WORKING GROUP ON CUMULATIVE EFFECTS ASSESSMENT APPROACHES IN MANAGEMENT (WGCEAM)

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Contents

i Executive summary

The goal of the Working Group on Cumulative Effects Assessment Approaches in Management (WGCEAM) is the development of a common and consolidated CEA framework to implement such assessments in different strategic planning and regulatory context considering the different settings regarding data, knowledge, and decision-processes. Case studies will be used to apply and further develop the framework. This work is expected to provide guidance on data and knowledge needs to apply such a common CEA framework in different strategic planning and regulatory settings.

In this report a cumulative effects assessment framework for management was developed and two case studies (i.e. North Sea and the Gulf of St Lawrence) were identified for WGCEAM review in 2020. The case studies will help identify knowledge gaps and science needs in the application of a common CEA framework in a management context.

As developed, this CEA framework is to be primarily used to identify and prioritize the pressures that would need to be managed based on the vulnerability of the ecosystem components to those pressures (rather than predicting their effects). The rationale and set-ting of the framework means that it differs from a typical ecosystem status assessment where the responses of indicators are assumed to show the effects of human pressures. Furthermore, this framework is not intended to guide regulatory management on a sector by sector basis, but to identify the collective pressures that need to be reduced. Participants summarised current uses and applications of cumulative effects assessments in marine planning and regulatory processes in their countries, to provide insights into impediments.

The CEA framework assesses the vulnerabilities of ecosystem components to cumulative or collected pressures for a given ecosystem and management context. Following standard risk-based assessment practices, vulnerability is determined from the spatial and temporal overlap of the pressures and their effect potential. This is based on the pressure load and the resistance and recovery potential of the ecosystem component.

ii Expert group information

Expert group name	Working Group on Cumulative Effects Assessment Approaches in Management (WGCEAM)
Expert group cycle	Multiannual
Year cycle started	2019
Reporting year in cycle	1/1
Chair(s)	Vanessa Stelzenmüller, Germany
	Roland Cormier, Germany
	Gerjan Piet, The Netherlands
Meeting venue(s) and dates	28-31 October 2019, ICES HQ, Copenhagen, Denmark (8 participants)

1 Introduction

The first meeting of the working group focused on two terms of references. A first draft of a cumulative effects assessment framework for management that considers causal linkages between human activities, their pressures and the resulting perturbations to ecosystem components has been developed (ToR a). This initial outline of the framework was produced to guide regional case studies (ToR b) to be reviewed at the next WGCEAM meeting in year 2 (fall of 2020). As a proof of concept, two case studies, i.e. North Sea and the Gulf of St Lawrence , was put forward this year and together with other case studies in the following years this will help identify knowledge gaps and science needs in the application of such a framework in a management context.

As the basic premises, this framework should be in line with ICES vision for a CEA framework that can build on the information provided in, notably, ICES ecosystem overviews and provide information back into the ecosystem overviews process, i.e. the ecoregion overview with the major regional pressures. The final framework will enable the incorporation of uncertainty in relation to available information, natural variability together with a translation into confidence levels to advisory decision-making processes. Ultimately, the framework provides strategic guidance for management in prioritizing which sectors or pressures contribute most to the failure to achieve specific policy goals as identified in existing status assessments. In addition, it allows to retrieve potential future effects based on the trends of the pressures.

The participants concluded that this CEA framework is to be primarily used to identify and prioritize the pressures that would need to be addressed by, often sector-specific, management measures based on the vulnerability of the ecosystem components to those pressures instead of predicting their effects. Hence, this framework informs at a strategic level where key pressures are identified to for instance set priorities in marine planning and to develop the subsequent technical measures needed to reduce those pressures (Figure 1). The rational and setting of the framework differs clearly from a typical ecosystem status assessment where the responses of indicators (e.g. abundance of species, biological diversity) are assessed to conclude on the effects of human pressures. Management measures are implemented to manage the relevant activities to reduce their pressures on specific ecosystem components. It is assumed that the effects would be reduced through more effective management of the pressures.

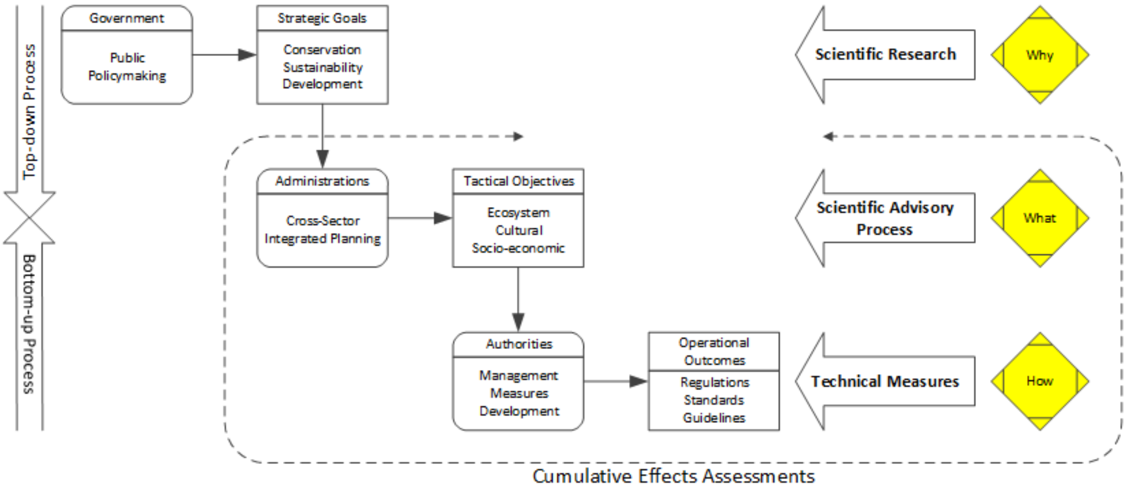

Figure 1. CEA strategic framework for identifying the priority pressures in planning (Adapted from Cormier *et al.* 2017).

Given the need to address common ecosystem and sector objectives in a management area or regional sea (Figure 2), this framework is not intended to guide regulatory management on a sector by sector basis.

The application of the framework reveals a priority list of the collective pressures to be considered in marine planning to be reduced by the environmental protection regulatory frameworks of the respective sectors. This avoids the current problem of sectors managing their respective pressures in relation to their regulatory or non-regulatory requirements while the collective pressures continue to generate perturbations of ecosystem components that leads to adverse effects.

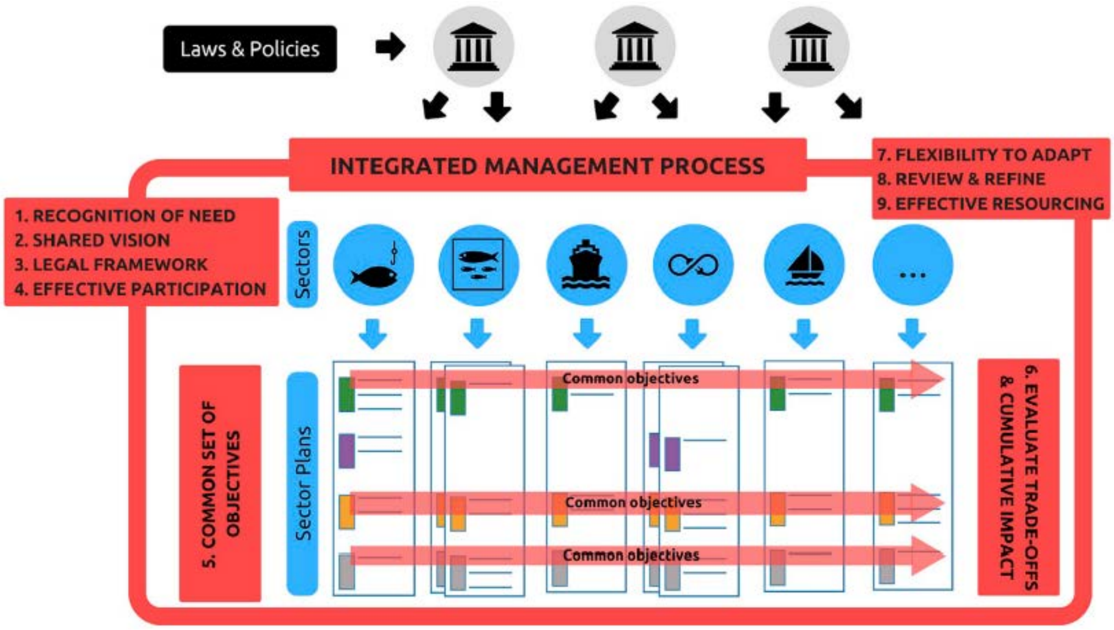

Figure 2. Cumulative impact assessment conducted within the context of multiple common objectives (taken from Stephenson *et al.* 2019).

