Activity-, pressures-, effects- and management response-footprints – walking the way to protecting biodiversity and managing human impacts in the sea

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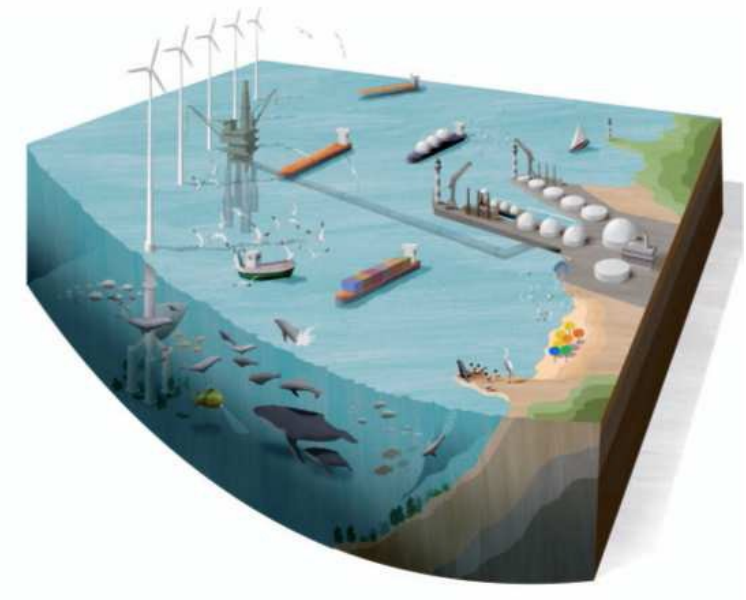
https://www.iecs.ltd

Challenges for estuarine/marine science & management:



There is only one big idea: *how to maintain and protect ecological structure and functioning while at the same time allowing the system to produce ecosystem services from which we derive societal benefits.*

- Recovery/coping with historical legacy
- Endangered coastal and marine ecosystem functions
- Legal & administrative framework
- Economic prosperity and delivery of societal benefits
- Coping with climate change & moving baselines & unbounded boundaries

In other words:

"to look after the natural stuff and deliver the human stuff"

DAPSI(W)R(M) framework


Marine Pollution Bulletin 118 (2017) 27–40

Contents lists available at ScienceDirect

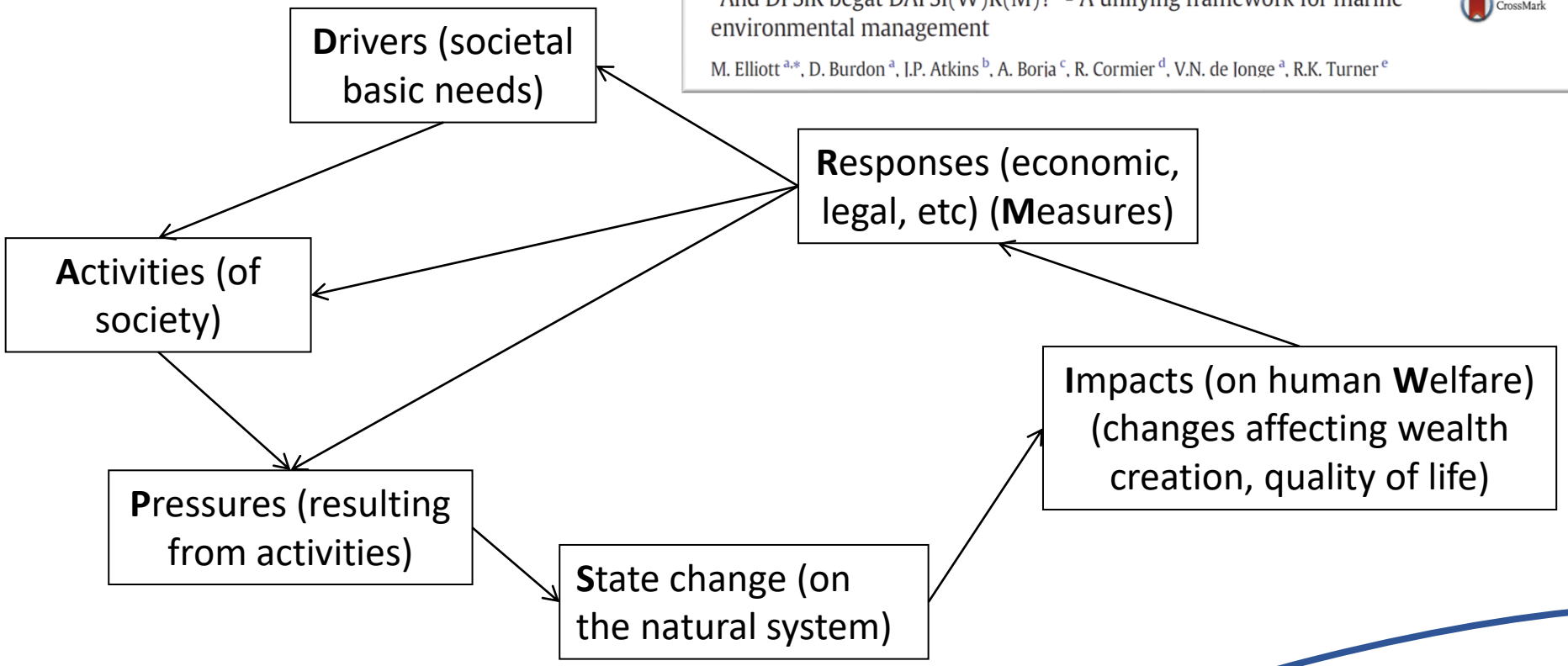
Marine Pollution Bulletin

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

Viewpoint

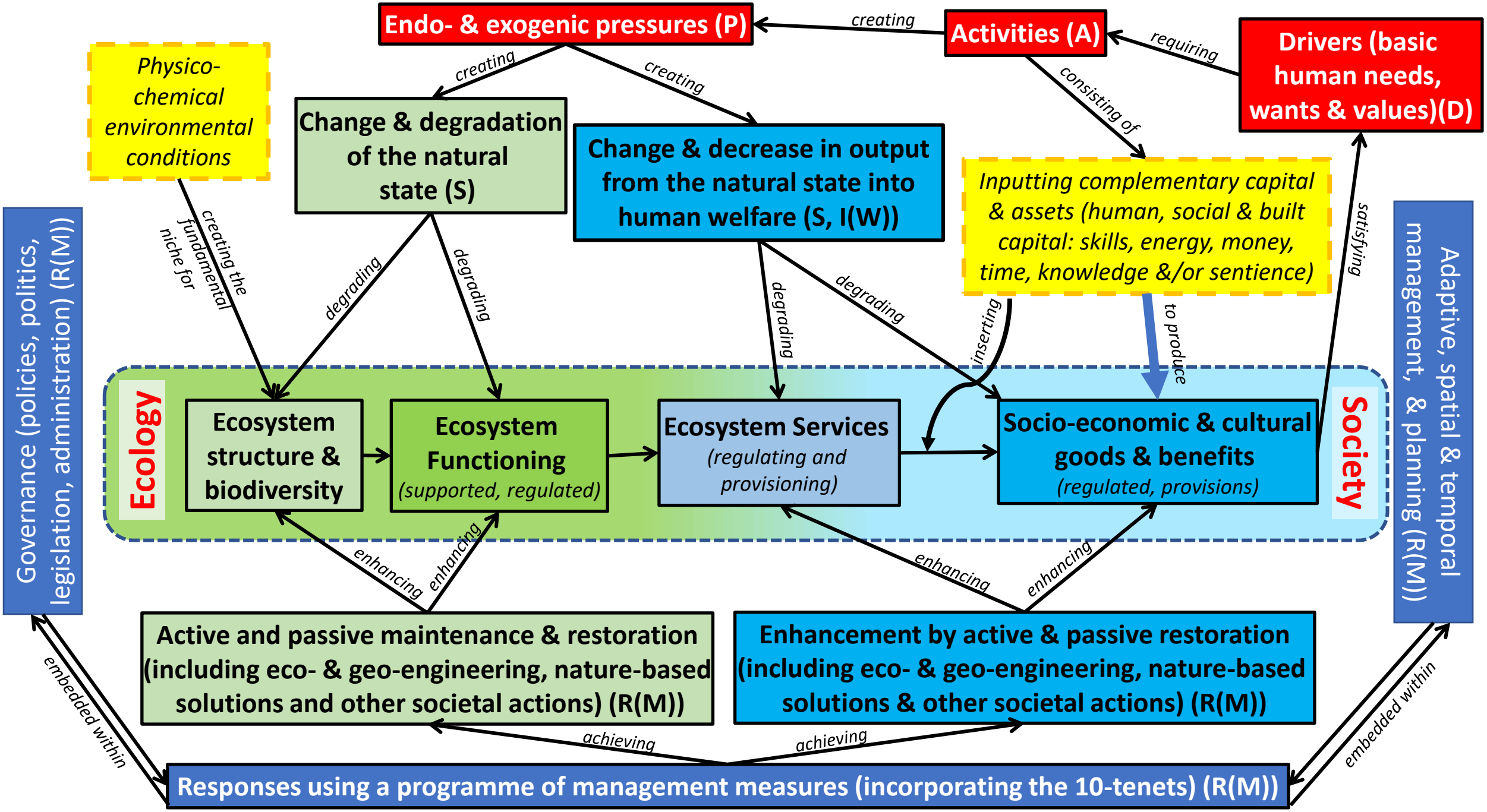
"And DPSIR begat DAPSI(W)R(M)!" - A unifying framework for marine environmental management

M. Elliott [a,*], D. Burdon [a], J.P. Atkins [b], A. Borja [c], R. Cormier [d], V.N. de Jonge [a], R.K. Turner [e]



(for each EnMP cf. ExUP)

Pronounced "dapsiworm"!


Endo- & exogenic pressures (P)
creating
Activities (A)
requiring
Drivers (basic human needs, wants & values)(D)
Physico-chemical environmental conditions
creating
creating
Change & degradation of the natural state (S)
Change & decrease in output from the natural state into human welfare (S, I(W))
consisting of
Inputting complementary capital & assets (human, social & built capital: skills, energy, money, time, knowledge &/or sentience)
satisfying
creating the fundamental niche for
degrading
degrading
degrading
degrading
inserting
to produce
Governance (policies, politics, legislation, administration) (R(M))
Ecology
Ecosystem structure & biodiversity
Ecosystem Functioning (supported, regulated)
Ecosystem Services (regulating and provisioning)
Socio-economic & cultural goods & benefits (regulated, provisions)
Society
Adaptive, spatial & temporal management, & planning (R(M))
enhancing
enhancing
enhancing
enhancing
Active and passive maintenance & restoration (including eco- & geo-engineering, nature-based solutions and other societal actions) (R(M))
Enhancement by active & passive restoration (including eco- & geo-engineering, nature-based solutions & other societal actions) (R(M))
embedded within
achieving
achieving
embedded within
Responses using a programme of management measures (incorporating the 10-tenets) (R(M))

Activities contributing to Endogenic Managed Pressures

Activity
Aquaculture
Extraction of living resources
Transport & Shipping
Renewable Energy
Non-renewable (fossil fuel) Energy
Non-renewable (nuclear) Energy
Extraction of non-living resources
Navigational Dredging
Coastal Infrastructure
Land-based Industry
Agriculture
Tourism/Recreation
Military
Research
Carbon Sequestration

Pressures
Smothering
Substratum loss
Changes in siltation
Abrasion
Selective extraction of non-living resources (habitat removal)
Underwater noise
Litter
Thermal regime change
Salinity regime change
Introduction of synthetic compounds
Introduction of non-synthetic compounds
Introduction of radionuclides
Introduction of other substances

Nitrogen and phosphorus enrichment
Input of organic matter
Introduction of microbial pathogens
Introduction of non-indigenous species and translocations
Selective extraction of species
Death or injury by collision
Barrier to species movement
Emergence regime change
Water flow rate changes
pH changes
Electromagnetic changes
Change in wave exposure

(adapted from Elliott et al 2017)

Examples of Exogenic Unmanaged Pressures (adapted from Elliott et al 2017)

Pressure	Description
Thermal regime change	Temperature change (average, range, variability) climate change (large scale)
Salinity regime change	Temperature change (average, range, variability) due climate change (large scale)
Emergence regime change	Change in natural sea level (mean, variation, range) due climate change (large scale) and isostatic rebound
Water flow rate changes	Change in currents (speed, direction, variability) due climate change (large scale)
pH changes	Change in pH (mean, variation, range) due climate change (large scale), volcanic activity (local)
Change in wave exposure	Change in size, number, distribution and/or periodicity of waves along a coast due to climate change (large scale).
Non-indigenous species introductions	Increase in species from outside the management area

(adapted from Elliott et al 2017)

What are we managing? - Hazards, risks and their prevention, from single activities to whole areas

Exogenic unmanaged pressures ***(where the consequences are managed in the management area but the causes require global action)***	**Endogenic managed pressures** ***(where the causes and consequences are managed within the management area)***
Alien species	New infrastructure
Sea level rise (or loss?)	Energy generation
Increased temperature	Petrochemical industries
Increased storminess	Dredging and navigation
Flooding and erosion	Wetland loss and gain
Changes to catchment run-off	Urban discharges
Repercussions of NAO	Mine-water discharges
Agricultural runoff in catchment	Subsidence
Saline ingression	Historical pollution residues

And opportunities!

