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Making bivalve-reef restoration financially viable: using growth models to quantify fluxes of carbon and nitrogen

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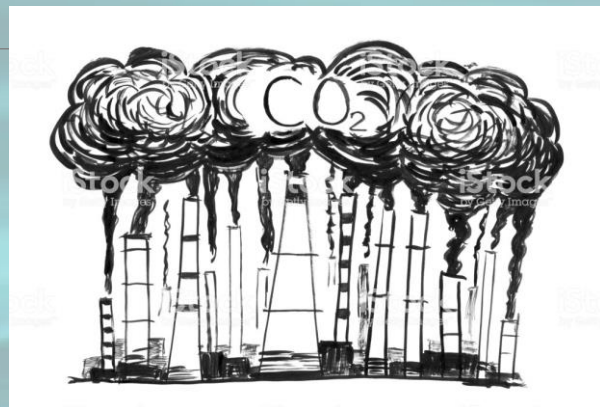
Restoration



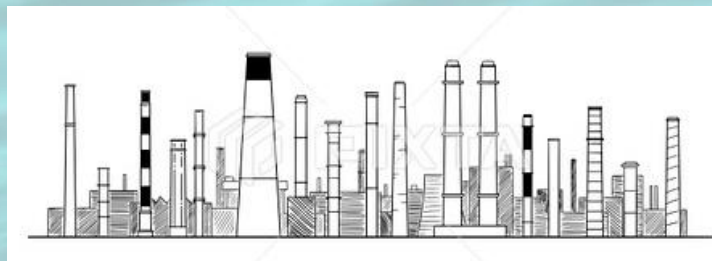
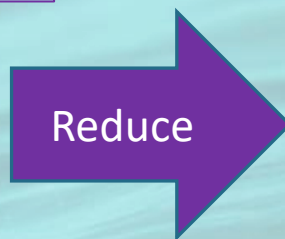
- UN Decade of Ecosystem Restoration
 - 2020-2030
- shellfish reefs among the aquatic ecosystems to be restored
 - High degradation
 - Ecosystem engineers – positive cascading effects
- Restoring not only the physical habitats but the associated functions and deriving services
- It can be costly: average oyster reef restoration \$300,000 / ha



Financing mechanisms

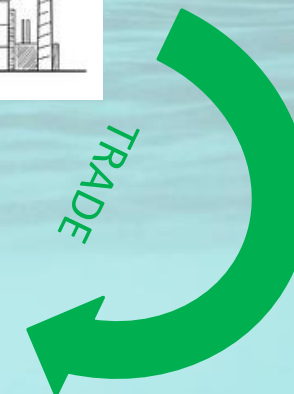


1



2

Offset projects
Reef
restoration?



Carbon credits: 1 credit = 1 tonne of CO_{2eq}

Nutrient trading : 1 credit = 10 kg of N (or P)

SFG model of Ostrea

FORCING FUNCTIONS

Food
(Chlorophyll-a + POC)

Temperature



PARAMETERS

Related to anabolism & catabolism from experimental data in literature. Within this study the maximum clearance rate was calibrated



SHELL

$$\frac{dW_s}{dT} = k_{SH} \frac{A - C}{\epsilon_{OS} * OS + \epsilon_{IS} * IS}$$

