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Marine SABRES Deliverable 3.2

# The Simple SES Guidance and Cross-cutting Theme Briefing Papers.

# DOCUMENT INFORMATION

This deliverable represents a synthesis of extensive research and insights structured to provide clarity and guidance in the understanding and management of Social-Ecological Systems (SES). This document is organised into two primary sections:

**Section 1: The Simple SES Guidance Document**
This section is divided into three integral parts, each offering a unique perspective and methodology for SES analysis:

Part 1 - The Process and Information Management System (PIMS): Focuses on the Process and Information Management System (PIMS), laying the foundation for systematic SES management.

Part 2 - The Integrated Systems Analysis: Presents an Integrated Systems Analysis, offering a holistic view of SES components and their interactions.

Part 3 - The Simple Social-Ecological System Analysis: Introduces the Simple SES Analysis, providing a streamlined approach for efficient yet comprehensive SES examination.

**Section 2: Cross-Cutting Theme Briefing Papers**
Following the SES Guidance Document, the second section comprises an array of briefing papers, each addressing a key theme relevant to SES. These papers enhance understanding and offer insights into various aspects that intersect with SES, enriching the overall framework of the document. The topics covered include:



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## Marine SABRES Deliverable 3.2 Simple SES Guidance

# Simple Social-Ecological Systems Guidance Documents

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# DOCUMENT INFORMATION

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# DISCLAIMER

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*"Simplicity is complexity resolved."*
*- Constantin Brancusi*

## Introduction - The Integrated Systems Analysis (ISA)

Marine and estuarine management requires an excellent understanding of the interdependent ecological, economic and social sub-systems in these environments and a pragmatic appreciation of what can be managed, and what is outside the control of the environmental manager. A literature review, and SWOT analysis informed by the theory of systematic reviews and evaluation based on the Marine SABRES project proposal criteria revealed the Integrated Systems Analysis (ISA) (Figure 1) (Elliott et al., 2020) to be the most appropriate framework for supporting such work and for encapsulating the main features of marine management (see also Smith et al., 2023).

A systems approach to marine management entails what aspects to analyse within a system and the methodologies used to ensure that credible, salient, legitimate data are both created and collected. This guidance document aims to create a workbook to be employed by the participants of the EU Horizon Europe project Marine SABRES at the case study areas, the Demonstration Sites. Including all aspects of the management process in this workbook provides an overview of the ISA process pictured in Exhibit 1, together with the steps involved in undertaking the social-ecological system analysis. As such, this report contributed to Deliverable D3.1 of the project.

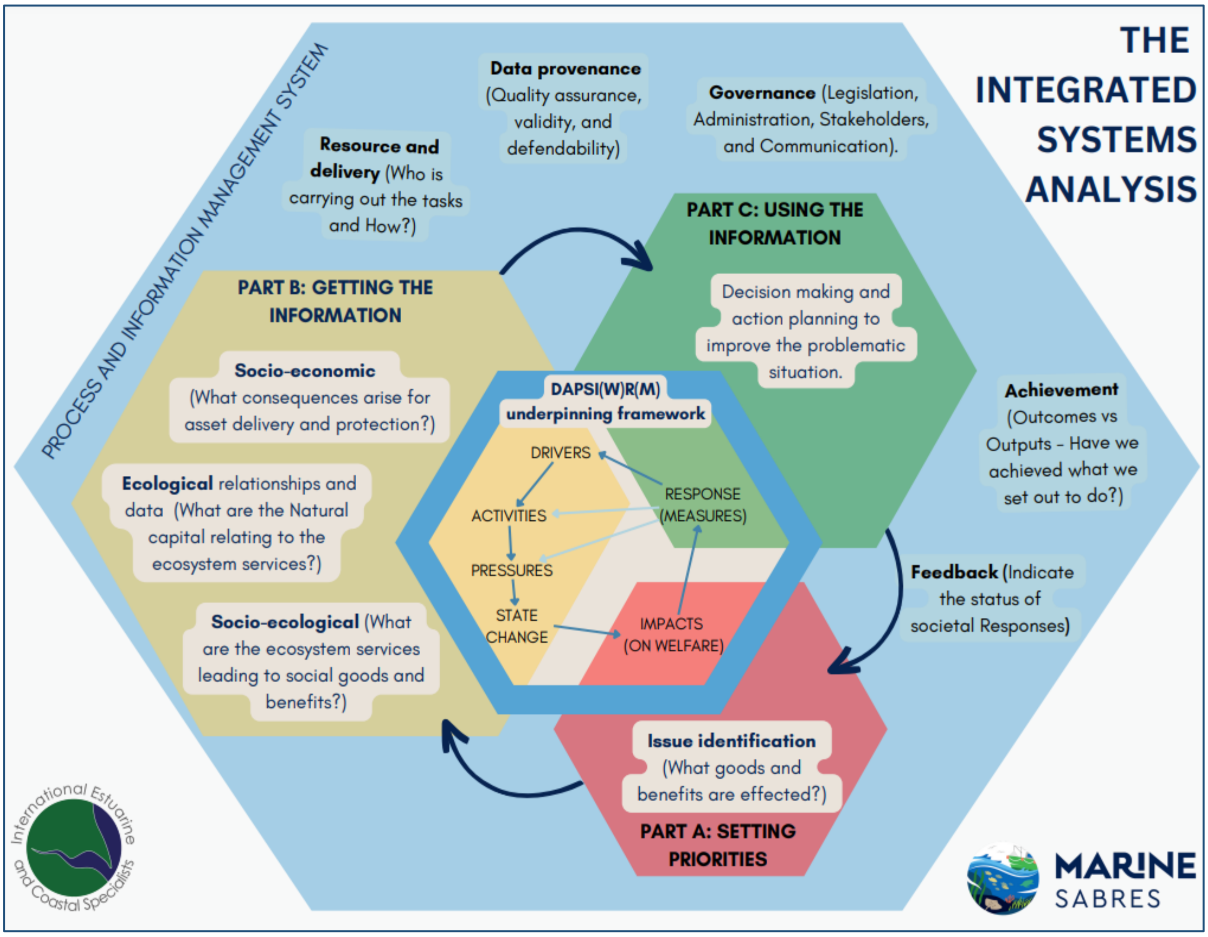



*Figure 1: The integrated systems analysis, adapted from Elliott et al. (2020).*

This document, Deliverable 3.2 Section A of the Marine SABRES project, aims to provide a step by step guide to application of the Simple SES management plan through designing and constructing the Simple SES for application within the DAs. This guidance document is supported by Briefing Papers on the cross-cutting themes as a deliverable of Task 3.2 (D3.2 Section B), within Marine SABRES project. Structured in three parts, this document gives an overview of the Process and Information Management System with relevant steps to undertake to ensure that credible and legitimate project foundations are in place (Part 1). This is followed by an overview of the ISA process and the relevant need-to-know information (Part 2), then a step-by-step guide of the ISA analysis is provided (Part 3) accompanied by supporting information on systems approaches used, frequently asked questions, and further resources (Appendix 1 and the Briefing Papers).

# Part I: The Process and Information Management System

This section of the guide provides an overview of the various frameworks and approaches compiled and combined in an ISA; the literature review (Deliverable 3.1) that informed the design of the SES will be found on the Marine SABRES SharePoint in folder T3.1 under WP3 once reviewed. These various approaches were determined by the literature review aforementioned and comprise of systems thinking concepts to help operationalise the SES. The Process and Information Management System (PIMS) is an encompassing system within the ISA approach which directs management in logistically and multi-sectoral considerations of marine management.

## Using the DAPSI(W)R(M) Framework for Issue Structuring

Marine and estuarine management operates at the interface between natural and human systems. The Marine SABRES project explicitly recognises the complexity of such systems and the multiplicity of stakeholders involved in the marine and estuarine context. Good management is based on having the best possible understanding of the system or systems that one is trying to manage but, given the multifaced nature of marine and estuarine systems, no one stakeholder or stakeholder group has a privileged position that offers a holistic view. Each stakeholder view is limited and it is only by bringing stakeholders together to share their views of marine and estuarine systems that a more holistic view can be approached. Consequently, the processes of identifying and engaging stakeholders, enabling stakeholders to articulate and share their knowledge of the system (often referred to as issue structuring), critically managing information, and governance become paramount and are reflected in the interpretation of the Integrated Systems Analysis approach detailed in this guide.

At the heart of the Integrated Systems Analysis approach is the DAPSI(W)R(M) model (pronounced *dap-see-worm*) (Elliott et al., 2017a), based on the identification of:

- **D**rivers – the human needs and wants such as food, shelter, security, life fulfilment, etc.
- **A**ctivities - the means of obtaining those human needs, such as fishing for food or observing a scenic view.
- **P**ressures - the mechanisms of change in the natural or human systems emanating from the activities, such as physical disturbance to the seabed.
- **S**tate changes - the degree of change on the natural system and ecology resulting from the pressures e.g. erosion and turbidity leading to reduced fish populations.
- **I**mpact - on human **W**elfare e.g. reduction of fish catch per unit of effort.
- **R**esponses - using management **M**easures and the amendment or creation of policies, together with behavioural changes e.g. seasonal closure, changes in net size, and changes in consumer purchasing behaviour towards more eco-friendly goods.

Originally the DAPSI(W)R(M) diagram was given as operating counter-clockwise due to the logical chain of one element giving rise to or affecting the next (see Figure 2). It is suggested here that in any investigation of a complex marine issue, the model be used in a clockwise way (see Figure 3) with Impact on human welfare being the starting point, as changes in it are often the motive for an investigation of the system and stakeholders can have strong views of how changes in the system have affected the availability of societal goods and benefits. Further information can be found in the DAPSI(W)R(M) Briefing Paper (*BP3: Cause-Consequence-Response Chains – DAPSI(W)R(M)*). The implementation of the current guidance can eventually be linked to the stakeholder-created mind-maps following the WP 2 stakeholder interviews.

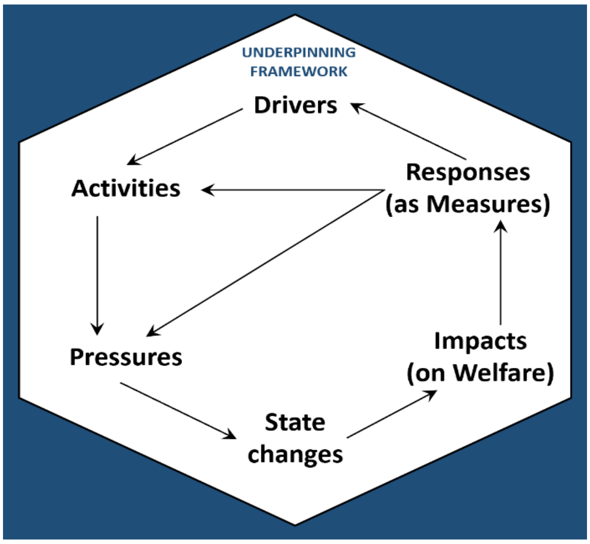



*Figure 2: The original counter-clockwise DAPSI(W)R(M) Framework.*

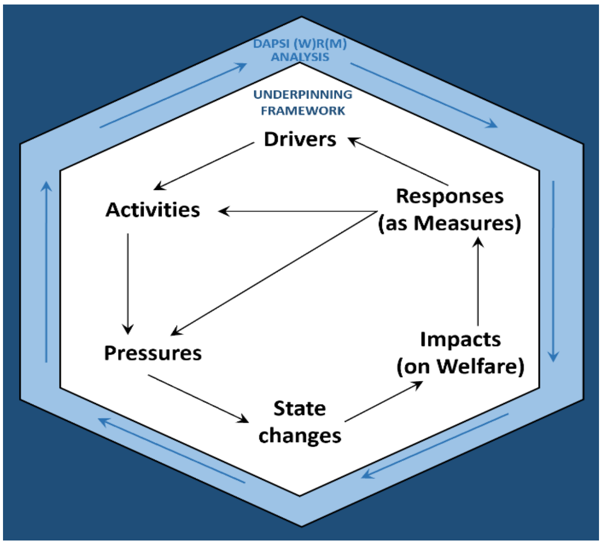



*Figure 3: The proposed clockwise DAPSI(W)R(M) Framework analysis.*

This guide is designed to enable Demonstration Area (DA) participants to conduct a DAPSI(W)R(M) analysis in a step-by-step way and, in so doing, to generate the necessary data and information. As such, Excel spreadsheet templates have been created to record these data. It is suggested that a lead member of the DA group takes responsibility for creating and updating the data spreadsheets. The DAPSI(W)R(M) framework is then used as the basis for a three-part process, an Action Learning Cycle (Zimmer, 2001), (see Figure 4), to investigate and to improve the system under study; this is summarised as Part A – Setting priorities, Part B – Getting the information, and Part C – Using the information.

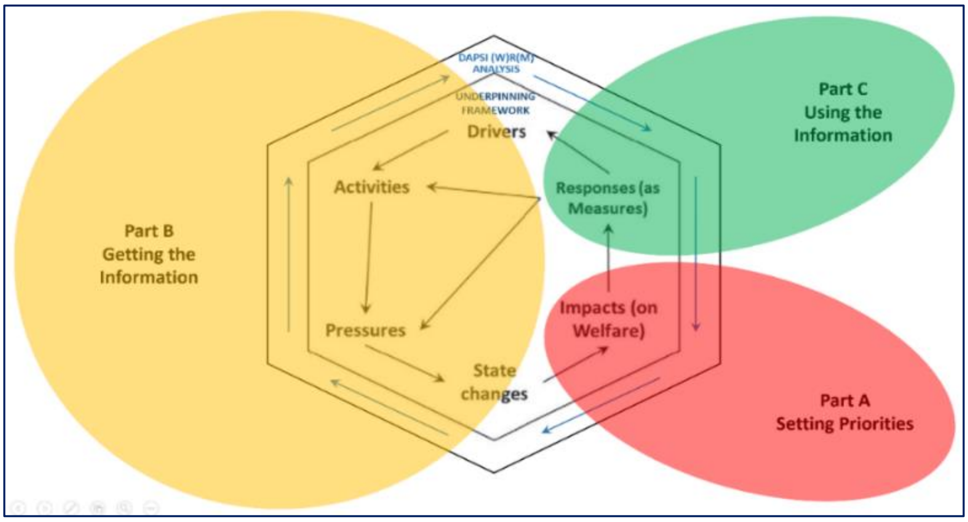



*Figure 4:The DAPSI(W)R(M) based Action Learning Cycle (Unpublished, Atkins and Gregory, 2023)*

## Process and Information Management System (PIMS)

The PIMS is a crucial component of an Action Learning Cycle (Zimmer, 2001), as it plays a vital role in maintaining good governance and ensuring information provenance and management throughout the process (Figure 5) (BP10: *Process and Information Management System)*. The PIMS encompasses seven key elements, each requiring inputs from the DA participants within WP4 to create a successful and sustainable management system:

1. DA process management
2. Resource management
3. Stakeholder identification and engagement
4. Communication and impact management
5. Data provenance and management
6. Evaluation
7. Governance

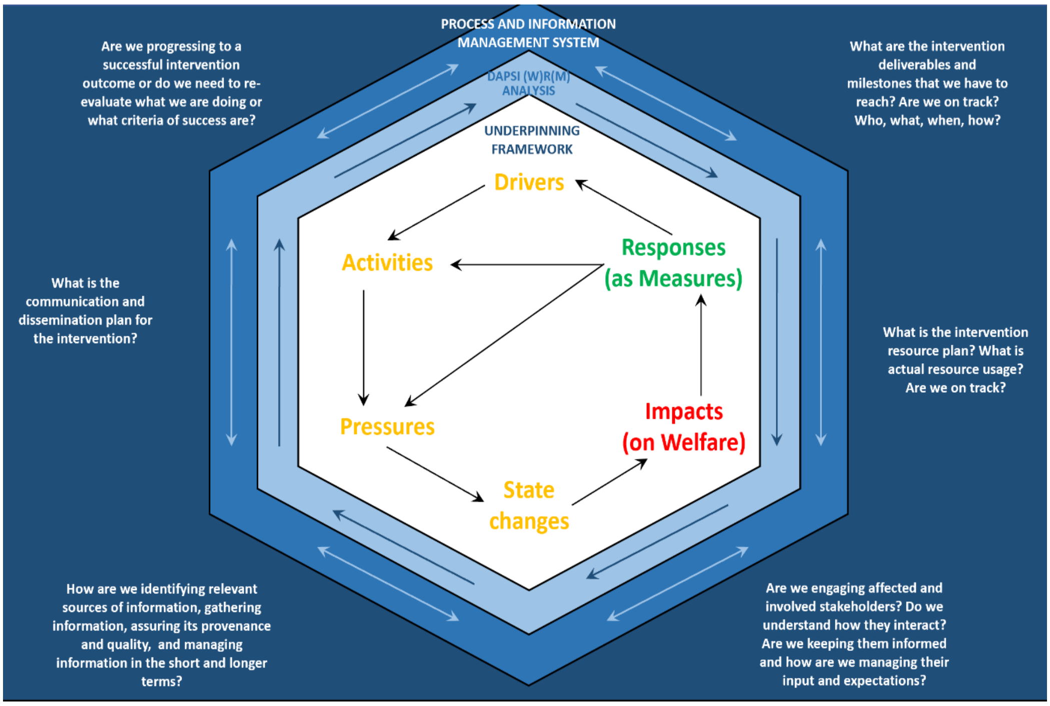



*Figure 5: The PIM System surrounding considerations for the ISA analysis (Unpublished, Atkins and Gregory, 2023).*

These seven aspects are explained within this section. A corresponding PIMS Excel sheet provides templates and tables, such that completing these Tables/Tasks/Considerations gives a reliable, and organised foundation to analyse the social-ecological system (SES) of the DA and its component areas (Figure 6).

The Excel document allows a tick box checklist to indicate the progress of completion of the tasks. All necessary information to complete the Excel workbook is found within this section of the guidance.

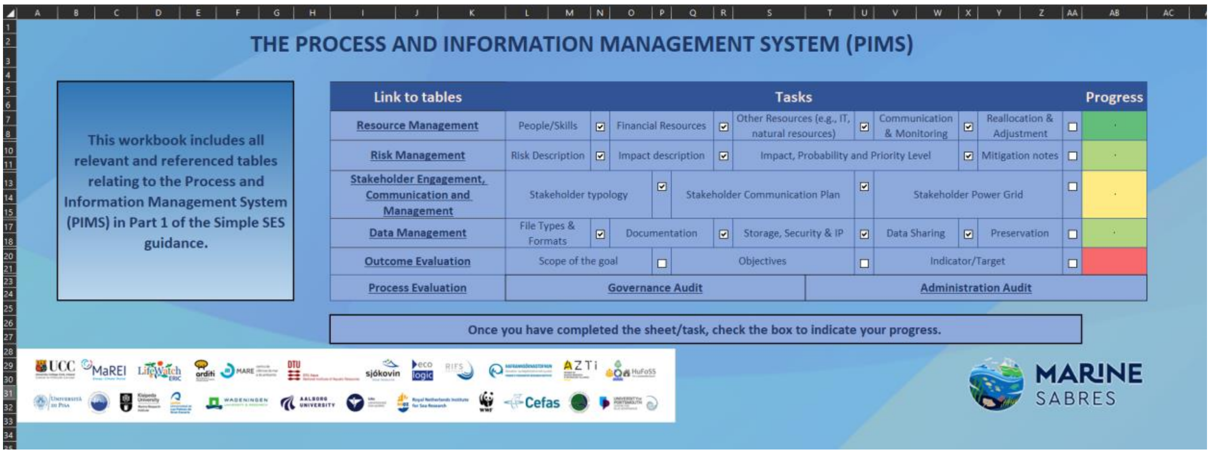



*Figure 6: The Process and Information Management System, supporting the completion of the Social-Ecological System (SES) process for each DA or component area.*

## Demonstration Area Management

In essence, the Marine SABRES project aims at defining a Simple Socio-Ecological System (SES) that can be used either for the whole of each case-study area, the Demonstration Areas, or, in the case of the Arctic Northeast Atlantic and Macaronesia DAs, their three component areas. The actions in this guidance aim to allow the proposed management plan for the DA or its component areas to be derived and tested as based on the underlying SES. The SES chosen after review is the Integrated Systems Analysis (ISA) which is regarded here as an action learning cycle with the output from one iteration of the cycle becoming the input for the next. As a consequence, the ISA is regarded as an ongoing process rather than typical project management as a one-off undertaking. However, as each of the DAs is carrying out an iteration of the ISA action learning cycle, it is appropriate to refer to DA Management and relevant to draw on project management best-practice with each iteration of the ISA cycle being managed according to the processes of initiation, implementation and closure.

### *Initiation Phase*

Each area requires an area problem-definition statement to be defined indicating the main challenge (the goal or vision) in the management of the area (i.e. a definition statement that can be derived by and/or shared with stakeholders). That statement should be divided into objectives (e.g. Table 1) and able to identify the key people involved, resource availability, the key tasks and the duration of the management actions as well as benefits (progress towards the vision). Many of the management actions in the initiation phase are also associated with Part A of ISA, such as stakeholder identification and engagement and their initial definition of evaluation criteria (i.e. what successful management looks like or what difference such environmental management is intended to achieve (for example Table 1)).

*Table 1: An example of the three DAs (the Tuscan Archipelago, Arctic Northeast Atlantic, and Macaronesia) overall goals. Complete this table in the PIMS Excel under 'outcome evaluation' and tailor the goal to your management plan.*

| DA Sites | The broad scope of the goal |
|---|---|
| The Tuscan Archipelago | Tourism and conservation of seagrass beds: We will restore seagrass beds by finding alternative mooring solutions. The recovery of seagrass beds from physical disturbance will be assessed by replicated diving surveys to assess the recovery rate in terms of biodiversity, protection from invasive species and carbon sequestration. Measures to promote more sustainable mooring and boat use across private users and commercial charter companies will be developed. |

| | |
|---|---|
| Arctic Northeast Atlantic | Impact of climate change and challenges surrounding commercial fisheries: The focus will be on important species, including both commercial species (e.g. mackerel, capelin and cod) and demersal fisheries (e.g. cod, capelin) and those with particular conservation value (e.g. marine mammals and elasmobranchs). We will examine the effects of climate change and changing oceanographic conditions to identify likely shifts in species distribution and abundance and potential areas of conflict. Together with stakeholders, we will also examine the capacity of communities to respond to environmental change and identify and implement the measures required to change human behaviour. |
| Macaronesia | Conservation and restoration of biodiversity and the benefits of ecotourism: The focus will be on both benthic habitats, non-migratory species and locally successful protection measures, as well as migratory species (e.g., marine mammals, sharks, tunas, seabirds) whose habitat straddles the three island groups and which provide different types of societal benefits. Existing coastal restoration and conservation projects in Macaronesia will be analysed to identify the quantitative benefits of restoration to tourism activities, including the bird and marine mammal watching sectors. Lessons learned will be transferred to the application of a region-wide effort to develop a biological conservation corridor for migratory species such as cetaceans, seabirds and fishes. |

### *Implementation phase*

The implementation phase relates to tracking the progress and managing the DA or its component areas thereby using the definition statement to create a management plan which indicates what needs to be done, by when and by whom and allocates available resources accordingly. The management plan is the central document that is used for the duration of the management cycle; this entails getting agreement and acceptance from all participants on aspects such as the project milestones, phases and tasks, as well as who is responsible for each task, associated timelines and what deadlines are to be met. Gantt charts may be useful to support the management plan and implementing the management plan requires:

**Risk management:** Following creating the management plan, it is important to assess any factors that could prevent the ability to meet deadlines (Figure 7), for example, personnel changes. A risk log can be used to record and grade risks and hence it carries an associated action plan to minimise the identified risk. This may be linked to issues management and as such refers to concerns related to the project raised by any stakeholder. In the absence of any other risk log in place, the template on the 'Risk Management' sheet of the PIMS Excel workbook can be used.

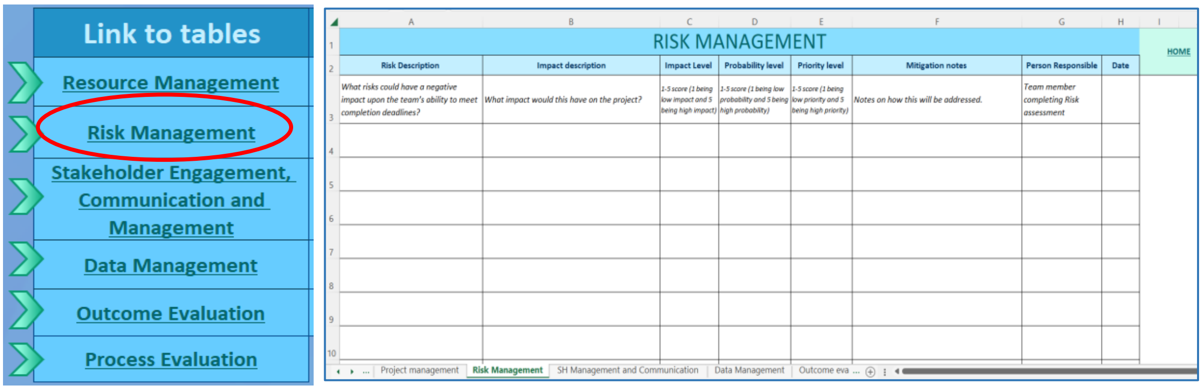


*Figure 7: Screen-shot indicating the position of the Risk Management item template.*

**Quality control:** this identifies the quality of the tasks and it ensures that relevant standards are met e.g. data management and General Data Protection Regulation (GDPR) specific to the area management; this is detailed further in the data provenance section but also in the Data Management Plan for the Marine SABRES project.

**Progress control:** Is the monitoring of the management plan and the production of regular progress reports to communicate the progress of the management plan to relevant stakeholders of the project. As most management plans encounter challenges, it is important to review the direction of the management plan and monitor the degree to which the plan is followed and take appropriate action if there is a deviation by employing regular progress tracking. This is achieved by having established, and recorded in the management plan, regular checkpoints during its duration. Further guidance is given in Resource Management and Evaluation sections.

**Change control:** Is necessary because few projects go exactly to plan so changes will need to be made to the length, direction and type of tasks carried out by the team. Such changes should be documented by the team together with the likely impact on the project if the change is to be implemented (e.g. will it affect the finish time of the project, will the project run over budget, are there sufficient resources) and then informing relevant stakeholders of the implications and alternatives that the request for change has identified.

The implementation phase ends once the project has achieved its objectives as outlined in the definition statement.

### *Closure phase*

The purpose of a formal closedown to the project is to address all issues generated by the project, to release team members from the project and go through a 'lessons learnt' exercise. At this phase, it may also be necessary to gain a formal sign-off on the project as confirmation of its completion. A review meeting by the team to formally end the project is recommended to go over any outstanding issues such as ongoing maintenance, the closing of project files and to conduct an evaluation or team review of how well the project has performed against the original definition statement and also the stakeholder-generated criteria of success. As the ISA is an ongoing learning cycle, the team may also reflect on the process (e.g. what did we do well, what mistakes did we make) so that the team can learn from this project and make further iterations of the cycle more successful; this is further detailed in evaluation.

## Resource management

Resource management is the efficient and effective development and deployment of resources when they are needed. Such resources may include financial resources, inventory, human skills, production resources, information technology (IT) and natural resources. When in the initiation phase, there is the need to know what specific resources will be required to execute the project such that specified objectives are met (Figure 8).

The first step in resource management involves determining resource requirements, which include people, skills, and finances. All required resources should be identified, secured, and allocated across the different phases of the project with budgets agreed upon by the team. The next step in resource management entails managing the assembled resources by clearly defining and communicating roles and responsibilities. Maintaining consistent, transparent communication is vital to ensure that team members have an up-to-date understanding of individual tasks and timelines throughout the project lifecycle. Throughout the project, continuous monitoring of resource usage is essential. If necessary, resources may need to be reallocated, and any changes should be communicated and agreed upon by the team to support the successful completion of the project. To document these steps, complete the resource management table in the PIMS Excel document to organise the account for relevant resources for the project.

