Cumulative impacts on biodiversity and new tools to guide marine policy and governance

Christopher Lynam

With collaborations with Ángel Borja, Myron Peck, Jacob Carstensen, Nadia Papadopoulou, Marta Coll, Torsten Berg, Vanessa Stelzenmüller, Jesper Andersen, Heliana Teixeira, Miguel C. Leal, Stelios Katsanevakis, Gerjan Piet, Jacqueline Tamis, Amaia Barrena, Maria C. Uyarra, Michael Elliott and more

Together we are working for
a sustainable blue future

Centre for Environment Fisheries & Aquaculture Science

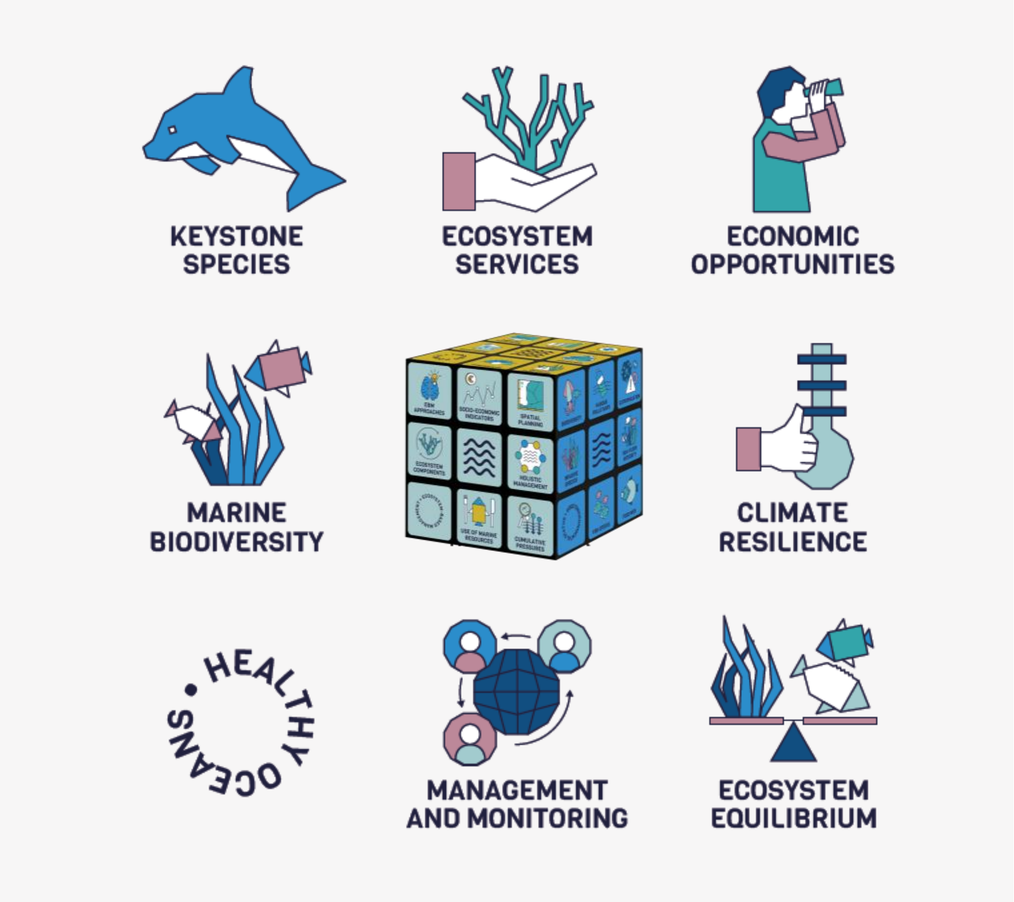
Cefas

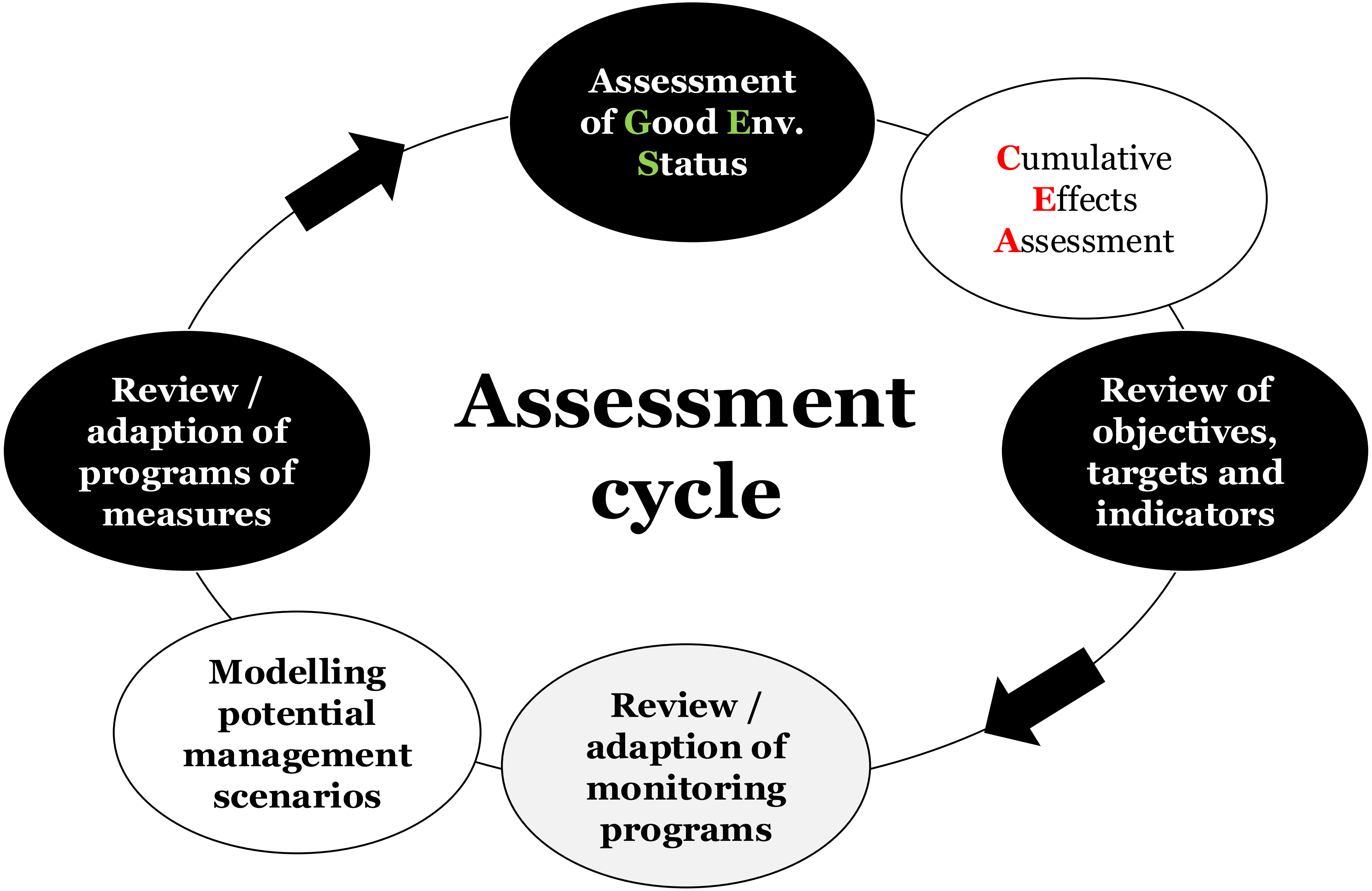
Key European Marine Policies for Biodiversity

- European Union's Marine Strategy Framework Directive (MSFD)
- UK Marine Strategy (UKMS)

Strategies by Regional Seas Convention (e.g):

- The Convention for the Protection of the Marine Environment of the North-East Atlantic (Oslo-Paris Convention, OSPAR)
- Baltic Marine Environment Protection Commission (Helsinki Commission, HELCOM)





Lynam CP, Uusitalo L, et al. (2016) Uses of Innovative Modeling Tools within the Implementation of the Marine Strategy Framework Directive. Front. Mar. Sci. 3:182. doi: 10.3389/fmars.2016.00182

OSPAR Quality Status Report 2023

Goal: “Good Environmental Status”

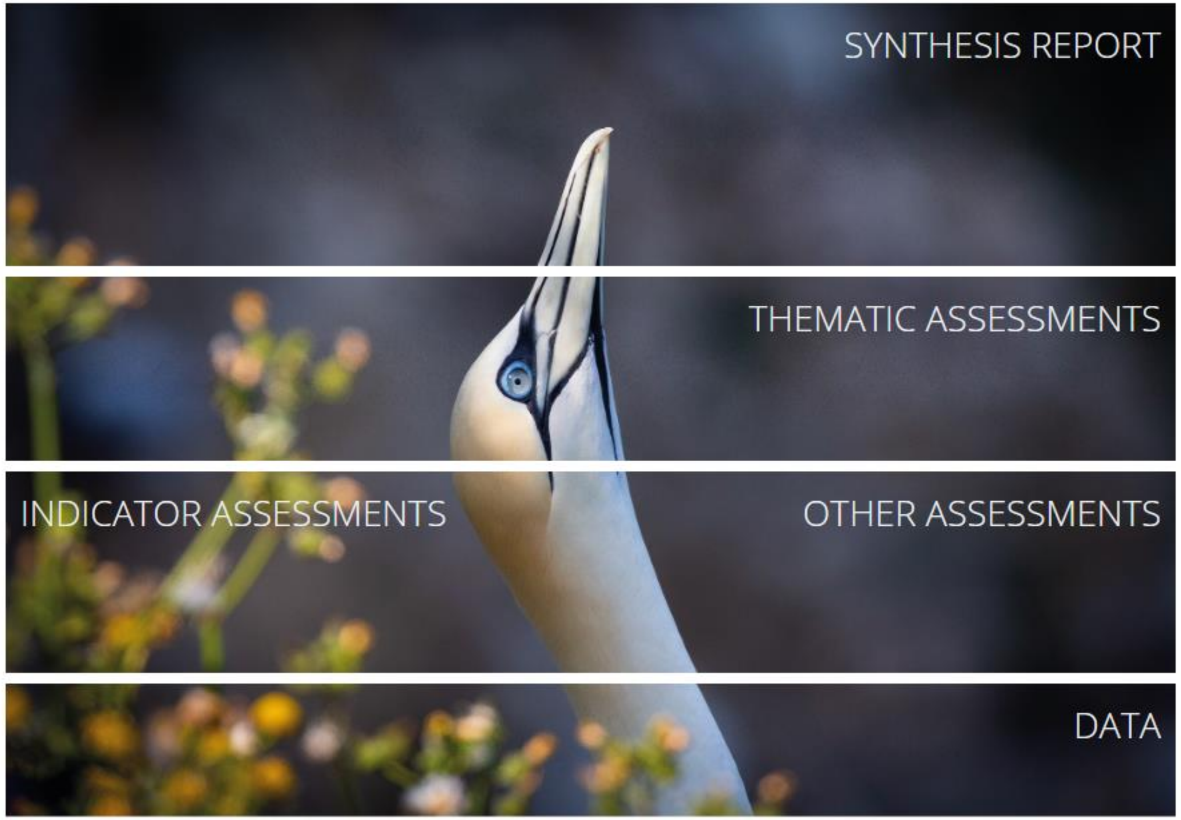
Thematic Assessments supported by indicators

