Informing sustainable marine environmental policy through understanding saltmarsh vegetation - nutrient dynamics

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Marine Evidence Conference
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UK Centre for Ecology & Hydrology

THANKS TO…

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NCEA Natural Capital and Ecosystem Assessment

Thriving Nature for people and planet — Natural England

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Jo Preston
Andy VanDerSchatte Olivier

Cefas

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University of Plymouth

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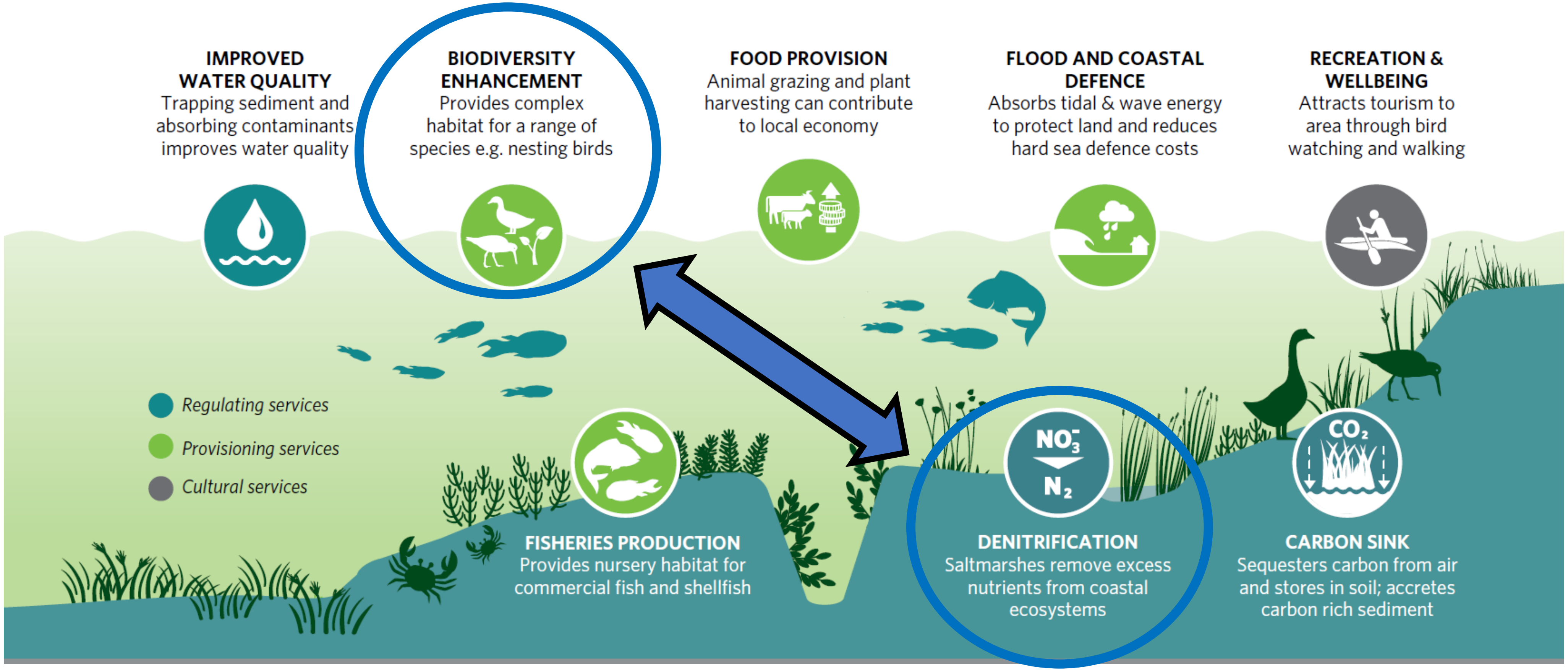
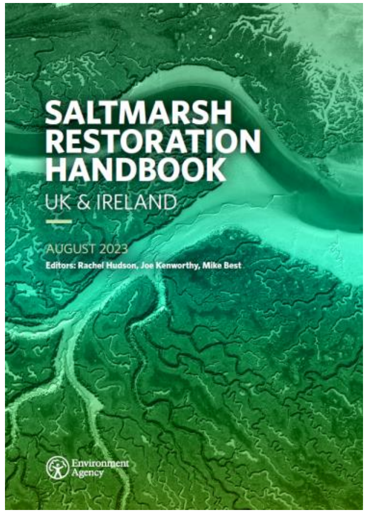
THE IMPORTANCE OF SALTMARSH…

Multiple demands…





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STAKEHOLDERS

…means multiple interests and policy drivers

Environment Agency

Better places for people and wildlife ->
Sustainable Development
Ecosystem Services Provided?

Thriving Nature for people and planet — Natural England

Nutrients -> Saltmarsh integrity
Favourable Conservation Status?

