
RUNNING TIDE
The Global Ocean Health Company

Shellfish Ecosystem Services (Nitrogen Removal and Filtration) As Case Study for the Reykjavik Protocol Environmental Credit Generation Architecture

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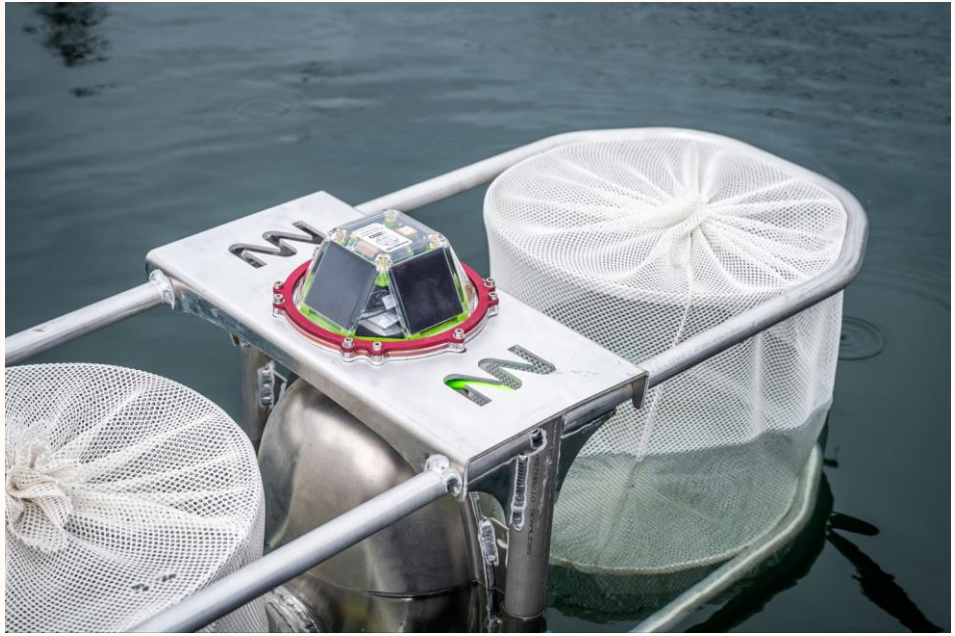
Providence, Rhode Island

RUNNING TIDE

- Global Ocean Health Company
- Design, implement, and quantify nature-based interventions to remove carbon, restore marine ecosystems, and revitalize coastal communities
- Multidisciplinary team of scientists, engineers, and maritime operators
- Headquarters Portland Maine, Iceland office, remote workforce



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akorn ENVIRONMENTAL CONSULTING, LLC

- Expert conservationists at nexus of science, policy, and outreach to benefit planet, wildlife, and people
- Responsibly managing, restoring, protecting natural resources including restorative aquaculture
- National footprint with Silver Spring, Maryland office

Today’s talk

Oyster ecosystem services quantified:
- Broad Cove, Casco Bay
  - Nitrogen removal
  - Water filtration

Reykjavik Protocol - Environmental credits
- Parallels to Chesapeake Bay nutrient credit trading program

(All graphics by akorn environmental using Pixlr AI Image Generator)

