO_2^- uptake was observed in a core collected at EXR on 8-Aug-2017 (-6 µmol NO_2^- m^{-2} h^{-1}). Nitrite fluxes were not significantly different between stations, but were significantly different between summer and winter (p = 0.040). Nitrite fluxes did not vary significantly as a function of temperature (R^2 = 0.001 , p = 0.0.822), nor did they have a significant relationship with O_2 uptake (R^2 = 0.005, p = 0.658).

All stations showed mean NO_3^- consumption, except for ARTG (8.8 (±0.5) µmol NO_3^- m^{-2} h^{-1}). EXR had the lowest mean NO_3^- flux (-80.1 (±0.1) µmol NO_3^- m^{-2} h^{-1}). Average NO_3^- flux throughout the Sound was 2.2 (±1.0) µmol NO_3^- m^{-2} h^{-1}. Nitrate was significantly different between stations. ARTG was significantly different from CLIS (p=0.0210), ELIS (p=0.0003), EXR (<0.0001), and WLIS (p= 0.000). EXR was significantly different from WLIS (p=0.0412). Nitrate was statistically significant as a function of temperature (R^2= 0.240, p = 0.001), but not as a function of O_2 uptake (R^2 = 0.074, p = 0.05018).

The most western sites (EXR, WLIS, and ARTG) were sources of DIP, while the most eastern sites were a sink for DIP. The highest DIP uptake was observed at WLIS (20-Jul-16) with a flux of 37 µmol DIP m^{-2} h^{-1}, the lowest was at ARTG (8-Aug-17) -3.38 µmol DIP m^{-2} h^{-1}. Overall, WLIS had the highest mean DIP flux (9.3 (±2.1) µmol DIP m^{-2} h^{-1}) and CLIS has the lowest mean flux (-0.4 µmol DIP m^{-2} h^{-1}). The mean flux across all stations and sampling dates is 4.8 (±1.1) µmol DIP m^{-2} h^{-1}. DIP flux was not significantly different between stations. Dissolved inorganic phosphorus did vary significantly with temperature (R^2 = 0.328, p = 0.000) and did not vary significantly with O_2 uptake (R^2= 0.001, p = 0.858).

Nitrous Oxide and Methane Flux across the Sediment Water Interface: Nitrous oxide fluxes in cores ranged from -184 to 185 nmol N_2O m^{-2} h^{-1}. The greatest N_2O production occurred at all sites during the August 2017 collection (11 to 53 nmol N_2O m^{-2} h^{-1}). Fluxes of N_2O were not significantly different between stations. On average, Long Island Sound sediments were a source of N_2O (10 ±8 nmol N_2O m^{-2} h^{-1}). Sediment N_2O production (i.e., positive fluxes) was observed in a majority of the cores (22 positive, 9 negative, and 14 zero). There was no significant relationship observed between temperature (R^2 = 0.013, p = 0.452), NO_3^- flux (R^2 = 0.019, p = 0.367) or O_2 uptake (R^2 = 0.005, p= 0.658).

Methane fluxes ranged from -161 to 461 nmol CH_4 m^{-2} h^{-1} in cores, with the highest positive flux observed in a core collected 20-Jul-16 at EXR and the lowest, negative flux in a core collected in 8-Aug-2017 also at EXR. On average, Long Island Sound sediments produced CH_4 (23 (±18) nmol CH_4 m^{-2} h^{-1}), with ELIS emitting the most CH_4 compared to the other four stations. However, methane fluxes were not significantly different between stations. No sediment CH_4 production or consumption (i.e. zero fluxes) were observed in a majority of the cores (13 negative, 12 positive, and 20 zeros). There was no significant relationship between CH_4 and temperature (R^2 = 0.0246, p =0.304), yet there was a significant difference between CH_4 and O_2 uptake (R^2 = 0.2017, p=0.003).

