**NYC City Council Hearing**
**May 5, 2021 – 1 PM**
**Hart Island and the City's Public Burial Process**
**& Assistance Program**

Thank you for inviting me to testify today. I am Melinda Hunt, founder of The Hart Island Project. Our mission is to provide assistance to family and friends of people buried on Hart Island. We host a free, online database of graves and plot locations for burials starting in 1980. We advocate for transparency and preservation of the historic, natural burial process on Hart Island and designating City Cemetery a National Monument.

Today, I wish to testify about the importance of Hart Island to the people of New York especially during this pandemic. The burial process has served New York City through many epidemics. Providing safe access and a comforting experience to low income people of color who are disproportionately buried in City Cemetery should be a priority.

I wish to address removing dangerous buildings and restoration of the landscape to provide a comforting experience for visitors and encourage the city to to preserve the burial process as part of climate change initiatives as well as the history of New York City. Hart Island is preapproved for the National Historic Registry and it should be designated a National Monument following this pandemic.

Hart Island was originally laid out as rural cemetery, a respite from urban life. The workhouse was separate from the burials. Prison buildings in poor condition do not provide a sense of peacefulness to visitors. They are shameful reminders of terrible times on Hart Island. The buildings are now dangerously close to the graves. The city must provide access to gravesites as a result of the 2015 settlement to the NYCLU lawsuit. We recommend removing all buildings from Hart Island and using the footprints as new burial space.

One year ago the city experienced a dramatic increase in deaths from COVID-19. Morgue trucks appeared outside hospitals. Triple the usual number of bodies were released for burial on Hart Island. The city increased burial assistance and counseling to families. But Hart Island remains a hidden and scary place and people are reluctant to agree to a city burial.

On April 3, 2020, inmate labor ended on Hart Island thanks to legislation passed by the City Council that transferred jurisdiction to Parks. Now there needs to be a concerted effort to reduce the stigma of city burials. The best way to do this is to fully explain the burial process and restore the landscape.

There needs to be a public relations campaign conducted by city officials. Common graves need not be shameful. My family plots at Woodlawn in the Bronx are three deep and my family buried a child the same year New York City purchased Hart Island. I buried my father in the same plot as that baby, his grand uncle, 150 years later. How is that different from a City Burial? It was a lot more expensive but my father died outside the city so Hart Island wasn't an option.

Why then, isn't Hart Island a good place to send the body of a loved one? Because it was run by the prison system for a century and a half. Now, the city officials must work to lift that stigma.

Last year, the Medical Examiner gave families enough time to make private arrangements. It was the funeral system, not lack of burial space on Hart Island that made those freezer trucks necessary. Bodies remained in freezer trucks for months because families dreaded sending the bodies of their relatives to Hart Island. City burial records show that many elderly people who died in April 2020 were not buried until October. Think of how much additional suffering those families went through trying to decide what to do while their loved one was in freezer truck.

There has been no public relations campaign to inform the public of improvements on Hart Island. The shoreline has been restored and new city docks installed. City officials including members of the city council still have not visited the graves of New Yorkers buried there during COVID. The burial process appearing in drone photos was seen as negative because it wasn't explained, let alone owned by elected officials. Fear of city burials is unnecessary.

During a health crisis, a city burial is a much better choice than hiring a funeral director because the private cemeteries and crematoria could not easily meet demands for their services. Scaling up was not a problem on Hart Island because burial process is designed for epidemics. New York easily buries 25 bodies in an hour and keeps track of each grave within a plot of 150. Private funeral directors, private cemeteries and crematoria in New York were overwhelmed last spring.

How is a city burial different than family plots at Woodlawn? It's not only a lot cheaper but a burial or cremation at Woodlawn is a lot more time and paperwork for the family. Both are beautiful locations. In my mind, there is no difference between a burial next to a member of my family or another New Yorker except the cost and maybe the arguments between family members about what constitutes a proper burial and who gets to deliver a eulogy. One requires a lot of paperwork and arguing, the other is totally free and has nice people a HRA to help.

The public needs to be reminded that common graves were once common and all burials were green. Now that inmate labor has ended, lots of people will choose a natural burial on Hart Island if they understand that cremation isn't green or free. The City of New York should make Hart Island a place people want to be buried on public land managed by Parks. It should be a great place in our city to visit.

Hart Island is the only natural burial ground in New York City as well as the largest municipal cemetery in the country. It is a historic and completely sustainable green burial ground. The City Council needs to publicly acknowledge that our historic burial process is much better for the environment than cremation or private burials in concrete vaults. This needs to be the message.

Of all cities in the United States, New York City has the most democratic and environmentally sustainable method of handling its dead.

Here are my suggestions for more positive steps forward:

1) Remove the buildings quickly.

2) Develop a masterplan for restoring the landscape with native plants and engage the public in learning how natural burials support the ecosystem.

3) Develop a public relations strategy for encouraging people to choose natural burials as a way to preserve green space in New York City and beyond.

4) Include Hart Island as part of planning for climate change.

5) Show that you care about low-income New Yorkers by visiting the graves of their friends and family and inviting them to be part of turning Hart Island into a National Park that honors their contributions to building our city and country.

Mother's Day is this Sunday. Hart Island is a beautiful and sacred place that should be open on Mother's Day every year. Let's celebrate the end of this pandemic by planting a landscape of tomorrow to honor lives lost to COVID.

Thanks you for permitting me to speak today.

PUBLIC ADVOCATE FOR THE CITY OF NEW YORK

# Jumaane D. Williams

**TESTIMONY OF PUBLIC ADVOCATE JUMAANE D. WILLIAMS
TO THE COMMITTEE ON PARKS & RECREATION AND COMMITTEE ON HEALTH - OVERSIGHT HEARING
MAY 5, 2021**

Good afternoon,

My name is Jumaane D. Williams, and I am the Public Advocate for the City of New York. I thank Chair Koo and Chair Levine for holding today's hearing.

Over a year ago, our world changed. Our City shutdown along with the rest of the world to stop and contain a virus. Unfortunately, many lives were lost. Over 32,000 New Yorkers have died because of COVID-19. Those figures do not just represent a person lost. They include a young woman ready to go to nursing school. A beloved grandmother with stories that her family loved to hear. A technician who helped others during September 11th. All gone. Their families, friends, and countless others affected by the sudden loss of life amid a pandemic.

At Hart Island, we are reminded of the loss of life in our City. About one in 10 COVID-19 victims are projected to be buried at the island. Tragedically, most of those buried are people of more color. This highlights how communities of more color endured disproportionate deaths from COVID-19. From infection to injection, people of more color are overlooked and forgotten. The consequences are evidence through trauma and fear. People of more color are more likely to hold jobs that cannot be done at home, yet put their health at high risk from the virus.

In addition, the island reminds us why our City needed to close early in the pandemic. Even now, the Governor and the Mayor continue to go too fast in reopening without a careful evaluation of public health data. The Governor wants to open the state by May 19th, while the Mayor wants to open the City by July 1st. These conflicting announcements can undermine public confidence and suggest decisions are made out of politics. Our City does not need politically-made decisions. It needs scientifically-made decisions.

Otherwise, we will continue to see people dying. Even today, there are still people dying from COVID-19. Worse, deaths are disproportionately higher in communities of more color. The death rate for Black and Latinx New Yorkers is 1.66 and 1.85 times higher than white New Yorkers, according to the New York City Department of Health and Mental Hygiene. This tragedy is an ongoing issue that should be addressed.

At the same time, some of those buried at Hart Island are there because there was no surviving family member or the next of kin could not be contacted. The cost of a private funeral can be high, particularly during a pandemic. It took over a year before federal financial support from FEMA could be given to people requiring financial support for funerals and burials. The federal stimulus provides more than $200 million for COVID-related funeral and burial costs. Up $9,000 is given per person, even retroactively. I commend our New York leadership in Washington for attaining this funding that brings financial relief to struggling families and friends.

Yet more can be and should have been done. Some do not have details of who they were within our City records, such as the lack of a first name or age at the time of death. Some are yet to be buried. We do not even know how many at Hart Island have died because COVID-19. Of course, the pandemic overwhelmed our City's funeral homes and burial sites. Yet those who have passed cannot be forgotten even in death.

The administration needs to explain what it will do for those yet to be buried or those with family members or friends yet to be contacted. This should not be a task for the next administration. If there is something we can do, we should do it. It is the least that the City can do for New Yorkers at the front of the pandemic.

I cannot emphasize enough that the loss of life from COVID-19 is both traumatic and tragic. If we are to rebuild New York City, we must remember not to forget those who lost their lives. It is the least that we can do. I again thank the chairs for today's hearing.

NYC Council and the Committees on Health and Parks and Recreation
Public Hearing: Hart Island and the City's Public Burial Process and Assistance

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May 5, 2021

My name is Alexandra Barker. I am a registered architect with degrees from Harvard University. I have an office in New York where I have practiced for 23 years on a range of projects that include institutional, cultural, retail, and residential work. I am also a professor at Pratt Institute and the Assistant Chair and founding member of the Graduate Architecture and Urban Design program.

I am testifying today as a trustee for The Hart Island Project regarding two issues relating to preserving the historic burial process on Hart Island. The first concerns the urgent need to remove abandoned buildings and the second relates to the potential for grade modifications to the site to provide new burial space and address sea level rise due to climate change.

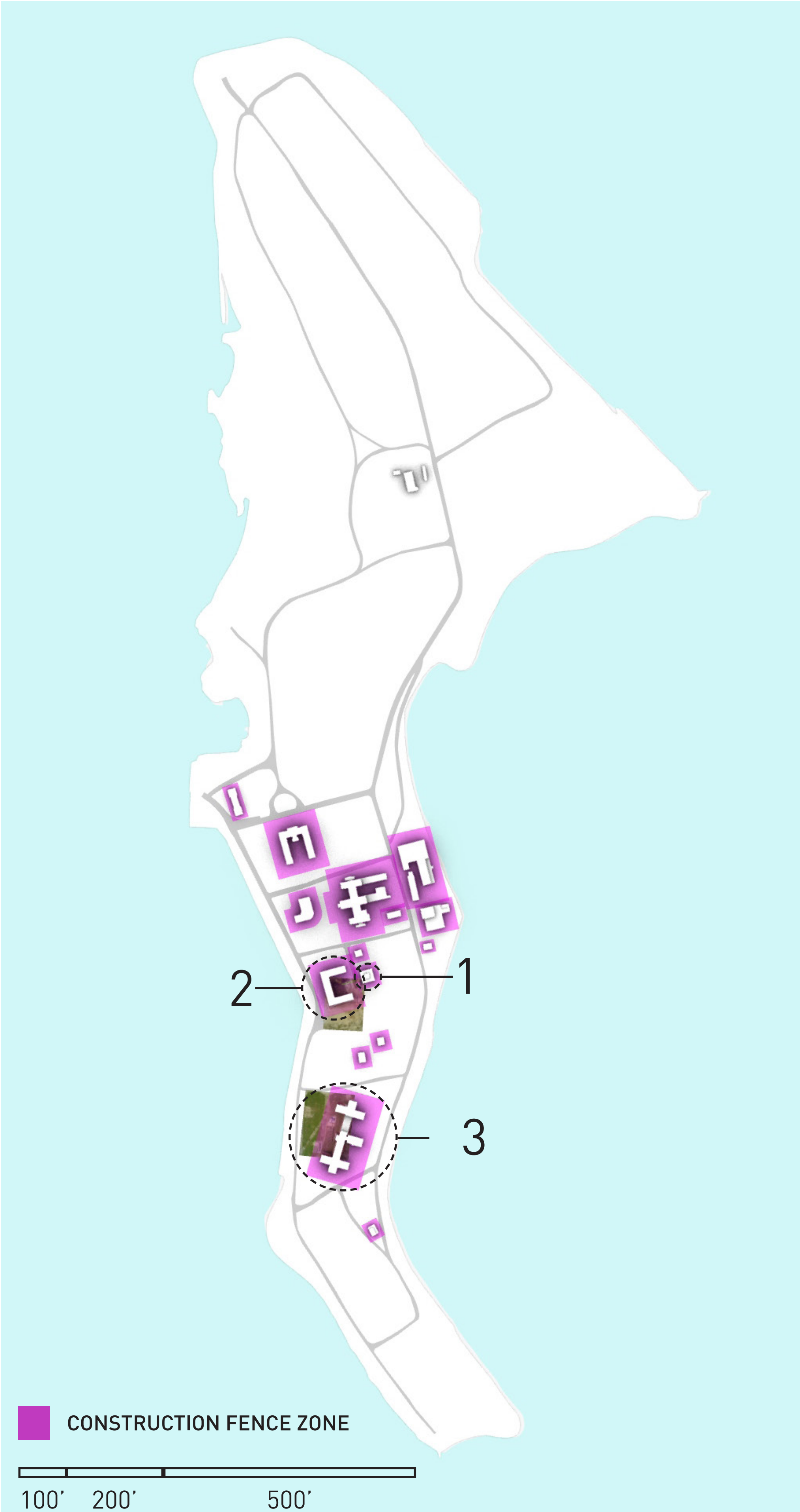
Existing Buildings: Recent burial sites exist within 10 feet of some of the existing brick structures, which are currently unenclosed and unprotected. The walls are crumbling and in danger of collapse. The cheap option would be to erect a fence to keep visitors safe. According to New York City Department of Buildings regulations, this fence needs to be located at a distance from the building that matches the height of the walls or greater. It also needs footings that go down to the frost line.