GONADS

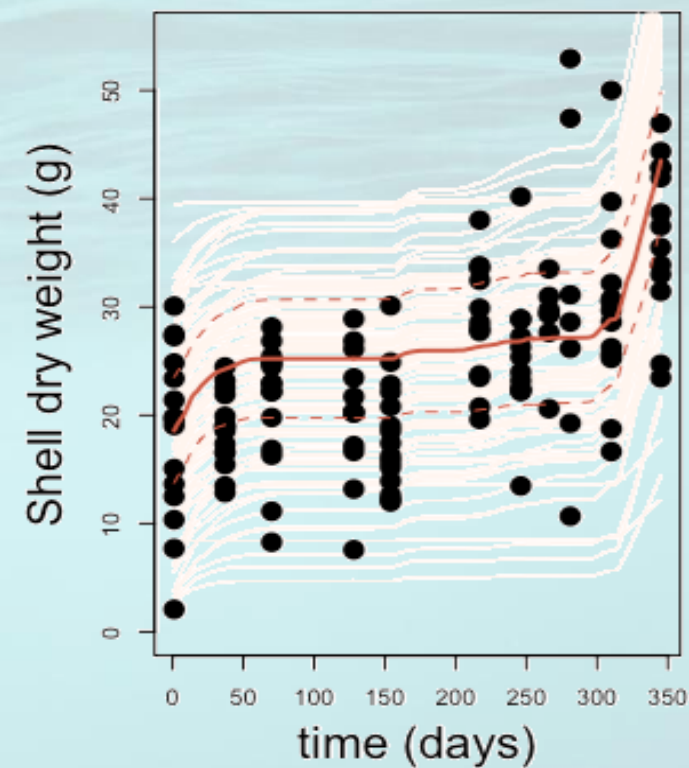
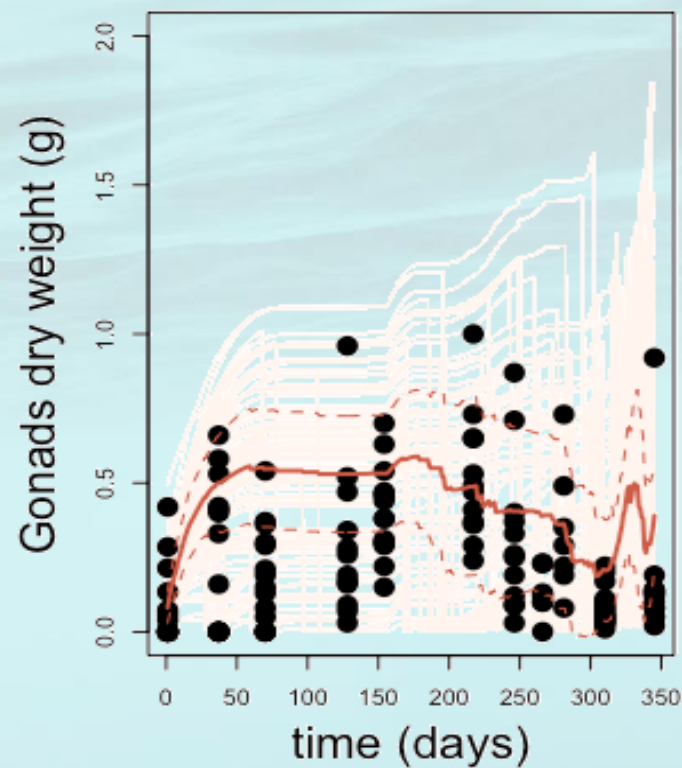
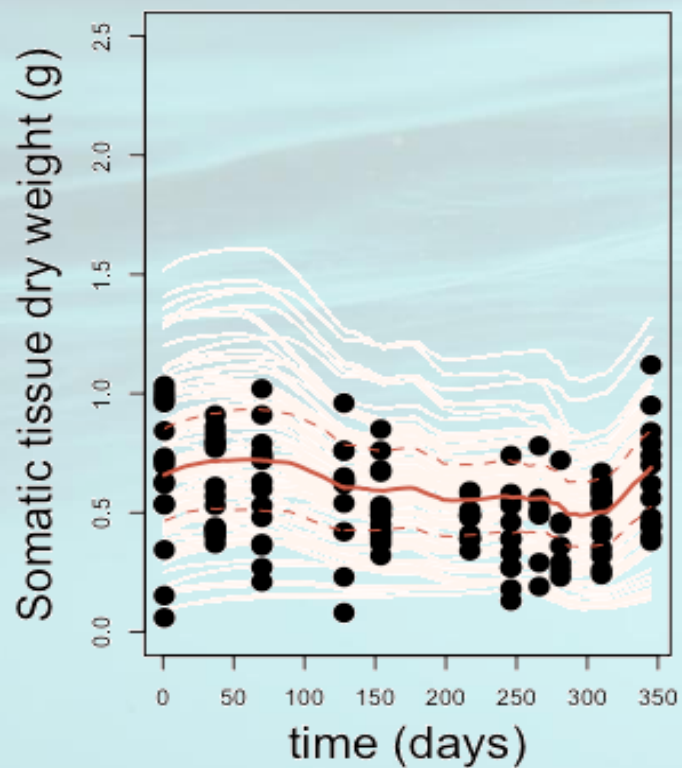
$$\frac{dW_r}{dT} = k_R \frac{A - C}{\epsilon_R}$$