State based

1. Marine Birds
2. Marine Mammals
3. Fish
4. Benthic Habitats
5. Pelagic Habitats
6. Food webs

Pressure based

1. Non-Indigenous Species
2. Eutrophication
3. Underwater Noise
4. Hazardous Substances
5. Marine Litter
6. Climate Change
7. Human Activities
8. Offshore Industry
9. Radioactive Substances



https://oap.ospar.org/en/ospar-assessments/quality-status-reports/qsr-2023

Assessment by indicators. e.g. fish and foodweb

Size Composition in Fish Communities

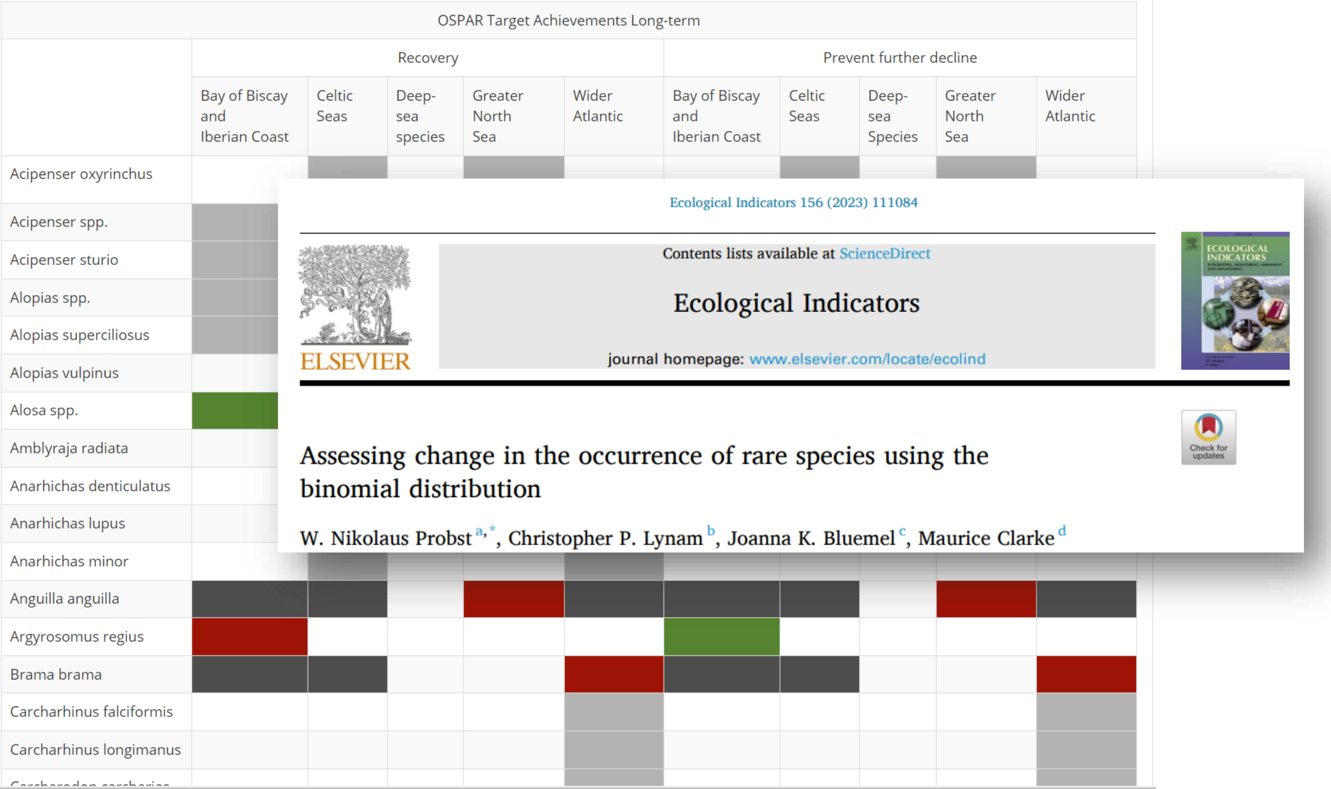
Read More ›

Proportion of Large Fish (Large Fish Index)

Read More ›

Recovery of Sensitive Fish Species

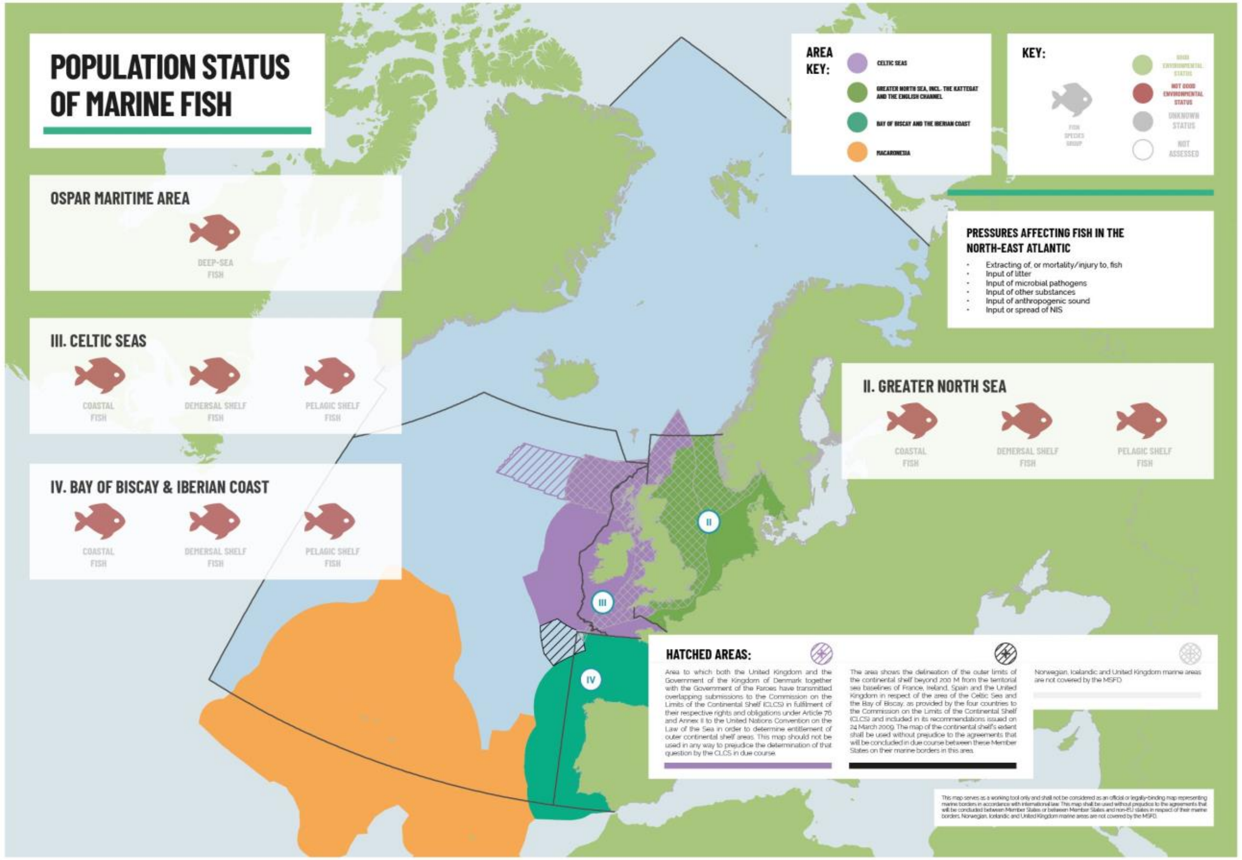
Read More ›

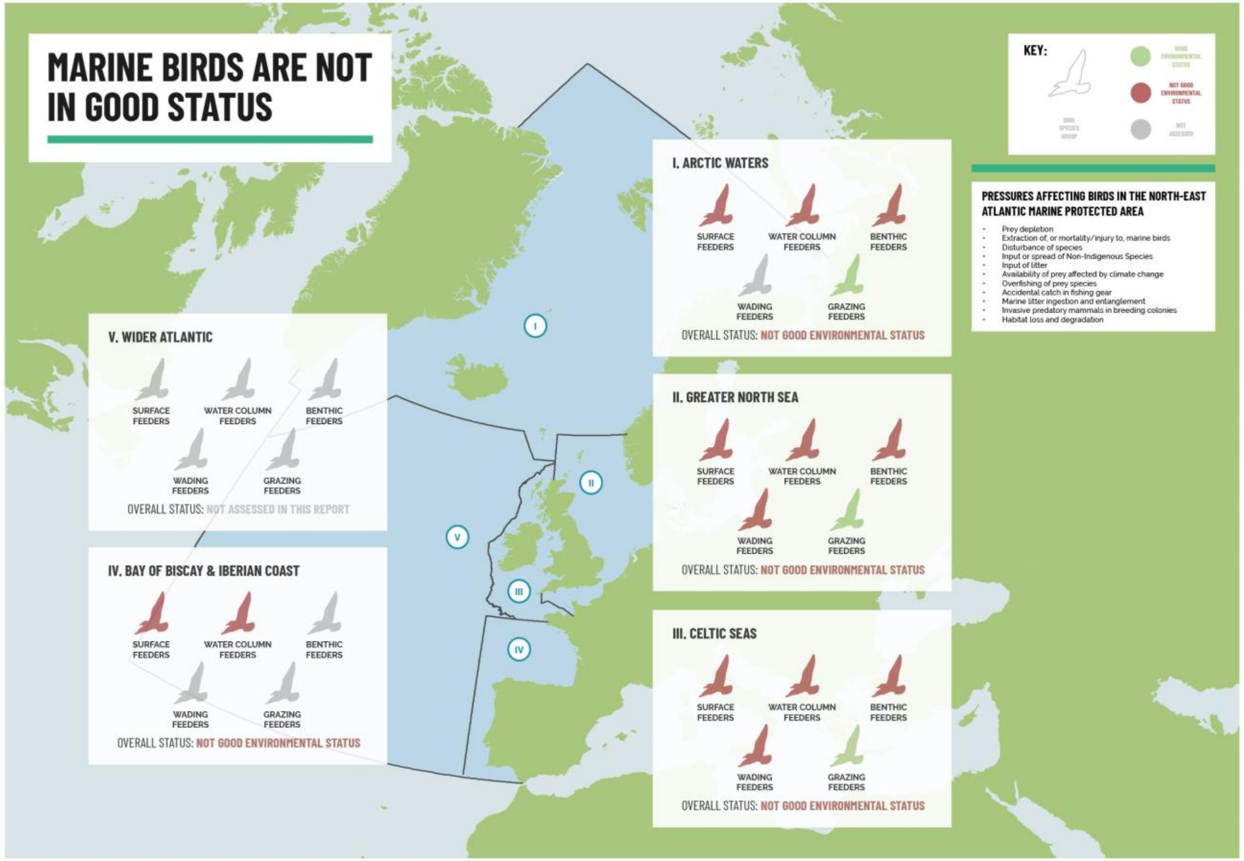


Lynam, C.P., Bluemel, J., Probst, N. 2022. *Recovery of Sensitive Fish Species*. In: OSPAR, 2023: The 2023 Quality Status Report for the Northeast Atlantic. OSPAR Commission, London. Available at: https://oap.ospar.org/en/ospar-assessments/quality-status-reports/qsr-2023/indicator-assessments/recovery-sensitive-fish-species/

Multiple indicators aggregated to give overall assessments by theme

Puffin with catch of sandeels © Shutterstock





Aggregated following McQuatters-Gollop, A., Guérin, L., et al., 2022. Assessing the state of marine biodiversity in the Northeast Atlantic. Ecological Indicators 141:109148

Many assessments are trends-based or use historical baselines as a reference period or based on expert judgement

Indicator targets and limits

Problem:

- Human activities and climate change have already changed ecosystems so past states may no longer be relevant

Alternative to historical baseline approach for assessment of indicators?