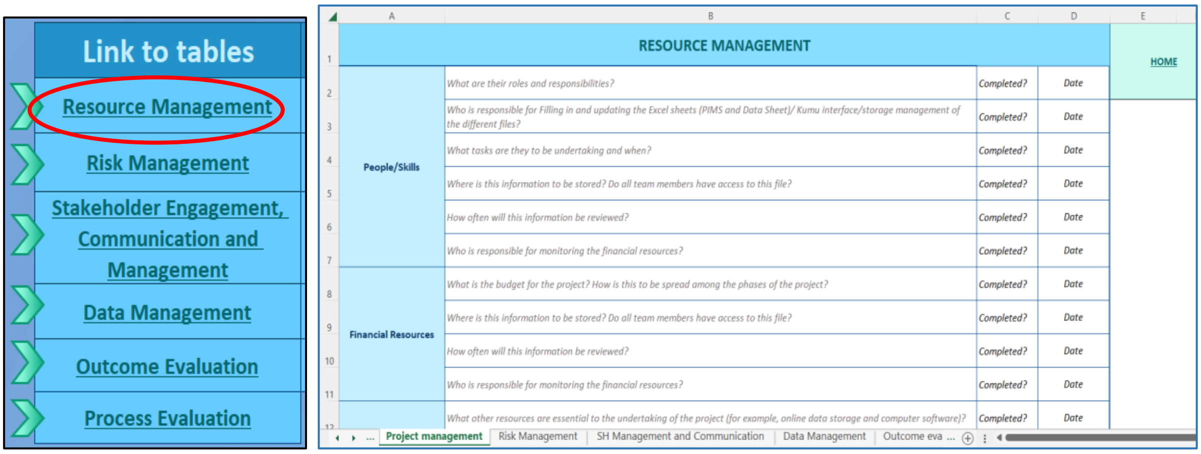


*Figure 8: Screen-shot indicating the position of the Risk Management item template within the PIMS Excel.*

## Stakeholder identification and engagement

When taking a systems approach to the marine environment, which is a complex and multifaceted system, it is impossible to comprehend the whole system, hence we make boundary decisions to aid simplicity and clarity. Boundary decisions mean defining what or who is relevant and included inside the boundary and relegating that or those considered non-relevant and excluded from the environment. This method of stakeholder identification and engagement sets the scope of the analysis.

Defining boundary decisions involves determining which elements or individuals are relevant and included within the boundary while excluding those deemed irrelevant. This practical aspect is crucial, as wider boundaries require more time and resources for analysis, yet they yield greater benefits, particularly in terms of expanding the knowledge base. Therefore, it is essential to strike a balance between costs and benefits in a defensible and transparent manner. Accountability is important in this context as the individuals or elements included within the boundary have a say in shaping improvements (and by association, evaluation of the intervention). This includes defining the appearance of the improvements, setting objective(s), and determining how the intervention is designed to achieve desired outcomes.

An almost inevitable implication of being aware of boundaries is the need to adopt a multi-stakeholder perspective. This requires being critical about whom is the client for the intervention, going beyond any singular commissioning group, and also relying on generic stakeholder lists in order to suggest identifying who the stakeholders really are in the specific situation. Hence, we are not merely seeking to continue existing relations in terms of who is involved but to ask the more critical question of who ought to be involved with due consideration to equality, diversity and inclusion (EDI) (BP13: *Equality, Diversity and Inclusion*).

Our approach to stakeholder engagement is critical and based on a set of principles (see Table 2) that require reflection and discussion of what constitutes both justifiable and pragmatic boundaries of engagement. In multi-stakeholder settings, conflicts of interest are addressed, ideally, through procedures considered fair by all, while recognising that there may be no quick solution to the focal issue.

*Table 2: Stakeholder principles and implications (Gregory et al., 2020 based on Pouloudi et al., 2016)*

| **Stakeholder principles recognise that:** |
|---|
| 1. The set and number of stakeholders are context and time-dependent |
| 2. Stakeholders may have multiple roles |

| | |
|---|---|
| 3. | Different stakeholders, even within the same group, may have different values and perspectives, which may be explicit, implicit or hidden |
| 4. | Stakeholder roles, perspectives and alliances may change over time |
| 5. | Stakeholder relations and power matter in the shifts in their roles, perceptions and alliances |
| 6. | The definition of stakeholder groups for inclusion also represents boundaries of exclusion and marginalisation |
| 7. | Causes and issues from which stakeholders derive a sense of identity from may affect trust, co-operation and value creation in an issue-based stakeholder network |
| 8. | Researchers and funders are stakeholders too, and they may be surrounded by other stakeholder groups with associated interests |

Newton and Elliott (2016) highlight various different types of stakeholders in the marine environment that may be relevant to the DA projects. Firstly, there are those creating the marine pressures (the 'inputters' and the 'extractors' – respectively those who put waste, structures, land-claim, etc., into the sea, and those who remove resources such as space, fish and shellfish, seabed and water, from the sea). Next is the 'regulators' which include those who have a duty to control these potentially-damaging activities, these stakeholders may be found in the administration analysis as part of the governance activity (further information in BP11: Governance). The 'affectees' are the parts of society affected by these activities and regulations, either positively or negatively, and the 'beneficiaries' are those who benefit from the uses and users of the seas (e.g. a coastal community benefitting from tourism in the marine environment). Finally, the 'influencers' are the policymakers, politicians, educators, researchers and lobbying groups (e.g. environmentalists, conservationists) who attempt to control the behaviours of the other stakeholders (Newton and Elliott, 2016). It is of note that some bodies, such as a port authority or fishing cooperative, can be included in all of these types of stakeholders.

For more information on identifying and engaging stakeholders, please refer to the Briefing Paper (BP13: *Stakeholders and Stakeholder Consultation).* To document stakeholders to include, complete the 'Stakeholder engagement, communication and management sheet in the PIMS Excel workbook.

## Communication and impact management

Effectively engaging with stakeholders requires giving attention to how stakeholders are identified and engaged. It also means giving appropriate consideration to what information is disseminated, to whom and in what form, and about recognising political/power alliances and identity impact on the construction of understandings of the context, focal issues and stakeholder interactions.

Ackerman and Eden (2011) suggest the need for stakeholder management strategies that specify "when and how it is appropriate to intervene to alter or develop the basis of an individual stakeholder's significance" (p.180). For this purpose, Ackermann and Eden (2011) suggest the use of a power/interest grid (see Figure 9). The four quadrants of the grid can be seen as defining four categories of stakeholders. Stakeholders in the upper two categories are those with the most stake (i.e., most 'interest') in the issue but with varying degrees of power: those to the right-hand side enjoy more power, i.e. they have 'influence', but may or may not actually be concerned about the issue. 'Players' are those interested stakeholders who also have a high degree of power to support (or to sabotage) the outcome of the intervention, whereas 'Subjects', while interested, have less influence. The two lower categories can perhaps be seen more as 'potential' stakeholders who have not (yet) displayed much interest in the issue. 'Context setters' may have a high degree of power over the future of the issue, particularly in terms of influencing the future context within which responses (plans, policies, etc) will need to operate. The last quadrant, the 'Crowd', (currently) exhibits neither interest in nor power to influence the issue of concern.

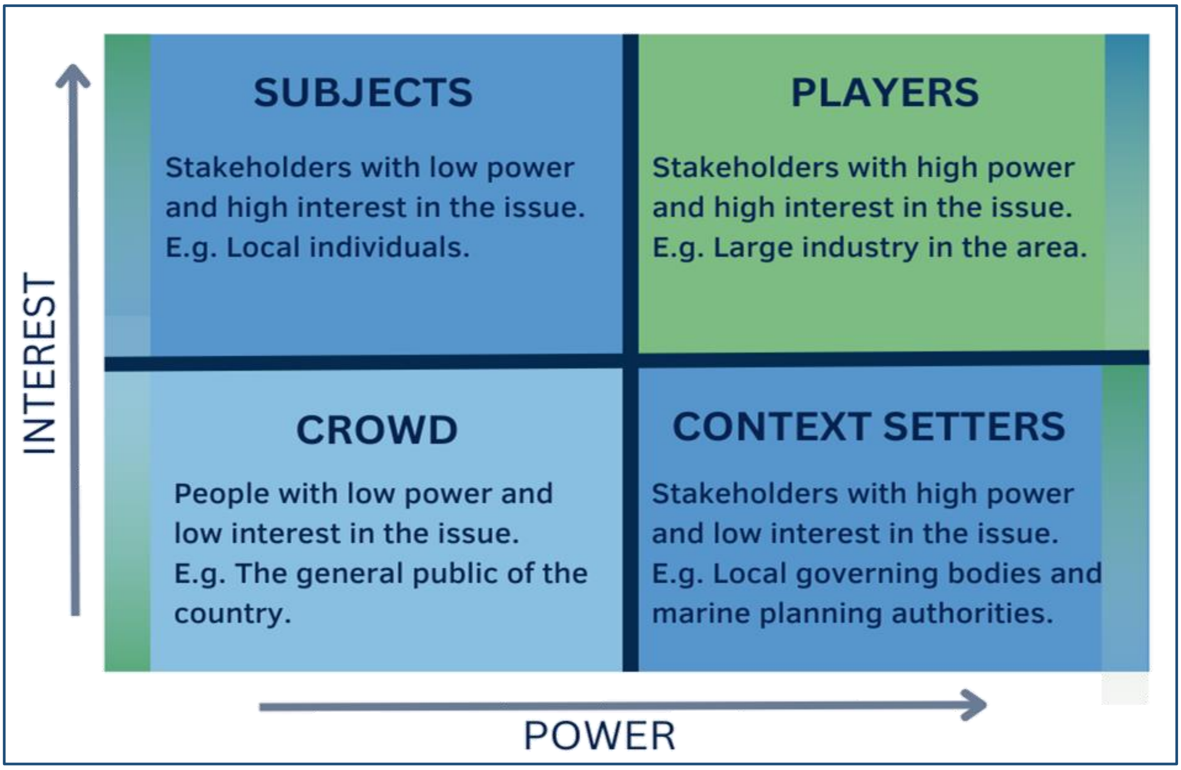



*Figure 9: Stakeholder Power-Interest Grid redrawn from Ackermann and Eden (2011).*

When stakeholders respond to a particular action they do so with reference to other stakeholders and how they might respond. Exploring the impact of stakeholder relationships stems from the extensive literature on social networks. The actions of one stakeholder can generate a dynamic of responses across a range of other stakeholders. Indeed, Fliaster and Kolloch (2017, p.698) suggest that *"stakeholders are likely to orchestrate their activities and thus develop a much stronger bargaining power. Furthermore, some stakeholders do actively search for coalition partners that can help promote their particular agenda and exert additional impact"*. In the same way, the power of a stakeholder can often be described in relation to their position in the network of other stakeholders.

This interactional aspect of stakeholder analysis can be depicted as a 'Stakeholder Influence Network Diagram' which aims to indicate both the formal and informal relationships that are the bases of such social networks (later we will recommend the software package Kumu and it is worth noting that this can be used for social network analysis). Taking stakeholder disposition (positive or negative) into account reveals potential opportunities and dangers. A centrally-located stakeholder, with many links both in and out, who is perceived as being negatively disposed towards the intervention, can have a significant detrimental impact (via their influence over others), and so it is critical that they are successfully managed. In this case, the obvious options are to attempt to change their negative disposition and/or to reduce their power.

When considering stakeholders, it is beneficial to acknowledge that different stakeholder groups may have different communication traditions and preferences. The general public, policy-makers and politicians may want very brief information (sound bites, headlines, tweets and one-page briefing notes). In contrast, specialists may create a large amount of (often unsuitable) material (theses, reviews, scientific papers, consultant reports) which then needs 'interpreting' and usually summarising for the public and politicians (the so-called 'dissemination diamond'; Elliott et al., 2017b). It is frequently argued that different disciplines and different sectors are 'not talking the same language' (Ostrom, 2009), so a stakeholder-based communication strategy is necessary to support, if relevant, conflict resolution and thus enable complementarity between stakeholders. The various stakeholders have to be included in all aspects and there should be feedback loops to ensure that they can receive information, act on it and have an influence (as in theory should be the case in all Environmental Impact Assessments; Glasson and Therivel, 2019).

Logistical considerations for engaging stakeholders should include:

**When they are contacted**: ideally after ethical considerations, but sufficiently early to be included throughout the process.

**Why they are contacted:** Through written communication to gain their consent and advise how communication will take place throughout the process.

**How they are contacted:** Considerations for the minimising time of stakeholders used, the design of communication should account for stakeholder fatigue by proper planning and considering compiling questionnaires and limiting the number of workshops.

For further information on Stakeholder communication and managing impact please refer to the Stakeholder Briefing Paper (BP13: *Stakeholders and Stakeholder Consultation*). To explicitly map stakeholder power and address communication styles, please complete the 'Stakeholder engagement, communication and management' sheet in the PIMS Excel workbook (Figure 10).

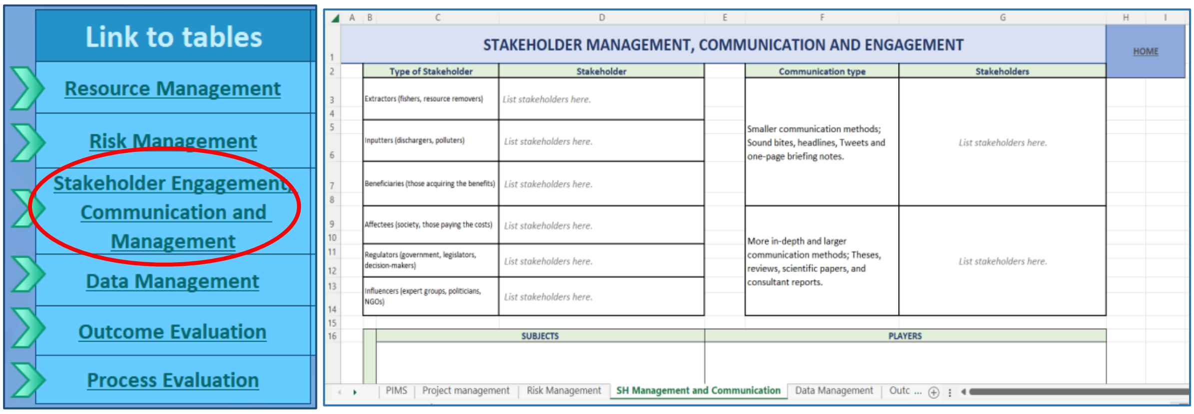



*Figure 10: Screen-shot indicating the position of the Stakeholder, communication and engagement and a view of the Excel sheet in the PIMS workbook*

## Data provenance and management

Data provenance centres around the assurance of a defendable knowledge-evidence base of data, and its conversion to information and knowledge that includes conventional laboratory and field science as well as traditional knowledge (i.e. indigenous knowledge) (Kaiser et al., 2019), and citizen science generated knowledge.

A data management plan (DMP) is a written document outlining the plans for managing research data both during and after the project. The Marine SABRES project has an overall DMP which we recommend to be referenced in ensuring the DA application is in line with this Marine SABRES approach to GDPR and data provenance (this document can be found on the Marine SABRES SharePoint). The plan should address what types of data will be collected and how the data will be documented, stored, shared and preserved. Within the PIMS Excel workbook, a DMP template is available to use if the user does not already have one in place.

**REMEMBER:**
The cost of data sharing and management should be included in your resource management plan. This may include people, equipment, infrastructure and tools to manage, store, analyse and provide access to data. In summary, consideration needs to be given in the resource plan to:

- Collecting and 'cleaning' new data
- The analysis of newly-acquired and legacy data
- Ongoing data curation and preservation
- Providing access and data sharing.

Further information: A Guide to Research Data Management (2021) (https://bl.iro.bl.uk/concern/generic_works/986a209d-d124-4509-a0f2-06248994149d?locale=en), from the British Library.

To explicitly consider and document relevant data provenance and management aspects, please complete the 'Data Management' sheet in the PIMS Excel workbook (Figure 11).

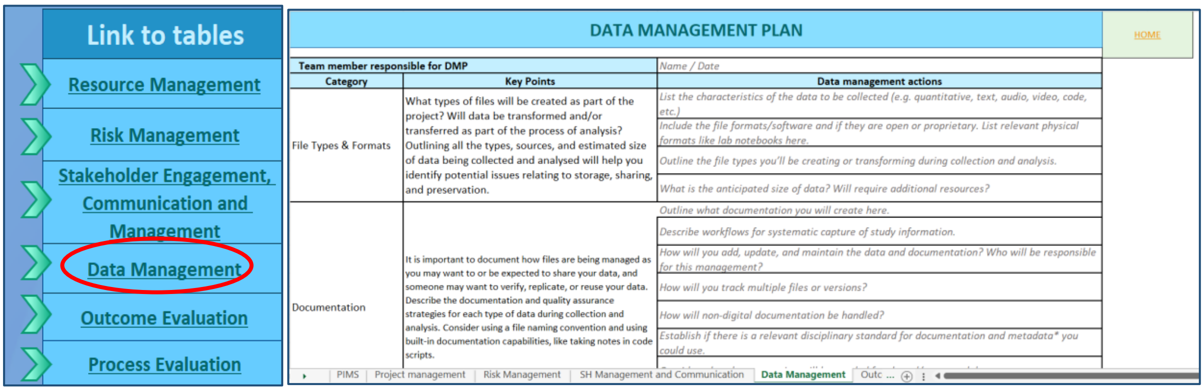



*Figure 11: Screen-shot indicating the position of the data Management Excel sheet in the PIMS workbook.*

## Evaluation

Participants in a multi-stakeholder setting usually define their own evaluation criteria in relation to specified goals and objectives. In terms of the ISA process, there is the need to involve two considerations in evaluation:

### *Process evaluation*

Given the need to assess various stakeholder perspectives about the value or merit of the process (also known as value claims) within the process context, there is a need to assess whether or not participants felt that their voices had been heard. Rouwette (2011) suggests that it is important to evaluate the extent to which the intervention served to 'improve communication between decision-makers, foster consensus and create commitment'.

This evaluation may take the form of a short questionnaire covering topics such as communication (if all participants contributed to the discussion), consensus (if participant opinions converged as they discussed options for their respective positions), commitment (what was the participant level of engagement with the analysis exercise?), and final messages (what was learnt?). A draft evaluation questionnaire is in the 'process evaluation sheet' in the PIMS Excel workbook (Figure 12).

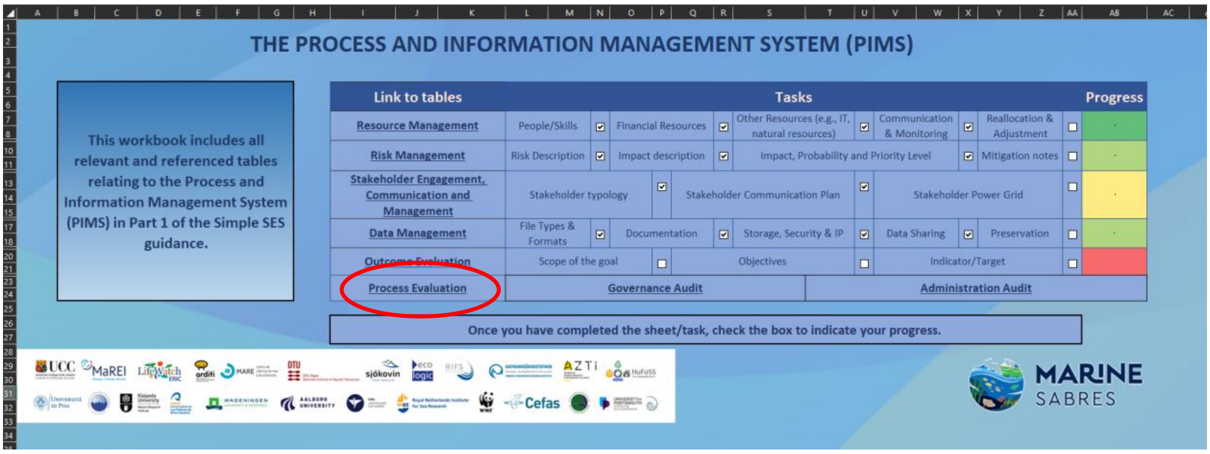



*Figure 12: Screen-shot indicating the position of the Process Evaluation Excel sheet in the PIMS workbook.*

## *Outcome evaluation*

The overall aim of ISA is to create Response Measures that are accepted by decision-makers and implemented in the form of amendments to existing or newly required policies, laws, etc. with the overall aim of achieving the requires objectives and vision for environmental benefit. The definition statement should contain the goal and specific objectives of the marine management plan. Each objective should not only be SMART (Specific, Measurable, Achievable, Realistic and Time-bounded) but also spatially bounded (local/national/international) together with indicators (proxy measures) identified whose change can be measured against reference or baseline conditions.

It is axiomatic that management requires assessment, measurement and monitoring against desired conditions which may the baseline or reference condition. In common with being SMART, the desired final state should be time-defined, with appropriate intermediate assessments to check progress. The information necessary to assess the state of the indicator should be determined and how and by whom this will be collected and analysed (this should also form part of the DA marine management plan with necessary resources to support the evaluation being allocated). In essence, this should assess whether the vision and objectives set for the management area are achieved by the proposed management actions.

It is emphasised here that all of these attributes, even if general, require indicators otherwise it is not possible to determine either what management is required or if the management has had the desired effect. For example, community structure requires indicators for the level of biodiversity (such as species richness, and presence of alien species); human health status can be determined through indices of welfare and well-being (Biedenweg et al., 2016; Breslow et al., 2016), and societal benefits can be measured in terms of the amount of cultural heritage, recreational opportunities and fish caught, among others.

Given the above, DA participants should develop a set of objectives and indicators to indicate successful and sustainable marine management as indicated in the 'Outcome evaluation sheet' within the PIMS Excel workbook (Figure 13).

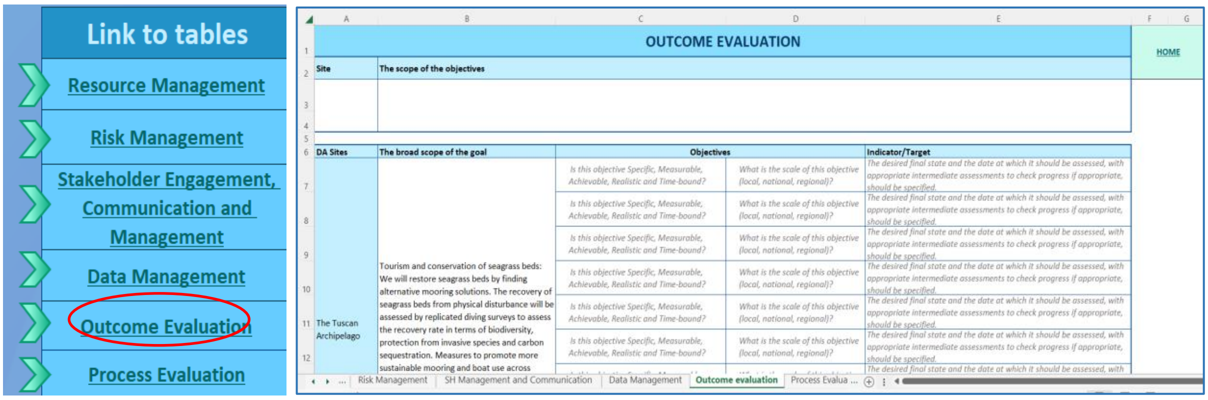



*Figure 13: Screen-shot indicating the position of the Outcome Evaluation on the PIMS home Sheet and a view of the Excel sheet in the PIMS workbook.*

## Governance Sub-System

Governance in marine management is defined as the sum of policies, politics, administration, and legislation (Boyes and Elliott 2014). Within the EU, various initiatives have been developed to promote sustainable marine management, such as maritime spatial planning, protecting marine habitats, and encouraging cross-border cooperation. The system of laws, regulations, statutes and agreements are comprised of 'hard law' and 'soft law'. Hard law refers to legally binding rules that can be enforced in a court, such as the Water Framework Directive (WFD; European Commission, 2000) or the Marine Strategy Framework Directive (MSFD; European Commission, 2008). On the other hand, soft law includes non-binding agreements, declarations, and principles that may involve legally-binding arbitration, such as the Regional Seas Conventions (OSPAR and HELCOM). Boyes and Elliott (2014) gives the marine legislation complexity while Boyes and Elliott (2015) indicates the organisation complexity required to achieve those legislative instruments; Cormier et al. (2022) indicate the vertical and horizontal integration across those management responses (see BP11: *Governance).*

While international agreements such as the UN Convention on Law of the Sea (UNCLOS) provide mechanisms for dispute resolution, including both legal proceedings and arbitration, other conventions such as Regional Seas Conventions might have different mechanisms for addressing disputes. For EU members the Directives are legally binding on Member States and can result in infraction proceedings in the European Court of Justice if breached. Following the Single European Act, these are then enacted by Regulations within a Member State. Those national laws then apply to individuals or organizations within the country, with sanctions through the country legal system. For those nation states in Marine SABRES not in the EU, they require their own means of following the European Directives or at least achieving the same aims. Irrespective of EU membership, all nation states require the integration of laws and regulations at different levels: local, national, regional, and global. This vertical integration ensures a comprehensive legal framework for managing marine resources.

Fulfilling the competing legislative requirements for comprehensive and holistic marine management also requires horizontal integration in which instruments are coordinated across the sectors (fishing, aquaculture, sea-bed mining, navigation, etc.) (Boyes and Elliott, 2014). Combining both horizontal and vertical integration results in a holistic, coordinated legal system that merges legally binding and non-binding instruments for managing the seas and for meeting set visions, objectives and targets (Figure 1). Moreover, it allows defining Response Measures to instigate the required change within the behaviour of the system; the Governance Briefing Paper (BP11) presents an exercise to collate, describe and map and understand the relevant EU policies and equivalent applicable to the relevant DA. This exercise will allow the governance horrendogram for each DA to be completed; note that these horrendograms have already been created for certain areas in the MarinePlan sister project and in other publications such as the GPSAZORES project (https://www.gpsazores.com/media/GPSAzores_Report_WP1_ntVEqu9.pdf).

