WORKSHOP ON CUMULATIVE EFFECTS ASSESSMENT APPROACHES IN MANAGEMENT (WKCEAM)

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International Council for the Exploration of the Sea
Conseil International pour l'Exploration de la Mer

H.C. Andersens Boulevard 44-46
DK-1553 Copenhagen V
Denmark
Telephone (+45) 33 38 67 00
Telefax (+45) 33 93 42 15
www.ices.dk
info@ices.dk

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Editors

Roland Cormier • Gerjan Piet • Vanessa Stelzenmüller

Authors

Silvana Birchenough • Philip Boulcott • Roland Cormier • Steven Degraer • Susan Doka • Mike Elliott • Matthew Gubbins • Adrian Judd • Leena Laamanen • Henn Ojaveer • Gerjan Piet • Darcy Pickard • Dave Reid • Vanessa Stelzenmüller

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i Executive summary

The Workshop on Cumulative Effects Assessment Approaches in Management (WKCEAM), convened by Vanessa Stelzenmüller, Roland Cormier, and Gerjan Piet, at ICES headquarters, Copenhagen, Denmark, 26–27 February 2019. There were 17 participants from Belgium, Canada, Estonia, Finland, Germany, Ireland, The Netherlands and the United Kingdom, including participants from ICES Secretariat.

Cumulative effects assessment (CEA) approaches are considered as key to sound policymaking and planning in governance and management. Their actual implementation in marine planning and management processes is yet to be seen. Cumulative effects are the result of multiple activities that exert pressures on ecosystem components and their functions. The meeting focused discussions of the differences between CEA approaches in governance, marine planning and regulatory processes with particular attention to the scientific information needed of such processes. Presentation and breakout group discussions were used to examine the differences in these processes to understand ways to improve the usability and uptake of CEA and to identify science needs.

The report is structured along the terms of reference that shaped the agenda. The first day was dedicated to the relevance of CEAs in environmental policies, marine planning and regulatory processes while the second day outlined the scientific and data challenges to operationalize CEAs in such processes.

Based on the findings, WKCEAM recommends the creation of a Working Group on Cumulative Effects Assessment in Management.

ii Expert group information

Expert group name	Workshop on Cumulative Effects Assessment Approaches in Management (WKCEAM)
Expert group cycle	Annual
Year cycle started	2019
Reporting year in cycle	1/1
Chairs	Roland Cormier, Canada
	Gerjan Piet, the Netherlands
	Vanessa Stelzenmüller, Germany
Meeting venue and dates	26–27 February 2019, ICES Headquarters, Copenhagen, Denmark (17 participants)

1 Opening of the meeting

The WKCEAM Co-Chairs, Vanessa Stelzenmüller, Roland Cormier and Gerjan Piet, opened the meeting welcoming the participants and reviewing the topics for the discussions. The chairs emphasized that the discussions should keep in mind the differences in CEA approaches in relation to different scientific information needs in governance, management, marine spatial planning and regulatory decision-making. The aim is not only to provide the means to improve the usability and uptake of current cumulative effects assessment approaches, but also to identify future research directions in CEA science.

2 Adoption of the agenda

The agenda was adopted by all participants and was adjusted to allow time for pertinent presentations and discussions.

3 Terms of reference

a) Review the differences in the factors (data, knowledge, decision-process) being considered regarding cumulative effects assessment (CEA) in relation to environmental policies, marine spatial planning (MSP) and regulatory processes;

b) Recommend a scientific focus for a new CEA Working Group.

4 Background

Cumulative effects assessment (CEA) approaches are considered as key to sound policymaking and planning in governance and management. While the need for CEAs is widely accepted, their actual implementation in marine planning and management processes is yet to be seen. Cumulative effects are the result of multiple activities that exert pressures on ecosystem components and their functions. In Figure 1, the general setting of a CEA is described together with the elements and linkages that need to be assessed. Broadly, these elements can be categorized in the knowledgebase on the intensity and footprint of human activities and related management measures and on the response of ecosystem components which depends on their resistance and recovery potential from their relative exposure to pressures. Current research focuses on the framing of CEAs (Stelzenmüller *et al.*, 2018), the periodicity of pressure-state relationships in complex settings (Piet *et al.*, 2017) and the integration of many vulnerability assessment results (Piet *et al.*, 2019). Further the ICES workshops WKRASM and WKPASM highlighted the need to understand the effectiveness of management measures implemented to reduce the pressures generated by human activities. In a follow-up workshop WKBCNS, the methods to parameterize and quantify estimates of pressure loads after the implementation of specific management measures has been developed (Cormier *et al.*, 2018). Hence, in the past many CEA frameworks have been developed often using different terminologies. This plethora of approaches has led to a large variation of research agendas for CEAs (Foley *et al.*, 2017) and makes comparisons among methods and the results difficult.

Ecosystem-based management (EBM) should acknowledge the complexity of socio-ecological systems (SES) and account for the ecological, economic and social effects of management measures. In most countries collective pressures generated by human activities are managed by regulatory frameworks implemented for specific sectoral regulatory activities or marine spatial planning (MSP) processes. The ultimate challenge of using the current CEA approaches to guide the implementation of EBM is to identify the main threats that compromise the achievement of societal goals, the sectors that cause them and recommend to sector-specific regulatory authorities how to mitigate those threats while considering trade-offs in policy objectives such as Blue Growth targets. From an environmental policy perspective, CEAs should focus management efforts in an attempt to optimize resource use while safeguarding or even restoring ecosystem health.

In line with Article 6 of the OSPAR Convention, Contracting Parties are obliged to undertake and publish at regular intervals Quality Status Reports (QSR) of the North East Atlantic marine environment and the human activities which it supports (including evaluation of the effectiveness of the measures taken and those planned for the protection of the marine environment and the identification of priorities for action). For the OSPAR QSR 2023 an ecosystem and risk-based approach has been developed to assess the effects of collective pressures from human activities on the quality status of the North East Atlantic (including the achievement of good environmental status under the MSFD). Recognising, that the main measures of quality status (including Good Environmental Status) are a suite of pressure and state indicators, OSPAR is initially focussing its assessment on those collective pressures that are likely to exert a change in quality represented by these indicators, incorporating an assessment of the effectiveness of management measures (aligned to Article 6 of the OSPAR Convention and Article 1(3) of the MSFD). The thinking on 'integrating' indicators as components of a 'model' ecosystem has been developed in dialogue with ICES Integrated Ecosystem Assessment (IEA) working groups, notably WGINOSE (Integrated Assessments of the North Sea) and WGMARS (Maritime Systems). The ISO standard bow tie analysis is the tool used to organise and assess the causes and consequences associated with the quality status represented by each indicator, the management measures applied to prevent or mitigate changes in quality status and to build associations between related groups of indicators in the assessment of collective (cumulative) pressures.