An effects-footprint (Elliott, Borja and Cormier in prep) is the spatial (extent), temporal (duration) and frequency aspects of

- a single pressure from a marine activity,
- all the pressures from that activity,
- all the pressures from all activities in an area, or
- all pressures from all activities in an area or emanating from outside the management area.

Hence, they include the near-field and far-field effects because of the dynamics and characteristics of marine areas as these encompass both endogenic and exogenic pressures operating in that area.

Conducted within the context and scope of policy objectives in marine planning, the operational elements from an earlier ICES workshop (ICES 2019); (Figure 3) were used to develop the framework to establish a vulnerability profile for a defined assessment area based on the identified sensitivity of ecosystem components and their exposure to pressures occurring in such boundaries. Such an approach would be conducted before an analysis of the effectiveness of the existing management measures to improve or implement new measures to reduce the pressures of concern (see a description of the a step-wise process in Stelzenmüller *et al.* 2018).

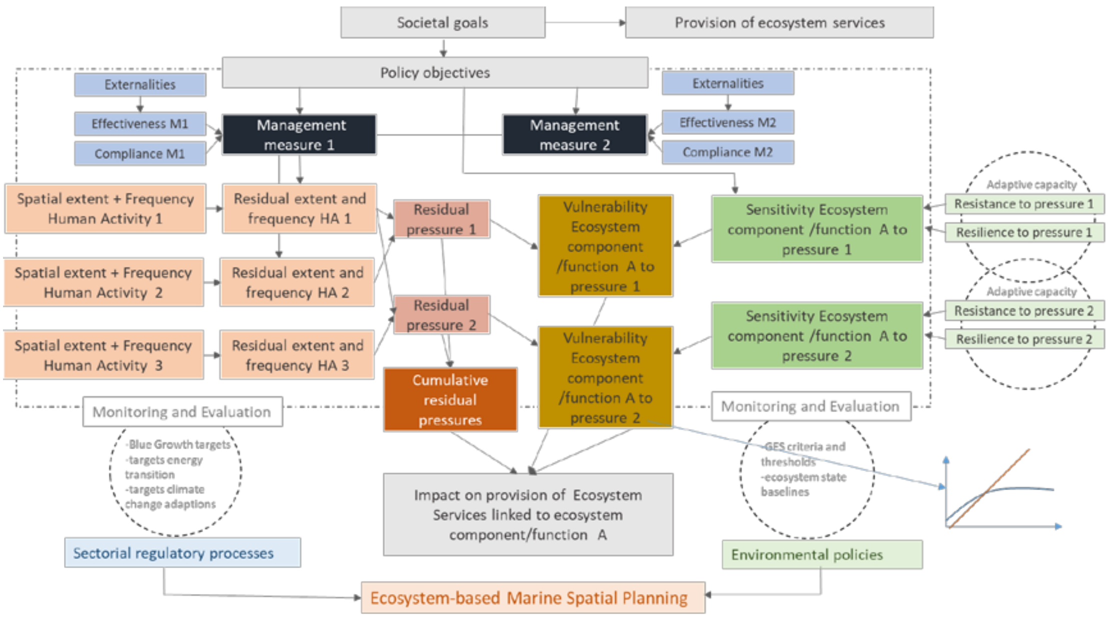

Figure 3. Information elements of a CEA in an operational context (ICES 2019).

Participants were also asked to provide the current uses and applications of cumulative effects assessments in marine planning and regulatory processes as insight into the impediments of such approaches in their countries (Annex 3). Given that wide range of terms used to express different aspects during the meeting, a glossary of definitions was also developed (Annex 4).

2 Vulnerability CEA Framework

The framework is designed to assess the vulnerabilities of ecosystem components to cumulative or collected pressures generated by human activities in a given ecosystem and management context (Figure 4). Although this framework would be informed by existing status assessments (e.g. MSFD, EOAR), in that these may provide focus or more weighting to those ecosystem components found to be in poor status. This framework is different from those existing status assessments in that the vulnerabilities of each ecosystem component to potential effects are based on the prioritisation of key causal relationships and key prevailing pressures (upper left box of Figure 4). Following standard risk-based assessment practices, vulnerability is based on the exposure and effect potential (De Lange, *et al.* 2010). In this framework, exposure is a function of the spatial and temporal overlap of the pressure and the ecosystem component. The effect potential is a function of the pressure load and the inherent resistance and recovery potential of the ecosystem component (upper right box of Figure 4). This information is then integrated into a vulnerability profile which ranks the vulnerabilities of all pressure/ecosystem component combinations occurring in that ecosystem.

Adapted from DFO (2013), a four quadrant schematic representation exposure/effect potential would be used to identify clusters of pressure/component vulnerabilities for management strategies that could be considered by planners and managers (lower right box of Figure 4). The pressure/component vulnerabilities in the upper left quadrant would be indicative of the need to reduce the load of a pressure in contrast to pressure/component vulnerabilities in the lower right quadrant being indicative of the need to reduce the spatial and/or temporal overlap between the pressures and the component. As a conceptual approach, it would provide the strategic setting needed in marine planning to identify the activities that are contribution to a given pressure as advice in regulatory processes (lower left box of Figure 4).

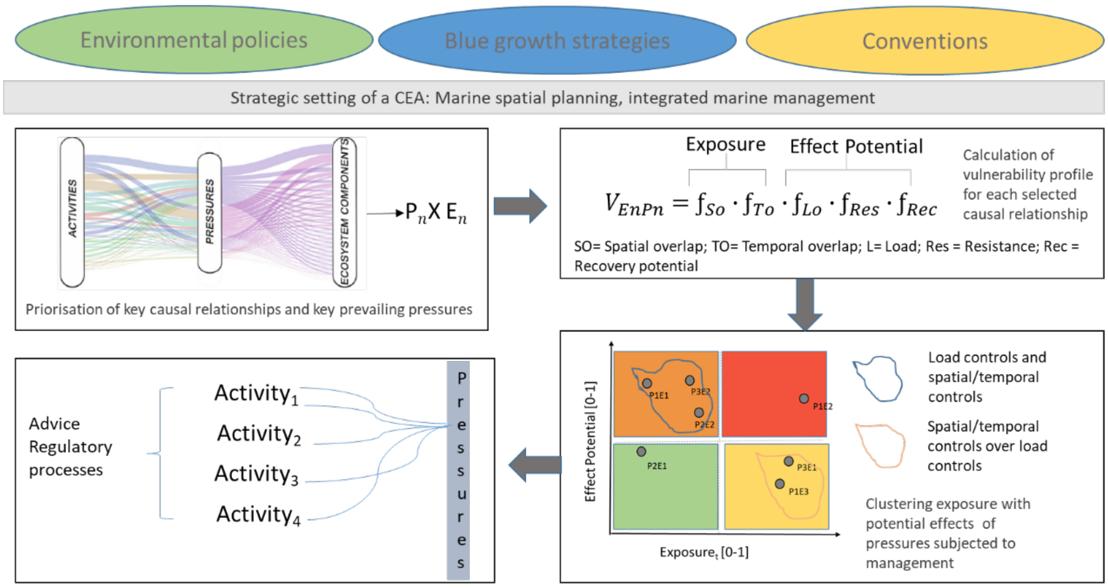

Figure 4. Conceptual CEA framework for management.