Shellfish Ecosystem Services

Benefits to people

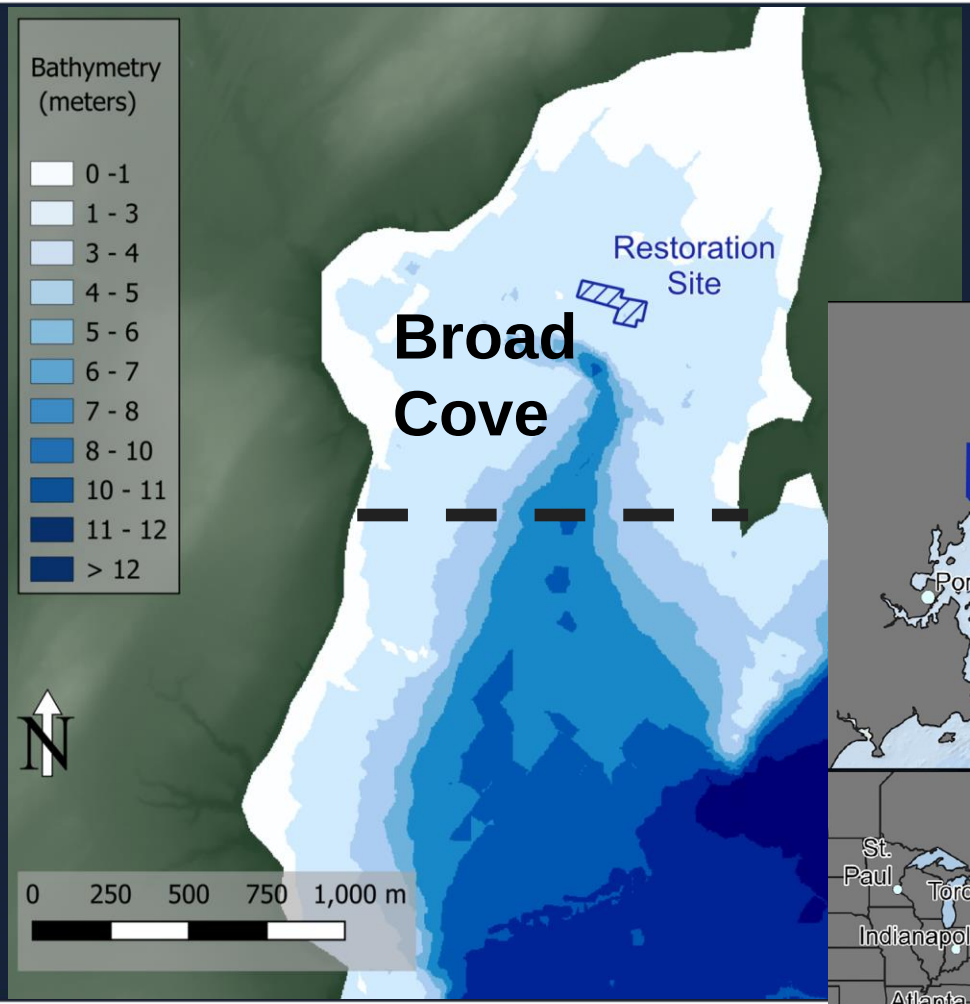
Nutrient cycling and water filtration

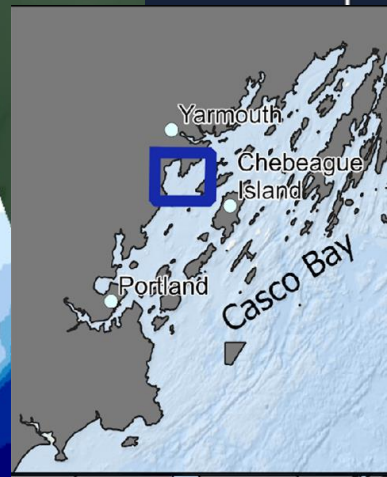
Provisioning, **Regulating**, Supporting, Cultural

Broad Cove
Casco Bay, Maine

Oyster restoration project (non-bioextractive)

- 500,000 planted Running Tide oysters
- Eastern oyster, diploid *Crassostrea virginica*
- On 4-acre lease: <1% area of cove





Goals of calculations

For **25-month project period**, calculate:

- **Nitrogen removed** from water column
- **Water filtration potential**

Use “conservative” empirical relations from most-local available measurements, and best-vetted literature results, to **demonstrate concepts**

Track contributions by:

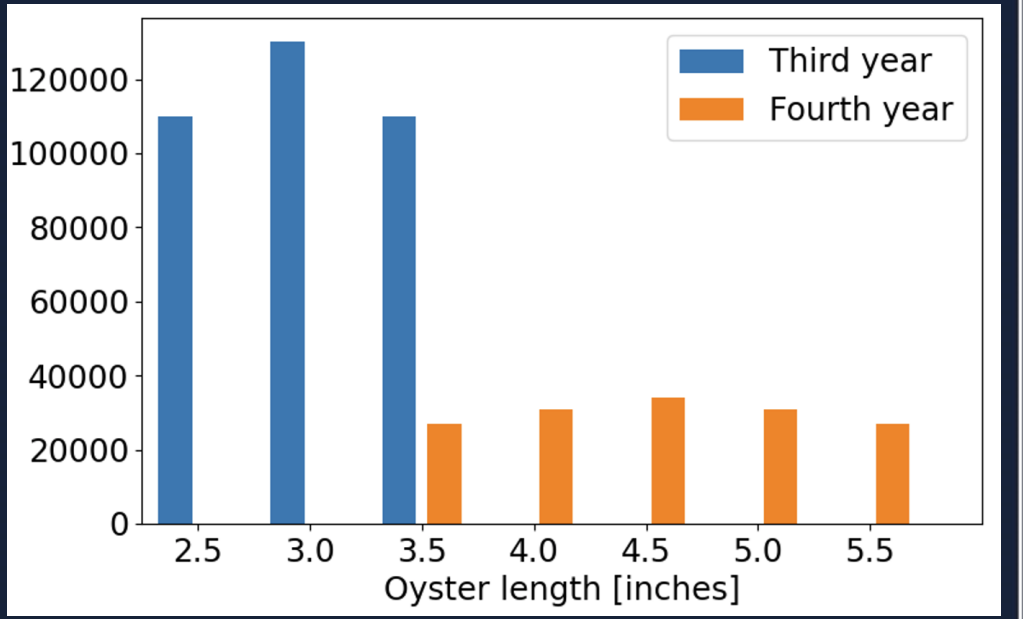
- **Each cohort** (same year class and initial size)
- **Each size range** (across all cohorts)

Initial oyster characteristics: Sep 1, 2023

500,000 total, two main groups:

- 350,000 third-year, 2.5-3.5”
- 150,000 fourth-year, 3.5-5.5”

Number of oysters



(Two cohorts with same 3.5” initial size but different year classes – third and fourth years)

Calculation inputs

Growth rate:
from Running Tide experience

Dry tissue weight and shell weight vs length:
from Grizzle et al 2017

Percent nitrogen by weight, in tissue and shell:
from Bigelow Labs measurements of Running Tide oysters
(consistent with Reitsma et al., 2017)

Potential filtration rate as function of dry tissue weight and temperature:
from zu Ermgassen et al., 2017

Methods considerations

Nitrogen removal

- Variability and uncertainties
  - Largest contributions
    - Dry tissue & shell weight as fcn of length
    - Unknown mortality rate/events
  - Smaller – percent N in tissue/shell
- Ground-truthing
  - Accurate field data on counts and sizes
  - Main constraint is frequency of sampling