Objective 3: *Synthesize existing data on SOD and sediment nutrient fluxes to determine if benthic-pelagic coupling has changed in LIS as it appears to have changed in Narragansett Bay.*

The main basin of LIS is lacking in benthic metabolism data and we found that full synthesis was unnecessary.

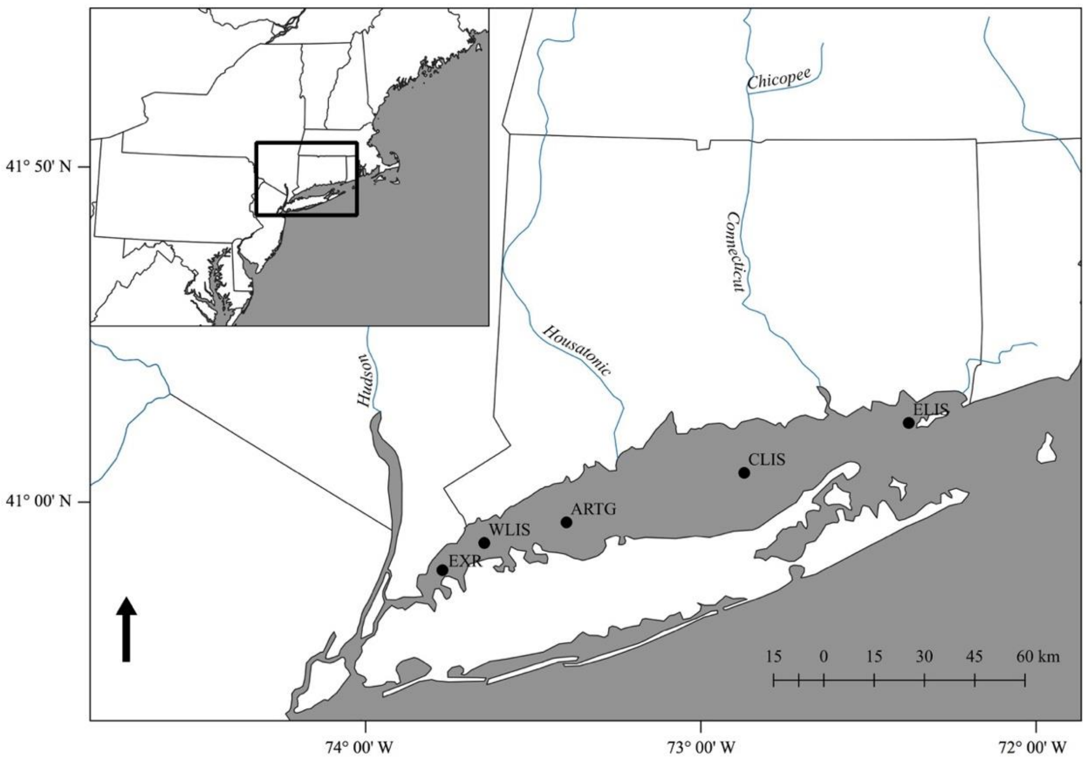

Figure 1: Map of sampling locations during 2016 and 2017 for benthic oxygen, dissolved inorganic nitrogen, dissolved inorganic phosphorus, net di-nitrogen, nitrous oxide and methane flux measurements in Long Island Sound, New York, USA. Stations include; Execution Rocks (EXR), Western Long Island Sound (WLIS), ARTG Buoy (ARTG), Central Long Island Sound (CLIS) and Eastern Long Island Sound (ELIS). GIS data layers were made with Natural Earth (naturalearthdata.com, September 2018) and are registered to the NAD83 (NSRS2007) datum, New York Long Island coordinate system.