Can we look forward:

- Model potential change once pressure is removed from the current system
- Measure difference in current state from unfished state

Project: DEVelopment Of innovative Tools for understanding marine biodiversity and assessing good Environmental Status

Coordinator : Angel Borja. AZTI

Ecological Indicators 72 (2017) 215–224

Contents lists available at ScienceDirect

ELSEVIER

Ecological Indicators

journal homepage: www.elsevier.com/locate/ecolind

Quantitative criteria for choosing targets and indicators for sustainable use of ecosystems

CrossMark

Axel G. Rossberg[a,*], Laura Uusitalo[b], Torsten Berg[c], Anastasija Zaiko[d], Anne Chenuil[e], María C. Uyarra[f], Angel Borja[f], Christopher P. Lynam[g]

Quantitative targets for ecological indicators

Christopher Lynam, Robert Thorpe, Murray Thompson, Karen van de Wolfshaar, Miriam Püts, Xavier Corrales, Giovanni Romagnoni, Konstantinos Tsagarakis, Mikaëla Potier, Georgia Papantoniou, Ghassen Halouani, Mike Heath, Raphael Girardin, Alex Kempf, Marc Taylor

SEAWISE

WORKING TOWARDS THE IMPLEMENTATION OF EBFM IN EUROPE

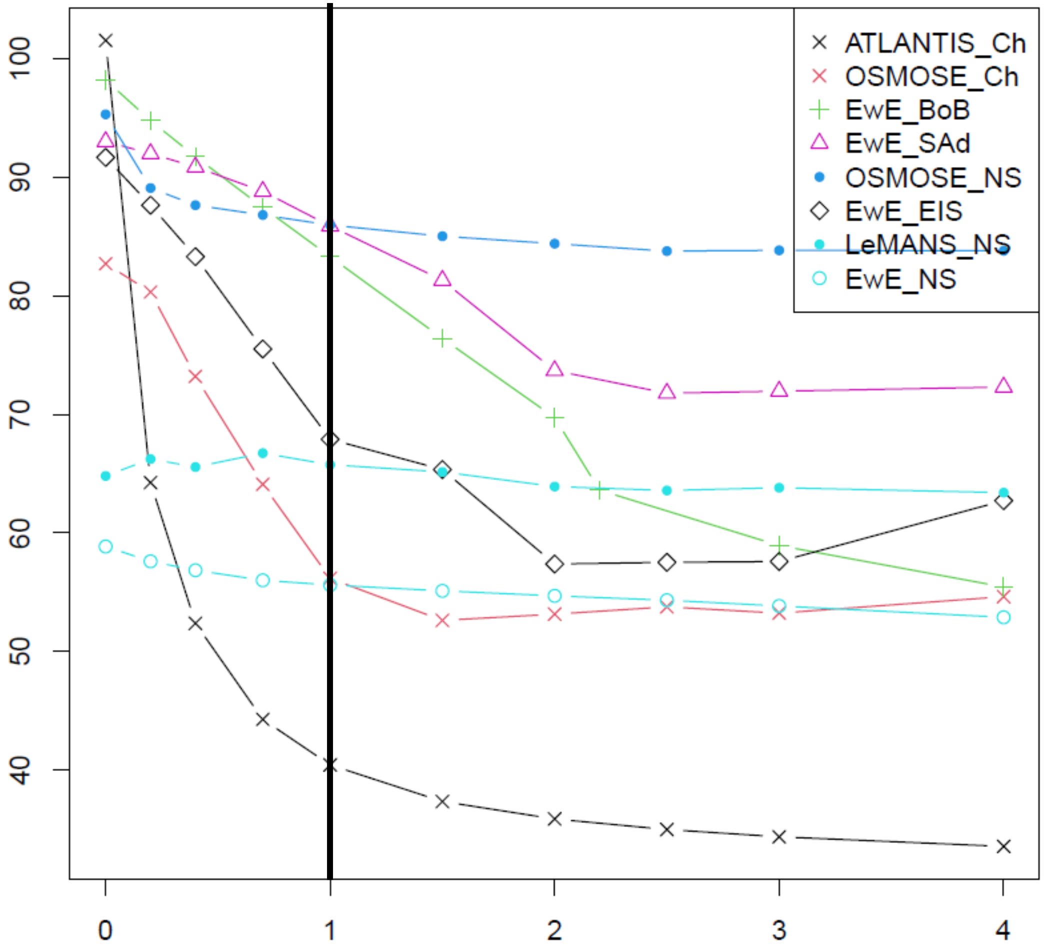
Coordinator : Anna Rindorf. DTU Aqua

Fishing mortality impact on species composition of demersal fish

Direction of relationship is **consistent** despite very different model communities and fisheries

Many large species in the ecosystem as a proportion by biomass

Mean Maximum Length [cm]



Fishing mortality multiplier

No fishing → 4 x current fishing levels

Fewer large species in the ecosystem as a proportion by biomass

Models used

EwE
OSMOSE
LeMans
ATLANTIS

Ecosystems

Ch = Eastern English Channel
BoB = Bay of Biscay
NS = North Sea
EIS = Eastern Ionian Sea
SAd = Southern Adriatic Sea

SEAWISE

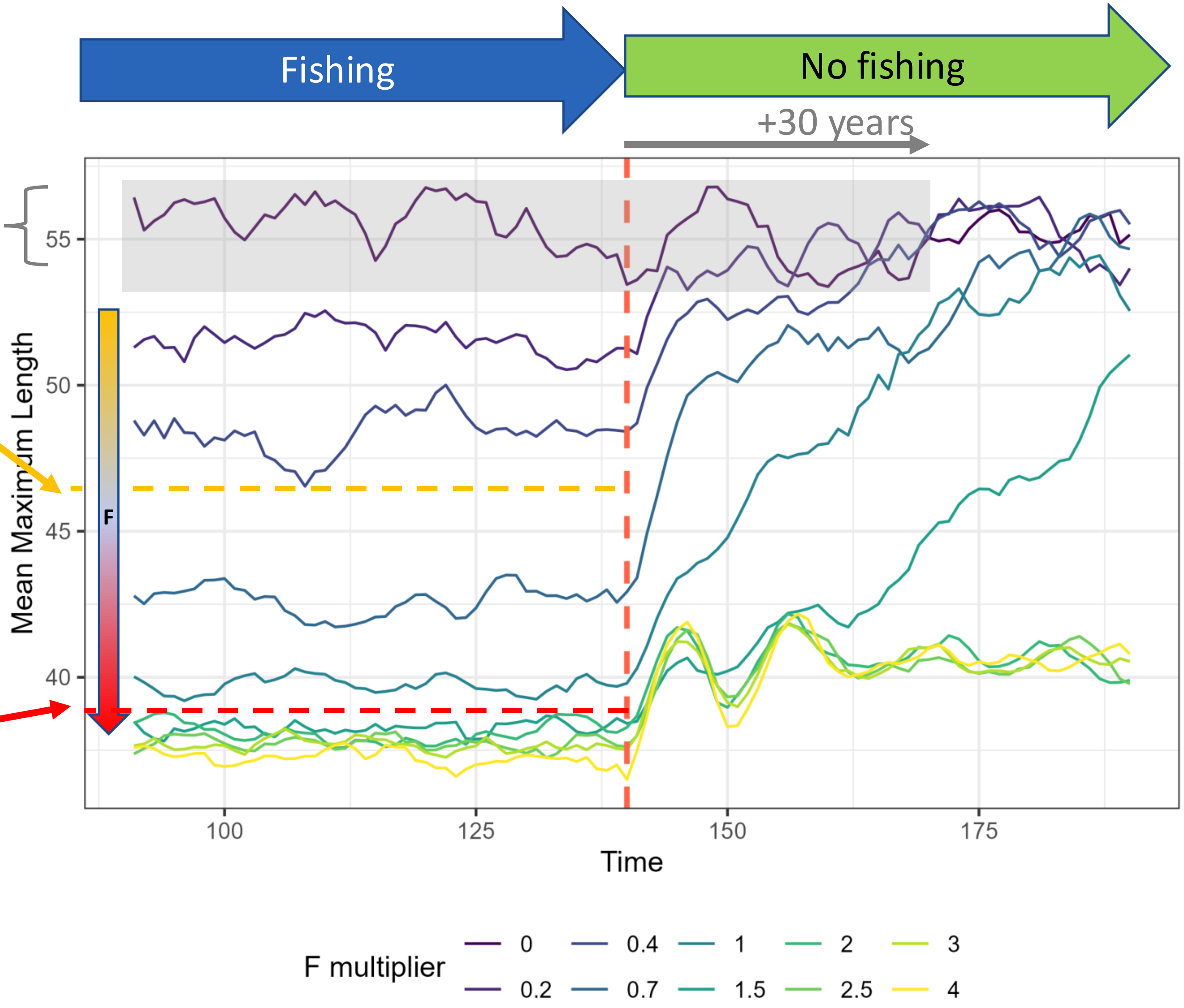
Eastern English Channel (OSMOSE)
MML of demersal and pelagic fish

Model sims by Ghassen Halouani
(Institut Français de Recherche pour l'Exploitation de la Mer)

Natural range (no fishing)

Target
MML > 47 cm
in order to return to unfished within 30 years

Limit
MML < 38 cm
may not fully return to unfished state



Recovery within 30 years if Fmultiplier ≤ 0.4

Very slow recovery following Fmultiplier of x1.5

Very little recovery following high Fmultipliers (≥2)

Still only 1 pressure

Multiple pressures are being addressed in European projects

We are working to expand the tools for

(i) assessing cumulative pressures

(ii) evaluating environmental status (“ocean health”)

(iii) understanding risks to ecosystem functioning and services

(iv) demonstrating management strategies

to recover lost biodiversity and safeguard the benefits humans derive from marine ecosystems