**EXAMPLE:** *Horizontal and Vertical integration of EU Marine Management*

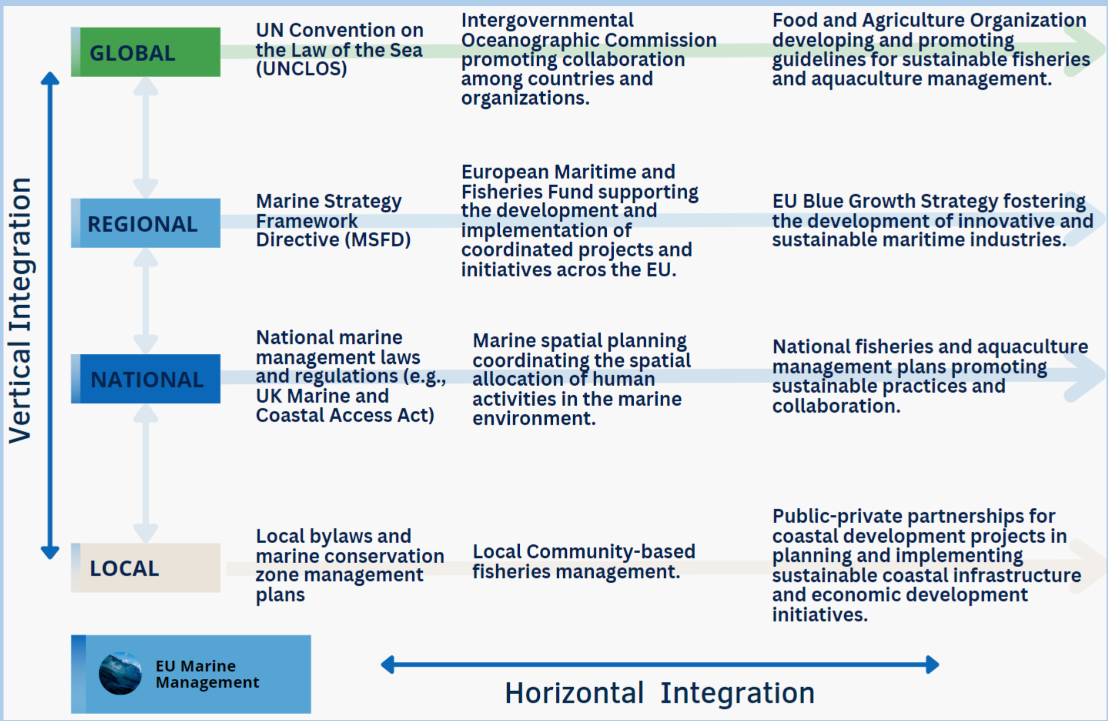



*Figure 14: An example of the different horizontal and vertical applications of EU marine management (Unpublished. Smith, 2023)*

### *Legislation and Administration audit guidelines*

These guidelines provide a set of instructions and templates for each Demonstration Area to complete both a legislation and administration audit to determine the governance of the Demonstration Area, particularly in relation to the protection and management of Marine Protected Areas (MPAs), Maritime Spatial Planning (MSP) aims and the Marine Strategy Framework Directive (MSFD) objectives. This information should then be mapped graphically on a horrendogram and an organogram for each Demonstration Area. Each Demonstration Area has a folder with templates on the Marine SABRES SharePoint area under WP4 – Task 4.1 – Governance Audit Guidelines.

Horrendograms have already been created for some European countries and should be used as a starting point for this project, however, any pre-existing diagrams should be checked for accuracy and inclusivity to the aims of Marine SABRES in an ever-changing policy landscape.

The following guidelines will help partners to identify relevant national legislation and policy which implement protective measures relating to MSP, MPA and MSFD at each Demonstration Area. Based on the original work of Boyes and Elliott (2014) and subsequent revisions (Elliott et al., 2022), horrendograms should be created for each Demonstration Area in Marine SABRES. The majority of the International and EU Directives shown in the centre of the governance diagram (Figure 14) should be common to all countries participating in this project. Differences may exist if your country has not ratified a Convention or is not a member of the EU, however, some similar legislative instruments may be in place influenced by bilateral agreements.

The plethora of legislation then requires Administrative considerations, the national and regional bodies, agencies, departments, etc. to implement, enact and enforce the vertical hierarchy of legislation. As with the instruments under which they are constituted, these bodies (summarised as a management organogram, e.g. Boyes and Elliott, 2015) need to be coordinated and integrated horizontally to accomplish the vision and objectives described above, particularly across interested stakeholders (Stephenson et al., 2019). In many countries, marine administration is sectoral with different bodies for fisheries, nature conservation, navigation, land-based pollution and planning such as with aquaculture, etc.. There are few, if any, countries which have a single marine management organization which covers all of the sectors, hence the need for effective coordination between these bodies. The Administration Audit requires participants gather the relevant information and create the administrative organogram for their DA.

Governance considerations within the scope of this SES look to the structures and processes in that people in societies make decisions and share power, create the conditions for ordered rule and collective power (Folke et al., 2005); more specifically the sum of the policies, politics, administration and legislation required in adaptive environmental management (Cormier et al., 2022).

**Legislation**

The legislation table found within the PIMS Excel sheets (as shown in figure 17) corresponds to the blank boxes shown in Figure 15, the template for this can be found in the accompanying PowerPoint called ‘Marine SABRES Horrendogram Template' and asks you to complete the following actions:

1. Firstly, state how the EU Directives are currently implemented through your own country legislation. In EU countries then these may be adopted through Regulations rather than Acts of Parliament whereas other countries will need sovereign Acts. You may be familiar with these already, but if not, then you may need to carry out research through official government agency websites, marine planning documents or marine literature. Given that this is official information, then it should be publicly available without having to contact individuals.
2. Think about the protection that a particular piece of legislation specifically provides for maritime spatial planning, marine protected areas and the MSFD and add it to the Governance sheet in the PIMS Excel sheet.
3. Once the legislation implementation audit has been completed, add the information to the corresponding boxes on Figure 16. A template of Figure 16 can be found in your folder on the Marine SABRES SharePoint area under WP4 – Task 4.1 – Governance Audit Guidelines.
4. If any of these legislative aspects do not apply to your Demonstration Area, then you can state this in Table 2 and the corresponding boxes on Figure 16 can be deleted.
5. As Marine SABRES is concerned with MPAs, MSP and MSFD, in addition to statutory legislation and International Conventions, several other marine area-based protection measures will also be included in the audit. The Governance sheet in the PIMS Excel asks you to consider other forms of marine area-based protection measures. These include Ecologically and/or Biologically Significant marine Areas (EBSAs), World Heritage Sites (WHS), Other Effective area-based Conservation Measures (OECMs), Particularly Sensitive Sea Areas (PSSA) and Vulnerable Marine Ecosystems (VME). Although not formally designated under International or European legislation, they can provide additional maritime protection to important marine ecosystems (see BP11 for information on Governance terminology). Should your Demonstration Area not include these additional measures, then please delete the relevant boxes from Figure 16.
6. If your country has additional protection measures beyond the International, Regional and European laws already considered in Figure 16, there is the opportunity of adding boxes to

complete the legislative landscape. This information should be added at the end of this table before including it on Figure 16.

7. Should you need to add any additional/clarifying information to Figure 16, footnotes could be included (as demonstrated in Figure 15 showing the governance situation for English/UK maritime areas).

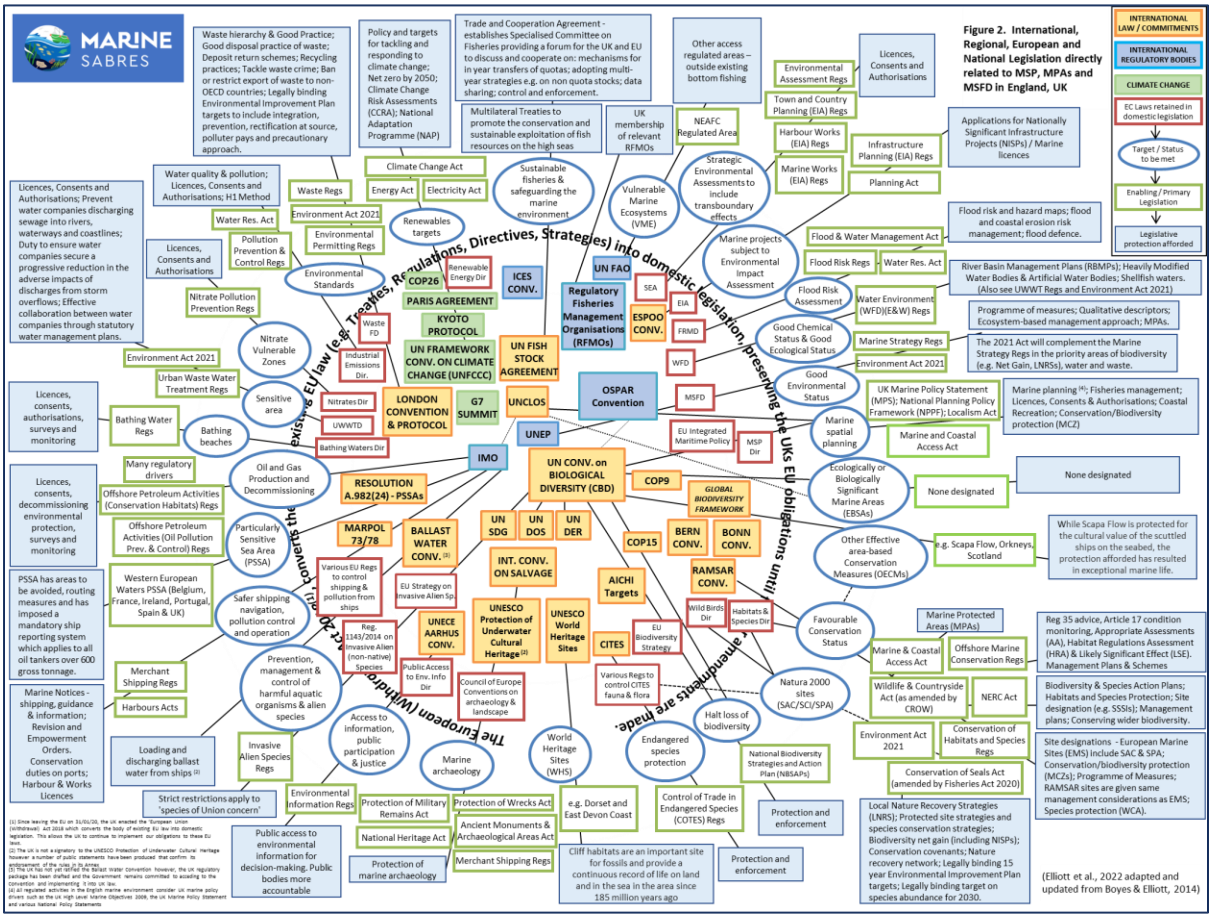



*Figure 15: Current UK Marine Governance (expanded and modified from Boyes and Elliott, 2014, 2016) relating to the post-Brexit changes and the implementation of new UK Acts (Elliott et al., 2022).*

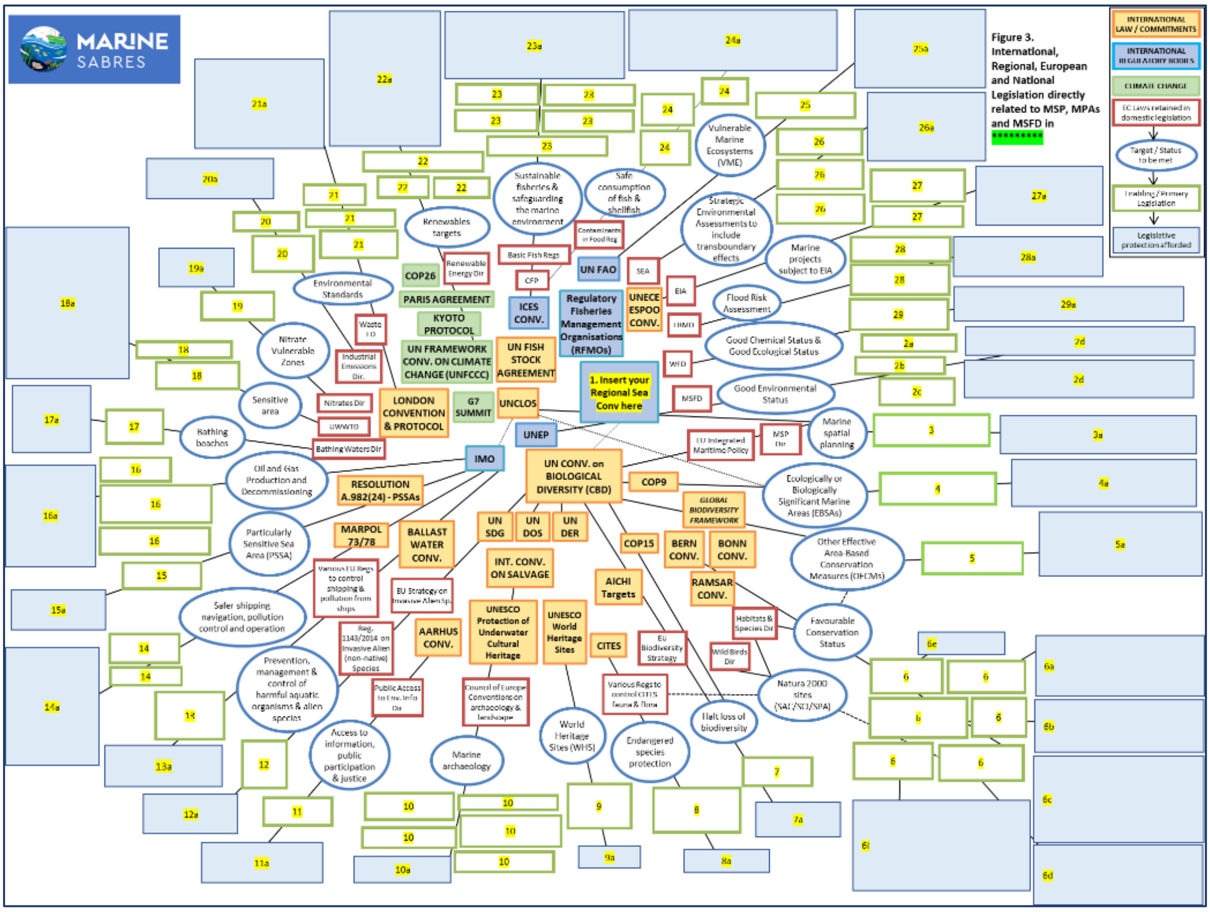



*Figure 16: Template for Demonstration Area legislation.*

## Administration

The following instructions will help Demonstration Area partners to identify and characterise the number of statutory organisations and agencies that have a strategic role in MSP, MSFD and managing and designating MPAs within the Demonstration Areas. This will assist in the creation of an organogram for your Demonstration Area as demonstrated in Figure 18 which gives an example of the UK Government marine organogram (predominantly for England) indicating the main bodies within each government department and their principal competencies (Elliott et al., 2015, 2022). As a subset, because of its importance for the marine environment, Figure 19 shows the dominant lead marine body in the UK (Department for Environment, Food and Rural Affairs (Defra)) and its associated agencies for marine management. The figures indicate that a country can have many government departments with a marine competency, not only the more obvious ministries and departments such as environment and trade, but also defence, foreign affairs and transport. You may have to indicate department/ministries that have joint responsibility, for example with a remit for climate change and the environment.

For understanding and mapping the administration organogram, the Administration sheet in the PIMS Excel will help you to identify organisations who play a role in the management of the Demonstration Area. This should be done by completing the following actions:

1. List the statutory organisations who have an active role in managing the marine environment. Statutory bodies are those who have been established under national, regional or local legislation as competent authorities and are working to meet policy objectives. A competent authority is one that has a specific remit under the legislation; you will notice that the EU Directives specifically refer to competent authorities. You are likely to find these management bodies by searching on government websites, in policy documents and relevant literature.

If you have many agencies involved (as in the UK (English) example shown in Figures 18 and 19), it may be useful to identify them on an activity by activity basis. This could be done by working clockwise around the horrendogram that you have created for your Demonstration Area to work out:

- Which agency/body takes the lead for the designation, management and enforcement of that particular sector (e.g. marine spatial planning, nature conservation, shipping, water quality, EIA, SEA, fisheries, oil and gas, renewables, etc.).
- Are there any other agencies who also have a role?

2. Hierarchy: If you have listed an agency or subsidiary body, please state under which government department they operate and to whom they report.
3. Overview: Describe the overall aim and vision of that organisation in relation to marine management.
4. Responsibilities: In the appropriate column, describe the specific role of each agency/body in relation to MPAs, MSP and MSFD.
5. You may find it easier to regroup/sort your rows if you have numerous agencies/bodies who operate under one main government department.
6. Now use the information collated in Administration audit Excel to create an organogram as shown in Figures 18 and 19; the template for this can be found in the accompanying PowerPoint called 'Marine SABRES Organogram Template'. This will be unique to each Demonstration Area and the style of your organogram may be personalised to fit the profile of marine management for your specific Demonstration Area.
7. It is suggested that Microsoft PowerPoint is used to create these figures, a template is given. However, should you wish to use or adapt Figures 18 and 19, a template similar to that presented for the English situation can be found on the Marine SABRES SharePoint area under WP4 – Task 4.1 – Governance Audit Guidelines called 'Marine SABRES Organogram Template'.

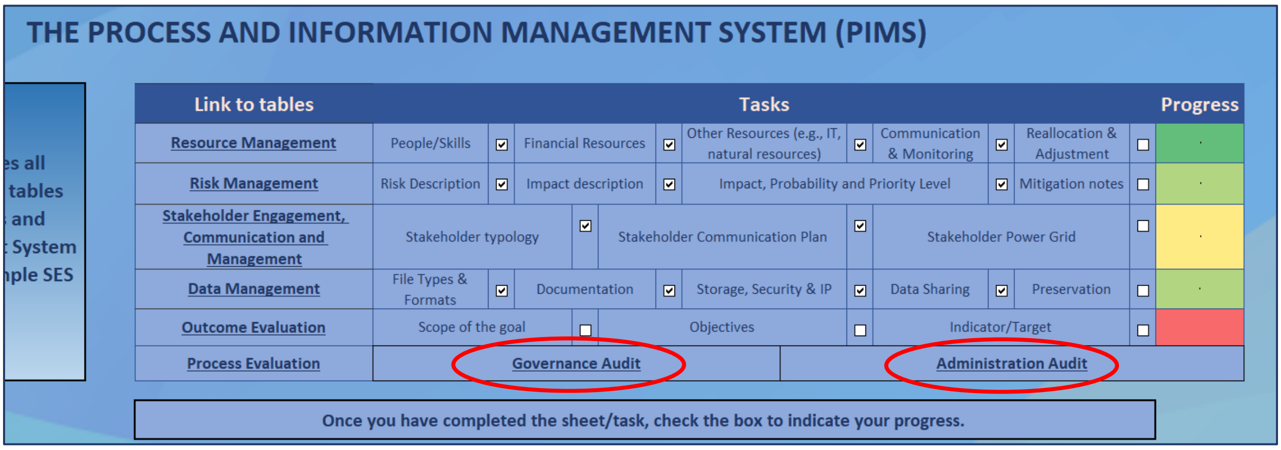



*Figure 17: Screen-shot indicating the position of the Governance and Administration on the PIMS home Sheet.*

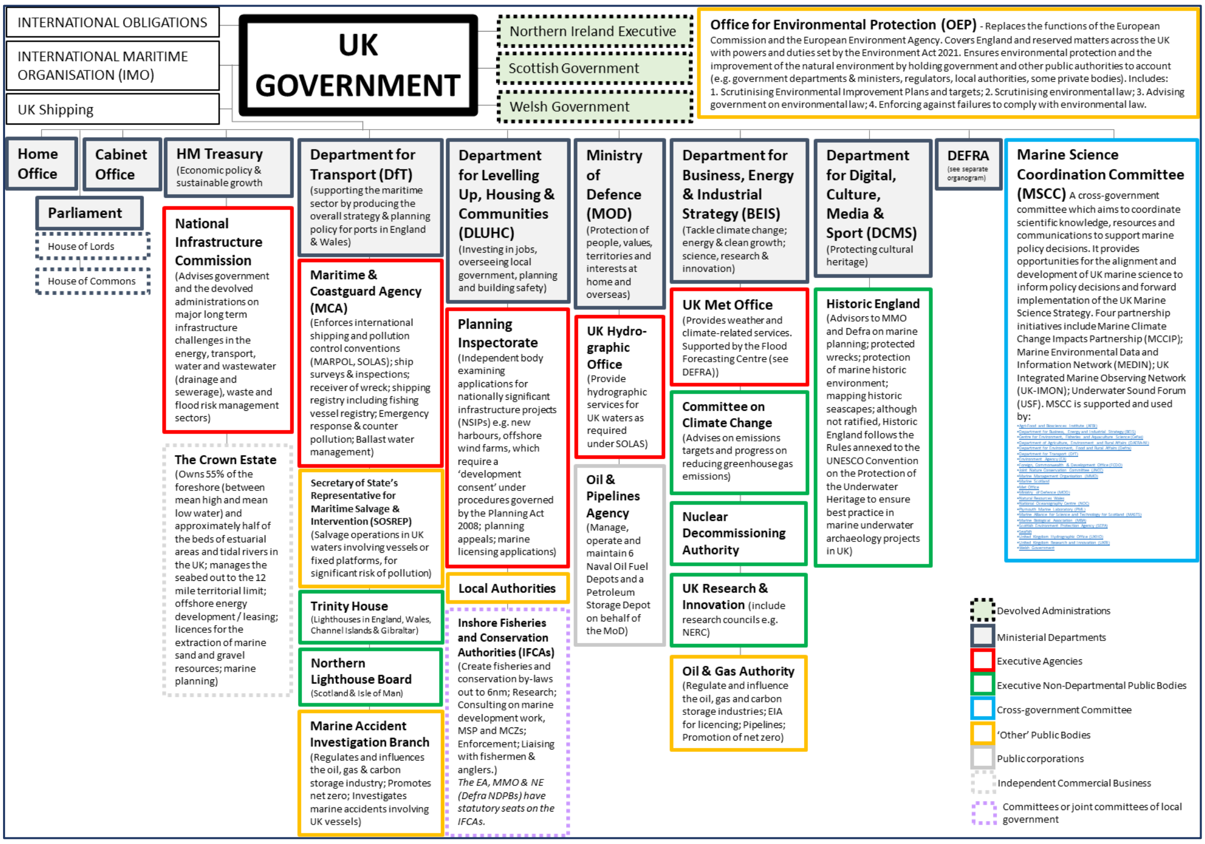



*Figure 18: The UK Government marine organogram (predominantly for England) indicating the main bodies and their predominant competencies.*

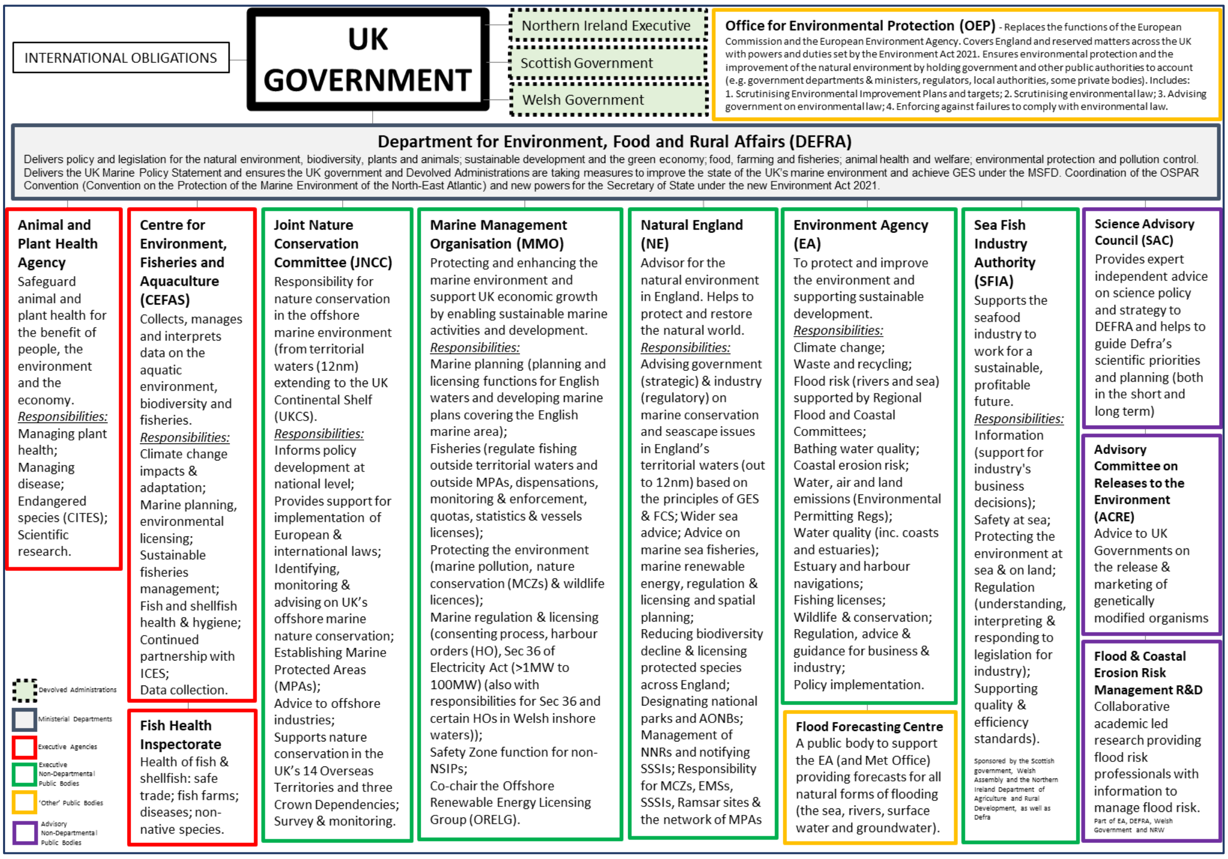



*Figure 19: Organogram specially detailing the agencies and bodies under DEFRA.*

# Part II: The Integrated Systems Analysis

## Overview – Integrated Systems Analysis Part by Part

Based on the above descriptions of both the DAPSI(W)R(M) and the PIMS, participants will then collate information to consider further each of the three parts of the Integrated Systems Analysis action learning cycle.

### *Part A:*

Part A explores the main problem(s) to be addressed in the DA and identifies the often numerous priority issues facing stakeholders in a complex marine system (see Figure 20). While different stakeholders may perceive the problem differently, it is important to explore creatively perceptions and to further understand the situation, as a common characteristic of complex problems is that the root cause is not always apparent at first inspection, nor is the solution obvious.

An appropriate starting point is a conceptual model created by and understandable to both sets of stakeholders in the Marine SABRES project – the high-level ones and the DA participants. For example, the use of 'Rich Pictures', cartoon-like and stakeholder-led expressions of the significant problem situation (Bell, et al., 2016). Exploration of a Rich Picture can lead stakeholders to confirm the priority issues regarding the impact on human welfare including the level (individual, regional, national or international) at which the issue symptoms are shown; this is known as the 'system-in-focus' covering complexity across three system levels with a system above (the meta-system) and systems below (sub-systems) the main system of concern. Although a stakeholder group in Marine SABRES WP2 is asked to focus on what are their priority issues, it would also be possible to validate perceptions through a Delphi exercise (online or through a face-to-face meeting) involving a wider group of stakeholders and a more formal prioritization process.

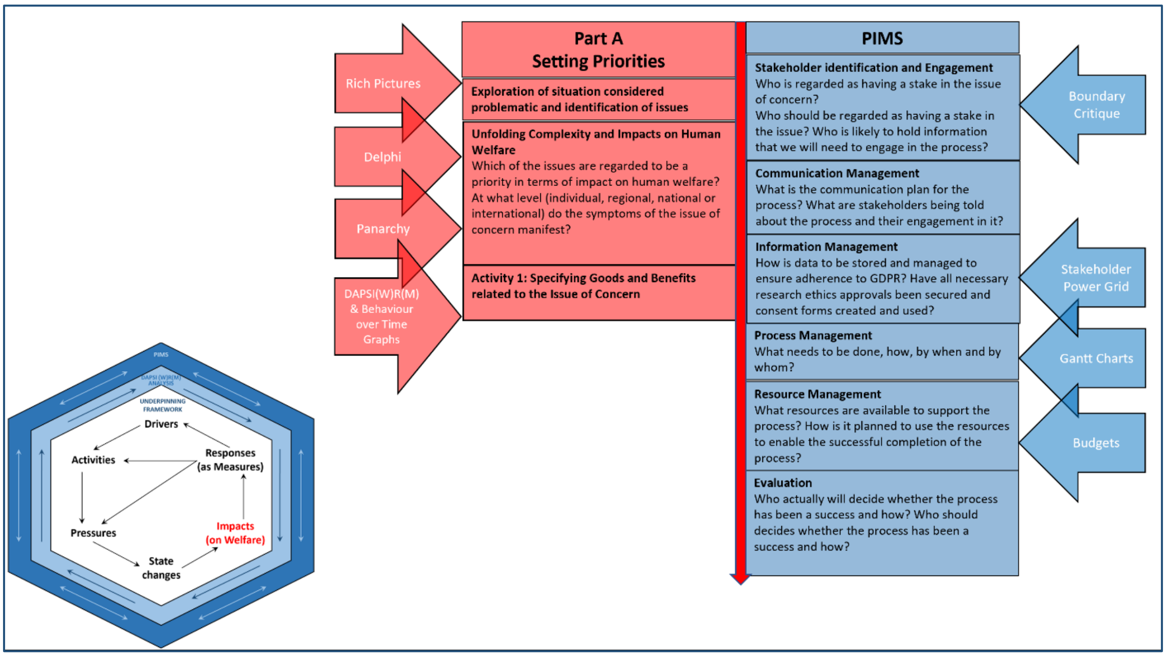



*Figure 20: Part A of the Integrated System Analysis which concerns setting priorities and PIMS considerations (Project and Information Management System) (Unpublished, Atkins and Gregory, 2023).*

### *Part B*

Part B focusses on getting information, using the DAPSI(W)R(M) structuring method, regarding the way in which key elements of the DA system of concern (state changes in ecosystem processes and services, pressures, activities and drivers) are changing or have changed (see Figure 21). These data include indicators of the DAPSI(W)R(M) elements, over a period of time, and from multiple data points (e.g. the previous and current state of an indicator). Supporting information on indicators, Ecosystem Services, Marine Processes and Functioning, and decision support tools can be found in the collection of Briefing Papers (BP3: Cause-Consequence-Response Chains – DAPSI(W)R(M) BP4:*Marine Processes and Functioning and Ecosystem Services;* BP5:*Goods and Benefits and Societal Wellbeing;* BP6:*Indicators;* BP7:*EBM Tools)* which support the SES.