SOMATIC tissue

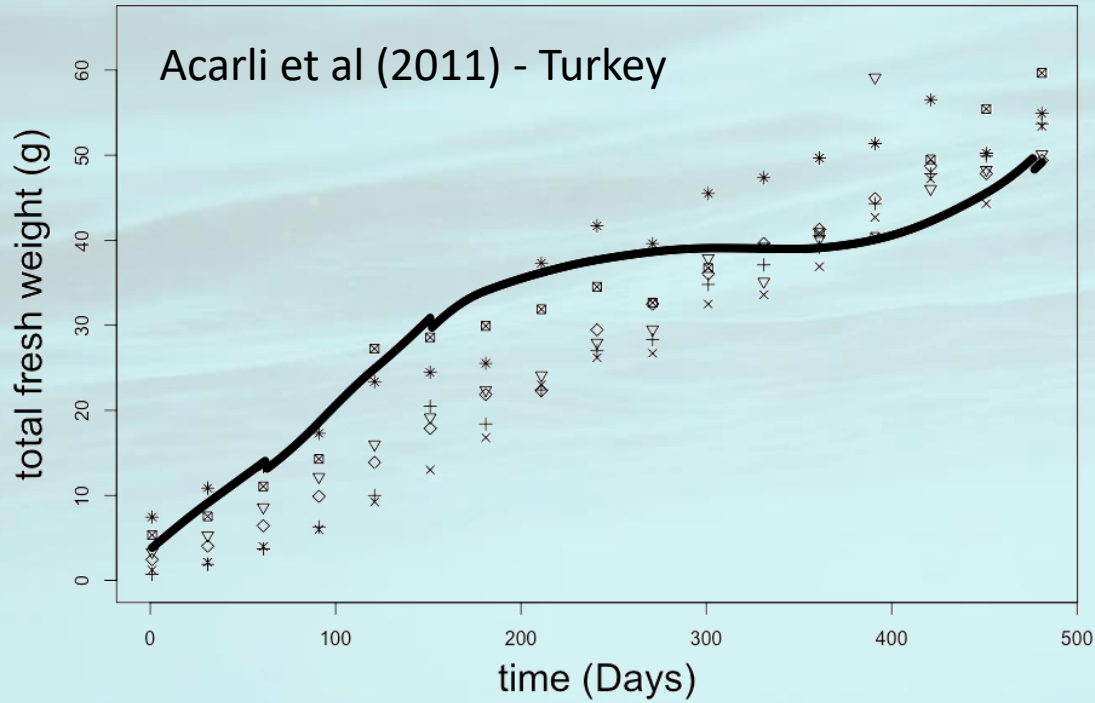
$$\frac{dW_b}{dT} = (1 - k_R - k_{SH}) \frac{A - C}{\epsilon_R}$$

Venice Lagoon

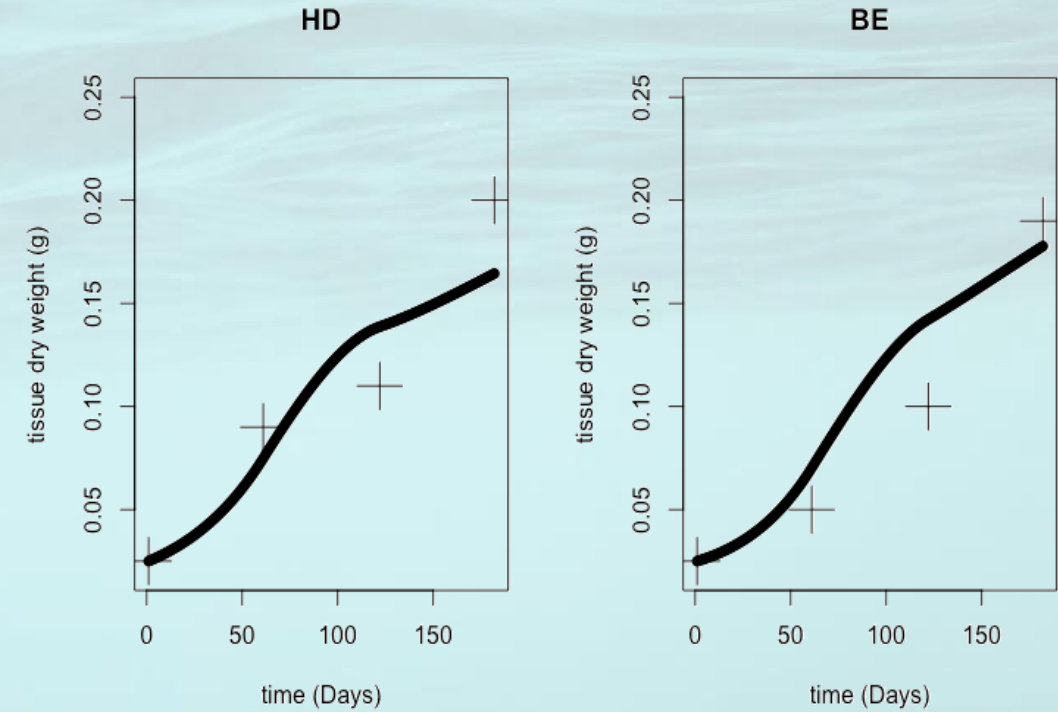
September 2021- September 2022



SFG – Comparisons with literature data



Pogoda et al (2011) - Germany



Calculating budgets



Somatic tissue
+ gonads

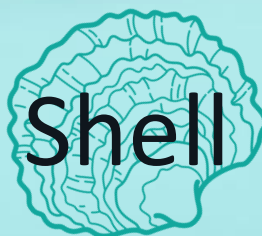
$$C_{soft} * \left(\frac{dWd}{dt} \right)$$