OBAMA-NEXT
https://obama-next.eu

GES4SEAS
www.ges4seas.eu

ACTNOW
www.actnow-project.eu

FutureMARES
www.futuremares.eu

Funded by the European Union

UK Research and Innovation

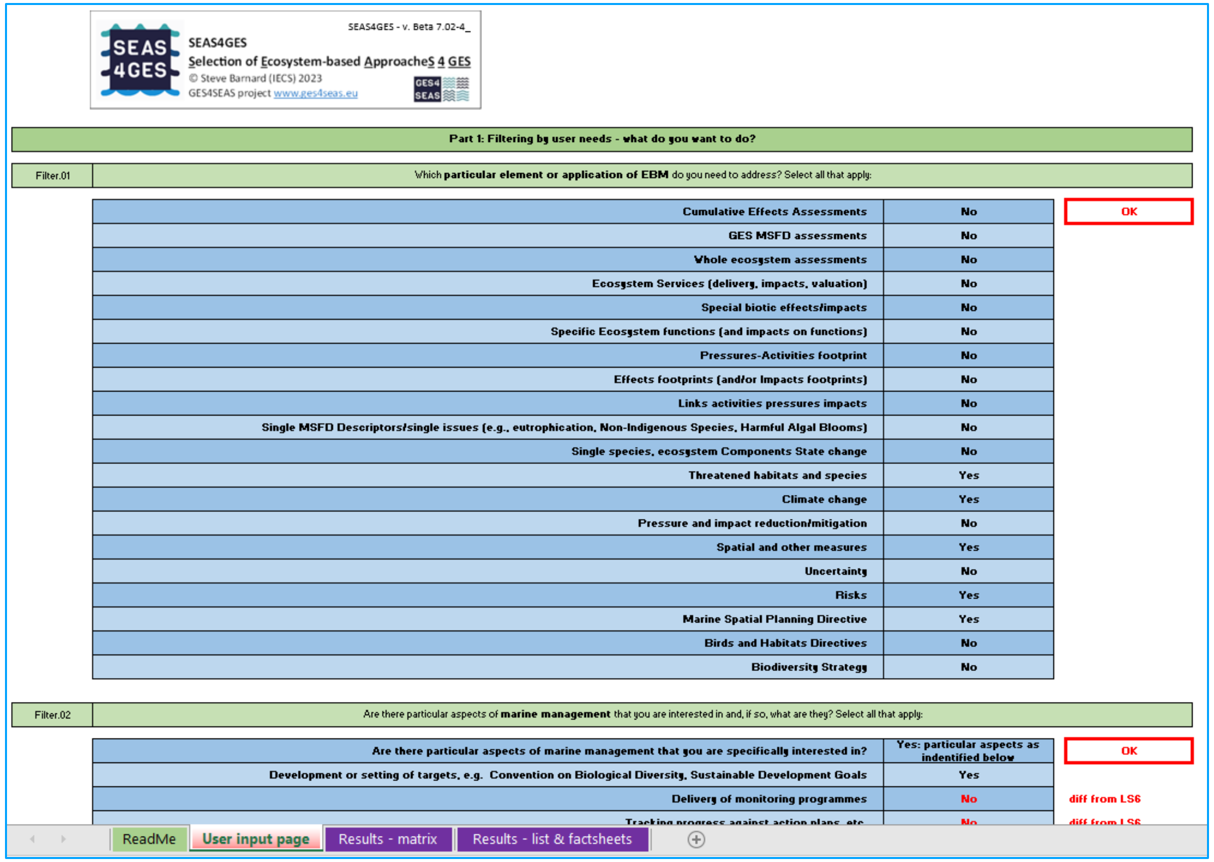
Nadia Papadopoulou with Chris Smith, HCMR
Mike Elliott with Anita Franco, IECS

Where to begin?

New Decision Support Tool

'Selection of Ecosystem-based Approaches for Good Environmental Status'

Questions: Status? Pressure? Effects? Policy? → Recommendations supported by factsheets



SEAS4GES - v. Beta 7.02-4_
SEAS4GES
Selection of Ecosystem-based ApproacheS 4 GES
© Steve Barnard (IECS) 2023
GES4SEAS project www.ges4seas.eu

Part 1: Filtering by user needs - what do you want to do?

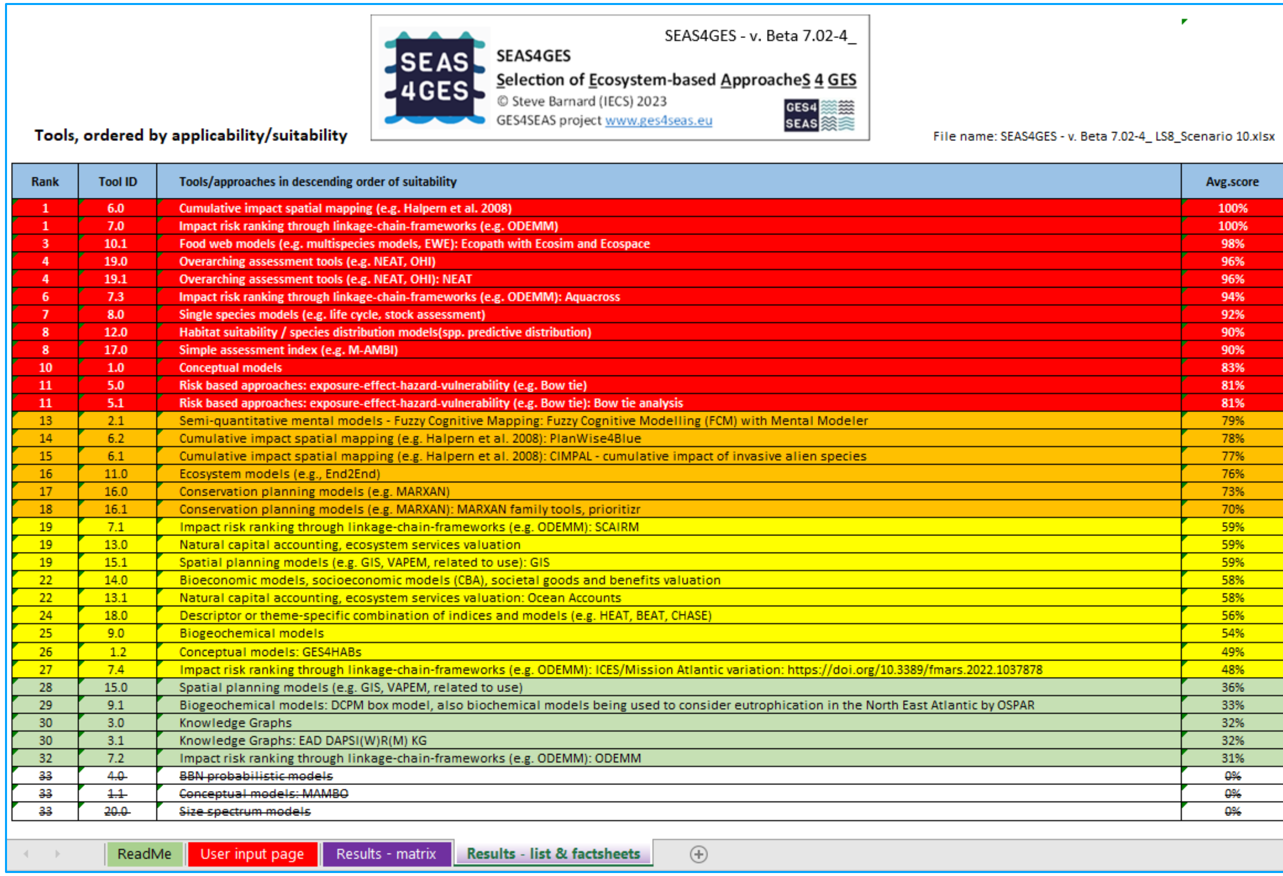
Filter.01 — Which **particular element or application of EBM** do you need to address? Select all that apply:

Cumulative Effects Assessments	No	OK
GES MSFD assessments	No	
Whole ecosystem assessments	No	
Ecosystem Services (delivery, impacts, valuation)	No	
Special biotic effects/impacts	No	
Specific Ecosystem functions (and impacts on functions)	No	
Pressures-Activities footprint	No	
Effects footprints (and/or Impacts footprints)	No	
Links activities pressures impacts	No	
Single MSFD Descriptors/single issues (e.g., eutrophication, Non-Indigenous Species, Harmful Algal Blooms)	No	
Single species, ecosystem Components State change	No	
Threatened habitats and species	Yes	
Climate change	Yes	
Pressure and impact reduction/mitigation	No	
Spatial and other measures	Yes	
Uncertainty	No	
Risks	Yes	
Marine Spatial Planning Directive	Yes	
Birds and Habitats Directives	No	
Biodiversity Strategy	No	

Filter.02 — Are there particular aspects of **marine management** that you are interested in and, if so, what are they? Select all that apply:

Are there particular aspects of marine management that you are specifically interested in?	Yes: particular aspects as indentified below	OK
Development or setting of targets, e.g. Convention on Biological Diversity, Sustainable Development Goals	Yes	
Delivery of monitoring programmes	No	diff from LS6
Tracking progress against action plans, etc	No	diff from LS6

ReadMe | User input page | Results - matrix | Results - list & factsheets



SEAS4GES - v. Beta 7.02-4_
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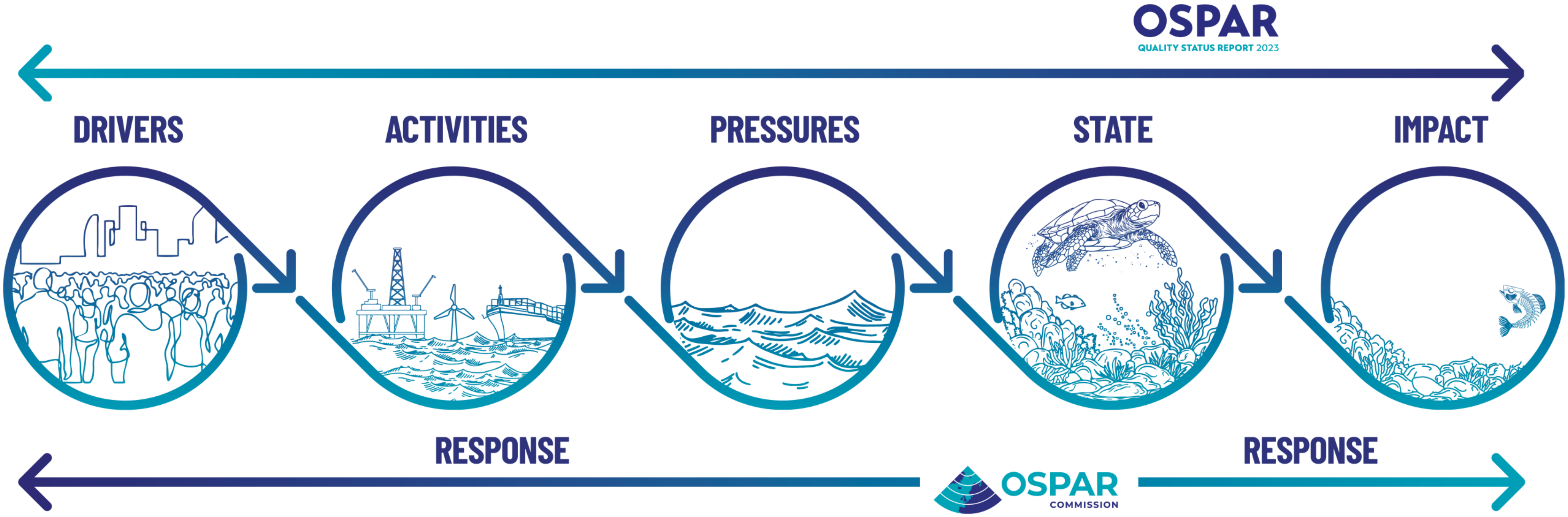
Tools, ordered by applicability/suitability

