Exploration of combining nature development and low-trophic aquaculture in offshore wind farms; a case study in the Dutch North Sea

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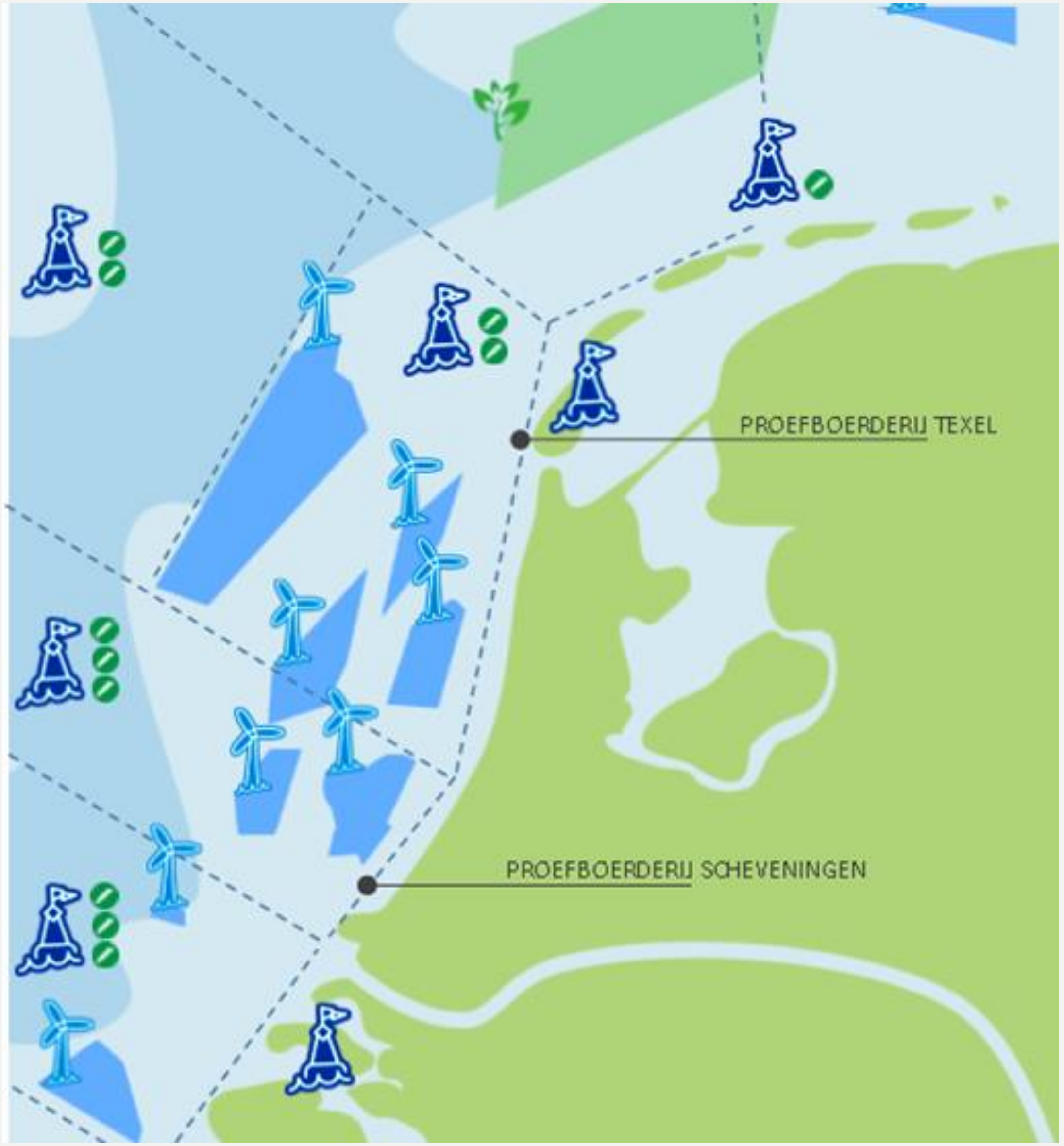
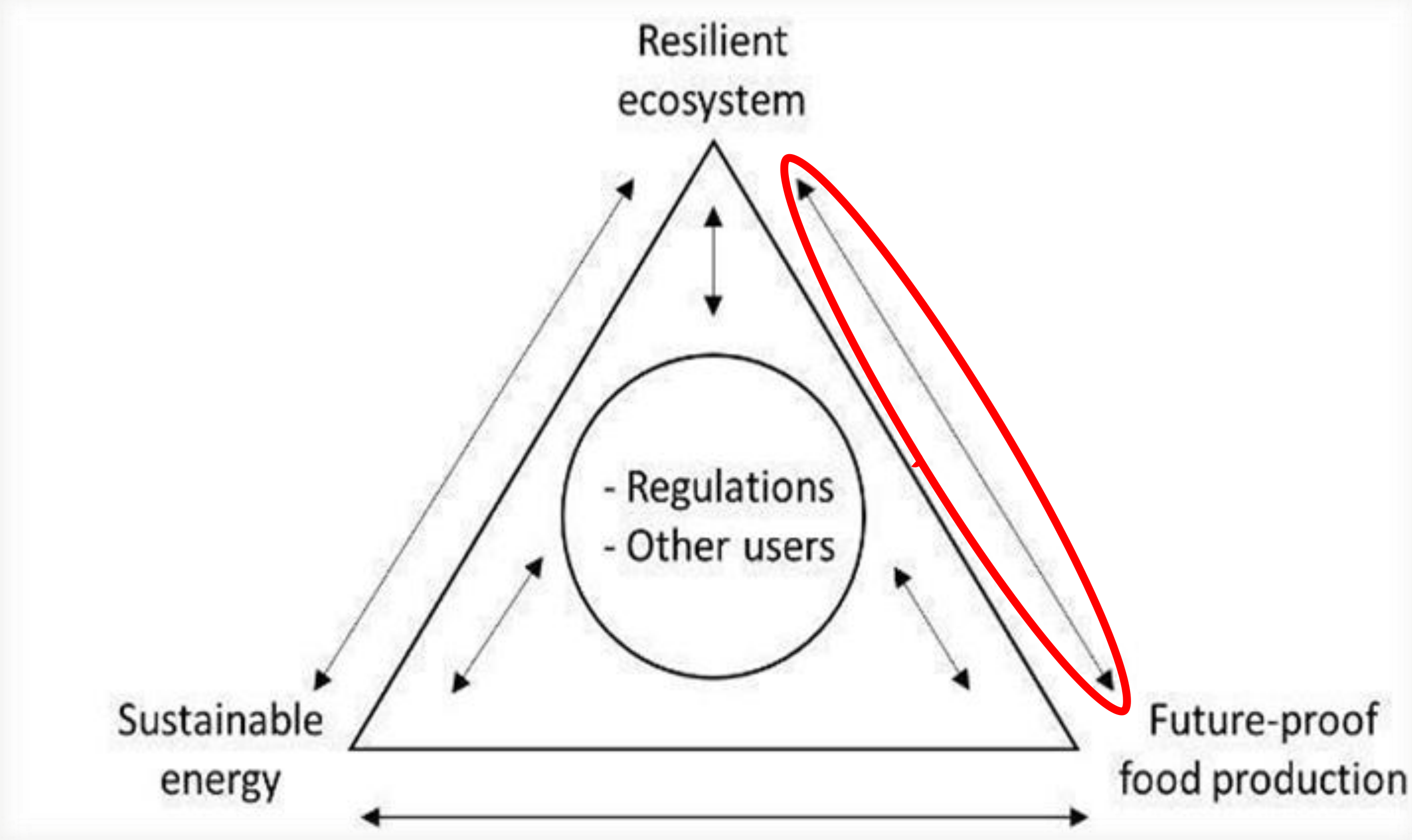
Dutch North Sea