HM Government

A Green Future: Our 25 Year Plan to Improve the Environment

Convention on Biological Diversity

Global Biodiversity Framework

UN environment programme

Protect 30% of the Earth's coastal system by 2030

13 CLIMATE ACTION

14 LIFE BELOW WATER

15 LIFE ON LAND

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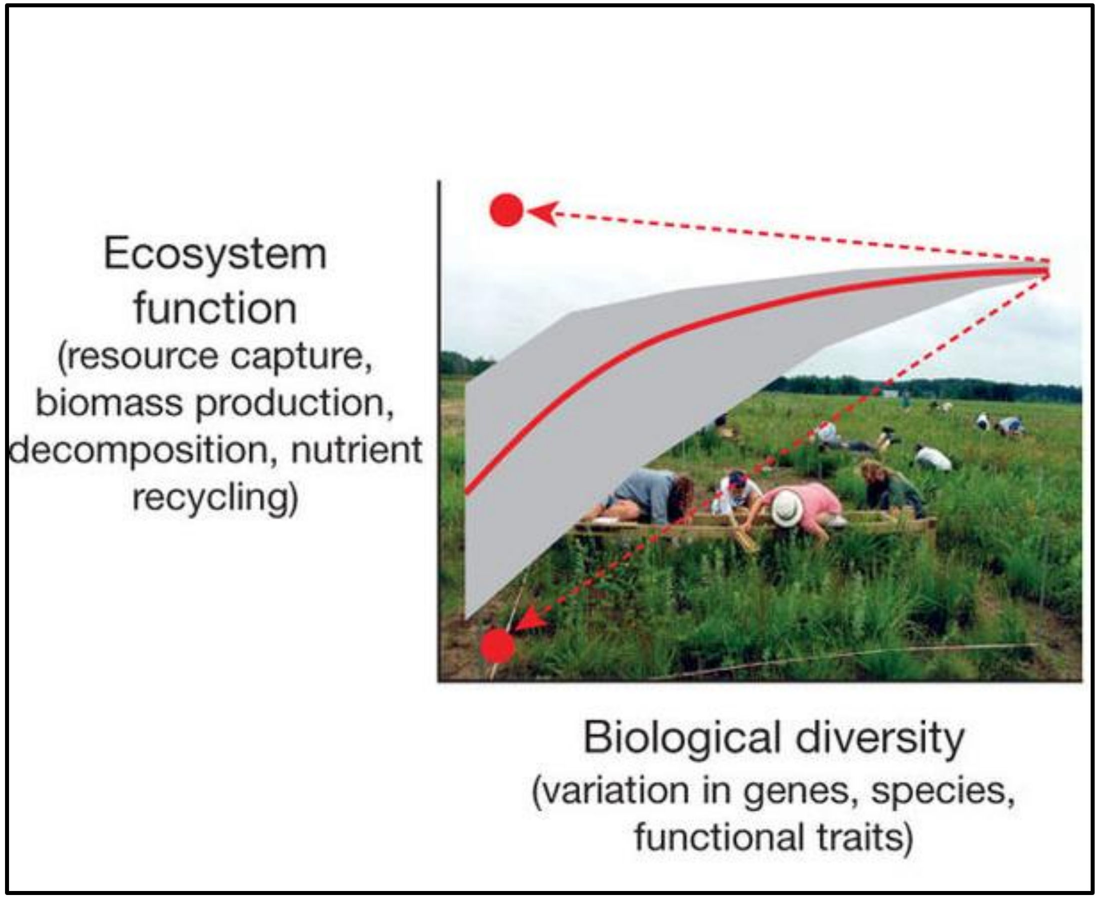
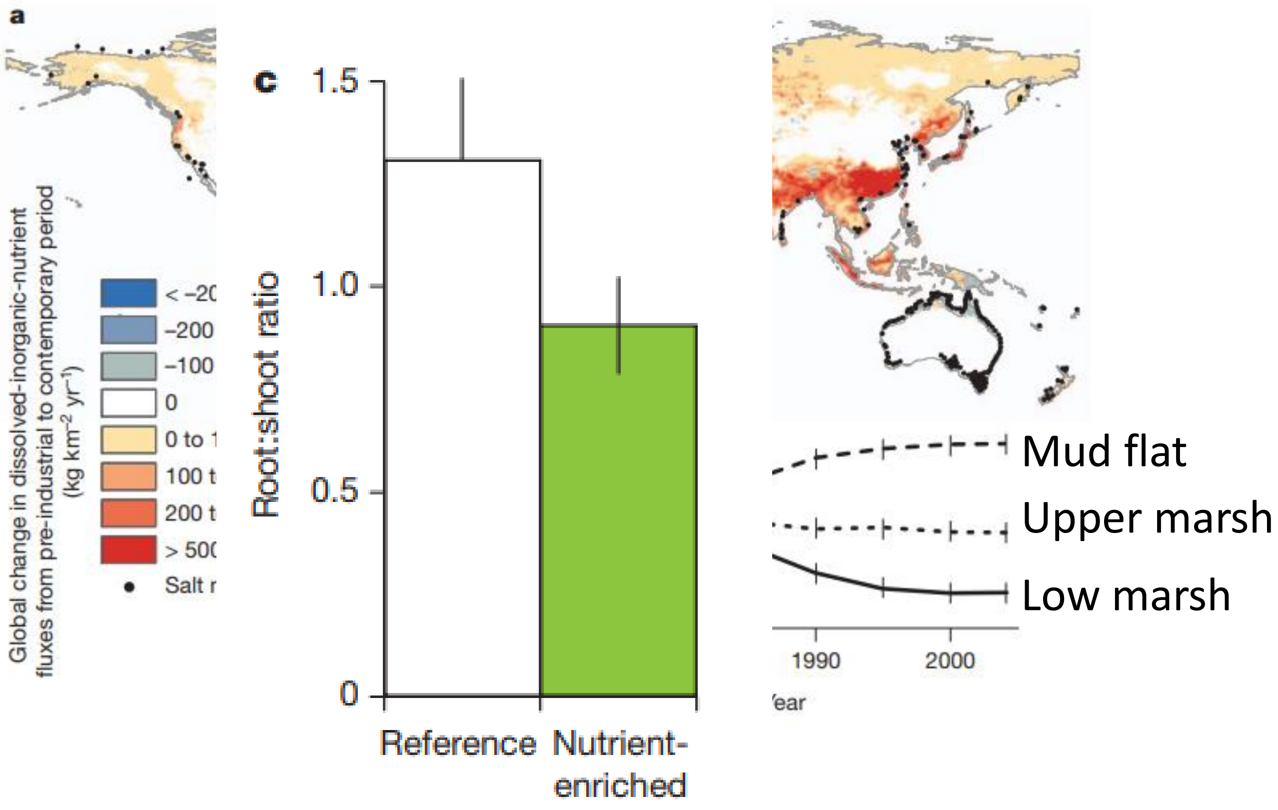
ECOSYSTEM FUNCTION - BIODIVERSITY

Win-Wins or Trade-Offs?



Cardinale et al. 2012 *Nature*



Deegan et al. 2012 *Nature*

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Denitrification: The Process and Its Importance

