SHELLFISH PRODUCTION - DELIVERING BENEFITS

"MORE WITH MOLLUSCS"

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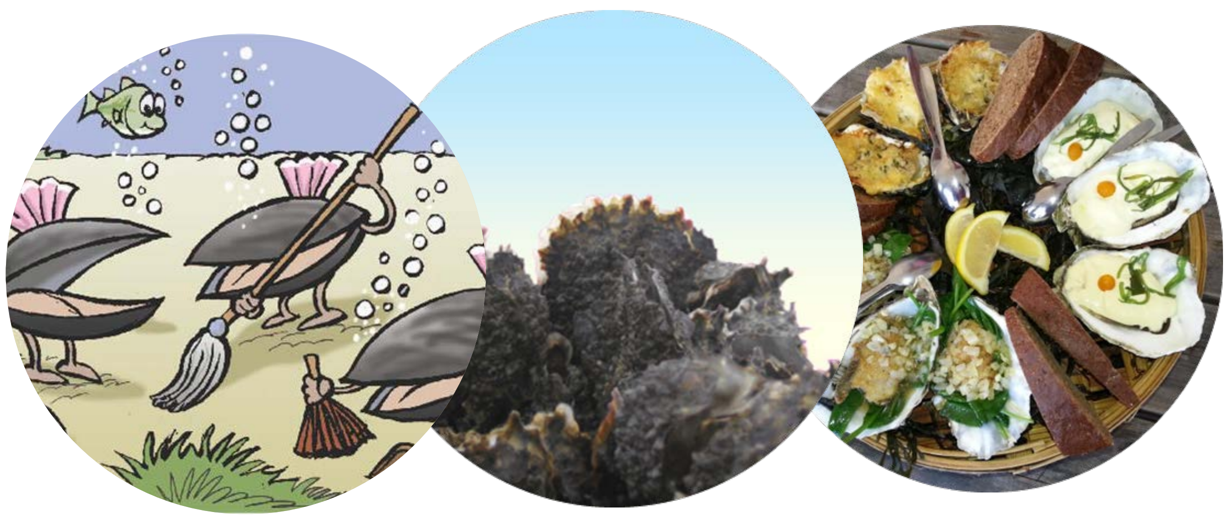

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ASSG conference, Oban 30/10-01/11 2019

OUTLINE

Review Goods & Services of Molluscs

Bivalves as a framework for sustainable management by integration of functions

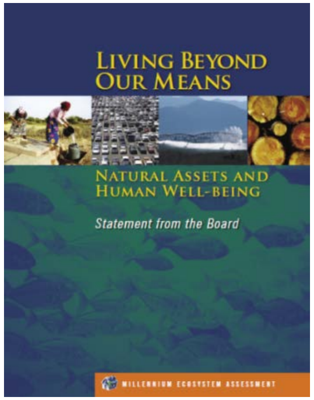
Goods & Services	Beaumont et al, 2007
Provisioning	**Products obtained from the Ecosystem**
Supportive	**Necessary for the production of all other ecosystem services, but do not yield direct benefits to humans.**
Cultural	**Non-material benefits people obtain from ecosystems**
Regulating	**Benefits obtained from the regulation of ecosystem processes**

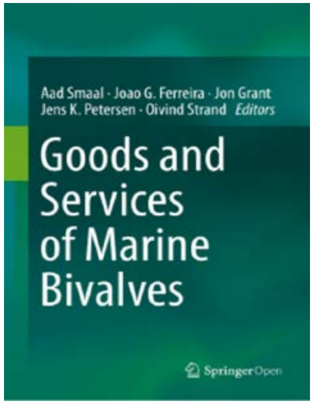
BACKGROUND : ECOSYSTEM G&S CONCEPT

How to include environmental impacts in decision making ?

- 1920+ : environmental economics: external effects need to be internalised as cost factor. How to valorize?
- 1970+ : valorize nature: what is the price of nature?
- 1992: Convention on Biodiversity, Rio de Janeiro,
  = ecosystem approach, holistic
  = **paradigm shift**: from *impacts* to *ecosystem functions*

- 2003: Millennium Ecosystem Assessment: quantification
- 2009: TEEB project: The Economics of Ecosystem functions and Biodiversity: case studies
- 2019: Goods and Services of Marine Bivalves
  23 review papers + introductions





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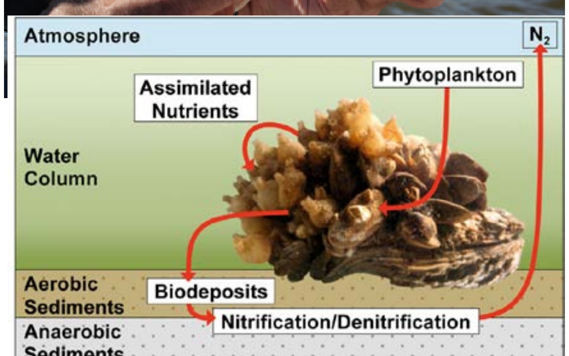
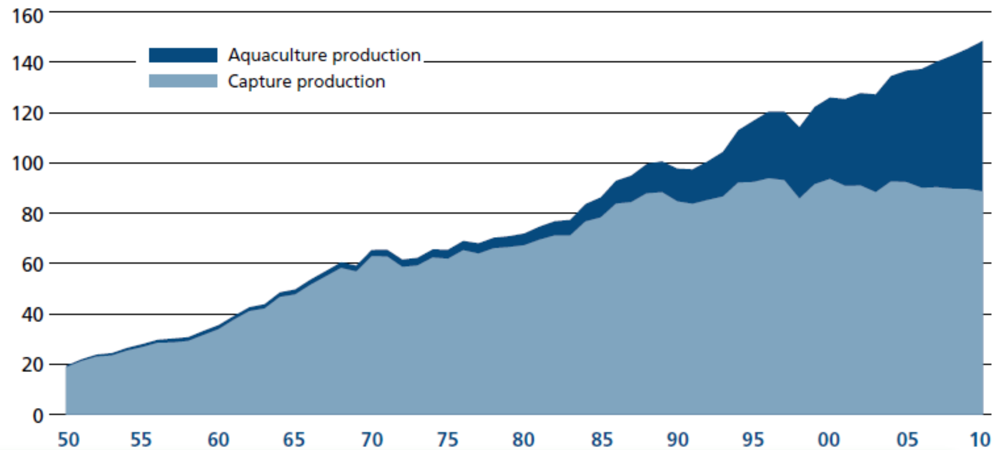
GOODS AND SERVICES OF Marine Bivalves



I - PROVISIONING:

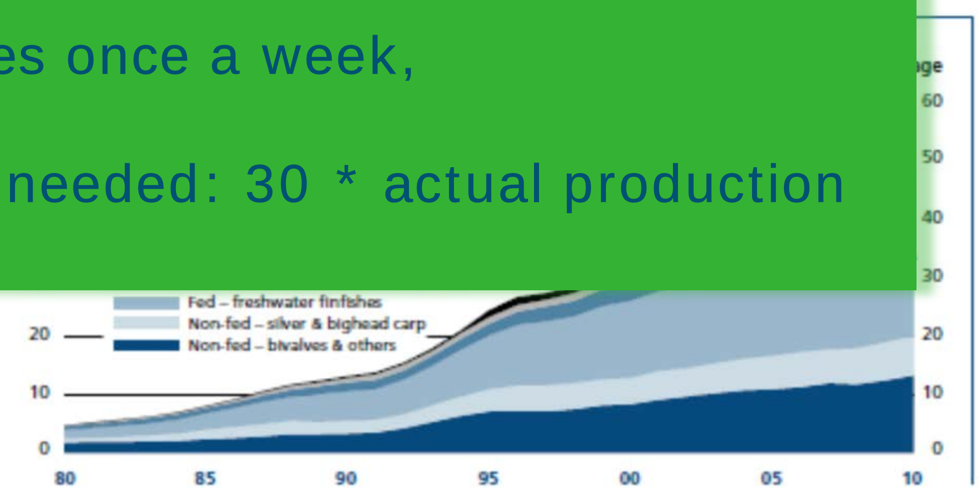
products obtained from the bivalves

- Food
- Pearls
- Shells



If 10^9 people eat bivalves once a week,

500.000 mln tons/year is needed: 30 * actual production



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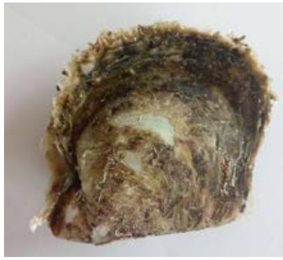
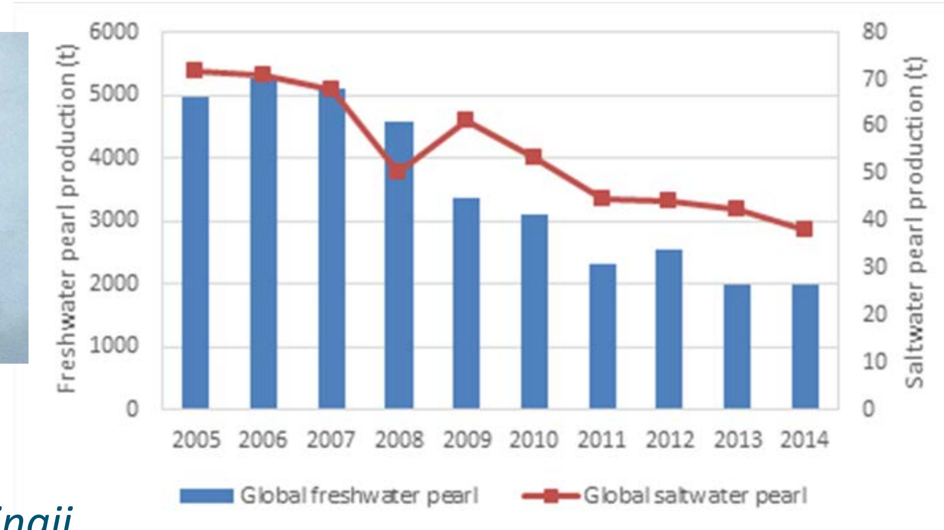
PROVISIONING: PEARLS



Pearl oyster
Pinctada martensii

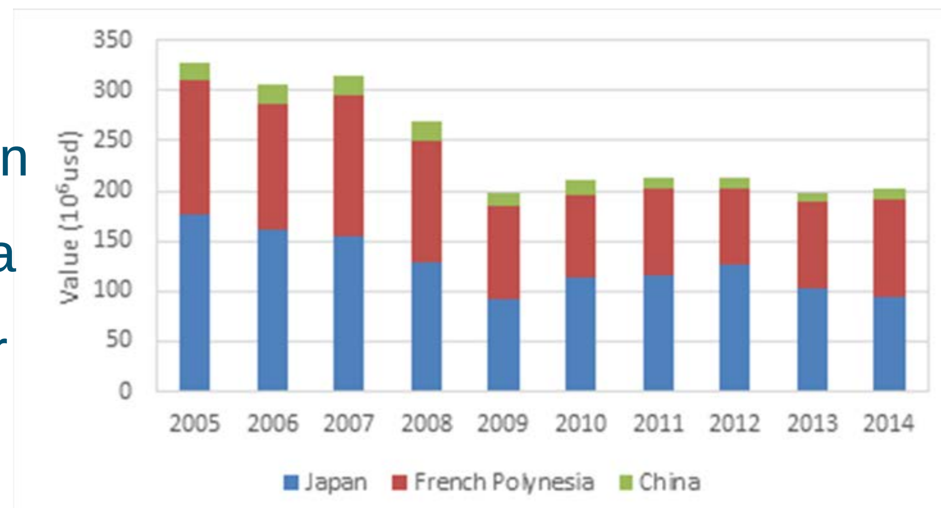
Akoya
pearls

Triangle sail
mussel
Hyriopsis cumingii



Pearl production and yield decreased due to overproduction of fresh water pearls from China

Marine pearls have much higher value



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PROVISIONING: SHELLS AS RAW MATERIAL

ISOLATION

BUILDING

SEED
COLLECTORS;
SUBSTRATE

ANNUAL PRODUCTION:
14 MTON =
4 MTON MEAT
10 MTON SHELL

Tremendous resource :
FURTHER APPLICATIONS ?

Opportunities for:
- Circular economy
- Climate robust economy

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Goods & Services	
Provisioning	**Food production: aquaculture √** **Pearl production √** **Raw material: shells √**
Supportive	**Biologically mediated habitat: shellfish reefs** **nutrient cycling** *Do not yield direct benefits to humans*
Cultural	**Cultural heritage and identity: scallop shells** **Cognitive benefits: sclerotology** **Leisure and recreation: shell collection** **Feel good or warm glow: decoration**
Regulating	**Bioremediation of waste** **Gas and climate regulation: C sequestration** **Disturbance prevention: eco-engineering**

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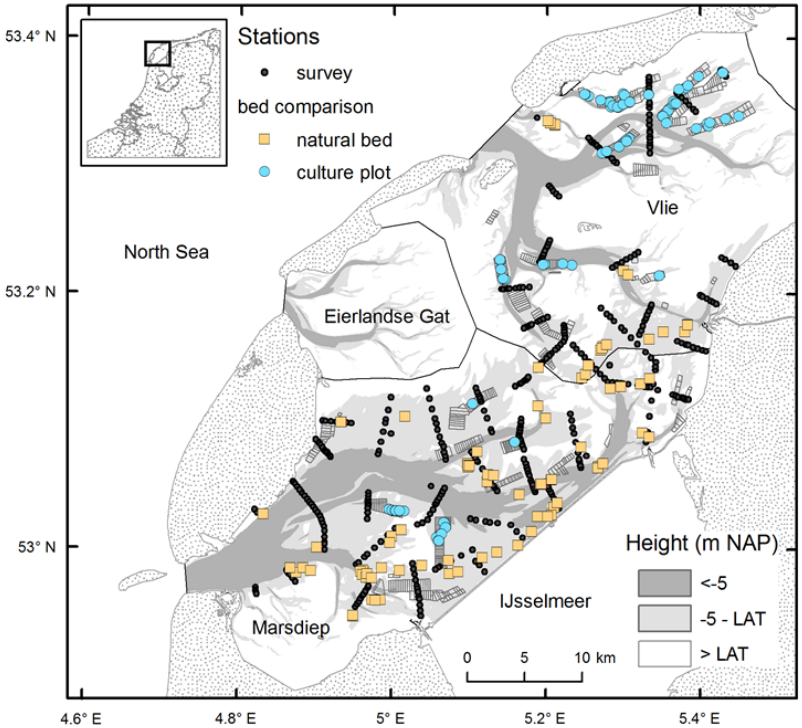
II SUPPORTIVE: HABITATS

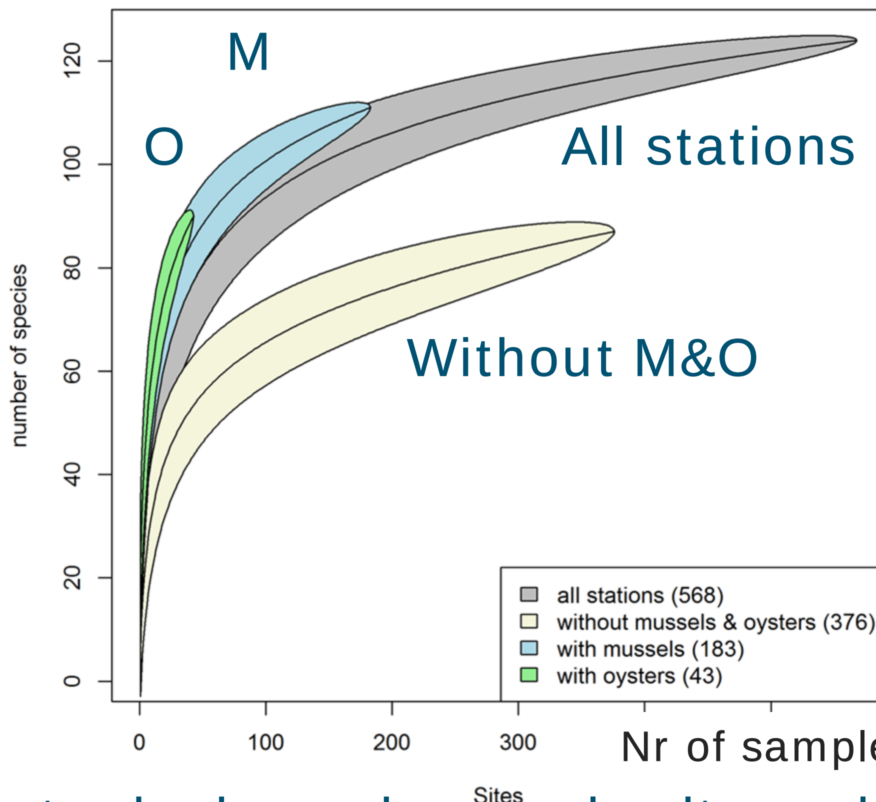
Shellfish assemblages are biodiversity hotspots for sessile and mobile fauna (Creaymeersch & Jansen 2019)

Fig. 7. Diagrammatic representation of cross-sectional view of a small *Mytilus* island. Many associated animals use several micro-habitats (shell surface of *M. edulis*, space in the patch, algae, sediments, etc.). Several inhabitants, *Typosyllis adamanteus kurilensis, Perinereis cultrifera, Notoplana humilis, Collisella heroldi, Littorina brevicula, Acanthochiton rubrolineatus, Hyale grandicornis, Jassa falcata* and *Hemigrapsis sanguineus*, and 2 kinds of algae, *Sargassum* and *Laurencia* are shown. *Chthamalus challengeri* are seen around the island