Participants identified the North Sea (Annex 5) and Gulf of St Lawrence (Canada) as case studies to apply and develop the CEA framework. The North Sea case study was used to illustrate an application of the framework and its related output (Annex 5). Both case studies will be developed in year 1 and further discussed and elaborated in the subsequent years. Other members countries are also invited to participate with their case studies.

3 References

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Annex 1: List of participants

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Annex 2: WGCEAM Resolution

A **Working Group on Cumulative Effects Assessment Approaches in Management (WGCEAM)**, chaired by Vanessa Stelzenmüller, Germany, Roland Cormier, Germany, and Gerjan Piet, the Netherlands, will be established and will work on ToRs and generate deliverables as listed in the Table below.

	Meeting dates	Venue	Reporting details	Comments (change in Chair, etc.)
Year 2019	28 October – 1 November	ICES HQ, Copenhagen, Denmark		
Year 2020	TBD October	TBC		
Year 2021	TBD October	TBC	Report by DATE to SCICOM	

ToR descriptors

ToR	Description	Background	Science plan codes	Duration	Expected Deliverables
a	Develop a cumulative effects assessment (CEA) framework suited to guide science advice on the development and implementation of ecosystem-based management	While the need for CEAs is widely accepted, their actual implementation in marine planning and management processes is yet to be seen. A common framework requires a review of the differences in the factors (data, knowledge, decision-process) being considered regarding cumulative effects assessment (CEA) in relation to environmental policies, an ecosystem approach to marine spatial planning (MSP) and regulatory processes. The framework should clearly outline: a) Science Requirements b) Advisory Requirements c) Requirements from other EGs	6.1, 6.2, 6.6,	Year 1	CEA framework suited to guide science advice on the development and implementation of ecosystem-based management.
b	Demonstrate the application of the CEA framework in one or more regional case studies	To advance the development of a generic CEA methodology and identify real research gaps one or more case studies will be used as a proof of concept. The initial focus should be on the North Sea and a Canadian bioregion where the CEA is conducted	6.1,6.2	Years 2	Scientific paper describing the application of the CEA framework in one or more regional case studies.

		with the available knowledge base..			
c	Produce generic guidance on data and knowledge needs for CEA's including: using qualitative and quantitative data, accommodating uncertainty, identifying information gaps based on the application of the framework in the above case studies	The application of the framework in case studies allows to i) indicate useful tool(s) for each step, ii) show the indicative datasets and types of data required in carrying out a CEA, iii) develop straight forward visualization tools for pressures, and iv) demonstrate end products and engage with potential clients. The latter point is essential to scope the potential usefulness of CEAs as part of ecosystem advice provided by ICES	6.1, 6.2,	Year 3	Generic guidance on data and knowledge needs for CEA's.
d	Liaise with other fora or expert groups both within ICES (i.e. Secretariat, Data Centre or expert groups) as well as outside ICES (e.g. OSPAR, EEA, HELCOM, JPI Oceans, CEAF, DFO, TC, ECCC) to work towards and consolidate a common CEA framework	The consolidation of a common CEA framework requires a continous collaborationa and exchange of expertise with other groups and fora working on CEAs	6.2, 6.4, 6.5	Year1-Year 3 (ongoing)	Consolidated common CEA framework.

Summary of the Work Plan

Year 1	During the first year the linkages to other groups working on CEAs have to be identified and established. The main goal is the development of a common and consolidated CEA framework allowing to implement CEA in different settings regarding data, knowledge, and decision-processes.
Year 2	In the second year the work will focus on the application of the CEA framework in case study areas. The North Sea and a Canadian bioregion will be the first case studies since data availbility and relevant scientific knowledge is most advanced.
Year 3	Emphasis will be on the provision of guidance on data and knowledge needs when applying the common framwork. This guidance will lead into a final recommendation on the usefulness of CEAs as part of ecosystem advice provided by ICES.

Supporting information

Priority	The current activities of this Group will lead ICES into issues related to the ecosystem effects of all marine human activities including fisheries, especially with regard to the application of the Precautionary Approach. Consequently, these activities are considered to have a very high priority.
Resource requirements	The research programmes which provide the main input to this group are already underway, and resources are already committed. The additional resource required to undertake additional activities in the framework of this group is negligible.
Participants	The Group is normally attended by some 20–25 members and guests.

Secretariat facilities	None.
Financial	No financial implications.
Linkages to ACOM and groups under ACOM	There are no obvious direct linkages.
Linkages to other committees or groups	There is a very close working relationship with all the groups under HAPISG. It is also very relevant to WGINOSE.
Linkages to other organizations	There are strong linkages to the OSPAR and HELCOM work on CEAs.

Annex 3: Setting the context for a CEA framework

Country perspectives on the use and need for CEA in decision making

1) How are CEA used to make decisions in your country?

Estonia: The PlanWise4Blue tool (PW4B) is developed to enable the maritime spatial planners, managers and the licensing authorities to assess the cumulative impact of multiple pressures on nature assets. Users with or without science training can use the portal to estimate areas impacted and changes to natural assets caused by any combination of pressure types.

We (Estonian Marine Institute, University of Tartu) recently developed a CEA tool named PlanWise4Blue tool that predicts both separate and synergistic effects — current and future — of a wide range of human activities. The tool was tested in the Baltic Sea region in coordination with the process of the Estonian Maritime Spatial Planning. This tool has been developed to assist with maritime spatial planning but is also applicable in other fields. The tool is currently usable rather as a discussion platform due to the lack of knowledge or data availability that may increase uncertainty of the model output.

Finland: CEA was part of FI MSFD assessment and it informed the state of benthic habitats under descriptor 6.

Germany: Currently no decisions are taken on the basis of a CEA. When reporting on the results of the standardised monitoring for offshore wind sites the contribution of the respective project to cumulative effects needs to addressed. At the same time in the revision process of the German maritime spatial plans cumulative effects have been identified to be addressed. Still it is only recognised as a relevant topic with no practical solution that aids decision making.

Ireland: Not really used at all, as far as I know. They will appear in Ecological Impact Assessments, but that is outside our remit. No use of them in MSFD, and for MSP, mainly additive and on the basis of mapped information.

Netherlands: Currently CEAs are (mis)used as part of single-sector (i.e. offshore wind) impact assessments and possibly mitigation.

Scotland: Routinely used to decide on single sector capacity issues in licensing and marine planning (planning consent) particularly marine renewables and aquaculture for endpoints such as nutrient loading, mobile species impacts. Marine Licensing under the Marine Scotland Act (2010), Marine planning under Town and Country Planning Act (2007).

Sweden: The use of CEA in connection to Environmental Impact Assessment is poor to non-existing in marine environment. Typically descriptive analyses are provided based on the knowledge of the consultant, no nationally standardised methodology (Based on interviews with managers and national reviews).

CEA in connection to Swedish MSP is operational over the national tool Symphony which is developed and owned by the Swedish Agency for Marine and Water Management. The tool follows the "Halpern approach"[1]. It is used as decision support for the currently developed national MSP to understand current cumulative impacts and potential future cumulative impacts. The tool is supported by spatial data on species and habitats, some pressure layers and by layers on human activities (which are translated to pressures over simple functions that give the likely propagation of the pressure from the HA[2]).