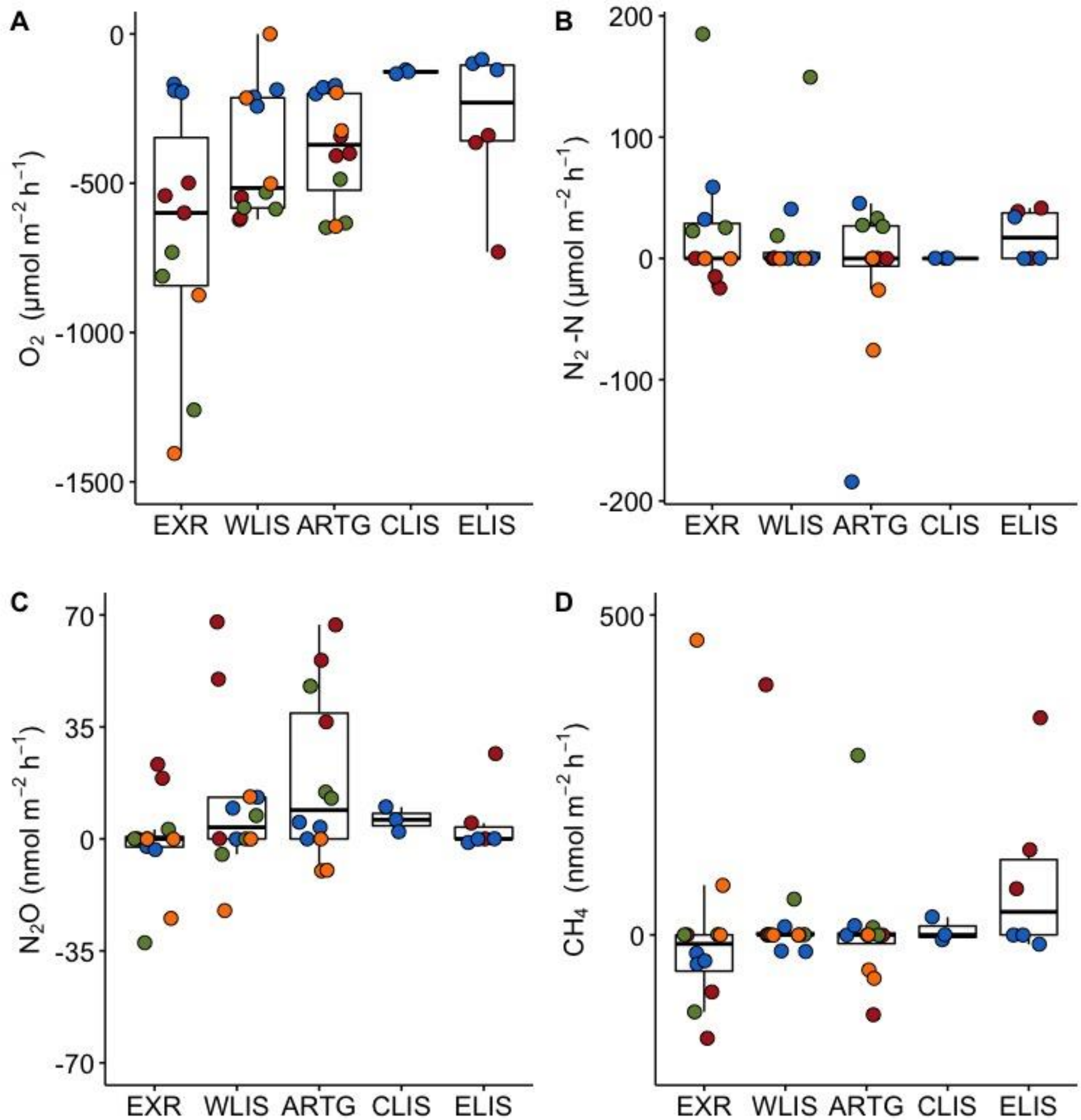

Figure 2: Rates of oxygen uptake (µmol m^{-2} h^{-1}) , di-nitrogen (µmol m^{-2} h^{-1}), nitrous oxide (nmol m^{-2} h^{-1}) and methane (nmol m^{-2} h^{-1}) flux across the sediment water interface from core incubations collected at five stations (Execution Rocks, Western Long Island Sound, ARTG Buoy, Central Long Island Sound and Eastern Long Island Sound) in Long Island Sound. Fluxes from collection dates shown are Summer 2016 (orange, n= 9), Winter 2016-2017 (blue, n=15), June 2017 (green, n=9), and August 2017 (red, n=12).