BIODIVERSITY WILD BEDS / CULTURE PLOTS



Nr of species



Nr of samples

Survey on wild mussel beds, oyster beds, and mussel culture plots;

2008 – 2010: 568 stations in 3 yrs

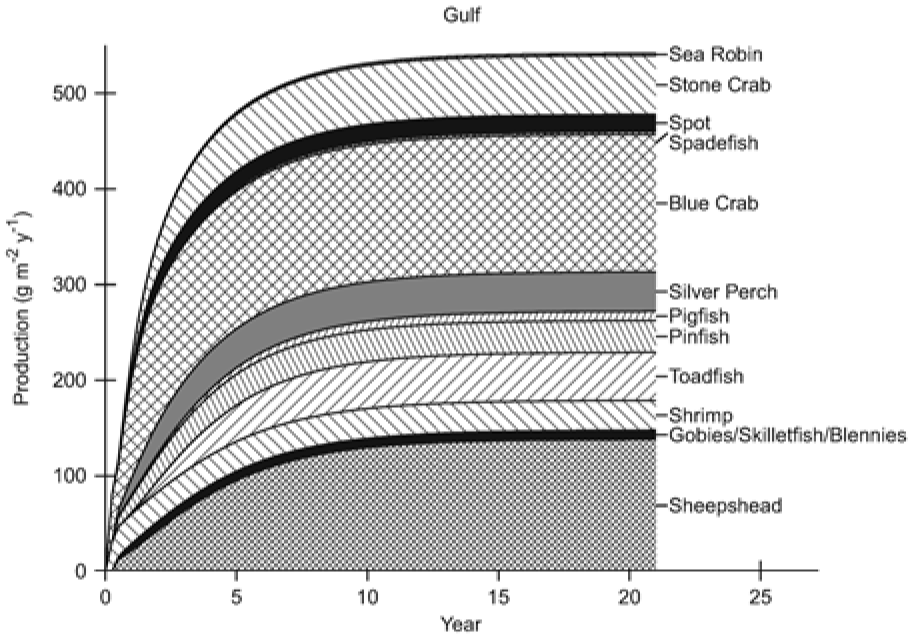
→ shellfish beds = biodiversity hot spots

SPECIES NR WILD BEDS / CULTURE PLOTS

- **84** species on wild beds (5 unique)
  > barnacles, sea anemone
- **102** species on mussel culture plots (23 unique)
  > ragworm, crab, starfish
- Salinity, spatial issues important

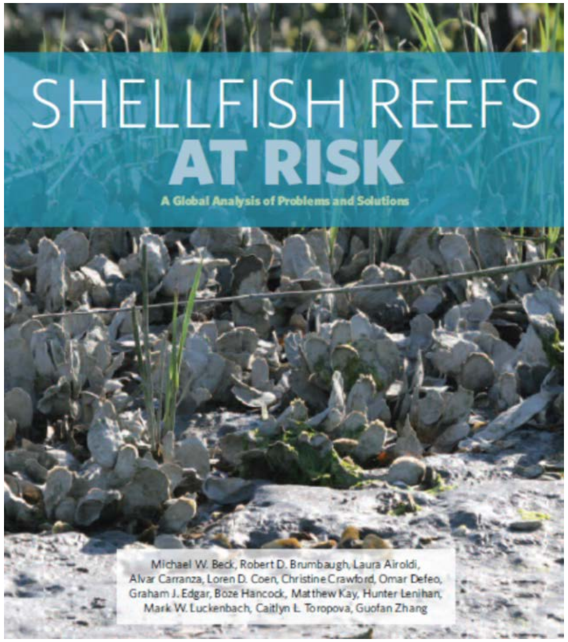
➢ Combine exploitation and nature conservation?
Profit & Planet

Enhanced Production of Finfish and Large Crustaceans by Bivalve Reefs



Hancock & Ermgassen (2019)

Status Flat Oysters in Europe: *Threatened*



TNC REPORT 2009

Ecoregion	Bay	Condition (3 2 1 0)	Species	References
Adriatic Sea		1	O. edulis	(1-8)
	Grado lagoon	0	O. edulis	(5, 7)
	Gulf of Trieste	1	O. edulis	(7, 9)
	Po Delta lagoons	0	O. edulis	(1, 8)
	Venezia (lagoon)	0	O. edulis	(2, 3)
	Limski Kanal	1	O. edulis	(4)
	Mali Ston Bay	1	O. edulis	(10)
Aegean Sea		1	O. edulis	(11, 12)
	Thessaloniki Bay	0	O. edulis	(11, 12)
Baltic Sea		1	O. edulis	(14-16)
Black Sea		1	O. edulis	(33, 34)
Celtic Seas		1	O. edulis	(50-64)
	Belfast Lough	1	O. edulis	(50-52, 65, 66)
	Bertraghboy Bay	1	O. edulis	(52, 67)
	Cardigan Bay	1	O. edulis	(50, 62, 66)
	Carlingford Lough	1	O. edulis	(50-52, 65, 66)
	Galway Bay	2	O. edulis	(51, 52, 68-70)
	Kilkieran Bay	1	O. edulis	(51, 52, 67, 69)
	Lough Foyle	2	O. edulis	(50-52, 65, 66, 68, 71)
	Menai Strait	1	O. edulis	(50, 54, 62)
	Milford Haven	1	O. edulis	(50, 53, 54, 62)
	Strangford Lough	1	O. edulis	(51, 72, 73)
	Swansea	1	O. edulis	(50, 53, 62)
North Sea		0	O. edulis	(107, 108)
	Dogger Bank English Channel	1	O. edulis	(50)
	Firth of Forth	0	O. edulis	(50, 54, 59)
	Rivers Crouch and Roach	2	O. edulis	(50, 53, 57, 58)
	The Wash	1	O. edulis	(50)
	Wadden Sea	0	O. edulis	(14, 15, 109-119)

(Airoldi & Beck, 2007)

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Background: History of North Sea Flat Oysters

Olsen map **1883**:

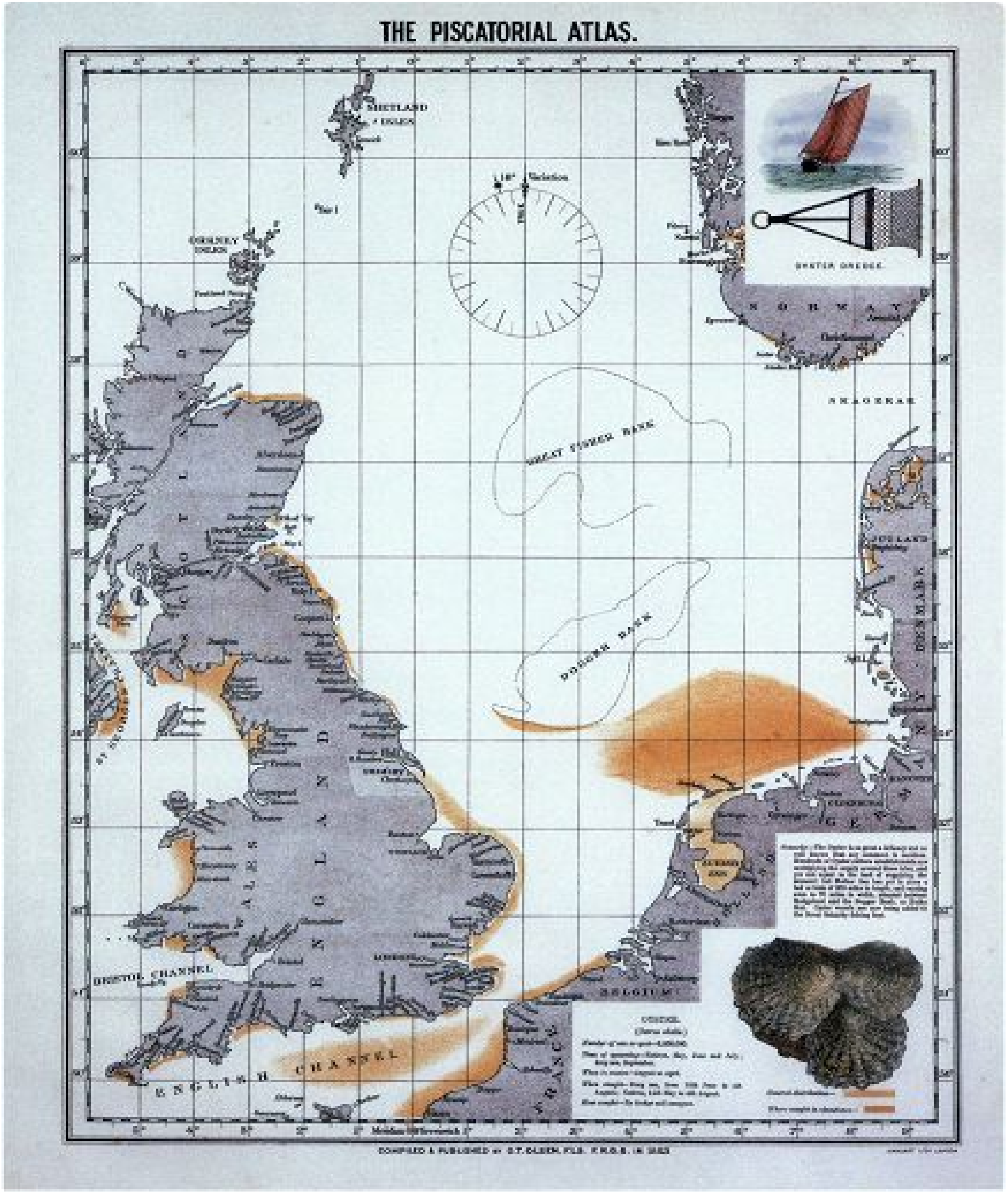
= North Sea oyster grounds

= Wadden Sea

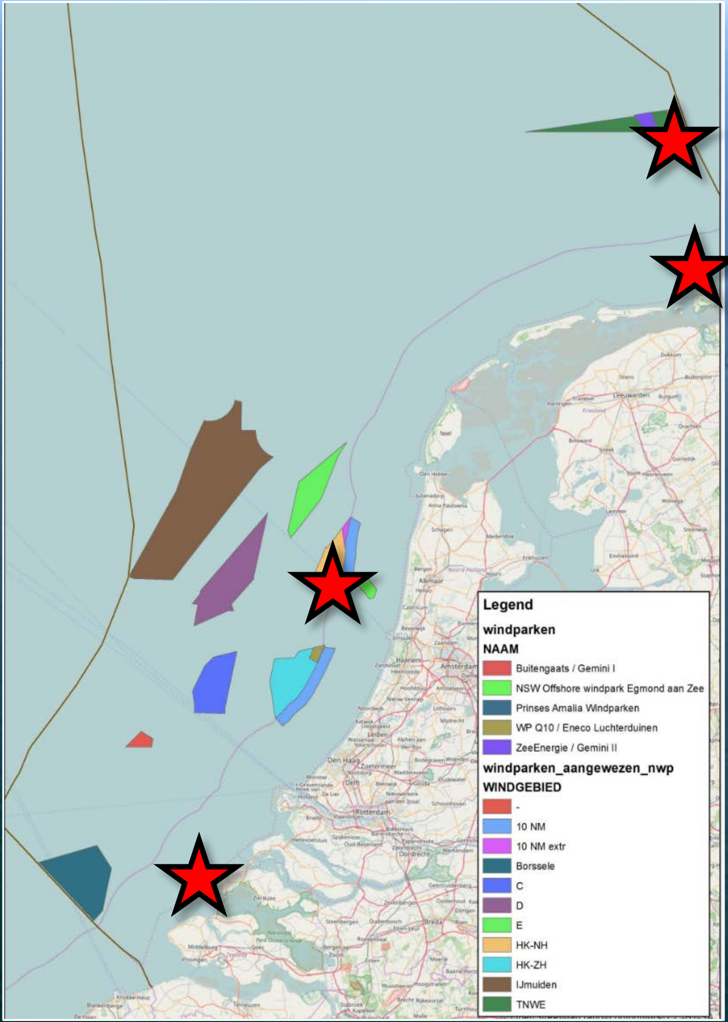
= Belgian coast

= English channel

Extensive Flat Oyster stocks have occurred

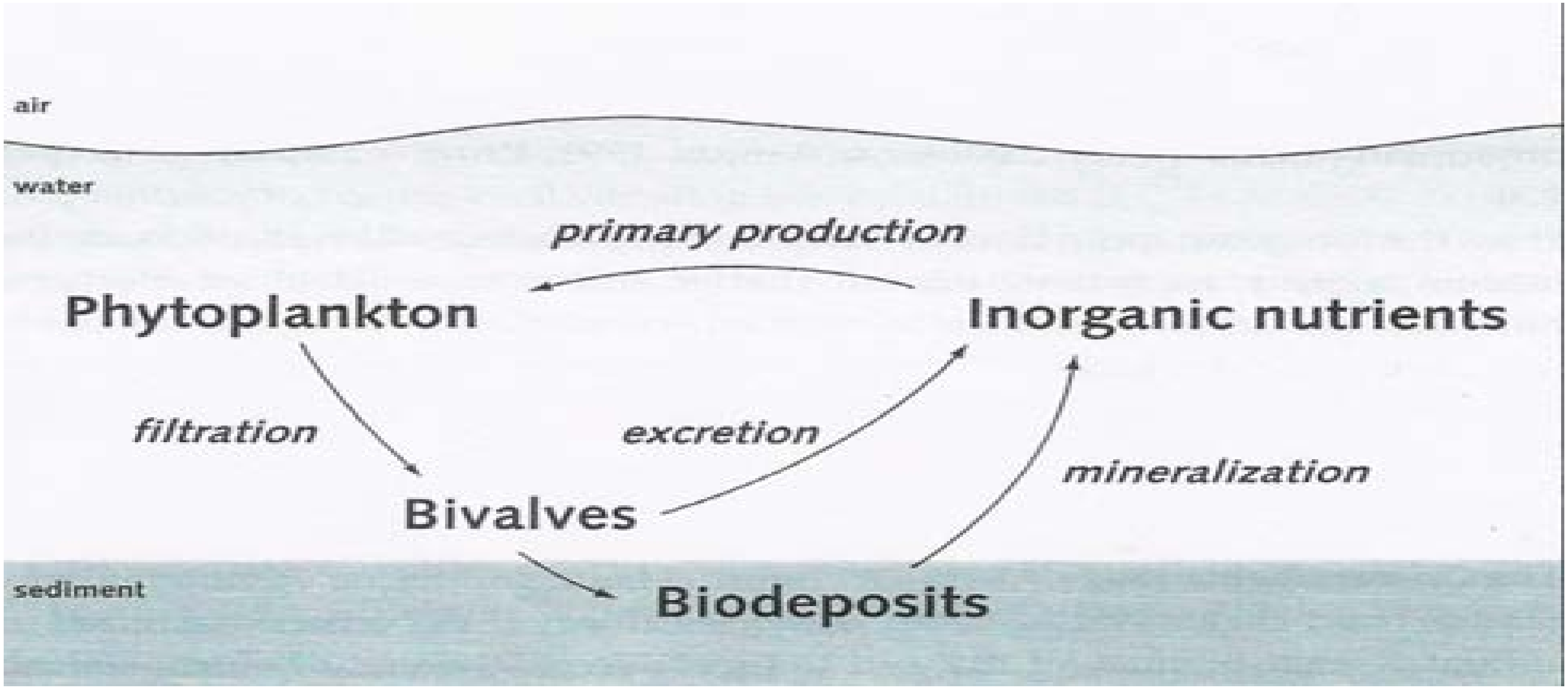


New offshore area’s
Multi-use of space
Potential for restoration
Enhance biodiversity
If successful: harvest potential?



SUPPORTIVE: NUTRIENT CYCLING

- biofiltration and biodeposition by bivalves
- stimulates nutrient regeneration and phytoplankton turnover
- motor in nutrient cycle
- *feedbacks* by the filter feeders



Goods & Services	
Provisioning	**Food production: aquaculture √** **Pearl production √** **Raw material: shells √**
Supportive	**Biologically mediated habitat: shellfish reefs √** **nutrient cycling √**
Cultural	**Cultural heritage and identity: scallop shells** **Cognitive benefits: sclerotology** **Leisure and recreation: shell collection** **Feel good or warm glow: decoration** *Non-material benefits*
Regulating	**Bioremediation of waste** **Gas and climate regulation: C sequestration** **Disturbance prevention: eco-engineering**

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CULTURAL SERVICES

Mythical: Venus
Goddess of love

Religious
La Toja San Sebastian church
Pilgrims carry Scallop Shells

Golden ages
"Eat oysters
Love longer"

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SCIENCE and EDUCATION

Shells as Archives

Archeology: record of human food habits and resources management

Sclerochronology: history traits and reconstruction of environmental and climatic changes through space and time

4TH INTERNATIONAL
SCLEROCHRONOLOGY
CONFERENCE
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Education

Shellfish restoration: Many projects in the US

Involves schools, local communities

In Europe flat oyster restoration initiated by WWF (NGO)

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RECREATION & LEISURE

- Collecting shells
- Sea gardening
  - Community issue
  - Experience in Denmark