Water filtration

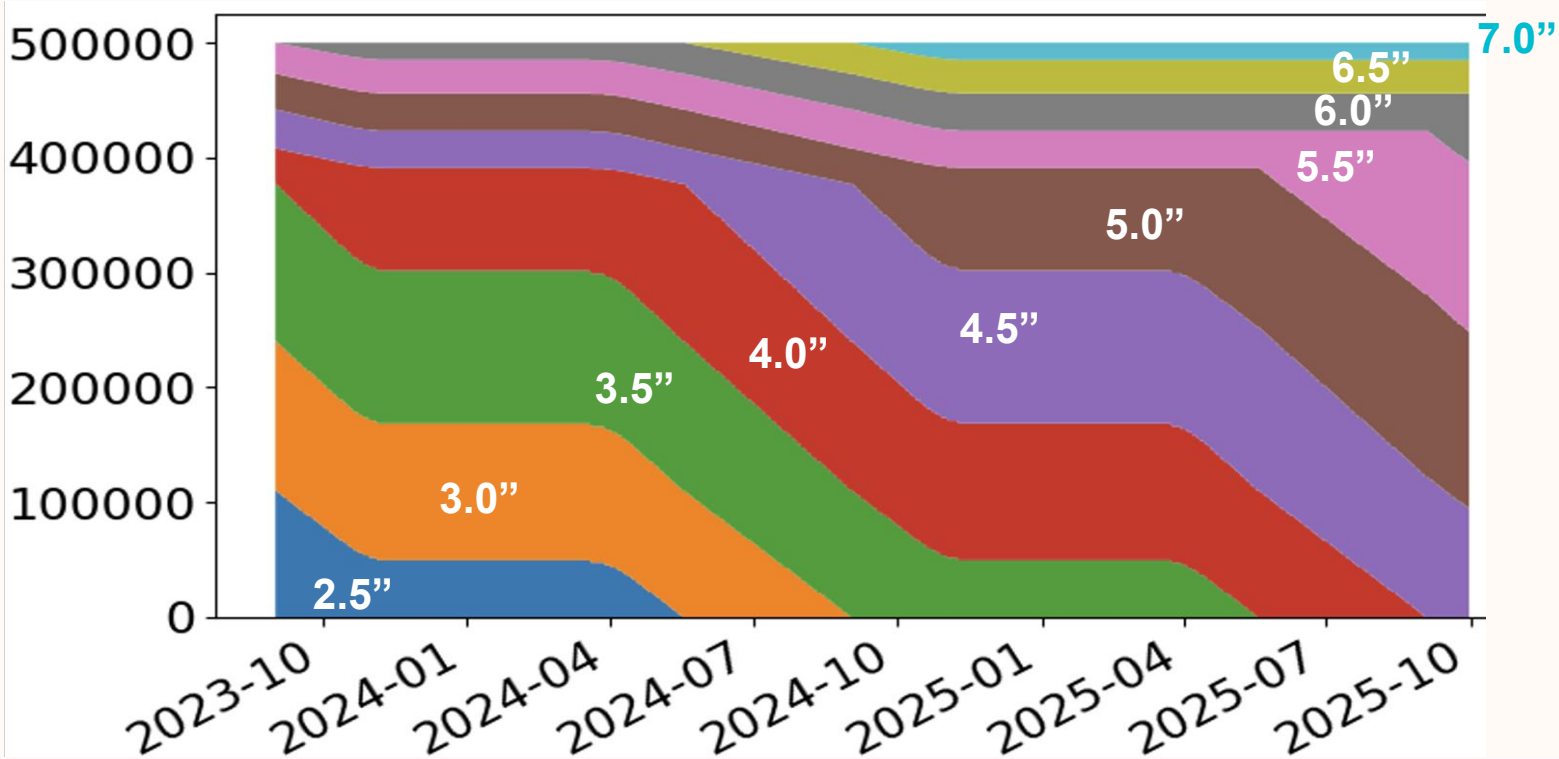
- Variability and uncertainties
  - Largest contribution unknown extent of re-filtration
    - Controlled by flow conditions
- Ground-truthing
  - Generally requires custom field study