HELCOM: A shared cumulative impact assessment for the Baltic Sea is developed over HELCOM using the Baltic Sea Impact Index (BSII). The index is developed to support marine environmental assessment and follows the "Halpern approach". Its basic use is to identify areas in the Baltic Sea were pressures and impacts are the highest compared to other areas. The tool is supported by spatial data on species, habitats and pressures. Some of the pressures layers are developed from information on human activities using simple functions that give the likely propagation of the pressure from the HA. The layers of the BSII are aligned with the classification of the MSFD[3] [4] [5].

The use of the BSII to support MSP concerning transboundary issues in the Baltic Sea is tested in the Pan Baltic Scope project, which is now in finalization. Report due in November 2019[6].

UK: Regulatory compliance to achieve / maintain GES. UK Marine Strategy Regulations (2010), Part 2, para 5 requires: *"(2) The marine strategy must apply an ecosystem-based approach to the management of human activities within the marine strategy area.*

(4) For the purpose of this regulation, an "ecosystem-based approach" means an approach which— (a) ensures that the collective pressure of human activities within the marine strategy area is kept within levels compatible with the achievement of good environmental status; and (b) does not compromise the capacity of marine ecosystems to respond to human-induced changes."

This aligns with MSFD, Article 1(3): *"... the collective pressure of human activities needs to be kept within levels compatible with the achievement of GES, ensuring that the capacity of marine ecosystems to respond to human-induced changes is not compromised."*

Marine Planning: Marine Plans are being developed in Scotland, Wales, Northern Ireland and England. The legislative requirement is the Marine and Coastal Access Act 2009 and the Marine Policy Statement 2011. There is no explicit requirement for CEA in Marine Plans in the UK

[1] Halpern, B, SS Walbridge, KA Selkoe, CV Kappel, F Micheli, C D'Agrosa, JF Bruno, KS Casey, C Ebert, HE Fox, R Fujita, D Heinemann, HS Lenihan, EMP Madin, MT Perry, ER Selig, M Spalding, R Steneck & R Watson (2008) A Global Map of Human Impact on Marine Ecosystems. Science 319:948-952

[2] SwAM (2018) (Swedish Agency for Marine and Water Management, Havsoch Vattenmyndigheten) Symphony - Integrerat planeringsstöd för statlig havsplanering utifrån en ekosystemansats. Havsoch vattenmyndighetens rapport 2018:1, ISBN 978-91-87967-88-7

[3] HELCOM (2018a) State of the Baltic Sea – Second HELCOM holistic assessment 2011-2016. Baltic Sea Environment Proceedings 155

[4] HELCOM (2018b) HELCOM Thematic assessment of cumulative impacts on the Baltic Sea 2011-2016. Available at: http://stateofthebalticsea.helcom.fi/about-helcom-and-the-assessment/downloads-and-data/

[5] EC (2017b) Commission Directive (EU) 2017/845 of 17 May 2017 amending Directive 2008/56/EC of the European Parliament and of the Council as regards the indicative lists of elements to be taken into account for the preparation of marine strategies

[6] Bergström *et al.* 2019. Cumulative Impact Assessment for Maritime Spatial Planning in the Baltic Sea Region. Report from the Pan Baltic Scope project. www.panbalticscope.eu.

and the EU MSP Directive 2014 only makes reference to the MSFD requirement that *"... the collective pressure of human activities needs to be kept within levels compatible with the achievement of GES, ensuring that the capacity of marine ecosystems to respond to human-induced changes is not compromised."*

However, it is implicit that marine planning can help to manage cumulative effects.

Project level: Routinely used to decide on single sector capacity issues in licensing.

Marine Works (Environmental Impact Assessment) Regulations 2007 (As Amended), require applicants for marine licensing to describe the *"characteristics of the project, including accumulation with other existing or approved projects; the accumulation of the impact with the impact of other existing or approved projects; the accumulation of effects with other existing or approved projects, taking into account any existing environmental problems relating to areas of particular environmental importance likely to be affected or the use of natural resources* ***and*** *the description of the likely significant effects … must cover the direct effects and any indirect, secondary, cumulative, transboundary, short-term, medium-term and long-term, permanent and temporary, positive and negative effects of the project and the regulated activity. This description must take into account the environmental protection objectives established at Union or member State level which are relevant to the project and the regulated activity."*

NB. Nationally Significant Infrastructure Projects require deemed consents under the Planning Act 2008.

Under the Conservation of Habitats and Species Regulations 2017 (transposing the EU Habitats Directive), for projects (either alone or in combination with other plans or projects) are likely to have a significant effect on a designated nature conservation European site the regulatory authority must make an appropriate assessment of the implications for that site in view of the sites conservation objectives. Under para 64 *"(1) If the competent authority is satisfied that, there being no alternative solutions, the plan or project must be carried out for imperative reasons of overriding public interest (which, subject to paragraph (2), may be of a social or economic nature), it may agree to the plan or project notwithstanding a negative assessment of the implications for the European site or the European offshore marine site (as the case may be). (2) Where the site concerned hosts a priority natural habitat type or a priority species, the reasons referred to in paragraph (1) must be either— (a) reasons relating to human health, public safety or beneficial consequences of primary importance to the environment; or (b) any other reasons which the competent authority, having due regard to the opinion of the European Commission, considers to be imperative reasons of overriding public interest."*

2) Where do you think CEA are needed in your specific national setting?

Estonia: CEA has the potential to be used to guide the implementation of the MSFD Programme of measures and other relevant EU level requirements with aim to achieving the GES. CEA is gradually integrated into the MSP related Environmental Impact Assessments (EIA), Strategic Impact Assessments (SIA) and into the practices of Environmental Licensing Services.

The tool is currently being used to assess the effects of different pressures at the country scale but in future the same resource may be used to assess cumulative impacts locally at a spatial scale of 100 m.

Finland: (1) In assessments of MSFD benthic habitats; (2) inform MSP planning process in terms of meeting MSP's ecological objectives; (3) MPA management; (4) support other state assessments as a proxy for state of state-based observations are missing or are incomplete.

Germany: In the marine spatial planning process the main contributors to key adverse effects on the integrity of the sea bed and related functioning need to be identified. Thus the risk of cumulative effects should be addressed in the spatial planning process to enable better strategies in the final allocations of human uses.

Ireland: Clear requirement for MSFD, where MI are currently involved on behalf of the Department of Housing, Planning and Local Government (DHPLG). This is mainly via our membership of the CEA group at OSPAR. However, CEA has not yet generated any real momentum in MSFD in Ireland. Also needed in MSP for regional and local sea use planning, but little movement as yet. MI primary perception of need is integrate CEA into the Integrated Ecosystem Assessment (IEA) process. We have included multiple pressures in our IEA – via an extended ODEMM analysis. We have explored how a CEA might work in that context, and the requirement is to have an internationally agreed approach to that. We feel that an ODEMM modification is appropriate, as ODEMM allows for expert judgement, and much of the CEA understanding will remain expert judgement based for some time.

Netherlands: Needed to guide management (i.e. MSFD Programme of measures) toward achieving GES. To identify which ecosystem components are most likely to be (further) perturbed by the current and future activities and their pressures.

Scotland: Needed to improve decision making for Regional Marine Planning purposes (how much development / activity in a Marine Region).

Required to support an assessment of key pressures in Scottish Marine Regions as part of the review cycle for Scotland's National Marine Plan (to support a status assessment of Scotland's seas). Also required internationally to support the MSFD assessment process (through OSPAR).

Sweden: Clear requirement through EU directives for implementation of the MSFD, for EIA and in MSP, as also iterated nationally.

However, as stated above, implementation is not fulfilled (yet).

In MSP, relating the current CEA to effects of climate changes is identified as a priority.

Sweden and HELCOM: As the CEA addresses multiple dimensions and can potentially be connected also to societal aspects, it can be developed as a central tool for developing the ecosystem-based approach.

UK: To comply with the legislative requirements for GES.