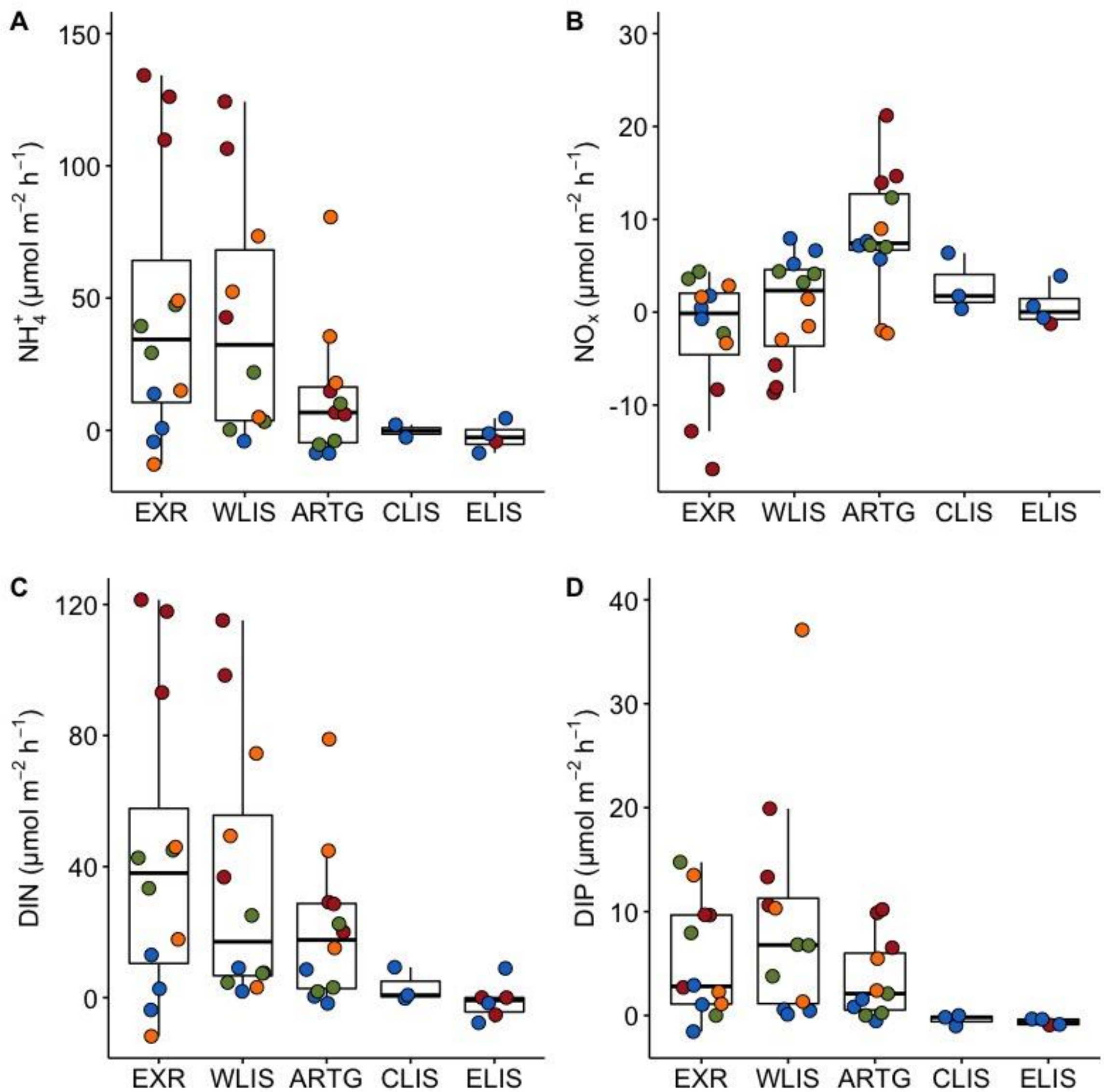

Figure 3: Rates of ammonium (µmol m^{-2} h^{-1}) , nitrate and nitrite (µmol m^{-2} h^{-1}), dissolved inorganic nutrients (nmol m^{-2} h^{-1}) and dissolved inorganic phosphorus (nmol m^{-2} h^{-1}) flux across the sediment water interface from core incubations collected at five stations (Execution Rocks, Western Long Island Sound, ARTG Buoy, Central Long Island Sound and Eastern Long Island Sound) in Long Island Sound. Fluxes from collection dates shown are Summer 2016 (orange, n = 9), Winter 2016-2017 (blue, n = 15), June 2017 (green, n = 9), and August 2017 (red, n=12).

C2. Scientific Abstract: Describe your entire project's results as if intended for a scientific meeting or publication.

**note this was used for the NEERS 2019 Spring Meeting*

Excess nitrogen (N) loading to coastal areas can stimulate surface water productivity and subsequently increase rates of organic matter deposition to sediments. Here we study how organic matter decomposition and nutrient cycling change along a gradient of N loading in Long Island Sound

(LIS), NY, a heavily impacted, tidal estuary on the eastern coast of the United States. We collected sediment cores seasonally in 2016/17 from five sites along a transect ranging from high nutrients and frequent hypoxia in the west to low nutrients and no hypoxia in the east. To quantify benthic metabolism, cores were incubated at *in situ* field conditions for sediment oxygen demand (SOD), net N_2 fluxes (i.e., net denitrification or net nitrogen fixation), fluxes of inorganic nutrients including ammonium (NH_4^+), nitrate (NO_3^-) and nitrite (NO_2^-) and sediment %C. We observed a strong gradient in summer SOD and NH_4^+ flux across the sites with the highest rates occurring at the western most sites exposed to high nutrient loading. Both mean SOD and NH_4^+ flux were positively correlated with %C ($R^2 = 