Generalizable

- Has also been applied to Atlantic Surf Clams in upweller

Oyster growth results

Number oysters (all cohorts)
by length range



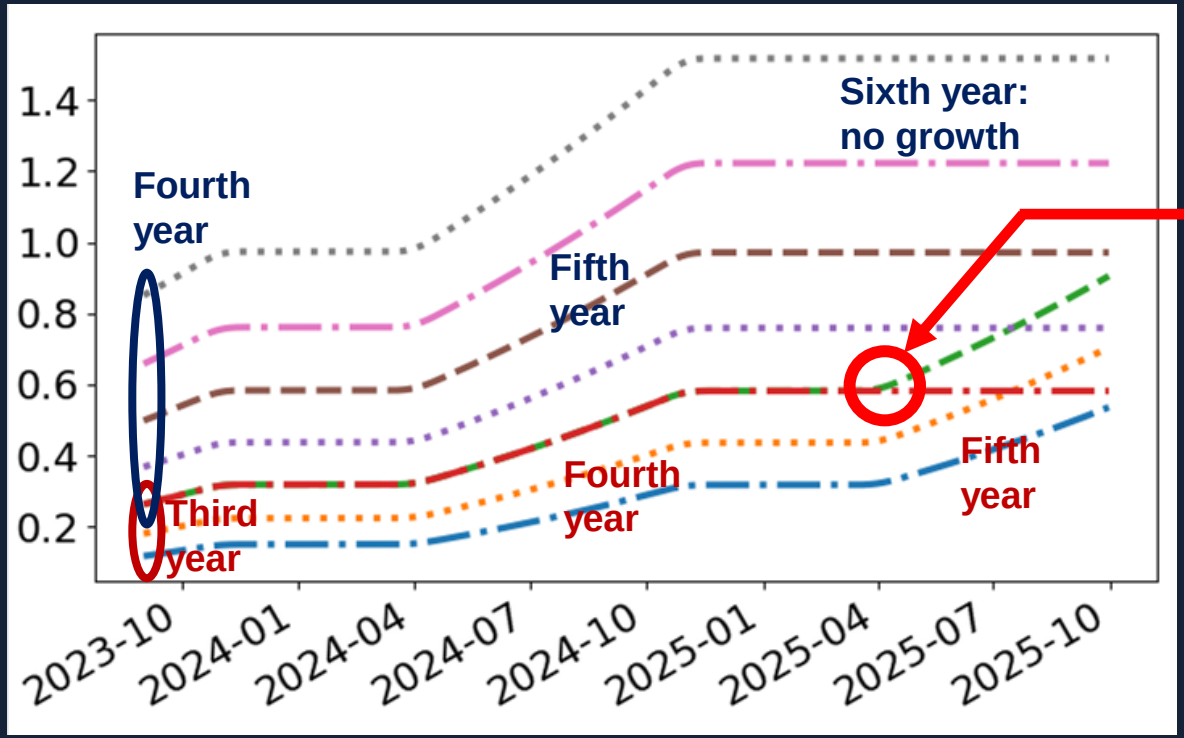
Nitrogen Results: **Individual oyster**

Calculations flow:

Length (2.5-5.5”) → Dry tissue weight (0.5-5g) → N in tissue (0.03-0.4g)

“ “ → Shell weight (25-140g) → N in shell (0.1-0.45g)

Nitrogen (total tissue and shell) [g]



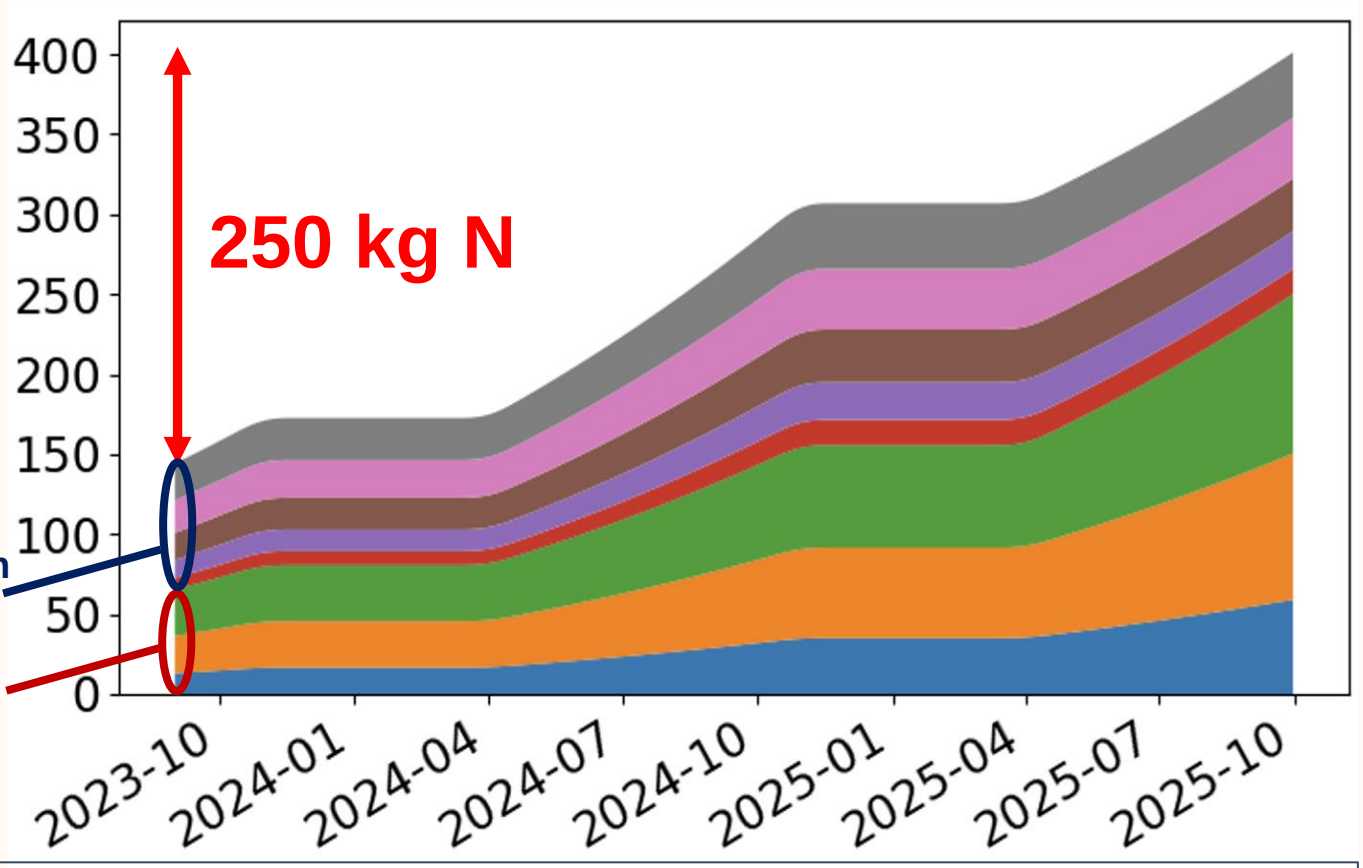
Independently track cohorts with same initial size but different year class

About 50/50 N in tissue and shell (for most sizes)

Nitrogen Results: All Oysters

by cohort

Nitrogen (total tissue and shell) [kg]