- Great potential for aquaculture
- Off-shore aquaculture is absent
- New OWFs create system tilt (1600km2)
- North sea is in not good environmental status
- Multi-Use; combination between windfarms, aquaculture and nature



North Sea strategy 2030 (IDON)

"Good environmental status"



"Offshore wind farms"

" Low-trophic aquaculture"

Multi-use

Low-trophic species are able to supply ecosystem services:

- High biological and economical potential

Area important for nature development and seabed restoration:

- Trawl fishing is prohibited

Research Question and aims

"Which type of low-trophic aquaculture in offshore wind farms is expected to best combine nature development objectives and aquaculture objectives in the Dutch North Sea?"

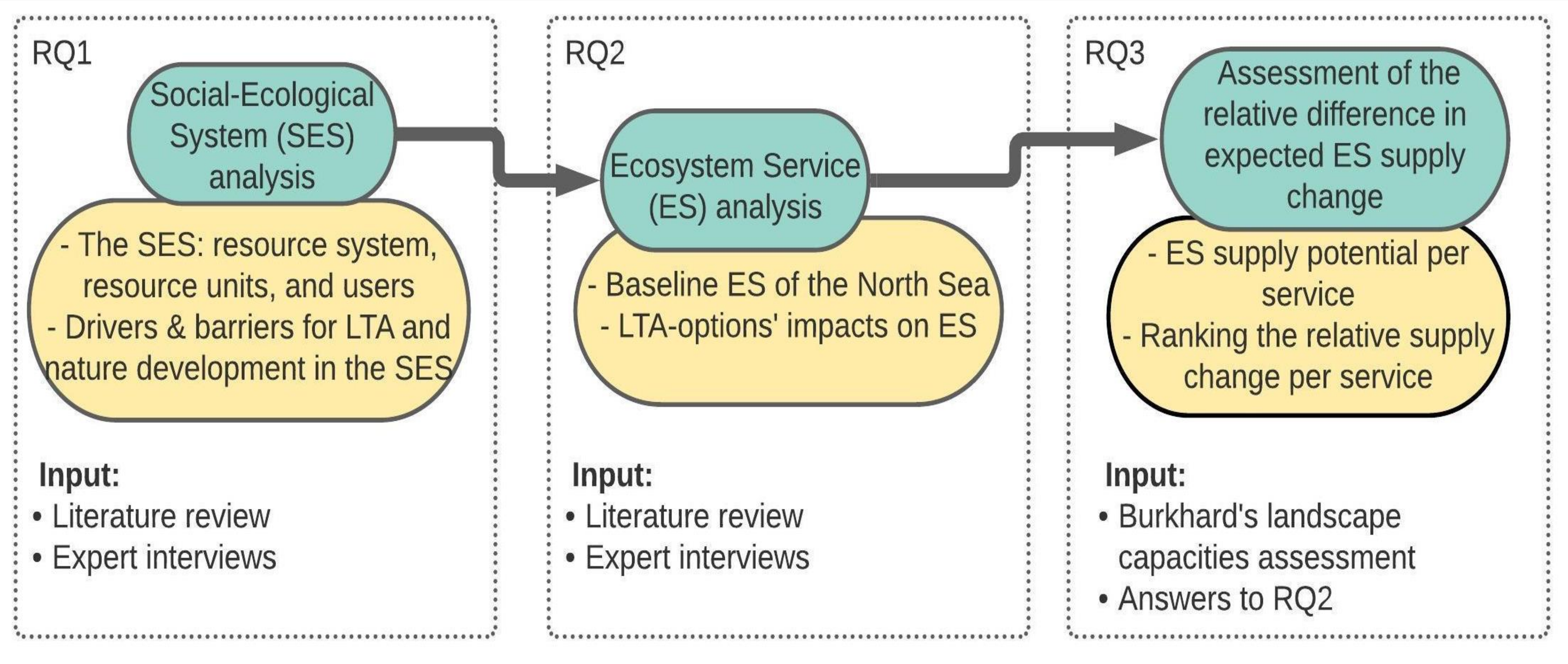
- State-of-the-art offshore LTA
- Synergies and threats
- Contribute to the sustainable management of multi-use activities

Ostrea edulis
(Flat oyster)

Mytilus edulis
(Blue mussel)

Saccharina latissima
(Seaweed)