This workshop aimed to shed light on the role and requirements for CEAs to be used in an actual management process where various tools (modelling or otherwise) can guide the implementation of sector-specific management measures. In addition, future research needs and the potential contribution of an ICES working group on the development of CEAs have been the focus of WKCEAM.

5 Environmental policies, marine planning and regulatory processes

Operational ecosystem-based management (EBM) is required to reduce the effects of human activities on ecosystem components and their functioning in order to achieve policy objectives in support of societal goals (Cormier *et al.*, 2017). However, it is the implementation of management measures developed by authorities in consultation with stakeholders that '*carry into effect*' the objectives set in planning. In a nutshell, the management measures need to address their expected outcomes to achieve the objectives to reach the goals.

Various legislation and policies stipulate that the effects of past, current and future activities need to be considered in decisions regarding the management of human activities (Jones, 2016). As part of the initial assessment conducted under the European Marine Strategic Framework Directive (MSFD); (The European Commission, 2017), an analysis of the predominant pressures and their impacts is required. Ultimately, a programme of measures would be developed and implemented to reduce the pressures generated by human activities to achieve or maintain good environmental status and, thus, carry into effect the goals and objectives of the directive. A CEA (preferably quantitative but otherwise qualitative) has a role in this process to ascertain an integrated perspective and guide EBM. Cumulative effects are a key requirements in most environmental impact assessment legislation in Europe and North America.

In other legislation such as the proposed amendments to the Canadian *Fisheries Act* (Canada, 2019), cumulative effects from a work, undertaking or activity resulting from a project proposal has to be considered in relation to the effects from past works, undertakings or activities from human development as one of the factors in the regulatory review. However, the regulatory approval process has to ultimately identify the avoidance, mitigation and offsetting (i.e. compensation) measures needed to comply with the prohibitions of the *Act*. In addition to fisheries management provisions, the *Fisheries Act* has been amended over time (e.g. 1977, 2012) to address conservation and protection provisions for fish and fish habitat in both freshwater and marine ecosystems through precautionary and ecosystem approaches within a regulatory framework context. From an ecological context, the use of ecologically significant areas and scientific advisory processes, the policies and program to carry into effect the Act are currently underway. In addition to the *Fisheries Act*, CEAs are also part of a broad range of Canadian legislation across jurisdictions and sectors.

In both, the intent of conducting a CEA is to ultimately inform decisions regarding the development of management measures needed to control the pressures generated by specific human activities. Although CEAs are part of a broad range of legislative requirements these have yet to become effective in such management contexts (Willsteed *et al.*, 2017). However, it is suggested that CEAs and planning are complementary when such planning is set in a regional or marine area where the significance of such assessments can better be imbedded in such plans and guide the management of human activities (Jones, 2016). Therefore, a CEA should inform the planning process as to 'what' policy objectives may be compromised as a result of the effects that were assessed (Figure 1). However, such CEA should also identify the predominant pressures that are causing the effects to guide the manager as to 'how' best to manage the activities to reduce the pressures and ultimately the negative effects. A CEA framework that could bridge cross-sectoral planning initiatives within sectoral regulatory frameworks would ensure that such an assessment is fit for the purpose of the implementation of management measures to achieve policy objectives in support of the societal goals.

As described in the MSFD and *Fisheries Act* examples, such a framework would have to deal with different selections of activities and their pressures resulting in effects that occur at very different spatial and temporal scales. Such a framework would have to incorporate different ecosystem and jurisdictional boundaries depending on legislation being used.

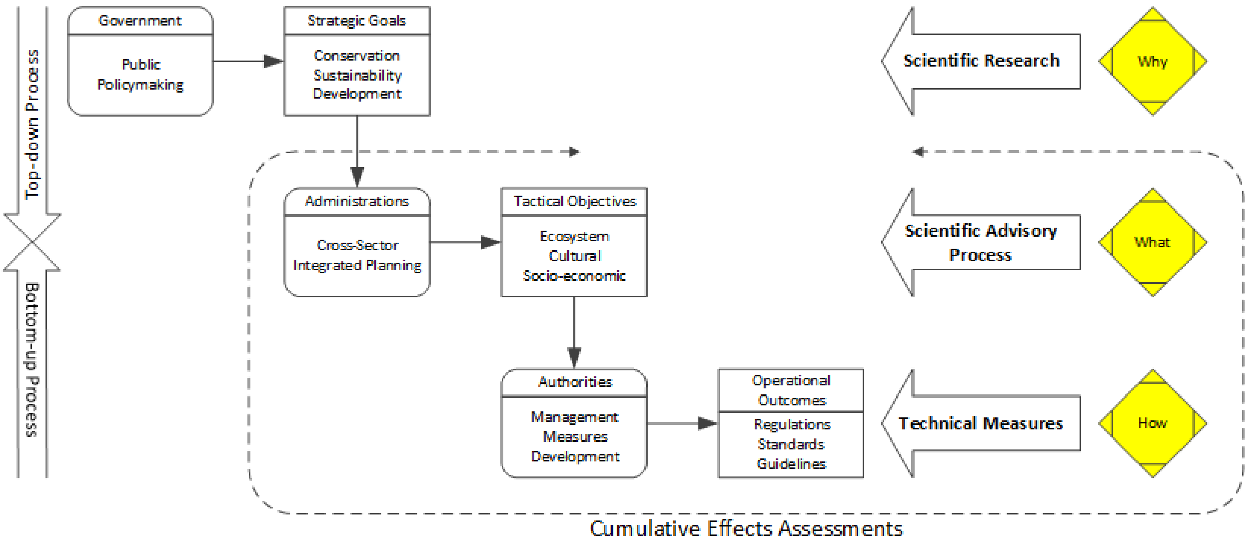

Figure 1. Science inputs to operationalize an ecosystem-based approach (adapted from Cormier *et al.*, 2017).

As a result of the breakout group discussions, it is clear that the role of CEAs is in informing cross-sectoral planning processes in addition to ecosystem overviews that could scope the issues for a CEA. In Figure 1, CEAs would not be considered relevant in policymaking to establish societal and environmental goals (Why) which is usually informed by scientific research and literature. A CEA would assess the effects in relation to the objectives being considered in planning such as the MSFD qualitative descriptions of GES, fisheries objectives, strategic environmental assessments, etc. The data would have to link in a fully integrated manner to the causal pathways of effects (What) from the activities, pressures and receptors where the CEA provides a common currency that combines the intensity/magnitude of the pressures to the sensitivity of a vulnerable ecosystem components into a common endpoint, e.g. the risk to the ecosystem component that is impacted and the risk of policy objectives that are not achieved. In planning, the output of a CEA would direct ecosystem-based management to the predominant pressures from human activities that compromise the achievement of societal goals. In an operational context, however, a CEA has to provide a higher level of certainty and understanding of the cause-effect pathways. Although there is a need for a higher level of resolution in an operational context compared to the planning process that is linked to the regulatory frameworks requiring that the pressures to be attributed to individual activities, often in specific locations in order to improve the performance of the management measures through licensing and permitting conditions, for example. That implies that CEAs have to bridge the planning process with regulatory frameworks to inform sector authorities as to the precautionary approach needed (e.g. caused by insufficient knowledge or data) or the improvements to current management measures that emerge in an adaptive management approach. Given the legal framework of such regulatory processes, uncertainty should explicitly be considered in relation to the required regulatory targets and/or marine environmental quality standards based on thresholds. CEAs should be able to bridge the planning and regulatory processes.