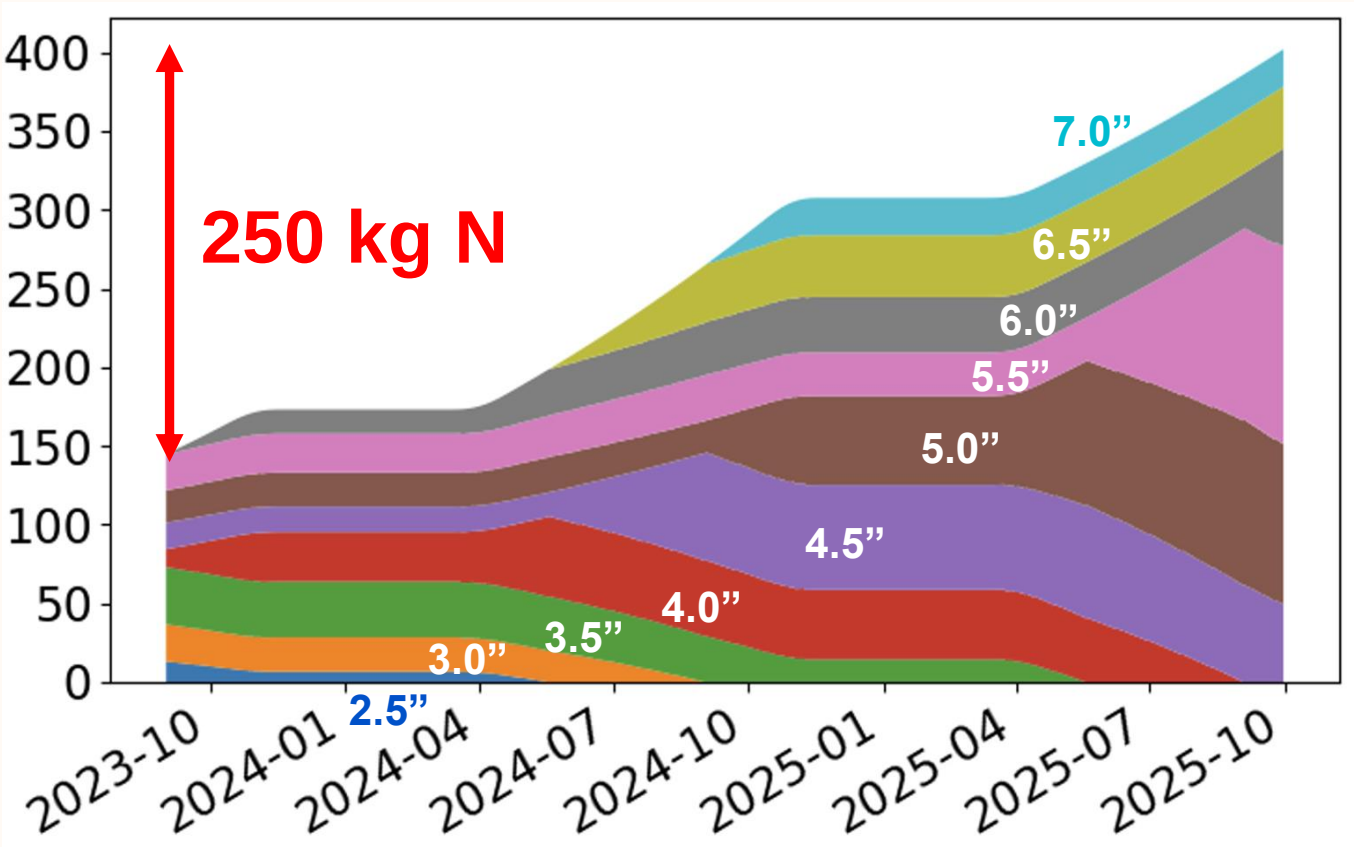


500,000 oysters remove ~250 kg N from water column over 25 months

Nitrogen Results: All Oysters

Nitrogen (total tissue and shell) [kg]

by size



500,000 oysters remove ~250 kg N from water column over 25 months

How much nitrogen is that?

250 kg
= 441 lbs
= 110 bags
fertilizer (40lb)

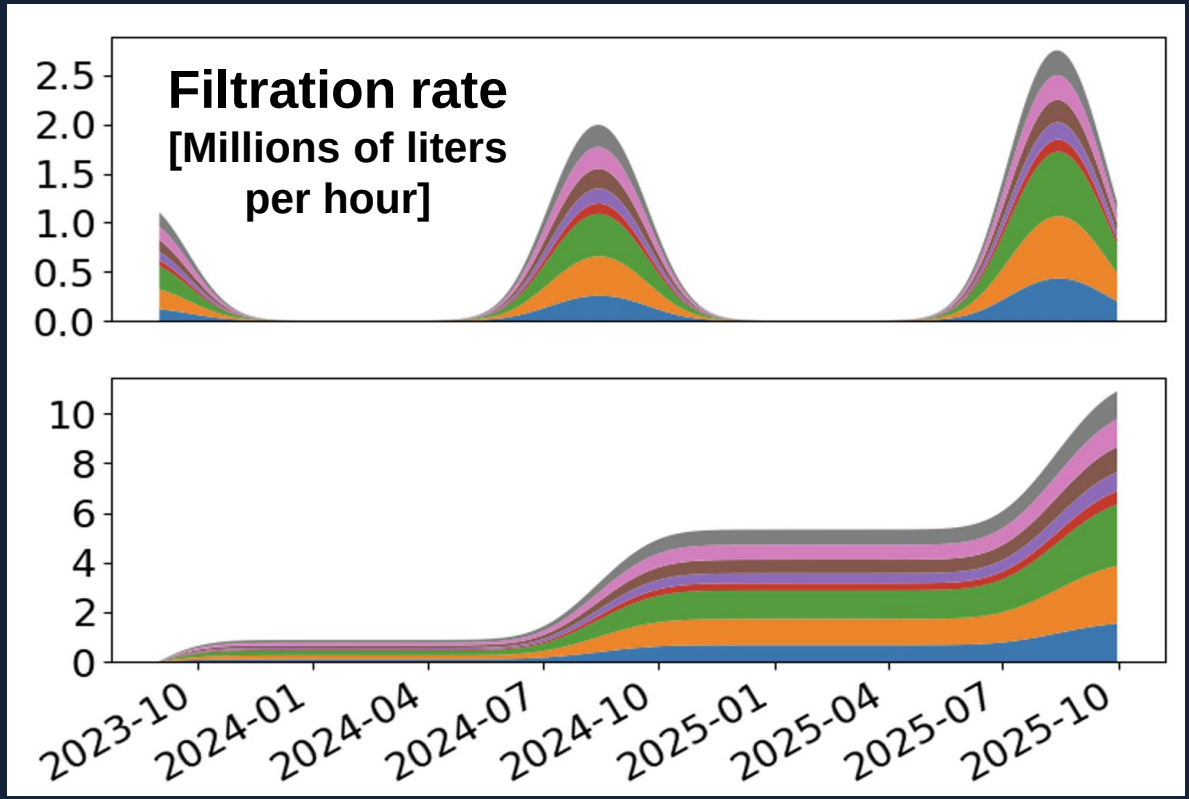
Oyster nitrogen removal
- 250 kg over 25 months
- Annualized rate **120 kg/year**