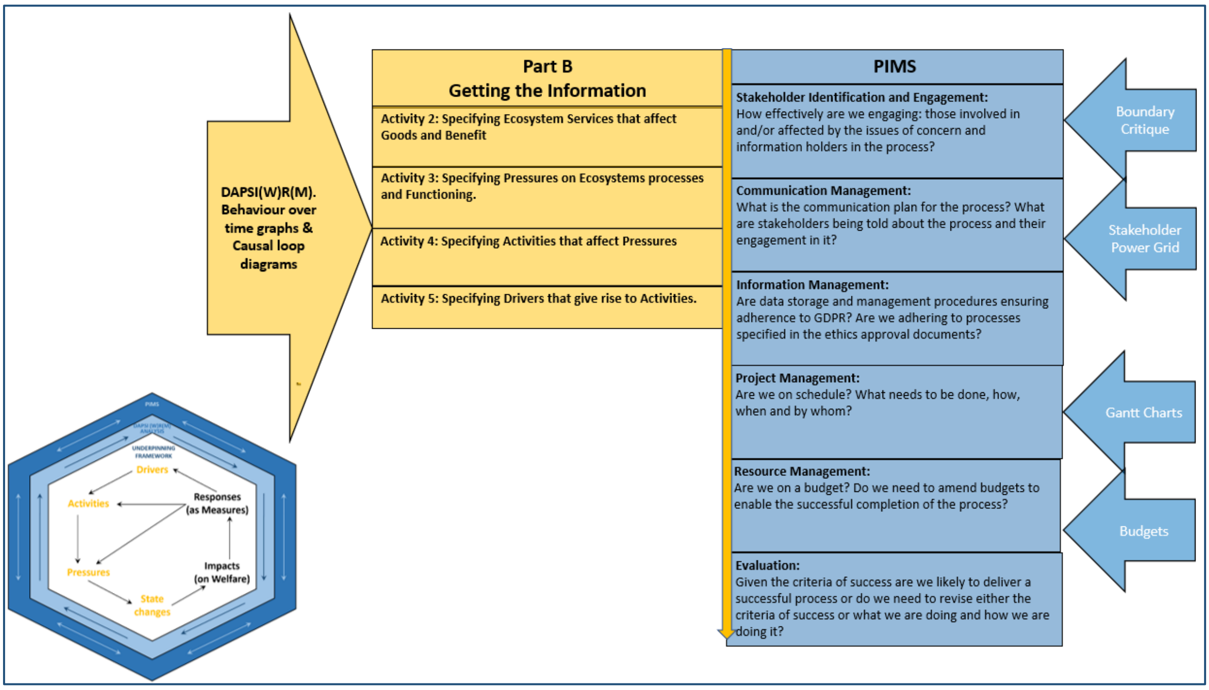



*Figure 21: Part B of the Integrated System Analysis which concerns getting the information and PIMS considerations (Project and Information Management System) (Unpublished, Atkins and Gregory, 2023).*

### *Part C*

Part C focusses on using the information gathered to create a shared understanding of system behaviour which forms the basis of the theory of change and how we can intervene in a system achieve a desired state (see Figure 22). Given the complexity of the marine environment as an SES, it is likely to involve multiple feedback loops and data gaps. It is important to test the robustness of policy and practice options, for example with respect to scenarios of potential futures, before giving recommendations to decision and policy makers.

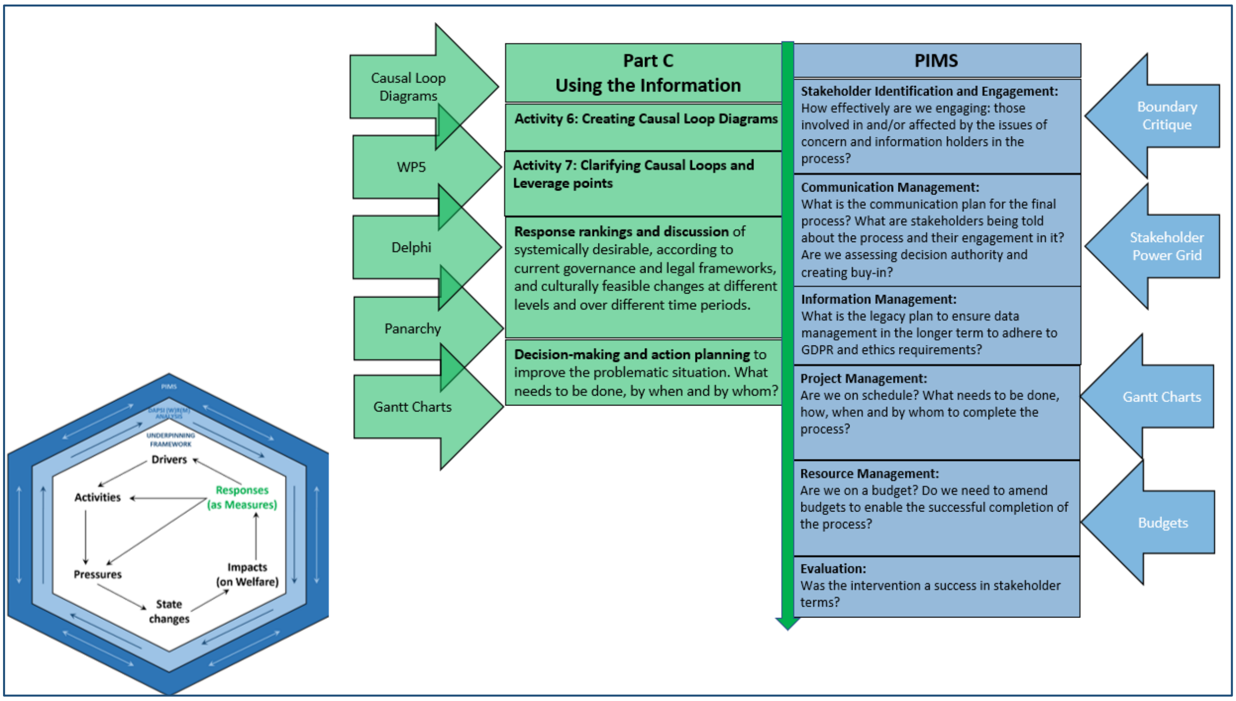



*Figure 22: Part C of the Integrated System Analysis which concerns using the information and PIMS considerations (Project and Information Management System) (Unpublished, Atkins and Gregory, 2023).*

## Visually Representing Complexity - DAPSI(W)R(M) and Causal Loop Diagramming

The DAPSI(W)R(M) framework (Elliott et al., 2017a), may be regarded to be either a deep structure, a driving feedback loop of how the world works, or a root mental and conceptual model, giving a feedback loop of our understanding of the marine natural and societal system (see BP3: *Cause-Consequence-Response Chains – DAPSI(W)R(M)*; Elliott, 2023). Using the DAPSI(W)R(M) framework in an issue structuring mode can identify causal logic chains, which can be recorded and explored in, for example, Excel spreadsheets. While DAPSI(W)R(M) supports the rigorous investigation of the system in focus, it can be detailed; similarly, the format of Excel spreadsheets is less of a visual way that emphasises the marine system dynamics.

Consequently, there is the benefit of using the discipline of systems thinking. The discipline of systems thinking helps us understand how the parts of a system interact to give rise to emergent behaviours and properties, and sometimes, particularly when these are negative, they may be regarded as unintended consequences. An example of an emergent phenomenon in the marine environment is cumulative pressures caused by human activities; for example, while the effect on ecosystems by different types of fishing is well-known, the combined consequence with other activities such as energy production and land claim, plus the effects of climate change on an ecosystem, is an emergent outcome of the system (e.g. Elliott et al., 2020a, 2018). The mantra of a system is more than the sum of its parts is an indirect reference to these emergent properties. Systems thinking encourages a shift away from linear cause and effect relationships to recognise that cause and effect can lead to the behaviour of a system to be complex and difficult to understand and manage (see BP9: *Systems Thinking*).

### *Causal Loop Diagrams*

A causal loop diagram (CLD) is a qualitative systems-based tool that shows the relationships between a set of elements that are variables (factors liable to change e.g. indicators) operating in a system. The basic premise of causal loop diagramming is that the structure of a system should fully explain its behaviour and the process of developing CLDs can help stakeholders converge on a shared understanding of system behaviour and also how to intervene in a system, by identifying root causes and manipulating leverage points, to help to achieve a desired state. This type of systems approach was discussed in the 1960s (Forester, 1961) and has been widely used and further developed since then (e.g., Rosnay, 1979; Richardson and Pugh, 1981; Senge, 1990; and Sterman, 2000).

Causal Loop Diagramming with stakeholders has already been used extensively in marine management (see, for example, Videira, 2012 and Figure 23); Marine SABRES is innovative in seeking to combine the DAPSI(W)R(M) framework with CLD by stakeholders.

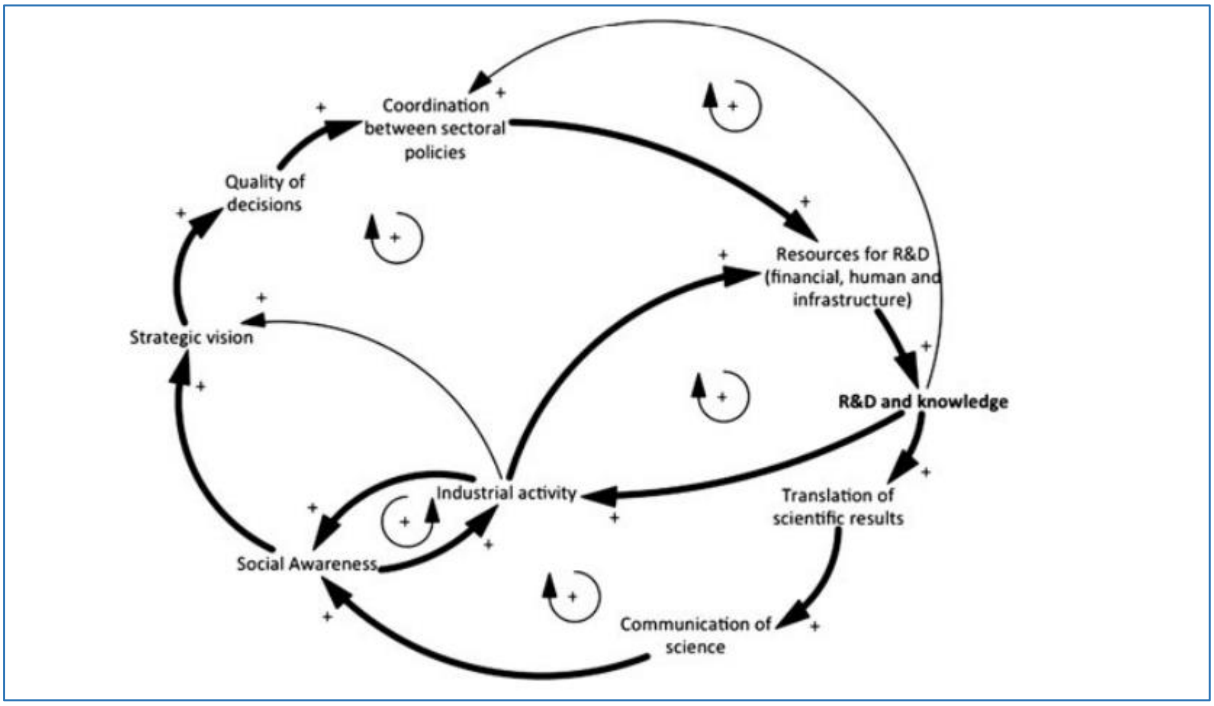



*Figure 23: Causal Loop Diagram for issue of 'R&D awareness and dissemination of ocean-related activities (Videira, 2012).*

A CLD can also be the foundation for quantitative modelling techniques e.g. system dynamics, for a more robust exploration of system behaviours and testing of policy and practice options before final decision-making and implementation. Figure 24 indicates the process of CLD-based investigation and modelling. It is emphasised that here the DAPSI(W)R(M) framework is suggested as an issue-structuring approach that supports stakeholders sharing their perceptions and mental models of how the system is structured and operates. This approach is therefore analogous to the mind-maps created by high-level stakeholder consultation in Marine SABRES WP2.

Further information on constructing CLDs is given in:
[https://core.ac.uk/download/pdf/289179095.pdf](https://core.ac.uk/download/pdf/289179095.pdf)

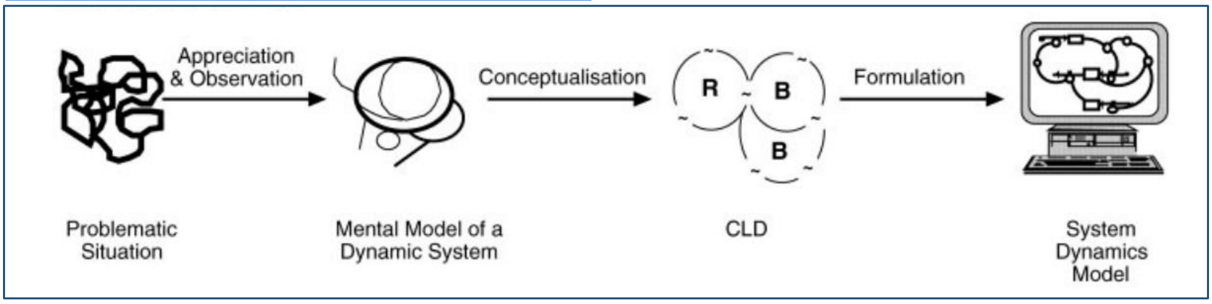



*Figure 24: A Causal Loop Diagram based process for issue conceptualisation and formulation (Lane, 2008)*

*Elements*

An element is a variable that is liable to vary or change (Oxford English Dictionary). In this context, an element has two attributes: a name (what it is called) and a 'level' (quantity, amount, size, magnitude, value). A variable can be almost any factor in a system; it may be quantitative e.g. population abundance, or it may be qualitative e.g. cultural belief or happiness. It is important to focus attention only on those varying attributes (variables) that are relevant to the issue of concern. In a complex system there are many variables, and we can (in principle) describe the state of the whole system by reporting the levels of all of these variables but this might not be possible or even desirable—either because of the large number of variables involved, or because it is not possible to determine their levels, or both. In addition, we can distinguish between endogenous variables, both influencing and influenced by other variables within the CLD, and exogenous variables, influencing but not being influenced. These are analogous to endogenic pressures, in which marine management addresses both the causes and consequences in a management area, and exogenic pressures, in which the causes are outside the area but the consequences are inside the management area and hence need addressing (e.g. Elliott et al., 2018).

**REMEMBER:**

Elements should be named using nouns or noun phrases. It is important that the name given to an element makes it clear that the thing or characteristic referred to is capable of change:

- Use clear language to describe elements in a neutral way that does not have any positive or negative connotations. In particular, do not use negative labels—use Amount of rain, not Lack of rain; Ability, not Inability. This avoids becoming confused by double negatives, e.g. a decrease in the lack of rain.
- Use a name that allows for variation and does not tie the level of the variable to an endpoint of its range. For example, use Level of Social Capital – not Low Social Capital or High Social Capital. If the name is preceded by an adjective such as 'high' or 'low' then you lock the variable into a particular state—it is no longer capable of variation.

### *Aggregation and disaggregation*

In order to allow interrogation of the CLD, elements may need to be 'aggregated' or 'disaggregated'; aggregation involves identifying related elements and expressing them as a single element that captures their overall effect (see Table 3). Aggregation is sometimes necessary when causal structure has been expressed in an excessive detail, using too many elements, that inhibits understanding of the system behaviour.

*Table 3: Examples of Element (Variable) Aggregation.*

| Related variables needing Aggregation | Example of Aggregated Variable |
|---|---|
| Rainfall, Humidity, Wind speed | Suitability of Climate |
| Level of pollution, Area of public green space, Air quality, Extent of tree canopy | Healthiness of urban environment |

Disaggregation involves replacing a single element with several elements that together more clearly explain the context and suggested causation. In some cases, an element needs to be disaggregated as it expresses a concept that is too high-level or too abstract to be quantified (see Table 4).

*Table 4: Examples of Element (Variable) Dis-aggregation*

| Original Variable | Possible components of disaggregated form |
|---|---|
| Desire for change in an issue of interest | Number of news reports<br>Number of public meetings |

| | |
|---|---|
| | Level of activity on social media |
| Effectiveness of land-use policy | Extent of forest regrowth<br>Richness and abundance of sensitive species<br>Area of invasive weeds |
| Level of urban development | Area of land cleared for new subdivisions<br>Number of building applications before council<br>Number of new businesses registered |
| Water quality | Concentration of pathogens<br>Concentration of suspended sediments<br>pH |
| Worldviews | Level of concern for the environment<br>Level of belief in anthropogenic climate change |

**REMEMBER:**

The process of aggregation and disaggregation are key to creating the appropriate level of detail for your CLD to address the questions posed. With this, and keeping it simple in mind, it is recommended that the number of elements in a CLD should be limited to about 15 to 20 in order to maintain overview and coherence (Haraldsson, 2004). It is likely that the process of creating an issue based composite CLD will lead you to exceed this recommendation but it is good to keep it in mind so that you simplify and aggregate to improve clarity and simplicity where possible.

Further information on aggregation and disaggregation:
https://core.ac.uk/download/pdf/289179095.pdf

*Connections*

In CLDs, elements are represented as labelled nodes with the connections between associated elements shown as arrows giving the direction of the influence. Normally a causal connection will be uni-directional. Connections are either:

- Reinforcing—denoted by a '+' or an 's' as the elements (variables) move in the same direction, an increase or reduction in one element causes an increase or reduction in the element it influences;
- Opposing—denoted by a '–' or an 'o' as the elements move in opposite directions, an increase one element causes a decrease in the element it influences.

Figure 25 describes the connections between elements. Whilst there is the need to be aware of the different types of signifying link polarity in CLDs, for the sake of consistency it is recommended that the '+' and '-' signalling convention is used consistently in the DA analysis.

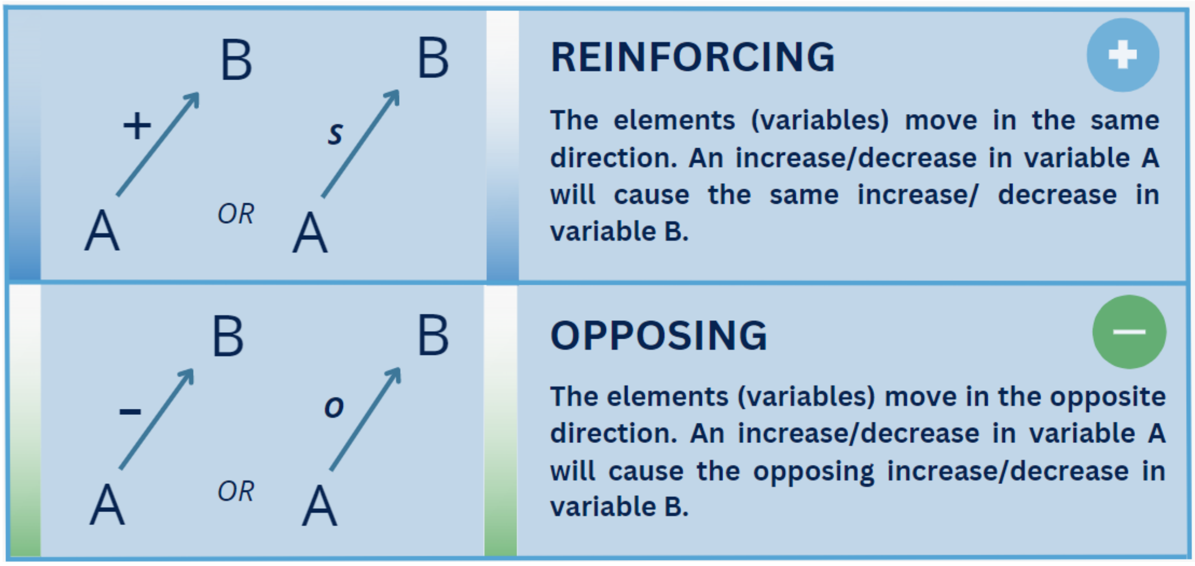



*Figure 25: Polarity signs in Causal Loop Diagrams redrawn from Lane (2008). An 's' and an 'o' are also used to symbolise the type of relationship.*

When there are multiple connections between elements, they can form causal or feedback loops. A feedback loop is a closed sequence of causes and effects, that is, a closed path of action and information (Richardson and Pugh, 1981). Causal loops are either reinforcing (vicious or virtuous circles) or balancing, where self-correction occurs within the system. Every causal loop should tell a story that links cause and effect through feedback:

- Reinforcing — engine for the growth or decline of a system.
- Balancing — a steady state of a system.

### *System Scales and Levels*

A system is manifested in scales and levels which importantly place the system-in-focus and our representation of it in CLDs in time and space, i.e. what systems interact beneath (sub-systems) and what interact above (meta-system):

**Temporal scale and delays:** This can range from seconds to minutes or years to infinity. The temporal scale of a system is set according to the time-feedback mechanisms take in the system (aka 'delays'). The system behaviour can indicate the duration of feedback delays (time-lags). For example, if there is a time-lag in the impact of one variable on another of a century, then this determines the time-frame of the feedback loop. If an issue has a much shorter time-frame then we can choose to not include feedback with very long time-lags as their impacts will not be realized over the period of interest. However, it may be relevant to also develop CLD with longer time-frames to ensure that long, slow changes are not disregarded and also we must be sensitive to instances where the speed of change accelerates, such as climate change in different latitudes.

**Physical scale:** This is the spatial size of the system and is important given that the ability to affect system behaviour usually occurs over a shorter time-scale in smaller systems than larger ones; Figure 26 gives an example of the physical and temporal scales.

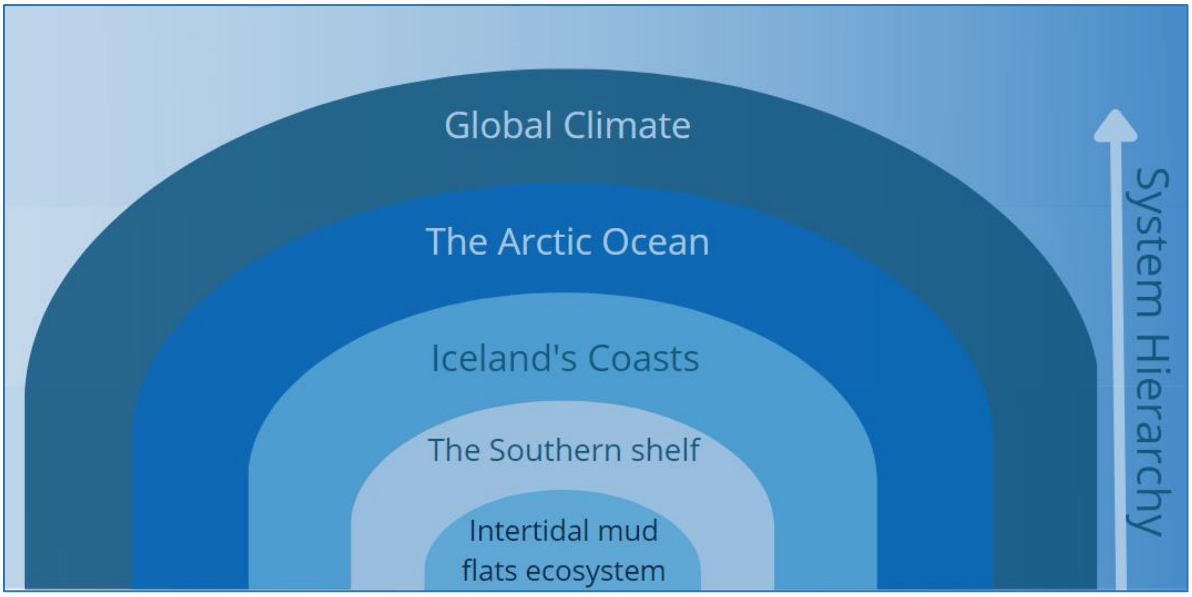



*Figure 26: Example of the varying scales of a systems boundaries using an Intertidal mudflat in the southern shelf of Iceland.*

**Interaction between Levels:** An issue can be manifest at many different levels so it is important to identify the level at which the Impacts of concern are being realised. On a physical scale, a single organism as a system is small and occupies a micro level compared to, for example, climate which has many system levels and occupies a large physical space at the macro level; although the two systems are different, they can interact. Climate can influence individual organisms and vice versa, but climate resides higher in the system level hierarchy which covers the several levels of biological organisation from the cell, through individuals to populations, communities and ecosystems. Models are built on systems that influence the level above them (meta-system) or below them (sub-systems). Therefore, it is necessary to identify where along the physical continuum the model is focussed, this is known as the level of abstraction.

Levels of abstraction in a causal loop diagram (CLD) refer to how broadly or specifically we represent elements within the diagram. For example, if we consider the activity of 'fishing', we can either keep it as a single entity or break it down into different types such as 'trawling', 'line fishing', and 'net fishing'. Higher levels of abstraction provide a broader view of the system, allowing us to observe overall trends, while lower levels of abstraction offer more detailed insights, highlighting specific trends in the system. Hence, the term 'level of abstraction' indicates the degree to which behaviours influence the system. Depending on the situation, this influence can be focal (centred on a specific element), spatial (affecting a particular area), or temporal (impacting a specific time period). It is of note that in seeking to portray complex systems in simple ways, detailed knowledge of the underlying sub-systems and elements may not just be unnecessary but actually counter-productive in inhibiting our ability to 'see' underlying structures; hence, such lower level systems may be regarded as 'black boxes' particularly which may also assist with maintaining a consistent level of understanding. In such black boxes, the inputs into and outputs from the black box may be known even if the black box internal functioning is unknown (Odum, 1971).

This guide integrates the DAPSI(W)R(M) and CLD analyses to increase the understanding of how the focal issue creates multiple affects, identified by creating impact-based CLDs, and also a composite CLD for the issue overall. Simple CLDs are often hand-drawn but the large and interlinking number of elements and connections may be difficult to represent on a hand-drawn model; hence, there are several data visualisation software packages that are available to support the building of CLDs. Some software packages (e.g. Vensim, iThink) provide additional model building features that mean that stock and flow and system dynamics models, which give enhanced analysis and simulation capability, can be built from CLDs, whereas other software packages (e.g. Kumu, Gephi) are more focussed on network analysis and associated tools of analysis. After considering these different tools, this guide has adopted integrating DAPSI(W)R(M) analysis with CLDs using Kumu software as Excel spreadsheets; the latter allow prior data from an analysis software program to be easily integrated.