File name: SEAS4GES - v. Beta 7.02-4_ LS8_Scenario 10.xlsx

Rank	Tool ID	Tools/approaches in descending order of suitability	Avg.score
1	6.0	Cumulative impact spatial mapping (e.g. Halpern et al. 2008)	100%
1	7.0	Impact risk ranking through linkage-chain-frameworks (e.g. ODEMM)	100%
3	10.1	Food web models (e.g. multispecies models, EWE): Ecopath with Ecosim and Ecospace	98%
4	19.0	Overarching assessment tools (e.g. NEAT, OHI)	96%
4	19.1	Overarching assessment tools (e.g. NEAT, OHI): NEAT	96%
6	7.3	Impact risk ranking through linkage-chain-frameworks (e.g. ODEMM): Aquacross	94%
7	8.0	Single species models (e.g. life cycle, stock assessment)	92%
8	12.0	Habitat suitability / species distribution models(spp. predictive distribution)	90%
8	17.0	Simple assessment index (e.g. M-AMBI)	90%
10	1.0	Conceptual models	83%
11	5.0	Risk based approaches: exposure-effect-hazard-vulnerability (e.g. Bow tie)	81%
11	5.1	Risk based approaches: exposure-effect-hazard-vulnerability (e.g. Bow tie): Bow tie analysis	81%
13	2.1	Semi-quantitative mental models - Fuzzy Cognitive Mapping: Fuzzy Cognitive Modelling (FCM) with Mental Modeler	79%
14	6.2	Cumulative impact spatial mapping (e.g. Halpern et al. 2008): PlanWise4Blue	78%
15	6.1	Cumulative impact spatial mapping (e.g. Halpern et al. 2008): CIMPAL - cumulative impact of invasive alien species	77%
16	11.0	Ecosystem models (e.g., End2End)	76%
17	16.0	Conservation planning models (e.g. MARXAN)	73%
18	16.1	Conservation planning models (e.g. MARXAN): MARXAN family tools, prioritizr	70%
19	7.1	Impact risk ranking through linkage-chain-frameworks (e.g. ODEMM): SCAIRM	59%
19	13.0	Natural capital accounting, ecosystem services valuation	59%
19	15.1	Spatial planning models (e.g. GIS, VAPEM, related to use): GIS	59%
22	14.0	Bioeconomic models, socioeconomic models (CBA), societal goods and benefits valuation	58%
22	13.1	Natural capital accounting, ecosystem services valuation: Ocean Accounts	58%
24	18.0	Descriptor or theme-specific combination of indices and models (e.g. HEAT, BEAT, CHASE)	56%
25	9.0	Biogeochemical models	54%
26	1.2	Conceptual models: GES4HABs	49%
27	7.4	Impact risk ranking through linkage-chain-frameworks (e.g. ODEMM): ICES/Mission Atlantic variation: https://doi.org/10.3389/fmars.2022.1037878	48%
28	15.0	Spatial planning models (e.g. GIS, VAPEM, related to use)	36%
29	9.1	Biogeochemical models: DCPM box model, also biochemical models being used to consider eutrophication in the North East Atlantic by OSPAR	33%
30	3.0	Knowledge Graphs	32%
30	3.1	Knowledge Graphs: EAD DAPSI(W)R(M) KG	32%
32	7.2	Impact risk ranking through linkage-chain-frameworks (e.g. ODEMM): ODEMM	31%
~~33~~	~~4.0~~	~~BBN probabilistic models~~	~~0%~~
~~33~~	~~1.1~~	~~Conceptual models: MAMBO~~	~~0%~~
~~33~~	~~20.0~~	~~Size spectrum models~~	~~0%~~

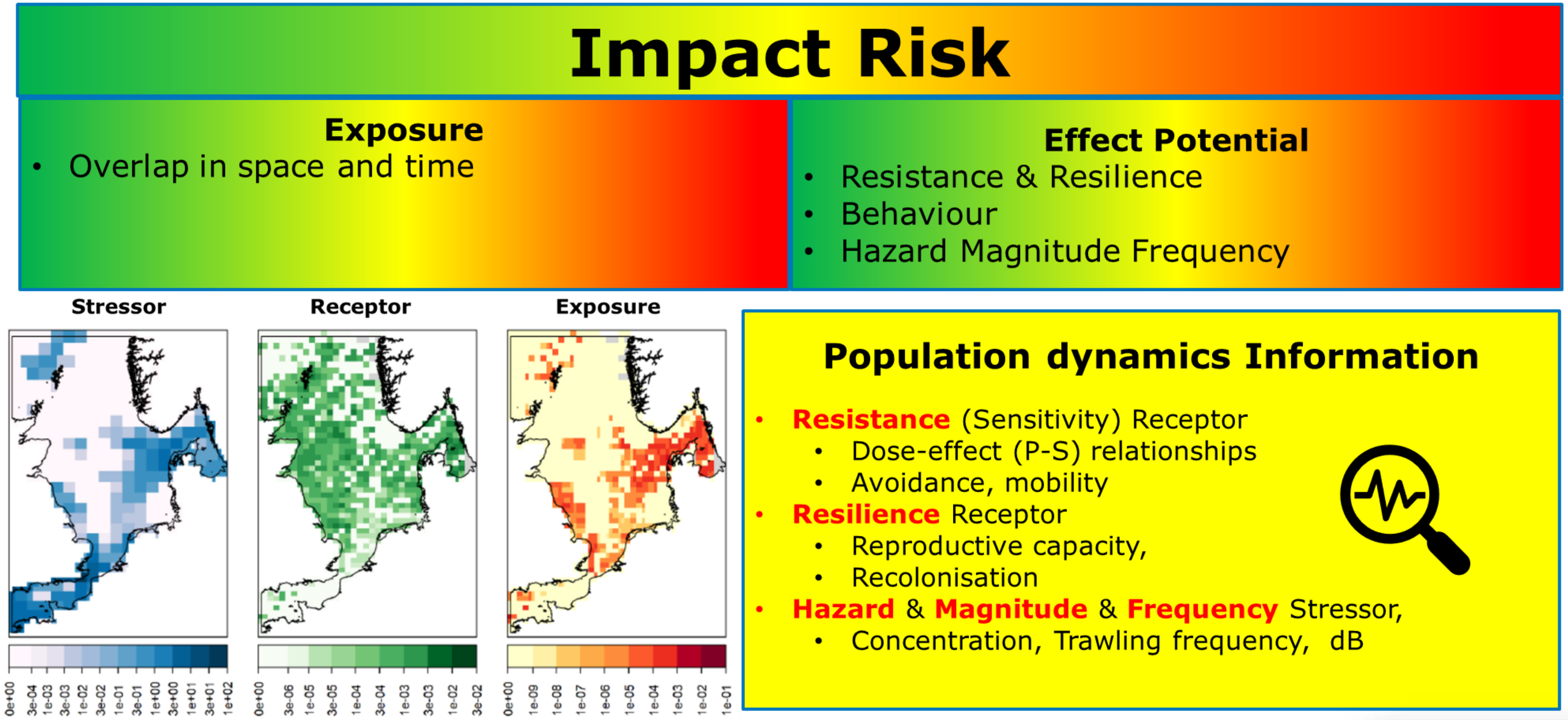
ReadMe | User input page | Results - matrix | Results - list & factsheets

Cumulative Impact Assessment



https://oap.ospar.org/en/ospar-assessments/quality-status-reports/qsr-2023/synthesis-report/assessing-state-ne-atlantic/#thematic-assessments-applying-a-holistic-approach

Many risk based approaches (Halpern framework)
One novel approach (Piet et al., 2021):



WAGENINGEN UNIVERSITY & RESEARCH

Figure by Gerjan Piet (WUR)

Piet et al., 2021. A roadmap towards quantitative cumulative impact assessments: every step of the way. STOTEN 784, 146847

SCAIRM Cookbook

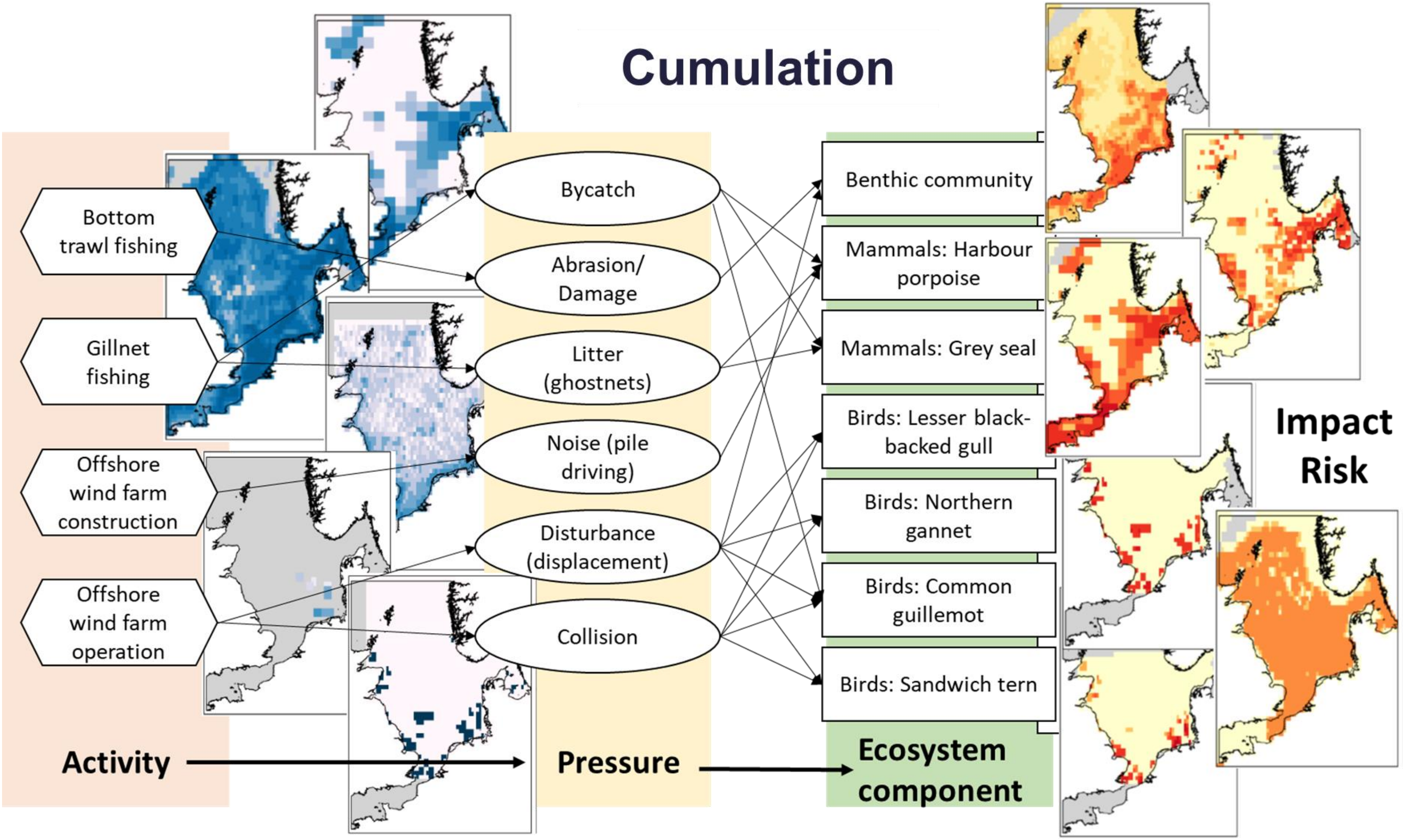
Guidelines for Cumulative Impact Assessment including constructing a linkage framework