Broad Cove
- Long-term mean water column total nitrogen concentration ~0.2 mg/L (Running Tide data)
- Estimated volume 4.3 billion liters
- Standing stock water column nitrogen **approx. 860 kg**

500,000 oysters, on <1% area of Broad Cove seafloor, can:
remove 14% of cove water column nitrogen in a year

Water Filtration Results: All oysters cumulatively

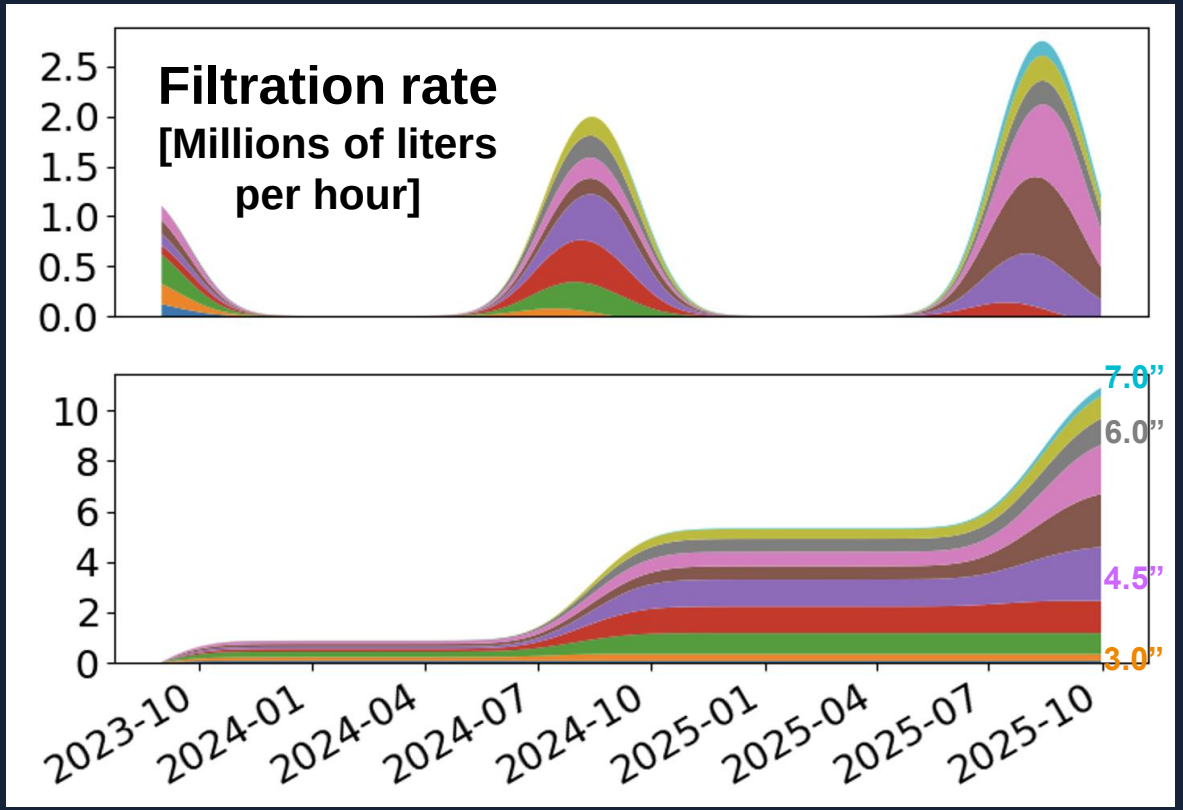
by cohort



500,000 oysters filter up to ~11 billion liters over 25 months

Water Filtration Results: All oysters cumulatively

by size

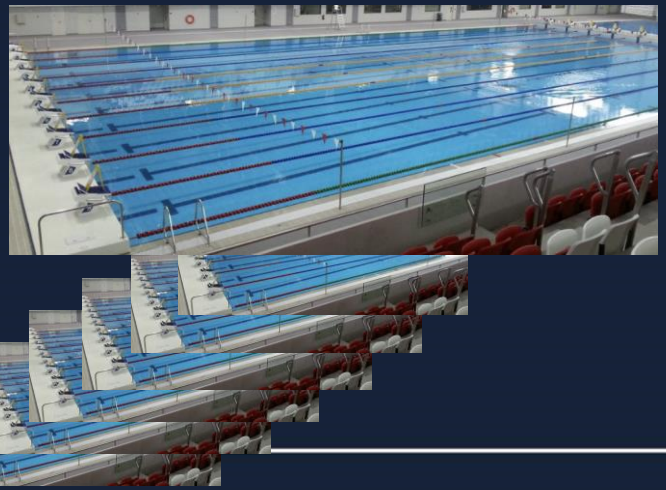


Volume filtered
[Billions of liters]

500,000 oysters filter up to ~11 billion liters over 25 months

How much filtration is that?