0.69$, $p = 0.05$; $R^2 = 0.77$, $p = 0.03$, respectively). Sediment NO_3^- and NO_2^- effluxes were highest from the moderately impacted mid-LIS site, while the high and low impacted sites were dominated by uptake. N_2 fluxes were variable and did not differ between sites (mean: 10 µmol N_2-N m^{-2} h^{-1} (SE ±8) Overall, LIS sediments have a 28% N removal efficiency, yet this can only remove 6.5% of total N loading to the system.

C3. Problems Encountered: Describe difficulties encountered during the project, e.g., problems with experimental protocols, and how they were resolved.

Originally, we wanted to measure flux of carbon to the sediments via water column sediment traps. After speaking with our colleagues though, we learned that this was not logistically or financially possible. Instead, we focused on quantifying more sediment properties such as chlorophyll-a and C:N. Such properties can provide insight on how much organic matter is reaching the benthos.

C4. New Research Directions: We added in the measurement of benthic fluxes of nitrous oxide and methane – two powerful greenhouse gases. Additionally, one of our collaborators, Dr. Craig Tobias, as well as others are now focused on quantifying water column nutrient cycling as a way to better understand the biogeochemical cycling of Long Island Sound.

C5. Interactions: We presented our research in two STAC meetings (2018) and interacted via annual reporting.

C6. Presentations and Publications:

<u>Publications:</u>

(1) Mazur, C.I., Al-Haj, A., Sanchez-Viruet, I., Ray, Nicholas, Fulweiler, R.W. Benthic pelagic coupling in Long Island Sound along a gradient of anthropogenic stressors. *In preparation for Biogeochemistry.*

<u>Presentations:</u>

(5) Fulweiler, R.W., Mazur, C.I., Al-Haj, A., Sanchez-Viruet, I. (2019) Quantifying Benthic-pelagic Coupling in Long Island Sound: Summary of Results. Long Island Sound Conference.