Through work in OSPAR we are taking a systems, risk-based approach to CEA focusing on the collective pressures from human activities likely to change GES as measured by the suite of indicators.

This differs from other approaches (e.g. HELCOM) which take a map-based approach (derived from Halpern *et al*).

Marine Planning: As Matt has said for Scotland - needed to improve decision making for Regional Marine Planning purposes (how much development / activity in a Marine Region).

Required to support an assessment of key pressures in UK Marine Plan Areas as part of the review cycle for National / Regional National Marine Plans.

Project level: needed to maintain ecologically coherent network of MPAs, balancing social and economic benefits from use of marine resources with conservation objectives for protected sites.

3) What are the types of questions you want CEA to answer?

Estonia: CEA estimates are based on best available knowledge from manipulative and correlative experiments and thus form a link between science and management. When CEA is used in real maritime spatial planning and management situations then the results can be used to minimize adverse environmental effects, suggest effective mitigation actions and ultimately reach sustainable planning and management solutions in the focus areas.

Assesses economic benefits of sectors such as fisheries, aquaculture, reed harvesting, wind energy, maritime transport and recreation along with the CEA analysis. Assess CEA on a broad range of ecosystem service.

Finland: (1) indicate if vulnerable or protected areas face too high pressures; (2) help establishing better linkage between activities, pressures and state; (3) support monitoring of environmental status where state-pressure link is clear; (4) inform which activities are behind the pressures/effects in an area.

Germany: Which are the human activities contributing most the risk of cumulative effects? Which management strategies could help to reduce such as risk?

Ireland: Principally, once we have identified the multiple pressures acting on a single ecosystem component, how do we go about treating them together? So, if we have elasmobranchs experiencing species removal pressure from fishing, pressure from litter, contaminants, food web changes, what is a sensible and pragmatic way of treating these together. Again within ODEMM, this could be a few broad categories, simply identifying that pressure A is likely to additive, antagonistic, synergistic or non-linear in interaction with pressure B???

Netherlands: Prioritize among activities and their pressures where management should focus on and what type of management, e.g. spatial (where) or otherwise.

Scotland: Help set thresholds for regional capacity (renewable energy, aquaculture)

Sweden: The basic need is to identify the most significant issues that management needs to focus on, such as areas of high concern with respect to cumulative impacts, or which ecosystem components are particularly susceptible to cumulative impacts. The questions are easy to formulate but require a lot of ecological understanding to answer.

In a development situation, the CEA needs to identify if the cumulative impact is acceptable and how impacts can be alleviated.

Sweden and HELCOM: At the strategic level, the CEA can support the development of policy and of agreements to meet overarching management objectives more efficiently.

UK: The type of question which we are focussing on in our work in OSPAR is: *"What is the likelihood that the collective pressures from human activities will cause change capable of affecting the achievement of quality status (good environmental status) and how should these changes be managed?"*

Marine Planning: Help set thresholds for regional capacity (renewable energy, aquaculture, tourism, shipping).

Project level: Help set thresholds for regional capacity (human activities within (and outside) of MPAs.

Annex 4: Cumulative Effects Assessment Terminology and definitions

Pathways to impact

Cumulative (or 'collective' cf MSFD) pressures – the net result of multiple residual pressures acting together on an ecosystem or ecosystem component

Cumulative / in combination – The residual or additive result of pressures or effects acting together

Cumulative effects – The net effect of cumulative pressures

Cumulative Effects Assessment (CEA) – Cumulative effect assessments (CEAs) are defined as holistic evaluations of the combined effects of human activities and natural processes on the environment, and constitute a specific form of environmental impact assessments

Cumulative impacts – The net impact of cumulative effects

Direct and indirect effects – Direct effects are measurable changes on receptors caused by identifiable pressures. Indirect effects act through intermediary processes, are hard to measure or identify a clear cause: effect mechanism.

Ecosystem component / Receptor / valued component – Terms used interchangeably under different jurisdictional processes to mean identifiable parts of marine ecosystems potentially subject to pressures. These are usually habitats [structural abiotic and biotic components with an ecosystem function or service] or species (or taxonomic group / life cycle stage / trait specific grouping), often of conservation importance. (NB ecosystem functioning and ecosystem services themselves can be relevant receptors for the purposes of CEA application).

Effect – The change in an ecosystem receptor resulting from the application of a pressure

Effects-footprint – The spatial and temporal extent of the effects of pressures arising from an activity. Sometimes implies the magnitude of these effects within the footprint.

Environmental Impact Assessment (EIA) – A project level assessment of impacts, with legal requirements for CEA at the outcome level

Exogenic and endogenic pressures - Pressures which act from outside (or within) the footprint of a receptor or ecosystem component. It is often difficult to manage the causes of exogenic pressures (e.g. climate change) requiring greater focus on mitigation in management.

Exposure – An ecosystem component experiencing a specific pressure (based on frequency, duration, concentration, intensity etc.). This is the spatial and temporal overlap of pressure and a component/receptor multiplied by the pressure load / magnitude.

Impact – The negative effects on ecosystems or ecosystem components resulting from the effect of pressures. In socioeconomic systems described as "Welfare"

Intensity - The magnitude of a pressure or resulting effect or impact

Magnitude (or load) – The size or scale of a pressure acting on a component / receptor. Can also be a frequency.

Marine / Maritime (EU) Spatial Planning (MSP) - A process of allocating space to achieve specific objectives. An Objective level process requiring CEA outputs.

Pressure – The mechanism by which activities and developments exert effects on ecosystem components

Processes, tools and methodology

Capacity – The ability of an ecosystem or ecosystem component to accommodate pressures before reaching thresholds or tipping points. NB often relates to carrying or assimilative capacity. (NB different to biological carrying capacity).

Effectiveness (of measures) – Likelihood of measures to produce the expected pressure reduction to avoid an undesired effect.

Input control – A management measure required to achieve a target. ISO terminology. In MSFD terminology these are management measures that influence the amount of a human activity that is permitted.

Output control – A threshold term used in ISO terminology as the trigger for management action. MSFD definition is a management measure that influences the degree of perturbation of an ecosystem component that is permitted.

Recovery – The ability or rate of an ecosystem component to return to pre-disturbed state after cessation of a specific pressure

Residual pressure – The net pressure arising from the interaction of multiple activities and developments, taking account of the management measures ('prevention control' cf bow tie terminology) in place.

Resilience – The ability of an ecosystem component to recover after application of a stressor.

Resistance – The ability of an ecosystem component to withstand a specific pressure without effect

Sensitivity – The extent to which an ecosystem component is likely to be negatively affected if exposed to a specific pressure. A function of resistance and recovery potential.

Severity – The size or scale of the effect of a pressure on a component / receptor

Strategic Environmental Assessment (SEA) - An EU member state terminology. A strategic level assessment of the impacts of sectors or plans. An Objective level process requiring CEA outputs.

Stressor – A combination of activity/development and pressure acting in a potentially negative manner on an ecosystem component. Often used interchangeably for pressure

Susceptibility – Whether an ecosystem component / receptor is sensitive to a pressure or not

Target terminology relevant to CEA

Thresholds – Acceptable limits determined by society, applied to pressures, effects or impacts and used as a trigger for management measures. Can relate to quality standards, capacities, tipping points.

Top event – Terminology used in bow tie analysis to describe an adverse outcome marine managers would wish to avoid. Often relates to impacts resulting from exceedance of thresholds or tipping points.

Vision, Goal, Objective, Outcome – A hierarchical set of targets relevant for different levels of marine management: Political, strategic / cross sectoral, Project specific / application of measures

Vulnerability – The risk of negative impact on an ecosystem component as a function of its sensitivity and exposure to a specific pressure of known magnitude. Equivalent to 'impact risk'

Annex 5: North Sea Case Study

Framework

The aim of the CEA is to assess the vulnerability of the ecosystem and its components to the cumulated pressures of the combined human activities. Management is aimed at mitigating the pressures such that vulnerability is reduced which increases the likelihood that a healthy ecosystem is achieved. While a decrease in vulnerability should ultimately result in an improved ecosystem status there is no direct relationship between the two.