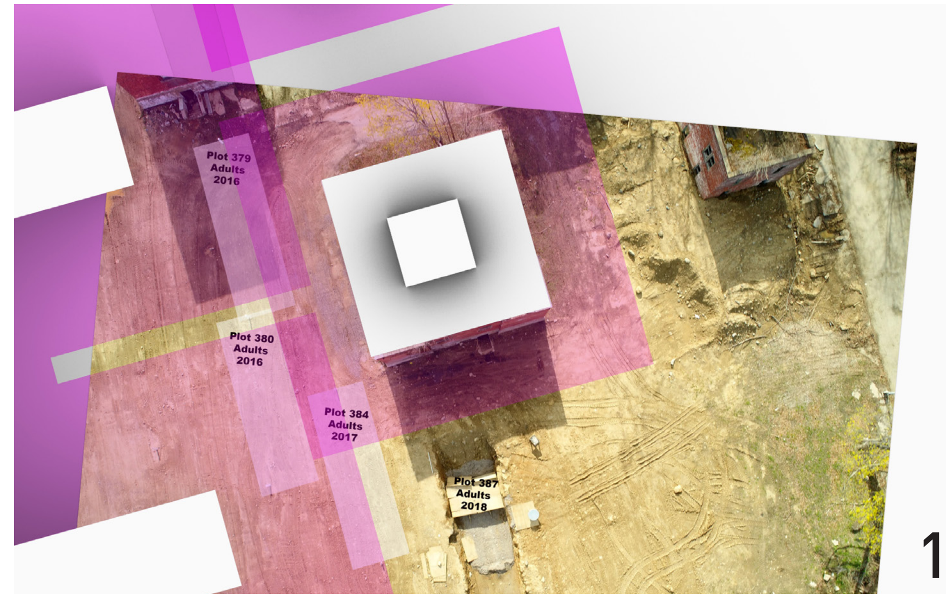
As you can see from the diagram I prepared, locating a fence in that position will obstruct access to many of recent gravesites. Keeping visitors safe using fencing means restricting access which is contrary to the settlement in the 2015 federal class action lawsuit that requires physical access to actual graves. The only way to safely maintain access to actual graves is to remove the buildings. Furthermore, if all building materials are removed from the site, that land will be available for an estimated 9,000 additional burials.

Grade Modifications: I believe it is possible to continue to bury using the current system of common plots and substantially increase the city's burial capacity by adding soil to northern areas of the island that are flat and where existing graves are older than 30 years. As you can see in the attached image, I have identified two areas that meet this criteria. Adding 8 feet of additional soil would protect these sites from erosion and flooding and would provide capacity for adding an estimated 67,000 additional burials, or another 40 years of burials based on the rate of burials since 1980. Grade elevation would also provide protection for the island from storm surge in much the same way that is now planned for East River Park in Manhattan.

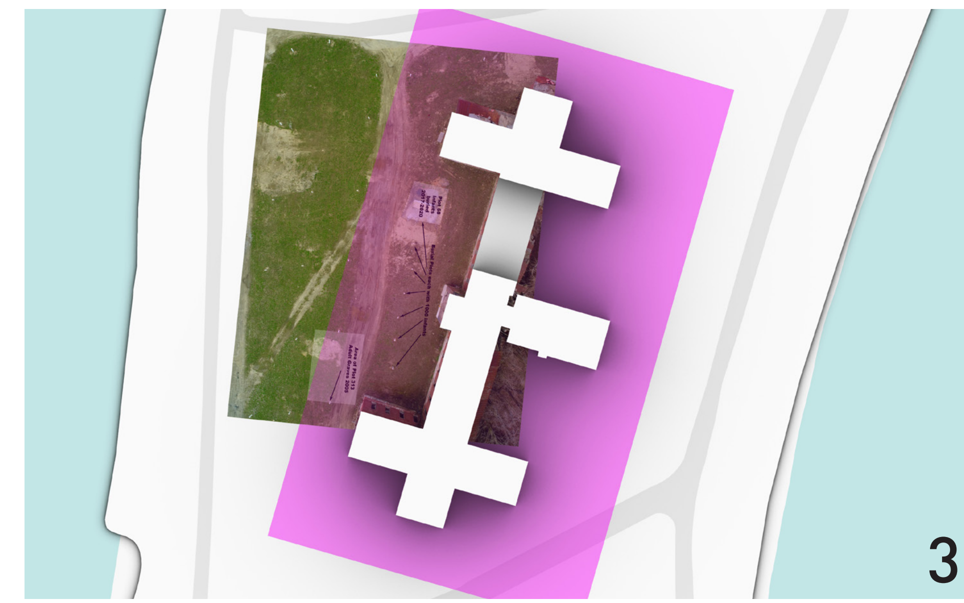
In summary, I believe that the removal of the buildings on Hart Island is absolutely necessary to allow visitors to safely access gravesites as well as improve their experience. This removal will have the added benefit of creating new space for burials. The addition of soil to the north end of the island will protect existing graves and provide an increase in burial capacity for generations to come.

Thank you for allowing me time to testify today.








- Fencing would have to be located at a distance that matches the height of the buildings

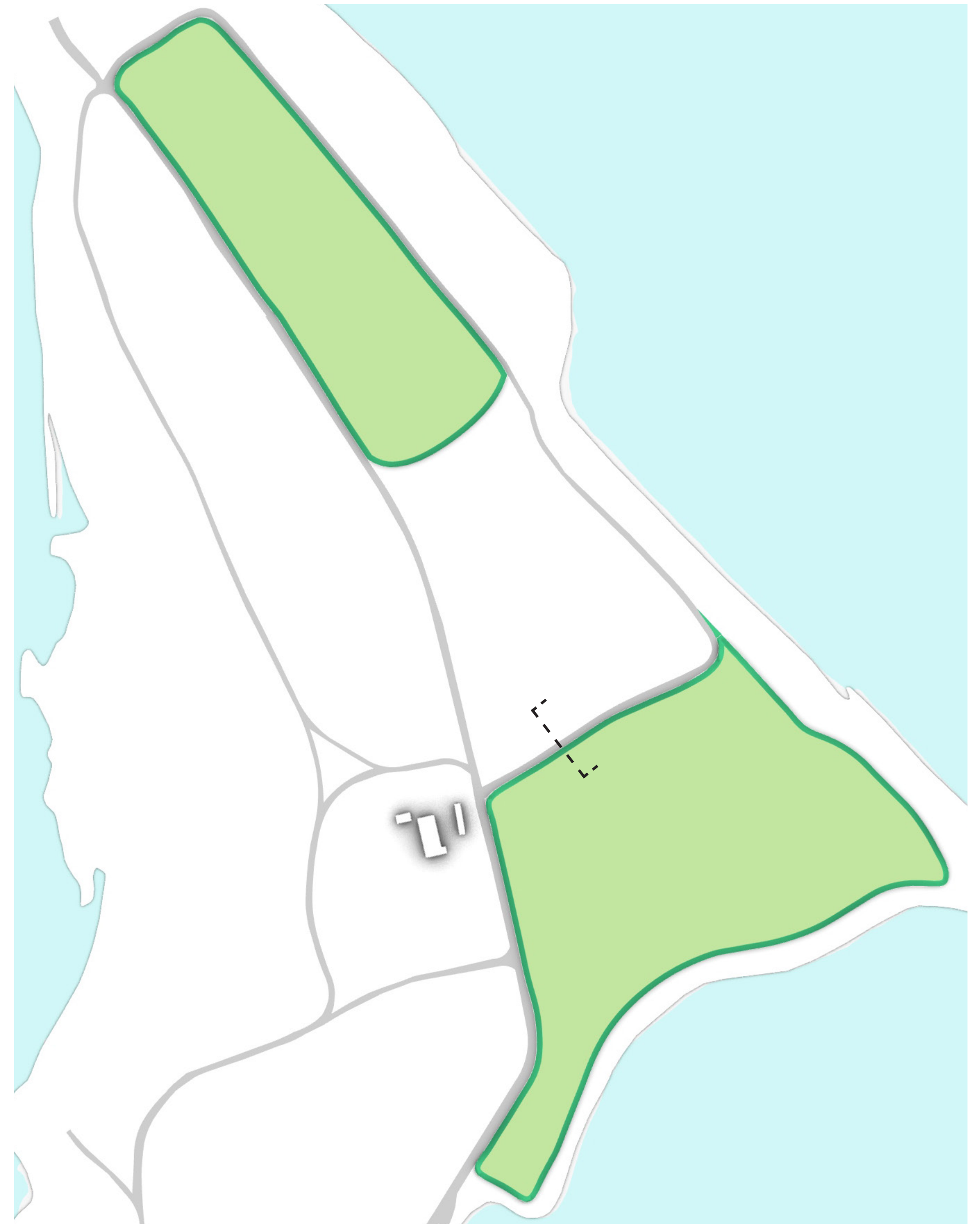
- Families have the right to access physical grave locations

- Fencing would block access to graves adjacent to buildings

- Abandoned prison buildings offer a negative experience of city burials which is contrary to the purpose of a cemetery

**Note: Construction fence would be subject to NYC DOB Regulations**
NYC 2014 Building Code, Chapter 33, Safeguards During Construction Or Demolition, Section BC 3307, Protection Of Pedestrians

# CONSTRUCTION FENCE

## Opportunity:

- Increase city's burial capacity by adding soil to northern areas of Hart Island

- Graves over 30 yrs will remain intact

- An estimated 67,000 can take place in the raised areas

- Sea level rise will be offset by higher land

**Note: Filled land is subject to OSHA Regulations**
OSHA, Safety and Health Regulations for Construction, 1926 Subpart P, Excavations, 1926 Subpart P App B, Sloping and Benching

# FILLED LAND

City Council Hearing May 5, 2021

Hart Island

As a resident of City Island for over 45 years, and as an officer of both the City Island Civic Association and the City Island Historical Society, I would like to speak out on two aspects of the proposed Burial Capacity Study proposed by the Human Resources Administration for Hart Island.

As noted in the study, the only access to Hart Island is by ferry from City Island, and the only mention of City Island was in this context, with no reference to the fact that our community deserves to be included in any and all aspects of the Hart Island issue. I believe that access to Hart Island should be made part of this study, especially as burials and visitation in the future are expected to increase. There was to have been such a study held by the Department of Transportation during the last two years, but to my knowledge this was never carried out; if it was, why were community members not included? Now that New York City has a viable ferry system, Hart Island should be considered as a destination for visitors traveling by ferry from other parts of the city. The bodies of the deceased should also be transported from locations other than City Island.

More important, however, is the issue of cremation, the study of which is being proposed and which I believe should be removed from the Burial Capacity Study. I believe I speak for virtually all City Island residents and businesses when I say that the very idea of putting a crematorium on Hart Island will meet with unanimous opposition. The Environmental Protection Agency does not regulate the emissions produced by crematoria, although it has been documented that such emissions can contain mercury and other hazardous substances, and there are no other federal rules or regulations regarding crematoria.