Draft version 02

October 2023

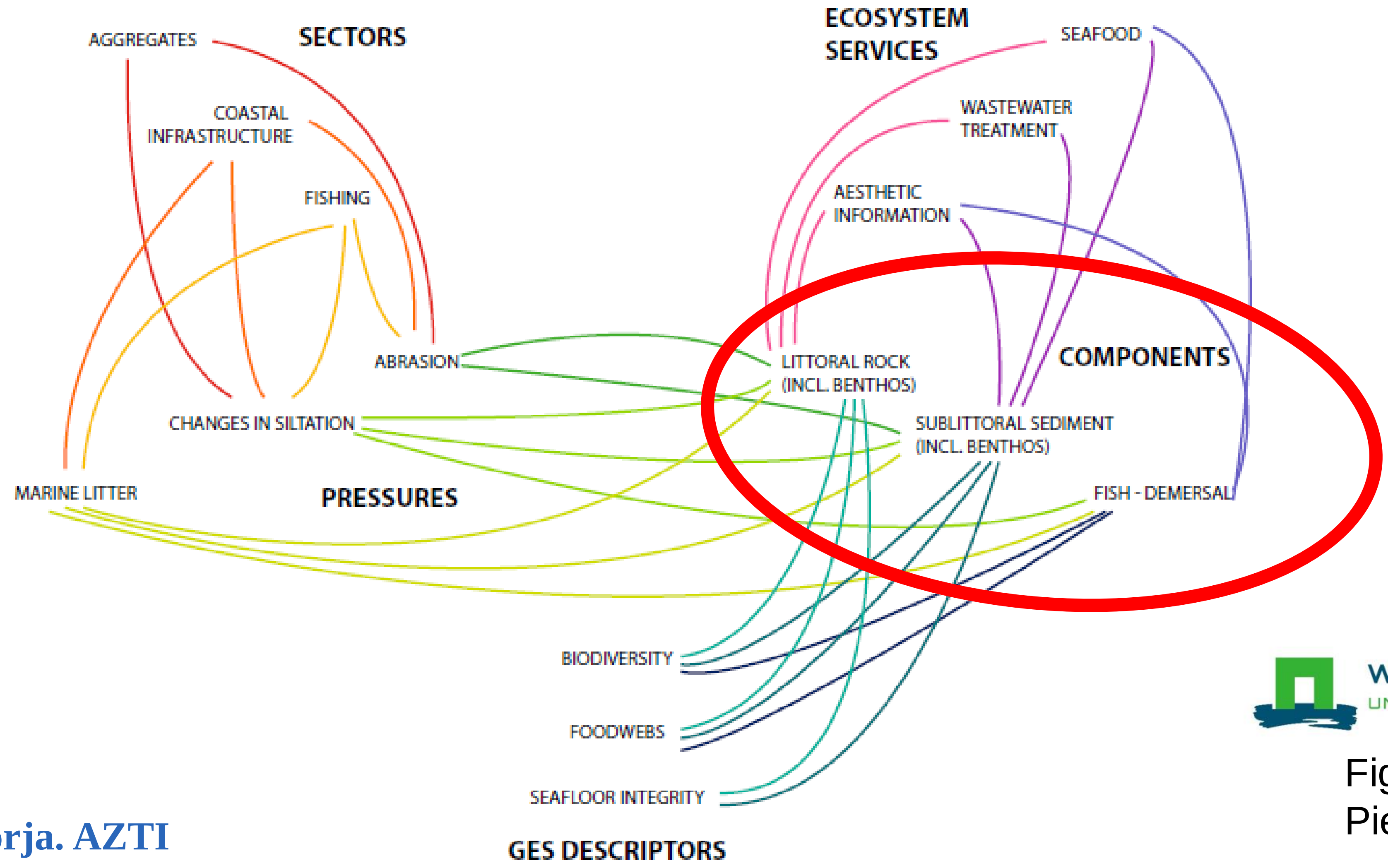
Multiple chains

Figure by Gerjan Piet (WUR)



Piet., G., et al., 2023. SCAIRM: A spatial cumulative assessment of impact risk for management. Ecological Indicators. 157. 111157

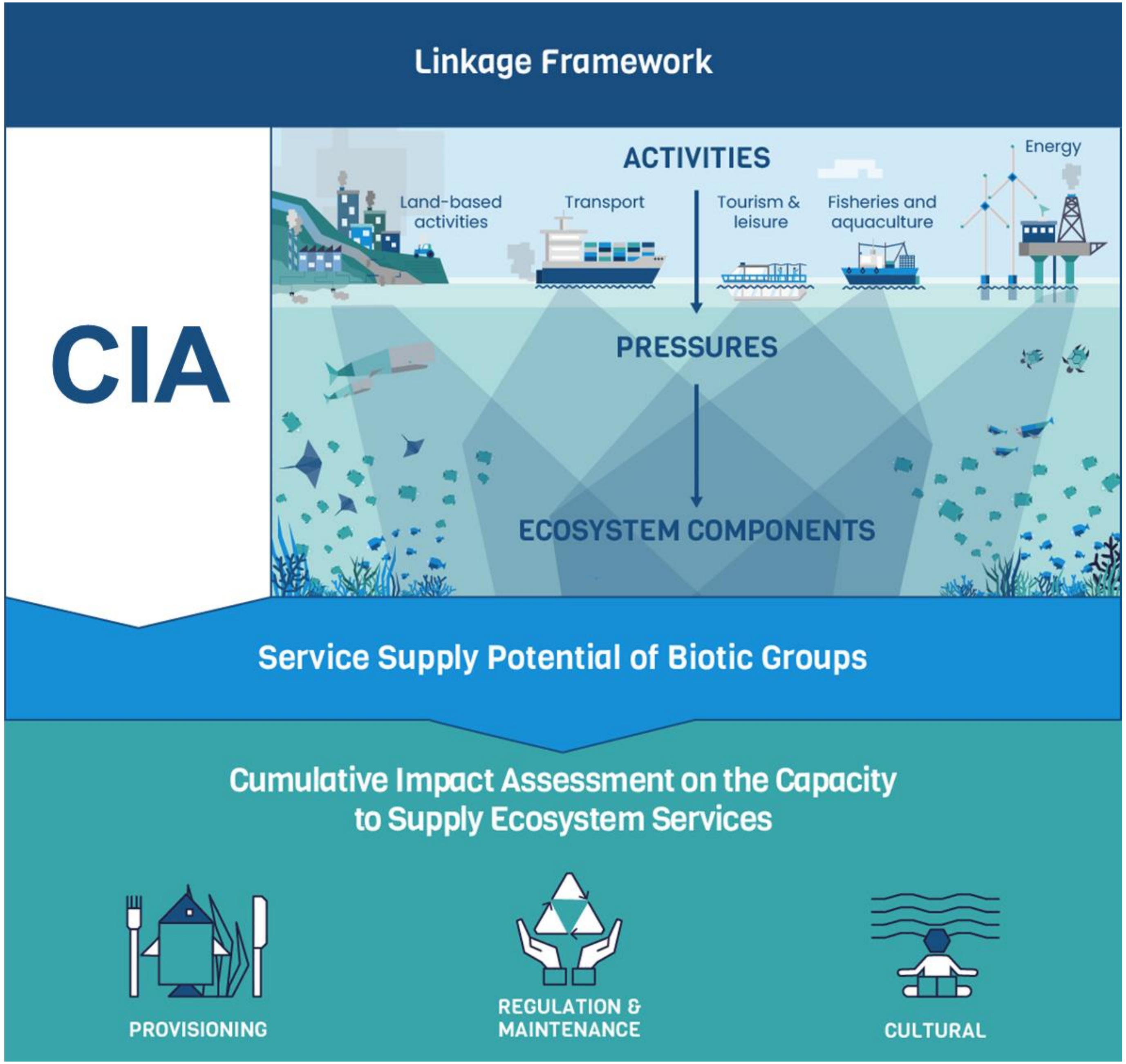
Linking Cumulative Impact Assessments to Ecosystem Services

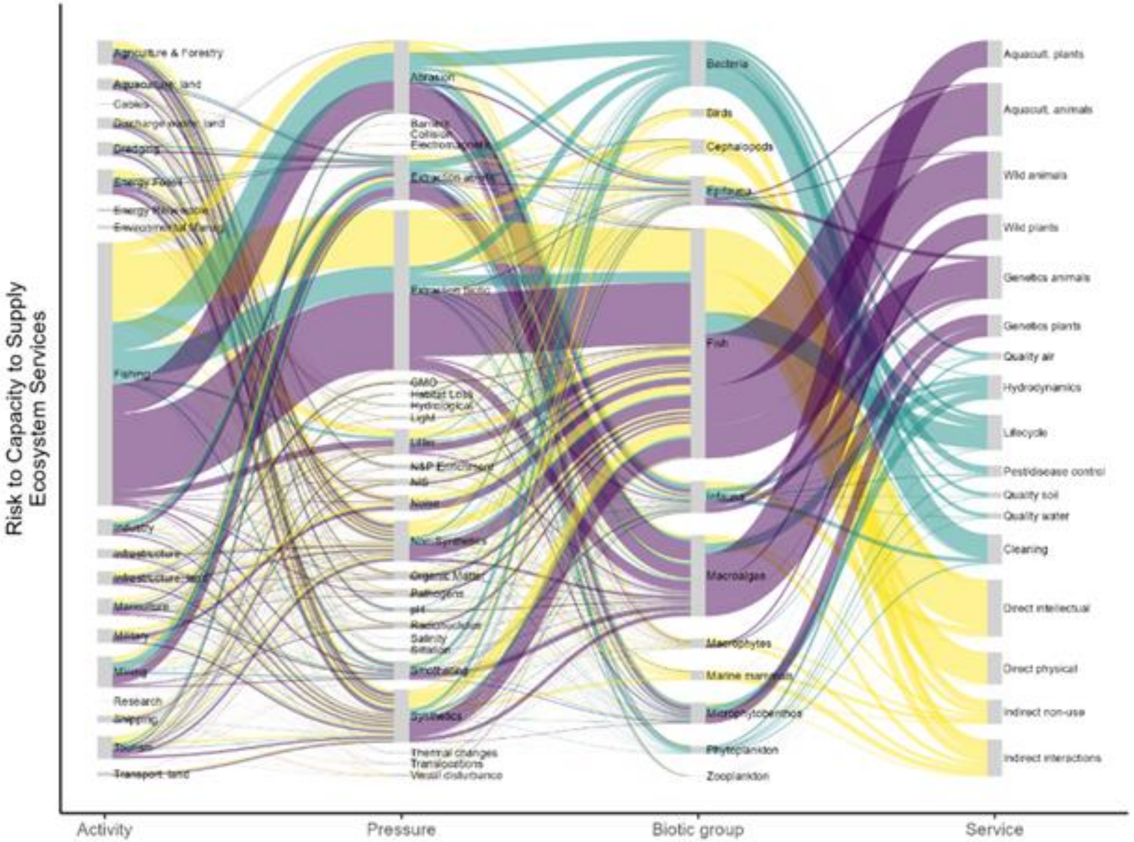


www.ges4seas.eu

Coordinator : Angel Borja. AZTI

Figure by Gerjan Piet (WUR)





Piet et al., *accepted*.
A Cumulative Impact Assessment on the capacity to supply Ecosystem Services.
Science of the Total Environment