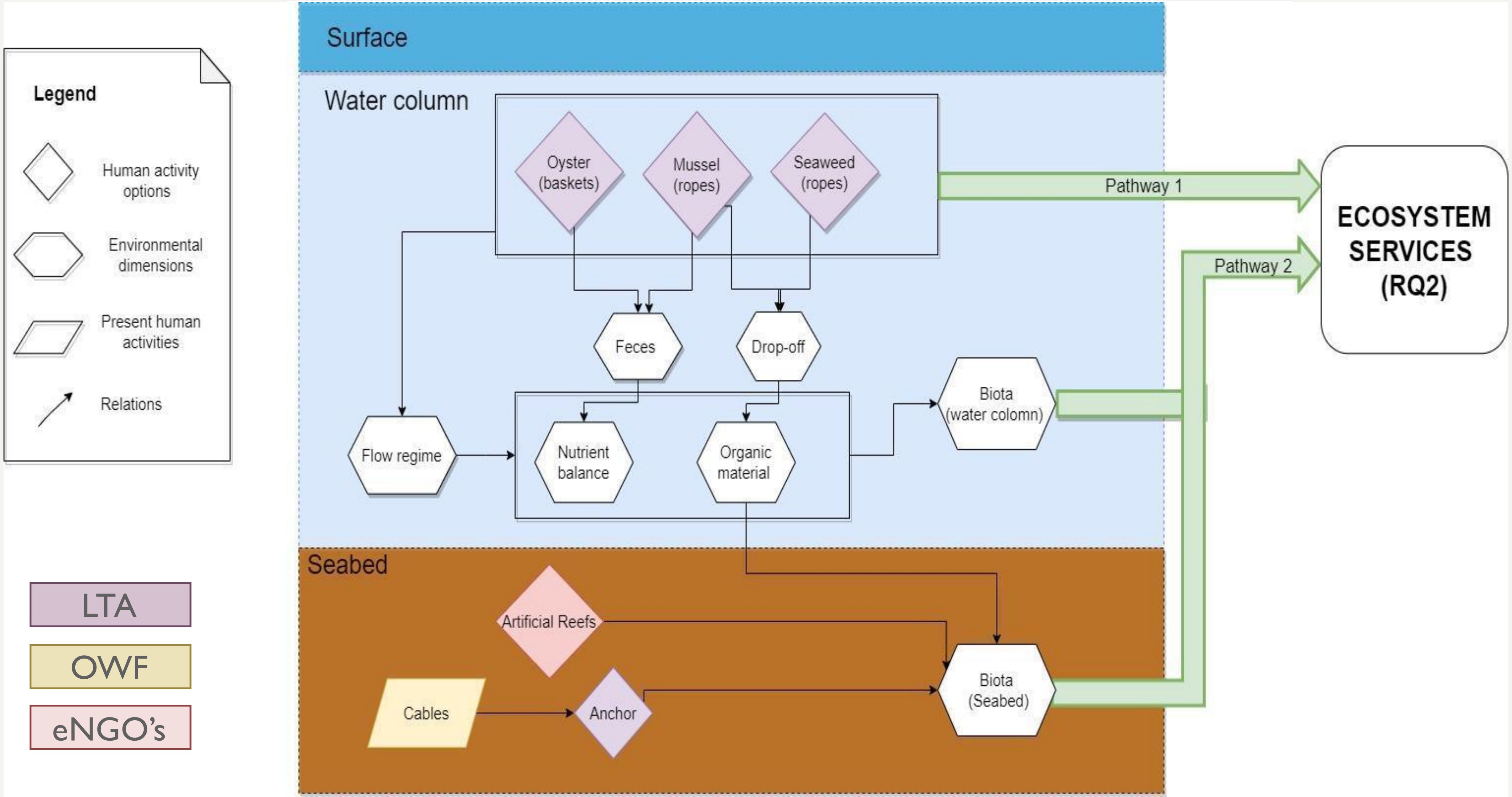
Methods


RQ1
Social-Ecological System (SES) analysis
- The SES: resource system, resource units, and users
- Drivers & barriers for LTA and nature development in the SES
Input:
• Literature review
• Expert interviews
RQ2
Ecosystem Service (ES) analysis
- Baseline ES of the North Sea
- LTA-options' impacts on ES
Input:
• Literature review
• Expert interviews
RQ3
Assessment of the relative difference in expected ES supply change
- ES supply potential per service
- Ranking the relative supply change per service
Input:
• Burkhard's landscape capacities assessment
• Answers to RQ2

Sector	Interviews (2021) (n=7)
Energy	1
Environmental Non-Governmental Organisations	2
Aquaculture (LTA)	2
Facilitator (LTA)	1
Pilot initiatives (LTA)	1
Research & consultancy	1
Other	-

RQ1

Social ecological system: the OWFs in the Dutch North Sea



RQ1

Drivers and barriers

''Obviously you don't want a sea farm in the wings of a windmill'

- Logistics
- Cost related to offshore production
- Seaweed: no-market, low economic value

Potential driver: tender principles

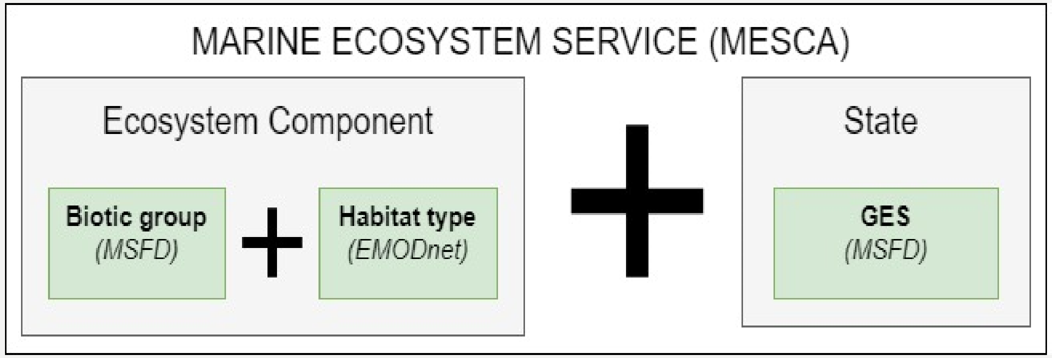
- Nature inclusive anchor
- Partial harvesting
- Sailing together to the site

'Seabed is protected by cultivation above it, which makes it a place where the fishermen no longer can fish.'