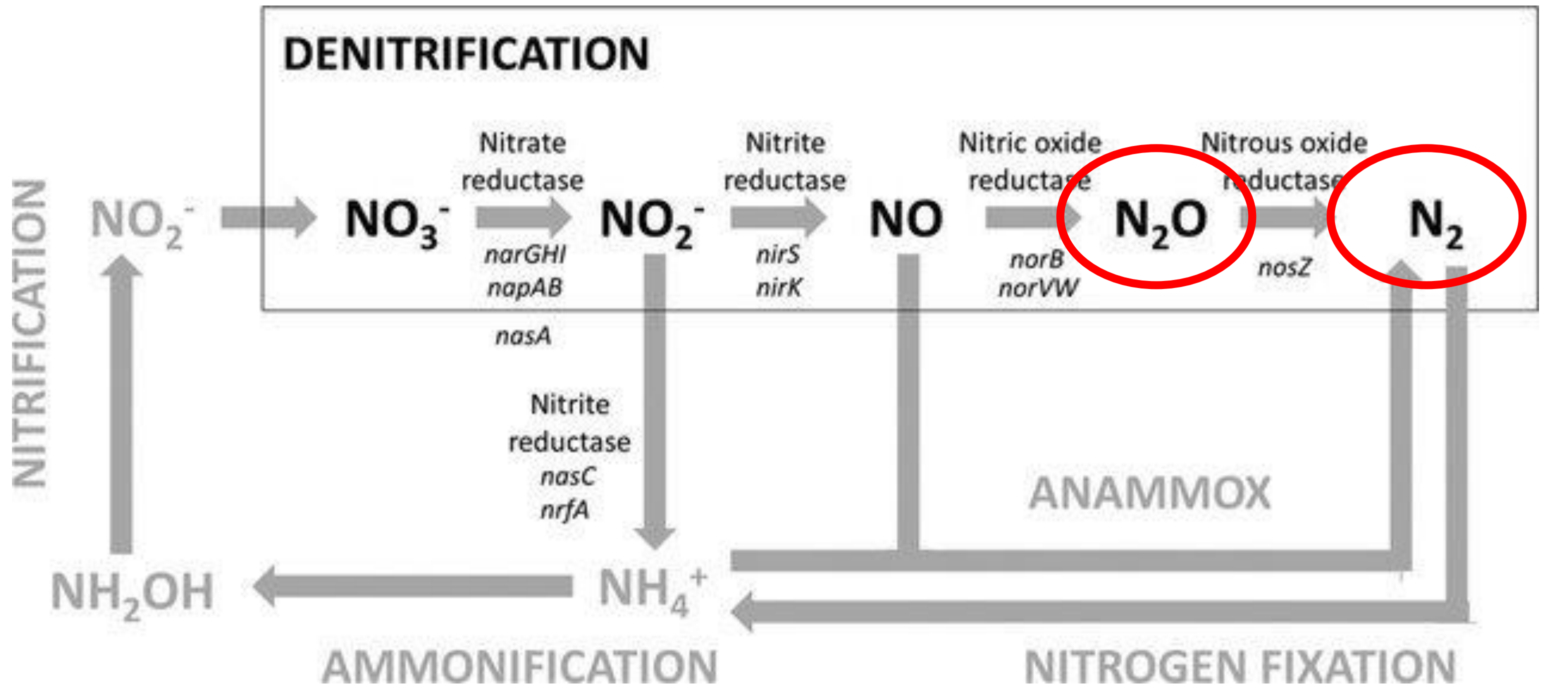

Table 1 Properties of different ecosystems on nitrogen accumulation and transfer potential (adapted from Galloway et al. 2003)

Ecosystem	Accumulation potential	Transfer potential	N_2 production potential
Atmosphere	Low	Very high	None
Wetlands, streams, lakes, rivers	Low	Very high	Moderate to high
Agro-ecosystems	Low to moderate	Very high	Low to moderate
Marine coastal regions	Low to moderate	Moderate	High
Groundwater	Moderate	Moderate	Moderate
Forests	High	Moderate to high	Low
Grasslands	High	Moderate to high	Low

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After Groffman et al. 2006
After Baggs 2008

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Ashok and Hait 2015

NCEA Natural Capital and Ecosystem Assessment

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Denitrification Rate: Influencing Factors

Oxygen
Carbon availability
pH
Temperature

NO_3^- → Denitrifier Community Composition → N_2O, N_2

PROXIMAL CONTROLS

Vegetation
Carbon Substrate
Temperature
Moisture
Predation
Disturbance

→ Denitrifier Community Composition

DISTAL CONTROLS

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after Wallenstein et al. 2006

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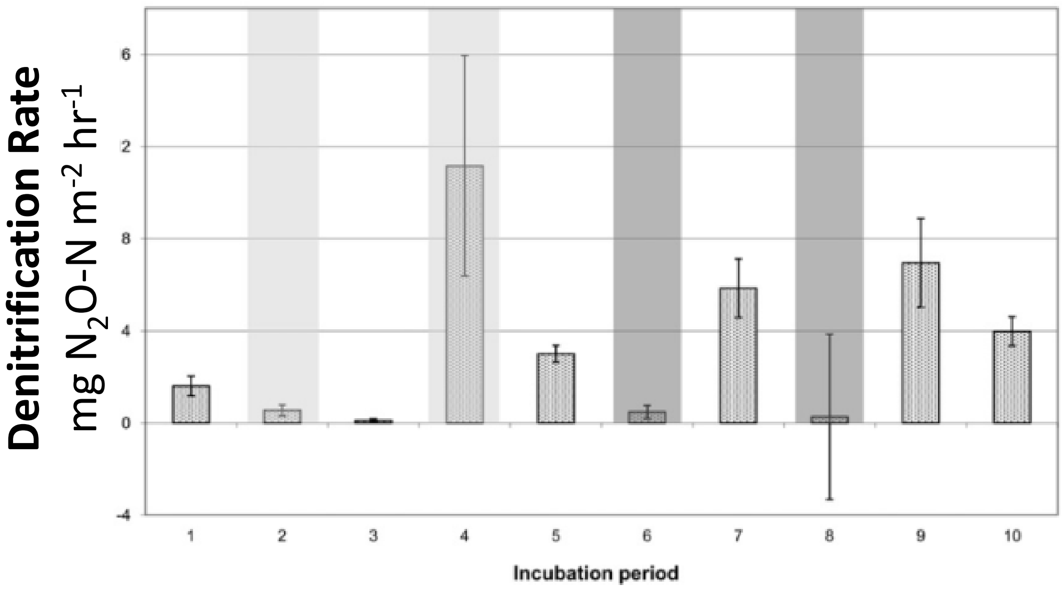
Denitrification Rate: UK Evidence

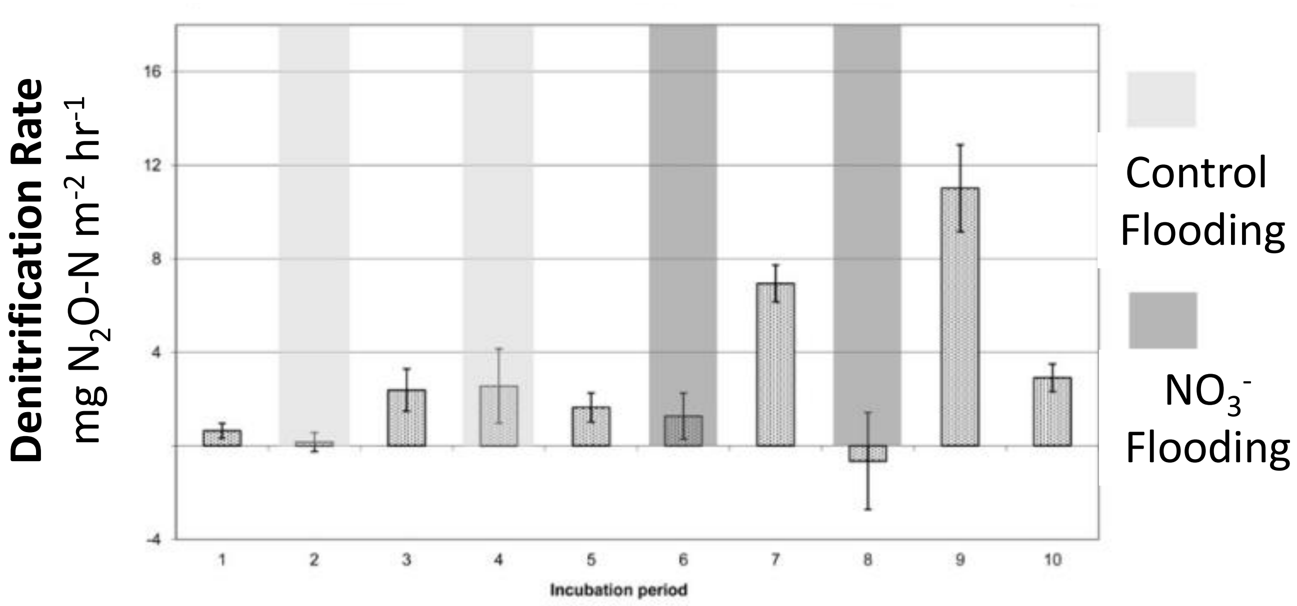
Variation Across Season?
Variation Across Marsh Zone?