11 billion liters
= 2.9 billion gallons
= 4400 Olympic swimming pools



Oyster filtration
- 11 billion liters over 25 months
- Annualized rate **5.3 billion liters/year**

Broad Cove
- Strongly tidal, residence time on the order of days
- Estimated volume **4.3 billion liters**

500,000 oysters, on <1% area of Broad Cove seafloor, can:
filter more than its volume in a year

Summary:
Broad Cove Oysters

Ecosystem services of 500,000 oysters

- 350,000 third-year, 2.5” – 3.5”
- 150,000 fourth-year, 3.5” – 5.5”

Calculations

- Based on empirical relations using most-local available measurements
- Track cohorts (same age & initial size)
- Also track by size range

Over 25 month period

- Remove ~250 kg N from water column
  - Annually: ~120 kg N
    - ~14% nitrogen standing stock of cove
- Potentially filter ~11 billion liters
  - Annually: ~5.3 billion liters
    - More than cove volume

Example of interactive dashboard for client

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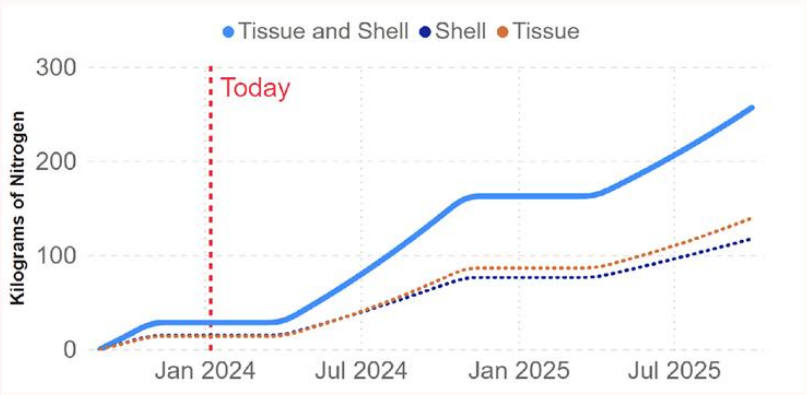
Search reports

SeaTrees: Broad Cove Oyster Restoration in Casco Bay, Maine, USA

Project Overview | **Oyster Nitrogen Removal** | Oyster Water Filtration | Biodiversity: Underwater Images | Biodiversity: eDNA | Continuous Water Quality Monitoring | Gallery

Nitrogen removed by 500,000 Running Tide oysters in Broad Cove since Sep 1, '23 as of Jan 8, '24 (today)

kilograms	=	pounds	=	50 lb bags fertilizer
28.4		62.6		12.5



Tissue and shell

Shell

Tissue

Last updated: Jan 8, '24

Next update: Jan 9, '24

Update cycle: Daily

Methods

On Sep 1, 2023, Running Tide oysters planted at the site numbered about 500,000. There were two main groups: about 350,000 oysters with 2.5" to 3.5" lengths, in their third growth year; and about 150,000 oysters with 3.5" to 5.5" lengths, in their fourth growth year. Running Tide analyses of nitrogen content in these oysters were used to calculate the nitrogen in all the oysters, collectively, as of that date.

Nitrogen removed from the water column by oysters, displayed here, is due to their growth since the beginning of the project. The growing season in this region is from the start of April to

Web-based, privately shared data portal

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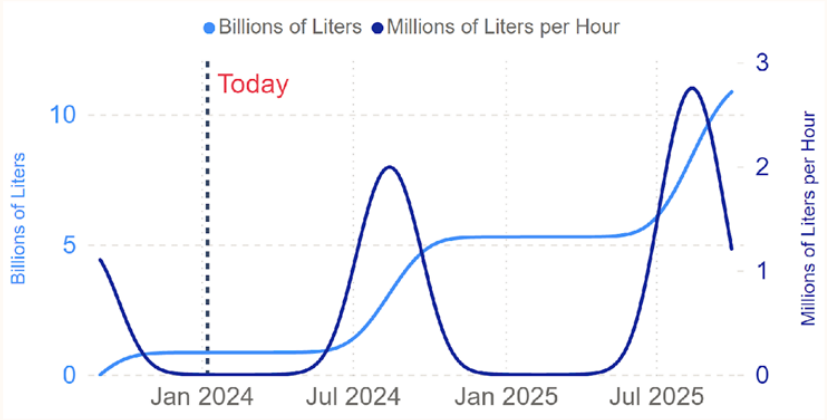
Water filtered by 500,000 Running Tide oysters in Broad Cove since Sep 1, '23 as of Jan 8, '24 (today)

Billions of Liters	=	Billions of Gallons	=	Olympic swimming pools
0.85		0.23		340.80



Credit: Chesapeake Bay Foundation

Last updated: Jan 8, '24

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Methods

Filtration rates of individual oysters are typically in the range of about 1-2 liters per hour (6-12 gallons per day) and can reach as high as 8 liters per hour (50 gallons per day) for short periods, depending on the environment and size of the oyster. Filtration varies throughout the day depending on the amount of food particles in the water, the water flow conditions, and other factors. Oysters enter a state of dormancy when temperatures drop below a threshold temperature outside of the growing season of April through October. The long-term average rate of filtration increases with water

www.reykjavik-protocol.com

REYKJAVIK PROTOCOL

www.reykjavik-protocol.com

What is it?