I believe that it would be a waste of both time and money to study the potential for a crematorium on Hart Island, as there is currently no power on the Island to run such a facility and the negative response from the neighboring communities, including City Island, would be considerable. The very fact that the Human Resources Administration would consider placing a crematorium adjacent to the largest public park in New York City, let alone City Island with its 4500 inhabitants, indicates a lack of understanding of the negative response that such a proposal would face and a waste of funding to study the issue.

Barbara Dolensek

Vice President, City Island Historical Society; Second Vice President, City Island Civic Association

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21 Tier Street, Bronx NY 10464

**From:** Cathy Cebek <catc921@yahoo.com>
**Sent:** Thursday, May 6, 2021 4:44 PM
**To:** Balkan, Em
**Subject:** Hart Island Hearing held 5-5-21

EBalkan ,

Please enter these documents to the record .
-A Letter from the City Island Civic Association
-Report from the City of New York Sanitation.
-Letter from a City Island Resident that worked for Sanitation as one of the Environment Police Officers in the above report .

Thank you for your help regarding registering , testifying and entering documents to the record.Your professionalism and prompt responses  was very much appreciated . I hope our community was heard clearly .Thank you.

Regards,
Cathy Cebek

September 25, 2019

On Tuesday evening, September 24, 2019, the City Island Civic Association membership voted on the following Bills regarding Hart Island at the general membership meeting:

Bill 906: transferring jurisdiction of Hart Island from the Department of Corrections to the Department of Parks and Recreation. Membership voted in opposition to this Bill.

Bill 909/909B: regarding ferry service from City Island and a study of the service. Membership voted in opposition of this Bill.

Bill 1580: creation of a task force regarding burial process. Membership voted in favor of having City Island represented on the task force with residents included as part of the task force.

Tom Smith
Treasurer
City Island Civic Assn

CB10 Member

# THE CITY OF NEW YORK Department of Sanitation

INTRA - DEPARTMENTAL CORRESPONDENCE

Environmental Police Officers (E.P.O.)
Corrections Officers (C.O.)
Coast Guard

TO: Kevin Smyley, Inspector General

FROM: E.P.O.Thomas McMahon/Patrick Dugan ← Are E.P.O.'s McMahon & Dugan still alive?

SUBJECT: Hart Island

Ferry from City Island to Hart Island - Captain Herity
(Deck Hands) Mr. Wilkenson
Aspinalli
Remicci
Harris

On this day, March 13, 1985, both Environmental Police Officers (McMahon & Dugan), met at 0730 hours on City Island to make arrangments to go to Harts Island. We approached a man standing on the ferry, Mr. Wilkenson, who is employed as a deck hand and asked him what time the next ferry would be leaving for Hart Island He informed us to check in at the trailer to the left of the ferry dock. We then spoke to Captain Herity who operates the ferry. He said that it would be around 8:30 a.m. when they would make the first trip. Accompanying the Captain in the trailer were three deck hands (Mr. Aspinalli, Mr. Remicci, Mr. Harris). We asked them about their schedule and they told us that they all work from 7a.m. to 3:30p.m. and that the last run from the island is at 3:00p.m. They are employed Tuesday thru Friday with no service on the weekend or Monday.

We spoke to the Correction Officers at the entrance to the ferry (Konovitch, Alt, Sumpter) who informed us that ther are presently 48 inmates living on the Island. Ther is a Correction boat next to the ferry that provides 24 hour service to Hart Island for the Correction Department.

We then walked to the ferry and waited for it's departure. The ride to Hart Island takes about ten minutes. During the ride over we spoke to a Mr. Roberts who is the Chief Engineer on the ferry. Mr. Roberts informed us about the Coast Guard regulations concerning the water ways surrounding Hart Island. Mr. Roberts also told us that his ferry is used to transport supplies, personnel, hospital vehicles and a morgue truck. Since Hart Island is used as a Potters Field that is the reason for the morgue truck.

When we arrived at Hart Island we were met by a Correction Officer (Moore) who took us to the Headquarters Office where we were introduced to Captain Ruppert. Captain Ruppert explained to us the complete use of Hart Island. Presently the 48 inmates on the Island are assigned duties at the burial plots and the kitchen area, also at some of the maintenance buildings.

Captain Rupert then proceeded to take us on a combination walking and driving inspection of the entire Island. Our first stop was at a burial site where we watched a bulldozer digging a hole for approximately 150 unclaimed bodies, some of which would be arriving this morning. We then walked towards the northern end of the Island where we observed human bones. A skull was also seen on the beach area. It was explained to us that this was a rather common thing to happen since the city has been burying bodies there for almost 80 years and the water has caused some erosion at the older burial spots.

After we left the burial sites we proceeded to the old United States Army missile site.. Both Environmental Police Officers descended into the two missile launch sites for a closer examination. These launching sites are about thirty feet underground and are made of reinforced concrete. Ther is an accumulation of water in the missile cradle area (about 1 and 1/2 ), but aside from that the area was clean and free from any drums or other possible toxic materials. It must be noted however that also in the area was a stationary crane that was used for unloading the missiles into an underground compartment. This compartment has been cemented over and was impossible to examine. After leaving the missile site we began to examine the area and about forty (40) odd buildings on the ninty (90) acre island

It was obvious from the very beginning that there were many 55 gallon drums on the island. On closer examination it was found that these drums, or at least many of them did contain an unknown substance. About 150 five gallon drums were found under a crawl space in one of the buildings. These five gallon drums bore markings describing them as paint, belonging to the U.S.Navy at Brooklyn,New York. These cans were scattered around in many of the other buildings also. Almost all of these drums were full. We also noted that in most if not all the buildings there is a great amount of possible Asbestos material falling from pipes and laying on the ground.

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## Hart Island

Growing up as a teenager on City Island many of us first recognized harts island as a nikey missile site who rockets raised every once in a while for our amusement. As we grew it became a rite of passage to go to the forbidden island for a peek. Be it by boat or swimming this Bronx Treasure Island captured our imagination. Rummaging thru the skeletons on the northeast beaches of Harts Island. Or playing hide and seek with a bunch of guys. As we grew older many of our friends had family that worked on Harts Island and their stories were remarkable about the old prison, naval base and the everyday running of the island.

Then came the 60's when someone decided to turn over Harts Island to Phoenix house. Concerts, love fest and drinking and smoking! An unsupervised heaven, (no pun Richie), for young adults. I said all I am going to say about that.

Then came the abandoned years. Most people are under the assumption that harts island was wrecked by phoenix house! Very untrue it became the black hills gold rush, local prospectors of brass, copper and plumbing, stain glass, windows, and anything that was worth any amount of money for city islanders and friends!

In the mid eighty I was assigned by the city council to conduct an environmental assessment of the island. To my joy I embarked on an assignment that brought back many fond memories. I was given free access to the island for as long as I needed to conduct the inspection. The purpose of the inspection was so that the city council could render a decision on what the island land could be used for in the future. The first idea that was knocked down was an incinerator! It would be way too expensive to barge or truck garbage to the island. If my memory serves me correctly there were upwards of 47 structures on the island. Which included treatment plants, electric buildings, office buildings, barracks type structures homes and a church? A real life city within a city.

My inspection revealed that there were thousands of 30 gallon cans of lead paint beneath many of the structure, Hundreds of 55 gallon drums containing PCB's and other toxic liquid. There was asbestos scattered thru out the buildings and a large asbestos covered pipe running above ground on the east side of the island. There was scattered jet fuel bunkers sealed on the island. Of which the Department Environmental Protection and the State Department of Conservation could not get permission to unse these sites. Also unknown too many were that there were burial grounds on the southern part of the island which were used for unexplained deaths and contaminated bodies. Due to these facts I believe that the city council concluded that Harts Island is better left alone as potters field!

I have met Malassia Hunt and found her to be very dedicated to the harts Island Project! And thought do believe that people have the right to visit loved ones buried on Harts Island I do believe that the monthly visit and annual mass is more than enough provision for family and friends. And that the correction Department should be praised on making this venture easily possible for anyone.

What does disturb me about Hart Island is that recent demolition of building has followed proper procedures in removing the hazardous material from the demolition areas. I do believe that Harts Isla is not suitable for inhabitants unless proper removal of all the hazardous material is performed. My judgement is that bodies are buried all over the island and that use of the land for any purpose that a burial ground or bird sanctuary could be dangerous to the public.

Respectfully submitted:

Thomas S McMahon

From: Carol DiMedio
cdmuf2@comcast.net
Subject: Hart Island Testimony
Date: May 3, 2021 at 6:12:07 PM
To: Me cdmuf2@comcast.net, Johnny Office drdimedio@comcast.net

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Carol DiMedio
18 Katie Way
West Chester, Pennsylvania 19380
Tele: 610-431-0756
Cdmuf2@comcast.net

May 3,2021

Written Testimony for Hart Island Meeting

My name is Carol DiMedio. My Grandfather Luigi Roma is one of approximately 1 million people buried on Hart Island. My Grandparents immigrated from Southern Italy. Shortly after they arrived, my Grandmother died in childbirth and so did her baby. My Mother and 2 brothers were placed in 3 different orphanages. My Grandfather visited my Mom every weekend then suddenly stopped visiting. She never knew what happened to him. We searched for him for years including calling cemeteries, police departments, Funeral Homes and online searches. I learned about Melinda Hunt and The Hart Island Project. I contacted her. This was my last chance of finding him. My Mom was in her 90's and was beginning to decline from dementia. Melinda looked through handwritten records and found he was buried there. When she told me I was both relieved to have found him but devastated to know he was buried on Hart Island. I had learned it was maintained by the Department of Corrections, had mass graves, buildings falling apart, etc. No family members were permitted to visit Hart Island until very recently. I had to get there and be close to him for the first time in my life. I told my Mom I found out where her Father was buried. I lied saying it was the most beautiful cemetery. She needed closure and peace. I was required to show proof I was related. The Department of Corrections sent papers explaining some dangers such as the possibility of injury due uneven ground, etc. My husband and I waited months for our visit because only certain days and times were available. When my husband and I arrived we had to show our drivers licenses, turn in our cell phones and were not permitted to take photos. We were taken to Hart Island by ferry. I was excited to finally be near my Grandfather but nervous not knowing what Hart Island would be like. I watched as my foot touched Hart Island's soil thinking this was the first time I was ever near my Grandfather. Since he was buried so long ago my husband and I were taken to a different area. It was the most beautiful crisp fall day. The sun was glistening on the water as birds flew above. I brought 3 roses one for my Grandfather and 2 for the others buried there which I placed on the ground. Although it was very emotional I finally felt peace. My fear was replaced with peace. I was able to acknowledge he was there somewhere and I was with him. I saw the disintegrating buildings and the pipes used as markers. We saw where babies were buried as well as the people who had died from AIDS. We heard deer walking through the leaves in the woods. I looked around and thought about the treasure there. We had to give those souls the dignity and respect they deserved. We had to honor them. It must be made easier for families and others to visit their loved ones buried there. Shortly afterward the care of Hart Island was transferred from the Department of Corrections to the Parks Department. I was hopeful it would be easier for people to visit. It seems these things are happening. At this point the buildings are still there. This past year so many COVID victims are being buried there. Today Hart Island is more important than ever. It is a part of history. People from all walks of life are taken there sometimes there is no place else to go. It doesn't matter who you are or the reason you ended up there. Hart Island could truly be beautiful, historic and comforting to families and loved ones instead of a place of fear and deterioration. Hart Island could be a place of reflection for all of us - how we all got here and where we have to go. Hart Island might become one of the few places where people can be buried. My hope is that people could feel the peace and comfort that I felt. It's very sad but my Mom died of

COVID. I know the heartbreak of no last goodbyes, no hugs, kisses or final touch. I also know the peace I felt standing on Hart Island with my Grandfather. I want the people whose families or loved ones who died of COVID to know Hart Island can be made even more beautiful if the work continues to make it that way. Thank you to Melinda Hunt and all the people who have worked tirelessly to improve Hart Island for people like my Grandfather, my Mom and me.
>> Carol DiMedio
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The Gaia Institute

May 5, 2021

Honorable Mark Levine
Chair, New York City Council Health Committee
City Hall
New York, NY 10007

Dear Chair Levine and Members of the Health Committee:

For a century and a half, Hart Island has offered New Yorkers a final resting place. Coronavirus reminds yet again of our need for this. Still within city limits, this incomparable landscape at the water's edge extends a deep, even unexpected respect to those who die in the City through a practice in which humankind has participated for nearly a hundred millennia. Earth between meadow, forest and coastal edge is opened to those citizens who come with few options. Like New York at its very best, this works to deny entrance to no one.