The essence of marine management (RA&RM; OA&OM):

Risk Assessment:

- Where are the problems and what changes do they cause? (ExUP & EnMP)
- What is their impact on ecosystem structure and functioning?
- What are the repercussions for ecosystem valuation based on economy-ecology interactions?
- What are the future environmental changes and economic futures?

Risk Management:

- What governance framework is there, what do stakeholders need & what are successes & failures?
- What can we do about the problems, hazards & risks and how to address them now and in the future?
- How 'good' is the decision-making?

And the corollary: Opportunity Assessment and Management

(Elliott, 2014 Mar. Poll. Bull.; Cormier et al 2019 OCMA, and others)

Hazard & Risk Typology: Source of Problems & Cause for Management

Hazards in Estuaries, Coasts and Seas leading to Risk (depending on assets)
A) Surface hydrological hazards (e.g. flooding)
B) Surface physiographic removal by natural processes - chronic/long-term (e.g. erosion)
C) Surface physiographic removal by human actions - chronic/long-term (e.g. land-claim, space removal)
D) Surface physiographic removal - acute/short-term (e.g. cliff failure)
E) Climatological hazards - acute/short term (e.g. storminess)
F) Climatological hazards - chronic/long term (e.g. NAO changes, sea-level rise)
G) Tectonic hazards - acute/short term (e.g. earthquakes, land-slip)
H) Tectonic hazards - chronic/ long term (e.g. subsidence, isostatic rebound)

= Risk Assessment & Risk Management (RA&RM):
- Hazard Identification:
- Risk Assessment:
- Risk Management:
- Risk Communication:

(Modified and Expanded from Elliott et al., 2014, 2019)

Challenge #1 – determining the hazards and their resulting risks

Hazards in Estuaries, Coasts and Seas leading to Risk (depending on assets) (cont.)
I) Anthropogenic microbial biohazards (e.g. sewage pollution)
J) Anthropogenic macrobial biohazards (e.g. non-indigenous species)
K) Anthropogenic introduced technological hazards (e.g. infrastructure, sediments)
L) Anthropogenic extractive technological hazards (e.g. fishing, aggregates)
M) Anthropogenic acute chemical hazards (e.g. oil spills)
N) Anthropogenic chronic chemical hazards (e.g. diffuse and point-source contaminants)
O) Anthropogenic acute geopolitical hazards (e.g. wars, unrest, terrorism)
P) Anthropogenic chronic geopolitical hazards (e.g. human migrations, civil-war)

All hazards caused or exacerbated by climate change or the societal responses to climate change!!

Ocean & Coastal Management 93 (2014) 88–99

Contents lists available at ScienceDirect

Ocean & Coastal Management

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

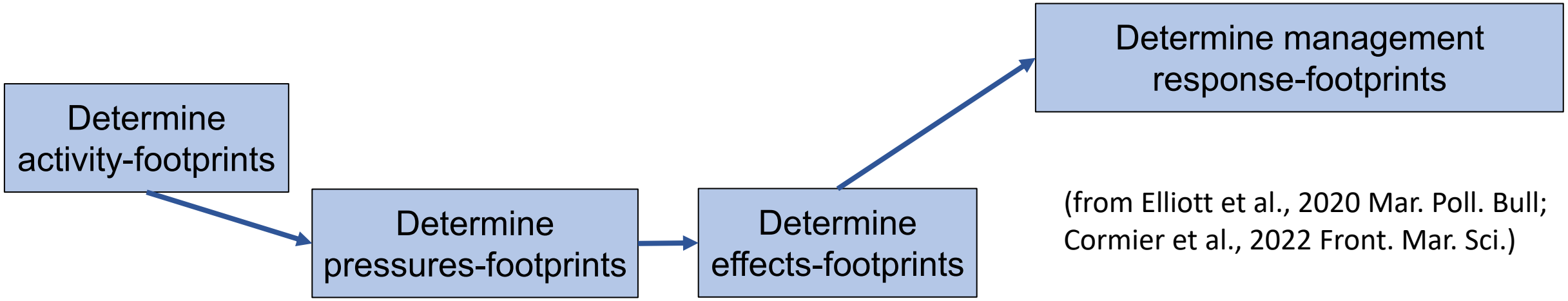
Review

A typology of marine and estuarine hazards and risks as vectors of change: A review for vulnerable coasts and their management

Michael Elliott [a,*], Nicholas D. Cutts [a], Anna Trono [b]

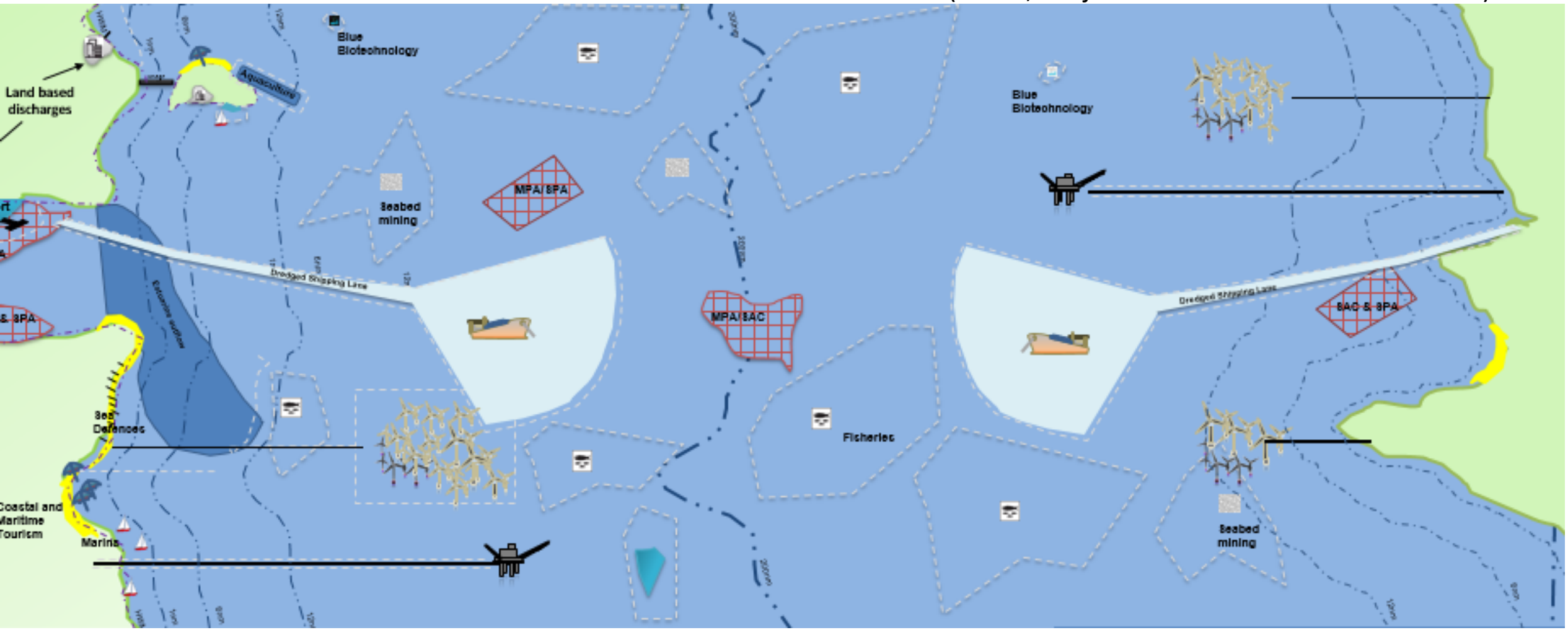
The Need to Define, Understand and Quantify Footprints

1. Activity-footprints
2. Pressures-footprints
3. Effects-footprints
4. Management Response-footprints



(from Elliott et al., 2020 Mar. Poll. Bull; Cormier et al., 2022 Front. Mar. Sci.)

(Elliott, Borja & Cormier 2020 Mar. Poll. Bull.)

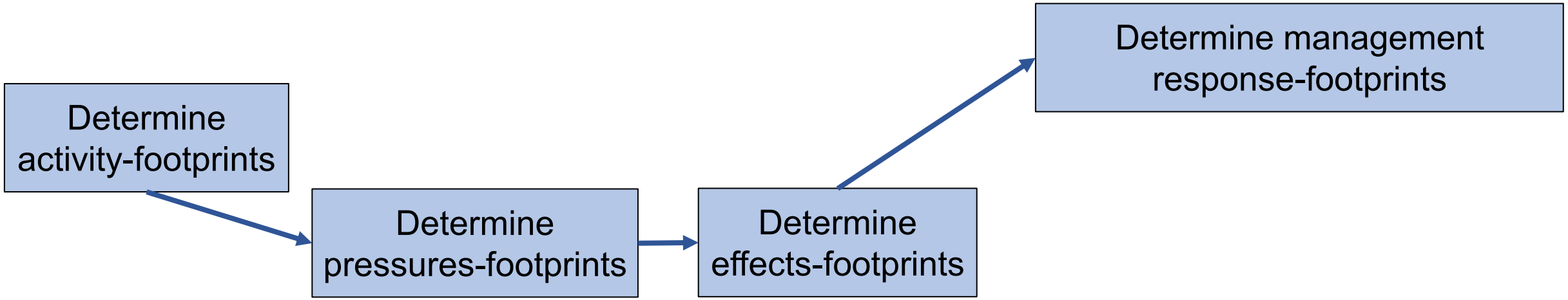


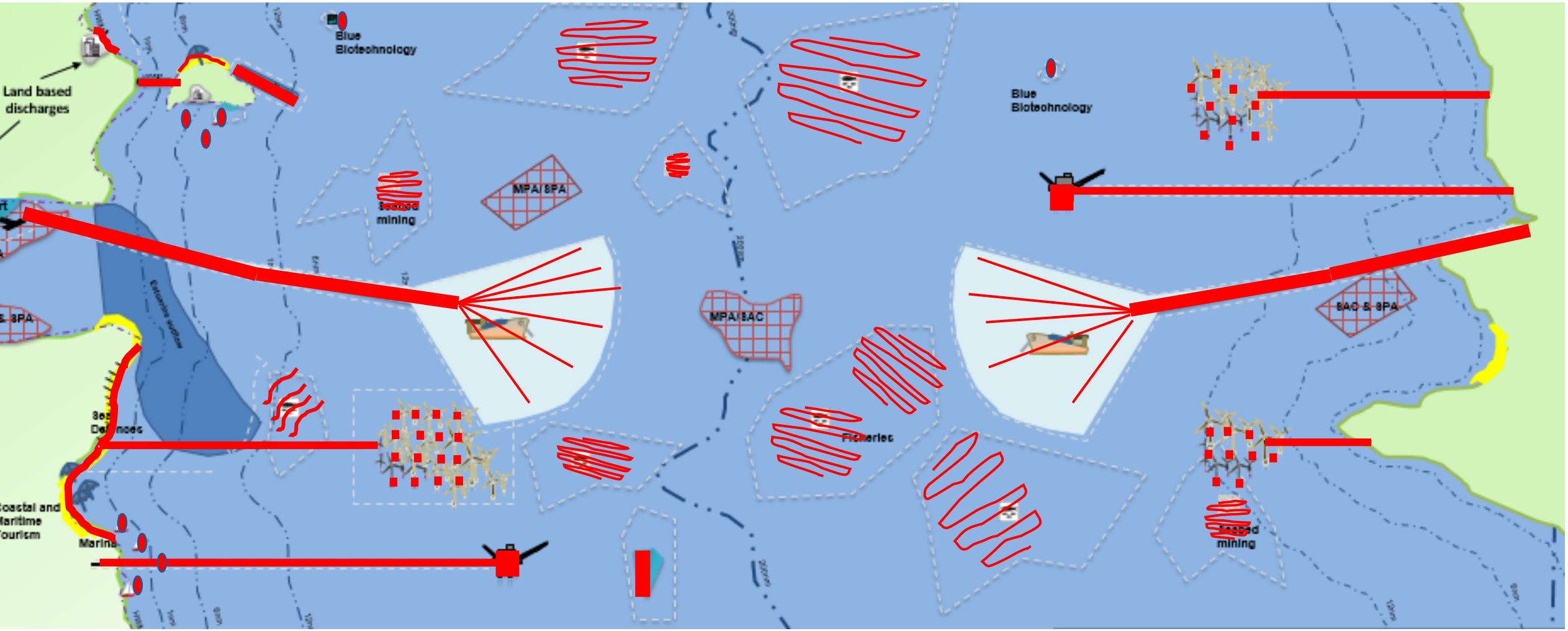
Challenge of multi-use international seas: Stylised transnational sea area showing activity footprints and transboundary Marine Protected Areas and fishing grounds – to reflect the challenges of complex marine management

Management of a complex transboundary area

Activity-footprint

The area and/or time, based on the duration, intensity and frequency of an activity which ideally has been legally sanctioned by a regulator in an authorisation, licence, permit or consent, and which should be so clearly defined and mapped in order to be legally-defendable; it should be both easily observed and monitored and attributable to the proponent of the activity.