- Operational framework and process flow for environmental credit generation
- Roadmap to responsibly go from initial project design to credit sales, including roles of necessary third parties
- Supplier-led: nature-deployed environmental credit companies (to date, mainly carbon and biodiversity)

Aims:

- Solve structural issues in how credits are brought to market
- Identify and mitigate risks and uncertainties, conflicts of interest or perverse incentives

REYKJAVIK PROTOCOL

What is it?

www.reykjavik-protocol.com

Currently at 60+ signatories and counting

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Reykjavik Protocol

PRINCIPLES

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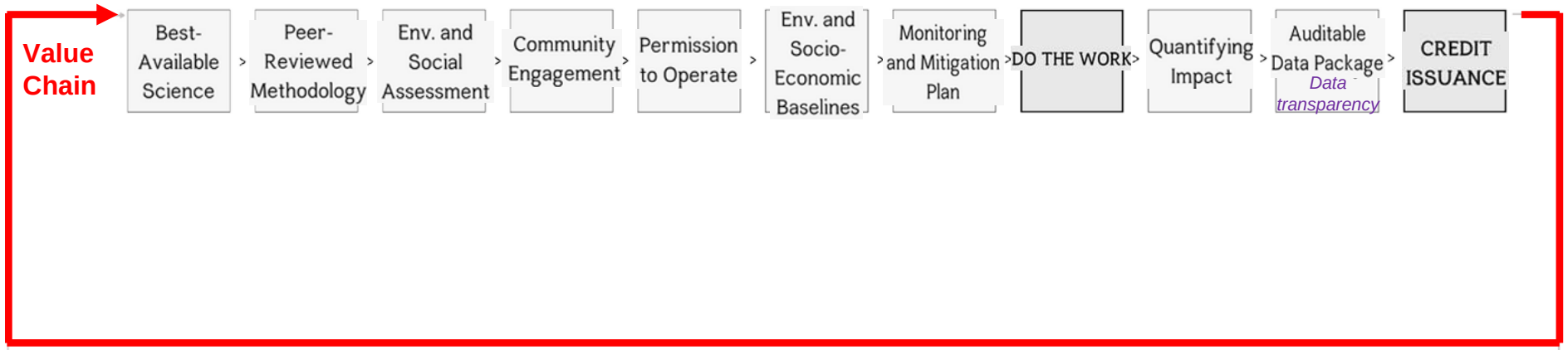
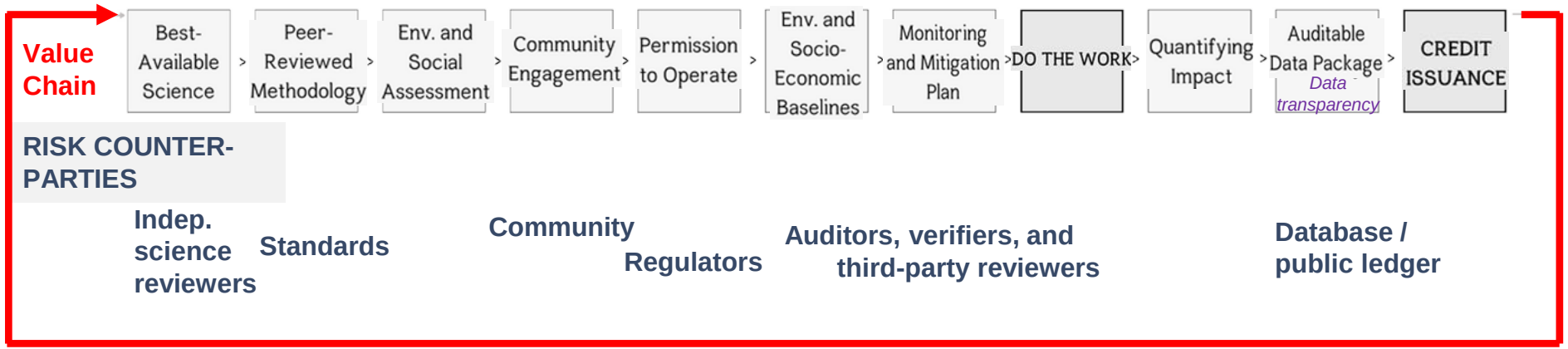


Reykjavik Protocol

PRINCIPLES



Reykjavik Protocol

PRINCIPLES

Parallels with Chesapeake Bay Nutrient Credit Trading Program (e.g., Weber et al. 2018)

Oyster BMP Expert Panel	*(same) Others?*	*Watershed Associations*	*State env. regulators*	*Oyster BMP Expert Panel (measurement protocol) Others?*	*VA DEQ NPS Nutrient Credit Registry RIBITS*

Summary and conclusions

- **Demonstrated oyster nitrogen removal and filtration calculations**
  - Method based on most-local available empirical data
  - Tracks cohorts and size ranges
  - Has also been applied to Atlantic surf clams
  - Web-based interactive data portal privately shared to client
- **Broad Cove, Casco Bay, Maine: 500,000 oysters initially 2.5-5.5”**
  - 4-acre lease occupying <1% cove seafloor
  - Annual nitrogen removal ~120 kg, ~14% of cove water column nitrogen
  - Annual filtration potential ~5.3 billion liters, more than total volume of cove
- **Introduced Reykjavik Protocol**
  - Environmental credit generation architecture
  - Identified parallels with existing program (Chesapeake Bay nutrient trading)
  - Potential role in broader application of shellfish ecosystem services credits

Questions? dan.codiga@runningtide.com

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