RQ2

Creating the baseline

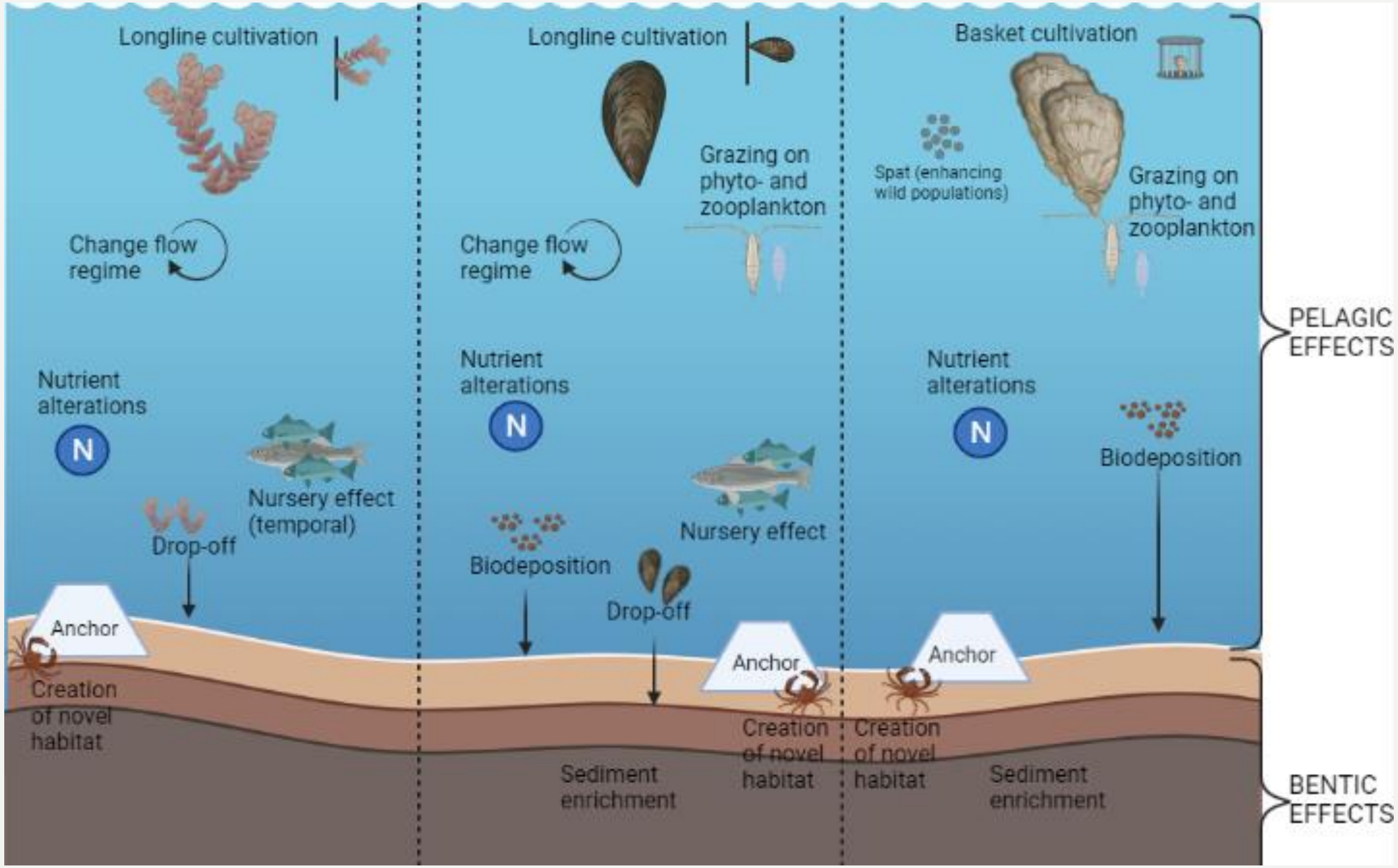
(MESCA Approach from Culhane et al., 2019)



ES no.	ES name	Current Status
P1	Seafood from Wild Plants and Algae	M
P2	Seafood from Wild Animals	M
P3	Plant and Algal Seafood from Aquaculture	M
P4	Animal Seafood from Aquaculture	M
R1	Waste and Toxicant Treatment via Biota	M
R2	Waste and Toxicant Removal and Storage	M
R3	Oxygen Production	M
R4	Seed and Gamete Dispersal	G
R5	Maintaining Nursery Populations and Habitats	N
R6	Gene Pool Protection	N
R7	Pest Control	M
R8	Disease Control	M
R9	Sediment nutrient cycling	N
R10	Chemical Condition of Seawater	M
R11	Global Climate Regulation	M
C1	Scientific and educational	G
C2	Heritage	M
C3	Aesthetic	G
C4	Existence	G
C5	Bequest	G

RQ2

Identification of key modifications across three forms



S. latissima *M. edulis* *O. edulis*

RQ2

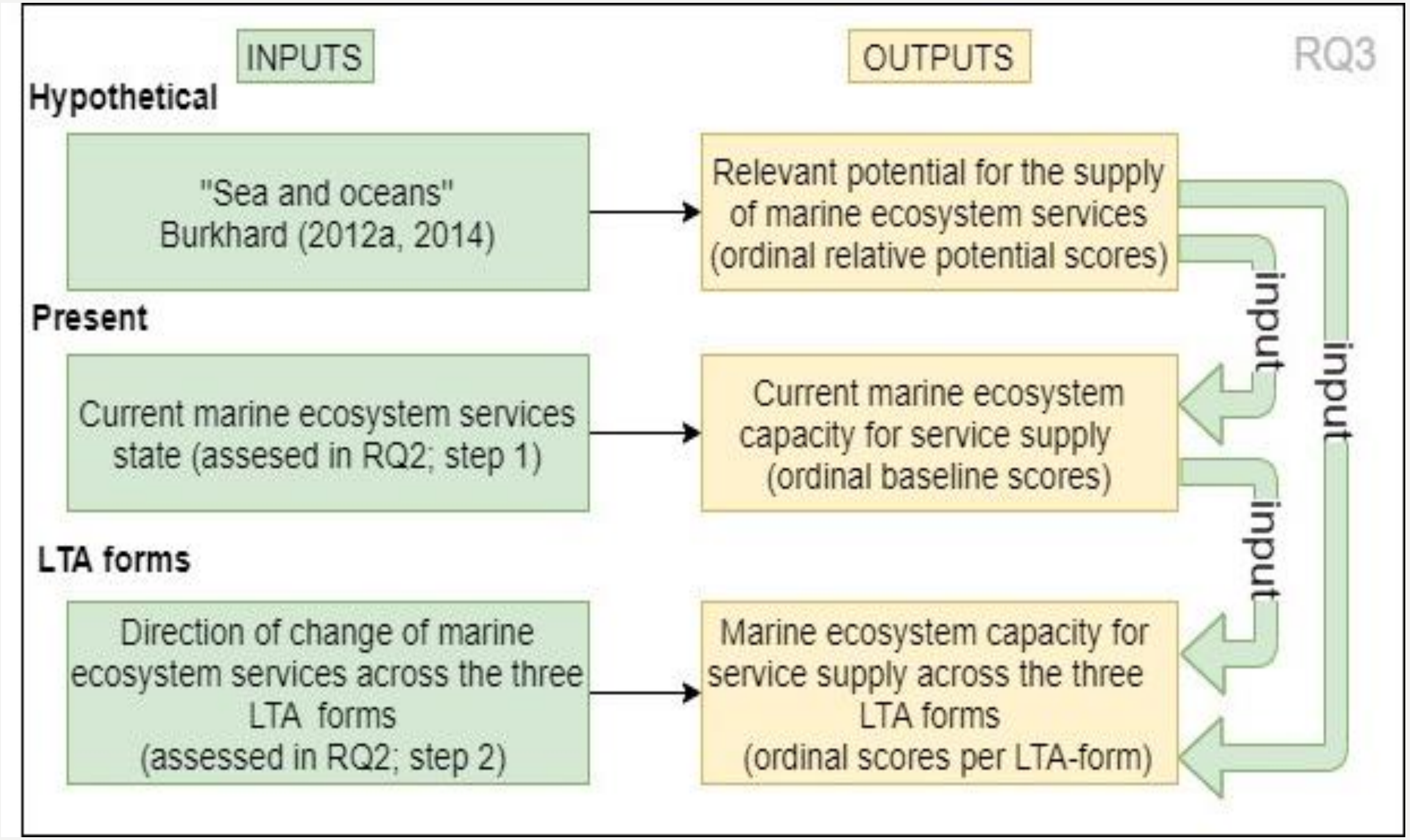
Expected impacts on the supply of ecosystem services