Vulnerability (V) is a function of Exposure and Effect Potential. Exposure (Ex) can be constructed from the spatial overlap (So) and temporal overlap (To). Effect Potential (EP) is determined by the pressure intensity (I) and the sensitivity of the ecosystem component (S).

$$V = f\ (Ex, EP)$$

Both Exposure and Effect Potential should be calculated such that they give a value 0-100%. For Exposure this then reflects the proportion (%) of the ecosystem component that is potentially perturbed by the pressure. For the Effect Potential this represents the proportion (%) of the ecosystem component that is actually perturbed to a level where its contribution to ecosystem integrity and functioning is compromised. In practice, this equates to a certain instantaneous mortality (%) from the knock-on effect of the pressure at a specific intensity (I) on the ecosystem component. Here instantaneous is understood as the % mortality that occurs in the assessment year. However, in the event that this knock-on effect occurs its persistence depends on the persistence of the pressure and the recovery potential of the ecosystem component. Thus even after a management measure is implemented it may take some time before the effect decreases. This time lag emerges because the persistence of the pressure determines how fast the residual pressure decreases while the recovery potential of the ecosystem component determines how fast this component will recover once the pressure subsides. Therefore, Effect Potential captures both an instantaneous aspect and a persistence.

$$EP = f(\text{Intensity*Sensitivity, Recovery capacity, Persistence})$$

North Sea case study

If we base ourselves on the probability theory for the combination of Exposure and Effect into Vulnerability we need to take two concepts into consideration:

- Additivity: $P(A \& B) = P(A)+P(B)-P(A)*P(B) = PA+(1-P(A))*P(B)$
- Independence: $P(A \& B) = P(A)*P(B)$

It is important to consider the relationships between spatial, temporal and severity scores. If we treat Exp_s and Exp_t as additives and (the Severity of) Effect (SE) as independent then we should calculate the vulnerability (V)

$$V = ((So + (1- So) * To) + SE)/2$$

In this case study we used the results from (Borgwardt, 2018) (see figure A1) to calculate vulnerability.

Table 1. Impact risk criteria with their categories (after Robinson *et al.*, 2013) and assigned numerical scores (adapted from (Knights *et al.*, 2015)) used to weight each impact chain

Description		Standardized score
Spatial extent	Spatial overlap of each activity-pressure combination with an ecosystem component	
Exogenous	The activity occurs outside of the area occupied by the ecosystem component, but one or more of its pressures would reach the ecosystem component through dispersal	0.01
Site	The activity overlaps with the ecosystem component by **up to 5%** of the area occupied by the EC in the case study area	0.03
Local	The activity overlaps with the ecosystem component by **between 5 and 50%** of the area occupied by the EC in the case study area	0.37
Widespread patchy	The activity overlaps with the ecosystem component by **between 50 and 100%** of the area occupied by the EC in the case study area, but the distribution within that area is patchy	0.67
Widespread even	The activity overlaps with the ecosystem component by **between 50 and 100%** of the area occupied by the EC in the case study area, and is evenly distributed across that area	1
Dispersal	Effect of the dispersal of the pressure on realised area of spatial overlap	
None	The pressure does not disperse in the environment	0.01
Moderate	The pressure disperses, but stays within the local environment	0.1
High	The pressure disperses widely and can disperse beyond the local environment	1
Frequency	Temporal overlap of each activity-pressure combination with an ecosystem component	
Rare	Occurs approximately **1–2 times** in a 5 year period but may (or may not) last for several months when it occurs	0.01
Occasional	Can occur in most years over a 5 year period, but **not more that several times a year**	0.11
Frequent	(1) occurs in **most years** over a 5 year period, and **more than several times** in each year, or (2) can occur in **1–2 years** in a 5 year period but also in **most months** of those years	0.33
Very frequent	Occurs in **most months** of **every** year, but is not constant where it occurs	0.72
Continuous	**Constant** in **most or all** months of a 5 year period	1
Persistence	Length of time that is needed that a pressure disappears after activity stops	
Low	0 to <2 yr	0.01
Moderate	2 to <10 yr	0.06
High	10 to <100 yr	0.55
Persistent	The pressure never leaves the system or > 100 yr	1
Severity	Likely sensitivity of an ecosystem component to a pressure where there is an interaction	
Low	An interaction that, irrespective of the frequency and magnitude of the event(s), never causes a noticeable effect for the ecosystem component of interest in the area of interaction	0.01
Chronic	An impact that will eventually have severe consequences at the spatial scale of the interaction, if it occurs often enough and/or at high enough levels	0.1
Acute	A severe impact over a short duration	1

For the calculation of Exp_s and Exp_t a requirement is that it needs to be understandable in a "real life" context as at some point we should be able to replace these scores with something we have actually measured. The advantage is now that the Exp_s scores are aligned to how we calculate Exposure based on available maps, i.e. where dispersal of a specific pressure adds to the extent of activity footprint.

Exposure

Exposure is determined by the spatial and temporal overlap. For spatial overlap we propose to calculate an impact score is based on a combined score of extent and dispersal which together creates a "Exposure spatial" score. We propose two different approaches (see Excel for how these were calculated): (1) based on a logic interpretation of what the scores stand for and hence how they should be combined, (2) by assuming a chance event. By simply multiplying (numeric) scores of extent and dispersal (or frequency and persistence), spatial (or temporal) effects may be either underestimated (when the scores are both small) or overestimated when they are both large. Maybe it is better to consider the two scores as chance processes when combining them into an overall spatial (or temporal) exposure score. This can be achieved by scaling the scores of both aspects between 0 and 1 and treat them as dependent chance processes. The combined 'chance' is then calculated by the sum of both chances minus the product of both the chances (see Excel).

Spatial Overlap		Dispersal		
		None	Moderate	High
Extent		1	10	100
No overlap	0	1	10	100
Ex	1	2	11	100
Site	3	4	13	100
Local	37	38	43	100
Widespread Patchy	67	67	70	100
Widespread Even	100	100	100	100

With regard to the temporal overlap we assume that the spatial overlap applies throughout the assessment year unless stated otherwise because seasonal differences in the spatial distribution of either the pressure or the ecosystem component or both, apply. In that case a seasonal weighting to the different seasonal spatial overlaps should be applied. By default the temporal overlap is 100%.

Effect Potential

In previous studies the pressure Intensity and Sensitivity were combined into the Effect Potential which, in practice, did not include pressure intensity which was implicitly assumed to be at a certain (but unspecified) level. Three qualitative categories were used, i.e. Low, Chronic, Acute (see figure A1). The resilience of the ecosystem components was adopted from Knights

Resilience	The resilience (recovery time) of the ecological characteristic to return to pre-impact conditions. Recovery times for species assessments were based on turnover times (e.g. generation times). For predominant habitat assessments, recovery time was the time taken for a habitat to recover its characteristic species of features given prevailing conditions	**Recovery (years)**	
None	The population/stock has no ability to recover and is expected to go "locally" extinct. The recovery in years is predicted to take 100+ years	100	1.00
Low	The population will take between 10 and 100 years to recover. A raw value taken as the midpoint between the range boundaries	55	0.55
Moderate	The population will take between 2 and 10 years to recover. A raw value taken as the midpoint between the range boundaries	6	0.06
High	The population will take between 0 and 2 years to recover. A raw value taken as the midpoint between the range boundaries	1	0.01

	Fish	Mammals	Birds	Sublittoral sediment	Littoral sediment	Deep sea habitat	Pelagic water column (inc. plankton)
NEA	L	L	L	M	H	L	H

The first step of the CEA, the calculation of vulnerability is the basis for the V-profile.