DECORATION

Goods & Services	
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Regulating	**Bioremediation of waste** **Gas and climate regulation: C sequestration** **Disturbance prevention: eco-engineering** *Climate robust management, Blue-green solutions, circular economy*

REGULATING: BIOFILTRATION

Mitigate turbidity;

Mitigate eutrophication

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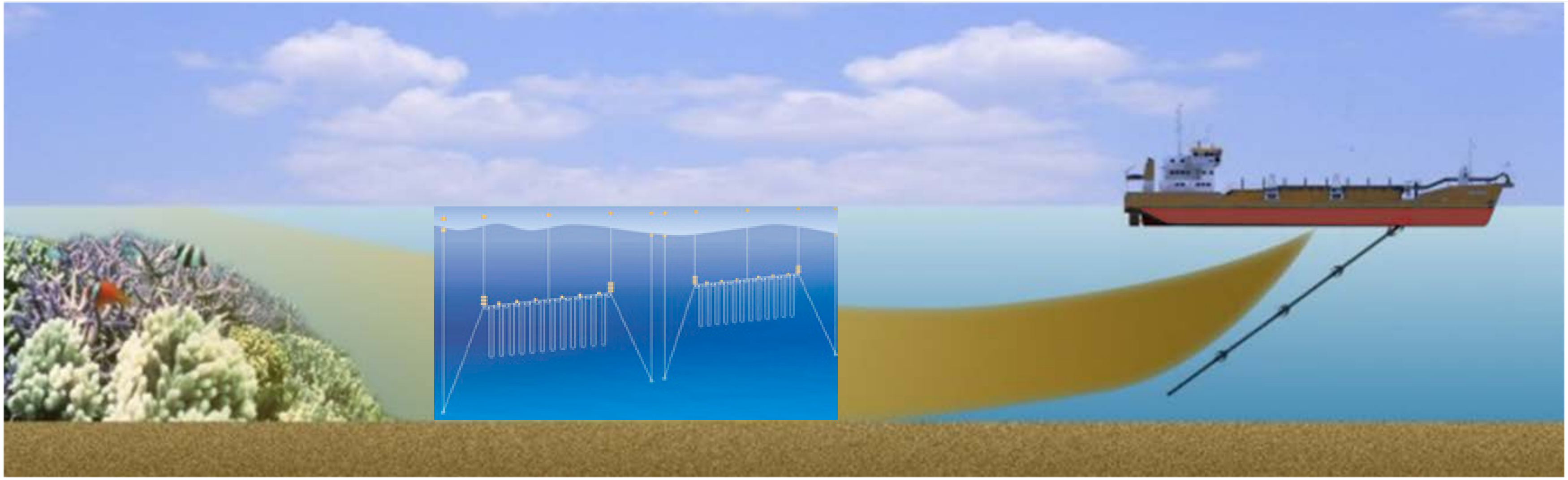
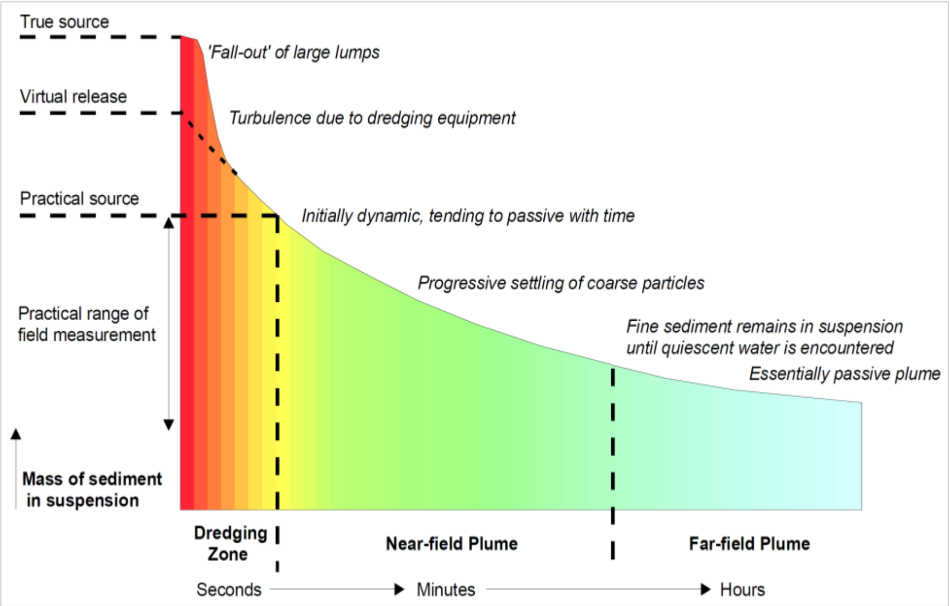
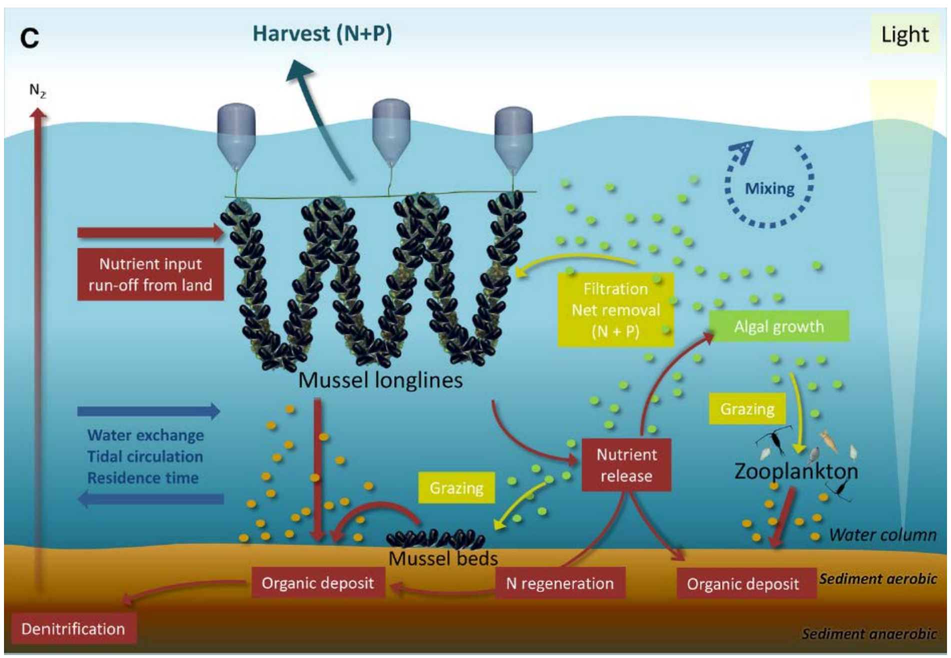
Biofiltration: reduction of turbidity due to dredging

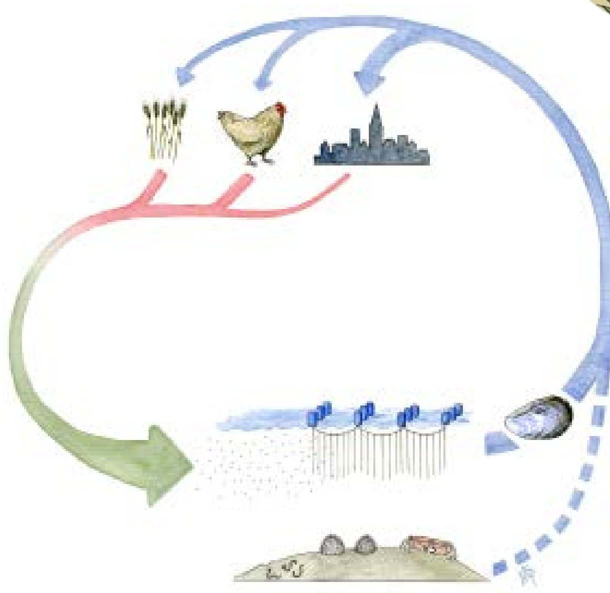




BIOREMEDIATION: diffuse N&P sources

- Nutrient extraction through harvest
- Denitrification
- Enhance transparency
- Nutrient regeneration





To be considered:

How effective is it

Where to locate

What to do with the product

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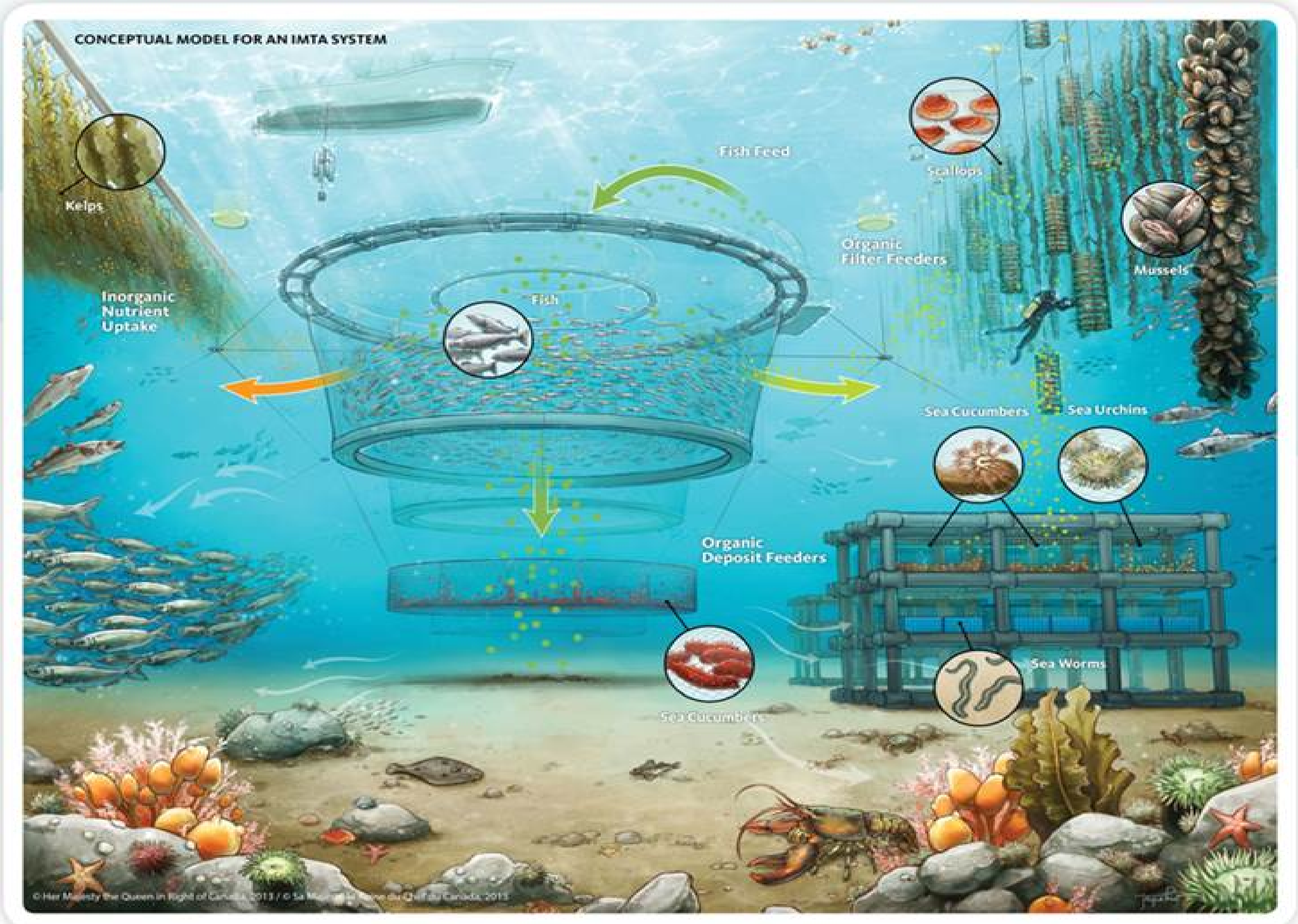
INTEGRATED MULTITROPHIC AQUACULTURE **IMTA**



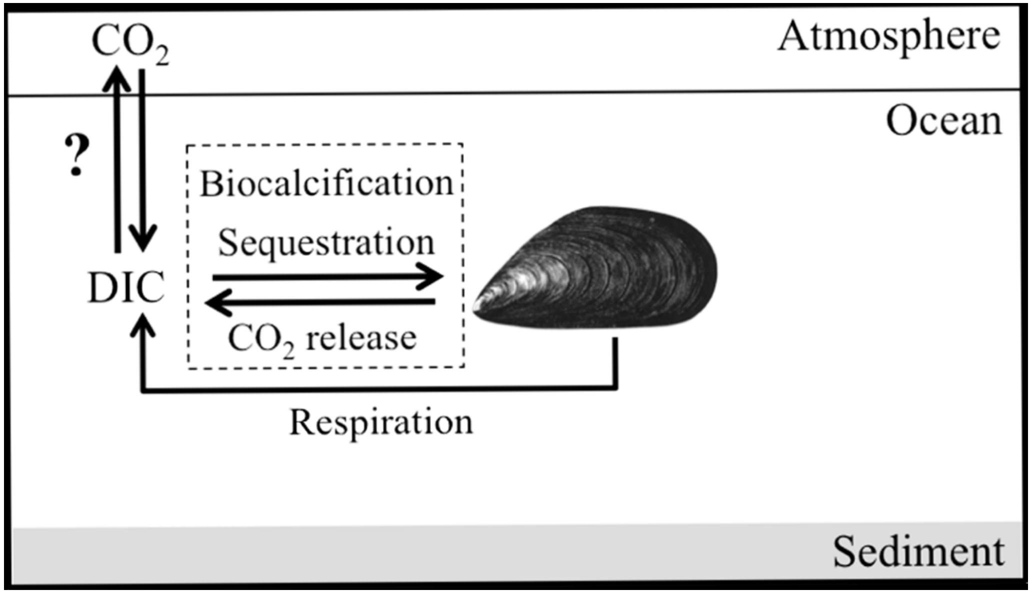
BIVALVE CARBON SEQUESTRATION

Bivalve shell formation involves :

Respiration: $CH_2O + O_2 \rightarrow CO_2 + H_2O$

Biogenic calcification: $Ca^{2+} + 2HCO_3^- \leftrightarrow CaCO_3 + CO_2 + H_2O$

C Sequestration: CaCO3 formation



DEBATE:

WHAT IS NET EFFECT

ON C BUDGET ?

Filgueira et al., 2015

CARBON SEQUESTRATION

Table 1. Carbon fluxes in different bivalve species: sequestration (carbon content in the shell), biocalcification (carbon released during biogenic calcification), respiration (carbon released through respiration of organic matter), balance (sequestration minus biocalcification and respiration), ratio balance/sequestration, and bibliographic references.

Species (Habitat)	Sequestration $gC\ m^{-2}y^{-1}$	Biocalcification $gC\ m^{-2}y^{-1}$	Respiration $gC\ m^{-2}y^{-1}$	Balance $gC\ m^{-2}y^{-1}$	Balance/ Sequestration	Reference
Potamocorbula amurensis	23.9[a]	18.0	37.0	-31.1	-1.30	Chavaud et al. 2003
Mytilus edulis (sheltered)	3.8	2.3[a]	1.9	-0.4	-0.09	Hily et al. 2013
Mytilus edulis (semiexposed)	129.2	77.4[a]	44.3	7.6	0.06	Hily et al. 2013
Mytilus edulis (exposed)	45.0	27.0[a]	19.6	-1.6	-0.03	Hily et al. 2013
Crassotrea gigas (sheltered)	286.8	172.0[a]	11.9	103.0	0.36	Hily et al. 2013
Crassostrea gigas	15.5[a]	11.1	32.7	-28.3	-1.83	Lejart et al. 2012
Chlamys farreri	78.1	54.0	71.7	-47.6	-0.61	Jiang et al. 2014
Ruditapes philippinarum	98.2	66.7	272.4	-241.0	-2.45	Mistri & Munari 2012
Arculata senhousia	46.0	11.7	50.4	-16.1	-0.35	Mistri & Munari 2013
Mytilus galloprovincialis	1639.2	1041.6	2253.6	-1656.0	-1.01	Munari et al. 2013

[a] shell dissolution is included in this term

Most studies: no net sequestration through bivalves

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CARBON SEQUESTRATION of bivalve culture

Filgueira et al (2015) :

- Bivalves are culture for consumption, not as C sink
- Meat and shell formation to be considered separate
- Respiration for shell formation 10 % of C intake

Results: effective net C sequestration

Species (Habitat)	Sequestration $gC\ m^{-2}y^{-1}$	Biocalcification $gC\ m^{-2}y^{-1}$	Respiration $gC\ m^{-2}y^{-1}$	Balance $gC\ m^{-2}y^{-1}$	Balance/ Sequestration	Reference
Potamocorbula amurensis	23.9	18.0	3.7	2.2	0.09	Chavaud et al. 2003
Crassostrea gigas	15.5	11.1	3.3	1.1	0.07	Lejart et al. 2012
Chlamys farreri	78.1	54.0	7.2	16.9	0.22	Jiang et al. 2014
Ruditapes philippinarum	98.2	66.7	27.2	4.2	0.04	Mistri & Munari 2012
Arculata senhousia	46.0	11.7	5.0	29.3	0.64	Mistri & Munari 2013
Mytilus galloprovincialis	1639.2	1041.6	225.4	372.2	0.23	Munari et al. 2013