The Parks Department's removal of the old buildings, - derelict survivors of the City's long history of island asylums, could now free acres to serve this hallowed end. Such potential imposes expense, but here at this site offers an even greater opportunity. Old ships and subway cars now become reefs put to work in the rebuilding of fisheries. These old structures hold even more promise.

The crane company on City Island has the necessary equipment to move and position brick, stone and mortar of these old buildings along Hart Island's eastern coastline. Shoreward of such fringing reef protection, ten or more acres salt marsh and mussel bed could be created and restored. Such living structure would capture and store more than forty tons of carbon every year.

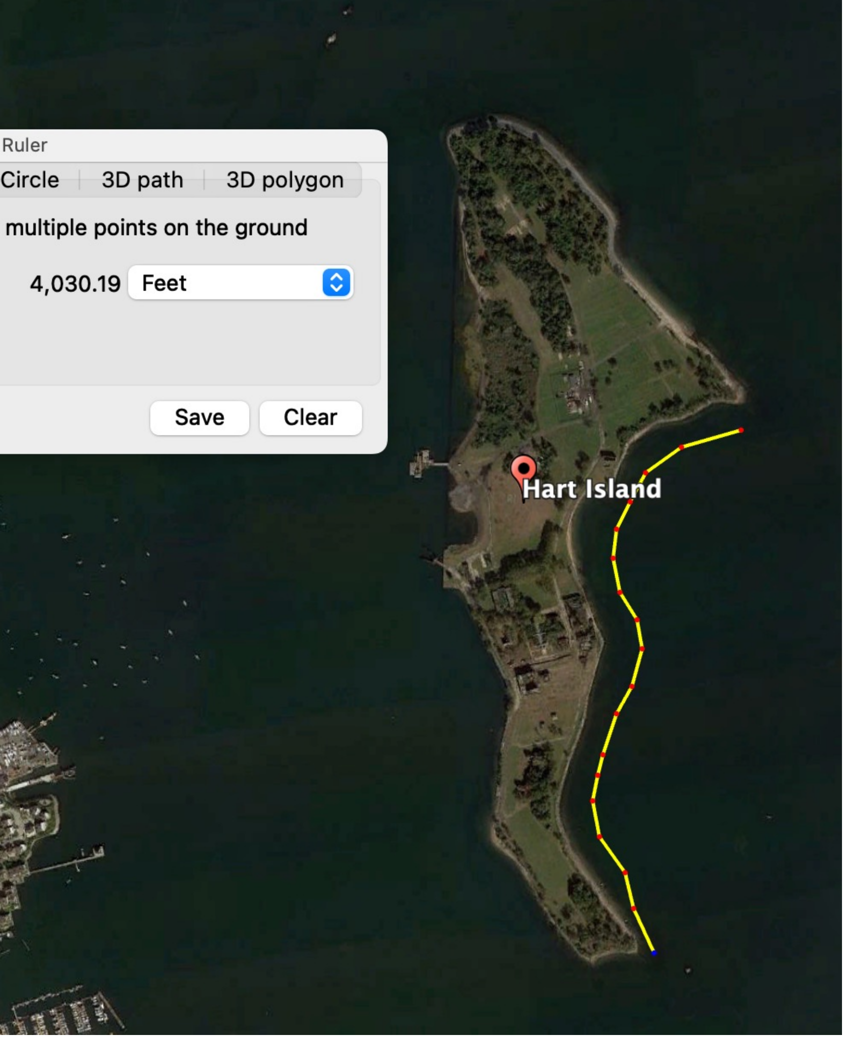
The ribbed mussels that knot themselves into salt marsh would work to remove the most detrimental nutrient from surrounding waters, --tons of nitrate from the City's treated wastewater discharge at Tallman Island & Hunts Point. This may be the only opportunity for disposing of these old structures that does not guarantee ever increasing climate change.

Land disposal demands trucks and fuel, roadway traffic turning gas & oil into exhaust, adding still more $CO_2$ to the forty billion excess tons we already have in the atmosphere. Built into reef & marsh, though, these old buildings would work in perpetuity to clean the waters and build the fisheries of Western Long Island Sound.

How to preserve the spirit of such a land? This is perhaps the only opportunity we have for a hundred acre refuge, held in trust to offer comfort to those who come to remember someone they have lost. There is also the potential to work with the original inhabitants. A thousand or more native plants have lived for millennia in what is now Pelham Bay Park, a mile across the Sound. Likely many of these beings inhabited Hart Island as well. Two hundred species of migrating birds pass through these woodlands, meadow, and marsh, fall & spring. Such feathered encounters perhaps invoked in Lenape people a feeling for the spirit connecting earth & sky. Such presence, this eternal return of warblers, wrens, waxwings, sparrows, swifts, swallows, &c, also connect our seemingly local ecology with tundra far to the north, tropical rainforest to the south.

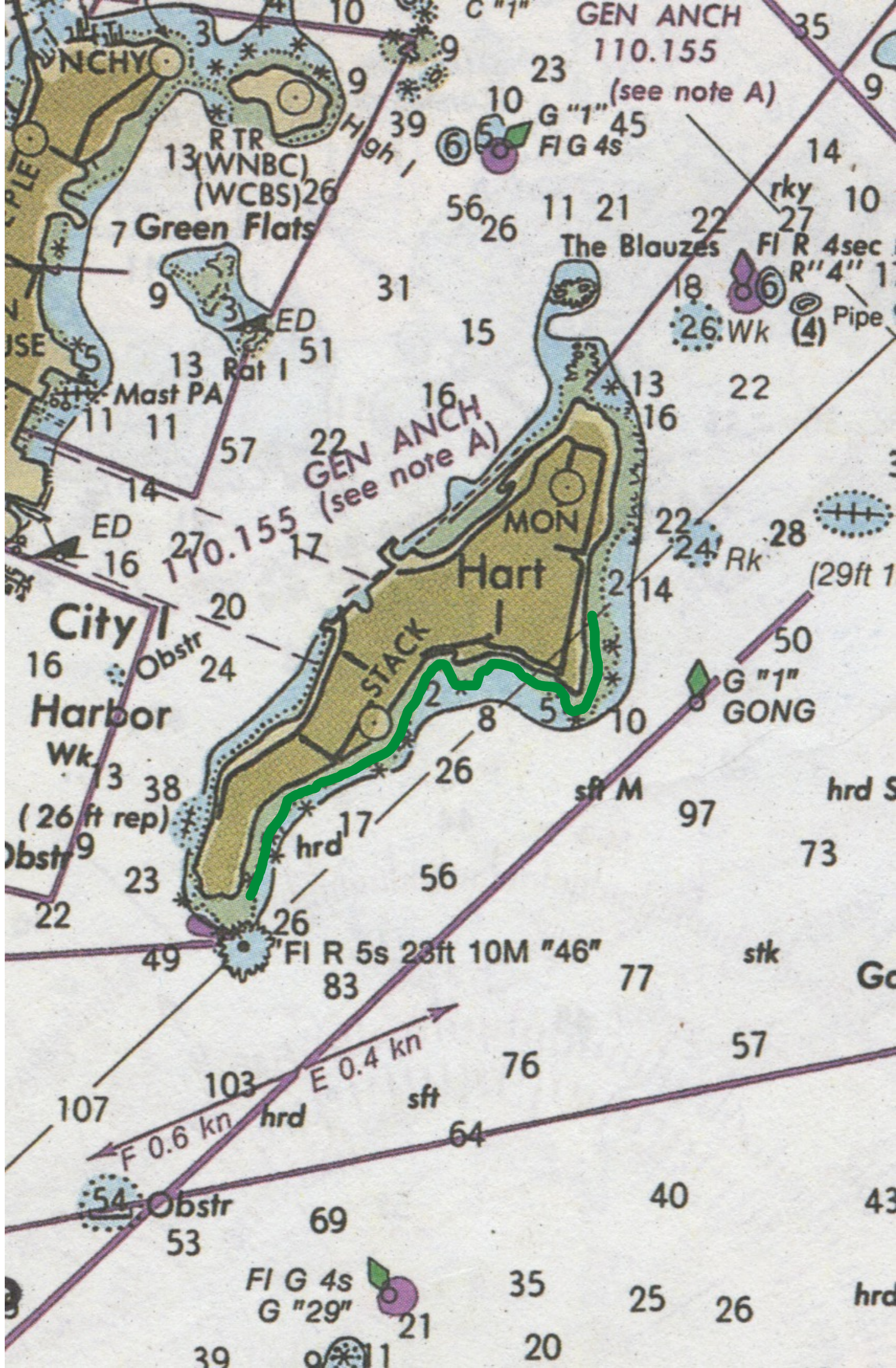
Apparently, the people who lived here long before our ancestors arrived, the Lenape, would leave food or nutriment near the graves dug for their loved ones. Perhaps we could learn from this and create a refuge for the diversity of life, with visitors invited to leave native milkweed, aster, goldenrod, cardinal flower, planted in the moist earth of Hart Island, living offerings to the enduring spirit of the land near the graves of family & friends, and generations of New Yorkers.

Paul S. Mankiewicz, Ph.D.
Director




Hart Island’s shallow eastern edge offers thousands of feet of opportunity where deconstructed buildings could be used to create reef and marsh.

Ten acres of marsh edge, the length pictured to the left at about 100 foot of width, would capture about 45 tons of carbon per year



Seaweed, salt marsh cordgrass, & ribbed mussel beds,--each & all significant nitrogen sinks, develop at intertidal edges.

Just one acre of mussel bed like these shown can filter about 90 million gallons of water a day.


Coupling oyster reef-wave break protection with saltmarsh & ribbed mussel habitat development

This model likely reflects New York’s historical coastal ecology-fringing oyster reef abutting near shore salt marsh

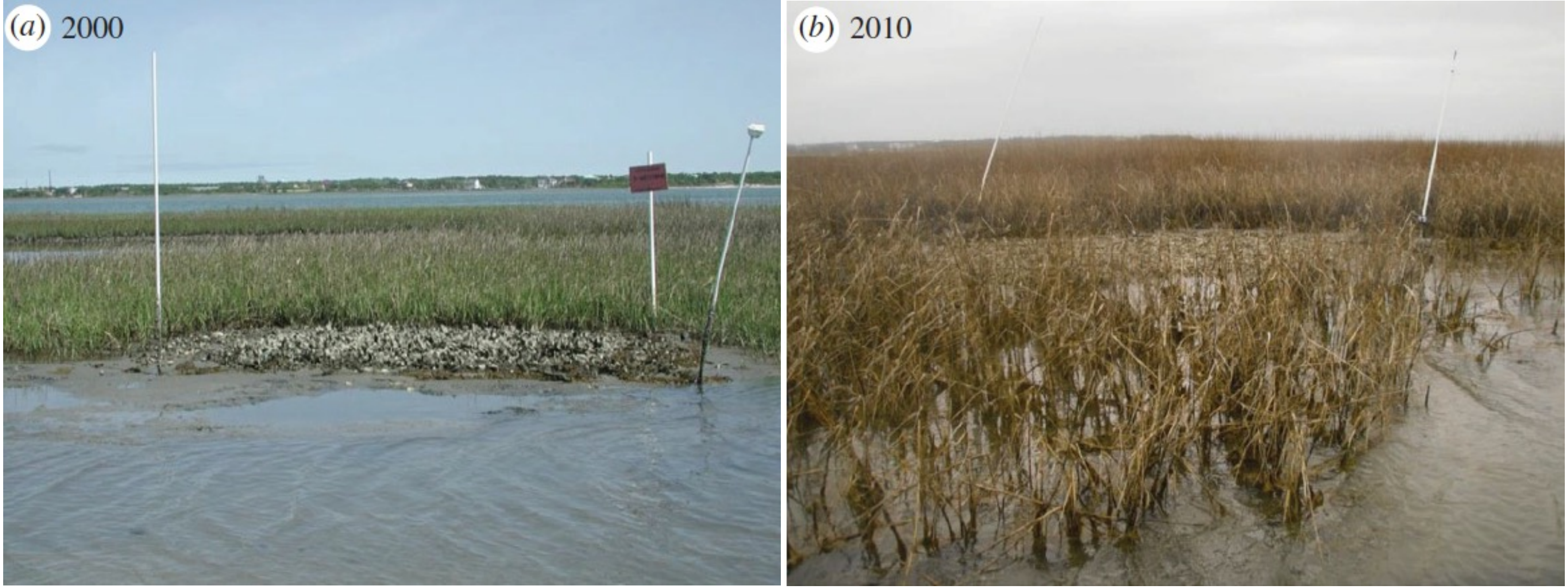



**Figure 4.** Shellfish reefs facilitate expansion of other blue carbon habitats. (*a*) Representative oyster reef—saltmarsh interface soon after the reef was created. (*b*) Seaward expansion of saltmarsh (*S. alterniflora*) since construction, resulting from the accumulation of sediments within and around the oyster reef. (Online version in colour.)