Managed Realignment (MR) >>> Intact Saltmarsh (SM)
Less Influence of Nitrate Amendment on MR cf. SM

Managed Realignment



Intact Salt Marsh



after Blackwell et al. 2010

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Denitrification: Methods

after Almaraz et al. 2020

“It is a miserable process to measure…” Groffman et al. 2006

METHOD	STRENGTHS	WEAKNESSES	APPLICATIONS	CAUTION
Acetylene inhibition	Targets N_2 production from denitrification. High throughput. Low cost and easy to learn	Limited in situ capability. Indirect method.	Comparisons among sites or experimental treatments.	Likely underestimated rates. Bias due to sample variation in soil texture/moisture.
Direct measurement (Helium gas flow)	Directly measures N_2 production. Accurate estimation of N_2O to N_2 yield.	Low throughput with custom instrumentation. No in situ capability.	Comparisons among sites or experimental treatments.	No partitioning of sources of N_2 and N_2O e.g. anammox or Feammox contribution of N_2. Overestimation of N_2O production?
15N-NO_3 tracer	Targets N_2O and N_2 production from denitrification	Low throughput and high-cost label. Limited in situ capability	Experiments in N-rich environments	Overestimates because of process stimulation e.g. in low N environments. Biased rates if label not homogeneously distributed.
15N-N_2O pool dilution	In situ measurements, targets N_2O reduction to N_2 by denitrification.	Low throughput with high cost. Requires expensive equipment.	Field measurements using surface flux chambers in which soils are not flooded.	Estimated gross N_2O uptake rates cannot be equated with N_2 production rates. Unknown depth of soil probed by method.
N_2:Ar	In situ measurements, no addition of substrates or inhibitors.	Does not target N_2 production from denitrification. Requires expensive equipment.	Not recommended for (upland) soils due to high detection limit.	
Clumped isotopes of N_2	In situ measurements, no addition of substrates or inhibitors.	Does not target N_2 production from denitrification. Requires expensive equipment.	Field measurements using soil depth profiles to obtain in situ estimates	Estimated N_2 production rates depend on assumptions used to estimate rates from soil depth profiles of Δ_{30}. Unknown biases/artifacts.

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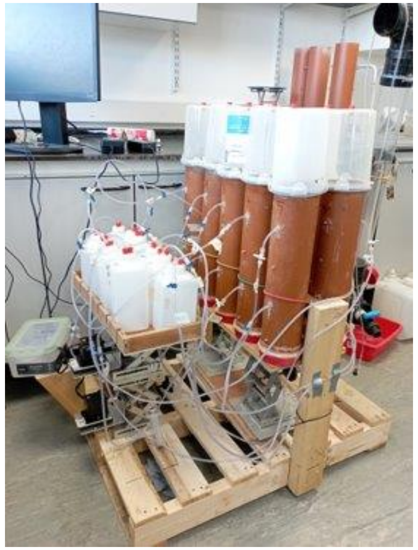
Denitrification: A Preliminary Study

Thorney Island, Solent, England

3 saltmarsh zones
1 mudflat*
1 seagrass meadow*
X
2 seasons (end Oct, end Jan)
8 quadrats per zone (5 in Jan)

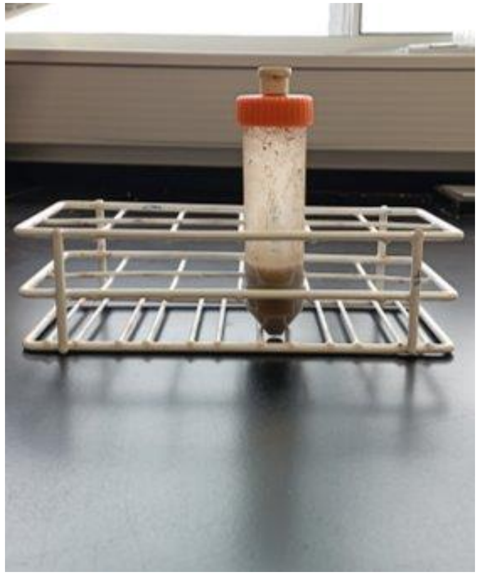
CORE METHOD



2 cores per quadrat
3 grab samples @ 5, 10 and 15 cm
3 pore water samples @ 5, 10 and 15 cm