6 Scientific information needs to operationalise a CEA

The nature of the freshwater and marine environment, in terms of connectivity and heterogeneity of ecosystem components, functions and processes, the uncertainty in biophysical processes together with varying levels of intensity of human activities determine the complexity of CEAs (see Figure 2). This figure was presented at the onset of the workshop to capture the essential CEA knowledge requirements, consisting of human pressures and how their impacts are determined by the vulnerability of ecosystem components to these pressures. What was considered the technical assessment of the direction and strength of those linkages that form the actual CEA is indicated by the dashed line in Figure 2. Considerations on the provision of ecosystem services and estimates of socio-cultural effects are deemed to be outside the remits of a CEA. However, to operationalize EBM (see previous section) the scientific input needed goes beyond those indicated in Figure 2 (dashed line) to inform both the planning and regulatory processes. Current focus of CEA is on the identification of key pressures contributing most to observed cumulative effects. This knowledge is required to inform the cross-sectoral planning processes and its main requirement is that it needs to integrate the adverse effects of a multitude of activities and their pressures on the relevant receptors.

Throughout the workshop the group distinguished clearly a second type of scientific input to a CEA, that are the technical measures that should inform regulatory processes, which require more sophisticated, fully quantitative models that can provide the necessary level of detail but which are usually only for a single activity and only covering one or a few pressures. This interaction is covered in Figure 2 by the cross-section of a CEA with monitoring and evaluation processes, hence comprising the evaluation of the effectiveness of management measures. At present the available CEAs are usually risk-based approaches (also referred to as vulnerability assessments accounting for both the exposure to a pressure and the sensitivity of an ecosystem component to such a pressure) based on expert judgement. At WKCEAM, a process was outlined that advances the knowledge base from those based on mostly qualitative to quantitative data which is spatially explicit. The difference between the two types of scientific inputs are aligned to the conceptual framework for ecosystem risk assessment (ERA) developed by Holsman *et al.*, 2017 (see Figure 3). The cross-sectoral CEA explicitly covers the right-hand side of the Figure 3 whereas the single-sector models cover the left-hand side of figure.

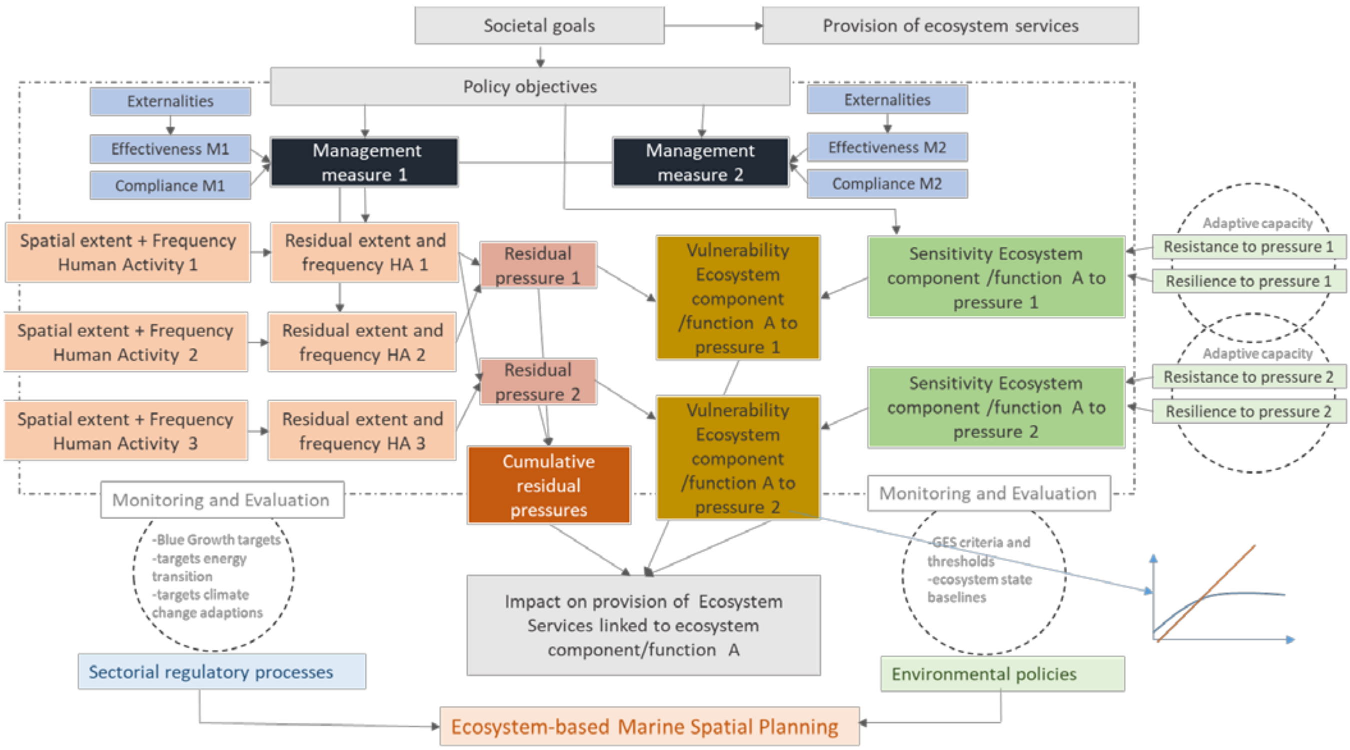

Figure 2. Information elements of a CEA in an operational context.