Salt marshes & reefs grow and develop to increase capacity over time, as the marsh in the foreground above has done, storing carbon in the process of cleaning water and building fisheries.

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# Oyster reefs as carbon sources and sinks

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Carbon burial is increasingly valued as a service provided by threatened vegetated coastal habitats. Similarly, shellfish reefs contain significant pools of carbon and are globally endangered, yet considerable uncertainty remains regarding shellfish reefs' role as sources (+) or sinks (−) of atmospheric $CO_2$. While $CO_2$ release is a by-product of carbonate shell production (then burial), shellfish also facilitate atmospheric-$CO_2$ drawdown via filtration and rapid biodeposition of carbon-fixing primary producers. We provide a framework to account for the dual burial of inorganic and organic carbon, and demonstrate that decade-old experimental reefs on intertidal sandflats were net sources of $CO_2$ ($7.1 \pm 1.2$ MgC ha$^{-1}$ yr$^{-1}$ ($\mu \pm$ s.e.)) resulting from predominantly carbonate deposition, whereas shallow subtidal reefs ($-1.0 \pm 0.4$ MgC ha$^{-1}$ yr$^{-1}$) and saltmarsh-fringing reefs ($-1.3 \pm 0.4$ MgC ha$^{-1}$ yr$^{-1}$) were dominated by organic-carbon-rich sediments and functioned as net carbon sinks (on par with vegetated coastal habitats). These landscape-level differences reflect gradients in shellfish growth, survivorship and shell bioerosion. Notably, down-core carbon concentrations in 100- to 4000-year-old reefs mirrored experimental-reef data, suggesting our results are relevant over centennial to millennial scales, although we note that these natural reefs appeared to function as slight carbon sources ($0.5 \pm 0.3$ MgC ha$^{-1}$ yr$^{-1}$). Globally, the historical mining of the top metre of shellfish reefs may have reintroduced more than 400 000 000 Mg of organic carbon into estuaries. Importantly, reef formation and destruction do not have reciprocal, counterbalancing impacts on atmospheric $CO_2$ since excavated organic material may be remineralized while shell may experience continued preservation through reburial. Thus, protection of existing reefs could be considered as one component of climate mitigation programmes focused on the coastal zone.

## 1. Introduction

Carbon sequestration is a crucial service provided by marine ecosystems in buffering global climate change. In particular, vegetated coastal habitats, such as salt marshes [1], seagrasses [2] and mangroves [3], are strongly autotrophic ecosystems that fix $CO_2$ in excess of what is respired and therefore act as disproportionately valuable carbon sinks [4]. This excess carbon is buried in sediments at a rate accounting for roughly 50% of the approximately 250 Tg C buried throughout the entire ocean each year [1]. This burial rate is remarkable considering that these vegetated habitats cover less than 0.5% of seafloor bottom, and troubling given the severe threats facing coastal ecosystems dominated by these foundation species [5]. A dual injury occurs when these habitats are lost, resulting from both the decreased burial capacity of coastal ecosystems, and the release of formerly dormant carbon pools back into the biosphere [3]. As such, there is now national and international momentum to catalogue and protect coastal marine carbon stocks [6,7].

Like vegetated 'blue carbon' habitats, shellfish reefs are severely endangered worldwide (65–85% losses over the last 100 years) [8,9], resulting in forfeiture of several ecosystem services of recognized importance, such as water filtration, denitrification, shoreline stabilization and nursery provision [10]. Moreover, shellfish reefs are uniquely coupled to marine (e.g. phytoplankton, benthic microalgae) and terrestrial (e.g. plant detritus) primary producers via the filtration and subsequent deposition of particulate organic matter (hereafter 'seston') as faeces and pseudofaeces into an accreting reef matrix [11,12]. Without this tight benthic–pelagic coupling and rapid burial mediated by shellfish reefs, seston would remain available for consumption by other heterotrophs that contribute little to carbon burial. Here, we define burial as material that is deposited below the taphonomically active zone (TAZ) of a reef. Therefore, this buried material does not interact with overlying waters or the atmosphere and is potentially stored over centennial to millennial scales [13]. While respiration is a significant carbon transformation within shellfish reefs, the same is true for vegetated coastal habitats that support rich faunal assemblages [14]. Like salt marshes, seagrasses, and mangroves, coupled seston–shellfish reef ecosystems contribute to localized mass burial of newly fixed, excess, organic carbon, and thus may play a notable role in mitigating atmospheric build-up of $CO_2$.

Recently, carbon burial has been proposed as an incentive for shellfish-reef conservation primarily due to the carbon in shell material [15]. Indeed, carbon sequestration via this pathway is a logical assumption because shellfish build carbonate shells and this material is abundant in the fossil record [13]. However, biosynthesis of calcium carbonate liberates protons from bicarbonate ($Ca^{2+} + HCO_3^- = CaCO_3 + H^+$), and subsequently contributes to the formation of excess carbonic acid ($H^+ + HCO_3^- \rightleftharpoons H_2CO_3$) followed by venting of carbon dioxide into the atmosphere ($H_2CO_3aq \rightleftharpoons H_2O + CO_2$) [16–18]. Burying this shell has no further direct impacts on atmospheric $CO_2$, but probably precludes the erosion and dissolution of shell material that would return $CO_2$ concentrations to pre-shell-formation (i.e. lower) levels. Still, the climate-related consequences of shell production and burial ($CO_2$ source) and organic carbon deposition ($CO_2$ sink) within shellfish reefs on carbon cycling are largely additive (but opposite in direction). Thus, the role of shellfish reefs as $CO_2$ sources or sinks ultimately depends on the relative balance between organic (org-C) and inorganic (inorg-C) carbon burial. Analogous biogeochemical processes occur throughout pelagic ecosystems, where the ratio of diatom (org-C heavy) to coccolithophore (inorg-C heavy) production determines the strength of the regional atmospheric–oceanic $CO_2$ flux [19,20].

To determine whether shellfish reefs represent $CO_2$ sources or sinks, quantitative data on burial rates and pools of org-C and inorg-C within this biogenic habitat are needed. Despite a vast literature on shellfish biology and related functions (e.g. alkalinity regulation) [21], few studies have examined emergent shellfish reef properties such as carbon composition and accretion rates (electronic supplementary material, figure S1). Those touting shell burial as a carbon sink have not accounted for the carbonate chemistry that vents $CO_2$ to the atmosphere during shell biosynthesis, while those excluding oyster reefs as blue-carbon-related habitats may not have included credit for the rapid burial of recently fixed organic carbon within the reef matrix. In response to these uncertainties, we generated estimates of buried org-C and inorg-C within experimental and natural eastern oyster reefs (*Crassostrea virginica*). Subsequently, we also produced a preliminary, first-order estimate for the $CO_2$-related outcome of global shellfish habitat loss (oyster reefs, dense aggregations of mussels, etc.) resulting from destructive fishing practices, degraded water quality and shoreline development.

## 2. Methods

### (a) Carbon composition of oyster reefs

We quantified pools and rates of org-C and inorg-C burial within eastern oyster reefs (*C. virginica*) by sampling 19 constructed, experimental reefs and three natural reefs within or near the Rachel Carson National Estuarine Research Reserve (North Carolina; electronic supplementary material, figure S2). The 19 experimental reefs we sampled in the Rachel Carson Reserve were created in 1997 or 2000 (electronic supplementary material, table S1), and are representative of natural reef sizes in this region [22]. These reefs were constructed as $5 \times 3 \times 0.15$ m mounds of 'cultch' shell (electronic supplementary material, figure S3), and developed following natural patterns of oyster recruitment, growth and mortality [23]. Experimental reefs crossed landscapes and inundation regimes, located either on intertidal sandflats ($n = 7$), shallow subtidal sandflats ($n = 3$) or fringing the seaward edge of saltmarsh ($n = 9$), which expanded the generality of our results. To evaluate the representativeness of our experimental-reef data, we also cored one natural intertidal sandflat oyster reef and one natural saltmarsh-fringing oyster reef, as well as one 2.5 m thick relic oyster reef with its top buried 1 m below the sediment surface in the upper North River Estuary (approx. 8 km north of our experimental reefs in the Rachel Carson Reserve). Natural reefs were selected based on their proximity and rough morphological similarity to experimental reefs, and because companion studies provided information on the age of those specific natural reefs necessary for considering the capacity of reefs to support long-term carbon burial. Specifically, an articulated oyster from the base of each natural/relic reef facies was radiocarbon dated at Woods Hole Oceanographic Institution's mass spectrometry facility, and used to estimate the age of these three natural reefs at 45–263 cal yr BP, 0–245 cal yr BP and 4436–4147 cal yr BP, for the intertidal sandflat, saltmarsh-fringing and relic subtidal oyster reefs, respectively. Ages were calibrated to years before present (AD 1950 = 0 BP) at the 95% confidence interval using the CALIB 7.1 program [24].

During 2011, we sampled experimental and natural reefs using a combination of biological (quadrat counts for live oyster density on reefs constructed in 1997; $n = 10$; electronic supplementary material, table S1) and geological (vertical through-reef cores followed by shell and sediment analyses; all reefs; figures 1 and 2; electronic supplementary material, figure S4) methods, as well as three-dimensional laser scanning of experimental reefs to measure reef accretion. To quantify the carbon composition of reefs, we drove 10 cm diameter aluminium pipe vertically through the X–Y centre of each oyster reef using a gas-powered jack hammer. Cores sampled the entire reef structure (10–55 cm deep) and a few decimetres of the underlying substrate. Cores were sectioned continuously in 5 cm vertical increments. To control for carbon burial in the absence of oyster reefs, we examined the carbon composition of sediments beneath experimental reef/cultch material in each core, thus establishing a before–after comparison design. Within each core section, large shell material (more than 2 mm) was separated, washed to remove sediments or shell hash, dried, photographed (electronic supplementary material, figure S5)