No abstract

(4) **Mazur, C., Sanchez-Viruet, I., Al-Haj, A., Fulweiler, R.W. Benthic metabolism along a nutrient gradient in Long Island Sound, NY. (Oral) 2019 New England Estuarine Research Society (NEERS). York, ME. **Won Ketchum prize for best graduate student talk

Excess nitrogen (N) loading to coastal areas can stimulate surface water productivity and subsequently increase rates of organic matter deposition to sediments. Here we study how organic matter decomposition and nutrient cycling change along a gradient of N loading in Long Island Sound (LIS), NY, a heavily impacted, tidal estuary on the eastern coast of the United States. We collected sediment cores seasonally in 2016/17 from five sites along a transect ranging from high nutrients and frequent hypoxia in the west to low nutrients and no hypoxia in the east. To quantify benthic metabolism, cores were incubated at *in situ* field conditions for sediment oxygen demand (SOD), net N_2 fluxes (i.e., net denitrification or net nitrogen fixation), fluxes of inorganic nutrients including ammonium (NH_4^+), nitrate (NO_3^-) and nitrite (NO_2^-) and sediment %C. We observed a strong gradient in summer SOD and NH_4^+ flux across the sites with the highest rates occurring at the western most sites exposed to high nutrient loading. Both mean SOD and NH_4^+ flux were positively correlated with %C ($R^2 = 0.69$, $p = 0.05$; $R^2 = 0.77$, $p = 0.03$, respectively). Sediment NO_3^- and NO_2^- effluxes were highest from the moderately impacted mid-LIS site, while the high and low impacted sites were dominated by uptake. N_2 fluxes were variable and did not differ between sites (mean: 10 µmol N_2-N m^{-2} h^{-1} (SE ±8) Overall, LIS sediments have a 28% N removal efficiency, yet this can only remove 6.5% of total N loading to the system.

(3) **Mazur, C.I, Sanchez-Viruet, I., Al-Haj, A., Fulweiler, R.W. (2018) Benthic metabolism along a nutrient gradient in Long Island Sound, NY. (Oral) Boston University Earth and Environment Graduate Student Seminar. **Awarded Outstanding Graduate Student Talk

No abstract

(2) Fulweiler, R.W., Mazur, C.I., Al-Haj, A., Sanchez-Viruet, I. (2018) Quantifying Benthic-pelagic Coupling in Long Island Sound: Preliminary Results. STAC meeting.

No abstract

(1) Mazur, C. I., Sanchez-Viruet, I., Al-Haj, A., and Fulweiler, R.W**.** Biogenic Gas Fluxes Across the Sediment-Water Interface Along a Gradient of Anthropogenic Stressors. (Poster) 2018 Ocean Sciences Meeting. Portland, OR.

Sediments provide critical ecosystem functions of nutrient remineralization and removal. The impact of anthropogenic stressors (e.g., excess nutrients, rising temperatures) have been shown to alter these fluxes. Here we studied the fluxes of key biogenic gases across the sediment-water interface in a highly impacted, tidal estuary on the east coast of the United States (Long Island Sound (LIS), NY). Specifically, we chose five sites along a gradient of impact, from high nutrients/frequent hypoxia in the western portion of the Sound to low nutrients/no hypoxia in the eastern portion of the Sound. Sediment cores were collected seasonally in 2016/17 and incubated at *in situ* field conditions for sediment oxygen demand (SOD), net N_2 fluxes (i.e., net denitrification or net nitrogen fixation) and fluxes of nitrous oxide (N_2O) and methane (CH_4). Preliminary data reveal a strong gradient in summer sediment oxygen demand across our five sites with peak demand at sites exposed to the highest nutrients and surface water column chlorophyll. In contrast, summer net sediment N_2 fluxes were highly variable. Peak net denitrification (66 ±30µmol m^{-2} h^{-1}) was found in fall/winter at the most impacted station. We also observed high rates of net sediment N-fixation in fall/winter (-92 ±35 µmol m^{-2} h^{-1}) at a station in the moderately/low impacted mid-LIS. In general, the sediments were a source of both N_2O and CH_4. We will discuss how these fluxes respond to a range of *in situ* environmental conditions throughout a full seasonal cycle. We will also present the N removal capacity of LIS sediments in relation to nutrient inputs from land. Our findings hope to provide a better understanding of realistic targets for restoration of estuarine ecosystems experiencing similar shifting environmental settings.