Activity-footprint

Management of a complex transboundary area

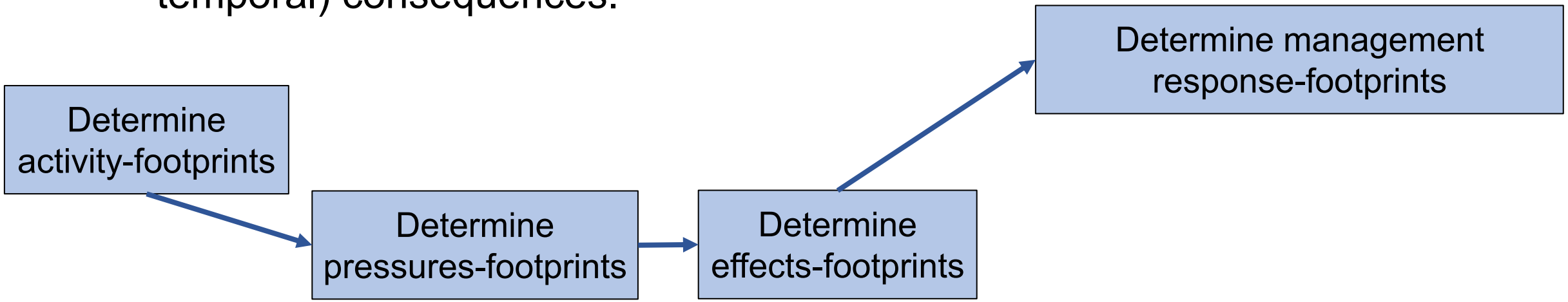
Seabed dredging – an example of the licence area being much bigger than the activity-footprint

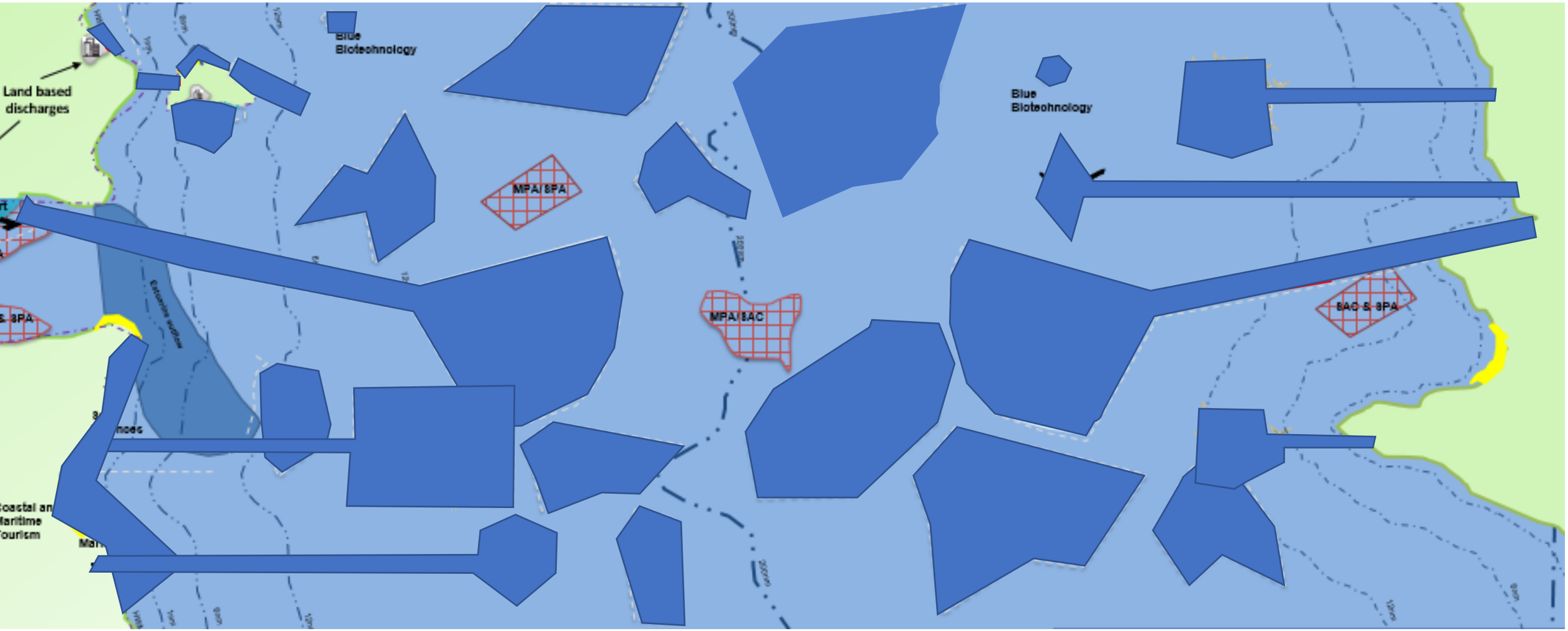
Trailing suction hopper dredger

Pressures-footprint

The area and time covered by the mechanism(s) of change resulting from a given activity or all the activities in an area once avoidance and mitigation measures have been employed (the endogenic managed pressures). It does not necessarily coincide with the activity-footprint and may usually be larger but could be smaller.

It also needs to include the influence and consequences of pressures emanating from outside the management area (the exogenic unmanaged pressures); given that these are caused by wide-scale events (and even global developments) then these are likely to have larger scale (spatial and temporal) consequences.





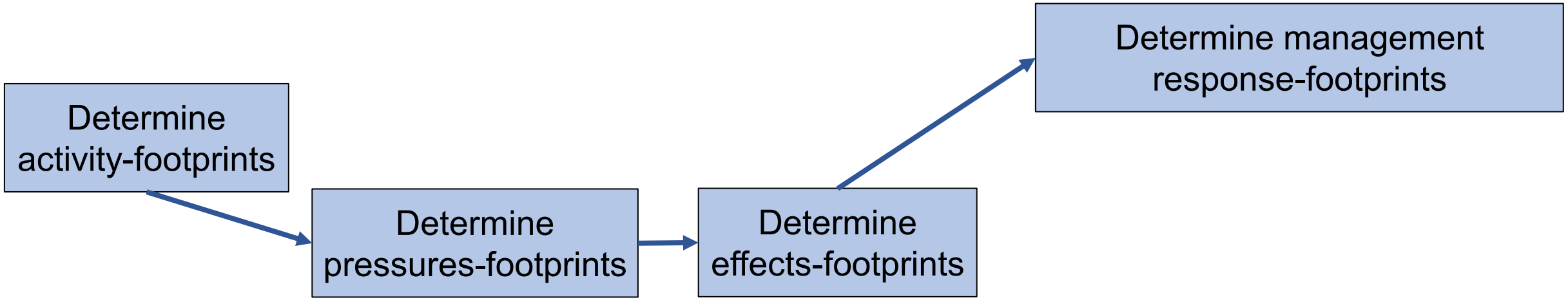
Activity-footprint

Pressures-footprint & EIA area? = Σ
Cumulative Effects Assessment?

Management of a complex transboundary area

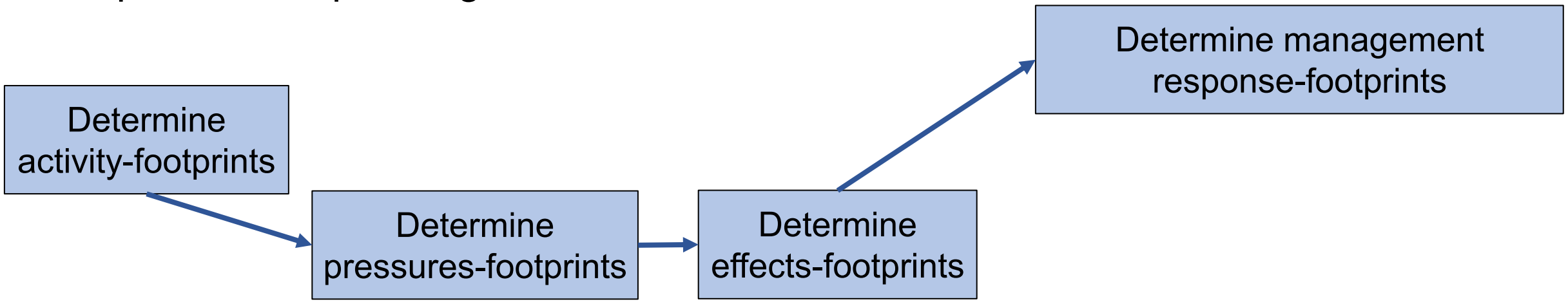
Effects-footprints

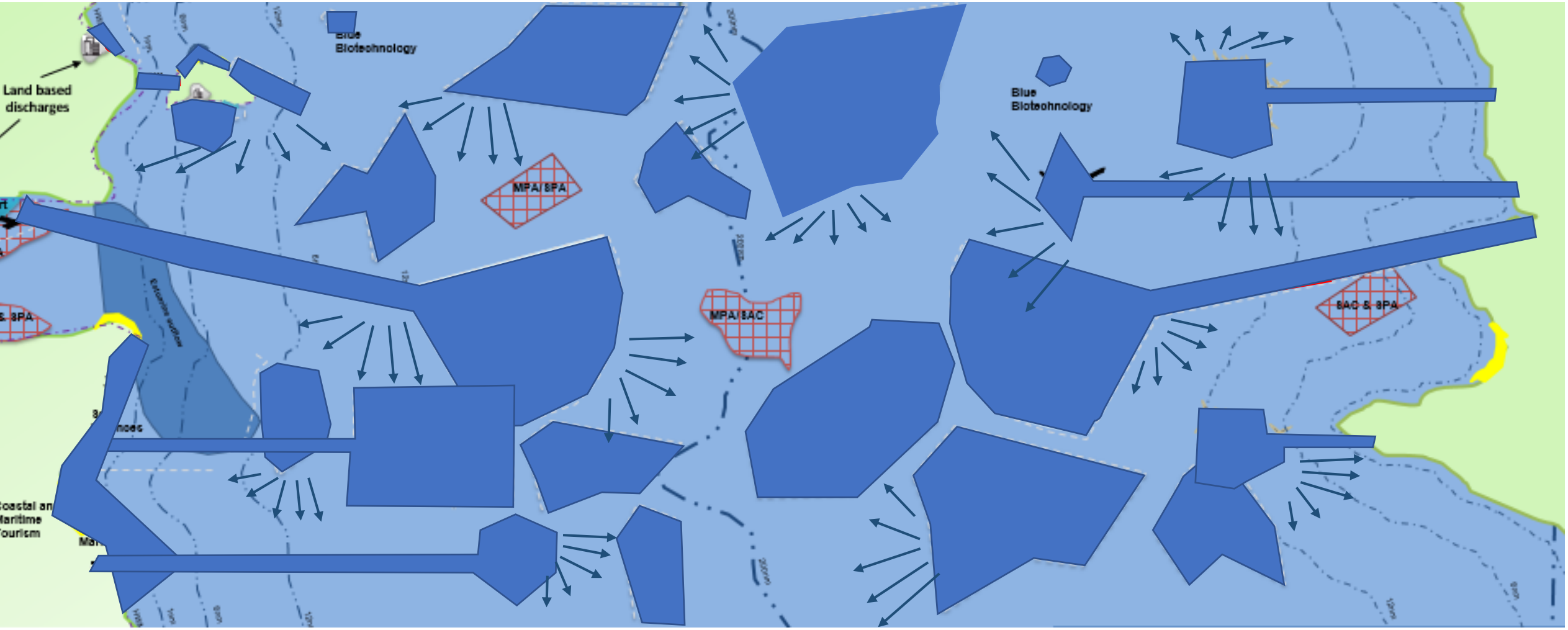
The spatial (extent), temporal (duration), intensity, persistence and frequency characteristics resulting from:
(a) a single pressure from a marine activity,
(b) all the pressures from that activity,
(c) all the pressures from all activities in an area, or
(d) all pressures from all activities in an area or emanating from outside the management area.



Effects-footprints

- They include both the adverse and positive consequences on the natural ecosystem components and on the ecosystem services and societal goods and benefits.
- They need to include the near-field and far-field effects and near- and far-time effects because of the dynamics and characteristics of marine areas and the uses and users of the area.
- They may be larger in extent and more persistent than the causing activity-footprint and the resulting pressures-footprints.
- They also need to encompass the effects of both endogenic and exogenic pressures operating in that area.





Activity-footprint

Pressures-footprint & EIA area? = Σ
Cumulative Effects Assessment?

Effects-footprint

Management of a complex transboundary area

Activity-footprint

Pressures-footprint & EIA area? = Σ
Cumulative Effects Assessment?