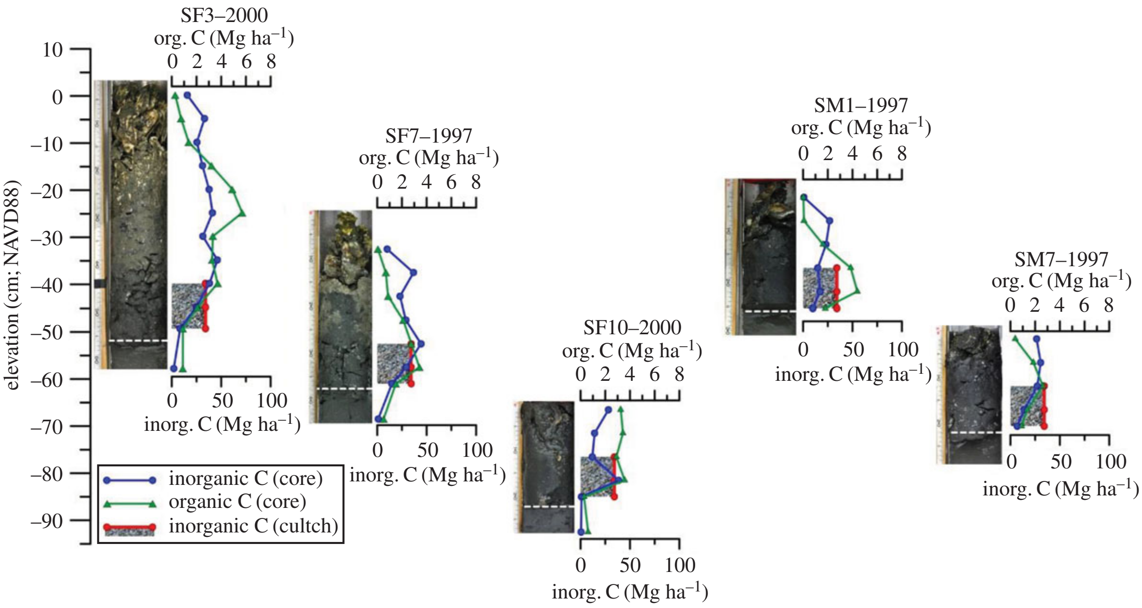


**Figure 1.** Carbon composition of restored sandflat and saltmarsh-fringing oyster reefs. Org-C (green points/lines) and inorg-C (blue points/lines) data were generated for each 5 cm core section via CHN analyses of sediments and shell weight measurements (with conversions to carbon weights). Five representative reefs are displayed (see electronic supplementary material, figure S4 for complete dataset). For each core photo–profile pair, the white-dashed line represents the base of the experimental reef. The hatched box (bounded in red data points/line) represents the inorg-C used in reef construction in the lowest 15 cm of each reef. Carbon data in cores were generally characterized by mid-reef maxima, reflecting the complex interstices within the taphonomically active zone, as well as dissolution (inorg-C) and lack of biofiltration (org-C) within the cultch shell near the bottom of the reefs, or below in the sandflat unit. Data within each core were vertically integrated to determine carbon burial rates over the lifetime of the reef. Core data are plotted with respect to their absolute vertical position (NAVD88). In labelling each core profile, 'SF' designated reefs constructed on sandflats, and the 'SM' designated reefs constructed adjacent to saltmarsh. The number immediately following the SF or SM designation identified the replicate number of each reef, and the last four digits note the year in which experimental reefs were established. (Online version in colour.)

and weighed. The remaining sediments and finer-grain shell hash were dried and weighed, and percentage $CaCO_3$ was determined using an HCl acid digestion. The combined weights of large shells and shell hash were converted to carbon weight based on shell being composed of approximately 11.1% inorganic carbon and less than 0.5% organic carbon [25]. Changes in inorganic carbon weights within reefs between construction (oyster shell cultch) and coring (new growth + cultch) were calculated by subtracting initial (1997 or 2000) from observed (2011) shell weights within each core section (electronic supplementary material, figure S5).

Remaining sediments were dried, ground, fumed with 1N HCl, and re-dried prior to induction in a Perkin Elmer CHN analyzer (Model 2400) to determine percentage organic carbon. Bulk-weight and percentage-carbon data of sediments were combined to quantify org-C in each core section. Measurements of org-C and inorg-C were vertically integrated to produce estimates of carbon in reefs. Before combining org-C and inorg-C data to determine whether reefs functioned as sources or sinks, the influence of total alkalinity on $CO_2$ partial pressures was accounted for by assuming 0.6 mol of $CO_2$ release for every 1 mol of carbon bound in shell [16]. These data, combined with explicit knowledge of the age of each reef, allowed determination of annual carbon burial rates.

With these data, we calculated the amount of inorganic carbon within each reef that would have contributed to the venting of $CO_2$ as: weight of shell (final − cultch weights) × 0.95 (fraction of inorganic material in shell [25]) × 0.111 (fraction of carbon, by weight, in $CaCO_3$ [25]) × 0.6 (to account for alkalinity of DIC in the ocean). Similarly, we calculated the amount of organic carbon within each reef that would have contributed to the removal of $CO_2$ as: weight of shell (final − cultch weights) × 0.0136 (fraction of organic material in shell [25]) × 0.36 (fraction of carbon, by weight, in organic material [25]) + Σ{weight of sediments in each core section × approximately 0.0134 (fraction of carbon in sediment, evaluated on a core-section-by-core-section basis)}. We then subtracted the organic carbon pool from the inorganic carbon pool to determine if reefs were sources (+) or sinks (−). Data were scaled to annual carbon burial/release rates based on the age of each reef on a per hectare basis.

To quantify vertical accretion rates of experimental reefs, digital elevation models (DEMs) of reefs and the surrounding seafloor (used to estimate vertical positions of reef bases; North American Vertical Datum of 1988; hereafter NAVD88) were created using a Riegl LMS-Z210ii terrestrial laser scanner (electronic supplementary material, figure S6). The Riegl system provided three-dimensional resolution of less than 1.5 cm that could be exploited to determine vertical accretion rates (m yr$^{-1}$) using an endpoint method (i.e. [height$^{2011}$ − height$^{\text{initial}}$]/[time]). Additionally, oyster densities were determined for the experimental reefs constructed in 1997 by collecting multiple, randomly placed 0.25 m$^2$ quadrat samples on reefs and enumerating all living oysters within each quadrat.

We used a series of regression and ANOVA analyses to explore the patterns and controls of carbon burial in oyster reefs. Regressions compared rates of org-C and inorg-C burial against one another, as well as in relation to reef-scale live-oyster density, vertical position of reefs relative to NAVD88, and reef accretion. Separate regression analyses were run for sandflat (intertidal + subtidal) and saltmarsh-fringing oyster reefs. In all regressions, we used a variant of the Akaike information criterion (AIC) to determine the model order that provided the best fit for the data (balancing model specificity and generality) where: $AIC = 2k + n[\ln(RSS/n)]$, and $k$ is the model order, $n$ is the number of observations, and RSS is the residual sum of squares between the observed and fitted data. In all instances except for trends in org-C, inorg-C burial, and $CO_2$-relevant carbon flux versus 2010 live oyster densities, a linear fit between variables was determined to be best. In all cases that employed linear fits, we tested whether the slope of data was significantly different from zero. We used ANOVA to consider the $CO_2$-related flux of carbon among reefs distributed across various landscape settings and aerial exposures. Data

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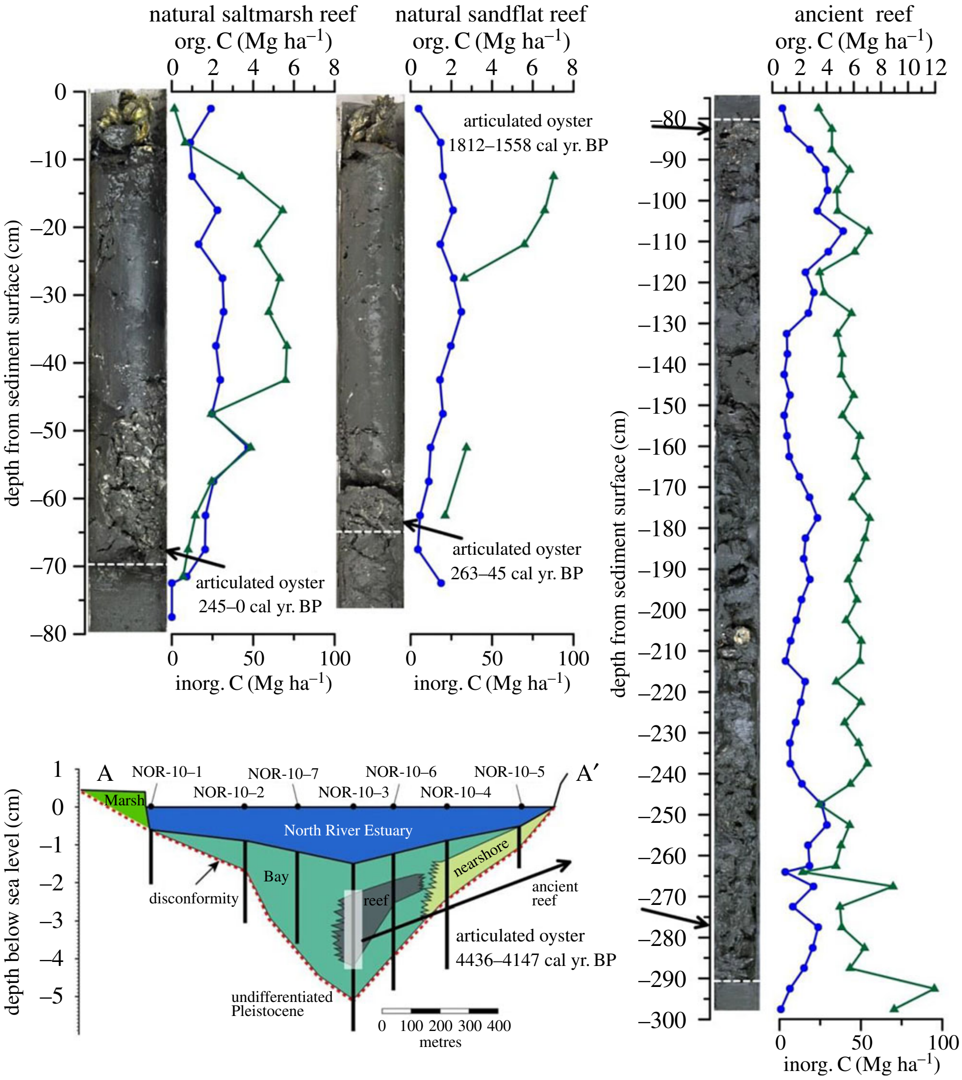


**Figure 2.** Carbon composition of natural saltmarsh-fringing, sandflat and subtidal relic oyster reefs. Org-C (green points/lines) and inorg-C (blue points/lines) data were generated for each 5 cm core section via CHN analyses of sediments and shell weight measurements (with conversions to carbon weights). For each core photo-profile pair, the white-dashed line represents the lower and upper (ancient reef) limits of reefs. Inset shows where the relic reef core was taken in the North River Estuary (A and A′ are included in electronic supplementary material, figure S2, which also shows the location of the two natural reefs). NOR-10-# labels across the inset identify the across-estuary location of additional cores collected to evaluate the distribution of reef material in the system. (Online version in colour.)

from all 19 experimental reefs were included in this ANOVA, with reefs grouped as intertidal sandflat, subtidal sandflat or intertidal saltmarsh-fringing oyster reefs. Data passed *F*-tests for homoscedasticity ($\alpha = 0.01$). Because a statistically significant difference in $CO_2$ flux was detected among reefs ($\alpha = 0.05$), we employed Fisher's *post hoc* test (insensitive to unequal sample sizes) to determine which specific group means differed.

### (b) $CO_2$-related effects of reef disturbance

We combined our data on the inorg-C and org-C stored in the top metre of natural oyster reefs with estimates of historical and extant shellfish reef cover to generate a first-order projection of changes in carbon buried in shellfish habitats following anthropogenic disturbance. While quantitative, site-specific data to constrain the global distribution of shellfish reefs (historic and present) are patchy, there are reliable estimates that estuarine environments cover 125 000 000 ha globally [26] and that within these coastal ecosystems, the cover of shellfish habitat has declined by 65–85% [8,9]. We extracted the data on estuary-by-estuary oyster cover (acreage) in these published shellfish-loss reports, and collected complementary data on the overall size of those same coastal systems to project that shellfish habitat cover within estuaries has declined from 5.1% to 1.9%, on average, presuming oyster loss rates are in line with other shellfish species. Based on the global footprint of estuaries, this corresponds to a loss of nearly 4 000 000 ha of shellfish habitat (i.e. reefs and aggregations). We combined this estimate with the mean org-C and inorg-C composition (i.e. carbon concentrations: g org-C $m^{-3}$ and g inorg-C $m^{-3}$) of the three natural and relic reefs we cored to project the amount of carbon disturbed by removing the top 1 m of shellfish habitat from these lost reefs (excluding the TAZ), as well as the carbon pools remaining in the top metre of approximately 2 375 000 ha of extant shellfish habitat (again, excluding the TAZ). We estimated carbon pools/losses in the top metre of reefs to make our results directly comparable to estimates in other blue carbon habitats [2], but acknowledge that in many areas, such as Chesapeake Bay, USA, several metres of reef material could have been removed due to historical fishing or mining [9].