Vegetation characterisation

SLURRY METHOD



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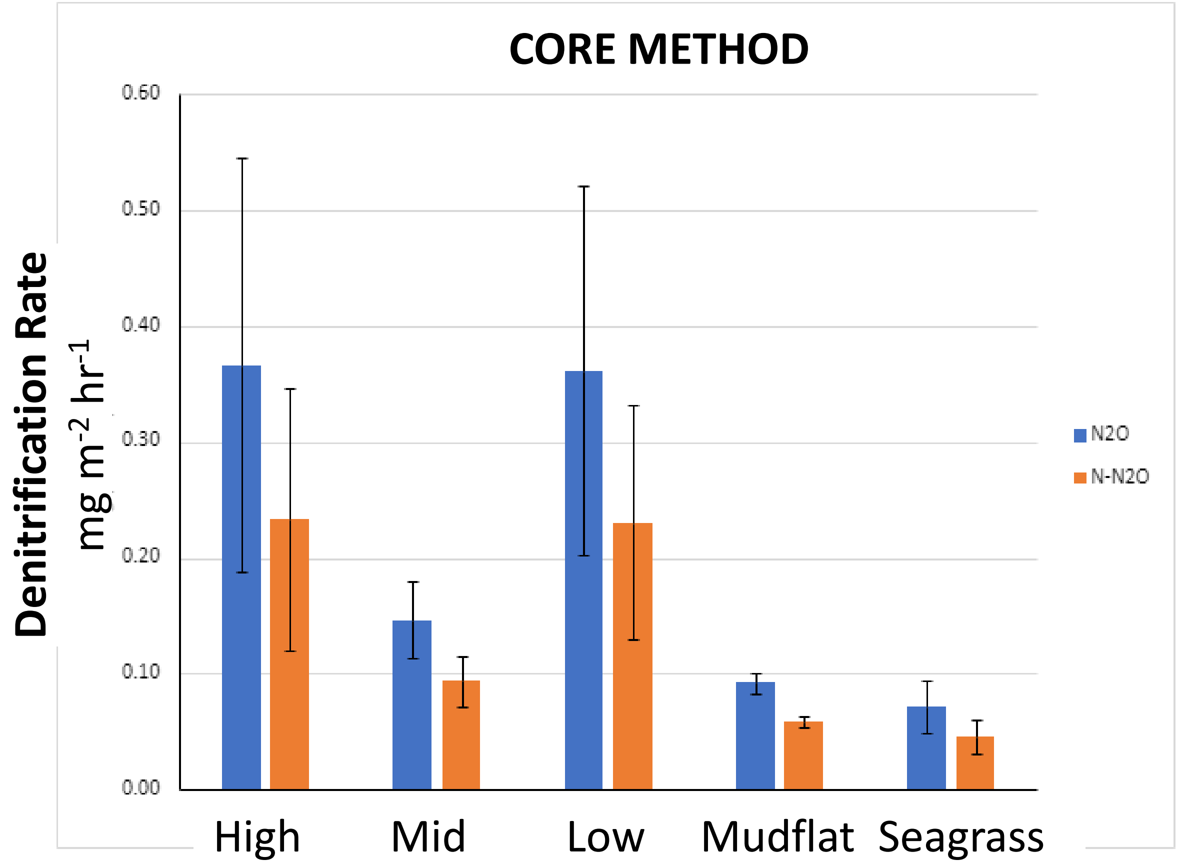
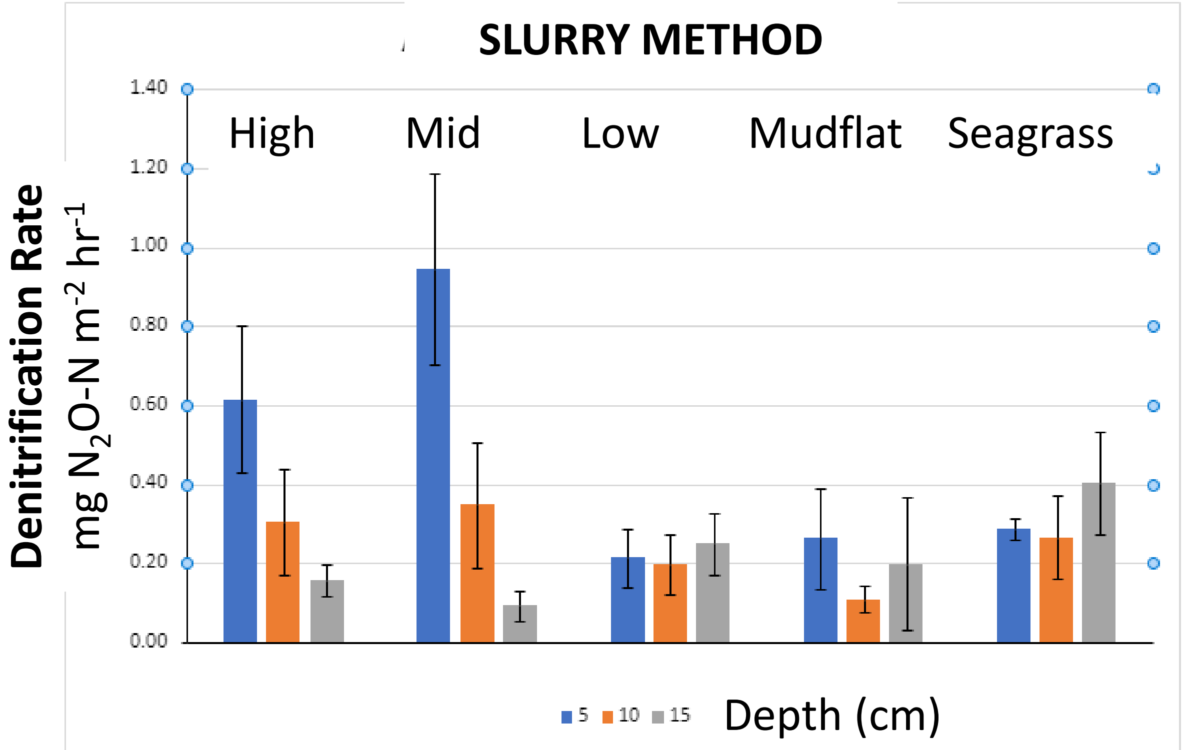
Denitrification: A Preliminary Study





Lower values with core method. Different patterns
Slurry method to per m^2 ?
Relationship with vegetation?

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Denitrification: The Upshot

- Results across seasons. Targeted sampling with minimal vegetation community difference in winter.
- Consider methodological review plus results of preliminary trials.
- Recommend nationwide sampling strategy to characterise denitrification rates.
- Consider additional sampling across some sites to characterise full nutrient cycles.
- What will happen to N_2O : N_2 yield when challenged with additional pollution in sites?

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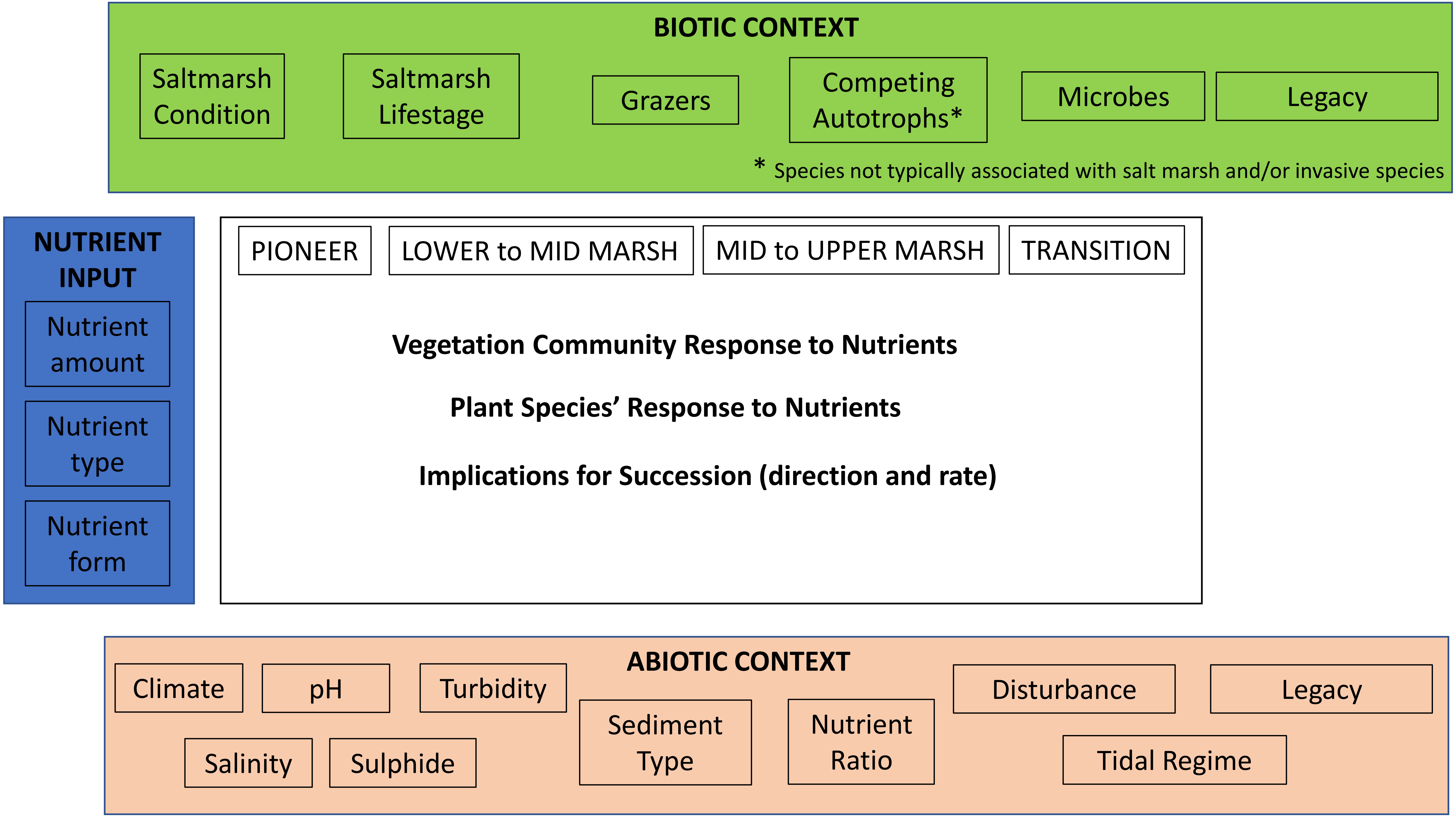
Nutrient Impacts on Saltmarsh Vegetation