ES no.	ES name	Current Status	Expected Impact (Seaweed)	Expected Impact (Mussel)	Expected Impact (Oyster)
P1	Seafood from Wild Plants and Algae	M	+[a]	none	none
P2	Seafood from Wild Animals	M	++[a, g]	++[d]	+[d]
P3	Plant and Algal Seafood from Aquaculture	M	+[a]	none	none
P4	Animal Seafood from Aquaculture	M	none	+[d]	+[d]
R1	Waste and Toxicant Treatment via Biota	M	+[b]	+[d]	+[d]
R2	Waste and Toxicant Removal and Storage	M	+[b]	+[d]	+[d]
R3	Oxygen Production	M	+[f]	-[d]	-[d]
R4	Seed and Gamete Dispersal	G	+/-[j]	+/-[j]	+[j]
R5	Maintaining Nursery Populations and Habitats	N	++[f]	++[f, g]	+[f, g]
R6	Gene Pool Protection	N	[-][e]	[-][e]	[-][e]
R7	Pest Control	M	[-][c]	[-][e]	[-][e]
R8	Disease Control	M	[-][c]	[-][e]	[-][e]
R9	Sediment nutrient cycling	N	+[a]/-	+/-[d]	+/-
R10	Chemical Condition of Seawater	M	+[a]/-[c]	+/-[d]	+/-[d]
R11	Global Climate Regulation	M	+[a]	+[d]	+[d]
C1	Scientific and educational	G	+[a, b]	+[h]	+[h]
C2	Heritage	M	none	none	+[i]
C3	Aesthetic	G	+[b]/-[a]	none	none
C4	Existence	G	+/-	+/-[h]	+/-[h]
C5	Bequest	G	none	+[h]	+[h]

Expected Impacts

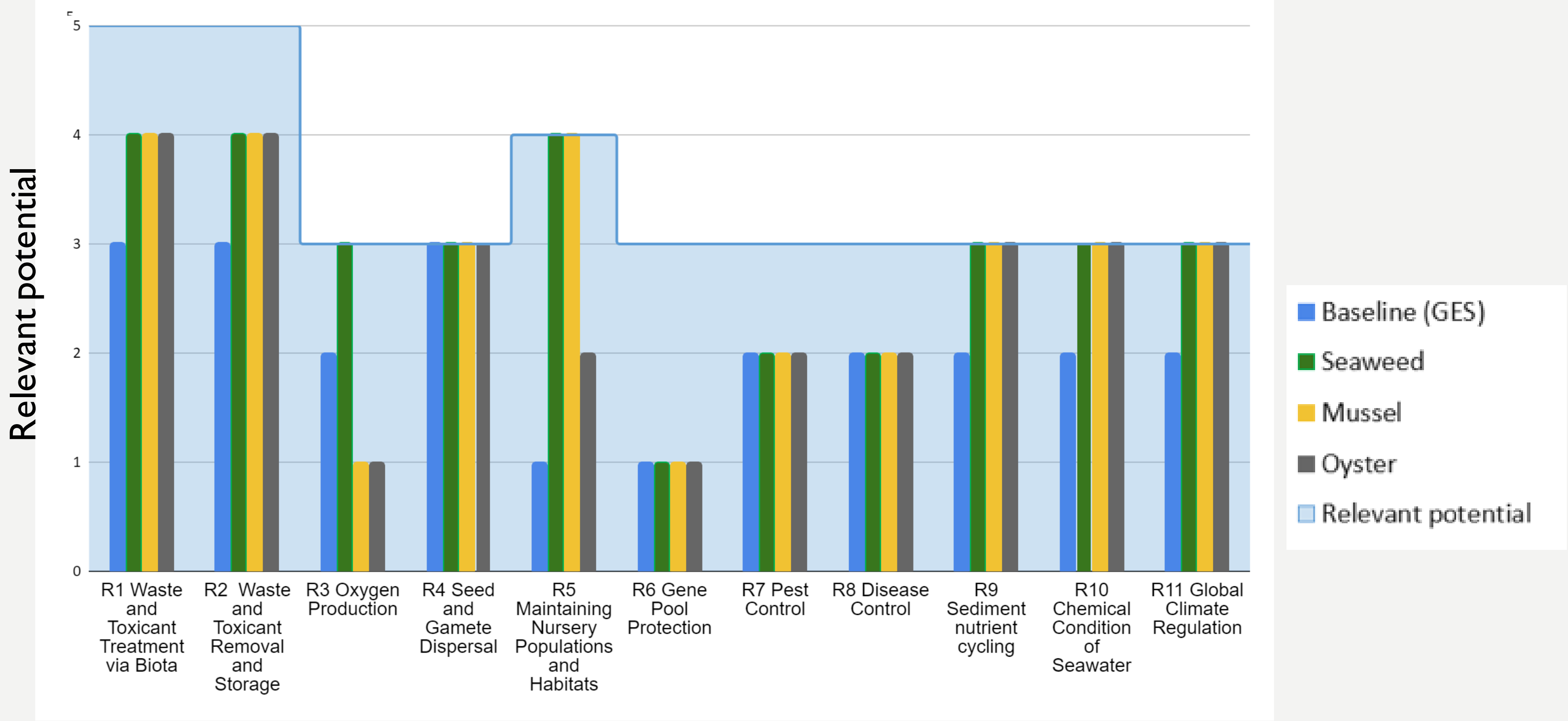
RQ3

Contribution of impact on reinforcing environmental status



RQ3

LTA-forms reinforcing environmental status



RQ3

S. latissima positively impacted most ecosystem services currently in ''not good'' or ''moderate status''

Discussion

Synergy between aquaculture and nature objectives seems possible but limited by (practical and economic) barriers of LTA-industry

Contributions to literature:

- Positive externalities aquaculture
- Offshore cultivation
- Two-sided relationship between state and ES supply
- Baseline created could be used for assessment of other multi-use activities