## 3. Results

### (a) Carbon composition of oyster reefs

We found that decade-old oyster reefs had captured 0.3–2.7 Mg org-C $ha^{-1}\,yr^{-1}$ (figure 3*a*), which are burial rates

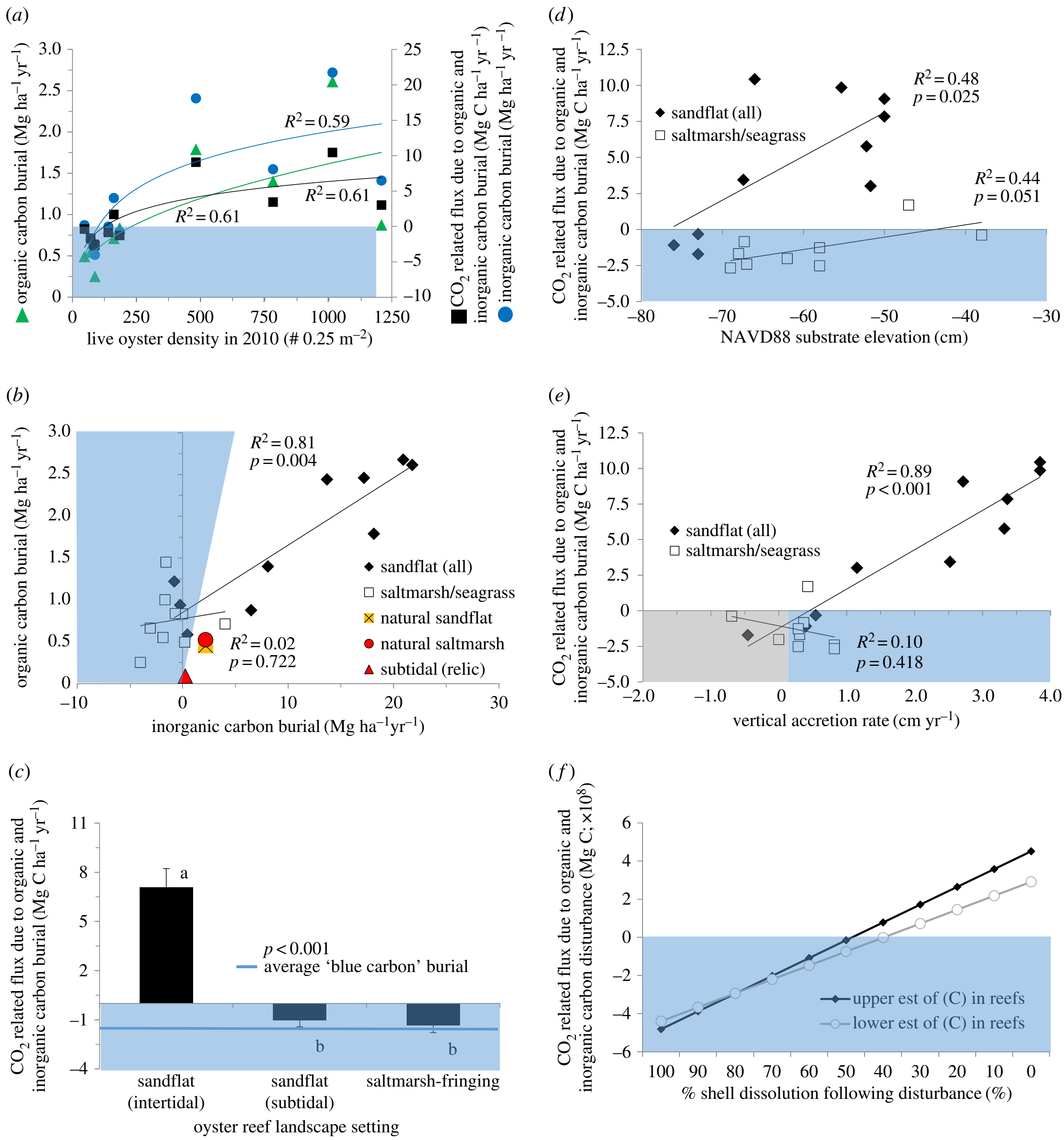


**Figure 3.** Effects of landscape setting, inundation regime and vertical accretion on org-C burial and inorg-C burial, and together, the climate-related carbon flux into or out of experimental oyster reefs. (*a*) Org-C and inorg-C burial rates scaled curvilinearly with live oyster density (density data were available for 10 of the 19 reefs included in this study). Following published estimates of 0.6 mol $CO_2$ production for every mol of $CaCO_3$ formation (accounting for total alkalinity effects), reefs that functioned as net carbon sinks fall within the blue-shaded region, typically at less than 200 live oysters 0.25 m$^{-2}$. (*b*) Org-C and Inorg-C burial were significantly, positively related to each other among sandflat oyster reefs, but not among saltmarsh-fringing oyster reefs. (*c*) Significant differences were observed in $CO_2$-related carbon release or burial among intertidal sandflat (95% CI: 1.0–13.1 Mg C ha$^{-1}$ yr$^{-1}$) and subtidal sandflat (95% CI: −2.4–0.3 Mg C ha$^{-1}$ yr$^{-1}$) or saltmarsh-fringing (95% CI: −4.1–1.4 Mg C ha$^{-1}$ yr$^{-1}$) oyster reefs (plotted as $\mu \pm 1$ s.e.), reflecting differences in live oyster densities. Among sandflat oyster reefs, the magnitude and direction of $CO_2$-related carbon flux was significantly affected by (*d*) the vertical position of the seafloor on which reefs were constructed and (*e*) vertical accretion rate, with thresholds apparent at −70 cm NAVD88 and approximately 1.0 cm yr$^{-1}$, respectively. For saltmarsh-fringing oyster reefs, those factors were not significant. Reefs that functioned as net carbon sinks fall within the blue- or grey-shaded regions (grey: accretion rates of reefs less than sea-level rise, and therefore these reefs are not likely to persist over decadal-centennial scales in the lower portions of estuaries [27]). (*f*) Net effect of shellfish reef disturbance on atmospheric $CO_2$ depends primarily on the fate of excavated shell material. Reef disturbance would contribute to $CO_2$ drawdown if more than 50% of excavated shell material were dissolved. (Online version in colour.)

equivalent to acknowledged blue carbon sinks (global mean: 1.23 Mg org-C ha$^{-1}$ yr$^{-1}$) [4,28]. Notably, org-C was almost completely absent in the cored sediments directly beneath reefs which served as our pre-reef controls (figure 1), indicating that reef presence was essential for long-term carbon burial in these sandy environments. Across all reefs, both org-C and inorg-C burial were related to live oyster density (via filtration, baffling and shell production) (figure 3*a*). Among sandflat reefs (intertidal + subtidal), org-C and inorg-C burial rates scaled together among ($R^2 = 0.81$; $p = 0.004$; figure 3*b*) and within ($R^2 = 0.35$; $p < 0.001$; figure 1; electronic supplementary material, figure S4) reefs, although this pattern was driven mainly by values observed within intertidal reefs (figure 3*b*). By weight, inorg-C (86% of total carbon) was approximately six times more abundant in intertidal sandflat reefs than org-C (14%). In contrast, org-C burial (68% of total carbon) was approximately double that of inorg-C (32%) within saltmarsh-fringing and subtidal oyster reefs, and there were weak relationships between org-C and inorg-C burial rates among reefs ($R^2 \leq 0.08$; $p \gg 0.05$; figure 3*b*; electronic supplementary material, figure S4). For subtidal sandflat (three out of three) and saltmarsh-fringing reefs (eight out of nine), coring revealed a net decrease in inorg-C weights as dissolution of cultch material slightly outpaced shell production and burial (initial: 102.8 Mg inorg-C ha$^{-1}$; figure 3*b*).

The role of oyster reefs as $CO_2$ sources or sinks was significantly (ANOVA: $p < 0.001$) affected by landscape setting (Fisher's *post hoc* test comparing intertidal sandflat and intertidal saltmarsh-fringing oyster reefs: $p < 0.001$) and inundation period (Fisher's *post hoc* test comparing intertidal sandflat and subtidal sandflat oyster reefs: $p < 0.001$). Using core data and literature-derived relationships between $CaCO_3$ formation (1 mol) and $CO_2$ production (0.6 mol) [16], we determined that intertidal sandflat oyster reefs were net sources of $CO_2$ ($7.1 \pm 1.2$ Mg C ha$^{-1}$ yr$^{-1}$), while subtidal sandflat reefs ($-1.0 \pm 0.4$ Mg C ha$^{-1}$ yr$^{-1}$) and saltmarsh-fringing oyster reefs ($-1.3 \pm 0.4$ Mg C ha$^{-1}$ yr$^{-1}$) were net carbon sinks (figure 3*c*). Subtidal sandflat and saltmarsh-fringing oyster reefs that functioned as carbon sinks were characterized by veneers of live oysters ($111 \pm 19$ oysters 0.25-m$^{-2}$) that contributed to the deposition of organic material without achieving long-term biosynthesis/burial of shell (figure 3*c*,*d*). Conversely, intertidal sandflat reefs experience lower levels of predation and bioerosion [27] and were characterized by tightly cemented clusters of live oysters ($874 \pm 159$ individuals 0.25-m$^{-2}$), resulting in preservation of shell material in the accreting reef matrix (figure 3*a*–*d*).

In vegetated estuarine habitats, vertical accretion rates (typically $\leq$1 mm yr$^{-1}$) scale positively with their carbon burial function [29], but this does not appear to be true for oyster reefs which are among the most rapidly accreting marine biogenic habitats [30]. Our laser scans (electronic supplementary material, figure S6) produced some of the first bioherm-scale measures of vertical accretion by oysters over decadal time scales, showing that the reefs that accreted most rapidly (maximum: 3.85 cm yr$^{-1}$) were also the largest $CO_2$ sources (figure 3*e*). In those reefs, shell material was the main constituent by weight of the accreting matrix (electronic supplementary material, figure S5). While all reefs we identified as $CO_2$ sources could accrete vertically more quickly than current sea-level rise (0.25–0.30 cm yr$^{-1}$), only 8 of 11 (73%) reefs functioning as carbon sinks appear capable of maintaining their position relative to rising sea levels based on projections for the century ahead (figure 3*e*).

Carbon pools and burial rates in natural reefs corroborated patterns documented in the decade-old experimental reefs we sampled. Notably, both org-C and inorg-C were present throughout cores of these natural reefs, dating back approximately 250 (intertidal sandflat and saltmarsh fringing) to approximately 4000 years (subtidal, relic) based on radiocarbon dating, confirming that long-term carbon storage is a property of shellfish reefs (figure 2). Down-core profiles of inorg-C within natural reefs (approx. 25 Mg C ha$^{-1}$ in each 5 cm core section) closely matched patterns from experimental reefs located on intertidal sandflats, but were approximately double the values recorded from experimental saltmarsh-fringing or subtidal reefs (figures 1 and 2). Regardless of landscape, org-C within natural reefs ranged between 2 and 6 Mg C ha$^{-1}$ across depths, on a par with experimental reefs that typically reached values of 4 Mg C ha$^{-1}$ (figures 1 and 2). Overall, org-C accounted for 21% of the carbon stock in natural reefs, and based on their respective ages (figure 2), all three natural reefs functioned as slight $CO_2$ sources across their entire lifetime (0.06–0.83 Mg C ha$^{-1}$ yr$^{-1}$; figure 3*b*).