$$N_{soft} * \left(\frac{dWd}{dt} \right)$$

Ingested

$$C = CR * POC$$

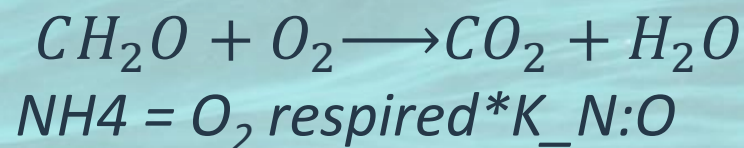
$$N = CR * POC * N:C$$



Shell

$$\left(\frac{dS}{dt} \right) * \psi(t) * prCaCO_3$$

Respiration



Excreted

$$1-AE * POC / 1-AE * POC * N:C$$

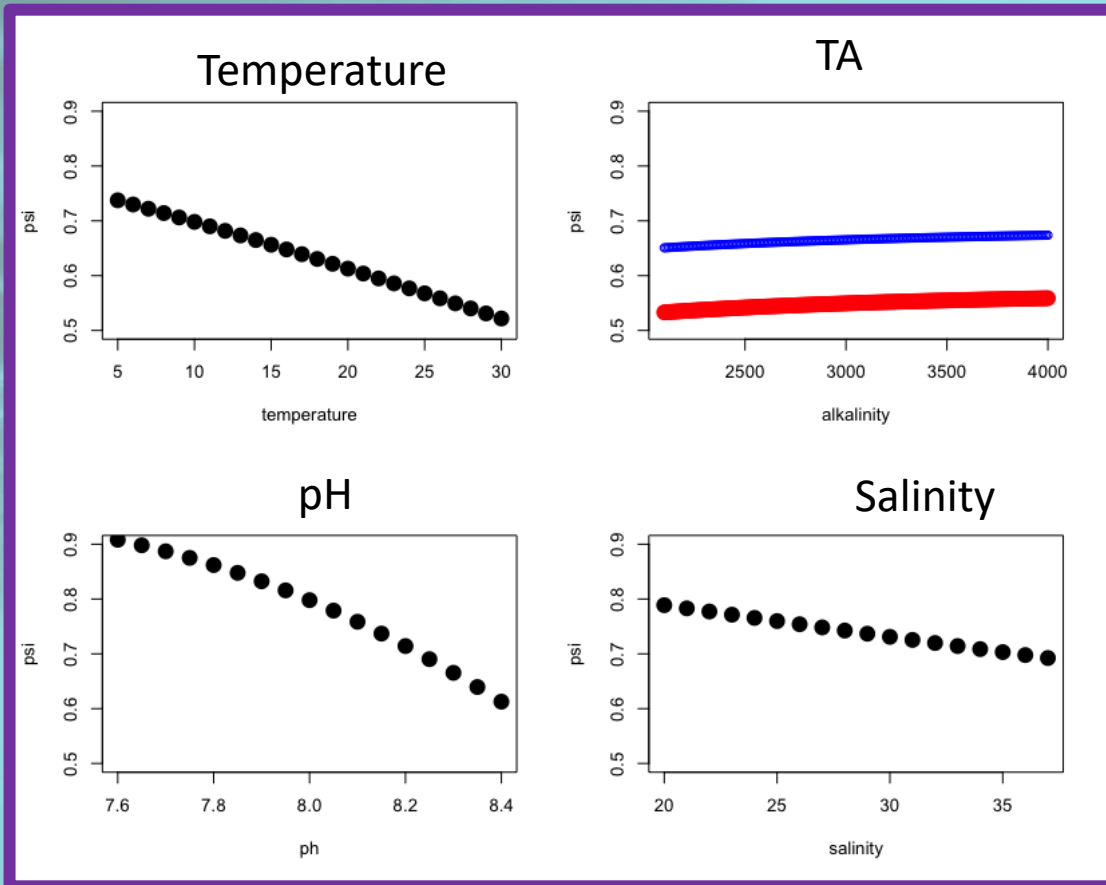
Calcification

Modelling seawater carbonate chemistry in shellfish aquaculture regions: Insights into CO₂ release associated with shell formation and growth