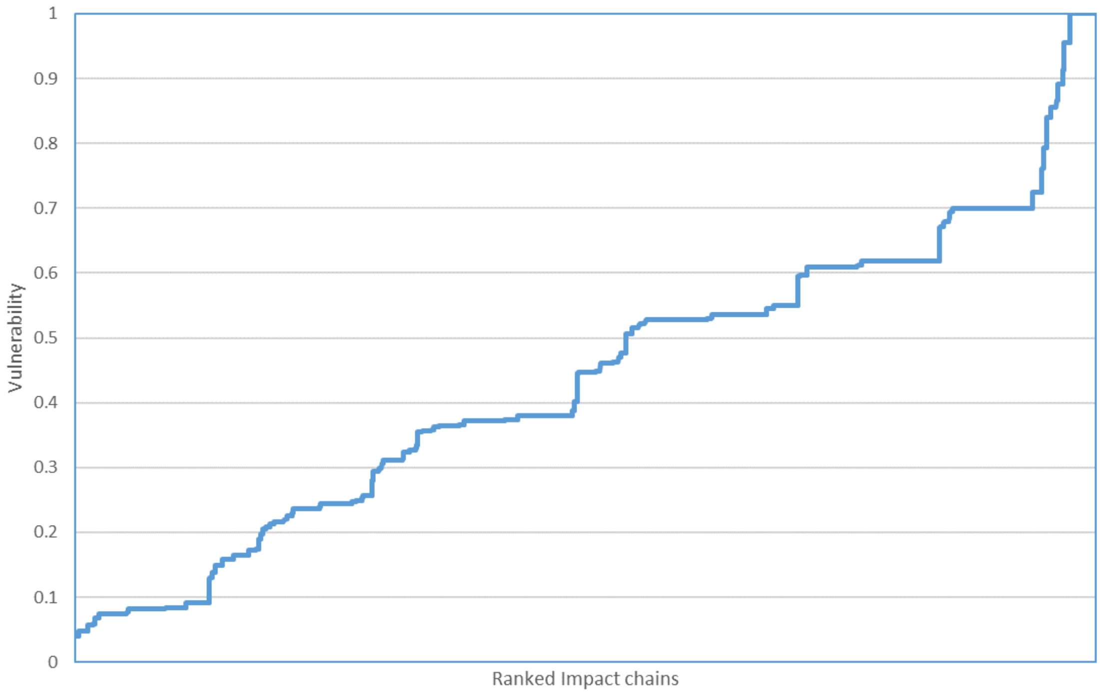
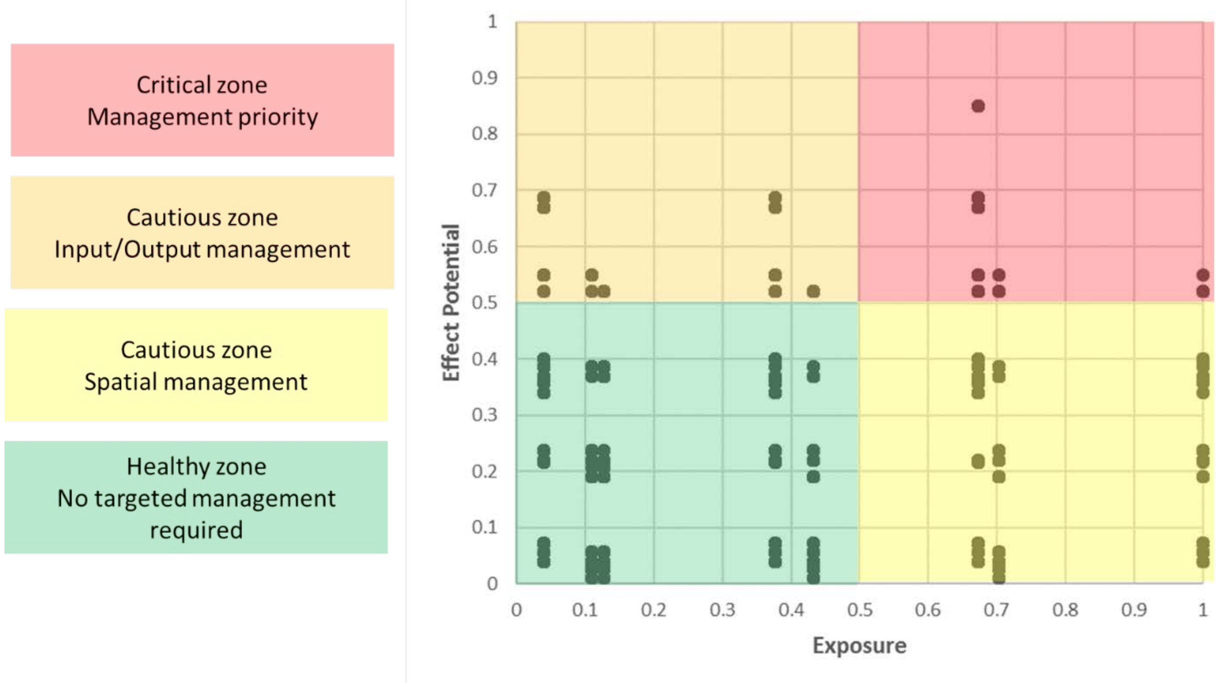


Figure A1. The North Sea V-profile represented as a ranking of all the causal chains based on their vulnerability.

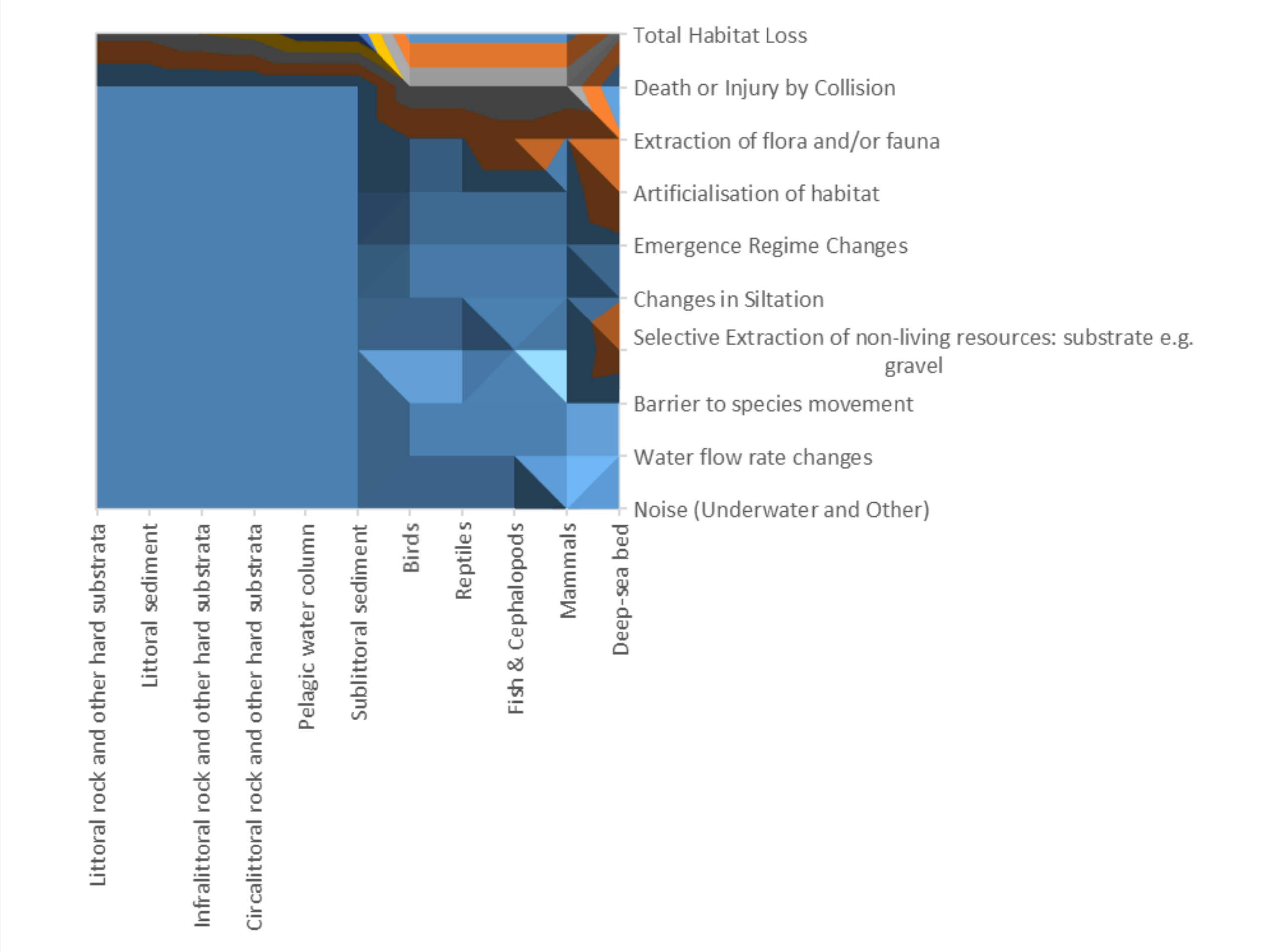
A representation of the vulnerability of the causal chains based on their Exposure and Effect Potential scores avoids the problem of bias caused by aggregation method (Piet *et al.*, 2017) because each causal chain is represented individually.