D. Accomplishments: Complete the following sub-sections:

D1. Impacts & Effects: Describe any significant impacts/effects that the project is expected to have or had on business or industry development, resources management, the behavior of user groups, and the advancement of scientific knowledge. Provide information on direct socioeconomic gains realized as a result of the project if available. For example, these might include new businesses created, businesses retained, new tools or information created, cost savings, new products or expanded markets, jobs created or retained, or social benefits resulting from new resource uses. Benefits must be documentable, and where possible, quantifiable. List anyone we could contact regarding accomplishments of this project. You can consult with our extension program for help obtaining this information or disseminating the results from this project. The National Sea Grant Office is very interested in this information to promote the Sea Grant program. Please contact our offices to discuss outreach about your project results to stakeholders. We will work with you on that.

The results from this study will be helpful in updating the nitrogen budget for LIS as well as helpful for determining future nitrogen loading rates to the system. Once our paper is accepted we will provide all the data in public data repository, so that future research, modeling, and management efforts will have access to it.

D2. Scholar(s) & Student(s) Status: For scholars, detail thesis completion status and graduation date for each Scholar. Please indicate the first post-graduation and/or present employment for each person, if applicable. For non-scholar students (undergraduate or graduate level) financially supported on your project, provide time period supported, degree program and date degree awarded (graduation date). For other students who were *not* financially supported but did participate on this project, please list their contribution. For this last group of students, please indicate that they were not financially supported.

Two research technicians were supported on this project. One of them has moved to the University of Maryland as a research technician, the other is currently a Ph.D. student at Boston University.

D3. Volunteers: NA

D4. Patents: NA

D5. Leveraged Funding: BU provided teaching fellowship to support to Claudia Mazur which allowed her to write the manuscript above.

E. **Stakeholder Summary:** Provide a summary of your project as if you were selling or describing your project to a potential "stakeholder" (a non-peer audience). Focus on the major issues and their importance, your results and what impact they have. Be sure to include "take-home messages" from your project.

Excess nitrogen from human activities (e.g., fertilizing lawns and farm fields, sewage, etc.) is discharged to coastal ecosystems at an alarming rate. This excess nitrogen can lead to a series of negative changes including the proliferation of harmful algal blooms, low oxygen conditions, and decreases in biodiversity. Denitrification is the microbial conversion of nitrate to di-nitrogen gas, it occurs in marine sediments, and can remove up to 50% of excess human-derived nitrogen entering coastal ecosystems. Long Island Sound (LIS) is a heavily impacted, tidal estuary on the eastern coast of the United States. Surprisingly, no direct measurements of sediment denitrification have occurred in this system, and very little is known about sediment nutrient cycling in general. We quantified denitrification at five stations across LIS and found that low rates that did not differ between sites. Overall, LIS sediments have a 28% nitrogen removal efficiency, yet this can only remove 6.5% of total N loading to the system.

F. **Pictorial:** Provide any additional images/photos of personnel at work, in the field or laboratory, equipment being used, field sites, organism(s) of study or links to websites, etc. Please include proper photo credits and a caption with date, location, names of people, and activity. These images are useful to document your project in future NYSG publications, websites and presentations.