## Causal Loop Diagramming in Kumu

Kumu is available at https://Kumu.io and an overview of the software is provided at https://Kumu.io/tour. Kumu is free to join and public projects can be created for free. If projects need to be kept private then it is necessary to pay for Pro Workspaces (see the Kumu pricing variants at https://Kumu.io/pricing). Once you have joined Kumu, various introductory materials are provided to get you started and familiarised with the software (https://docs.Kumu.io/getting-started/readme). We recommend that you watch the videos:

- '5-minute quickstart' (https://docs.Kumu.io/getting-started/readme#five-minute-quickstart)
- 'Kumu 101' (https://docs.Kumu.io/getting-started/Kumu-101)
- Then having a go at creating a causal loop diagram in your own sandbox (https://docs.Kumu.io/getting-started/first-steps).

Various templates are available in Kumu to automate aspects of the visualisation process and for the purposes of the DA project it is recommended that you select the causal loop template. Although all members of the group should familiarise themselves with the process of causal loop diagramming and the format of such diagrams in Kumu, we suggest that one member of the group takes responsibility for creating and updating the CLDs in Kumu. This, together with identifying who is responsible for updating the Excel spreadsheets, requires to be built into your Resource Management plan.

## Dynamic Complexity and Behaviour Over Time (BOT)

BOT graphs (also called 'reference modes') show the pattern of behaviour of elements over an extended period of time; e.g. a reinforcing loop may show a BOT of a virtuous or vicious nature as the growth or decline of something may have positive or negative consequences depending on the context. In BOT graphs, the horizontal axis represents time and the vertical axis represents the performance measure of interest. The important parts of BOTs are the overall directions and variations, not the value of the element. Therefore, BOTs usually give approximate indications rather than the exact value of the element. The behaviour of several elements can be shown in the same BOT graph.

Whilst the DAPSI(W)R(M) is useful for issue structuring, it may focus on identifying data gaps, but this requires further interrogation to fill those data gaps or understand their importance which may be constrained by the readily-available data. BOT graphs may overcome the data availability problem by building causal theories prior to data gathering. The BOTs can be used to connect past observed behaviour with future behaviour to help understand the underlying causal structures and, by developing our understanding of potential system behaviours, guide data acquisition for building or testing theories.

BOT graphs can be used to identify which types of system processes are occurring. For example, a rapidly increasing or decreasing behaviour over time graph indicates that reinforcing loops are influencing the system (see Figures A and B in Figure 26). In contrast, an oscillating behaviour over time would indicate that balancing feedback mechanisms are occurring in the system (see Figure C Figure 26).

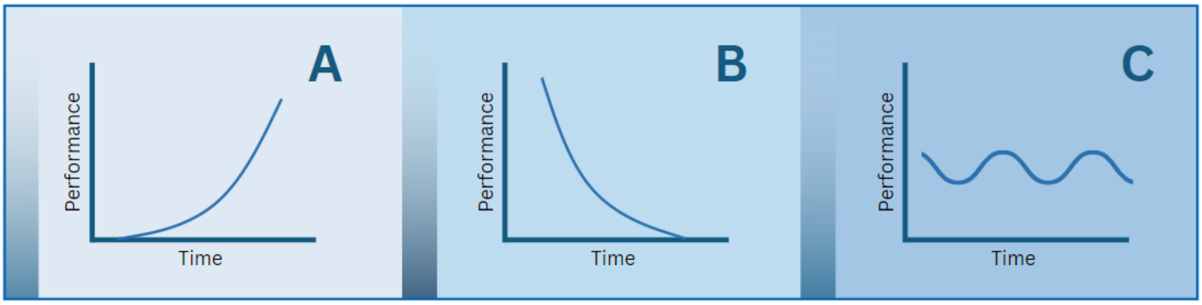



Figure 26. Behaviour over time Graphs – A and B represent reinforcing feedback loops, and C represents a balancing feedback loop; redrawn from Mclean, et al (2019).

In summary, the behaviour of elements key to the issue of concern are plotted in a BOT graph and a theory of causal behaviour is presented; data are then located to either prove or disprove the theory. Through an iterative process between theory-building and data analysis, we can build a better understanding of what is happening; further information is given in: https://thesystemsthinker.com/behaviour-over-time-diagrams-seeing-dynamic-interrelationships/.

## Summary of the recommended DAPSI(W)R(M)/CLD modelling process:

Below is a summary of the modelling process, the colours indicate the three phases of the ISA analysis; Red = Setting priorities, Yellow = Getting the information, Green = Using the information.

1. In the Marine SABRES project, the focus issue for each DA has been defined by stakeholder engagement in WP2. In future use, upon upscaling, the initial stage will include a process of issue identification using, for example, rich pictures.
2. Associated with the focal issue are a number of Impacts on human Well-being and it may be that we need to prioritise these by, for example, using the Delphi approach. In each DA or component part of a DA in Marine SABRES, the aim is to create a CLD for each of the priority Impacts together with a composite CLD of the Impacts that are focussed on the Issue and over a relevant time-horizon. The creation of one or more CLDs aims to increase our understanding regarding the behaviour of the system that is causing concern.
3. Taking each Impact in turn, identify the relevant indicator to measure the variable and record a time-horizon over which the effects on societal goods/benefits are manifest.
4. Repeating step three for the relevant DAPSI(W)R(M) framework elements, to examine and explain the Impact of concern. Using the DAPSI(W)R(M) framework in this way should help bound your CLD in terms of what is deemed relevant to include and also help you achieve a consistent level of understanding.
5. Define the Impact dynamically by reviewing historical data on key elements and drawing Behaviour-Over-Time charts for them. These charts can serve as reference points throughout the theory-building process, helping focus the conceptualization, and validate emerging theory.
6. Identify and label loops and identify key leverage points.
7. Explore the behaviour of the system by tracing out the loops and main issues (stories): start with a variable that is critical to the focal question and then trace out the loops that affect it. You can also conduct thought-experiments by hypothesizing about the behaviour over time of different elements and inferring the behaviour of other related elements. Do 'what-if' experiments of possible future scenarios and draw out the implications of those events on other elements.
8. Use your CLDs to build causal theories that draw out the interrelated behaviour of elements over time.
9. Access and analyse relevant data to help validate the BOTs, causal connections, and causal theories derived from your CLD.
10. Once you are satisfied that you have sufficiently developed, explored and validated each Impact based CLD, add it to your composite Issue-based CLD. Explore how this addition adds to your understanding of the system behaviour regarding the focal issue of concern. As with the Impact-based CLDs, explore the systems behaviour through tracing out the loops, storytelling, identification of leverage points and 'what if' analysis.

In bringing together the DAPSI(W)R(M) model, systems thinking in the form of causal loop diagramming and other approaches, and a system for good project and information management, the Integrated Systems Analysis therefore represents a significant shift in our thinking about how we tackle complexity in the marine environment on an ongoing basis as an action learning cycle (see Figure 27).

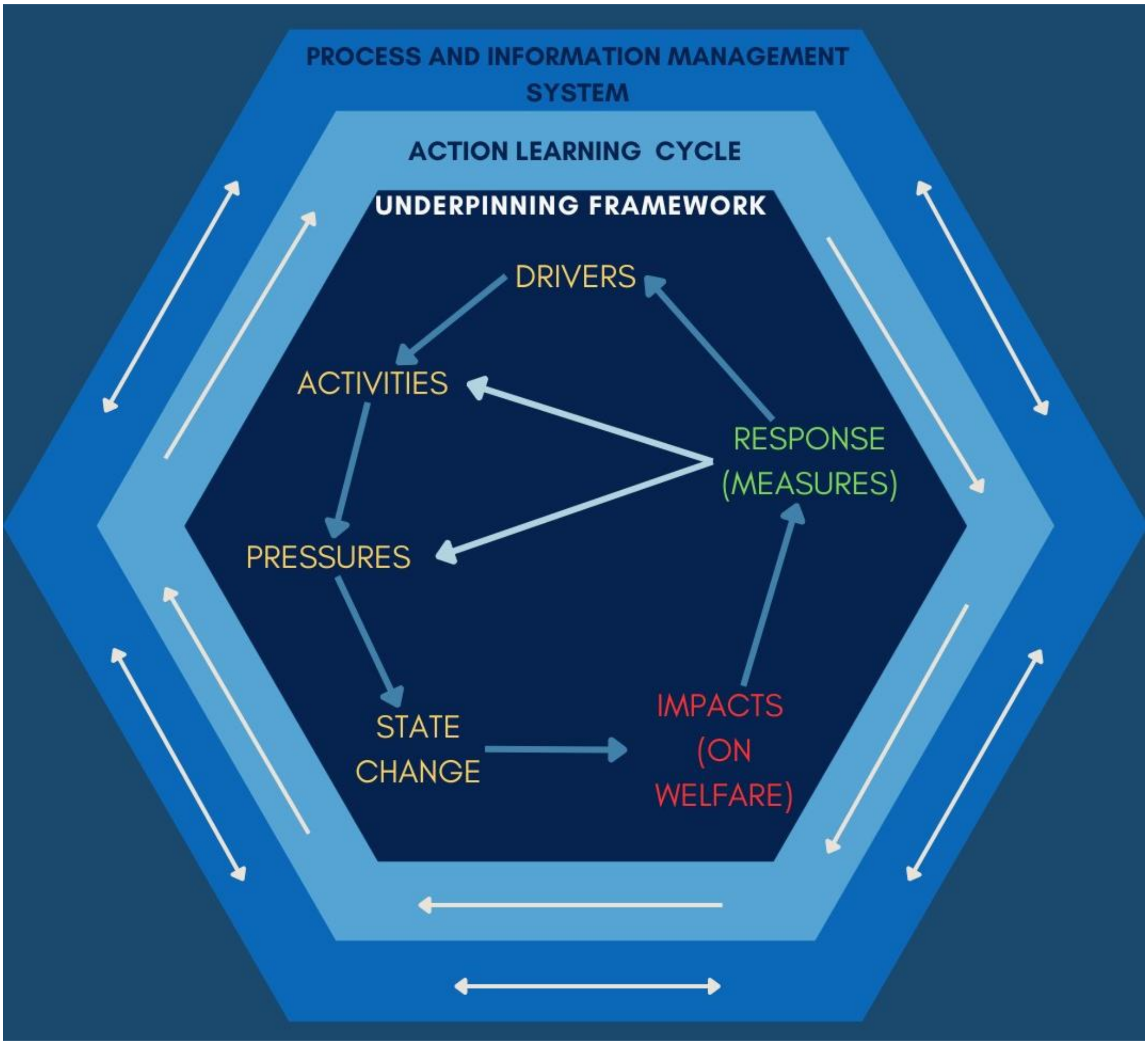



*Figure 27: The Action Learning Cycle of Integrated Systems Analysis.*

# Part III: The Simple SES Analysis

This section of the guide details the steps that are involved in undertaking an Integrated Systems Analysis. You will need the corresponding ISA Excel workbook to organise and store your data.

## Preliminary Exercise 0: Unfolding Complexity and Impacts on Welfare

This initial exercise sets the scope for the Impacts on Welfare as the result of the identified marine problems and focal issues of concern. As the latter have already been defined by stakeholders for each of the DAs in the Marine SABRES project document and by the mind-mapping exercise in WP2, the first task is to consider the questions in Table 5:

*Table 5: Table containing key considerations of setting the scope of the analysis.*

| Question to consider | Comments: |
|---|---|
| What are the impacts within the social system of the focal issue on human welfare and over what time-frame? | |
| At what spatial scale (individual, regional, national or international) do the impacts of the most pertinent issues occur? | |

In systems thinking, there are usually three levels of consideration: the metasystem, the system in focus (or focal level), and sub-systems. It is considering at the ocean environment from different vantage points.

- Metasystem: This is the highest, broadest level, such as considering the entire ocean environment as a whole, including all seas, marine life, climate influences, and human activities.
- System in Focus: This is the spatial area to be studied. It is more detailed than the metasystem but not as narrow as a sub-system. For instance, the system in focus could be the North Sea and all its related elements.
- Sub-systems: These are smaller, specific areas within the system in focus. For example, within the North Sea, a sub-system could be the ecosystem of a specific habitat or the fishing industry in a specific region.

It is especially important to identify on which level you are focusing on and why, to ensure consistency in your analysis and recommendations. Remember, suggestions relevant to one level might not apply to another.

Once you have defined your system of focus – for example, the impact of commercial fishing on the North Sea ecosystem, next identify the impacts these have on human welfare, such as economic benefits, job creation, and food provision. Maintaining a clear focus on the system in focus while also considering its role in the broader system and its various sub-components can help identify different levels of management actions and ensure consistency in the approach. Having clarified the focal issue/spatial system of interest and the impacts on human welfare, the next step orders these in terms of importance or priority. Starting with the impact of most importance, this guidance works through the DAPSI(W)R(M) cycle of analysis to create a causal loop diagram for this impact.

**Causal Loop Diagram scoping:**

When developing CLDs, a key to success is to find the appropriate level of detail that addresses the questions posed. When defining the scope of the CLD, there are three elements that need to be considered (Kim, 2000):

- The timeframe of interest – over what period of time did impact of interest unfold? Do actions and outcomes that occur on a daily, weekly, monthly or yearly basis need to be captured?
- The boundary (footprint) of the impact - what are the limits for what should be included in the diagram and what is regarded as external to it (respectively endogenic and exogenic features)?
- The level of system aggregation - what is the level of aggregation in the CLD or level of detail needed to understand patterns of behaviour across the different Drivers, Activities, Pressures, State changes and Impacts on Welfare? Will the focus be on capturing community regional, national or global dynamics?

It is of note that, when determining the scope of a CLD, the goal should always be to use CLDs to map key structural drivers for the issue of interest, not to try and map the feedback that drives behaviour in the entire, wider system (Sterman, 2000a). This is key to avoiding overly complex diagrams which may obscure key dynamics around the focal issue of interest. For further information on CLD Scoping see: https://academic.oup.com/heapol/article/37/10/1328/6654776

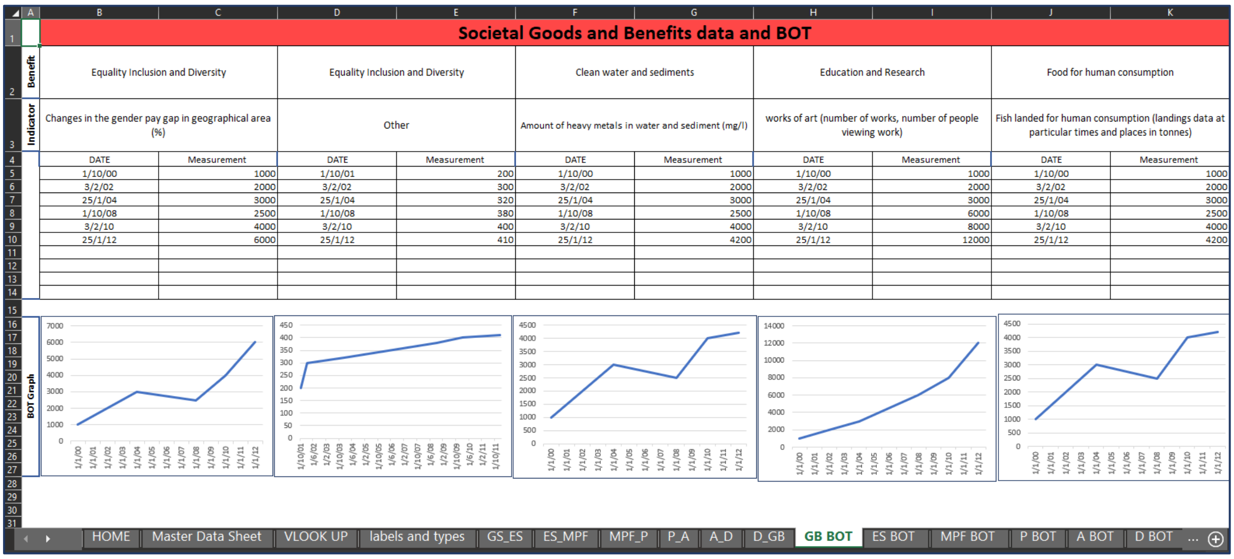
## Exercise 1: Specifying Goods and Benefits Related to the Impact on Welfare

1. Referring to the goods and benefits in the Excel drop down list and referring to BP6: *Indicators,* identify goods/benefits related to the issue of concern (Figure 28).
2. Using the drop-down list in (Column B) of the Master sheet, select the top five priority goods and benefits relating to the impact of concern.
3. Using the drop-down list (Column C) Identify indicators (quantity/quality) for each good/benefit (physical and/or monetary units).
4. Assign a concise name for the good and benefit in the Kumu indicator column (Column D).

| | A | B | C | D | E | F | G | H | I | J |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | | | | Exercise 1 | | | | | |
| 2 | | | | | | Good/Benefit Indicator Behaviour over time | | | | |
| 3 | Good/ Benefit Code | Location specific Good/Benefit | Indicator of Good/Benefit Quality/Quantity | Kumu Indicator Name (Four words or less describing the indicator) | Good/Benefit Indicator Data Source (Organisation and/or Named Individual) or Data Gap | What is the relevant period to assess indicator change? (Unit is always years) | Previous states ($T_{-1}$, $T_{-2}$_)? | Current state ($T_0$)? | Data confidence level (5 highly certain-0 highly uncertain) | Comment on Behaviour over time/Trend |

*Figure 28: Screen Clip of the Exercise 1 columns to complete.*

5. Identify data sources to populate the indicators, assess behaviour over time and stakeholders who may be able to provide these data (Column E).
6. Assess changes (trends) over time. What is a meaningful period of time to work across? (Columns F) and what data are available on previous states (Column G) and the current state (Column H).
7. Add the confidence level and any other comments to Columns I and J.
8. Use the Goods and Benefits Behaviour Over Time Graph link on the home Sheet to fill in the Sheet for data of the indicators (Figure 29).




| Societal Goods and Benefits data and BOT | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Benefit:** Equality Inclusion and Diversity | | Equality Inclusion and Diversity | | Clean water and sediments | | Education and Research | | Food for human consumption | |
| **Indicator:** Changes in the gender pay gap in geographical area (%) | | Other | | Amount of heavy metals in water and sediment (mg/l) | | works of art (number of works, number of people viewing work) | | Fish landed for human consumption (landings data at particular times and places in tonnes) | |
| DATE | Measurement | DATE | Measurement | DATE | Measurement | DATE | Measurement | DATE | Measurement |
| 1/10/00 | 1000 | 1/10/01 | 200 | 1/10/00 | 1000 | 1/10/00 | 1000 | 1/10/00 | 1000 |
| 3/2/02 | 2000 | 3/2/02 | 300 | 3/2/02 | 2000 | 3/2/02 | 2000 | 3/2/02 | 2000 |
| 25/1/04 | 3000 | 25/1/04 | 320 | 25/1/04 | 3000 | 25/1/04 | 3000 | 25/1/04 | 3000 |
| 1/10/08 | 2500 | 1/10/08 | 380 | 1/10/08 | 2500 | 1/10/08 | 6000 | 1/10/08 | 2500 |
| 3/2/10 | 4000 | 3/2/10 | 400 | 3/2/10 | 4000 | 3/2/10 | 8000 | 3/2/10 | 4000 |
| 25/1/12 | 6000 | 25/1/12 | 410 | 25/1/12 | 4200 | 25/1/12 | 12000 | 25/1/12 | 4200 |

*Figure 29: Screen clip of Behaviour Over Time Graphs sheet for the Goods and Benefits indicators.*

## Exercise 2: Specifying State Changes (Marine Ecosystem Processes and Functioning and Ecosystem Services) that affect Impacts on Welfare (Goods and Benefits)

State changes which affect the Impacts on Welfare (Goods and Benefits) are separated into Ecosystem services and Marine Processes and Functioning. Marine processes and functioning give rise to ecosystem services (provisioning and regulating services) which provide society with goods and benefits. Hence, this exercise details the logical chain of the impacts that ecosystem services have on goods and benefits (Exercise 2(a)). Followed by the relationship between ecosystem services and the marine functioning and processes (Exercise 2(b)).

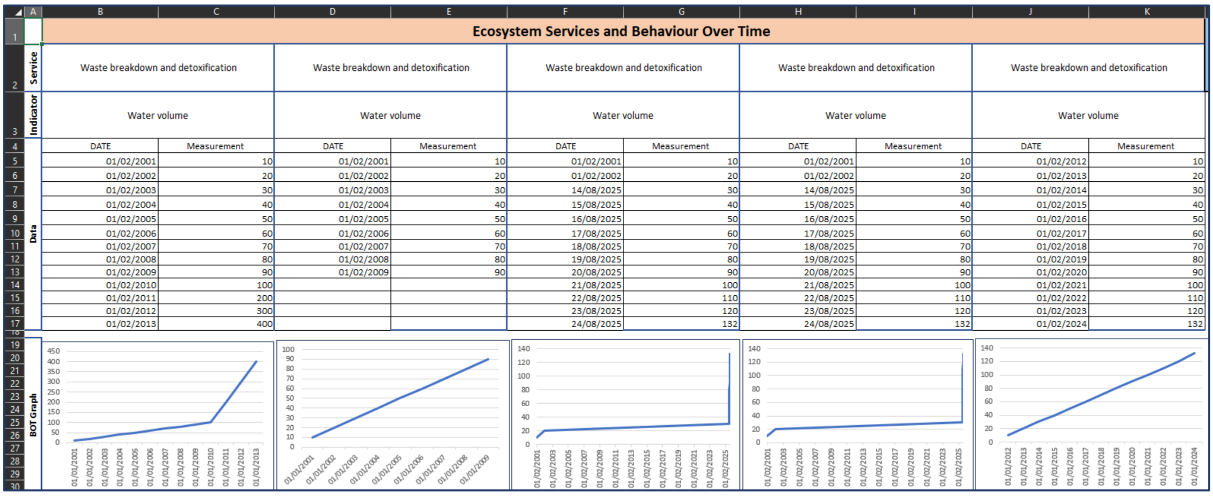
### *Exercise 2 (a) For Ecosystem services:*

1. For each good/benefit (Column B), with reference to BP6: *Indicators*, and using the dropdown list (Column L), specify the ecosystem service(s) that affect it (Figure 30).
2. Using the dropdown list (Column M), identify indicators for each ecosystem service (multiple indicators are possible – specify ecosystem service indicators in physical units only but not monetary units).
3. Assign a concise name for the Ecosystem Service in the Kumu indicator column (Column N).

| Exercise 2(a) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | Ecosystem Service Indicator Behaviour over time/Trend | | | | |
| Ecosystem Service Code | Ecosystem Service | Relevant Ecosystem Service Indicator(s) of Quantity and/or Quality | Kumu Indicator Name (Four words or less describing the indicator) | Ecosystem Service Indicator Data Source (Organisation and/or Named Individual) or Data Gap | What is the relevant period to assess indicator change? | Previous states ($T_{-1}$, $T_{-2}$...)? | Current state ($T_0$)? | Data confidence level (5 highly certain-0 highly uncertain) | Behaviour over time/Trend |

*Figure 30: Screen Clip of Exercise 2(a) master sheet columns to complete.*

4. Identify data sources to populate the indicators, assess behaviour over time and stakeholders who may be able to provide these data (Column O).
5. Assess changes (trends) over time. What is a meaningful period of time to work across (Column P) and what data are available on previous states (Column Q) and the current state (Column R)?
6. Use the Ecosystem Services Behaviour Over Time Graph link on the home page to fill in the Sheet for data of the indicators (Figure 31).
7. Add the confidence level and any other comments to Columns S and T.




| DATE | Measurement | DATE | Measurement | DATE | Measurement | DATE | Measurement | DATE | Measurement |
|---|---|---|---|---|---|---|---|---|---|
| 01/02/2001 | 10 | 01/02/2001 | 10 | 01/02/2001 | 10 | 01/02/2001 | 10 | 01/02/2012 | 10 |
| 01/02/2002 | 20 | 01/02/2002 | 20 | 01/02/2002 | 20 | 01/02/2002 | 20 | 01/02/2013 | 20 |
| 01/02/2003 | 30 | 01/02/2003 | 30 | 14/08/2025 | 30 | 14/08/2025 | 30 | 01/02/2014 | 30 |
| 01/02/2004 | 40 | 01/02/2004 | 40 | 15/08/2025 | 40 | 15/08/2025 | 40 | 01/02/2015 | 40 |
| 01/02/2005 | 50 | 01/02/2005 | 50 | 16/08/2025 | 50 | 16/08/2025 | 50 | 01/02/2016 | 50 |
| 01/02/2006 | 60 | 01/02/2006 | 60 | 17/08/2025 | 60 | 17/08/2025 | 60 | 01/02/2017 | 60 |
| 01/02/2007 | 70 | 01/02/2007 | 70 | 18/08/2025 | 70 | 18/08/2025 | 70 | 01/02/2018 | 70 |
| 01/02/2008 | 80 | 01/02/2008 | 80 | 19/08/2025 | 80 | 19/08/2025 | 80 | 01/02/2019 | 80 |
| 01/02/2009 | 90 | 01/02/2009 | 90 | 20/08/2025 | 90 | 20/08/2025 | 90 | 01/02/2020 | 90 |
| 01/02/2010 | 100 | | | 21/08/2025 | 100 | 21/08/2025 | 100 | 01/02/2021 | 100 |
| 01/02/2011 | 200 | | | 22/08/2025 | 110 | 22/08/2025 | 110 | 01/02/2022 | 110 |
| 01/02/2012 | 300 | | | 23/08/2025 | 120 | 23/08/2025 | 120 | 01/02/2023 | 120 |
| 01/02/2013 | 400 | | | 24/08/2025 | 132 | 24/08/2025 | 132 | 01/02/2024 | 132 |

*Figure 31: Screen clip of Behaviour Over Time Graphs sheet for the Ecosystem Services indicators.*

8. Next, we assess the relationship between ecosystem services and goods and benefits by clicking the ‘Adjacency matrix for GB &ES’ on the home Sheet (Figure 32).
9. Referring to the indicators BOT, use the drop-down cells in both adjacency matrices (Adjacency matrix and sensitivity matrix) to assign whether two variables have a ‘+’ (giving to) or ‘–‘ (taking away) connection and whether this is strong, medium or weak positive or negative.
10. NOTE: The matrix plots out the relationships between ecosystem services and goods/benefits on the causal loop diagram. Where possible, justify the strength of the relationship, as this information will be required to inform understanding of the model when it comes to evaluating response options.

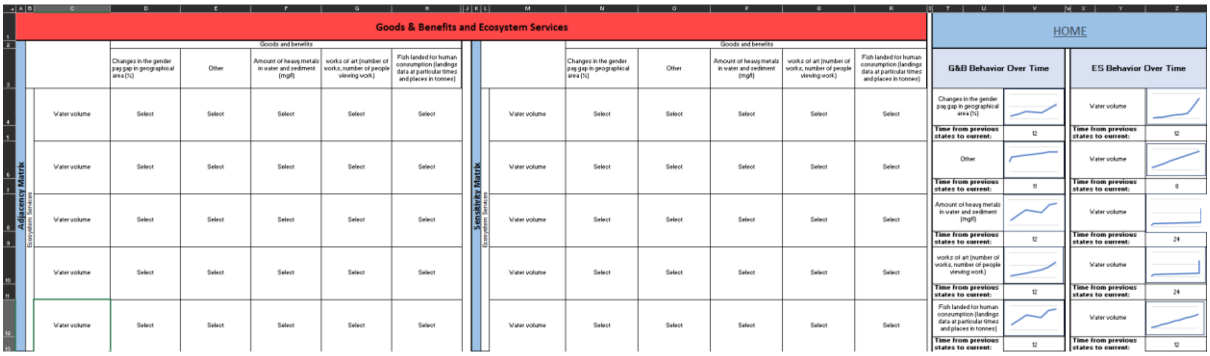



*Figure 32: Screen Clip of the Adjacency Matrix Excel sheet relating to Goods and Benefits and Ecosystem Services to complete. Cells worded ‘select’ contain the dropdown list, the rest of the matrix cells will be auto-populated from the master sheet.*

11. Export the KUMU sheet called ‘KUMU Goods and Benefits and Ecosystem Services’ to a .csv file. Go to Kumu and press the green + to upload.