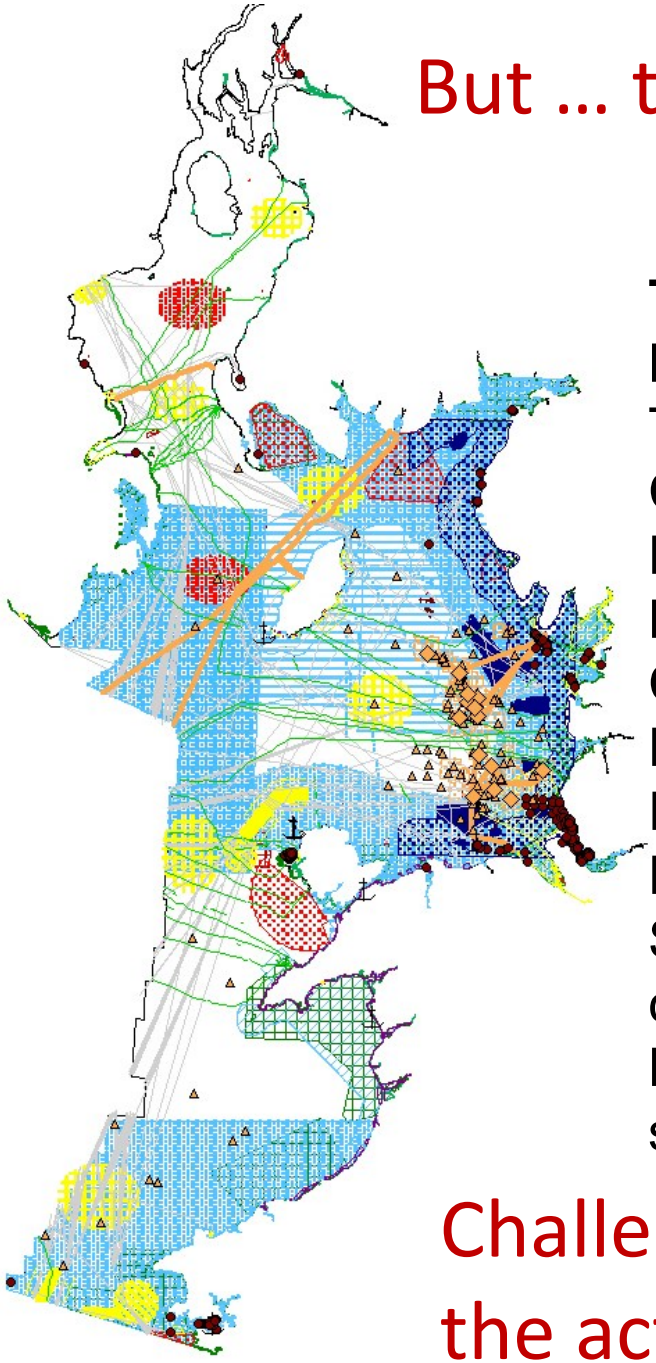
Effects-footprint

Static feature conservation management

Highly mobile feature conservation management

AND RESPONSES-FOOTPRINTS?

Management of a complex transboundary area



But … the reality:

To plan:

Land use & infrastructure
Tourism & recreation
Coastal defence
Ports & navigation
Military activities
Conservation
Dredging & disposal
Fishing & aquaculture
Renewable energy
Submarine communication cables
Mineral extraction (oil, gas, sand)

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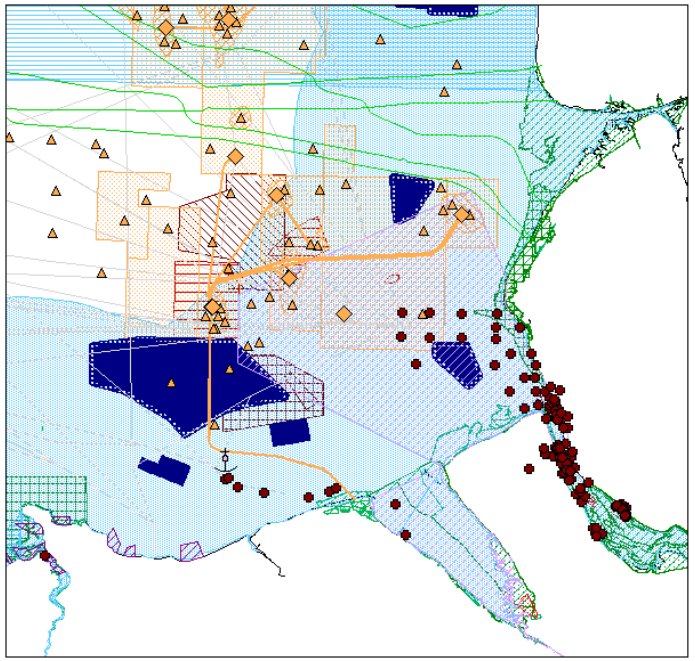
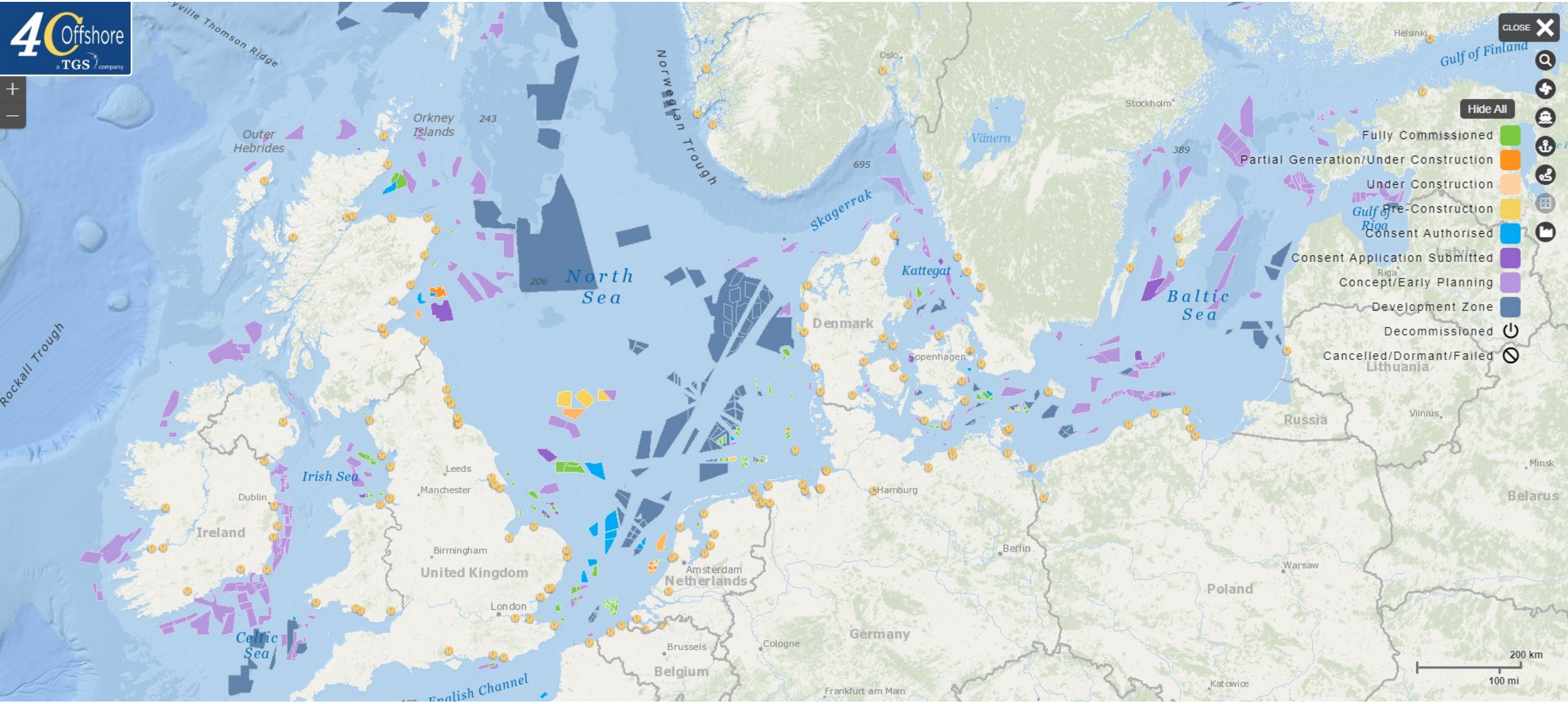
ScienceDirect
Marine Policy 31 (2007) 287–298
MARINE POLICY
www.elsevier.com/locate/marpol

A proposed multiple-use zoning scheme for the Irish Sea. An interpretation of current legislation through the use of GIS-based zoning approaches and effectiveness for the protection of nature conservation interests

Suzanne J. Boyes[a,*], Michael Elliott[a], Shona M. Thomson[a], Stephen Atkins[b], Paul Gilliland[c]

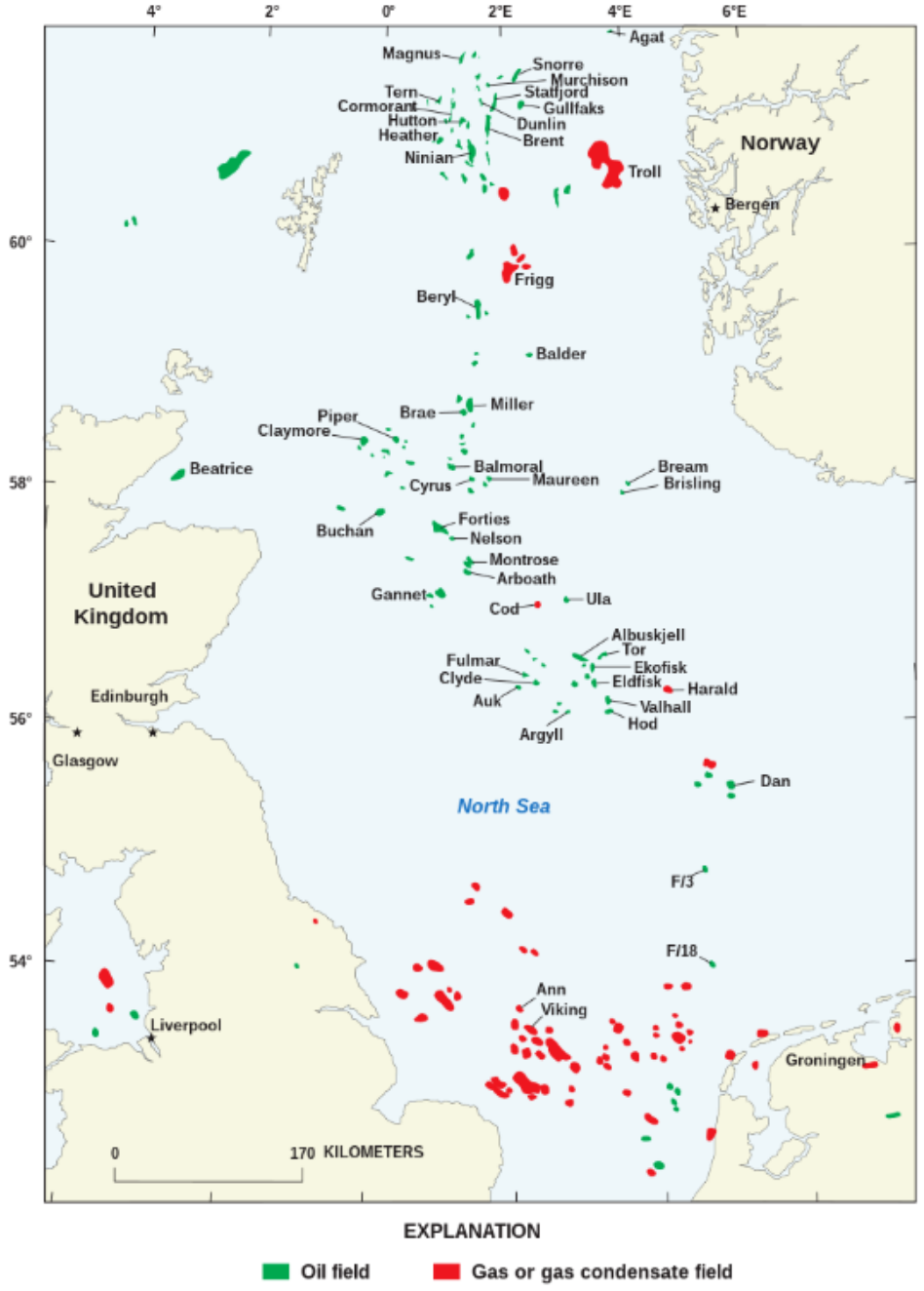


Challenge #2 – where and what are the sizes of the activity-, pressures- and effects-footprints?!