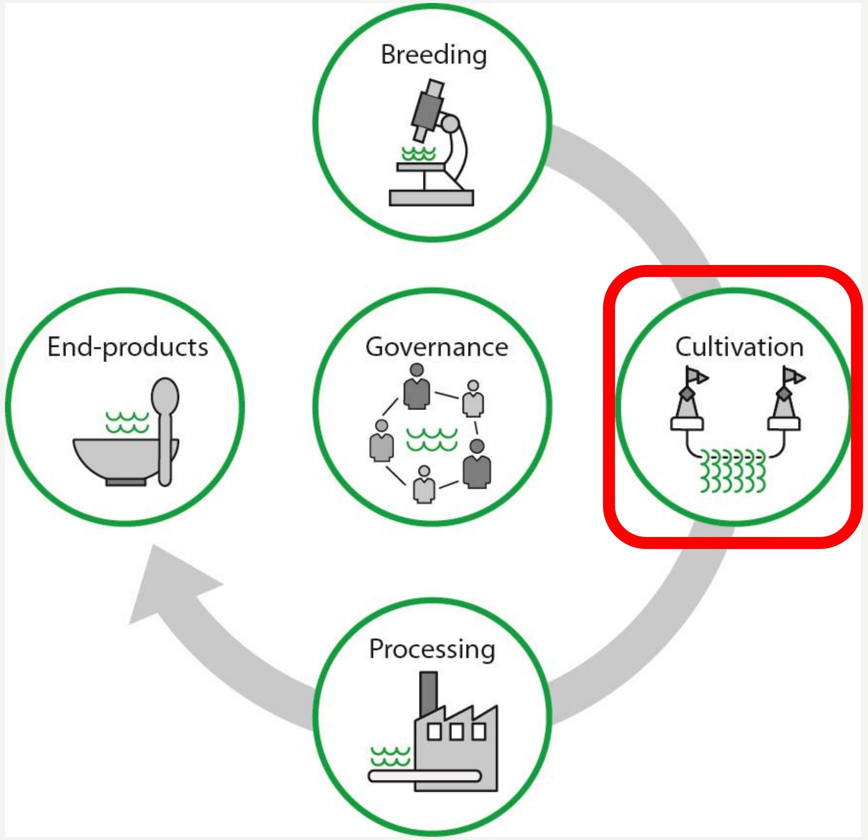
Discussion

Uncertainty:

- Scale
- Temporality and seasonality

Next steps for further research:

- Weighing the ES in their importance
- If data becomes available; quantitative assessment
- LCA on all three species



Conclusion

All three LTA-forms could contribute to the reinforcement of good environmental status.

Experts optimistic about the contribution of LTA to nature restoration and development

Sector-specific barriers limit:

- The opportunities for aquaculture off-shore
- The opportunities for nature enhancing aquaculture

Recommendations

Policy:

- Adjust tender principles to meet the all objectives of the North Sea strategy

LTA sector:

- S. latissima; combine cultivation with high economic species

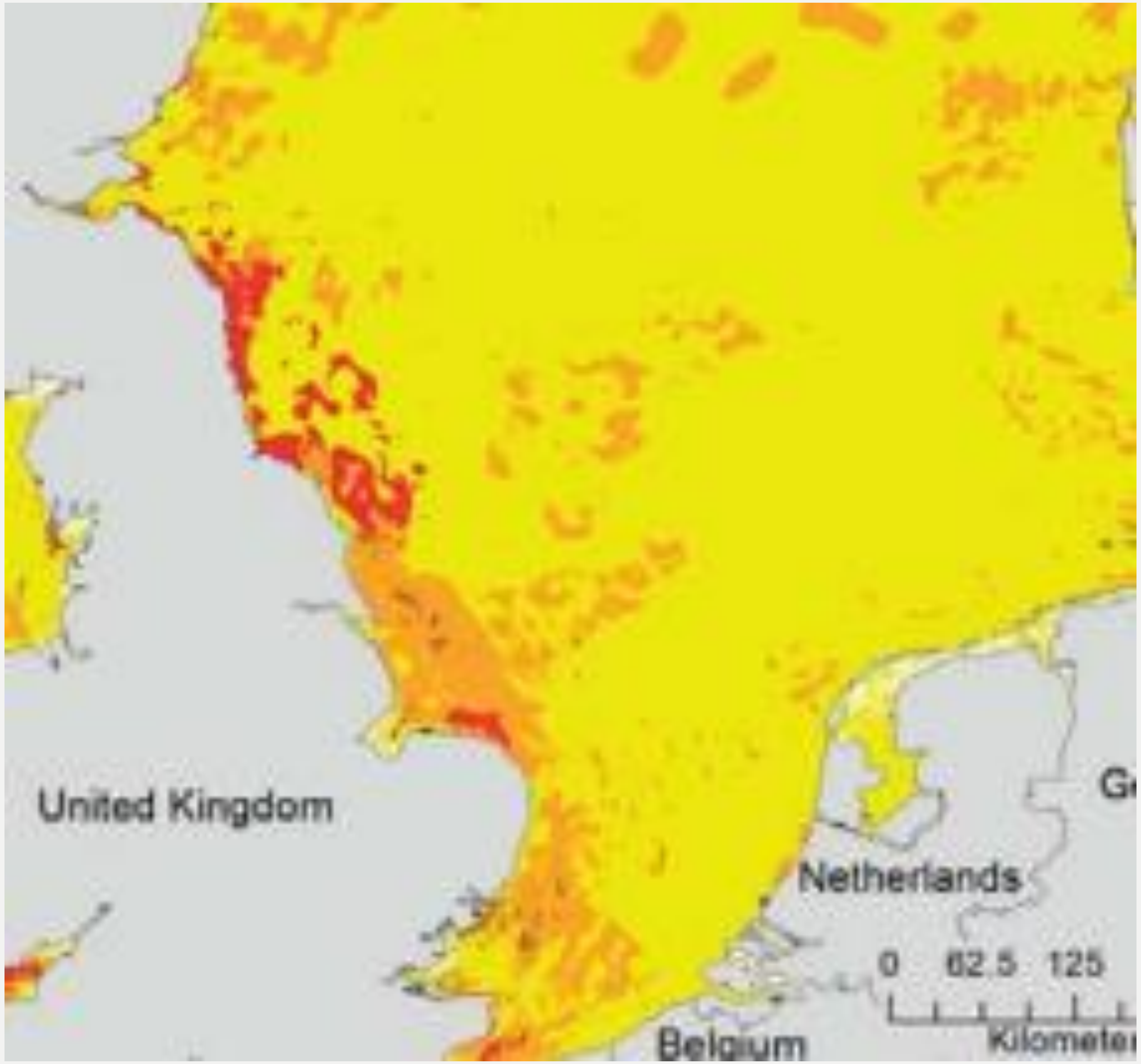
Questions?

Thank you for your diving into the North Sea with me

OPTIONAL SLIDES FOR QUESTIONS

EMODNET (HABITAT)

’Shallow Sublittoral Sediment”



Research questions

"Which type of low-trophic aquaculture in offshore wind farms is expected to best combine nature development objectives and aquaculture objectives in the Dutch North Sea?"