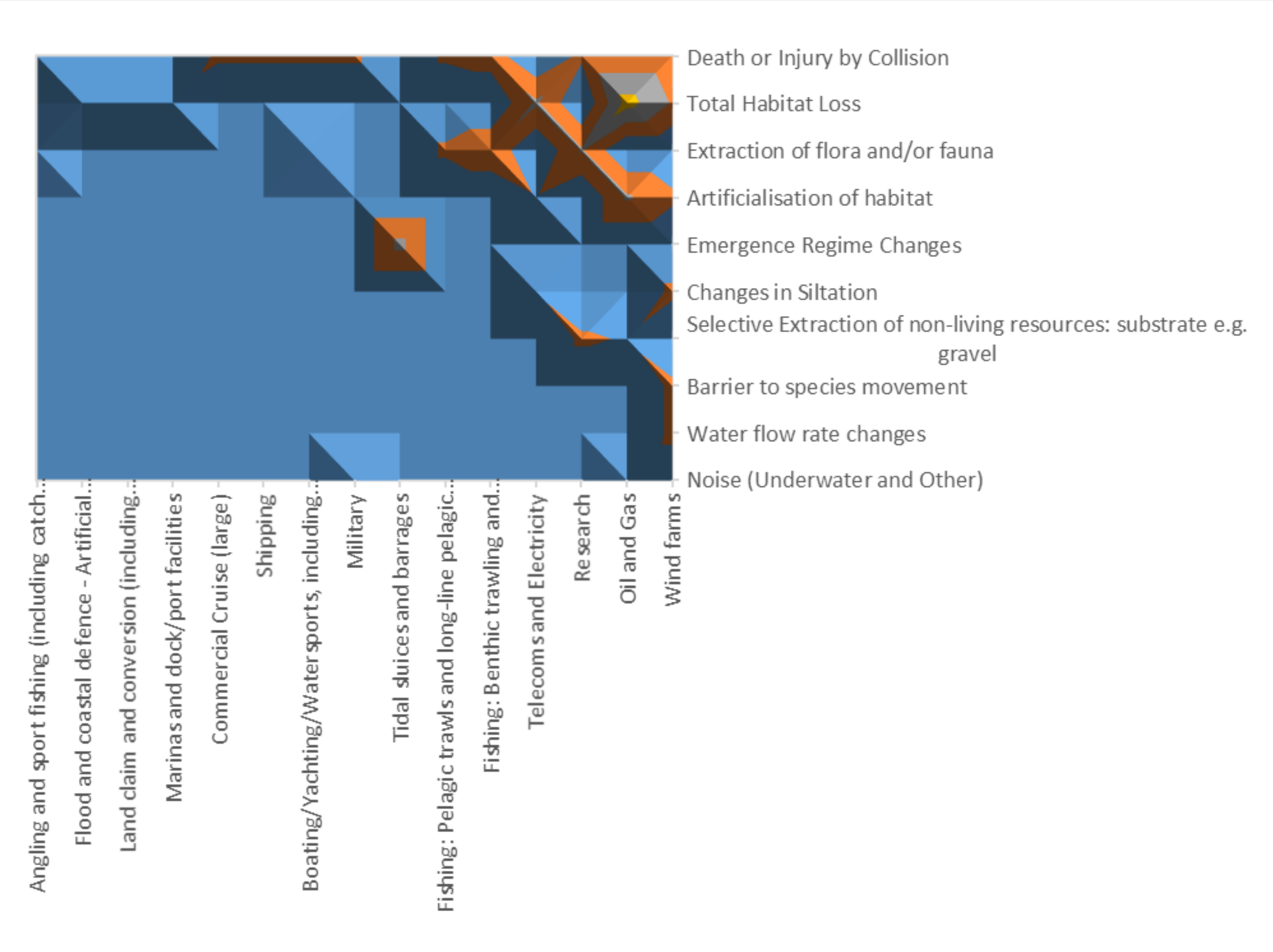
The four management quadrants in this representation are relevant for management as they distinguish between the causal chains for which:

- Management should be prioritised because they are most likely to generate cumulative effects as they represent sensitive components with high spatio-temporal overlap with a specific pressure. Any management that reduces the overall pressure load, the spatio-temporal overlap or both should be considered.
- Caution should be applied because they represent ecosystem components sensitive for a specific pressure. The overall load of this pressure should be mitigated through input and/or output control.
- Caution should be applied because the pressure overlaps spatially with a may generate cumulative effects. Input and/or output control is the likely the most appropriate management.
- No targeted management is required. They represent ecosystem components that are not sensitive with little spatio-temporal overlap with a pressure. They are likely to benefit from management measures directed at the pressures in the other management quadrants.



The figure A2 positions the causal chains in four management quadrants based on their perceived management priorities. To further guide management and increase its effectiveness additional information can be found in the figures A3 and A4 showing respectively the human activities (sectors) causing the main pressures and the ecosystem components most vulnerable to those pressures.


Total Habitat Loss
Death or Injury by Collision
Extraction of flora and/or fauna
Artificialisation of habitat
Emergence Regime Changes
Changes in Siltation
Selective Extraction of non-living resources: substrate e.g. gravel
Barrier to species movement
Water flow rate changes
Noise (Underwater and Other)
Littoral rock and other hard substrata
Littoral sediment
Infralittoral rock and other hard substrata
Circalittoral rock and other hard substrata
Pelagic water column
Sublittoral sediment
Birds
Reptiles
Fish & Cephalopods
Mammals
Deep-sea bed


Death or Injury by Collision
Total Habitat Loss
Extraction of flora and/or fauna
Artificialisation of habitat
Emergence Regime Changes
Changes in Siltation
Selective Extraction of non-living resources: substrate e.g. gravel
Barrier to species movement
Water flow rate changes
Noise (Underwater and Other)
Angling and sport fishing (including catch...
Flood and coastal defence - Artificial...
Land claim and conversion (including...
Marinas and dock/port facilities
Commercial Cruise (large)
Shipping
Boating/Yachting/Water sports, including...
Military
Tidal sluices and barrages
Fishing: Pelagic trawls and long-line pelagic...
Fishing: Benthic trawling and...
Telecoms and Electricity
Research
Oil and Gas
Wind farms

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