Offshore Wind Developments
– all stages

https://map.4coffshore.com/offshorewind/



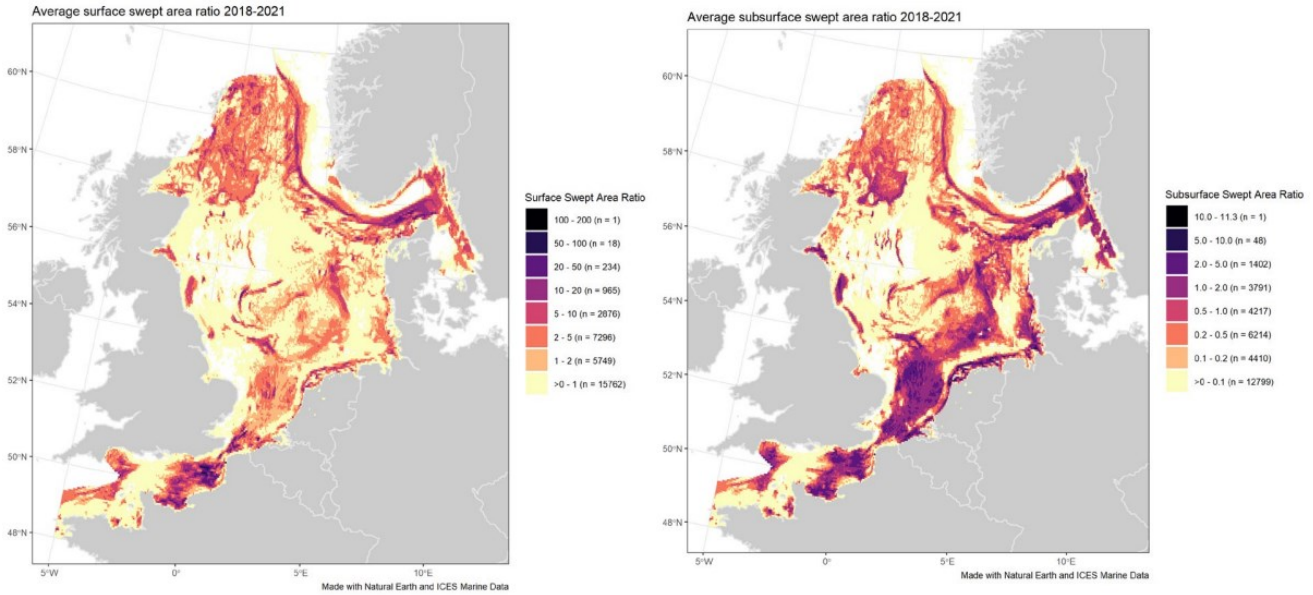


Figure 6 Average annual surface (left) and subsurface (right) disturbance by mobile bottom-contacting fishing gear (bottom otter trawls, bottom seines, dredges, beam trawls) in the Greater North Sea during 2018–2021 (with available data), expressed as average swept area ratios (SAR).

"ICES estimates that commercial fisheries have been deployed over approximately 569 000 km2 of the ecoregion in the period 2018–2021, corresponding to ca.85% of the ecoregion's spatial extent." (ICES Ecosystem Overviews Greater North Sea ecoregion Published 15 December 2022)

Country	Pipeline length (km)	Cable length (km)	Footprint km² (*)
The Netherlands	4,500	6,000	2,625
Belgium	163	914	269.25
UK	45,000	?	11,250
Norway	8,800	?	2,200
Germany	?	?	?
Denmark	?	?	?
Total			>16,350

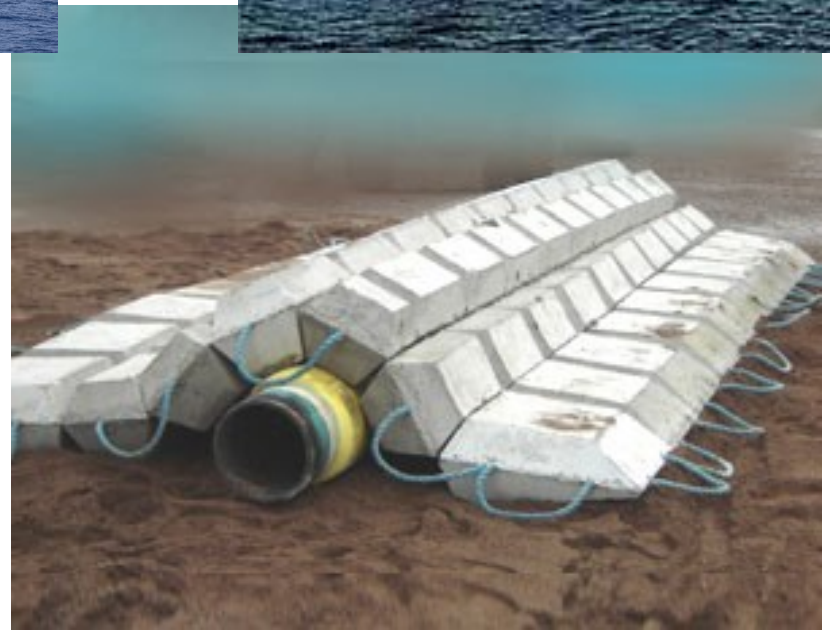
(* assuming 250m width as a conservative estimate for the area disturbed)

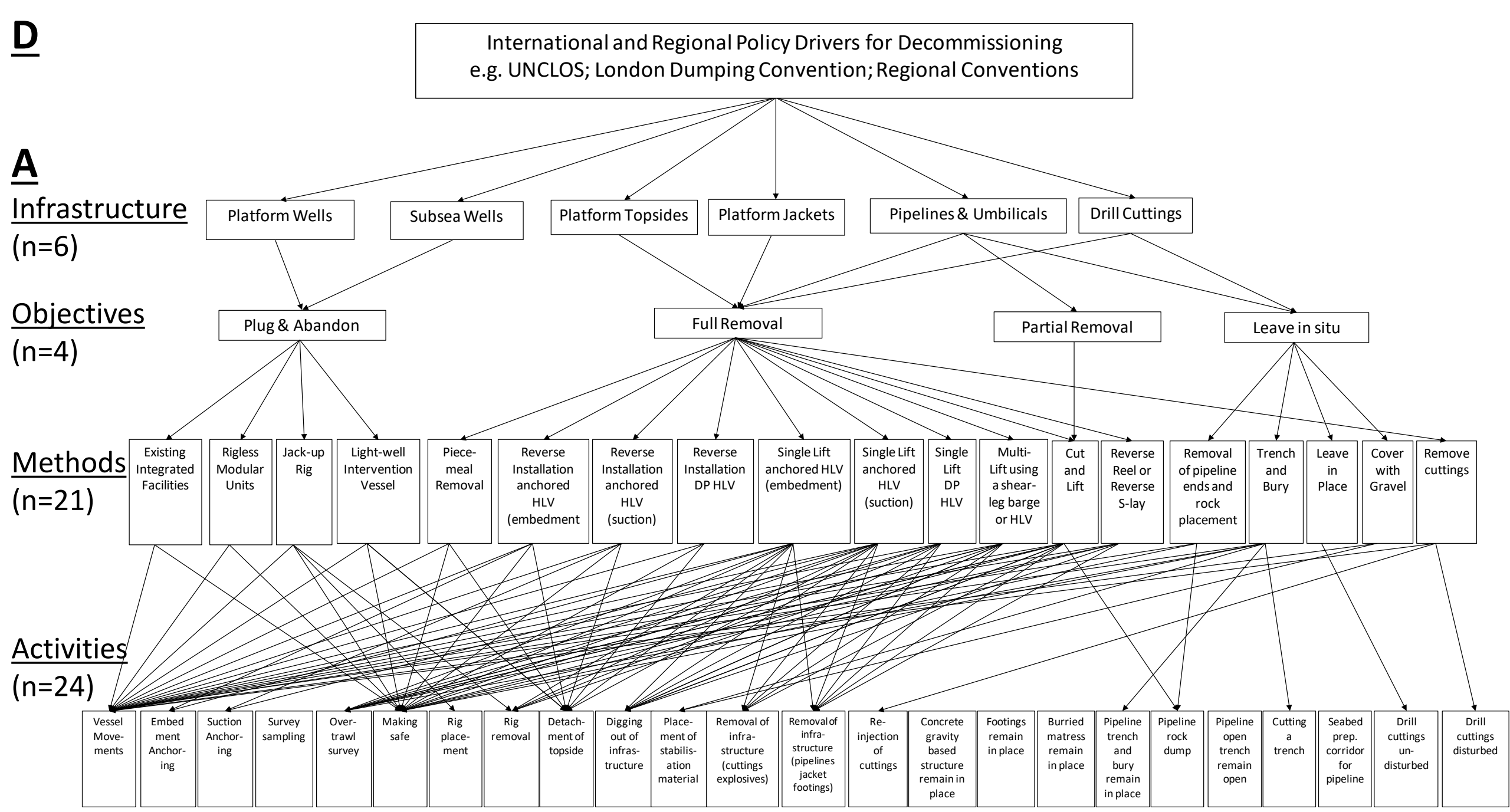
Main message – if it is difficult calculating the activity-footprint, how difficult will it be to calculate the pressures- and effects-footprints?!

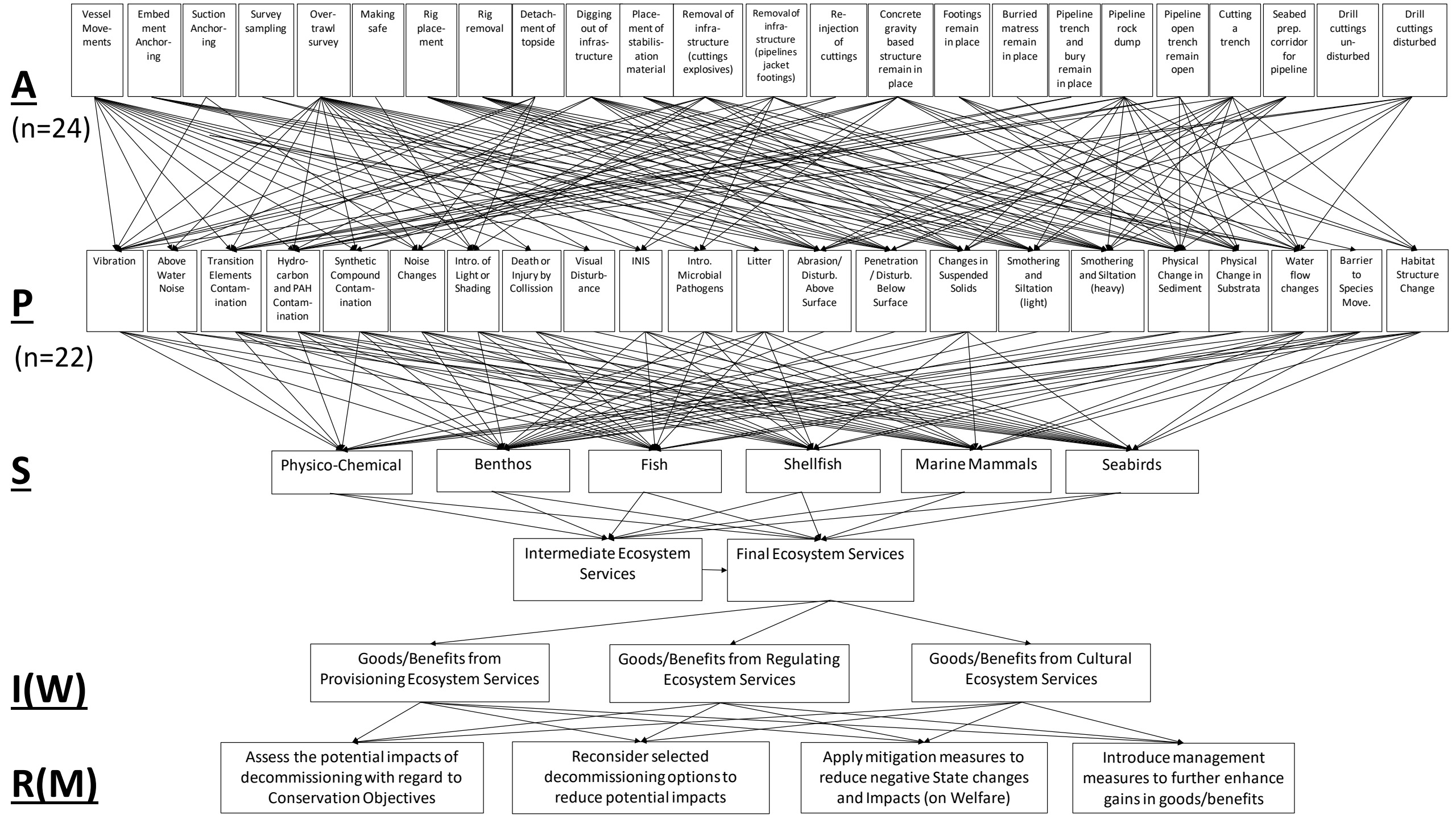
Preliminary estimates of activity-footprints:

North Sea Estimates	Km²
Area occupied by oil and gas rigs	165.6
OWF Turbine + scour protection	13.7
Wind farm occupied area	6,732.8
Aggregate extraction (UK North Sea)	licensed area 623.25 dredged 64.16 (10% of licensed area)
Seabed dredging (NL, DK, D, BE, UK)	5,528
Total (O&G, OWF, cables, pipelines, dredged)	>28,800
Total area North Sea	575,000 (i.e. >5% seabed occupied)