James P. Morris^{a, 1, 2}, Matthew P. Humphreys^{b, c, 1}

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ψ : the additional reduction in DIC required, relative to the amount of DIC converted into CaCO₃, such that there would be no net change in seawater pCO₂. Can be considered potential amount of CO₂ released by mollusc calcification (Morris & Humphreys, 2019)

$$\left(\frac{dS}{dt}\right) * \psi(t) * prCaCO_3 * 0.44$$



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Simulating reef restoration

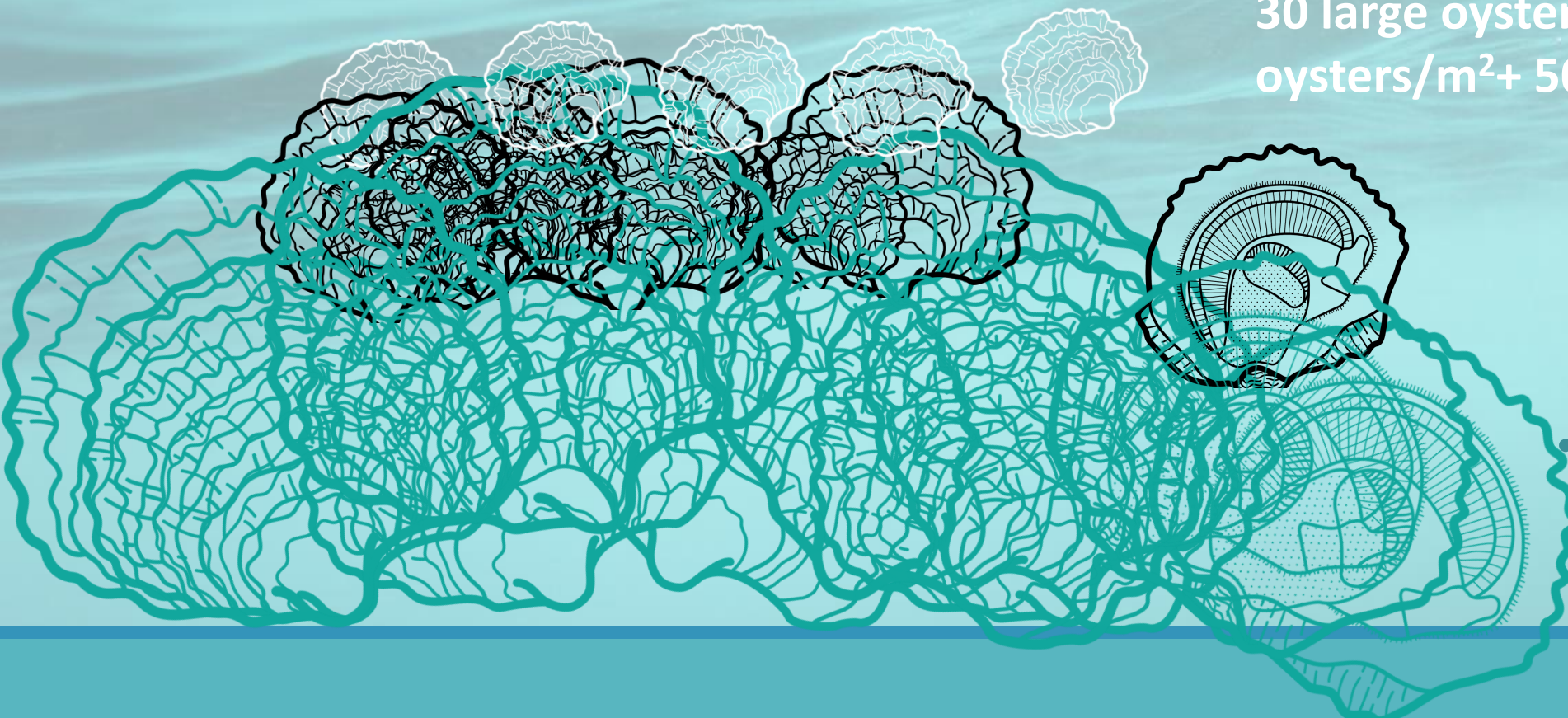


"Individual based population model, based on
Montercarlo simulations