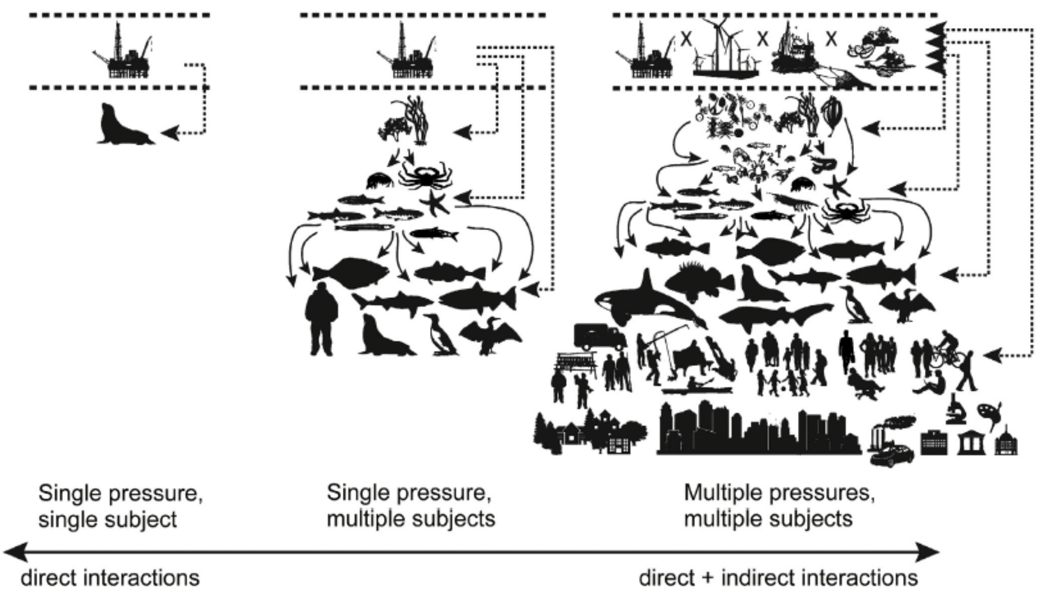

Figure 3. Conceptual framework for ecosystem risk assessment developed by (Holsman *et al.*, 2017).

To (further) operationalise the CEA the WKCEAM proposes a process based on Judd *et al.* (2015) but slightly modified so that it now consists of 4 phases (see Figure 4). The first phase is driven by the outcome of the "Why" in figure 1. In the 2nd phase all the structure of the CEA is developed consisting of all the relevant linkages between the stressor and the receptor or so-called cause-effect pathways (i.e. human activity-pressure-ecosystem component). In the 3rd phase the scientific evidence is collected and applied to estimate the amount of risk contributed by each of the cause-effect pathways. Finally, there is an evaluation of the performance of the CEA and the confidence in the quality of the knowledge base which then drives the next cycle of the iterative process to develop the CEA knowledge base.

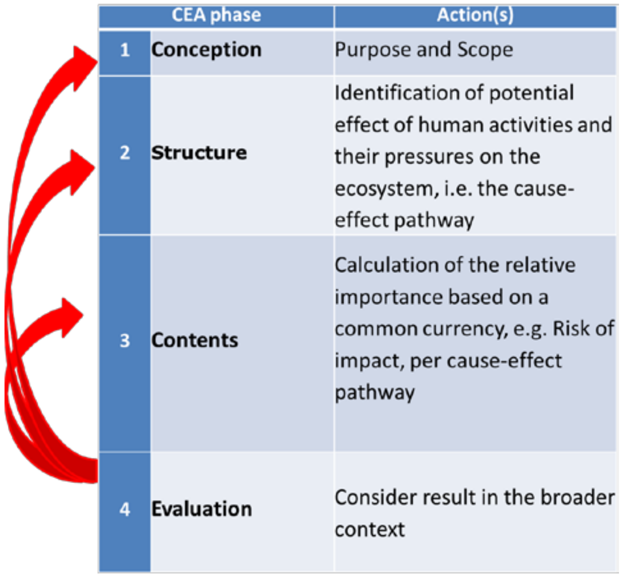

Figure 4. One cycle of the WKCEAM iterative process to develop the CEA knowledge base.

Two phases are further elaborated as these shape the scientific information needed for the CEA.

- Phase 2 requires an agreed typology of the elements that make up the so-called linkage framework (consisting of all relevant cause-effect pathways). For cause-effect pathways consisting of human activity-pressure-ecosystem components this implies fixed but region-specific categories for human activities, pressures and ecosystem components. An example of such a typology from the H2020 AQUACROSS project was presented at the workshop (see Annexes 3, 4, 5 and 6).
- Phase 3 is most dependent on the scientific knowledge available. Existing CEAs usually only based on qualitative information from expert judgement. An approach distinguishing information modules was presented and discussed. These information modules (see Figure 5) are supposed to simplify the process of improving the CEA knowledge base by gradually replacing each information modules per cause-effect pathway once more reliable information becomes available. With each replacement the confidence in the outcome of the CEA should improve. Two criteria were identified that should drive this process, i.e. Relevance (how much does this cause-effect pathway contribute to the overall risk) and Quality (to what degree is the quality of this information module, and hence the confidence, improved).

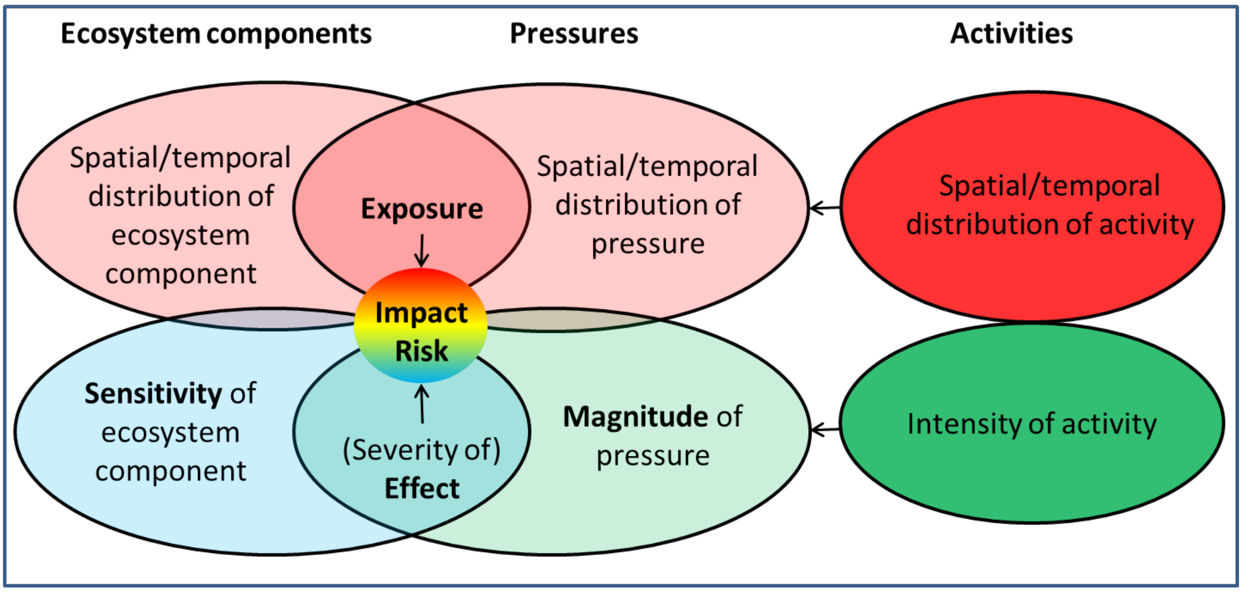

Figure 5. Information modules based on a risk-based approach. These apply for each cause-effect pathway.