Example Oil and gas and offshore wind infrastructure decommissioning




D
International and Regional Policy Drivers for Decommissioning
e.g. UNCLOS; London Dumping Convention; Regional Conventions
A
Infrastructure
(n=6)
Platform Wells
Subsea Wells
Platform Topsides
Platform Jackets
Pipelines & Umbilicals
Drill Cuttings
Objectives
(n=4)
Plug & Abandon
Full Removal
Partial Removal
Leave in situ
Methods
(n=21)
Existing Integrated Facilities
Rigless Modular Units
Jack-up Rig
Light-well Intervention Vessel
Piece-meal Removal
Reverse Installation anchored HLV (embedment
Reverse Installation anchored HLV (suction)
Reverse Installation DP HLV
Single Lift anchored HLV (embedment)
Single Lift anchored HLV (suction)
Single Lift DP HLV
Multi-Lift using a shear-leg barge or HLV
Cut and Lift
Reverse Reel or Reverse S-lay
Removal of pipeline ends and rock placement
Trench and Bury
Leave in Place
Cover with Gravel
Remove cuttings
Activities
(n=24)
Vessel Move-ments
Embed ment Anchor-ing
Suction Anchor-ing
Survey sampling
Over-trawl survey
Making safe
Rig place-ment
Rig removal
Detach-ment of topside
Digging out of infras-tructure
Place-ment of stabilis-ation material
Removal of infra-structure (cuttings explosives)
Removal of infra-structure (pipelines jacket footings)
Re-injection of cuttings
Concrete gravity based structure remain in place
Footings remain in place
Burried matress remain in place
Pipeline trench and bury remain in place
Pipeline rock dump
Pipeline open trench remain open
Cutting a trench
Seabed prep. corridor for pipeline
Drill cuttings un-disturbed
Drill cuttings disturbed


A
(n=24)
Vessel Move-ments
Embed ment Anchor-ing
Suction Anchor-ing
Survey sampling
Over-trawl survey
Making safe
Rig place-ment
Rig removal
Detach-ment of topside
Digging out of infras-tructure
Place-ment of stabilis-ation material
Removal of infra-structure (cuttings explosives)
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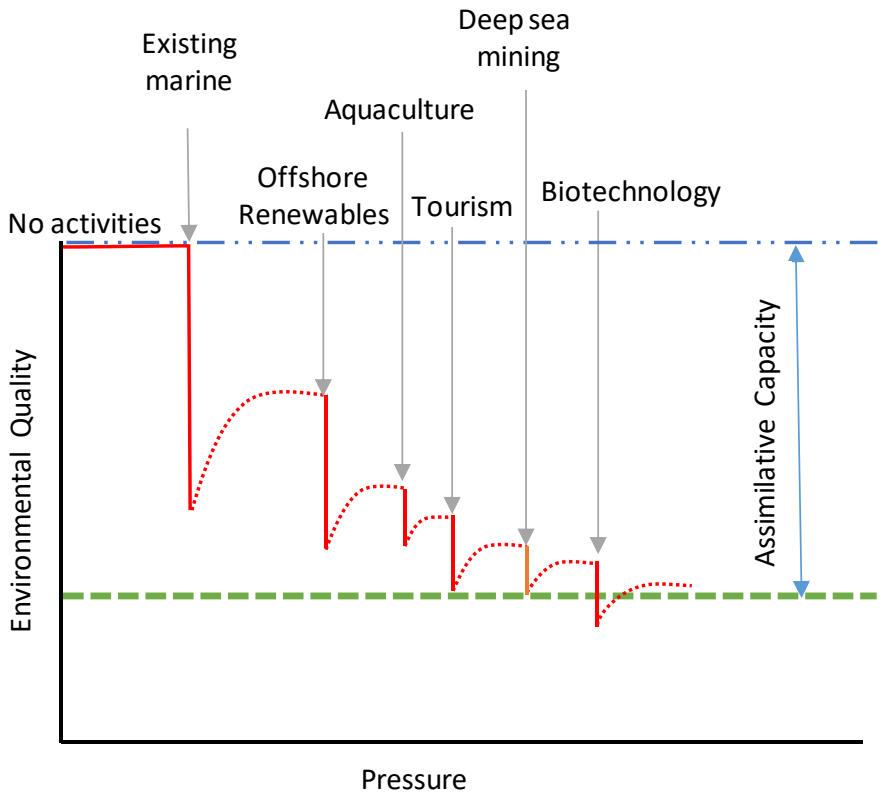
Pipeline trench and bury remain in place
Pipeline rock dump
Pipeline open trench remain open
Cutting a trench
Seabed prep. corridor for pipeline
Drill cuttings un-disturbed
Drill cuttings disturbed
P
(n=22)
Vibration
Above Water Noise
Transition Elements Contam-ination
Hydro-carbon and PAH Contam-ination
Synthetic Compound Contam-ination
Noise Changes
Intro. of Light or Shading
Death or Injury by Collission
Visual Disturb-ance
INIS
Intro. Microbial Pathogens
Litter
Abrasion/ Disturb. Above Surface
Penetration / Disturb. Below Surface
Changes in Suspended Solids
Smothering and Siltation (light)
Smothering and Siltation (heavy)
Physical Change in Sediment
Physical Change in Substrata
Water flow changes
Barrier to Species Move.
Habitat Structure Change
S
Physico-Chemical
Benthos
Fish
Shellfish
Marine Mammals
Seabirds
Intermediate Ecosystem Services
Final Ecosystem Services
I(W)
Goods/Benefits from Provisioning Ecosystem Services
Goods/Benefits from Regulating Ecosystem Services
Goods/Benefits from Cultural Ecosystem Services
R(M)
Assess the potential impacts of decommissioning with regard to Conservation Objectives
Reconsider selected decommissioning options to reduce potential impacts
Apply mitigation measures to reduce negative State changes and Impacts (on Welfare)
Introduce management measures to further enhance gains in goods/benefits

Environmental Quality Model incl. mitigation measures for cumulative Blue Growth Activities



(Elliott et al., 2018, Mar. Poll. Bull.; Borja et al Mar. Poll. Bull. 2011)

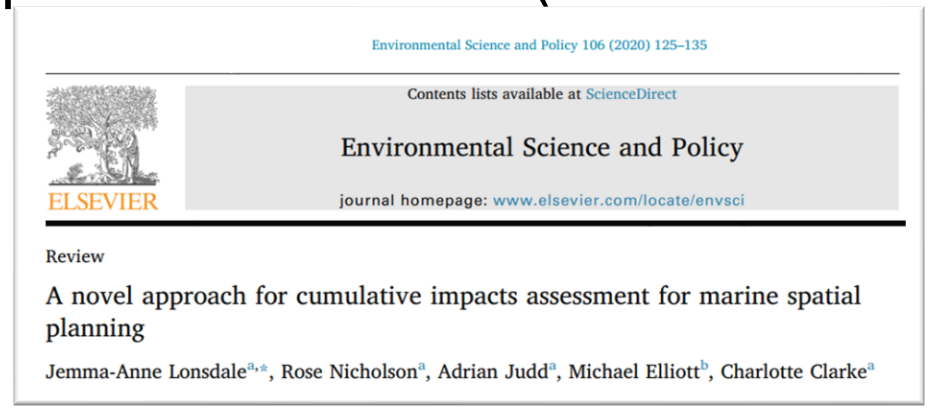
KEY

- Pristine marine environment with no activities
- GES threshold (∑ of 11 MSFD Descriptors)
- Trajectory of environmental quality as the marine area is used by multiple activities
- Regained environmental quality with mitigation and/or compensation measures

Challenge #3 – how do we cope with cumulative effects and the availability/loss of assimilative and carrying capacities?!

Cumulative Effects/Impacts Assessment – Challenges (1):

- Increasing our poor ability to measure the spatial and temporal effects-footprints of pressures from named activities
- Determining the extent, duration and frequency of the pressures from an activity, not just the activity itself in a place at a given time (not assuming an activity = a pressure) (see the DAPSI(W)R(M) framework)
- Determining the relative effects of endogenic managed pressures overlaid by exogenic unmanaged ones
- Giving a weighting to the different effects-footprints in space and time, not just assuming they are added linearly and arithmetically (may be antagonistic or even exponential)
- Knowing what is in an area, what activities, what receptors or relevance (at which area, when)


Environmental Science and Policy 106 (2020) 125–135

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Review

A novel approach for cumulative impacts assessment for marine spatial planning

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Cumulative Effects/Impacts Assessment – Challenges (2):

- Tackling the effects-footprints on the mobile receptors (mostly species) not just the sedentary ones (habitats and species)
- Accepting the assumption that CEA relates to ‘all impacts of all activities’ not just ‘all impacts of one activity/sector’ (the latter is just an EIA carried out properly – if we say ‘a CEA or offshore wind’ then this is a misnomer)
- Determining if there is a tipping point or threshold when all impacts are taken together and effects-footprints overlap
- Moving from an impact on the natural receptors to those on the human receptors (thus moving along the continuum from ecosystem structure and functioning, to ecosystem services, to societal goods and benefits)
- Tackling the conceptual difficulties in the continuum from EIA to CEA to SEA to MSP

Challenge #4 – how do we ensure the connectivity, coherence and/or equivalence between transboundary areas?

Challenge – Typology of the Key Aspects of Connectivity, Coherence and Equivalence

- Connectivity, equivalence or coherence in natural sciences - *Physico-chemical connectivity; Ecological connectivity; Conservation coherence, equivalence and connectivity.*
- Connectivity or equivalence in marine management - *Connectivity of human activity-, pressures- and effects-footprints and equivalence of management response-footprints; equivalence of monitoring, assessment and reporting.*
- Connectivity, coherence or equivalence in marine governance - *administrative equivalence; legislative connectivity or equivalence; equivalence of Maritime Spatial Planning (MSP); Marine Protected Areas (MPA)-designation coherence.*
- Socio-economic connectivity, coherence and/or equivalence - *societal connectivity and equivalence; cultural connectivity and equivalence; economic connectivity, equivalence and coherence; sectoral connectivity, coherence and equivalence.*
- Connectivity and equivalence in internationally-adopted principles.

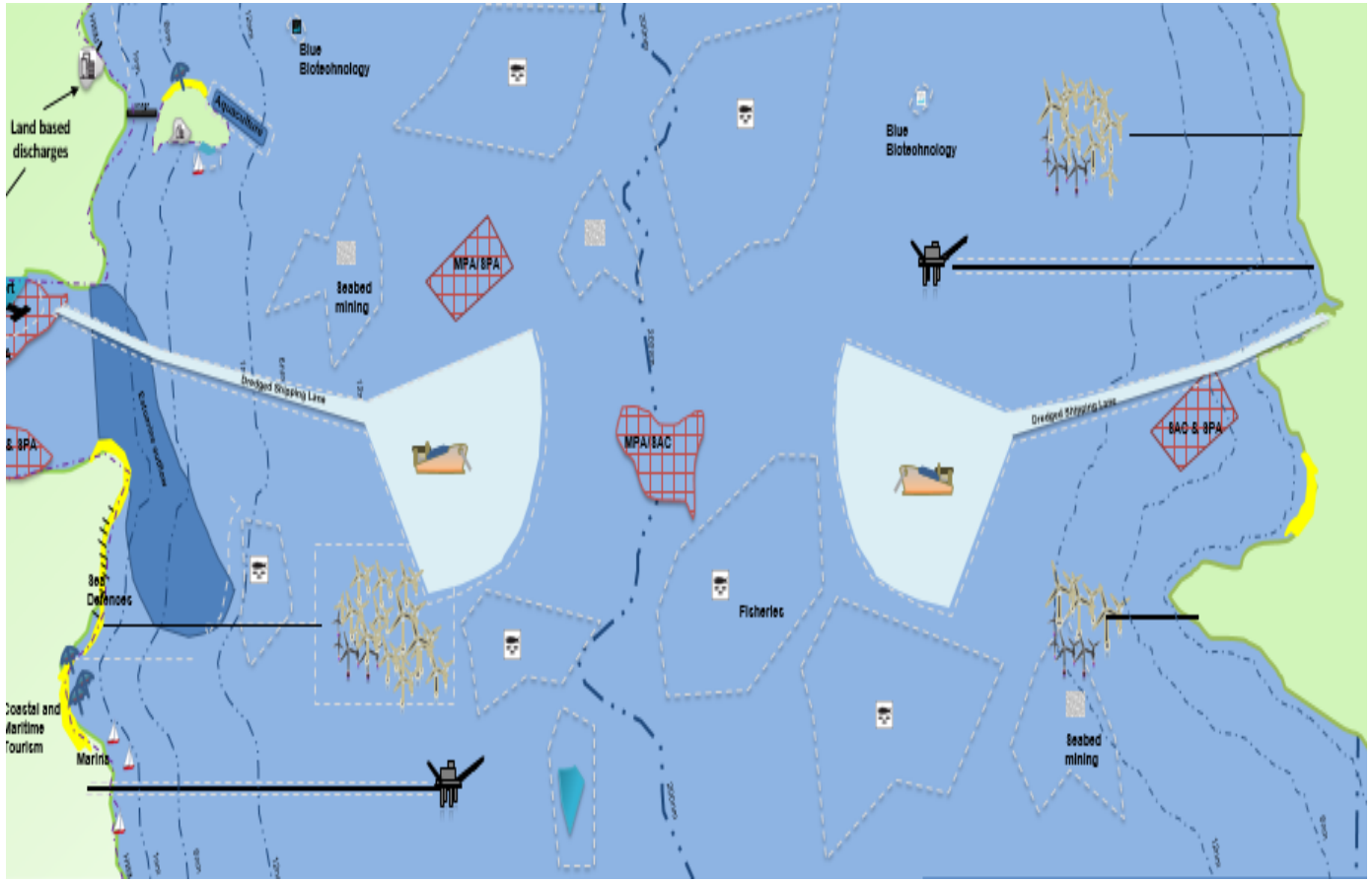
(Elliott, Borja & Cormier, submitted)