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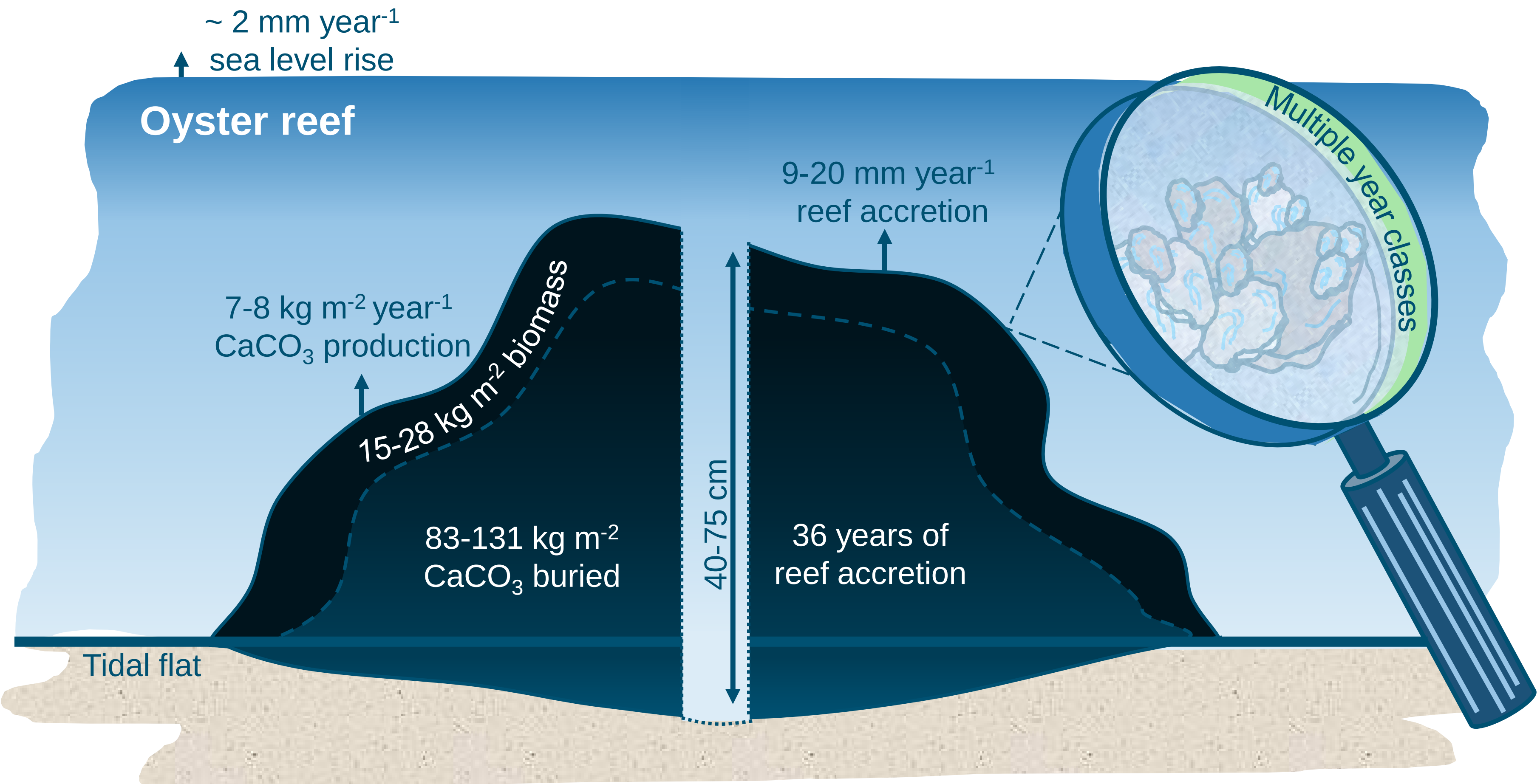
Significant biogenic carbonate masses



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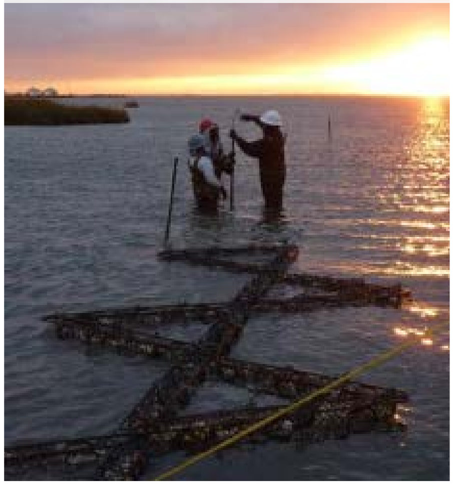
REGULATING : ECO-ENGINEERING







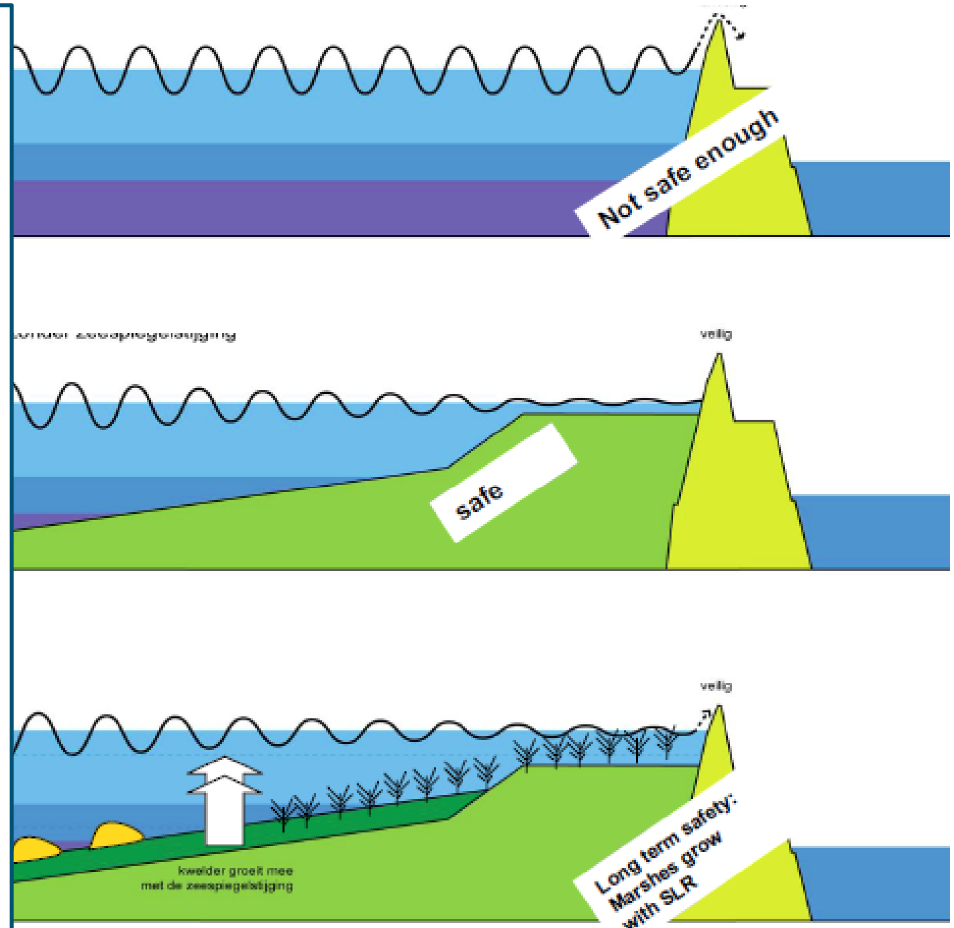
Pictures from http://projects.tnc.org/coastal/

BUILDING WITH NATURE

Hard barriers => Soft transition zones

RESILIENCE

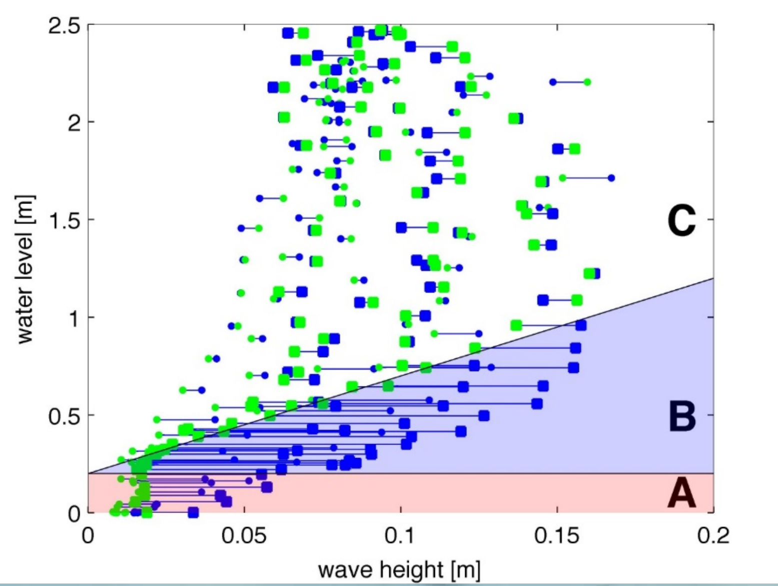
- use the natural dynamics of the ecosystem
- to create flexible and sustainable infrastructure (cost efficient)
- while enhancing nature values