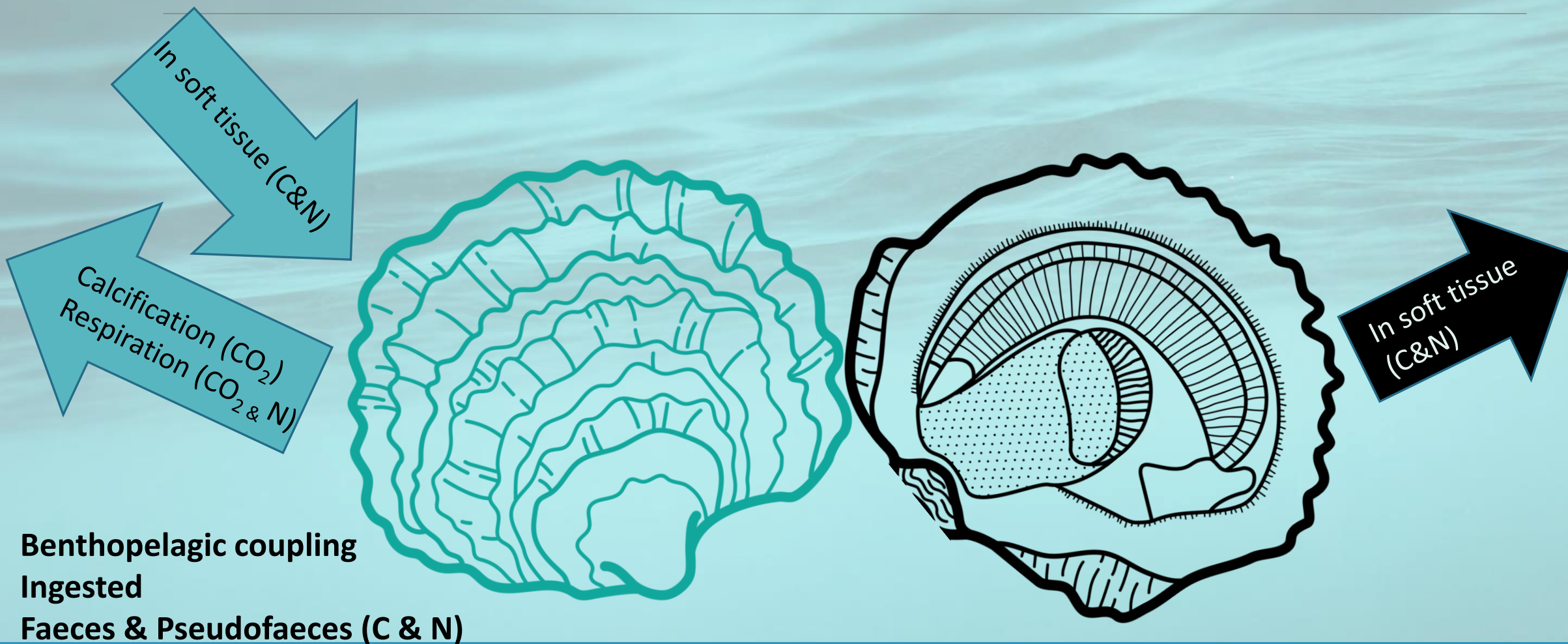
**Year 3 = 15% adult mortality + 50%
recruited mortality + recruitment =
30 large oysters/m² + 25 medium
oysters/m² + 50 small oysters**

**Year 2 = 30% mortality +
recruitment = 35 large
oysters/m² + 50 small
oysters/m²**

• **Year 1 = 50 medium
sized oysters/m²**



Simulating budgets



Benthopelagic coupling
Ingested
Faeces & Pseudofaeces (C & N)



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Results – CO₂eq

grams/m²

Year 3

SOFT: 220

CALC: 798 ;RESP: 549

Benthopelagic coupling:

IN 2075, OUT 50

Year 2

SOFT: 248

CALC: 554;RESP: 360

Benthopelagic coupling:

IN 1412 , OUT 34

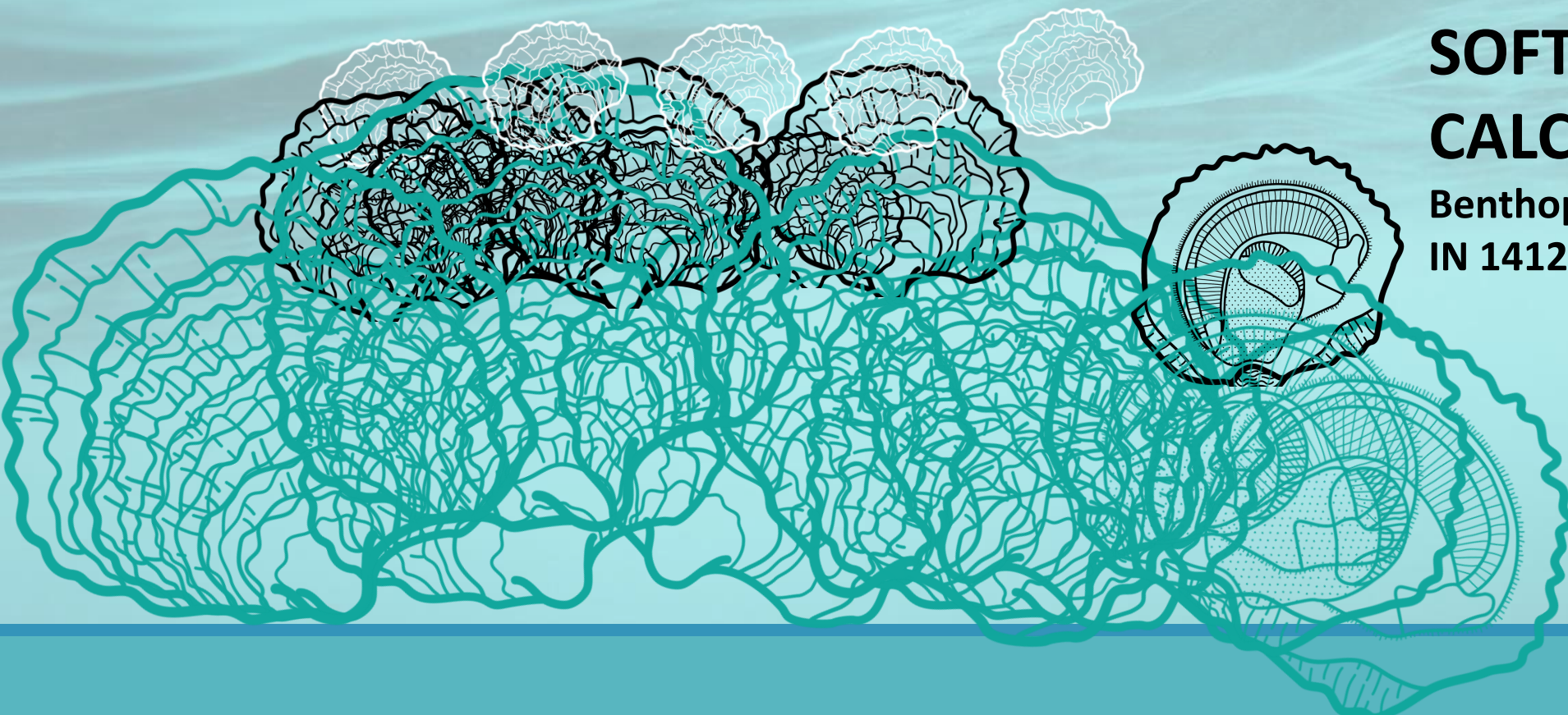
Year 1

SOFT: 163

CALC: 372; RESP: 27

Benthopelagic coupling:

IN 955, OUT 23

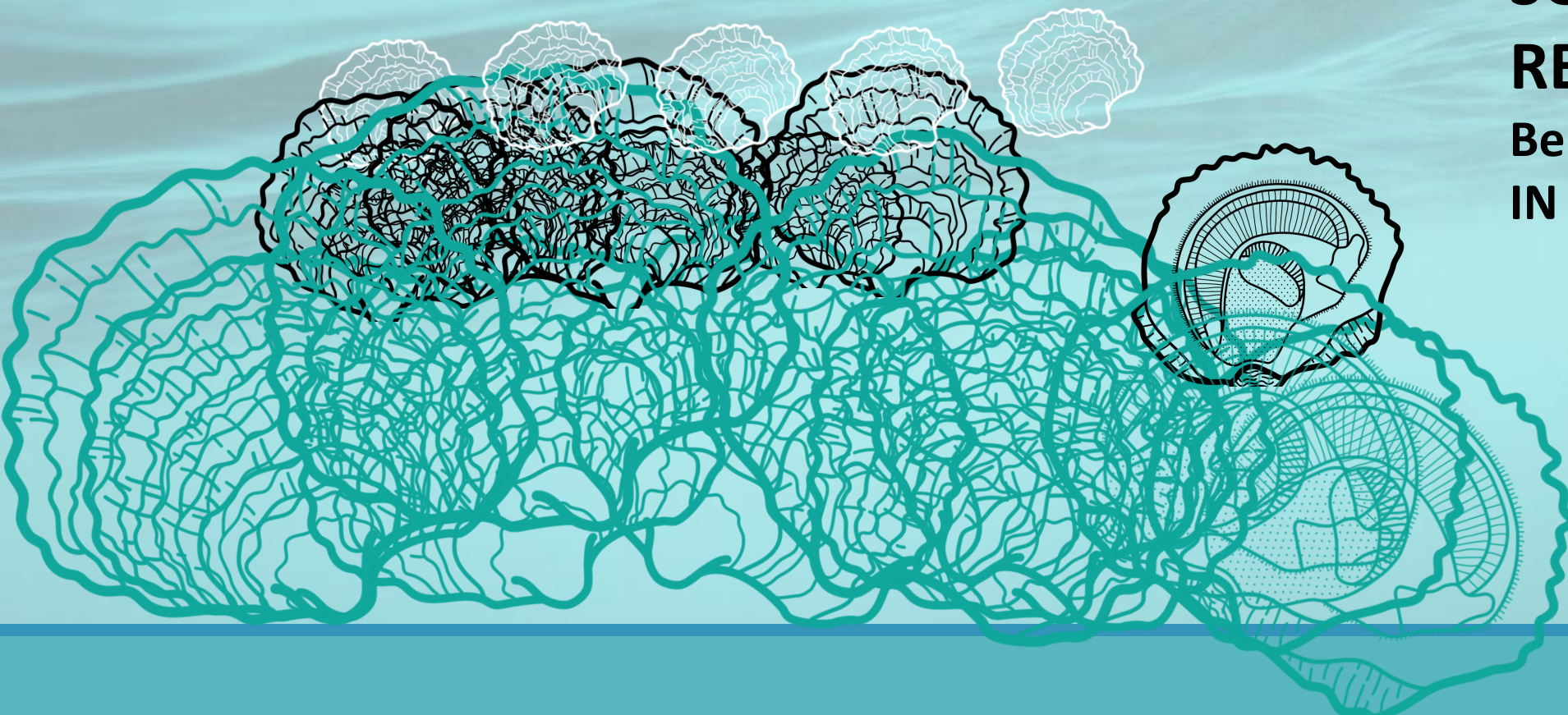




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Results – N

grams/m²



Year 3
SOFT: 9.9
RESP: 33

Benthopelagic
IN 90 OUT 33

Year 2
SOFT 10.9
RESP: 22
Benthopelagic
IN 62 OUT 23

Year 1
SOFT 8
RESP: 17
Benthopelagic
IN 45 OUT 18





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In monetary terms? Carbon

- In terms of Carbon, more needs to be understood in terms of the **fate & remineralisation of faeces and pseudofaeces** : the only component that could lead to sequestration
- with this data emissions from respiration and calcification outweigh the carbon content in soft tissue of live oysters
- Role of shell dissolution?

Carbon credits





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In monetary terms? Nitrogen

- For nutrients abatement
 - c.ca 10-30 credits/ha, from 1- 3 years – increasing with further reef development
 - values consistent with other reported for Chesapeake bay (40, calculated from noaa report)



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Future work



- Understanding remineralisation processes
- Investigate potential role of dissolution & dead shells within reefs
- Better understanding of ammonia excretion (value from Brigolin 2009 on *Mytilus*, and already likely overestimated)
- comparing POC from satellite and sampling



Conclusions

- Growth models can be a useful tool for quantification of fluxes
 - Modelling processes
 - Can be made context dependent (different forcings)
 - If scenarios of input forcings available can make future predictions
- This is still a simplification of the system: Biodiversity associated with oysters will contribute (e.g. seaweeds may use the N excreted, and infauna will rework faeces...)



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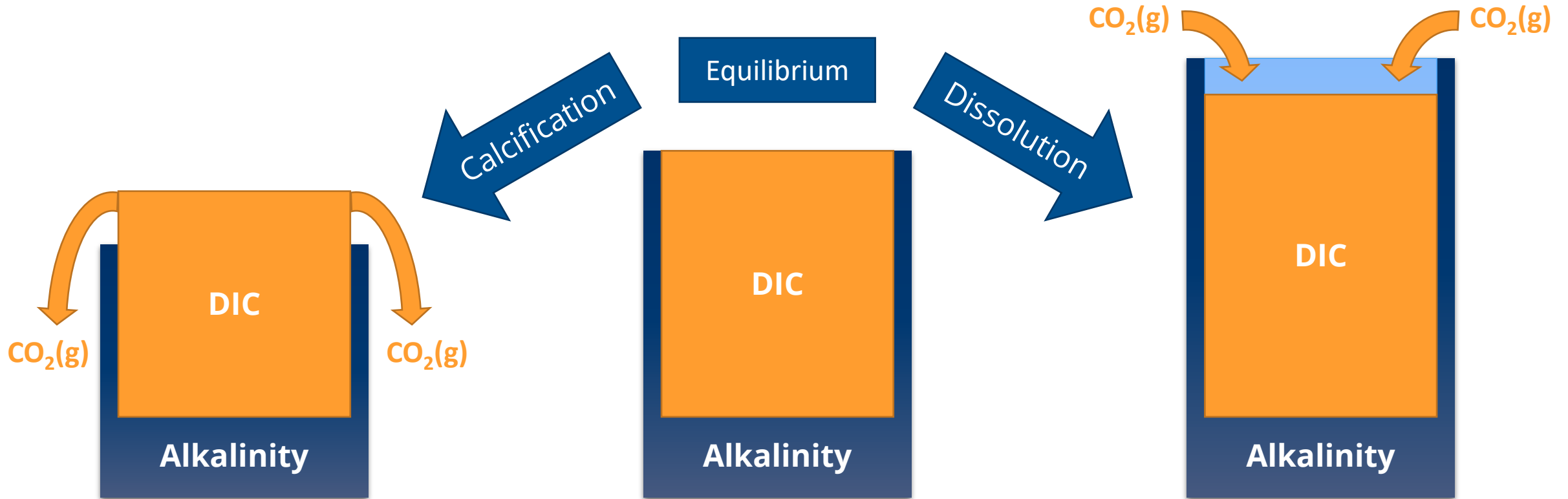
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ANY QUESTIONS?

Alkalinity, DIC and CO₂ equilibrium



From : Matthew Humphreys