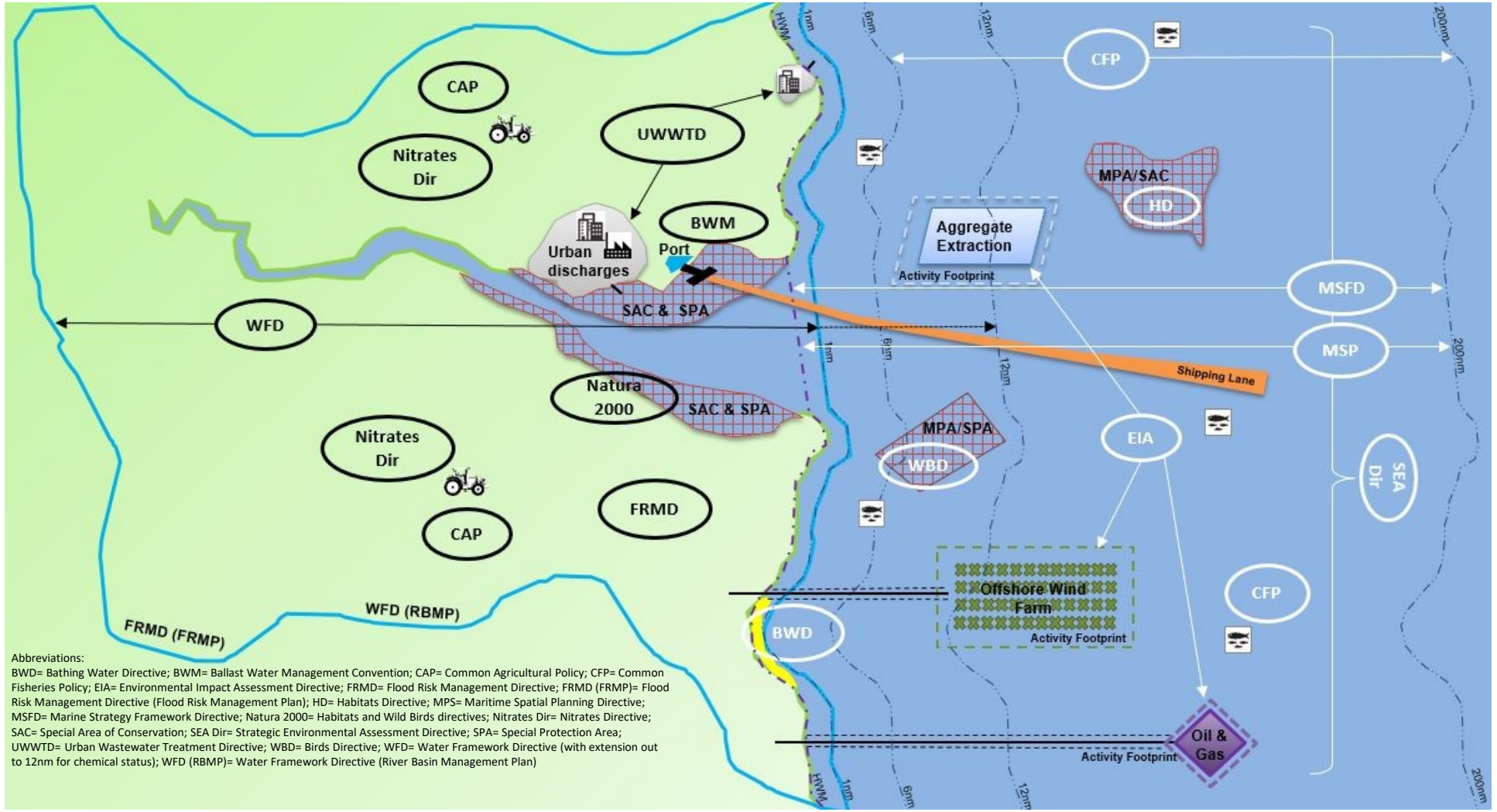
Challenge #5 - How do we put management into action?

- By management action
- By developing programmes of measures
- By developing monitoring schemes
- By linking monitoring to SMART indicators
- By feedback to check if management is working
- By implementing laws
- By having lots of management bodies
- By making industry get their house in order
- By realizing the management footprint
- By having visions, objectives, policies
- By using good and fit for purpose science

Where are we managing?

- A small area (the activity footprint)
- A middle sized area (pressures footprints)
- Middle to large areas (effects footprints)
- Whole estuaries
- Whole catchments/river basins
- Catchment-estuary-coastal areas
- Seas and sea regions
- Regional seas
- Areas Beyond National Jurisdictions
- The globe

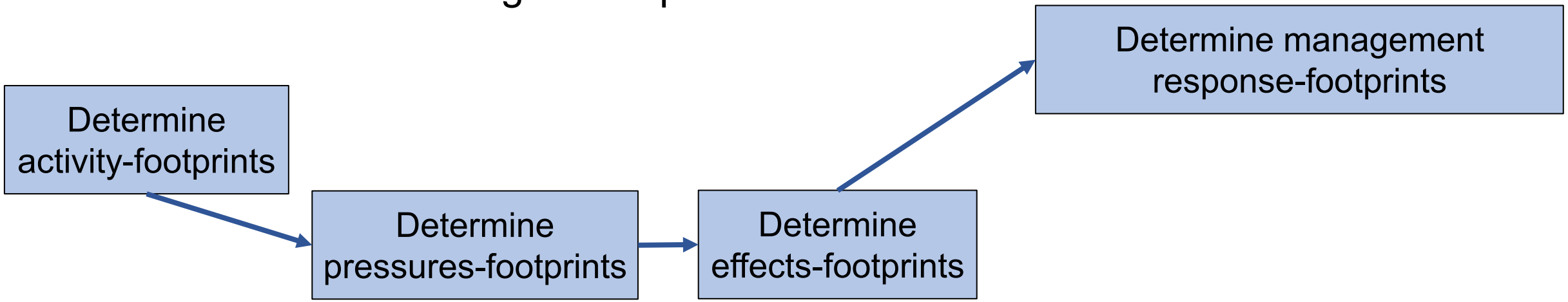


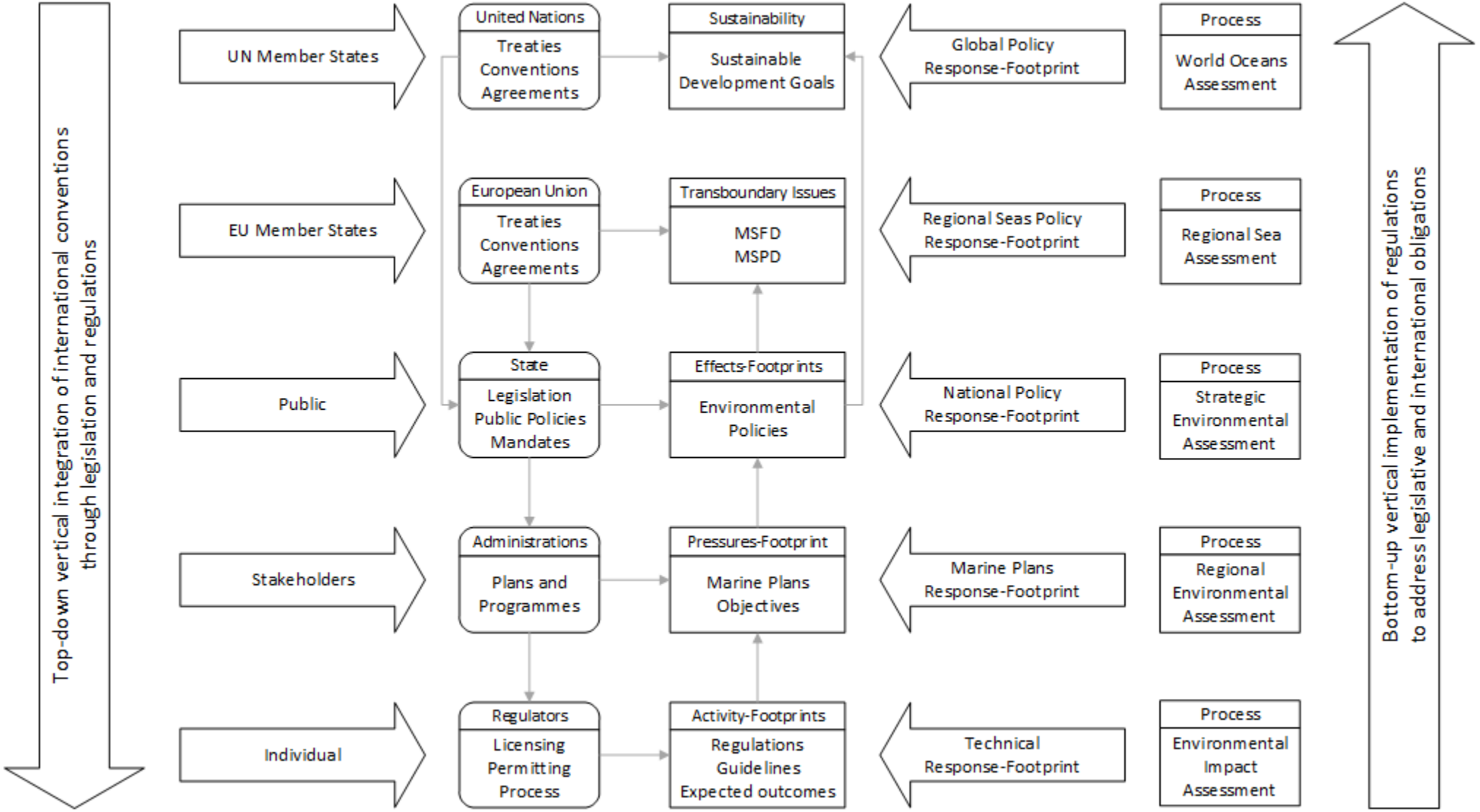


An example of Management response-footprints – the geographical scope and competencies of EU legislation

Management response-footprint

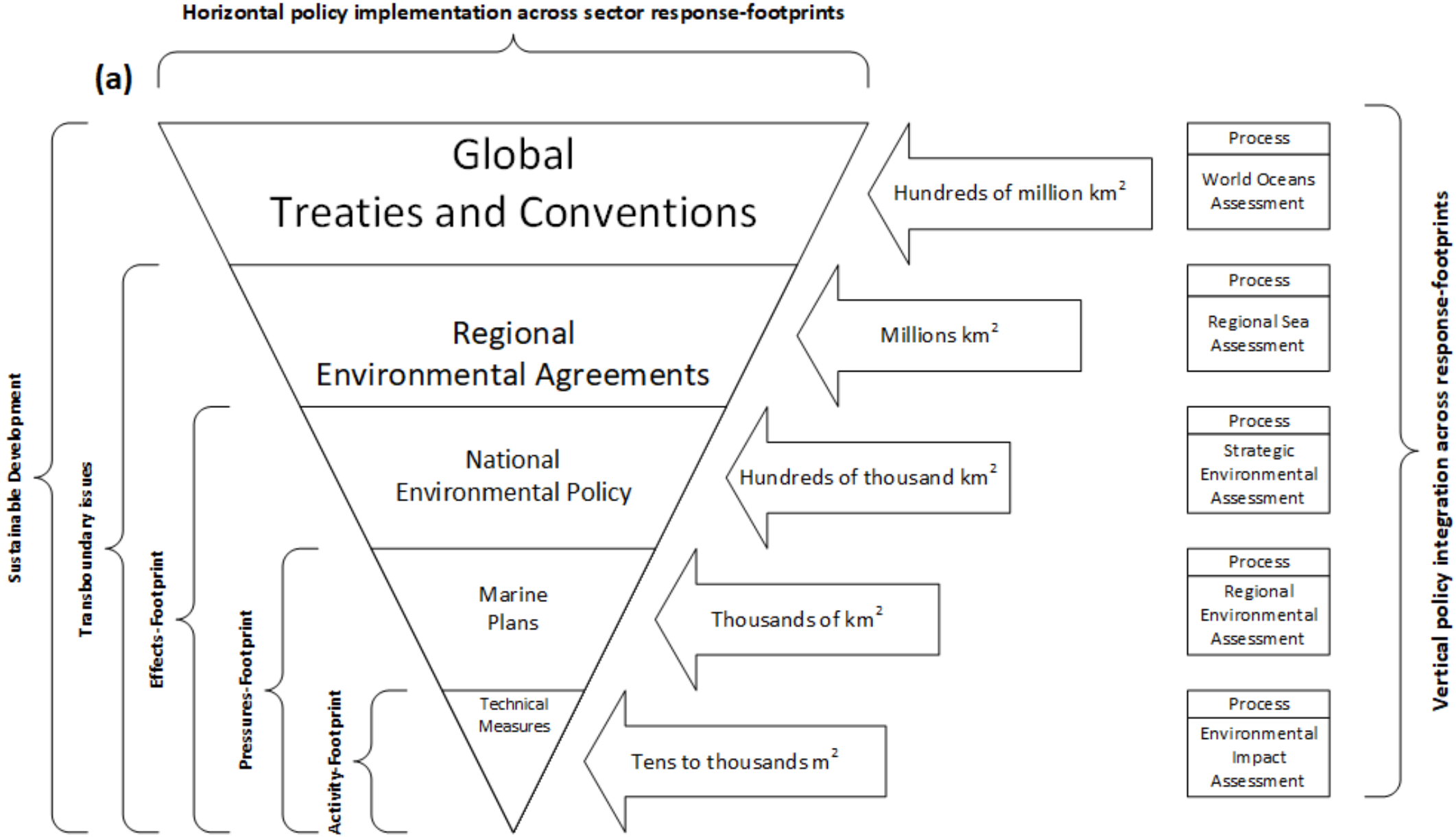
- The area and time covered by the governance means of monitoring, assessing and controlling the causes and consequences involved in the use of the marine environment through public policy-making, marine planning and regulatory processes.
- The policies, marine plans and technical measures produced by these processes indicate the means of determining if legal controls are satisfied, and of providing information and data to national and supra-national bodies.
- They focus on the area and/or time covered by the marine management actions and measures (e.g. programme of measures), including the distribution and range of a species.