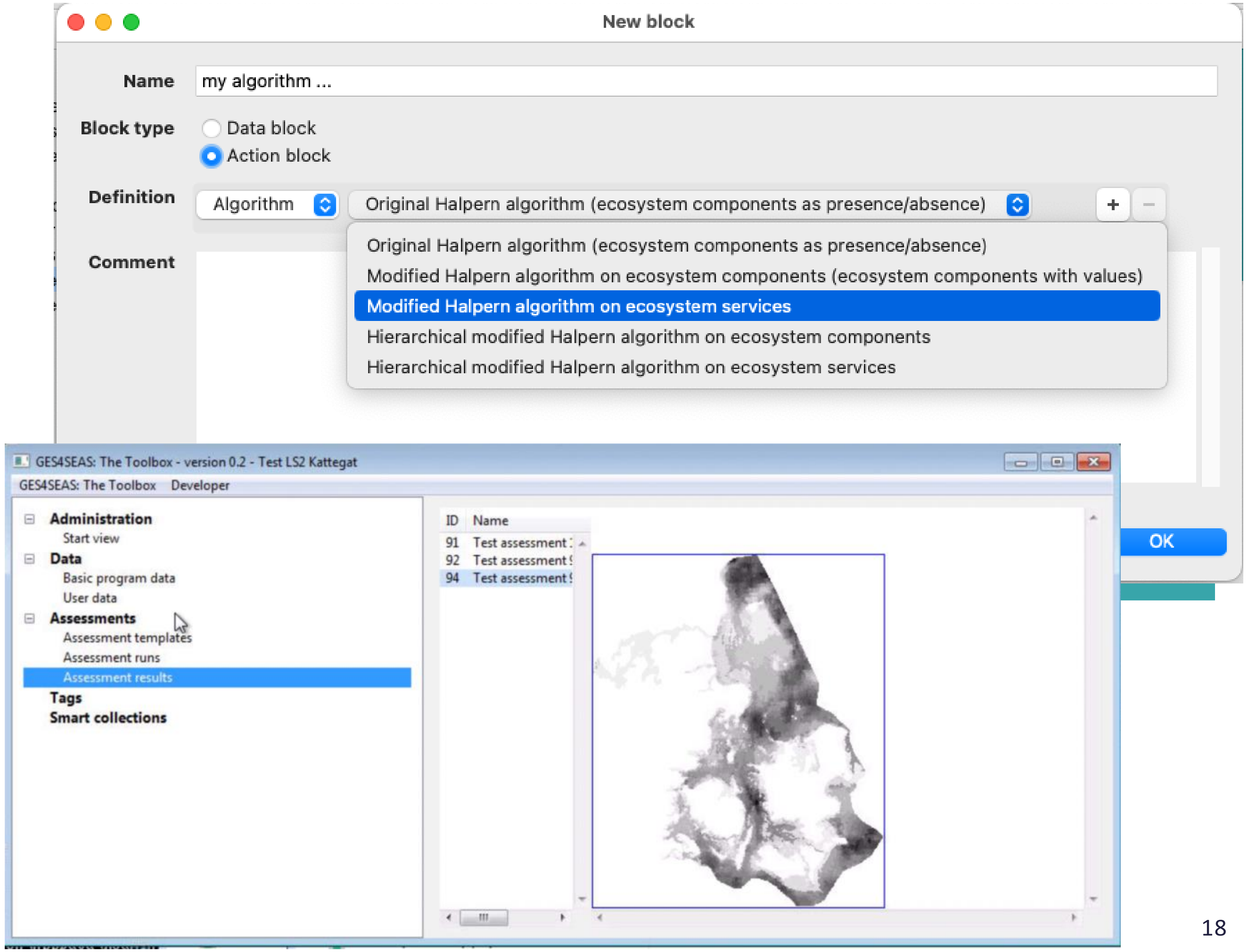
GES4SEAS Toolbox

In development by Torsten Berg, Jesper Andersen and Ciaran Murray

Ready-to-use templates for:

- MSFD assessments (Article 8) (aggregation/integration methods)
- Status assessment (maps)
- Cumulative Impact Assessment (maps)
- Scenario testing (without ecological processes and interactions)

... users can customize the templates and add their own templates



Coordinator: Myron Peck. NIOZ

Scenario modelling - European Seas under contrasting Climate Change trajectories with multiple management interventions

Marta Coll (CSIC), Christopher Lynam (CEFAS), Jeroen Steenbeek (EII), Xavier Corrales (AZTI), Lucia Espasandín (CSIC), Miquel Ortega (CSIC), Riikka Puntila-Dodd (Syke), Dorota Szalaj (CSIC), Maciej Tomczak (SU), Momme Butenschon (CMCC), Eider Andonegi (AZTI), Maria Dolores Castro (CSIC), Sonia Heye (Deltares), Trond Kristiansen (Farallon Institute), Luca van Duren (Deltares), Lauriane Vilmin (Deltares), Myron A. Peck (NIOZ)

Working with Ecopath International Initiative (EII)

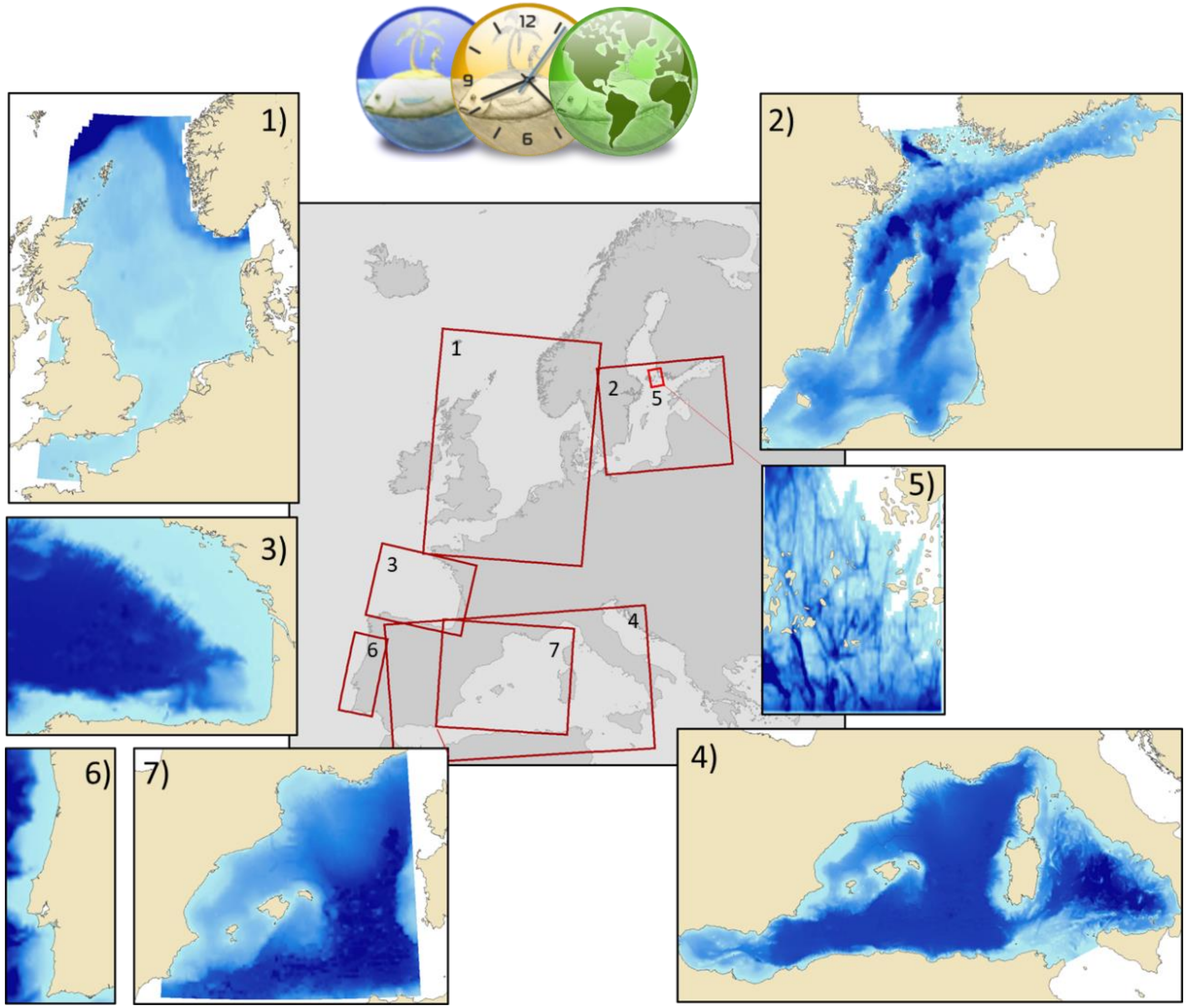
Food web (spatial-temporal) modelling tools

Four regional Ecospace models

1) North Sea (Cefas)
2) Central Baltic Sea (SU)
3) Bay of Biscay (AZTI)
4) Western Mediterranean (CSIC)

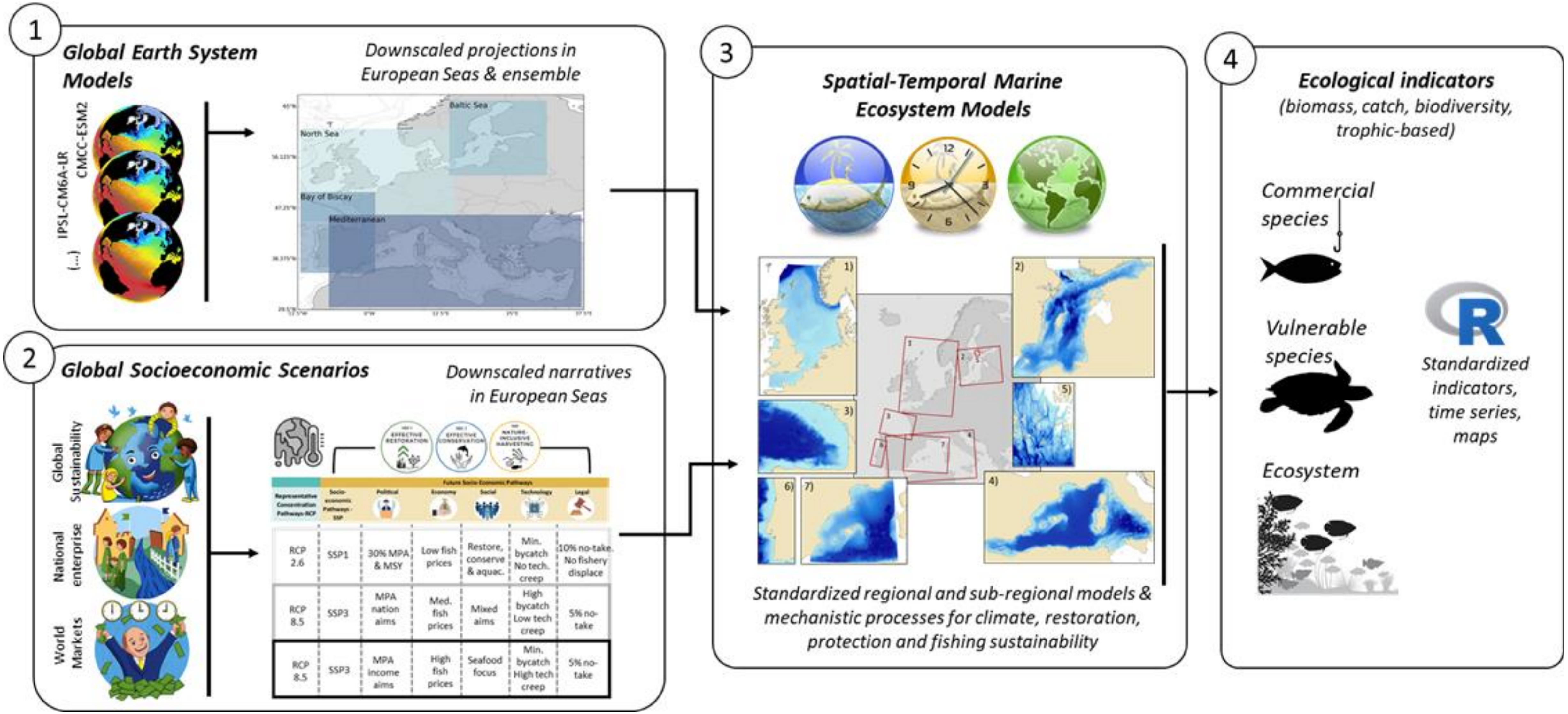
Three subregional Ecospace models

5) Archipelago Sea - Coastal Baltic Sea (Syke)
6) Portuguese Shelf (CSIC)
7) NW Mediterranean (CSIC)