7 Towards a common CEA framework and proof of concept

The group concluded that a generic framework for CEA based on the best practice elsewhere and taking into account the needs of the main actors (ICES, OSPAR, EEA, HELCOM, JPI Oceans; CEAF, DFO, TC, ECCC) should be developed. As a starting point some of the information presented and discussed at the WKCEAM is provided in the preceding sections and the biggest challenges for the operationalization of CEA were listed (Table 1). Table 1 reflects also a kind of checklist for key points to be considered by a CEA.

Table 1. Main challenges for the operationalization of a CEA.

Agree on a typology that can be consistently applied for that (often region-specific) EBM approach. This should be a fixed typology as it drives the scientific process to build the knowledge base. If at some later stage stakeholders require different categories then cross-walks between the existing typology and any new categories will need to be developed.
Improve our ability to estimate exposure. This includes estimating the footprints of the different stressors (i.e. pressures from specific activities) as well as the distribution of the receptors (i.e. ecosystem components). This applies to the mobile receptors (mostly species) as well as the sedentary ones (habitats and species).
Agree on a common understanding of what the concept of risk represents. Based on this, a unit of risk can then be decided upon (see Stelzenmüller *et al.*, 2018).
Determining the magnitude of the pressures from an activity, not just the activity itself in a place at a given time (not assuming an activity equals a pressure) (see the DAPSI(W)R(M) framework, Elliott *et al.,* 2017)
Develop criteria that allows an assessment of the quality of the available information and allow a process to replace this with better information
If possible, apply more appropriate and/or elaborate ways to combine cause-effect pathways, while often the default of summation can be appropriate it may well be synergistic or antagonistic. Also, consider if tipping points or thresholds may apply.
Accepting that CEA is a fully integrated approach which relates to cumulative effects of the combined effects of all activities not just the effects one activity or sector (the latter is just an EIA carried out properly – if we say 'a CEA for offshore wind' then this is a misnomer) (Elliott *et al.*, 2018 and 2019).
Determining the relative effects of endogenic managed pressures (pressures managed within the boundary of management area) overlaid by exogenic unmanaged ones (e.g. pressures that are either managed or not outside a management area and can include natural processes and the effects of climate change).
Consider expanding the CEA such that it also includes the supply of ecosystem services

To advance the development of a generic CEA methodology and identify real research gaps the use of one or more case studies as a proof of concept was suggested by the group. In the context of an ICES WG on CEAs the initial focus should be on the North Sea and a Canadian bioregion where the CEA is conducted with the available knowledge base. Doing so 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. Working on case studies allows further a direct engagement with other WGs to help build the knowledge base.

8 Conclusions

CEAs should be conducted within the scope and context of the water body being assessed. The planning objectives and expected outcomes of the management measures should, however, be specific, measurable, achievable, and realistic and time bounded (SMART); (Cormier and Elliott, 2017, Stelzenmüller *et al.* 2013). A CEA should outline the magnitude, as determined by extent, duration and frequency, of the activities in the assessment area with the spatial extent, dispersal, frequency and persistence of the pressures they generate (Borgwardt *et al.*, 2019). Consistent typology of activity-pressure-ecosystem component would help build the knowledge base (i.e. map the spatial and temporal aspects of the effect-footprints for the activities and their pressures to inform site specific receptors). This knowledge base would use relevant tools such as GIS, models or expert judgement to determine the exposure, i.e. how and when pressures and receptor overlap. A CEA should inform the IEA process regarding the potential cumulative effects of a given project while informing SEA and MSP initiatives as to the sustainability of development that is being considered including the socio-economic repercussions (Barnard and Elliott, 2015).

Cumulative effects are caused by the residual effects from activities operating within their respective legal and policy frameworks (Cormier, 2015). A CEA should play a key role in regulatory impact assessments that are typically required for regulatory decisions in most OECD countries as well as developing international technical measures to address transboundary or transnational influences. Finally, a CEA could inform subsequent assessment processes that would link the effects to ecosystem services and societal benefits in consultation with stakeholders via established processes that follow quality assurance principles (Cormier *et al.*, 2015).

The CEA should be used in conjunction with an integrated assessment as is currently done for several ICES marine regions (e.g. WGINOSE…) to identify if the implemented technical measures have actually succeeded in achieving the policy objectives. The CEA informs the more sophisticated single-sector models that can calculate in detail if the technical measures are likely to achieve the policy objectives. This implies that the indicators calculated by such models have to be able to detect changes in the receptors above the natural noise or variability to establish baselines or reference conditions. The significance of the change to a receptor as measured by the indicator would have to be coupled with thresholds or actions points for predetermined management actions as is the case in fisheries harvest control strategies (DFO, 2015). Ultimately, these models and the integrated ecosystem assessments should indicate if the prevention, mitigation and compensation measures including restoration have succeeded to reduce the pressures to the extent that policy objectives are achieved.

9 Recommendation

The participants of the workshop recommended the creation of an ICES Working Group on Cumulative Effects Assessment in Management. This Group would lead ICES into issues related to the integrated assessment of ecosystem effects of multiple human activities and their pressures. Given that the actual implementation of CEAs in marine management is lacking, the working group would review existing guidance and approaches to develop a CEA framework that could provide practical advice in the development of management measures which would be better aligned with operational management and regulatory processes. Case studies would be used to develop the CEA framework and test its applicability and demonstrate the application of such a framework in regional seas or biogeographic regions. The group would liaise with other ICES and non-ICES working groups related to cumulative effects assessment and data requirements.

Proposed draft terms of reference for such a work group:

a) Develop a CEA framework suited to guide science advice on the development of management measures
b) Demonstrate the application of the CEA framework in one or more regional case studies,
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,
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.

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Annex 1: List of participants

Name	Institute	Country	E-mail
Roland Cormier	Helmholtz Zentrum Geesthacht; Institute of Coastal Research	Germany	Roland.Cormier@hzg.de
Darcy Pickard	ESSA International	Canada	dpickard@essa.com
Mark Dickey-Collas	International Council for the Exploration of the Sea		mark.dickey-collas@ices.dk
Susan Doka	Fisheries and Oceans Canada	Canada	Susan.Doka@dfo-mpo.gc.ca
Matthew Gubbins	Marine Scotland; Marine Laboratory	United Kingdom	Matthew.Gubbins@gov.scot
Adrian Judd	Centre for Environment, Fisheries and Aquaculture Science	United Kingdom	adrian.judd@cefas.co.uk
Gerjan Piet	Wageningen Marine Research	the Netherlands	gerjan.piet@wur.nl
Dave Reid	Marine Institute	Ireland	dave.reid@marine.ie
Vanessa Stelzenmüller	TI Institute of Sea Fisheries	Germany	vanessa.stelzenmueller@thuenen.de
Henn Ojaveer	Estonian Marine Institute	Estonia	henn.ojaveer@ut.ee
Simon Jennings	International Council for the Exploration of the Sea		simon.jennings@ices.dk
Leena Laamanen	Finnish Environment Institute (SYKE); Marine Research Centre	Finland	Leena.Laamanen@ymparisto.fi
Silvana Birchenough	Centre for Environment, Fisheries and Aquaculture Science	United Kingdom	silvana.birchenough@cefas.co.uk
Philip Boulcott	Marine Scotland; Marine Laboratory	United Kingdom	p.boulcott@marlab.ac.uk
Steven Degraer	Royal Belgian Institute of Natural Sciences; Operational Directorate Natural Environment; Marine Ecology and Management	Belgium	steven.degraer@naturalsciences.be
Mike Elliott	Institute of Estuarine &Coastal Studies	United Kingdom	Mike.Elliott@hull.ac.uk