"To understand the impacts of nutrients on saltmarsh integrity so that the habitat feature can be maintained in a Favourable Conservation Status"

Objective 1: Collate the evidence on the impact of nitrogen (N) and phosphorus (P) compounds on the condition of typical saltmarsh species present in the UK marine environment

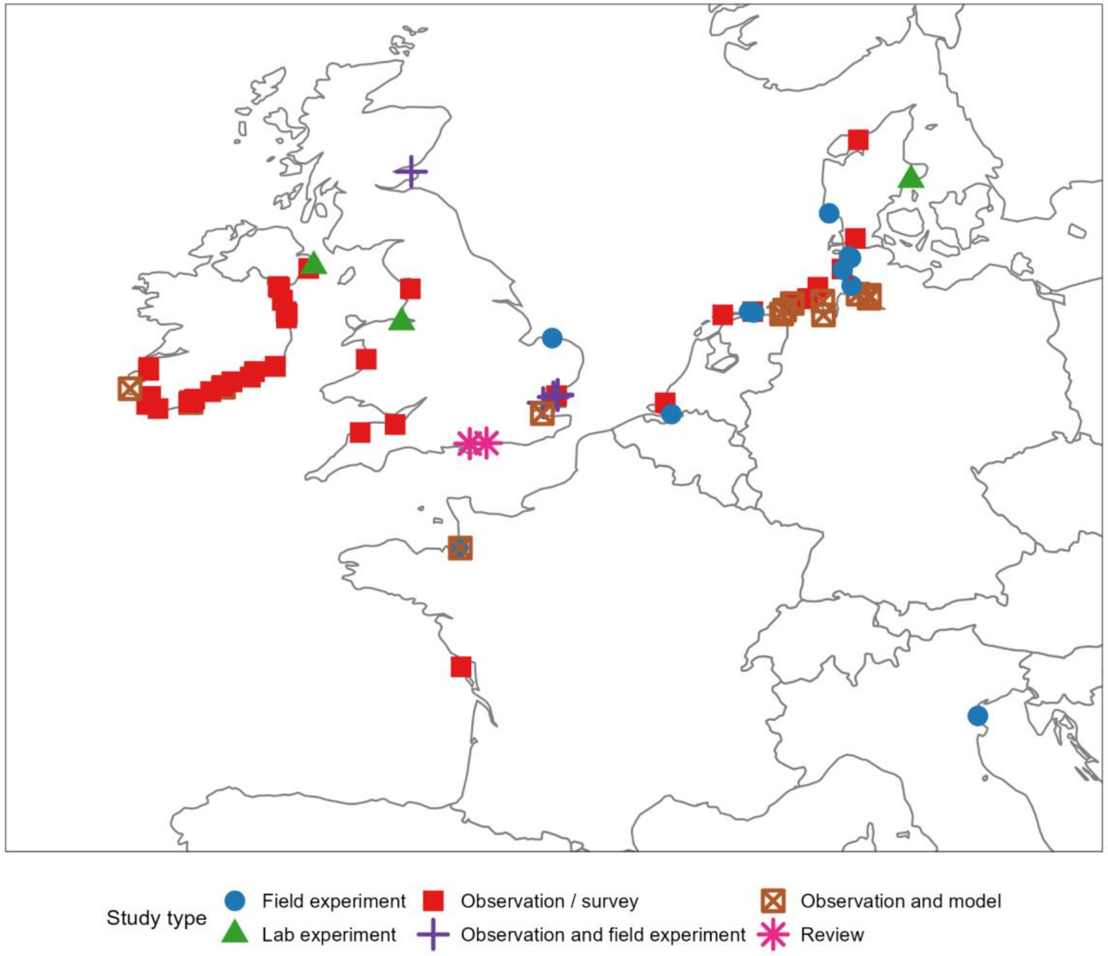
Objective 2: Collate the evidence for environmental (abiotic) factors that can affect the impact of elevated nutrients on saltmarsh species present in UK waters

Objective 3: Collate the evidence for ecological (biotic) factors that can affect the impact of elevated nutrients on saltmarsh species present in UK waters


BIOTIC CONTEXT
Saltmarsh Condition
Saltmarsh Lifestage
Grazers
Competing Autotrophs*
Microbes
Legacy
* Species not typically associated with salt marsh and/or invasive species
NUTRIENT INPUT
Nutrient amount
Nutrient type
Nutrient form
PIONEER
LOWER to MID MARSH
MID to UPPER MARSH
TRANSITION
Vegetation Community Response to Nutrients
Plant Species' Response to Nutrients
Implications for Succession (direction and rate)
ABIOTIC CONTEXT
Climate
pH
Turbidity
Salinity
Sulphide
Sediment Type
Nutrient Ratio
Disturbance
Legacy
Tidal Regime