Sub-research questions:

- *What are the drivers and barriers for three different forms of LT-aquaculture in the Dutch North Sea's OWF that could reinforce the environmental status?*
- *How would these forms of low-trophic aquaculture change the Dutch North Sea's ecosystem services?*
- *How would the changed ecosystem services' supply differ across these forms in terms of relative improvement in environmental status?*

Relevant potential Burkhard (2012A & 2014)

Legend	
0	No relevant potential
1	Low relevant potential
2	Relevant potential
3	Medium relevant potential
4	High relevant potential
5	Very high (maximum) relevant potential

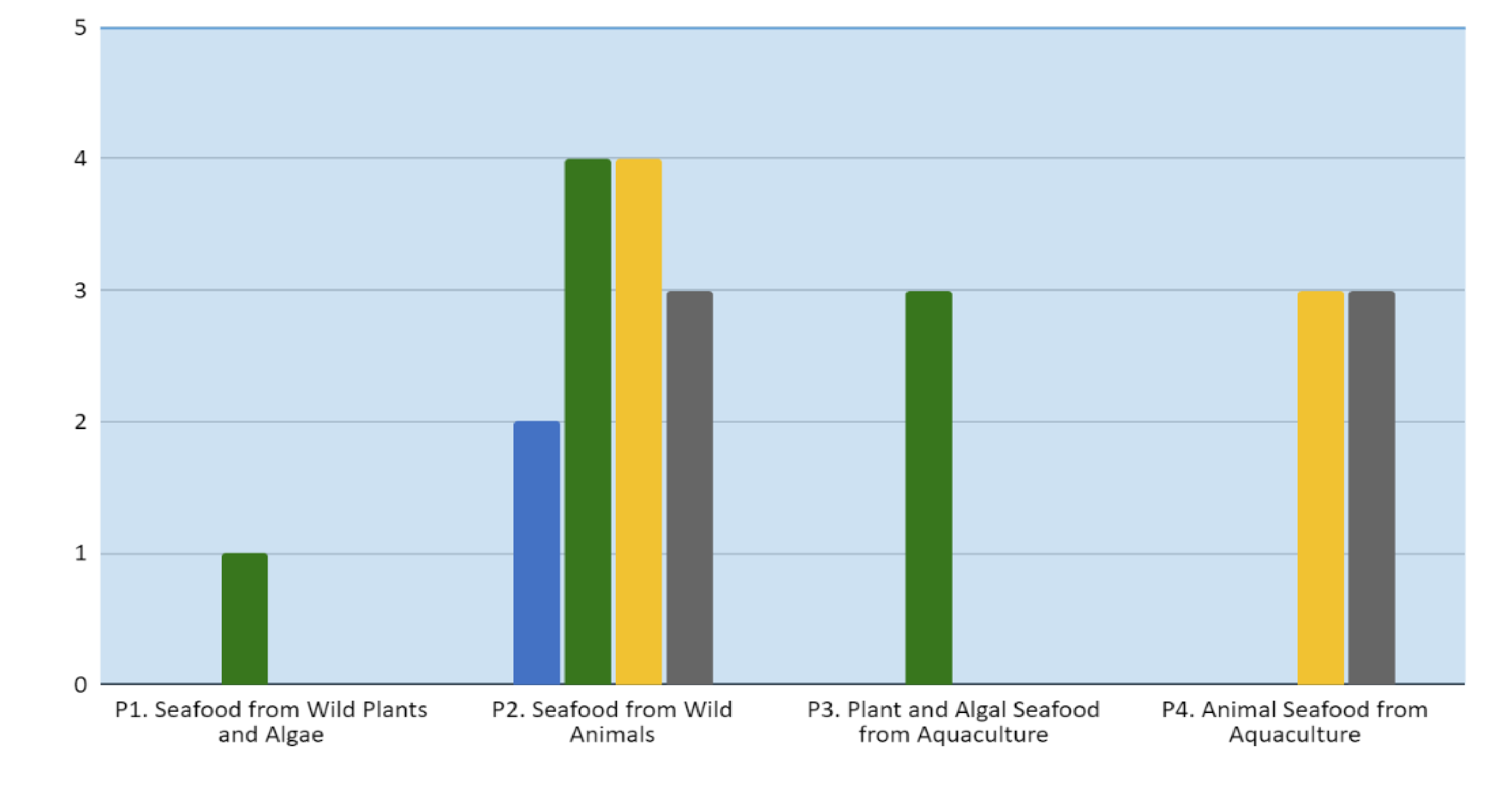
MSFD – Used to assign status

Good environmental status indicator	State (2018)
D1 Biodiversity	N
D2 Exotic species	G
D3 Commercial fish stocks	M
D4 Food web	N
D5 Eutrophication	M
D6 Soil floor integrity	N
D7 Hydrographical conditions	G
D8 Hazardous substances	M
D9 Hazardous substances in fish	G
D10 Litter	M
D11 Energy supply, including underwater noise	M