*Exercise 2(b) for Marine Ecosystem Processes and Functioning:*

1. For ecosystem service(s) (Column L), with reference to BP6: *Indicators,* and using the dropdown list (Column V), specify the marine processes and functioning that affect it/them (Figure 33).
2. Using the dropdown list (Column V), identify indicators for each marine process and function (multiple indicators are possible – specify ecosystem service indicators in physical units only but not monetary units)
3. Identify data sources to populate the indicators, assess behaviour over time and stakeholders who may be able to provide these data (Column W).

| Exercise 2(b) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | Marine Processes and Functioning Indicator Behaviour over time/Trend | | | | |
| Marine Processes and Functioning Code | Marine Processes and Functioning | Relevant Marine Processes and Functioning Indicator(s) Quantity and/or Quality | Kumu Indicator Name (Four words or less describing the indicator) | Marine Processes and Functioning Indicator Data Source (Organisation and/or Named Individual) or Data Gap | What is the relevant period to assess indicator change? | Previous states (T-1, T-2,...)? | Current state (T0)? | Data confidence level (5 highly certain-0 highly uncertain) | Comment on Behaviour over time/Trend |

*Figure 33: Screen clip of Exercise 2(b) master sheet columns to complete.*

4. Assign a concise name for the Marine Process and Functioning in the Kumu indicator column (Column X).
5. Assess changes (trends) over time. What is a meaningful period of time to work across? (Column Z) and what data are available on previous states (Column AA) and the current state (Column AB).
6. Add the confidence level and any other comments to Columns AC and AD.
7. Use the Marine Processes and Functioning Behaviour Over Time Graph link on the home page to fill in the Sheet for data of the indicators (Figure 34).

| Marine Processes and functioing and Behaviour Over Time | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Process and Function | Production | | Production | | Production | | Production | | Production | |
| Indicator | Net productivity by species (kcal/ha/yr) | | Net productivity by species (kcal/ha/yr) | | Net productivity by species (kcal/ha/yr) | | Net productivity by species (kcal/ha/yr) | | Net productivity by species (kcal/ha/yr) | |
| Data | DATE | Measurement | DATE | Measurement | DATE | Measurement | DATE | Measurement | DATE | Measurement |
| | 01/02/2023 | 11 | 20/02/1998 | 10 | 01/02/2023 | 10 | 01/02/2023 | 10 | 01/02/2023 | 10 |
| | 01/02/2024 | 22 | 20/02/2000 | 20 | 01/02/2024 | 20 | 01/02/2024 | 20 | 01/02/2024 | 20 |
| | 01/02/2025 | 25 | 20/02/2002 | 30 | 01/02/2025 | 30 | 01/02/2025 | 30 | 01/02/2025 | 30 |
| | 01/02/2026 | 35 | 20/02/2004 | 40 | 01/02/2026 | 40 | 01/02/2026 | 40 | 01/02/2026 | 40 |
| | 01/02/2027 | 50 | 20/02/2006 | 50 | 01/02/2027 | 50 | 01/02/2027 | 50 | 01/02/2027 | 50 |
| | 01/02/2028 | 60 | 20/02/2008 | 60 | 01/02/2028 | 60 | 01/02/2028 | 60 | 01/02/2028 | 60 |
| | 02/02/2029 | 20.00 | 20/02/2010 | 80.00 | 02/02/2029 | 80.00 | 02/02/2029 | 80.00 | 02/02/2029 | 80.00 |

BOT Graph

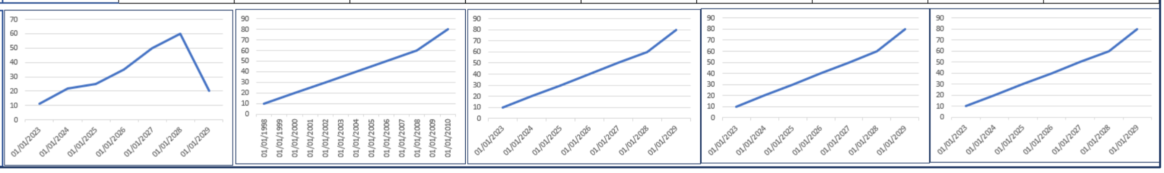


*Figure 34: Screen clip of Behaviour Over Time Graphs sheet for the Marine Processes and Functioning indicators.*

8. Next we assess the relationship between Marine Processes and Functioning and Ecosystem Services by clicking the 'Adjacency matrix and BOT for Ecosystem Services and Marine Processes and Functioning link on the Home Sheet (Figure 35).
9. Referring to the indicators BOT, use the dropdown cells in the both adjacency matrices (Adjacency matrix and sensitivity matrix) to assign if two variables have a + (giving to) or – (taking away) connection and if this is a strong, medium or weak positive or negative interaction.

NOTE: The matrix plots out the relationships between Marine Processes and Functioning and Ecosystem Services on the causal loop diagram. It is recommended to provide a justification of the strength of relationship, as this information will be required to inform understanding of the model when it comes to evaluating response options.

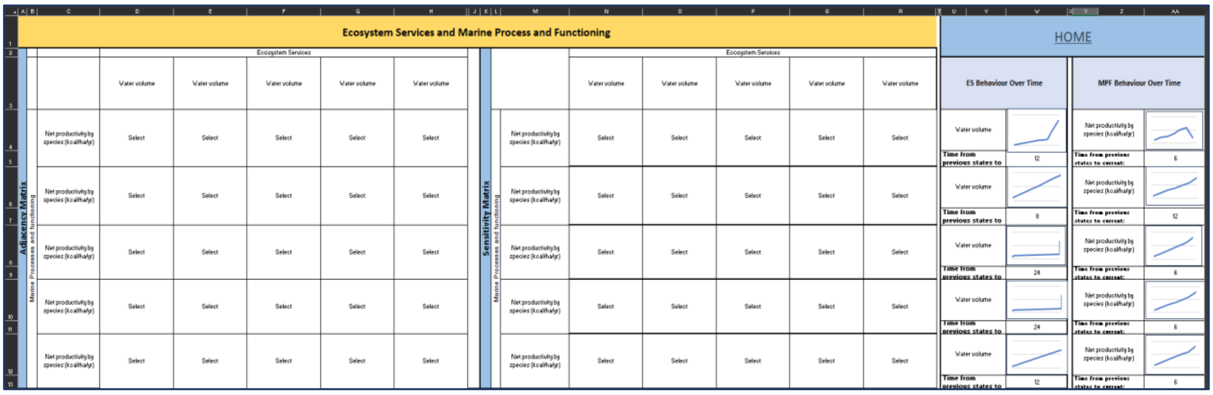



*Figure 35: Screen Clip of the Adjacency Matrix Excel sheet relating to Ecosystem Services and Marine Processes and Functioning to complete. Cells worded 'select' contain the dropdown list, the remaining cells will be auto-populated from the master sheet.*

10. Export the KUMU sheet called 'KUMU Ecosystem Services and Marine Processes and Functioning' to a .csv file. Go to Kumu and press the green + to upload.

## Exercise 3: Specifying Pressures on State Changes (Marine Ecosystem Processes and Functioning and Ecosystem Services)

1. For Marine Processes and Functioning (Column V), with reference to BP6: *Indicators,* and using the dropdown list (Column AF), specify the Pressures that affect its delivery or provision (Figure 36).
2. Using the dropdown list (Column AG), identify indicators for each marine process and function.
3. Assign a concise name for the Pressure in the Kumu indicator column (Column AH).

| AE | AF | AG | AH | AI | AJ | AK | AL | AM | AN | AO | AP | AQ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Exercise 3 | | | | | | | | | | | | |
| | | | | | | Pressure Indicator Behaviour over time/Trend | | | | | | |
| Pressure Code | Dominant Pressures | Dominant Pressures Indicator of Strength Quantity and/or Quality | Kumu Indicator Name (Four words or less describing the indicator) | Pressure Indicator Data Source (Organisation and/or Named Individual) or Data Gap | Local/Regional/National/International | What is the relevant period to assess indicator change? | Previous states (T-1, T-2,...)? | Current state (T0)? | Data confidence level (5 highly certain-0 highly uncertain) | Comment on Behaviour over time/Trend | ExP/EnMP | Policies/laws/programmes relevant to the EnMP |

*Figure 36: Screen clip of Exercise 3 master sheet columns to complete.*

4. Identify data sources to populate the indicators, assess behaviour over time and stakeholders who may be able to provide these data (Column AI).
5. Identify on what level the pressure occurs, e.g. Local, Regional, National or International (Column AJ).
6. Assess changes (trends) over time. What is a meaningful period of time across which to work (Column AK) and what data are available on previous states (Column AL) and the current state (Column AM)?
7. Add the confidence level and any other comments to Columns AN and AO.
8. Categorise each pressure as either an exogenic pressure (ExP) or an endogenic managed pressure (EnMP) (Column AP).
9. Identify policies, laws and programmes relevant to the management of the endogenic managed pressures (Column AQ).
10. Use the Pressures Behaviour Over Time Graph link on the home page to fill in the Sheet with data of the indicators (Figure 37).

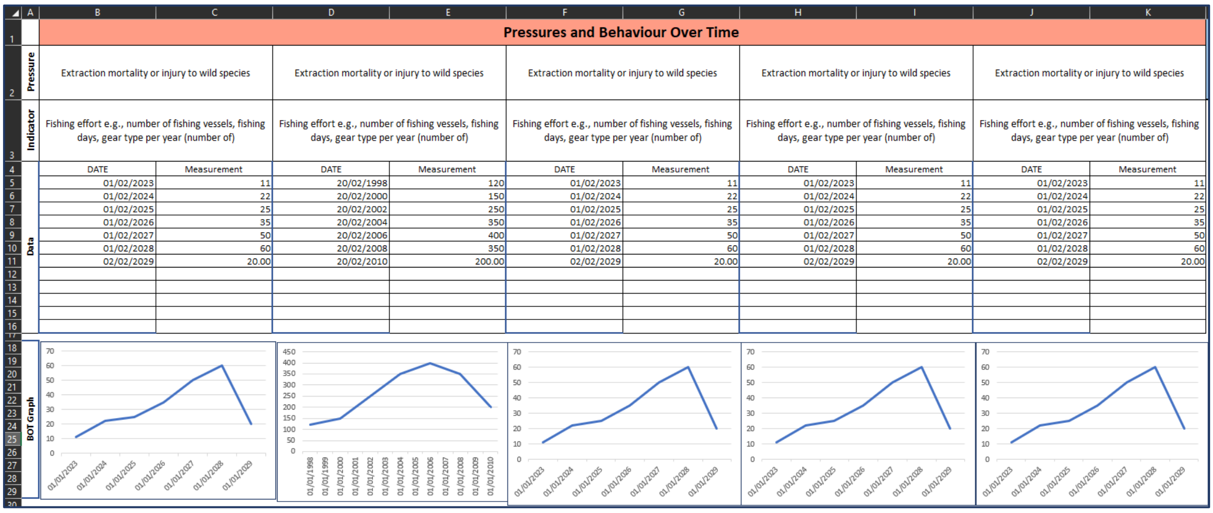



Figure 37: Screen clip of Behaviour Over Time Graphs sheet for the Marine Processes and Functioning indicators.

11. Next we assess the relationship between Pressures and Marine Processes and Functioning by clicking the 'Adjacency matrix for Marine Processes and Functioning and Pressures' on the home Sheet.
12. Referring to the indicators BOT, use the dropdown cells in the both adjacency matrices (Adjacency matrix and sensitivity matrix) to assign if two variables have a + (giving to) or – (taking away) connection and if this is a strong, medium or weak positive or negative (*Figure 38)*.

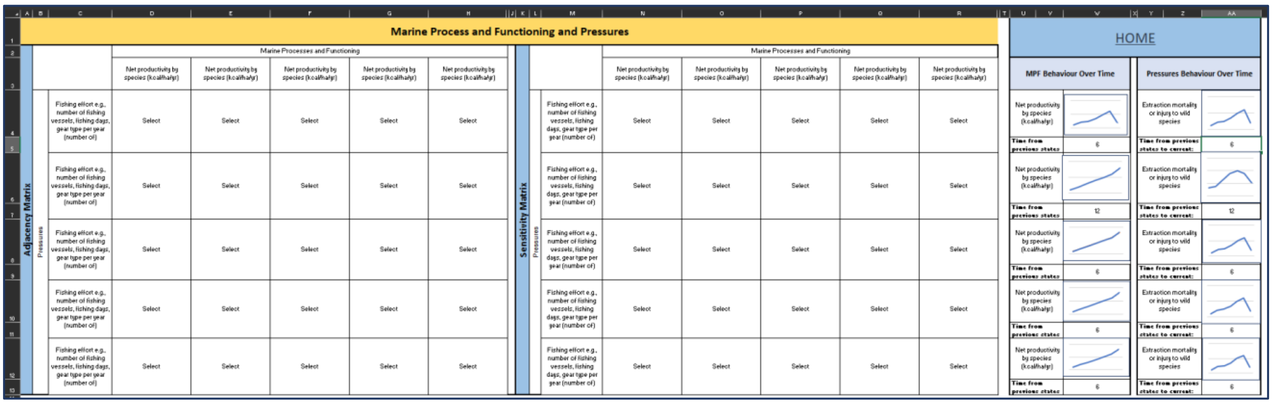



Figure 38: Screen Clip of the Adjacency Matrix Excel sheet to complete in relation to Marine processes and Functioning and Pressures. Cells worded 'select' contain the dropdown list, the rest of the cells will be auto-populated from the master sheet.

13. Export the KUMU sheet called 'KUMU Marine Processes and Functioning and Pressures' to a .csv file. Go to Kumu and press the green + to upload.

## Exercise 4: Specifying Activities that Affect Pressures

1. For each pressure (Column V), with reference to BP6: *Indicators,* specify the individual, group/sector, national and/or international economic and social activities that give rise to that pressure (Column AS) (Figure 39).
2. Using the dropdown list (Column AT), identify indicators for each marine process and function (multiple indicators are possible – specify ecosystem service indicators in physical units only but not monetary units).
3. Assign a concise name for the Activity in the Kumu indicator column (Column AU).
4. Identify data sources to populate the indicators, assess behaviour over time and stakeholders who may be able to provide these data (Column AV).

5. Specify if the Activity is carried out by an individual, group/sector, national and/or international economic and social entity using the dropdown list in Column AW.

| Exercise 4 | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Activity Indicator Behaviour over time/Trend | | | | | | | |
| Activity Code | Dominant Activites | Indicators of Activityties Scope/Scale | Kumu Indicator Name (Four words or less describing the indicator) | Activity Indicator Data Source (Organisation and/or Named Individual) or Data Gap | Activityfies Local (Individual, group/sector, national, international) | What is the relevant period to assess indicator change? | Previous states (T-1, T-2,...)? | Current state (T0)? | Data confidence level (5 highly certain-0 highly uncertain) | Comment on Behaviour over time/Trend | Agreements/Laws/ Policies/ Programmes | Comment on Implementation, Monitoring and Evaluation |

*Figure 39: Screen Clip of the Exercise 4 columns to complete.*

6. Assess changes (trends) over time. What is a meaningful period of time across which to work (Column AX) and what data are available on previous states (Column AY) and the current state (Column AZ)?
7. Add the confidence level and any other comments to Columns BA and BB.
8. Identify policies, laws and programmes relevant to the management of the activities (Column AK) and comment on how well they are implemented, monitored and evaluated (Column BC) and any comments on the implementation, monitoring and evaluating in Column BD.
9. Use the Activities Behaviour Over Time Graph link on the home page to fill in the Sheet for data of the indicators (Figure 40).

| Activities Behaviour Over Time | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Activity | Oil and gas infrastructure | | Oil and gas infrastructure | | Oil and gas infrastructure | | Oil and gas infrastructure | | Oil and gas infrastructure | |
| Indicator | Capacity in a (given period) in a (given geographical area) of (given activity) using (given technique) | | Capacity in a (given period) in a (given geographical area) of (given activity) using (given technique) | | Capacity in a (given period) in a (given geographical area) of (given activity) using (given technique) | | Capacity in a (given period) in a (given geographical area) of (given activity) using (given technique) | | Capacity in a (given period) in a (given geographical area) of (given activity) using (given technique) | |
| Data | DATE | Measurement | DATE | Measurement | DATE | Measurement | DATE | Measurement | DATE | Measurement |
| | 01/02/2001 | 10 | 01/02/2001 | 10 | 01/02/2001 | 10 | 01/02/2001 | 10 | 01/02/2012 | 10 |
| | 01/02/2002 | 20 | 01/02/2002 | 20 | 01/02/2002 | 20 | 01/02/2002 | 20 | 01/02/2013 | 20 |
| | 01/02/2003 | 30 | 01/02/2003 | 30 | 14/08/2025 | 30 | 14/08/2025 | 30 | 01/02/2014 | 30 |
| | 01/02/2004 | 40 | 01/02/2004 | 40 | 15/08/2025 | 40 | 15/08/2025 | 40 | 01/02/2015 | 40 |
| | 01/02/2005 | 50 | 01/02/2005 | 50 | 16/08/2025 | 50 | 16/08/2025 | 50 | 01/02/2016 | 50 |
| | 01/02/2006 | 60 | 01/02/2006 | 60 | 17/08/2025 | 60 | 17/08/2025 | 60 | 01/02/2017 | 60 |
| | 01/02/2007 | 70 | 01/02/2007 | 70 | 18/08/2025 | 70 | 18/08/2025 | 70 | 01/02/2018 | 70 |
| | 01/02/2008 | 80 | 01/02/2008 | 80 | 19/08/2025 | 80 | 19/08/2025 | 80 | 01/02/2019 | 80 |
| | 01/02/2009 | 90 | 01/02/2009 | 90 | 20/08/2025 | 90 | 20/08/2025 | 90 | 01/02/2020 | 90 |
| | 01/02/2010 | 100 | | | 21/08/2025 | 100 | 21/08/2025 | 100 | 01/02/2021 | 100 |
| | 01/02/2011 | 200 | | | 22/08/2025 | 110 | 22/08/2025 | 110 | 01/02/2022 | 110 |
| | 01/02/2012 | 300 | | | 23/08/2025 | 120 | 23/08/2025 | 120 | 01/02/2023 | 120 |

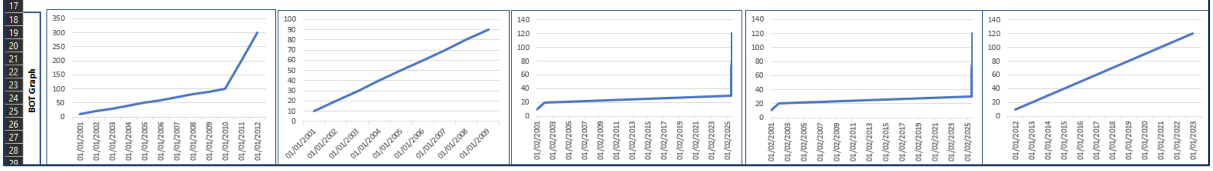



*Figure 40: Screen clip of Behaviour Over Time Graphs sheet for the Activity/ies indicators.*

10. Next we assess the relationship between Marine Processes and Functioning and Ecosystem Services by clicking the 'Adjacency matrix for Ecosystem Services and Marine Processes and Functioning on the Home Sheet (Figure 41).
11. Referring to the indicators BOT, use the dropdown cells in the both adjacency matrices (Adjacency matrix and sensitivity matrix) to assign if two variables have a + (giving to) or – (taking away) connection and if this is a strong, medium or weak positive or negative interaction.

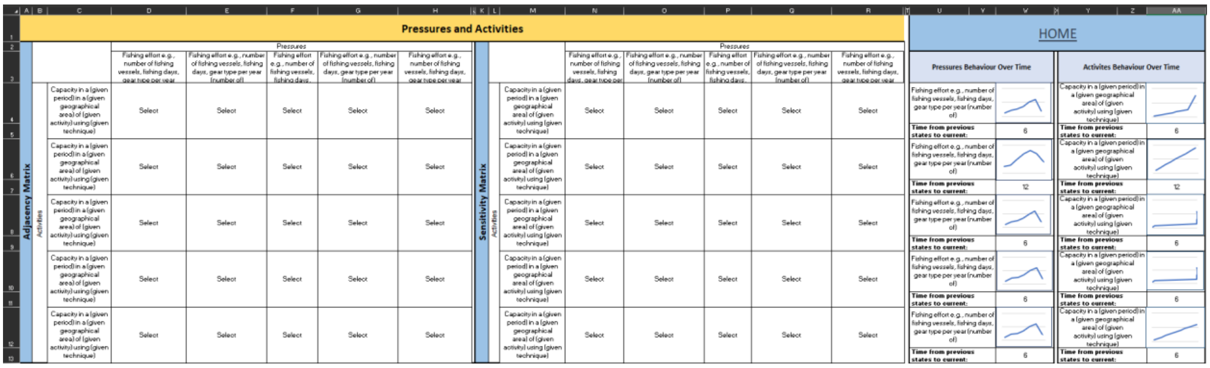



*Figure 41: Screen Clip of the Adjacency Matrix Excel sheet relating to Pressures and Activities to complete. Cells worded 'select' contain the dropdown list, the rest of the cells will be auto-populated from the master sheet.*

12. Export the KUMU sheet called 'KUMU Pressures and Activities' to a .csv file; go to Kumu and press the green + to upload.

## Exercise 5: Specifying Drivers that give rise to Activities

1. For each activity (Columns AS), with reference to BP6: *Indicators*, specify the human needs that each activity is aimed at satisfying (Column BF)? Is there anything else that is driving activities at different levels (individual, group, regional, national and international)? (Figure 42)
2. Using the dropdown list (Column BG), Identify indicators for the strength of needs (Column BG).
3. Assign a concise name for the Drivers/Needs in the Kumu indicator column (Column BH).

| BE | BF | BG | BH | BI | BJ | BK | BL | BM | BN | BO |
|---|---|---|---|---|---|---|---|---|---|---|
| Exercise 5 | | | | | | | | | | |
| Need Code | Need(s) | Indicator of Strength of Need(s) | Kumu Indicator Name (Four words or less describing the indicator) | Ecosystem Service Indicator Data Source (Organisation and/or Named Individual) or Data Gap | Pressure Indicator Behaviour over time/Trend | | | | | Comment on the Need and any current ecological, economic and social trends affecting it |
| | | | | | What is the relevant period to assess indicator change? | Current state (T0)? | Previous states (T-1, T-2,..)? | Data confidence level (5 highly certain-0 highly uncertain) | Comment on Behaviour over time/Trend | |

*Figure 42: Screen Clip of the Exercise 5 columns to complete.*

4. Identify data sources to populate the indicators, assess behaviour over time and stakeholders who may be able to provide these data (Column BI).
5. Assess changes (trends) over time. What is a meaningful period of time across which to work (Column BJ) and what data are available on previous states (Column BL) and the current state (Column BK)?
6. Add the confidence level and any other comments to Columns BM and BN.
7. Use the Drivers Behaviour Over Time Graph link on the home page to fill in the Sheet for data of the indicators (Figure 43).
8. Comment on any current ecological, economic and social trends affecting each need identified (Column BK).

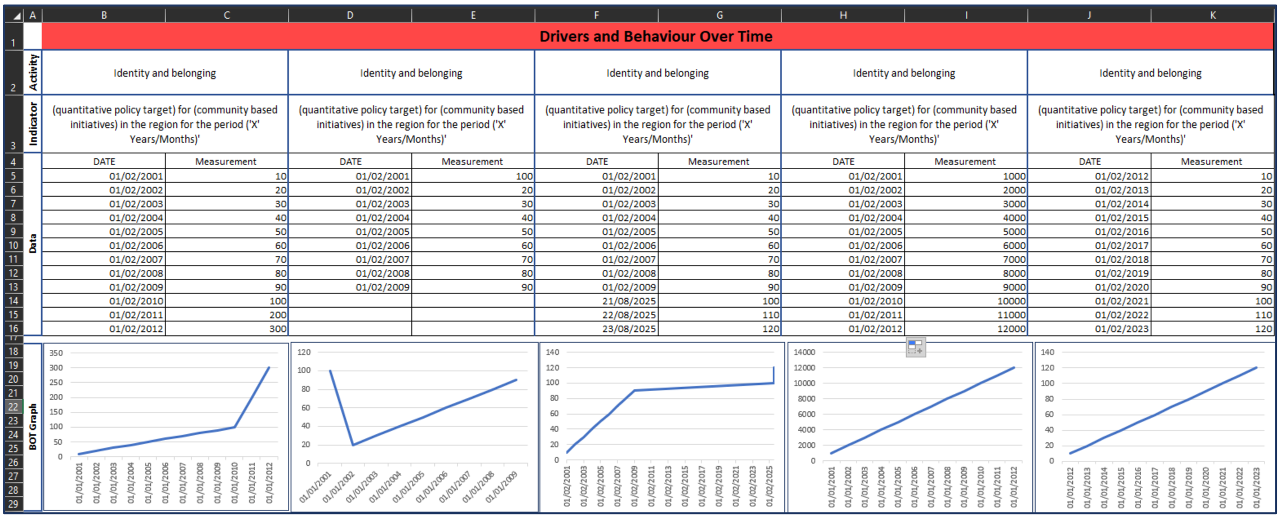



*Figure 43: Screen clip of Behaviour Over Time Graphs sheet for the Driver indicators.*

9. Next we assess the relationship between Activities and Drivers by clicking the ‘Adjacency matrix Activities and Drivers’ on the home page (Figure 44).
10. Referring to the indicators BOT, use the dropdown cells in the both adjacency matrices (Adjacency matrix and sensitivity matrix) to assign whether two variables have a + (giving to) or – (taking away) connection and whether this is a strong, medium or weak positive or negative interaction.

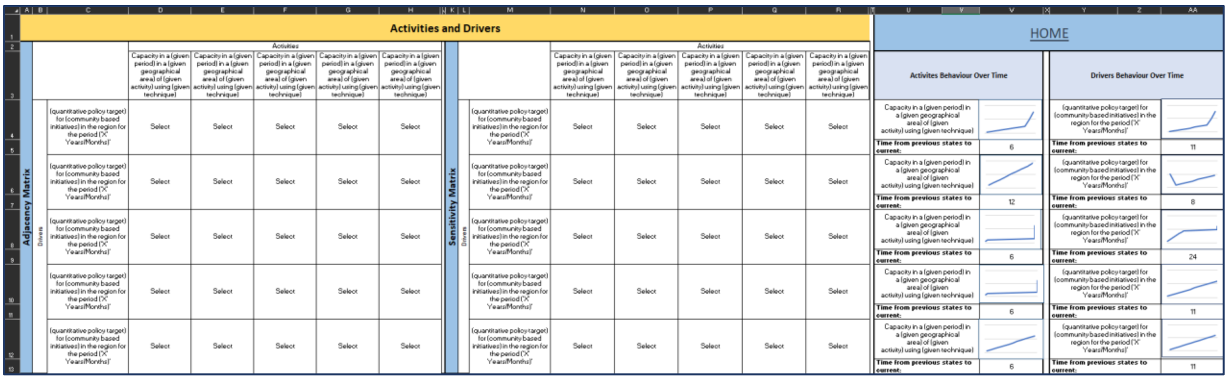



*Figure 44: Screen Clip of the Adjacency Matrix Excel sheet relating to Drivers and Goods & Benefits to complete. Cells worded ‘select’ contain the dropdown list, the rest of the cells will be auto-populated from the master sheet.*

11. Export the KUMU sheet called ‘KUMU Activities and Drivers’ to a .csv file; go to Kumu and press the green + to upload.