ECOSYSTEM FUNCTION - **BIODIVERSITY**

Literature Review: Evidence Sources



Map prepared by Els Dhiedt

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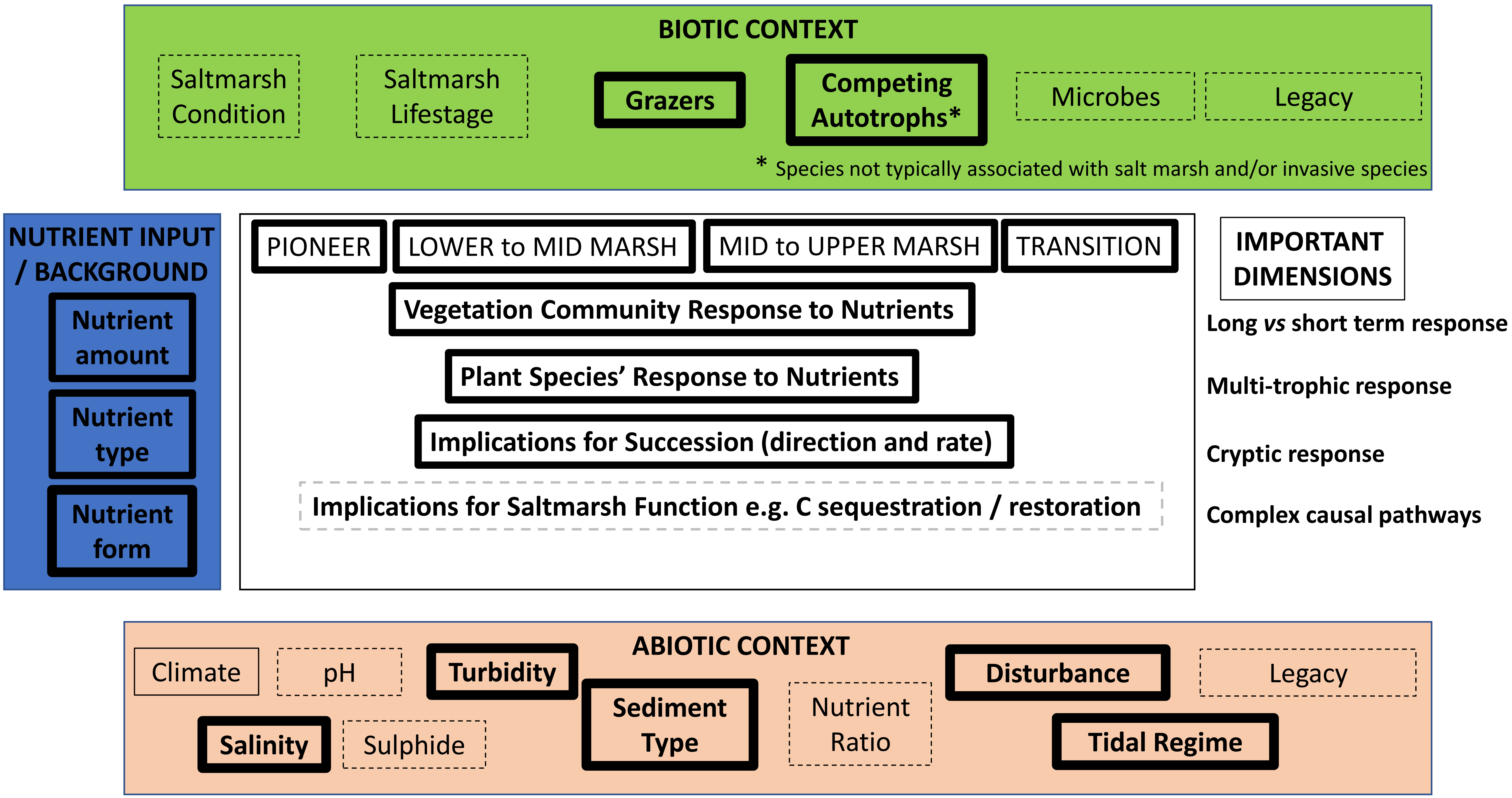
Thriving Nature for people and planet

NATURAL ENGLAND



BIOTIC CONTEXT
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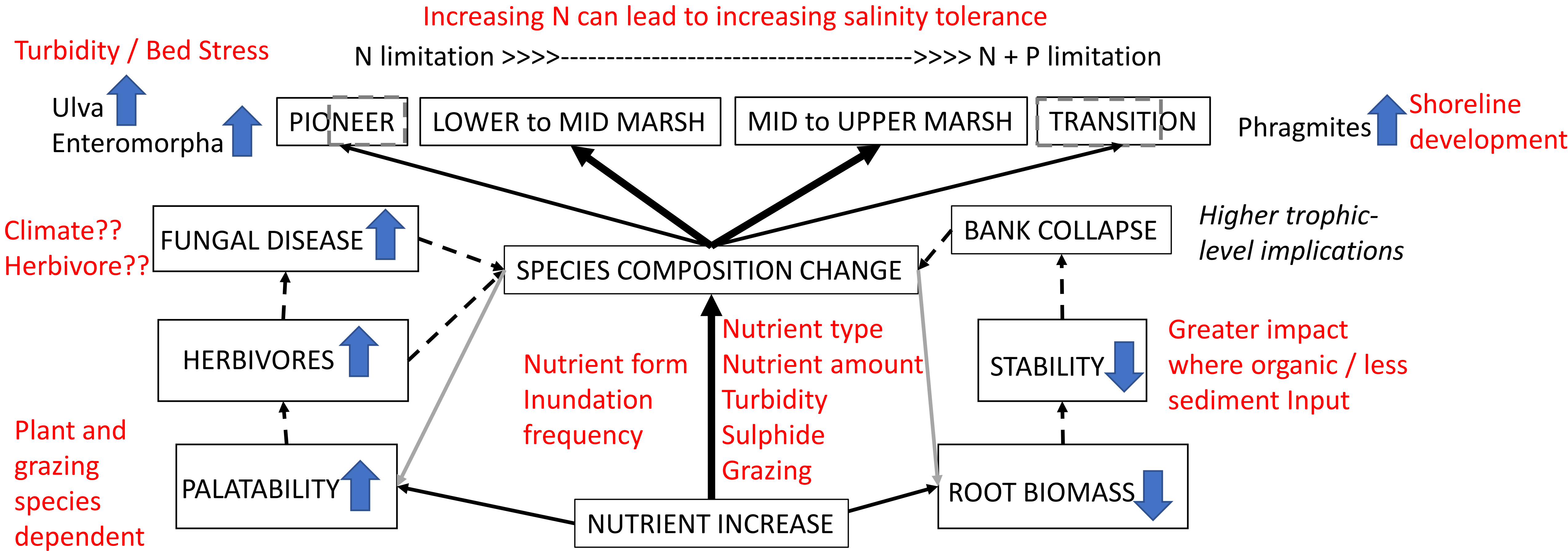
NUTRIENT INPUT / BACKGROUND
Nutrient amount
Nutrient type
Nutrient form
PIONEER
LOWER to MID MARSH
MID to UPPER MARSH
TRANSITION
Vegetation Community Response to Nutrients
Plant Species' Response to Nutrients
Implications for Succession (direction and rate)
Implications for Saltmarsh Function e.g. C sequestration / restoration
IMPORTANT DIMENSIONS
Long vs short term response
Multi-trophic response
Cryptic response
Complex causal pathways
ABIOTIC CONTEXT
Climate
pH
Turbidity
Disturbance
Legacy
Salinity
Sulphide
Sediment Type
Nutrient Ratio
Tidal Regime