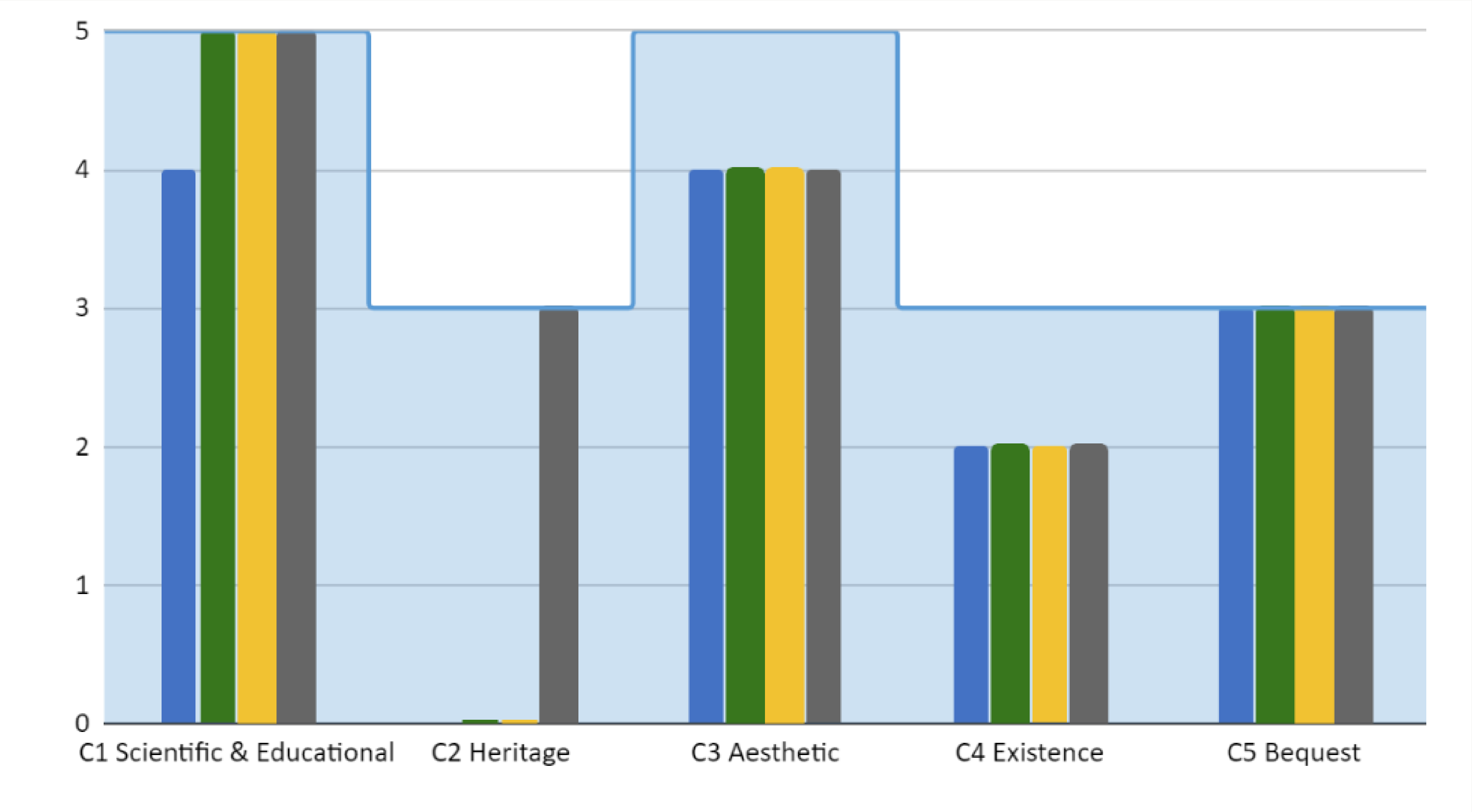
Culhane et al. (2019)

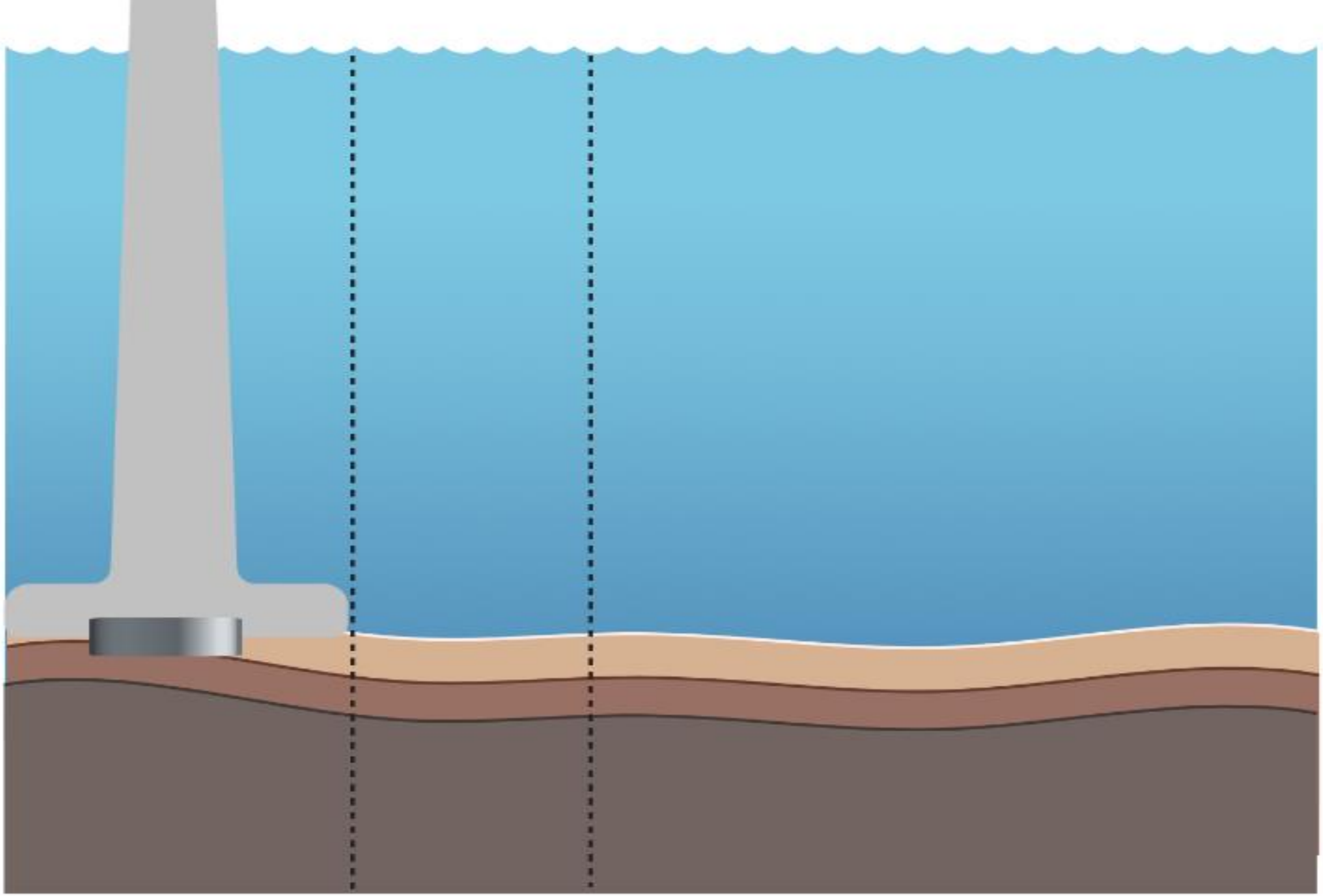
Habitat	Biotic Group	Note	Component
Shelf Waters	Birds		ShW_Bird
	Whales		ShW_Whal
	Seals		ShW_Seal
	Reptiles		ShW_Rept
	Fish		ShW_Fish
	Cephalopods		ShW_Ceph
	Phytoplankton		ShW_Phyt
	Zooplankton		ShW_Zoop
Shallow Sublittoral Sediment	Birds	feeding	SSS_Bird
	Whales	feeding	SSS_Whal
	Seals	feeding	SSS_Seal
	Reptiles	feeding	SSS_Rept
	Fish		SSS_Fish
	Cephalopods		SSS_Ceph
	Epifauna		SSS_Epif
	Infauna		SSS_Infa
	Macrophytes		SSS_MacrP
	Macroalgae		SSS_MacrA
	Micro-phytobenthos		SSS_Micro
	Bacteria		SSS_Bact

CULTURAL SERVICES



PROVISIONING SERVICES





Additional discussion points