Top -down and bottom-up integration of regional and national policies, plans and programmes, regulatory and non-regulatory frameworks for implementation, and footprints (Cormier, Elliott & Borja, Front. Mar. Sci. 2022)

The '*management response-footprint pyramid*'



(From Cormier, Elliott & Borja – 2022, Frontiers in Marine Science)

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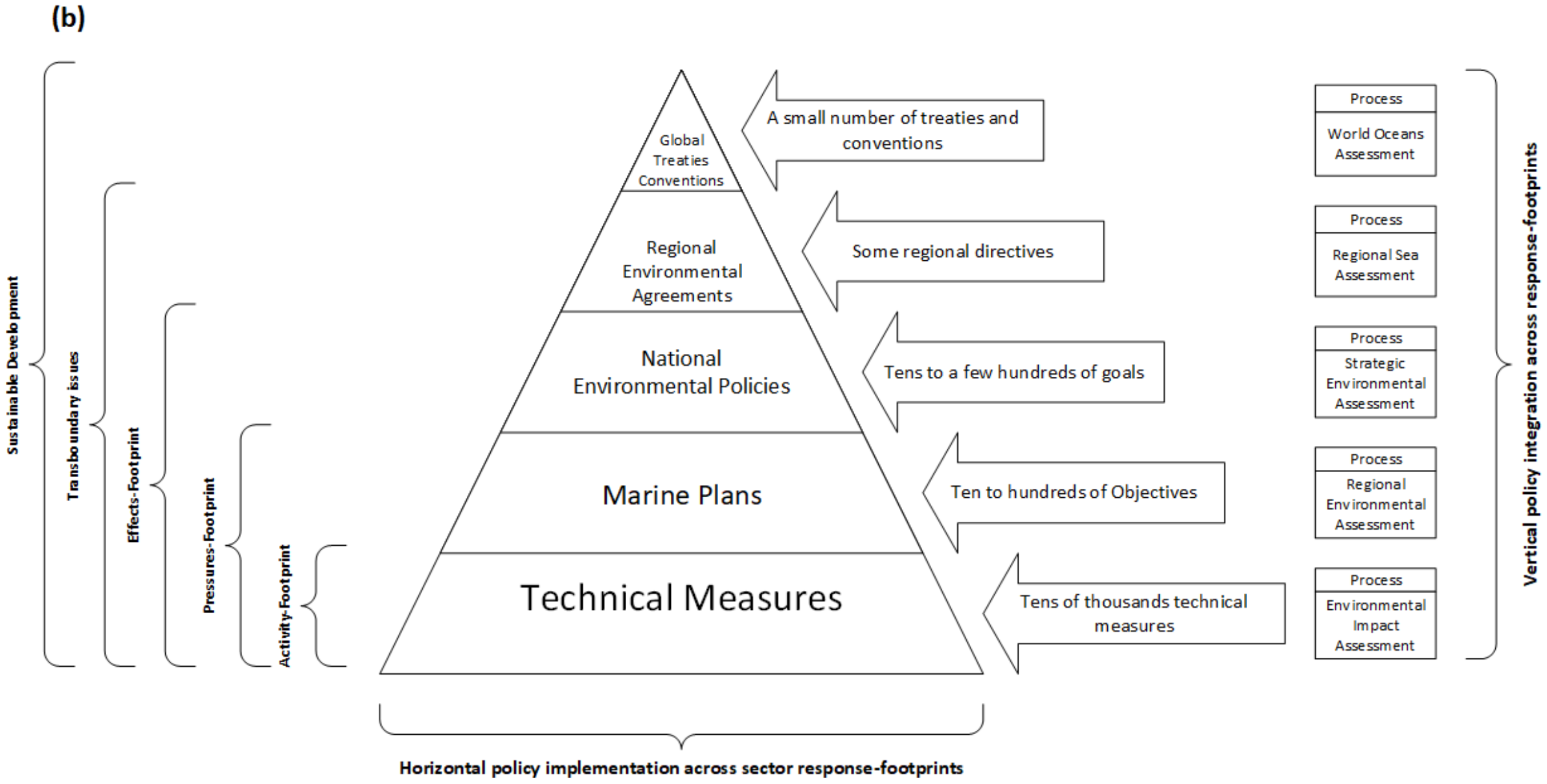

(From Cormier, Elliott & Borja – 2022, Frontiers in Marine Science)

Tackling the challenges – needs for measuring and managing change:

- Start off with SMART objectives
- Base management on good science
- Quantify the four footprints
- Emphasise that the system functions because of connectivity across all fields
- Collect data to use and use data collected
- Determine if management is working
- Have solid underpinning concepts
- Use ecological, socio-ecological and socio-economic valuation
- Harmonise the governance (policies, politics, administration and legislation
- ***Focus on the global primary activity footprint for causes to climate change and the response activity footprint for the consequences***

"I suppose I'll be the one to mention the elephant in the room."

"How come it's always the old, bald-headed guy with glasses in cartoons?"

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Michael Elliott [a,b,*], Ángel Borja [c], Roland Cormier [d]

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Angel Borja [a,*], Mike Elliott [b], Jesper H. Andersen [c], Ana C. Cardoso [g], Jacob Carstensen [c], João G. Ferreira [d], Anna-Stiina Heiskanen [e], João C. Marques [f], João M. Neto [f], Heliana Teixeira [g], Laura Uusitalo [e], María C. Uyarra [a], Nikolaos Zampoukas [g]

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Managing Marine Resources Sustainably – The 'Management Response-Footprint Pyramid' Covering Policy, Plans and Technical Measures

Roland Cormier [1*], Michael Elliott [2,3] and Ángel Borja [4,5]

Bringing it all together – the foundation for 4 Horizon Europe Projects 2022-2026

→ MarineSABRES, MarinePlan, MARBEFES, GES4SEAS ✓

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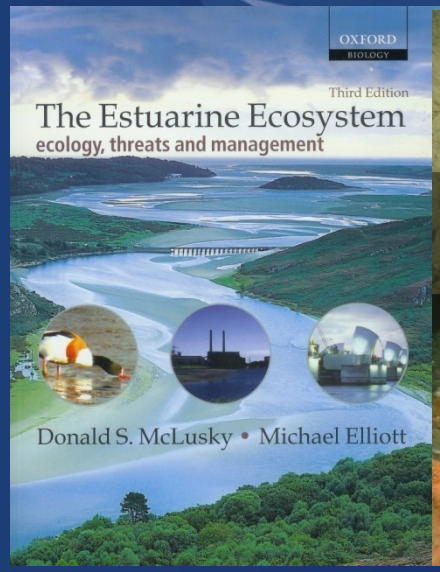

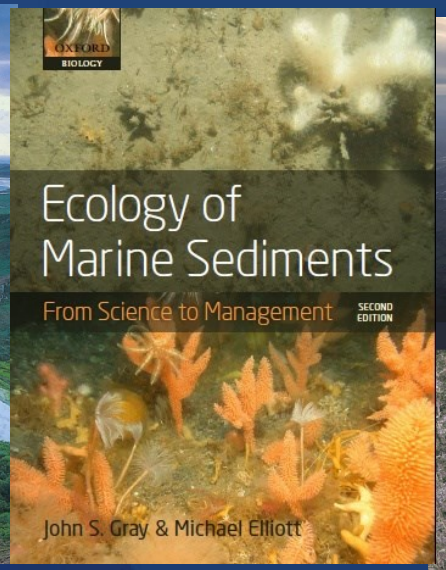

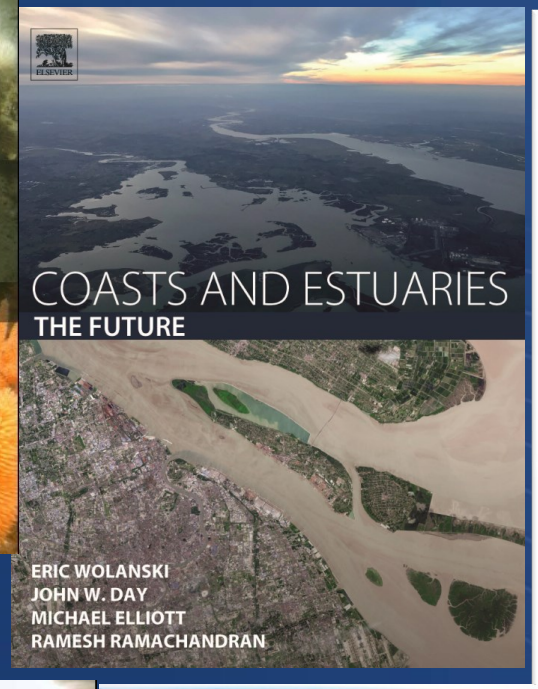

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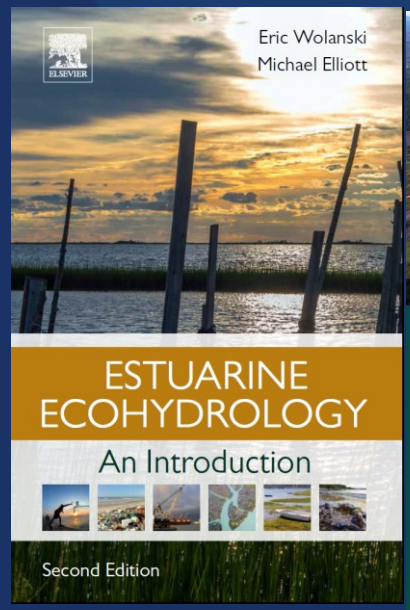

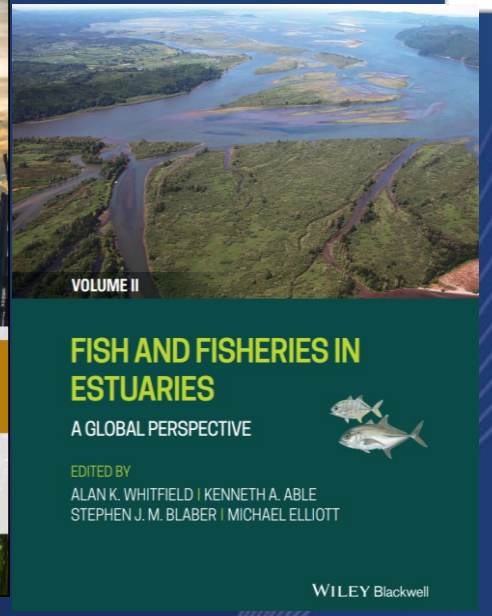

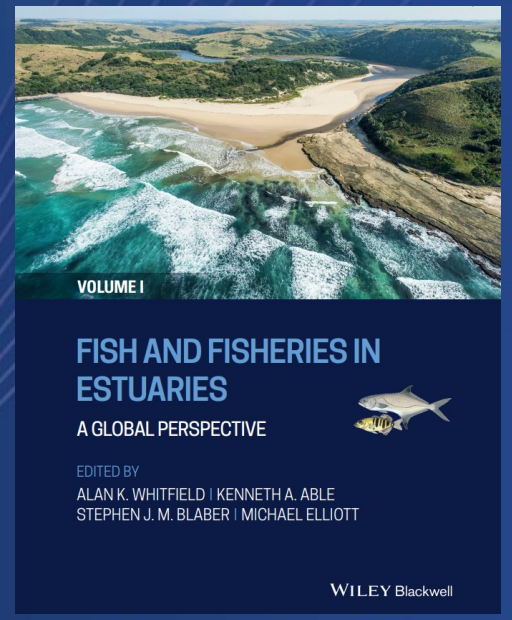

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