Sebastian Valanko	International Council for the Exploration of the Sea	sebastian.valanko@ices.dk

Annex 2: WKCEAM Resolution

2018/2/HAPISG07 A **Workshop on Cumulative Effects Assessment Approaches in Management** (WKCEAM), chaired by Vanessa Stelzenmüller, Germany, Roland Cormier, Germany, and Gerjan Piet, the Netherlands, will meet at ICES HQ, Copenhagen, Denmark, 26–27 February 2019 to:

a) Review the differences in the factors (data, knowledge, decision-process) being considered regarding cumulative effects assessment (CEA) in relation to environmental policies, marine spatial planning (MSP) and regulatory processes;

b) Recommend scientific focus for a new CEA Working Group.

WKCEAM will report by 30 March 2019 (via HAPISG) for the attention of SCICOM.

Supporting information

Priority	The current activities of Working Group for Marine Planning and Coastal Zone Management (WGMPCZM) are focused on the understanding of cumulative pressures to inform trade-offs between the benefits and risks of human activities in MSP and reduce the pressures through spatial-temporal measures.
Scientific justification	Current cumulative effects assessment (CEA) approaches are considered as key to sound policymaking and planning in governance and management. While the need for CEAs is widely accepted, their actual implementation in marine planning and management processes is yet to be seen. Cumulative effects are the result of the activities of multiple drivers that exert pressures on ecosystem components their functions (Figure 1). In concept, the ICES workshops WKRASM and WKPASM highlighted the need to understand the effectiveness of management measures implemented to reduce the pressures generated by human activities. In a follow-up workshop WKBCNS, the methods to parameterize and quantify estimates of pressures loads after the implementation of specific management measures has been develoepd. Conservation management strategies (e.g. spatial management restricting human uses) can, up to a point, protect ecosystem components and/or functions from cumulative effects of human activities. Hence the collective pressures generated by human activities are managed by regulatory frameworks implemented e.g. for specific sectorial activities or regulatory marine spatial plannig (MSP) processes. On one hand side the challenge of using current CEA approaches in such regulatory or spatial planning context is in determining the level of pressure generated by each individual sector operating in an area that are contributing to the effects identified by the assessment in order to deliver on e.g regulatory or Blue growth targets. From an environmental policy perspective CEAs should aid to prevent tipping points in pressure-state relationships to saveguard or restore ecosystem healh. The proposed workshop will review in detail the differences in CEA approaches in relation to different information needs in governance, management, regulators MSP and regulatory decision-making. The aim is not not only to provide the means to improve the usability and uptake of current cumulative effects assessments approaches, but also to identify future research directions in CEA science.
Resource requirements	The research programmes of the participants would provide the main input for this workshop. The additional resource required to undertake additional activities in the framework of this group is negligible.
Participants	The workshop would expect 10–15 participants.
Secretariat facilities	None.
Financial	No financial implications.
Linkage to the ICES Science Plan	ToR a): 6.2; 2.2; 6.1 ToR b): NA

Linkages to advisory committee	There are no obvious direct linkages with the advisory committees.
Linkages to other committees or groups	This workshop has linkages other ICES workshops on sea bed abrasion (WKBENTH, WKTRADE, WKBEDPRES etc.) as well as HAPISG EGs.
Linkages to other organizations	The workshop topic is linked to OSPAR Intersessional correspondence group on cumulative impacts (ICG-EcoC) and the UK Marine Monitoring and Assessment Strategy Pressures Group.

Annex 3: Typologies from the AQUACROSS project: Activities (headline activities in bold)

Agriculture & Forestry
Agriculture (crops and livestock)
Cultivation of crops and maintenance of pasture (Irrigation, drainage, change of riparian habitat, alteration of channels)
General (atmospheric emissions, runoff of nutrients) due to livestock
Forestry
Cultivation of forestry (Irrigation, drainage, change of riparian habitat, alteration of channels)
Aquaculture
Ex-situ aquaculture
Ex-situ (on land) aquaculture (water abstraction, waste discharge)
In-situ aquaculture
Fin-fish - operational (waste products, anti-fouling, predator control, disease and disease control, infrastructure effects on local hydrography, escapees, litter, anchoring/mooring of boats)
Fin-fish - set-up (atmospheric emissions for transport of brood stock/juveniles, interaction with seafloor during set-up of infrastructure, loss of gear)
Macro-algae - operational (waste products, anti-fouling, predator control, disease and disease control, infrastructure effects on local hydrography, litter, anchoring/mooring of boats)
Macro-algae - set-up (atmospheric emissions from boats (certain species), trampling (certain species), interaction with seafloor, removal of habitat-structuring species, loss of gear)
Shellfish - operational (waste products, anti-fouling, predator control, disease and disease control, infrastructure effects on local hydrography, litter, anchoring/mooring of boats)
Shellfish - setup (atmospheric emissions from boats, interaction with seafloor when dredging for brood stock, loss of gear, litter)
Environmental Management
Artificial reefs
Artificial reefs - construction (interaction with seafloor, habitat change, emissions from boats)
Artificial reefs - operational (localised changes in hydrography, visual cues)
Beach replenishment
Beach replenishment - operational (habitat change, smothering, contaminants (depends on nature of material added, atmospheric emissions)
Culverting lagoons
Culverting lagoons - construction (interaction with seafloor, habitat change, smothering, increased turbidity, noise, atmospheric emissions)
Culverting lagoons - operational (localised changes in hydrography)
Dredging (including capital and maintenance, and extraction and disposal of substrate)
Capital dredging - extraction of substrate (habitat change, interaction with seafloor, contaminant release, increased turbidity, noise)
Capital dredging - spoil/waste disposal (habitat change, smothering)
Maintenance dredging - extraction of substrate (habitat change, interaction with seafloor, contaminant release, increased turbidity, noise)
Flood and coastal defence - Artificial Structures: including levees, dykes, embankments, sea walls/breakwaters/groynes