## Exercise 6: Closing the Loop between Drivers and Impacts on Welfare (Goods/Benefits)

We can close the loop between drivers and goods/benefits by:

1. Following the ‘E6: Closing the loop’ link on the Home sheet to the Drivers and Goods & Benefits adjacency and sensitivity matrix.
2. Referring to the indicators BOT, use the dropdown cells in the both adjacency matrices (Adjacency matrix and sensitivity matrix) to assign if two variables have a + (giving to) or – (taking away) connection and whether this is a strong, medium or weak positive or negative interaction (Figure 45).

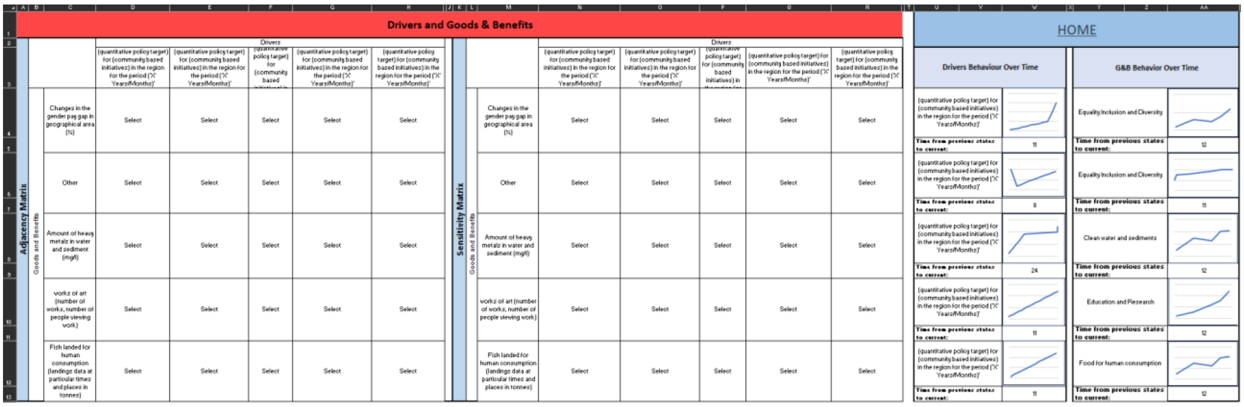



*Figure 45: Screen Clip of the Adjacency Matrix Excel sheet relating to Drivers and Goods & Benefits to complete. Cells worded 'select' contain the dropdown list, the rest of the cells will be auto-populated from the master sheet.*

3. Export the KUMU sheet called 'KUMU Drivers and Goods and Benefits' to a .csv file; go to Kumu and press the green + to upload.

## Exercise 7: Creating an Impact-based CLD

### *Data availability, System and Software Requirements*

The aim of the Integrated Systems Analysis is to approach the goal and/or problem to make the best-informed decision possible. A lack of data may hinder the application of the ISA in data-poor areas. Alternative data types, such as local knowledge, expert judgement, published literature on the area or lower-resolution data, could be used in such cases to support the analysis.

Additionally, it is important to note the computational demands of software such as Kumu and a sufficiently high specification computer will be required to prevent system crashes (this is unlikely to occur on systems with i7 and i9 processors, 10$^{th}$ Gen and above), especially with causal loop diagrams covering many connections between elements. We recommend using the filters along the bottom of the diagram to filter out other elements to conduct a loop analysis and conduct this in smaller chunks to prevent your browser from crashing (this process is detailed within Exercises 8 and 9).

**REMEMBER:**

A PIMS Consideration referring to Data Protection (information can be found in the PIMS Excel File) - note that the use of Kumu operates in public workspaces unless private maps are purchased. Further information on this within the Kumu software can be found here: https://docs.Kumu.io/overview/accounts-and-workspaces.

### *Preparing Kumu to import your adjacency matrices*

1. On the ISA excel workbook go to the sheet named 'Label and Type' and export the worksheet to .csv file with the same name.
2. Go to https://Kumu.io/ and create a new project in Kumu and choose the Causal Loop template. Give the project a name that relates to the Impact in focus.
3. Press the green button in the bottom middle of the screen and import the spreadsheet and 'Map all Type values to Description' (when you import tick the 'wipe existing map data on import') (Figure 46 & 47).

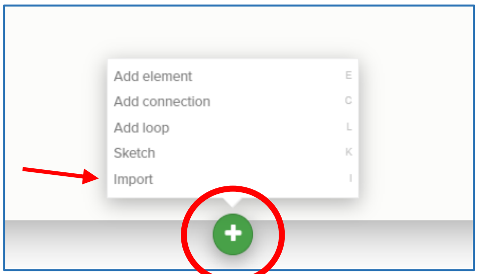



*Figure 46: Screen clip of how to import within the KUMU interface.*

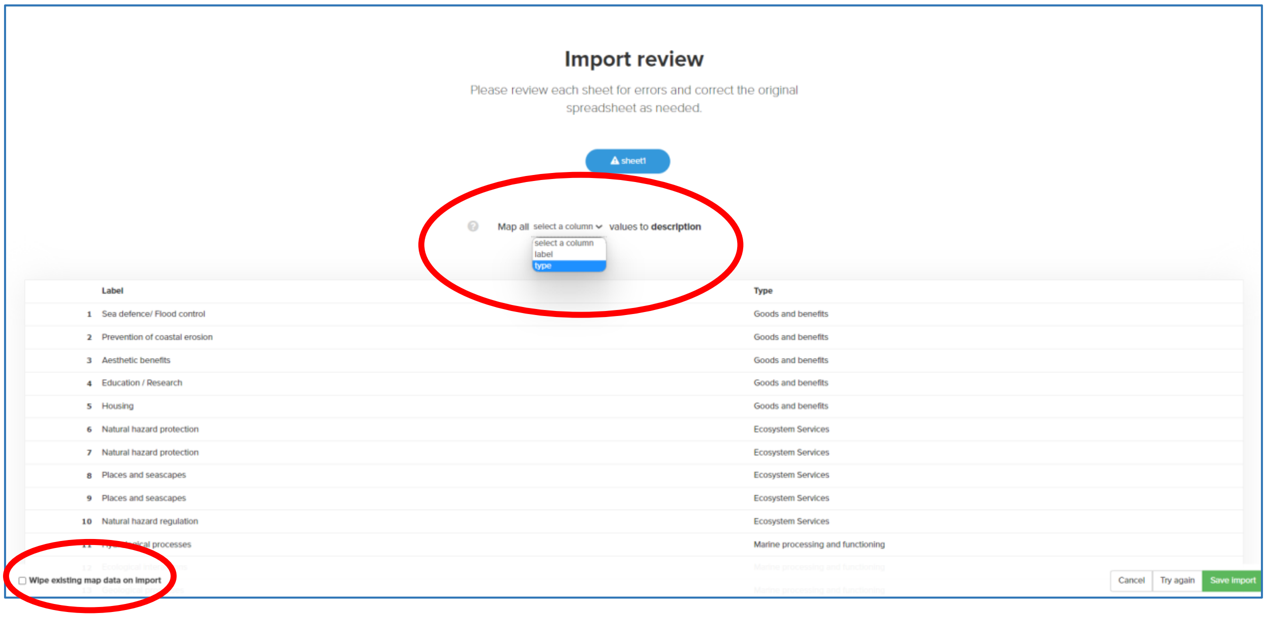



*Figure 47: Screenshot of the KUMU interface and where to click to iimport the labels and types csv file.*

4. Copy the all code from the file named ‘Kumu_Code_Style’ and paste in to the advanced editor in Kumu (Figure 48 & 49).

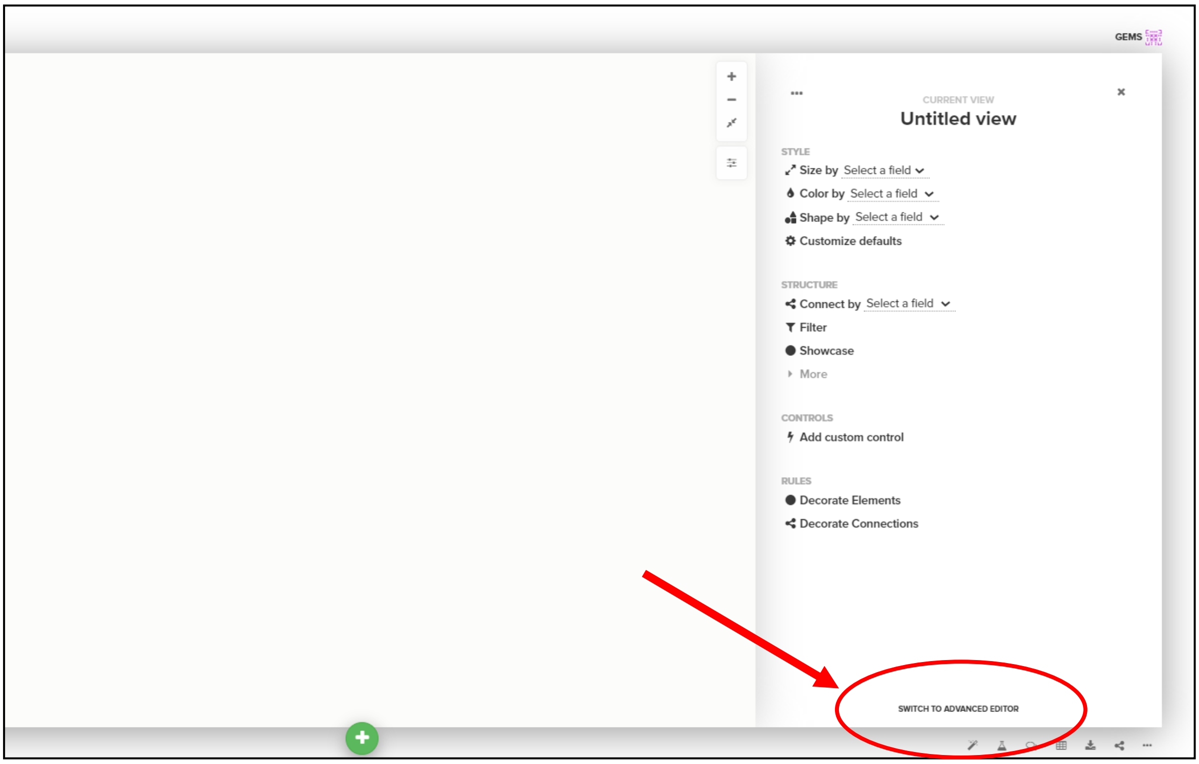



*Figure 48: Screenshot of the KUMU interface of where to click to access the advanced editor.*

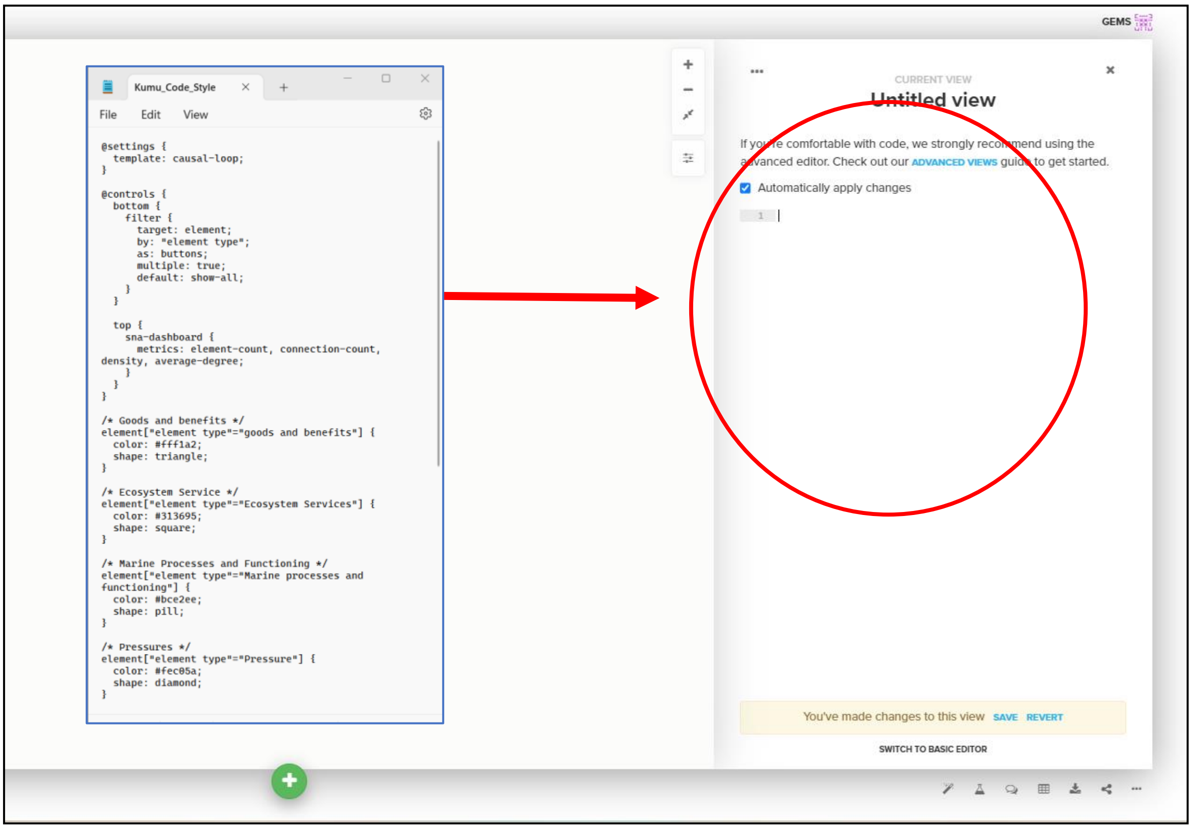



*Figure 49: Where to copy and paste the 'Kumu_Code_Style' within the KUMU interface.*

## Importing Adjacency Matrix and Decorating Connections

When completing the adjacency matrices in earlier exercises, this information is auto-populated a sheet in the workbook formatted to be compatible with the Kumu software. To retrieve these sheets and make them able to be uploaded into Kumu, please use the links on the home page in row 16 to download each sheet as a .csv file. Exercises 2 – 7 are included this step, although this is a stage to make sure all are downloaded, saved and named appropriately and imported to Kumu ready for the analysis.

**REMEMBER:**

A PIMS Consideration when downloading multiple .csv files, it is recommended to save them in a file altogether and name them appropriately so you can find the files easily when importing to Kumu.

1. If you have not already done so, download the six adjacency matrices as .csv files using the links in row 16 of the Home sheet to a locatable folder on your device (Figure 50).

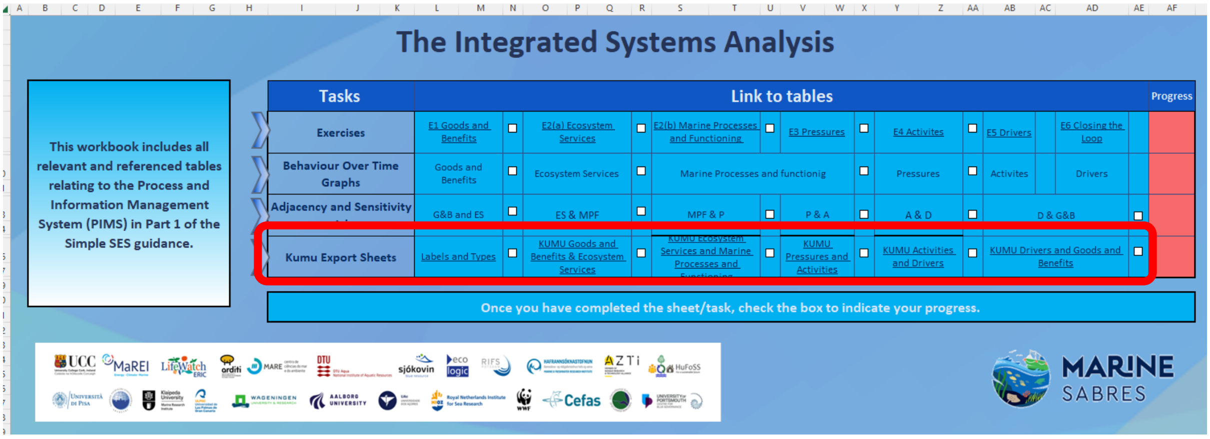



*Figure 50: Location within the ISA Excel document to locate the KUMU formatted information.*

2. Upload each of the csv files to Kumu using the import button (make sure you do not wipe previous data on import).
3. Now that you have customised the decoration of elements and connections, you should save this 'view' by giving it a name (see tabs at the top left-hand side) so that you will be able to see other Impact based CLDs that you create in this project through this view, that is with this decoration.

### *Reflecting on BOT alongside CLD*

At this point, you may wish to spend some time reflecting on the CLD that you have created, how it captures Dynamic Complexity and Behaviour Over Time (BOT) (https://thesystemsthinker.com/behaviour-over-time-diagrams-seeing-dynamic-interrelationships/).

BOT graphs (also called 'reference modes') show the pattern of behaviour of elements over an extended period of time e.g. a reinforcing loop may show a BOT of a virtuous or vicious nature as the growth or decline of something may have positive or negative consequences depending on the context. In BOT graphs, the horizontal axis represents time and the vertical axis represents the performance measure of interest. The important parts of BOTs are the overall directions and variations, not the numerical value of the element. Therefore, BOTs usually give approximate indications rather than the exact numerical value of the element. The behaviour of several elements can be shown in the same BOT graph.

Whilst the DAPSI(W)R(M) is useful for issue structuring, as it tends to lead us to focus on identifying data gaps, but not really doing anything about them or knowing whether they are important, so understanding can be constrained by the data that are readily available. BOT graphs can help break the data availability dilemma by building causal theories before we look to gather the necessary data. The BOTs can be used to connect past observed behaviour with future behaviour in a way that offers insight into underlying causal structures and through the development of our understanding of potential system behaviours guide our search for data to prove or disprove building such theory.

Behaviour over time graphs can be used to identify which types of system processes are occurring. For example, a rapidly increasing or decreasing behaviour over time graph indicates that reinforcing loops are influencing the system (see Figures A and B in Figure 46). In contrast, an oscillating behaviour over time graph would indicate that balancing feedback mechanisms are occurring in the system (see Figure C Figure 51).

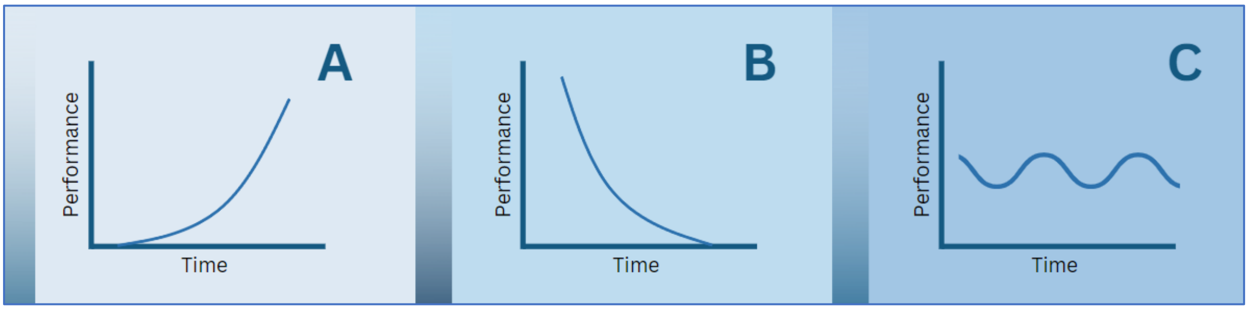



*Figure 51: Behaviour over time Graphs – A and B represent reinforcing feedback loops, and C represents a balancing feedback loop, redrawn from Mclean, et al. (2019).*

In summary, the behaviour of elements key to the issue of concern are plotted in a BOT and a theory of causal behaviour is articulated. Data are then sourced to either prove or disprove the theory. An iterative process between theory-building and data analysis will create a better understanding of the situation studied.

## Exercise 8: Moving from Causal Logic Chains to Causal Loops

The DAPSI(W)R(M) model as mapped on to risk assessment and management (Cormier et al. 2019) may be used to identify causal logic chains (e.g. using Bow-tie analysis) but this implies that the marine environment can be managed on the basis of linear cause and effect which may neglect important feedback interactions between elements unless sequential Bow-ties are created. Alternatively, Causal Loop Diagrams (CLDs) help us to understand how the parts of a system interact to give rise to emergent behaviours and properties, particularly how feedback can cause the behaviour of a system to be complex and difficult to understand and manage. Therefore, while DAPSI(W)R(M) can conceptualise many of the key elements and connections relating to our impact of concern, the analysis needs to be extended to focus on where there are feedback relationships that have not been captured so far and to allow closing some of the critical feedback loops.

As such, in undertaking the analysis, we first need to understand more about types of feedback loop and labelling conventions. There are sign and letter types of loop polarity indicator in CLDs:

A ‘positive feedback’ or ‘reinforcing’ loop - this type of loop is often marked with the letter ‘R’ or ‘R’ is included in the naming of the loop. This type of feedback loop can be associated with growth or decline.

A ‘negative feedback’ or ‘balancing’ loop - this type of loop is often marked with the letter ‘B’ or ‘B’ is included in the naming of the loop. This type of feedback loop can be associated a steady state or goal-oriented behaviour.

Loop polarity is often established by assessing whether there is an odd or even number of negative links in a loop – if there is an even number of negative links in a loop then the loop is likely to be a positive feedback loop; conversely, an odd number of negative links in a loop is likely to be a balancing loop. However, this short-cut way of working out the overall effect of a loop can lead to mislabelling so it is important to think about the logic of each loop that you identify as you label it. In addition, hash (#) marks on the connector arrows between elements denote delays between cause and effect.

When drawing small CLDs, feedback loops can be relatively easy to identify (video available at https://docs.Kumu.io/guides/what-are-loops) but when CLDs get larger then there can be feedback loops that drive system behaviour that are not so easy to identify. In order to detect such loops, Kumu has a useful automatic loop detection function:

1. Click on the green plus icon at the bottom of your CLD, and choose "Add loop" (Figure 52).
2. Click "detect loops automatically"
3. A menu will pop up on the left side of your CLD with the detected loops.


*Figure 52: Screenclip of where to click in the KUMU interface to conduct the automatic loop analysis.*

Loops are ranked from shortest (least number of elements) to longest (most elements) and placing the cursor over any loop name will indicate it both on the CLD and show which elements/connections are a part of it. It is important to name and save identified loops by Clicking on any loop number to give it a name and press enter on your keyboard (if you do not press enter then the name of the loop will not be registered). In order to edit a loop, click on the loop label to open its profile in the left side panel. In the bottom right corner of the profile, click the pencil icon to select and de-select connections that are a part of the loop (Figure 53).

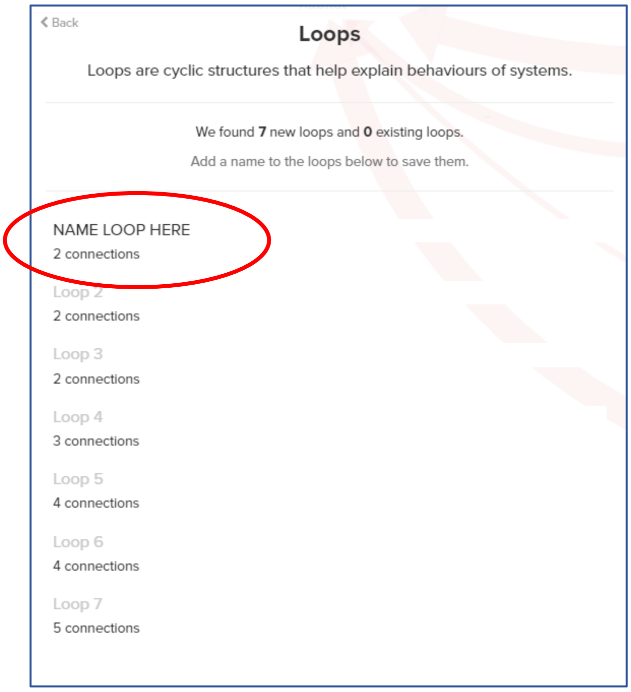



*Figure 53: Screenclip of where to click and type within the KUMU interface to name Loops in the diagram, which also saves loops on the map.*

Adding a name to a loop will add that label to your map in the centre of the loop. If the loop name is not immediately visible, then beware that it could be hidden behind an element. Remember, unnamed loops are not saved in your dataset.

You can generate a spreadsheet of all of the loops in your CLD using the Table function (this function also allows you to view and edit the underlying data in your map as a spreadsheet) see: https://docs.Kumu.io/guides/table. You can access Table by clicking the spreadsheet icon in the lower right corner of your map. It is recommended that you keep an Excel file of all of the loops in each of your CLDs (you may wish to create different sheets for each CLD). You may want to identify those loops that you believe are significant by, for example, using a bold font for their labelling.

Below you can find summary advice on how to phrase the CLD and avoid difficulties (Haraldsson and Sverdrup, 2021, modified from Richardson and Pugh, 1981).

*Variables should be self-explanatory:*

The variables in the CLD should be nouns or noun phrases, not verbs, i.e. variables which represent measurable quantities that can fluctuate (e.g., litres of water, population and money). These measurable quantities help to give the main storyline(s) in the diagram.

*The action is in the arrows:*

The arrows indicate the direction of the action in the story; for example, if spending increases and money decreases as a result, use an arrow (polarity) rather than a word to convey the decrease.

*Clarify the actions:*
Make it clear what a variable does when you send an action through (i.e., when an arrow is used); for example, write 'tolerance for poor water quality' rather than 'attitude towards water quality' as 'tolerance' is a more specific descriptor than 'attitude' (i.e., 'tolerance' and therefore 'intolerance' fall

under the category 'attitude'). In addition, rather than using causal links to mean 'and then', simply interpret the link as an increase or a decrease.

*Always use units:*
If no units are attached to the variables, they will need to be created. While some social or welfare variables may be difficult to quantify, using a scale (e.g., 0-100 or a Likert-like scale where numbers represent a range of responses from, for example, definitely not, not likely, likely, very likely, and definitely yes) is an acceptable way to define units. This is appropriate when dealing with dimensionless variables such as happiness, anger or stress.

*Use positive wording:*
Use positive expressions when labelling variables as experience suggests that users of the diagrams find positive expressions easier to interpret than negative expressions. When reading polarities in a loop, positive expression creates a better flow for the reader, whereas negative expression tends to create a double negative in the interpretation.

*Avoid double explanations of variables:*
If there is more than one event in a variable when an action runs through it, make these events new variables and explain what they do. For example, a variable named 'Fishing Activities'. This could include two distinct events: 'Commercial Fishing' and 'Recreational Fishing'. Each of these events could have different influences on the marine ecosystem, and thus, could create complexity in our model. To avoid double explanations of the 'Fishing Activities' variable, we should create these events as new variables, which can help clarify the overall system dynamics. Instead of having a single 'Fishing Activities' variable affecting, say, 'Fish Population', we would now have two distinct variables: 'Commercial Fishing' and 'Recreational Fishing'. Each of these new variables would then connect separately to 'Fish Population', allowing us to better understand and articulate their specific impacts and interrelationships within the marine ecosystem. By separating these activities into their own variables, we can more accurately represent their unique effects on the marine environment, such as the potentially more significant impact of commercial fishing due to its scale and intensity compared to recreational fishing.

**REMEMBER:**

*A loop has to have feedback, if not, it is not a loop* - Remember, only classify a feedback loop as reinforcing or balancing if it is circular.