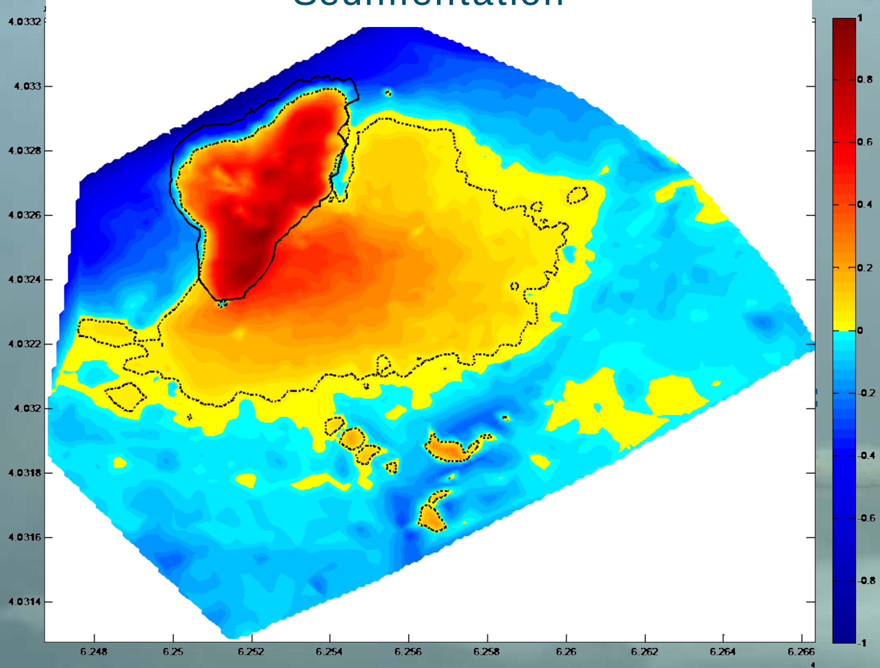
Oyster reefs in the Eastern Scheldt:

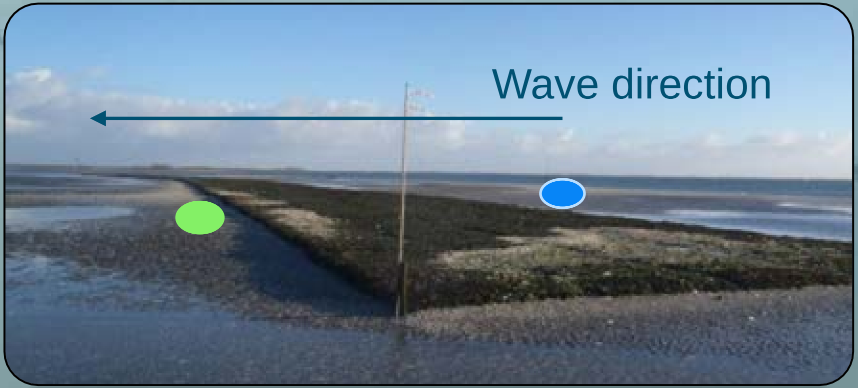
- Form structures
- Collect sediment
- Dampen waves
- Form habitat

Wave attenuation



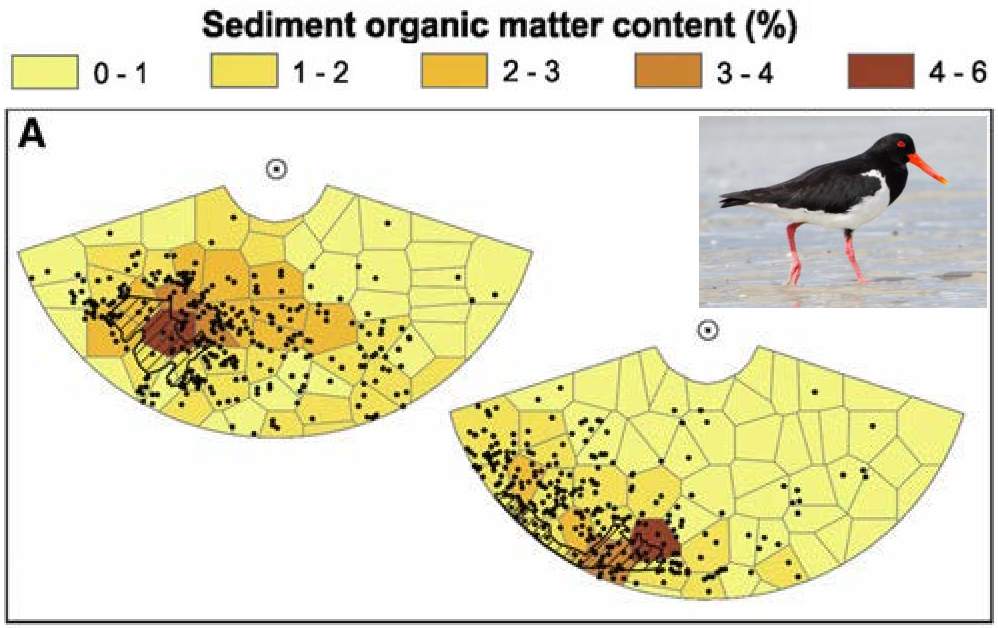
Sedimentation





Walles *et al.* 2014

Consumer-resource interactions are affected by reefs far beyond the boundaries of the reefs



Distribution of sediment organic matter content in relation to the distribution of oystercatchers. Black dots represent the positions of the birds.
Zee *et al*. 2012

High densities of cockles coastward of a mussel bed in the intertidal flats of Schiermonnikoog, The Netherlands.
Donadi *et al.* 2013

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IN CONCLUSION

THIS SETS AN AGENDA FOR

- AN INTEGRATED APPROACH
- BASED ON CASE STUDIES
- DEVELOPMENT OF TOOLS AND MODELS FOR QUANTIFICATION

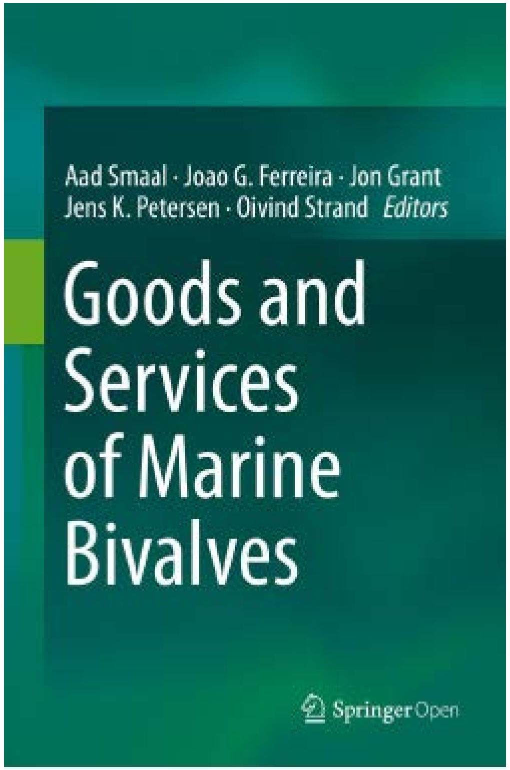
PERSPECTIVES: find synergies

Combination of services: **WHY**?

- To provide food for the growing world population, low food chain aquaculture is a **must**
- Given the worldwide loss of bivalve beds and reefs, shellfish restoration is a **must** as well
- Climate change and sea-level rise ask for eco-engineered solutions, shellfish reefs: **urgent**
- Bioremediation of nutrient input through bio-accumulation in bivalves is needed for diffuse nutrient sources control: **need**

These applications will profit from an integrated approach, as they all require space, technology and social acceptance

FURTHER READING:



Goods and Services of Marine Bivalves 595 p

Available online for Free / Hard copies:

www.springer.com

A global review of the ecosystem services provided by bivalve aquaculture

Andrew van der Schatte Olivier[1], Laurence Jones[2], Lewis Le Vay[1], Michael Christie[3], James Wilson[4] and Shelagh K. Malham[1]

1 School of Ocean Sciences, Bangor University, Menai Bridge, UK
2 Centre for Ecology and Hydrology, Bangor, UK
3 Aberystwyth Business School, Aberystwyth University, Aberystwyth, UK
4 Deepdock Ltd, Bangor, UK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