Coastal defence - Sea walls/breakwaters/groynes - construction (habitat change, sealing, interaction with seafloor, smothering, increased turbidity, noise, atmospheric emissions)
Coastal defence - Sea walls/breakwaters/groynes - operational (localised changes in hydrography and sediment distribution)
Land claim and conversion (including construction and operation)
Land claim - construction (habitat change, smothering, increased turbidity, noise, atmospheric emissions)
Land claim - operational (localised changes in hydrography)
Exogenous/Unmanaged (e.g. due to climate change)
Activities causing atmospheric emissions
Activities causing atmospheric emissions
Activities producing litter
Activities producing plastic
Climate Change
Climate Change
Fishing
Fishing: Benthic trawling and suction/hydraulic dredges
Benthic trawls and dredges - general (anti-fouling, ballast water, litter, lost gear)
Benthic trawls and dredges - mooring/anchoring (interaction with seafloor)
Benthic trawls and dredges - operations (interaction with seafloor, catch, bycatch, waste products)
Benthic trawls and dredges - steaming (atmospheric emissions, collisions)
Suction/hydraulic dredges - general (anti-fouling, ballast water, litter, lost gear)
Suction/hydraulic dredges - mooring/anchoring (interaction with seafloor)
Suction/hydraulic dredges - operations (interaction with seafloor, catch, bycatch, waste products)
Suction/hydraulic dredges - steaming (atmospheric emissions, collisions)
Fishing: Nets, potting/creeling (set up/recovery, operations)
Nets (fixed/set/gillnets/other nets/lines) - general (litter, lost gear, antifoulants)
Nets (fixed/set/gillnets/other nets/lines) - operational (catch, bycatch, waste products)
Nets (fixed/set/gillnets/other nets/lines) - set up/recovery (interaction with seafloor, atmospheric emissions)
Potting/creeling - general (litter, lost gear)
Potting/creeling - operational (catch, bycatch, waste products)
Potting/creeling - set up/recovery (interaction with seafloor)
Fishing: Pelagic trawls and long-line pelagic (including steaming, operations, mooring/anchoring)
Pelagic trawls - general (anti-fouling, ballast water, litter, lost gear)
Pelagic trawls - mooring/anchoring (interaction with seafloor)
Pelagic trawls - operations (catch, bycatch, waste products)
Pelagic trawls - steaming (atmospheric emissions, collisions)
Manufacturing (land-based) - operations
Manufacturing: Industry with discharges - operational
Specific to locality: Industry with discharges into coastal waters - operational (Industrial effluent discharge, abstraction of water)
Mining, extraction of materials
Mining, extraction of materials: including inorganic, maerl, rock/minerals, sand/gravel, salt

Inorganic mine and particulate waste - extraction of substrate (habitat change, interaction with seafloor)
Inorganic mine and particulate waste - spoil/waste disposal (habitat change, smothering)
Maerl - extraction of substrate (habitat change, interaction with seafloor, removal of habitat-structuring species)
Maerl - spoil/waste disposal (habitat change, smothering)
Rock/Minerals - coastal quarrying - extraction of substrate (habitat change, interaction with seafloor, contaminant release)
Rock/Minerals - coastal quarrying - spoil/waste disposal (habitat change, smothering)
Sand/gravel aggregates - extraction of substrate (habitat change, interaction with seafloor, contaminant release)
Sand/gravel aggregates - spoil/waste disposal (habitat change, smothering)
Non-Renewable Energy
Non-renewable power stations (land-based, coastal)
Power stations (land-based on coast) - construction (jetties and intake wells - habitat change, sealing, increased turbidity, noise)
Power stations (land-based) - operational (atmospheric emissions, abstraction of water, thermal discharge of cooling water, localised effects on hydrography, waste)
Oil and Gas
Oil and Gas - construction (drilling, anchoring, construction of wellheads, laying pipelines, oil spills)
Oil and Gas - decommissioning (anchoring, oil spills, removal of infrastructure where relevant)
Oil and Gas - exploration (seismic surveys, exploratory drilling and anchoring, oil spills)
Oil and Gas - operational (waste fluids and particulates to seafloor, surface litter and wastewater, oil spills)
Renewable Energy
Tidal sluices and barrages
Tidal barrages - construction (interaction with seafloor, habitat change (upstream and downstream) and localised sealing of habitat, barrier to movement for migratory anhadromous or catadromous species)
Tidal barrages - operational (change in tidal (and emergence) regime, barrier to movement for migratory anadromous or catadromous species)
Tidal sluices - construction (interaction with seafloor, localised sealing of habitat)
Tidal sluices - operational (localised changes in hydrography)
Wave energy
Wave energy - construction (cable laying - localised habitat change, noise)
Wave energy - operational (localised electro-magnetic changes around cables, localised change in flow of water)
Wind farms
Wind farms - construction (installation of turbines on seafloor includes interaction with seafloor, habitat change and sealing, laying cables)
Wind farms - operational (active cables on seafloor - electromagnetic changes, moving turbines - collisions, boats servicing and maintaining farms)
Research
Research
Research: General (anti-fouling, ballast water exchange, litter, oils leaching)

Research: Mooring/anchoring/beaching/launching (interaction with seafloor)
Research: Operations (specific to activity but can include: interaction with seafloor, catch, bycatch)
Research: Steaming (atmospheric emissions, collisions)
Residential & Commercial Development
Marinas and dock/port facilities
Marinas and dock/port facilities - construction (habitat change, sealing, interaction with seafloor, smothering, increased turbidity, noise, atmospheric emissions)
Marinas and dock/port facilities - operational (litter, light, noise, waste disposal)
Urban dwellings and commercial developments
Urban dwellings and commercial developments - construction (habitat change, sealing, interaction with seafloor, smothering, increased turbidity, noise, atmospheric emissions)
Urban dwellings and commercial developments - operational (contaminants e.g. from petrol stations, other commercial developments, litter)
Services
Military
Marine dumped munitions
Military: General (anti-fouling, ballast water exchange, litter)
Military: Mooring/anchoring/beaching/launching (interaction with seafloor)
Military: Operations (specific to activity but can include: seismic activities, sonar)
Military: Steaming (atmospheric emissions, collisions)
Shipping
Shipping: General (anti-fouling, ballast water exchange, litter)
Shipping: Mooring/anchoring/beaching/launching (interaction with seafloor)
Shipping: Steaming (atmospheric emissions, collisions)
Telecoms and Electricity
Telecoms and Electricity: Communication and electric cables - active operational (localised electro-magnetic changes)
Telecoms and Electricity: Communication and electric cables - laying cables (localised habitat change and smothering, interaction with seafloor, atmospheric emissions from ships laying cables)
Transport (roads, vehicles, other)
Transport - run off from roads, emissions, ...
Tourism/ Recreation and Non-Commercial Harvesting
Angling and sport fishing (including catch and release and stocking)
Angling (catch, bycatch, interaction with seafloor (gear, and anchors if offshore, atmospheric emissions and antifoulants if using boats))
Boating/Yachting/Watersports (without engine)
Boating/Yachting/Watersports (without engine)
Boating/Yachting/Watersports, including tourist boats (with engine)
Boating/Yachting - general (anti-fouling, ballast water exchange, litter, waste) (with engine)
Boating/Yachting - mooring/anchoring/beaching/launching (interaction with seafloor) (with engine)
Boating/Yachting - steaming (collisions)
Diving/Dive site - general (anti-fouling, litter, waste)
Diving/Dive site - mooring/anchoring/beaching/launching (interaction with seafloor)
Diving/Dive site - operations (trampling, spp extraction)