## (b) $CO_2$-related effects of reef disturbance

Estuarine ecosystems span 125 000 000 ha of Earth's surface [26]. While shellfish formerly covered 5.1% of estuarine bottoms, this figure has declined to 1.9% following global habitat loss and degradation (a 3 989 000 ha reduction) [9]. Excluding the TAZ, we estimate that removing the top metre of four million ha of shellfish habitats mobilized $3.71 \times 10^8$ Mg org-C (95% confidence intervals (CI): $2.91–4.51 \times 10^8$ Mg C) and $1.39 \times 10^9$ Mg inorg-C (95% CI: $1.22–1.55 \times 10^9$ Mg C). Presuming that disturbed org-C is remineralized [2], the net effect of shellfish reef disturbance on atmospheric $CO_2$ depends primarily on the fate of excavated shell material. Were all excavated shell material to be dissolved in seawater, reef disturbance would actually contribute to $CO_2$ drawdown via the shifting of dissolved inorganic carbon pools away from carbonic acid and towards bicarbonate/carbonate ($-4.61 \times 10^8$ Mg C, or $-16.88 \times 10^8$ Mg $CO_2$ scrubbed from the atmosphere) (figure 3*f*). This is, however, a highly unlikely scenario [21,25]. Rather, excavated shell was probably either reburied in surrounding sediments or extracted and deposited terrestrially. Presuming 100% preservation of excavated shell, global reef disturbance may have led to upwards of $16.88 \times 10^8$ Mg $CO_2$ introduced into the atmosphere ($4.51 \times 10^8$ Mg C respired; figure 3*f*). We project that $2.2 \times 10^8$ Mg org-C (95% confidence intervals: $1.72–2.68 \times 10^8$ Mg C) and $8.25 \times 10^8$ Mg inorg-C (95% CI: $7.27–9.23 \times 10^8$ Mg C) remain in the top 1 m of extant shellfish reefs.

# 4. Discussion

In the century ahead, a major challenge for scientists will be to mechanistically describe the controls and consequences of rising greenhouse gas emissions. Like vegetated blue carbon sinks, oyster reefs can be persistent features of estuarine landscapes over millennial time scales, and thus provide a potential repository for long-term organic carbon storage. Major research efforts have characterized carbon pools and fluxes among coastal environments to support inclusion of blue carbon habitats in existing frameworks to combat climate change, such as Nationally Appropriate Mitigation Actions (http://unfccc.int/focus/mitigation/items/7172.php). However, no existing international climate mitigation initiatives, such as the Blue Carbon Initiative (http://thebluecarboninitiative.org), consider the role of shellfish reefs in burying carbon and enhancing carbon storage in adjacent habitats, nor are there standardized and agreed-upon methodologies for assessing how shellfish reefs influence carbon cycling [28].

Here, we provide an estimate of carbon stocks in Atlantic-coast oyster reefs, and have also developed sound and repeatable methodologies for assessing the net source–sink dynamics of shellfish reefs. This builds from initial work that explored the role of oyster reefs in processing org-C and inorg-C [17,18], and provides entirely new data on the rates and pools of carbon buried within these biogenic habitats. Our results reveal that a subset of restored reefs have functioned as net $CO_2$ sinks (i.e. saltmarsh fringing and shallow subtidal), which is particularly important in a restoration context for site selection to optimize reef services. Indeed, our data highlight the need to consider landscape context in the siting of future restoration projects to maximize the $CO_2$-scrubbing services of shellfish reefs. Conversely, our data highlight that $CO_2$-related climate mitigation is not a service that should be expected/promoted for intertidal reefs constructed over unstructured sandflats.

The carbon storage benefits of conserving or restoring intertidal shellfish reefs may extend beyond the footprint of the reefs themselves. Remarkably, nearly half of all the fringing-saltmarsh reefs constructed in the Rachel Carson Reserve have facilitated localized, seaward expansion of saltmarsh, a recognized blue carbon habitat (figure 4). This indirect blue carbon function of shellfish reefs, not observed at paired control sites (i.e. saltmarsh edges without constructed reefs monitored since 1997) [23], probably occurred because oyster reefs serve as natural breakwaters, dampening wave energy and increasing sediment deposition and stabilization. Ultimately, this appears to have led to the accretion of the surrounding seafloor to a depth suitable for saltmarsh plant (*Spartina alterniflora*) recruitment and growth [29,31]. Thus, the overall blue-carbon-related services of marsh-fringing oyster reefs are potentially conservative given that we did not account for reef-mediated expansion (i.e. facilitation) of this adjacent habitat that also promotes the rapid burial of carbon. This dynamic could be considered in efforts to restore coastal systems using a landscape-level approach, in which the synergies of functions among multiple, interacting habitats are acknowledged.

While carbon stocks in natural reefs provide confidence that our experimental reefs are valuable models, we acknowledge some important nuances that merit further investigation. For instance, all three natural reefs functioned as carbon sources as they accreted. While this should be expected for the natural sandflat and relic reef we sampled based on geomorphological similarities with our experimental reefs constructed on isolated mudflats, this was a surprising result for the natural fringing reef. We note that this natural fringing reef bordered a deep channel, was relatively large (20 m in seaward–landward width and 60 m in along shore width) and was connected to a relatively narrow saltmarsh (10 m in seaward–landward width). Therefore, this reef may have functioned more like an isolated reef, highlighting the context-dependency of carbon burial within reefs. Natural-reef data also suggest that the magnitude of $CO_2$ flux from restored, intertidal reefs on mudflats related to inorg-C burial must attenuate over time from the high values we observed. This would follow from the initial, rapid accretion of constructed reefs as they rose toward a growth ceiling defined by sea level [30], and subsequent slower accretion bounded by sea-level rise. Conversely, for those fringing reefs that were not accreting fast enough to keep pace with sea-level rise, their role in capturing more carbon would


**Figure 4.** Shellfish reefs facilitate expansion of other blue carbon habitats. (*a*) Representative oyster reef–saltmarsh interface soon after the reef was created. (*b*) Seaward expansion of saltmarsh (*S. alterniflora*) since construction, resulting from the accumulation of sediments within and around the oyster reef. (Online version in colour.)

eventually vanish, although those reefs would continue to play a valuable role as a repository of organic carbon, as well as a rampart to protect the carbon in landward marshes [32].

Although organic : inorganic carbon burial within reefs differs across landscapes, the net effect of habitat destruction for all reefs (whether they functioned as sources of sinks before disturbance) is probably $CO_2$ release over climate-relevant time scales since excavated organic material may be largely remineralized, while shell may experience continued preservation through reburial. Reburial is particularly likely for the unarticulated shells of disturbed reefs that are no longer defined by the vertical structure of living reefs that rise above the surrounding seafloor/sediments. As with vegetated blue carbon habitats, loss of shellfish reefs could result in the release of formerly dormant organic carbon pools back into the biosphere. Indeed, approximately 20% of current annual anthropogenic $CO_2$ release is due to habitat modification and destruction [28]. In the broader context of global carbon emissions (7.2–10 billion Mg C $yr^{-1}$) [4], the anthropogenic disturbance of shellfish habitat has contributed a comparatively small yet significant amount (approx. 400 million Mg C from approx. 1700 to present). This estimate presumes, conservatively, the loss of only the top 1 m of shellfish habitat, although in some regions such as Chesapeake Bay, several metres of reef material were excavated [13]. However, existing or currently proposed legal protection preventing further disturbance of shellfish reefs is extremely limited and typically localized (e.g. no harvest shellfish sanctuaries) relative to the protections provided to vegetated blue carbon habitats. The potential economic benefits of carbon storage in undisturbed shellfish reefs could be included with other ecosystem services in cost–benefit analyses conducted as part of coastal resource management programmes [10].

While there is mounting interest in the role of coastal and oceanic environments in mitigating anthropogenic climate change by inducing long-term (i.e. millennial) burial of carbon, it is crucial to recognize that global $CO_2$ emissions challenge ecosystem integrity in every environment on Earth and the carbon burial services of blue carbon habitats are likely to evolve as climate changes. Marine communities are already responding to anthropogenic temperature increases (approx. 0.7 C globally over the last century) via altered primary production or trophic-transfer rates, changes in phenology and poleward distribution shifts [33]. As oceans absorb atmospheric $CO_2$, carbonic acid formation lowers marine pH and may impact the fitness of calcifying organisms [20,34]. With increasing urgency, data are also needed to explore how climate-change syndromes (e.g. sea-level rise, elevated heterotrophic metabolism in response to temperature rise, saltwater intrusion, increased storms/sedimentation, acidification) will impact the ability of remaining shellfish reefs to mitigate the rate and consequences of anthropogenic $CO_2$ increases.

Our data represent a first effort to constrain the climate-related services shellfish reefs may provide via carbon burial, and support global efforts to document missing $CO_2$ sources and sinks. As more reefs are sampled across gradients in depth, salinity, latitude, productivity, shellfish species, hydrodynamic regime, reef-associated community composition (predation and bioerosion intensity) and reef size, a more complete understanding of shellfish reef carbon dynamics should emerge. Additionally, future work should evaluate: (i) carbon metabolism beneath the TAZ of shellfish reefs; (ii) how much carbon being deposited within shellfish reefs is already recalcitrant; and (iii) the long-term, climate-related effects of decreasing total dissolved inorganic carbon concentrations via shell burial [35]. While researchers pursue these questions, our data reveal that natural and restored oyster reefs have already demonstrated the potential to bury organic carbon at rates similar to mangrove, salt-marsh and seagrass habitats. For the natural reefs we sampled, and the restored reefs on exposed sandflats, this benefit is offset by the simultaneous burial of inorganic carbon that results in the net venting of $CO_2$ as these reefs grow. Regardless of how reefs function as carbon sources and sinks, however, disturbance of all these reefs probably results in increased atmospheric $CO_2$. Thus, carbon sequestration and $CO_2$ release should be considered in concert with a host of other potential ecosystem services to properly evaluate the incentives for shellfish reef conservation.

Data accessibility. All raw data and calculations available at Dryad Digital Repository (http://dx.doi.org/10.5061/dryad.7nd95).

Authors' contributions. F.J.F., A.B.R., J.H.G. and M.F.P. conceived the experiments, while R.K.G., N.L.L., C.H.P. and J.T.R. provided design support. F.J.F., A.B.R., J.H.G. and J.T.R. performed the field experiments. F.J.F., A.B.R., R.K.G., M.F.P., and J.T.R. analysed the data and created the figures. F.J.F. drafted the manuscript and the other authors provided editorial advice.

Competing interests. We declare no competing interests.

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Hart Island Zoom today 5/5/21

Unfortunately, I was kicked out of the zoom call just as I was about to testify and ask questions. I was on the call for about 2 hours listening to all the officials testify, while patiently waiting my turn.

My concern for the indigent deceased is heartfelt and for their relatives as well. It is very unfortunate that the living relatives must go through a cumbersome process to be allowed to visit the departed. Many of these people are undocumented and do not have valid identification or other documents to be allowed to visit their deceased family members. They do not have access to bank statements or proof of address as they are undocumented and fear being deported.

I can't believe that NYC currently has over 700 bodies sitting in a temporary morgue in a storage facility. This is so disrespectful of the dead. I feel so bad for their relatives who can't afford a private burial and have to wait months for their loved one to be buried.

Hart Island should be treated as a solemn place for peace and comfort to those living. This discussion today made me think of a new "Disneyland" being proposed for this sacred burial ground. 52 million dollars will be spent knocking down some deteriorating structures in this economy. I agree it needs to be cleaned up and made safe for visitors but this dollar amount seems exorbitant. This place should not be a museum or a destination vacation spot. It should remain a public cemetery with some restrooms and a place to wait for the next ferry back. Perhaps a small nondenominational sanctuary for relatives to collect their thoughts could be included in this $52 million?

My other concern as a resident of City Island is how this ferry service will impact on the already overly trafficked community in which I live. As you may or may not be aware City Island is a small island located in the northeast Bronx directly south of Westchester County. City island is about 1.5 miles long and about .5 miles in diameter at the widest points. There are approximately 4000 residents and there is only one way in and one way out. During the warmer months (from Mother's Day through Labor Day) this island becomes a traffic nightmare, especially on the weekends. My concern is twofold. I am concerned about the safety and security (as there is no ongoing police presence nor emergency services present). The Bronx is the only borough without its own full time harbor patrol. There has been no guarantee of traffic agents to assist with the already overburdened traffic on the weekends.

My suggestion to help alleviate traffic and lack of parking here for ferry riders would be to create a ferry stop at nearby Orchard Beach. There is ample parking there that is free most of the year and could also be free to ferry riders. There are buses that go directly from the Pelham Bay #6 subway station to Orchard Beach. There are also buses along Pelham Parkway that are accessible from the #2, 4, 5 subway lines that go to Orchard Beach as well.

I think a better idea that will solve traffic and parking issues would be to move the ferry to Orchard Beach from its current location on City Island.

Respectfully,

Stuart Sorell

City Island resident

Sent from my iPhone