Coll, Lynam et al., 2024. D4.4 (submitted)

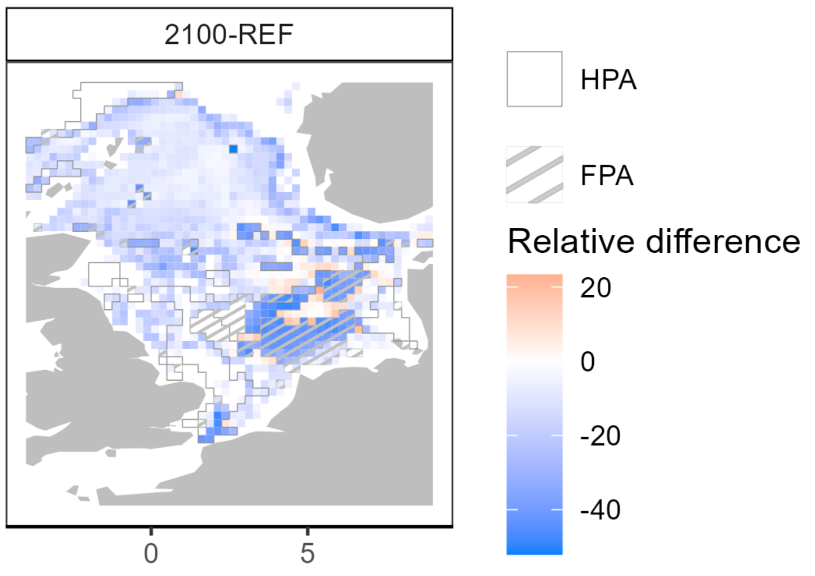
Overall Modelling Workflow



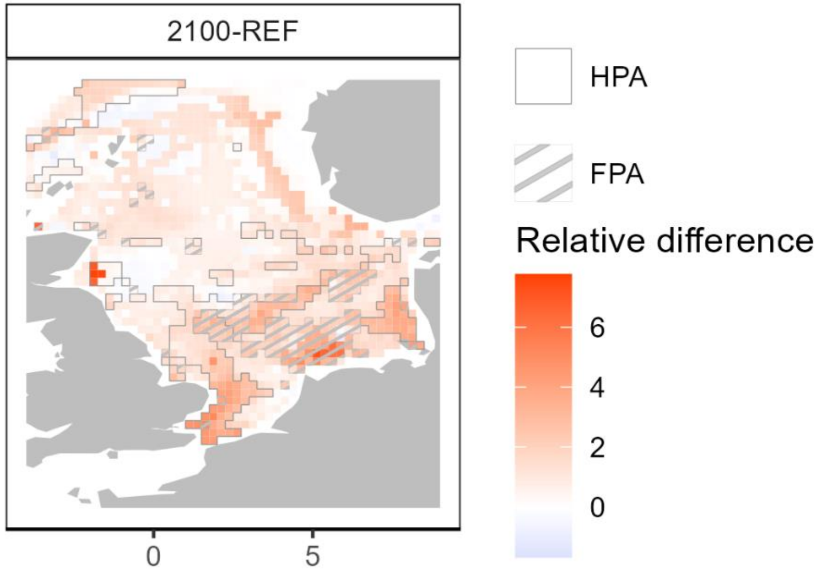
Global Sustainability

- Marine Protected Areas (30% by 2030)
- Restoration of native oysters by 2050
- Fishing effort reduced for sustainability
- Decrease bycatch rates by 99% (conservation)
- Decrease discards (unwanted fish) by 90%
- Assume mitigation of climate (RCP 2.6)
- Assume fuel price and fish prices increase

Demersal trawling (effort)



Shannon Diversity



Coll, Lynam et al., 2024. D4.4 (submitted)

Collaborative modelling

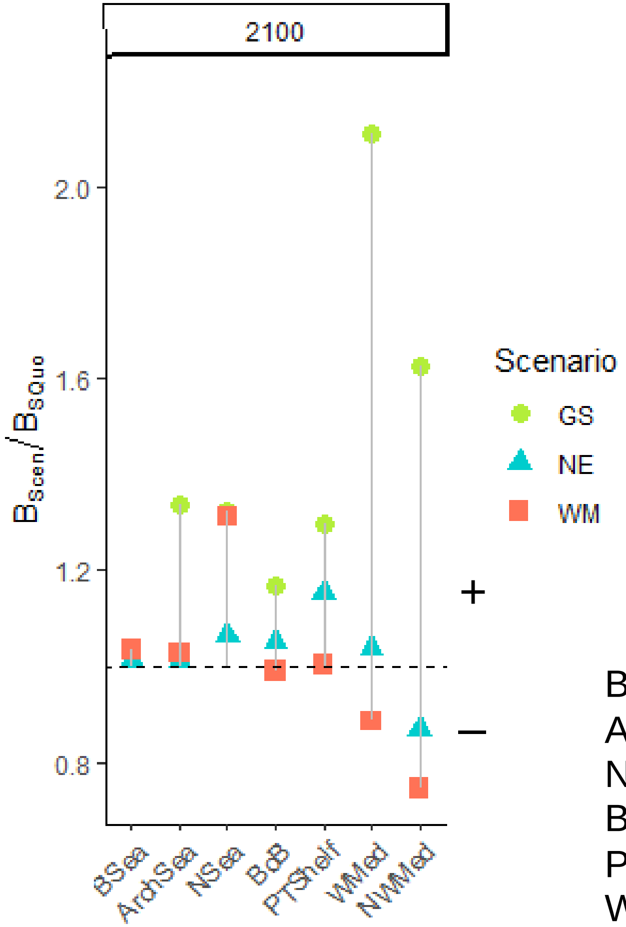
Demonstrable effects of management for conservation

Strongest in Mediterranean Sea

Largest effects of implementing no-take zones in climate mitigated scenario Global Sustainability (GS, RCP2.6)

(National Enterprise, NE, and World Markets, WM, follow RCP8.5)

Biomass of conservation species in no-take zones



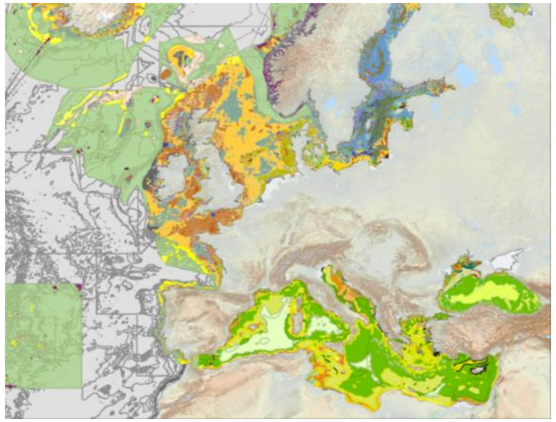
Bsea = Baltic Sea
ArchSea = Archipelago Sea (Baltic)
NSea – North Sea
BoB – Bay of Biscay
PTShelf – Portuguese Shelf
WMed - Western Mediterranean
NWMed – NorthWestern Med. Sea

Coll, Lynam et al., 2024. D4.4 (submitted)

Building on Ecospace scenarios to model potential effects of other pressures such as man-made structures

Future MARES

Offshore wind turbines off the North-East Coast of the United Kingdom. © Colin Ward



EMODnet Seabed Habitats (EUSeaMap) 2019

Decommissioning

Oil and gas central processing platform. © Shutterstock

GES4 SEAS

ACTNOW

Wind farms in European seas

EcoSTAR

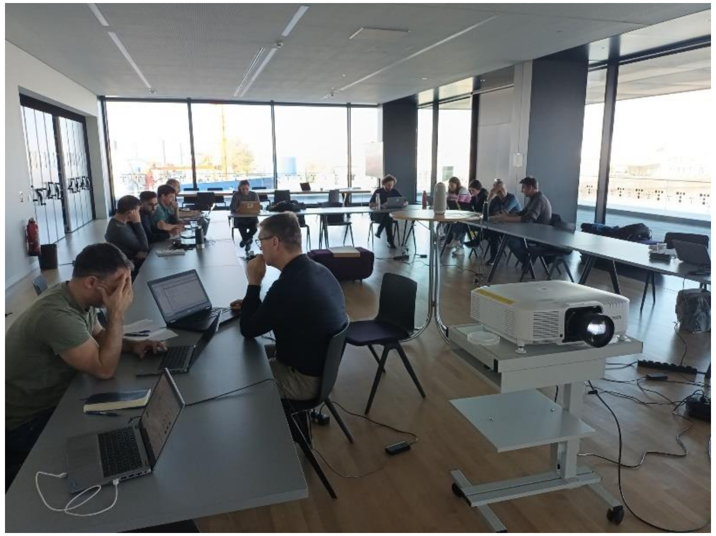
Ecosystem level importance of STructures as Artificial Reefs

University of St Andrews

600 YEARS

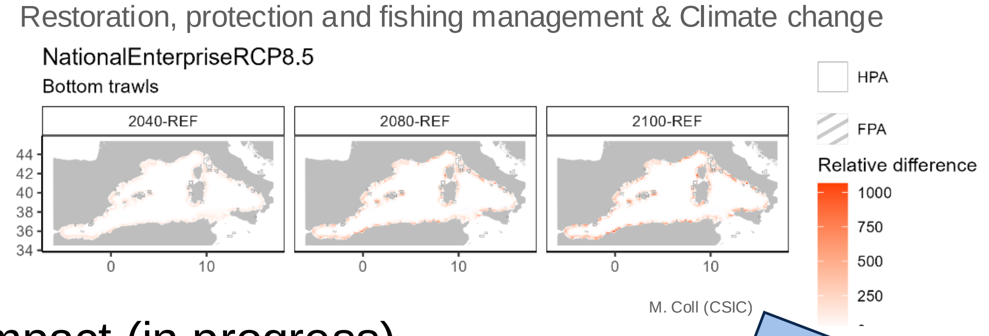
Oil and Gas decommissioning in North Sea

Model outputs are being used with the GES4SEAS toolbox to investigate importance of interactions in scenarios of change in (wider) cumulative impacts



Thünen Institute of Sea Fisheries, Bremerhaven, Germany 22 -25 April 2024

model (EwE-Ecospace) scenarios



cumulative impact (in progress)

Take home messages

- Human activities and climate change **impact marine ecosystems**
- We should monitor and assess change in pressures and **cumulative** impacts on state
- **Proactive management** can make a difference to mitigate pressure and impact
- Model “what-if” scenarios highlight **trade-offs** between **management options**
- **Marine Protected Areas and Restoration can play a key role** to help mitigate fishing and climate impacts.
- **Ecosystem-based management** interventions are crucial to enhance the resilience of ecological systems and improve our socio-economic future




Coll, Lynam et al., 2024. D4.4 (submitted)

Thank you for listening!

GES4 SEAS ACTNOW OBAMA –NEXT Future MARES Funded by the European Union UK Research and Innovation