Diving/Dive site - steaming (collisions)
Water sports - mooring/anchoring/beaching/launching (interaction with lakebed and banks; seafloor) (with engine)
Water sports - steaming (collisions, atmospheric emissions)
Collecting (bird eggs, individuals, curios, bait)
Bait digging - (trampling, interaction with seafloor, removal of habitat-structuring species)
Bird eggs - (trampling, removal of individuals)
Curios and keeping aquariums - (trampling, removal or release of flora/fauna)
Peels (boulder turning) - (trampling, removal of individuals)
Shellfish hand collecting - (trampling, interaction with seafloor, removal of individuals)
Commercial Cruise (large)
Cruise ships
Hunting, including wildfowling and spearfishing (shooting, lead shot, boating)
Wildfowling (shooting, lead shot, boating)
Shore recreational activities (including beaches, terrestrial sports, other shore activities)
Public beach - general (trampling, litter)
Seawater swimming pool
Tourist resort
Tourist Resort - construction (habitat change, sealing, smothering, increased turbidity, noise)
Tourist Resort - operational (effluent discharge, abstraction of water, litter)
Waste Management
Waste management - operational disposal of waste or other material and/or sewage treatment and storm overflows
Operational (effluent discharge, thermal discharge) due to disposal of waste or other material and/or due to sewage treatment and storm overflows

Annex 4: Typologies from the AQUACROSS project: Pressures (headline pressures in bold)

Biological disturbance
Extraction of flora and/or fauna
Introduction of genetically modified species
Introduction of Microbial pathogens
Introduction of non-indigenous species
Translocations of species (native or non-native)
Chemical changes, chemicals and other pollutants
Changes in input of organic matter
Introduction of Non-synthetic compounds
Introduction of Radionuclides
Introduction of Synthetic compounds
Litter
N&P Enrichment
pH changes
Salinity changes
Energy
Electromagnetic changes
Input of light
Noise (Underwater and Other)
Thermal changes
Exogenous/Unmanaged processes
Change in wave exposure (climate change, large-scale)
Emergence regime change (climate change, large-scale)
pH changes (climate change, large-scale)
Precipitation regime change (climate change, large-scale)
Salinity change (climate change, large-scale)
Thermal change (climate change, large-scale)
Water flow rate changes (climate change, large-scale)
Physical change
Abrasion/Damage
Artificialisation of habitat
Barrier to species movement
Change of habitat structure/morphology
Changes in Siltation
Changes in wave exposure
Death or Injury by Collision
Disturbance (visual) of species
Emergence Regime Changes
Selective Extraction of non-living resources: substrate e.g. gravel
Smothering
Total Habitat Loss
Water abstraction
Water flow rate changes

Annex 5: Typologies from the AQUACROSS project: Ecosystem components (headline ecosystem components in bold)

Mobile species
Birds
Fish & Cephalopods
Mammals
Reptiles
Habitats
Coastal
Atlantic and Mediterranean high energy circalittoral rock
Atlantic and Mediterranean high energy infralittoral rock
Atlantic and Mediterranean low energy circalittoral rock
Atlantic and Mediterranean low energy infralittoral rock
Atlantic and Mediterranean moderate energy circalittoral rock
Atlantic and Mediterranean moderate energy infralittoral rock
Coastal saltmarshes and saline reedbeds
Deep-sea bed
Deep-sea mud
Deep-sea muddy sand
Deep-sea rock and artificial hard substrata
Features of littoral rock
Features of littoral sediment
High energy littoral rock
Infralittoral rock and other hard substrata
Littoral biogenic reefs
Littoral coarse sediment
Littoral mixed sediments
Littoral mud
Littoral rock and other hard substrata
Littoral sand and muddy sand
Littoral sediments dominated by aquatic angiosperms
Low energy littoral rock
Moderate energy littoral rock
Pelagic water column
Sublittoral coarse sediment
Sublittoral mixed sediments
Sublittoral mud
Sublittoral sand
Coastal Terrestrial
Coastal dune heaths
Coastal dune scrub
Coastal dune woods
Coastal shingle
Coastal stable dune grassland (grey dunes)

Moist and wet dune slacks
Rock cliffs, ledges and shores, with angiosperms
Sand beach driftlines
Sand beaches above the driftline
Shifting coastal dunes
Soft sea-cliffs, often vegetated
Supralittoral rock (lichen or splash zone)
Unvegetated rock cliffs, ledges, shores and islets
Inlets Transitional
Atlantic and Mediterranean high energy circalittoral rock
Atlantic and Mediterranean high energy infralittoral rock
Atlantic and Mediterranean low energy circalittoral rock
Atlantic and Mediterranean low energy infralittoral rock
Atlantic and Mediterranean moderate energy circalittoral rock
Atlantic and Mediterranean moderate energy infralittoral rock
Coastal saltmarshes and saline reedbeds
Deep-sea bed
Deep-sea mud
Deep-sea muddy sand
Deep-sea rock and artificial hard substrata
Features of littoral rock
Features of littoral sediment
High energy littoral rock
Infralittoral rock and other hard substrata
Littoral biogenic reefs
Littoral coarse sediment
Littoral mixed sediments
Littoral mud
Littoral sand and muddy sand
Littoral sediments dominated by aquatic angiosperms
Low energy littoral rock
Moderate energy littoral rock
Pelagic water column
Sublittoral coarse sediment
Sublittoral mixed sediments
Sublittoral mud
Sublittoral sand
Oceanic
Deep-sea bed
Deep-sea mixed substrata
Deep-sea mud
Deep-sea muddy sand
Deep-sea rock and artificial hard substrata
Deep-sea sand
Pelagic water column
Shelf

Atlantic and Mediterranean high energy circalittoral rock
Atlantic and Mediterranean low energy circalittoral rock
Atlantic and Mediterranean moderate energy circalittoral rock
Pelagic water column
Sublittoral coarse sediment
Sublittoral mixed sediments
Sublittoral mud
Sublittoral sand

Annex 6: Typologies from the AQUACROSS project: Ecosystem services

Abiotic Provisioning
Abiotic materials
Energy abiotic
Nutritional abiotic substances
Cultural
Physical and intellectual interactions with biota ecosystems and land seascapes environmental settings
Spiritual symbolic and other interactions with biota ecosystems and land seascapes environmental settings
Cultural settings dependent on aquatic abiotic structures
Physical and intellectual interactions with land seascapes physical settings
Spiritual symbolic and other interactions with land seascapes physical settings
Provisioning
Materials
Nutrition
Regulation - Maintenance
Maintenance of physical chemical biological conditions
Mediation of flows
Mediation of waste toxics and other nuisances
Regulation Maintenance by abiotic structures
Maintenance of physical chemical abiotic conditions
Mediation of flows by natural abiotic structures