ECOSYSTEM FUNCTION - **BIODIVERSITY**



<u>LEGEND</u>

- Direct nutrient effect on vegetation
- Indirect nutrient effect on vegetation
- Feedbacks of species composition on other processes
- Nutrient-induced saltmarsh "squeeze"
- XXXX Variables influencing magnitude of compositional change in response to nutrient increase

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NUTRIENT REMOVAL

- What are potential and actual rates of denitrification across space and time?
- Do other processes significantly contribute to nutrient-N removal, and if so, under what conditions?
- How does eutrophication challenge the denitrification process and N_2O to N_2 yield?
- What are the removal rates of other nutrients?

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- Can we experimentally demonstrate nutrient impacts upon saltmarsh vegetation?
- How do microbes and other trophic groups respond to nutrient pollution?
- What are the nutrient input pathways driving saltmarsh change – and can we develop a metric of nutrient pressure?
- What are the long- as well as short-term consequences of nutrient pollution?

ECOSYSTEM FUNCTION – BIODIVERSITY – SOCIETY

Trade-Offs or Win-Wins: Perception and reality in saltmarsh conservation for biodiversity and sustainable environmental management

“The extent to which different stakeholders understand and support saltmarsh conservation may depend on whether saltmarsh capacity for nutrient removal trades-off with saltmarsh structural integrity and biodiversity values, or whether there are opportunities for win-wins”

Farmers

Developers

Conservation Groups

Local Government Association

PAS planning advisory service

Statutory Organisations

Sustainable Management of Marine Resources SuMMeR Centre for Doctoral Training

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UNIVERSITY OF PLYMOUTH

Thriving Nature for people and planet NATURAL ENGLAND

ECOSYSTEM FUNCTION – BIODIVERSITY – SOCIETY

Trade-Offs or Win-Wins: Perception and reality in saltmarsh conservation for biodiversity and sustainable environmental management

Objective 1: Understanding nutrient – biodiversity – structural integrity relationships in saltmarsh

Objective 2: Understanding stakeholder perceptions of saltmarsh-ecosystem service relationships

Objective 3: Exploring nutrient loading – nutrient removal relationships in saltmarsh

IMPORTANT: Objectives 1 – 3 – Saltmarshes in multiple environmental contexts

Objective 4: Managing nutrient – biodiversity relationships in saltmarshes – implications for sustainability

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NATURAL ENGLAND

Sustainable Management of Marine Resources

SuMMeR Centre for Doctoral Training

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Conclusions

- **Nutrients can have far-reaching impacts on saltmarsh structure, biodiversity, and function...**

- **...at least in theory and some literature evidence. Evidence from Wales, and the rest of the UK, is scarce.**

- **Preliminary results suggest denitrification rates vary as a function of saltmarsh zone. Study is ongoing. To inform the EA, CEFAS and their Combined Phytoplankton Macroalgae (CPM) model, and other stakeholders – need to understand what happens across environmental contexts. Investigate *in situ* as well as *ex situ* methods.**

- **To inform sustainable management, need to understand stakeholder perceptions and how saltmarsh processes in response to nutrient pollution, and other stressors, vary across contexts.**

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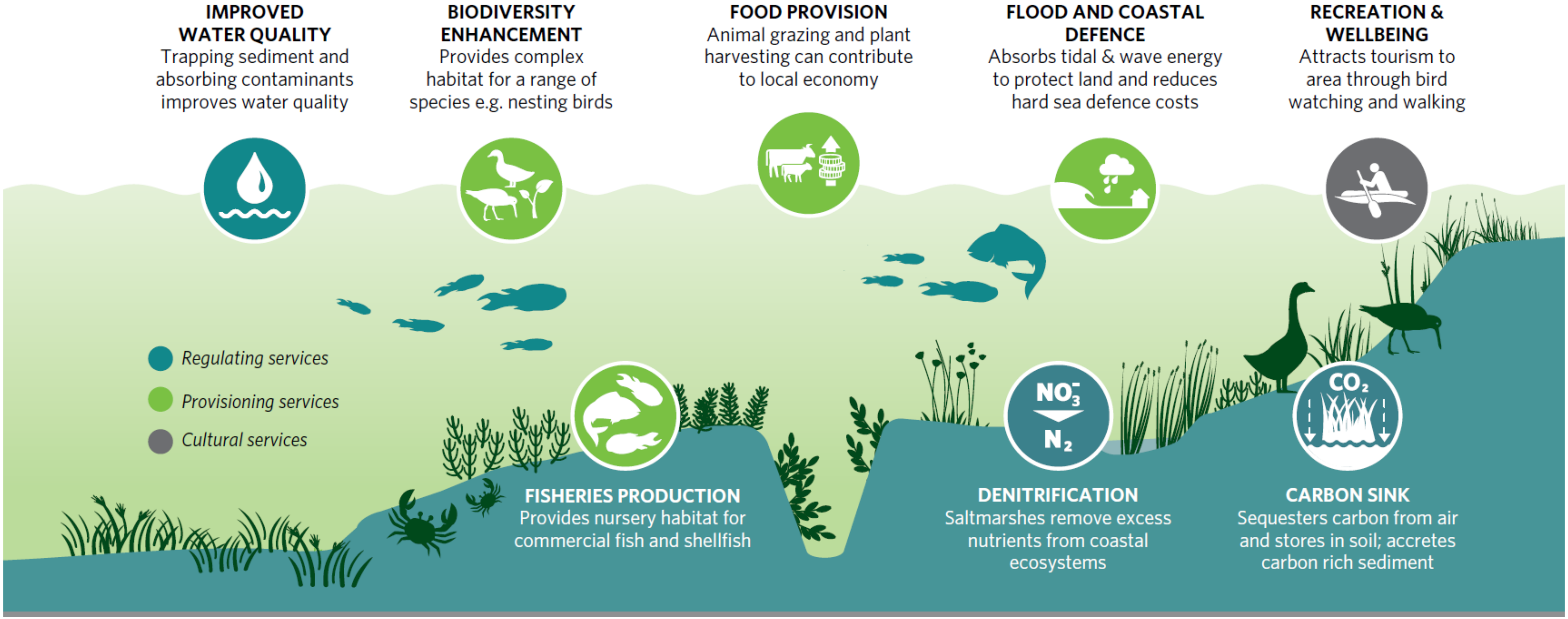
Thank you for listening.

Any Questions?



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