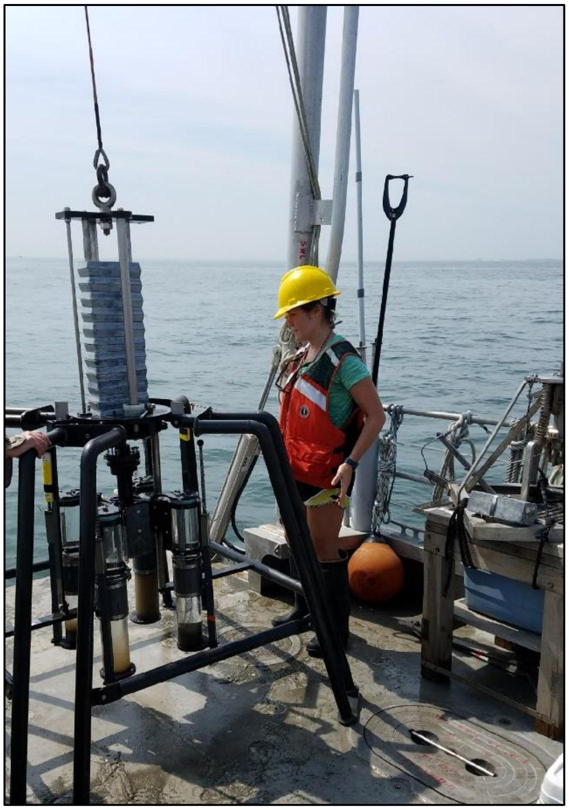

Figure 1. Boston University Ph.D. student Claudia Mazur inspects sediment cores collected via a multi-corer. Photo from Alia Al-Haj.

Figure 2. Boston University research technician Alia Al-Haj shows off a sediment core from Long Island. Photo from Claudia Mazur.


Figure 3. A close-up of a chlorophyll-a sample collected after filtering just 60 mL of surface water from Long Island Sound. Photo from Isabel Sanchez-Viruet.

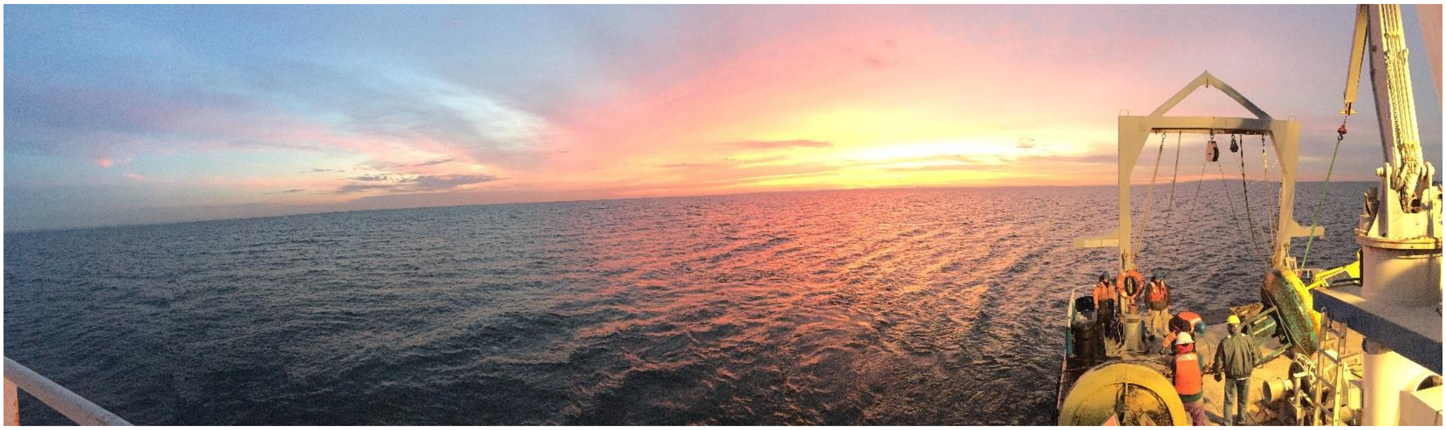

Figure 4. Sunset on Long Island Sound after a day of sediment core collection. Photo from Alia Al-Haj.