## Exercise 9: Exporting your CLD and Creating/Adding to your Issue-based CLD

*Exporting:*

In order to create a back-up of your CLD and also for creating/adding to the Issue-based CLD, it is necessary to export each of your Impact-based CLDs after you have created them. This is achieved by: Open your Impact-based CLD; Click on the 'Export' button in the bottom right hand corner (Figure 54); Select 'Export JSON' and the file will automatically save to your downloads folder. It is recommended that you rename the file and save it to your project folder as this is your back-up file. For the purposes of creating/adding to the Issue-based CLD, select 'Export XLSX' and the file will automatically save to your downloads folder. It is recommended that you rename the file and save it to your project folder.

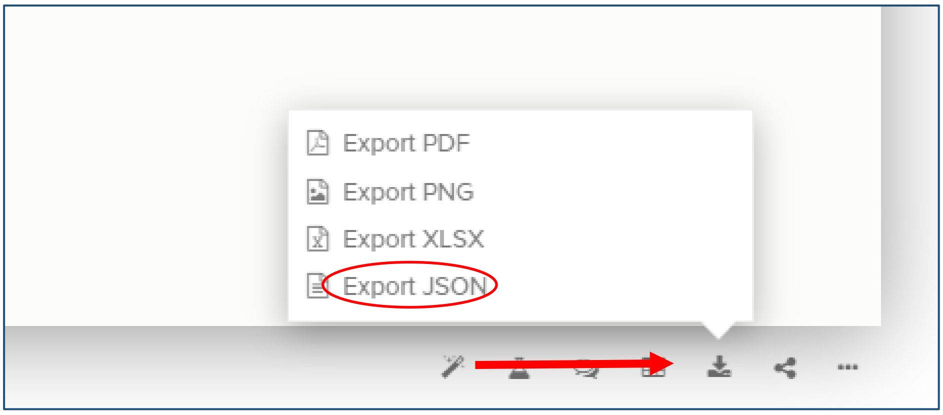



*Figure 54: Screenclip of where to click within the KUMU interface to export the data to a JSON file.*

*Creating an overall Issue-based CLD that is a composite of all of the separate Impact-based CLDs:*

- To create an Impact-based CLD, it is recommended that you create a new project in Kumu.
- To add your first Issue-based CLD to it, click on the green button in the bottom centre of your screen. Select 'import' and choose the .JSON file that you have just downloaded as this should carry the custom decorations of elements and links with it but you will have to label this view in your new project.
- Each time that you create a new Impact-based CLD, it is recommended that, after you have done a loop analysis, you export the file as an .xlsx and then import it to your Issue-based CLD (if you use an .xlsx file then it will add it to your Issue-based CLD but a .JSON file will not do this). It is possible that the process will create new causal loops that are not present at the individual Impact-based CLD level so it is important that each time you do an automatic loop analysis, name them and keep a note of any additional loops that are created.
- All of the loops that are present in the Impact-based CLDs will also be present in the Issue-based CLD and there may be significant additional loops that are also created. You may wish to do a loop analysis at the Issue level and cross check the loops identified in the Impact-based CLDs.

**REMEMBER:**

Some maps are simply too large for Kumu to automatically detect loops, as the number of loops on a highly inter-connected system map can quickly run into the thousands. If you notice that loop detection is not giving you any results, you can try one of two things: (1) try simplifying your map by deleting unnecessary elements and/or connections (see following section on clarifying), and (2) filter out one part of your map and run loop detection again. Make sure to save your loops before you filter another part of the map!

## Exercise 10: Clarifying

Once you have developed Impact-based CLDs for all your priorities and imported all of these into one composite Issue-based CLD, it is likely that the Issue-based CLD will be of highly complex with many elements and connections. Whilst the model may be seen to represent the complexity of the issue, it is likely to be somewhat difficult to comprehend and there is a need to focus on creating a simpler, fundamental version of the working model.

During model building, the complexity together with the information value is increasing but, given our limited cognitive capacity to comprehend complexity, we have to bear in mind that we can reach an optimal point where more information actually brings less value. Therefore, simplifying the module can add value and understanding - grasping the whole picture is more important, at this point, than the detail.

The simplification method is based on two activities: *endogenization* and *encapsulation* (Bureš, 2017). Prior to discussing these processes, it is first necessary to consider the elements in a CLD which are either endogenous, both influencing and influenced by other variables within the CLD, or exogenous, influencing but not being influenced by other variables. Because of the process that we have followed in constructing our CLDs, you are likely not to have any exogenous elements.

*Endogenisation*:

This process deals with elements in your CLD that only have an effect on other elements but are not influenced by anything within the system, these are known as exogenous elements. An example in a marine context might be the amount of sunlight that reaches the ocean surface. This has a direct impact on the photosynthesis rate of phytoplankton but is not directly affected by other elements within the marine ecosystem.

In endogenisation, we identify and list all these exogenous elements. By doing so, we make a record of their influence within the system. The purpose of listing these elements is so that we remember their impacts even when they are removed in the simplification process. After identifying and listing, we can remove these exogenous elements from the CLD. This is done to make the system easier to understand and ensure that all remaining elements in the CLD have influences that are contained within the system itself.

*Encapsulation:*

This process is focused on variables that only have one input and one output, known as Single Input Single Output (SISO) variables. In a marine context, an example might be the transformation of sunlight into photosynthetic energy by phytoplankton. This element takes one input (sunlight) and produces one output (photosynthetic energy).

To encapsulate, first, we identify and mark all SISO variables in the CLD. We do this so we can keep track of these transformation elements that help understand how the system dynamics move from one point to another. Next, we 'bridge' or bypass these SISO variables, effectively simplifying the CLD by removing these transformation steps and connecting the original input directly to the output. While doing this, we need to consider the polarity of the new link, which can be determined based on the number of links with negative polarities. For example, if sunlight (input) was linked to phytoplankton growth (output) through the SISO variable 'photosynthetic energy', in encapsulation we would remove 'photosynthetic energy' and directly link sunlight to phytoplankton growth.

*Remember, the goal of both endogenisation and encapsulation is to simplify the CLD, making it easier to understand the main connections and influences within the system, rather than getting lost in the details.*

## Exercise 11: Metrics, Identifying Root Causes and Leverage Points

Through their creation, CLDs serve to make clear your metal models (mind-maps), or those derived by the stakeholders during Work Package 2 activities. The CLD developed can be analysed and used in several ways (e.g. how to interpret a CLD - [https://www.linkedin.com/advice/0/how-do-you-use-causal-loop-diagrams-identify](https://www.linkedin.com/advice/0/how-do-you-use-causal-loop-diagrams-identify)) (see also, Haraldsson, 2021). The analysis of a CLD can identify leverage points for change (see Figure 55 for an analysis-based problem-solving map). By focussing on those elements that significantly influence system behaviour (multi-input and multi-output variables), we are better able to capture a meaningful explanation of system behaviour and identify how it can be influenced. These are the areas in the system where a minor alteration can have a significant effect on the system behaviour. To locate the leverage points, you should investigate the feedback loops that are causing the problem or hindering the defined goal and then consider how to weaken or break them.

Additionally, you should look for the feedback loops that are supporting the goal or resolving the issue and contemplate how to strengthen or create them. Furthermore, you should search for the delays or impediments that are creating inertia or instability in the system and contemplate how to reduce or increase them. Additionally, you should search for the parameters that are influencing the feedback loops and consider how to adjust or modify them. Lastly, you should aim to create the mental models that are forming the causal links and the feedback loops and contemplate how to challenge or change them (see also the stakeholder-created mind-maps in Marine SABRES WP2).

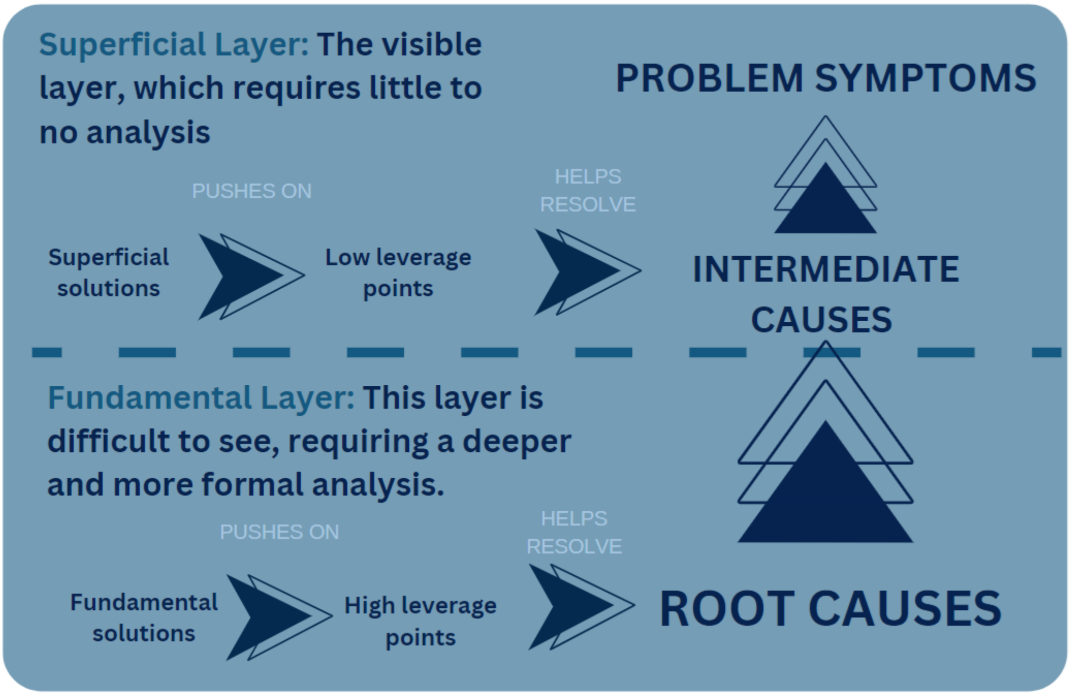



*Figure 55:An analysis-based problem-solving map redrawn from Lane (2008).*

Kumu offers a range of metrics and the following may be useful in analysing our CLDs (Table 6). These metrics were found in the Kumu documents, which can be accessed here.

*Table 6: Table extracted from the Kumu help documents which detail various metrics of analysis for CLDs.*

| Metric | Description |
|---|---|
| Degree | This counts the number of connections linking an element. |
| Closeness centrality | This measures the distance (in terms of the number of connections) each element is from all other elements. Elements with high outward closeness can spread information to the rest of the network most easily and usually have high visibility into what is happening across the network. |
| Betweenness centrality | This measures how many times an element lies on the shortest path between two other elements. In general, elements with high betweenness have more control over the flow of information and act as key bridges within the network. They can also be potential single points of failure. |

| | |
|---|---|
| Size | Size measures the number of neighbours of an element (plus the element itself). It is similar to degree but counts the number of elements instead of connections. |
| Indegree | Indegree measures the number of incoming connections for an element. In general, elements with high indegree are highly influenced by other elements. |
| Outdegree | Outdegree measures the number of outgoing connections for an element. In general, elements with high outdegree can reach a high number of elements and offer a potential point of leverage as small changes in this element may cascade throughout the system. |
| Eigenvector | Eigenvector centrality measures how well connected an element is to other well-connected elements. In general, elements with high eigenvector centrality are the leaders of the network, though they may not have the strongest local influence. |
| Reach (two-step out) | Reach measures the portion of the network within two steps of an element. In general, elements with high reach can spread information through the network through close 'friend-of-a-friend' contacts. |
| Reach efficiency | Reach efficiency normalizes reach by dividing it by size (number of neighbours). In general, elements with high reach efficiency are less connected but gain more exposure through each direct relationship. |
| MICMAC | MICMAC is a system analysis that explores element exposure (how much a given element is affected by other elements) and influence (how much a given element affects other elements). When plotted on an XY axis, these scores help you identify potential leverage points within the overall system. |

Certain fields also support weighting so you can include fields such as strength and frequency in the calculations. Betweenness, closeness and degree use connection fields for weighting while size and reach use element fields for weighting.

For the metrics that allow weighting, you will see an Advanced Options link once you select the metric. You can choose any numerical field for the weighting, but make sure you have values saved for the elements or connections based on which is used for the weighting. If you do not see the field you want to use listed, make sure the type for that field is set to numeric.

By default, all metrics are saved to a field with the name of the metric (betweenness calculations are saved to the "betweenness" field). Each time you run the metric the previous values are overwritten. If you wish to keep the previous values, rename the field (maybe it is "2014 betweeness" or "betweeness before") so that future saves do not overwrite the values.

Portraying which elements are the most well-connected can be achieved by combining metrics and sizing. First, run metrics to let Kumu calculate the number of connections of each element:

- Click on the "Metrics" icon in the bottom right corner of the map
- Select "Social Network Analysis" to open the Metrics menu
- Choose the "degree" metric from the dropdown list
- Click the large button "Discover the connectors/hubs" to see the results

- Kumu will automatically create a field called “degree” and save the values

**REMEMBER:**

- To rerun metrics (for example, if you added new elements and connections), just follow the same steps again.
- Metrics will not be calculated for elements that are filtered out of the map.
- To save multiple versions of the same metric, follow this guide
- You can run any of the metrics mentioned in this guide and then size based on them.
- Once the metrics are calculated, you can size your elements by going into Settings on the right and changing the "Size By" dropdown of the Basic Editor to the field of the metric you calculated (e.g. "degree"). More information on sizing can be found in this guide.

*In summary:*

- Walk through the major feedback loops, identify what type they are, and reduce them to the process that they are capturing
- Estimate the delays to estimate the timescale of each feedback loop
- Identify which elements and loops are dominant
- Consider if there are any aspects that are missing
- Consider the potential unintended consequences or side effects of intervening in the system
- Examining the above questions can help to provide a more comprehensive analysis of a CLD.

## Exercise 12: Presenting and validating a CLD and analysis

Presenting the CLDs that you have developed to stakeholders and gaining their comments and insights is an important part of validating your model. Validation is key to minimize any unconscious bias or ‘groupthink’ that may have been introduced by the group during development or misinterpretation of data.

When presenting your CLD to stakeholders, it is important to align the complexity of a CLD to the visual abilities of your audience (Barbrook-Johnson and Penn, 2022). If an audience will be discouraged or confused by large CLDs, or be confused by multiple interacting feedback loops, consider how the map can overcome this problem. The aim should not be to just produce a very simple CLD, although you may end up doing this, but to also think carefully about how you might frame and introduce it in ways which allow you to keep as much complexity as possible (e.g. introduce the impact CLDs first before presenting the issue-based composite CLD).

Kumu offers a number of features that may assist with this. Views offer many powerful features—decorations for sizing and colouring your data, filters for showing/hiding different items, controls for adding rich interactivity to your maps, etc. Different views can also be layered on top of one another via the @import syntax. For most maps, you can present a view that highlights your data in the best way possible, but more complex data demand a more complex visual approach, e.g. using different colour-coding and sizing rules, levels of focus, cluster connections. In essence, to get the most out of a more complex dataset, you will need to create several different visual variations (see the video at: https://docs.Kumu.io/guides/partial-views).

The focus feature (https://docs.Kumu.io/guides/focus) allows you to focus on one or more elements, connections, and loops, temporarily hiding the rest of the map. This is a very suitable tool for storytelling, allowing you to reduce the complexity of your system or network while you introduce the basic concepts behind your map. Focus is activated in one of two ways, by clicking and holding on any element, connection or loop or by selecting an element, connection or loop and then clicking the focus icon on the right side of your map. Once focus is activated, you can zoom in and out by degree using the + and - buttons. Click the focus icon again to bring the full map back into view.

Filter in the Basic Editor (https://docs.Kumu.io/guides/filter) Kumu code includes pre-defined sections. However, if you click the settings icon on the right side of the map, then click the icon to the right of **filter** to open up your filter settings you can amend these settings. If you are filtering by element or connection type, simply un-check the types you want to hide. To filter using other fields, use the "also include" and "but ignore" fields.

Click the 'Rocket' icon to the right of the input of each field to select what you want to hide or make visible. If you have hidden certain elements and connections using the type checkboxes, you can use the Also include tool to bring things back into view. However, you first have to un-check some of the boxes above, or this tool will have no effect. Use the 'But ignore' tool to hide elements and connections from your map. Anything you add here will override the settings in the checkboxes above and the 'Also include' tool.

Presentations in Kumu combine the best of PowerPoint, Prezi, and Kumu into one easy-to-use tool. Combine text, video, images and maps into a single, engaging presentation that anyone can access via URL (https://docs.Kumu.io/guides/presentations).

### *Stakeholder dialogue*

Stakeholder dialogue is the most popular method to validate CLDs simply by asking stakeholders questions such as:

- Does this make sense?
- Are we missing anything important in this section of the diagram?
- Is there anything that you feel should be removed in the diagram?
- Does this part of the system exist to your knowledge?
- Are appropriate system variables represented? If not, what variables are missing or should be removed?
- Are appropriate in- and out-flows represented? If not, what flows are missing or should be removed?
- Is the polarity of in- and out-flows accurately represented? If not, what changes would you make?
- Are delays in the system represented appropriately according to our knowledge of BOT? If not, what delays are missing, should be removed or changed?

Once the logic and structure of the CLD has been validated, it is important to focus on the dynamics and outcomes of your proposed responses, and a theory of change or storytelling approach can be used (https://blog.Kumu.io/how-systems-mapping-can-help-you-build-a-better-theory-of-change-4c85ae4301a8; Loops and Storytelling - https://www.youtube.com/watch?v=eZfIdWtFkRI).

## Exercise 12: Including Response (as management Measures) interventions in the system

Responses (as management Measures) affect the marine system in focus through management and operational actions (analogous to the operational and management controls in wider management systems, see Cormier et al., 2019). For example: an intervention such as an education initiative is an action and may be designed to change consumer tastes and preferences and therefore their needs and wants; for example, controls over certain fishing practices and gear restrictions will alter specific fishing activities. The CLD, based on the inclusion of particular indicators, and the BOT graphs capture the type and effect of past responses (measures) in the system (although, in practice, more recent responses may still be being implemented and/or their affects are still working through the system). It is necessary to identify new response(s) or changes in existing response(s) that are being considered as options to address the issue of interest, and identify which activity/ies in the system are affected by these interventions and how they are affected (i.e. a selected response may alter existing activity(ies) and/or create new activity(ies)).

Once you are satisfied that you have sufficiently developed, explored, validated and, where appropriate, simplified each Impact-based CLD and your composite Issue-based CLD, it is necessary to consider how to change the system behaviour to shift to a more desirable state. New response interventions being considered to address the focal issue/impact may involve taking action to change the current state of an element or introducing a new element in order to:

- Disrupt (positive/reinforcing loops) 'vicious cycles' and negative/balancing loops that might be suppressing desirable change.
- Encourage 'virtuous cycles' and or interrupting negative/balancing loops negative/balancing loops to support desirable change.

In addition, it is desirable to identify/seek to identify and influence leverage points, those elements that significantly influence system behaviour (multi-output elements). For each potential response being considered, it is important to trace through the effects of this through the system in focus articulating both storylines associated with dominant loops, the behaviour over time of key elements and the theory of change that will lead to an improved system state; it is necessary to keep a record of these.

In this final stage, response measures are chosen, and an action plan to implement can be arranged. The PIMS project stages can guide the closure of the project, and decisions relating to objective and goal evaluation can be made. The resulting response measures can include any relevant monitoring or future work, and the adaptive cycle will have this information for future iterations.

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# Appendix 1: Supporting information

## A Note on CLDs and Scenarios

As analogous to the Shared Socio-Economic Pathways (SSP) from the Intergovernmental Panel on Climate Change (IPPC, 2022.) which are developed in Marine SABRES WP5, Haraldsson and Bonin (2021) illustrate the use of Causal Loop Diagrams (CLD) in the analysis of the Scenarios for a Sustainable Europe in 2050 (SSE, 2050). The four scenario narratives (Ecotopia, A Pragmatic Path, Green Growth Paradigm, Utilitarian Technocracy for Good) from the SSE 2050 project were interpreted and contextualized to develop the CLDs in Kumu. In summary, scenarios and CLDs can be useful for informing responses by:

- Create a scenario CLD at the appropriate level (this may involve reinterpreting a global scenario CLD)
- Compare the scenario CLD with the already developed reference CLD

You can explore what would need to happen for the system to change from its current state (the reference state) to the scenario CLD state (theory of change) and ask - What actions could be taken to deal with any issues/impacts created through this process of change?

## Other useful links:

**Project management:** Extra information is available at: https://www.projectsmart.co.uk/lifecycle-and-methodology/introduction-project-management.php

**Kumu help:** https://docs.Kumu.io/about-Kumu/where-can-i-get-help

**Adjacency Matrix help**: https://docs.Kumu.io/frequently-asked-questions/how-do-i-restructure-my-adjacency-matrix

**Connection types:** https://docs.Kumu.io/guides/fields

**Systems Spaghetti:** https://blog.Kumu.io/juggling-conflicting-purposes-for-system-maps-1f973d384aeb

**Rich Pictures**: https://www.open.edu/openlearn/science-maths-technology/engineering-technology/rich-pictures

**Use of scenarios:** https://blog.Kumu.io/exploring-the-future-four-ways-to-combine-future-scenarios-with-causal-loop-diagrams-78a6869af05f

**Theories of change and CLDs:** https://blog.Kumu.io/how-systems-mapping-can-help-you-build-a-better-theory-of-change-4c85ae4301a8

**Use of Kumu for analysis:** https://onlinelibrary.wiley.com/doi/abs/10.1002/sdr.1701

## Further Reading:

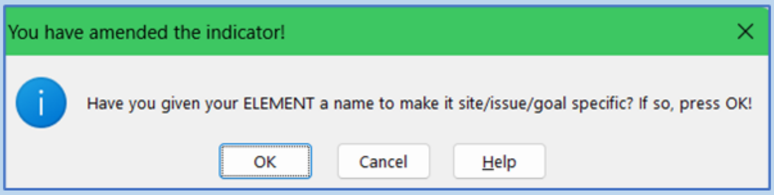
- Rigorously interpreted quotation analysis for evaluating causal loop diagrams in late-stage conceptualization Andrada Tomoaia-Cotisel, Samuel D. Allen, Hyunjung Kim, David Andersen, Zaid Chalabi

- Kenzie ES, Parks EL, Bigler ED, Wright DW, Lim MM, Chesnutt JC, Hawryluk GWJ, Gordon W and Wakeland W (2018) The Dynamics of Concussion: Mapping Pathophysiology, Persistence, and Recovery With Causal-Loop Diagramming. Front. Neurol. 9:203, https://www.frontiersin.org/articles/10.3389/fneur.2018.00203/full
- Causal Loop Diagrams in the book System Mapping : Barbrook-Johnson, P., Penn, A.S. (2022). Causal Loop Diagrams. In: Systems Mapping. Palgrave Macmillan, Cham. https://doi.org/10.1007/978-3-031-01919-7_4
- Get Your Model Out There: Advancing Methods for Developing and Using Causal-Loop Diagrams (PhD) Kenzie, E. S. (2021). *Get your model out there: Advancing methods for developing and using causal-loop diagrams* (Order No. 28318158). Available from Publicly Available Content Database. (2509246401). Retrieved from: https://www.proquest.com/dissertations-theses/get-your-model-out-there-advancing-methods/docview/2509246401/se-2
- Haraldsson, Hördur & Bonin, Daniel. (2021). Using systems approach to integrate Causal Loop Diagrams modelling in the foresight project Scenarios for a Sustainable Europe 2050. https://www.naturvardsverket.se/4a4387/globalassets/media/publikationer-pdf/6900/978-91-620-6975-9.pdf

## Frequently Asked Questions

**Q:** **In the ISA excel document, can we add to the possible categories? For example, we would like to add something about market pressures to Exercise 3, and Greenhouse emissions to Exercise 2(b) so that market-based mitigation solutions (for example) could be analysed later as a leverage point. In addition, it is likely that stakeholders will perceive other pressures that we have not yet envisioned, so it would be helpful to be able to add several categories (as there is only a single 'Other') category.**

**A:** Yes, the categories can be amended as necessary; if you change the indicators or the name of the element, you will get a pop-up that looks like the image below, prompting you to double-check it is site/issue/goal specific to ensure it is fit for purpose in the approach.




The other category can be selected multiple times in the element column to tailor and add your site/issue/goal-specific indicator.

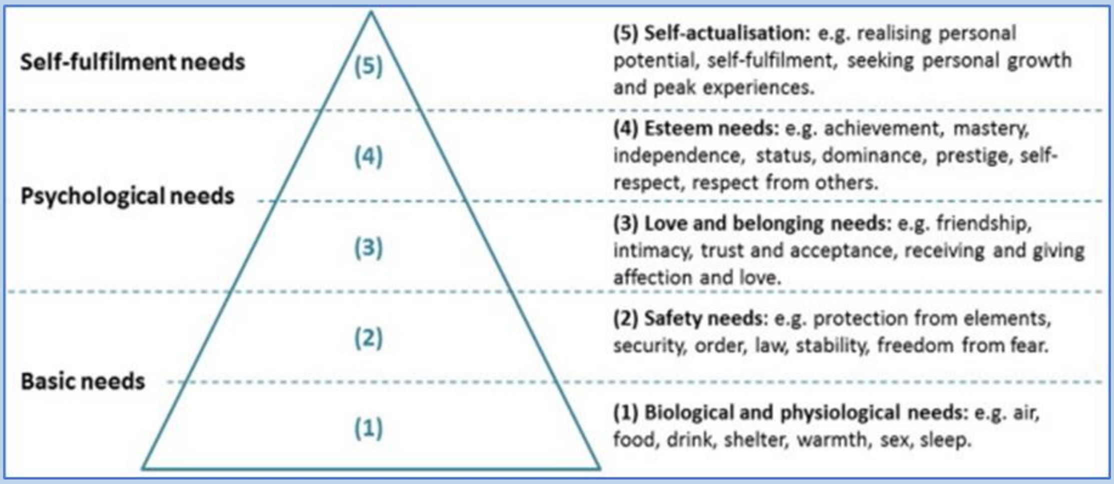
"*I wanted to provide some clarity on the application of the approach*": The exercises relate to DAPSI(W)R(M) elements to establish a causal structure. So, it is important here to distinguish activities, pressures, marine processes and functioning, and where things such as market pressures may fall under in the application. Pressures result from [human] activities - defined as the mechanisms (as rate processes) of change, in the way in which activity will change the natural and societal systems by modifying the structure and functioning of the system (Elliott et al., 2022). Hence, market pressures may be better suited as an Activity as the increase (pressure) of fisheries markets may increase greenhouse gas emissions (the pressure) on the marine process and functioning of the area.
For further information on the distinction, please see this paper: Elliott, M., Burdon, D., Atkins, J. P., Borja, A., Cormier, R., de Jonge, V. N. & Turner, R. K. (2017) "And DPSIR begat DAPSI(W)R(M)!" - A unifying framework for marine environmental management. Mar Pollut Bull, 118(1-2), 27- , https://doi.org/10.1016/j.marpolbul.2017.03.049

| | |
|---|---|
| **Q:** | **Is information from the legislative audit only inputted to Kumu in comment columns? How is it used in general? I would have expected compliance with certain legislature or other mandates (e.g., sustainability reporting) to be included more quantitatively under "Pressure" or "Need" - can it be instead done this way?** |
| **A:** | In general, the Legislation audit can give insights to complement the learning process undertaken throughout the ISA. On the master data sheet of the ISA, there are columns for notes on governance; this would include compliance with legislation and targets and mandates to provide applied information to the elements of the approach. Moreover, mandates can indicate the drivers of activities – such as a driver for clean water being (a quantitative policy target) for (households with fresh water) in the region for the period that warrants activities such as water abstraction or waste management.<br><br>Both the Governance and Administration tools aim to support the ISA in regard to the response measures to clarify and establish what rules are in place and who implements or changes these rules. This provides the information to potentially:<br>• Evaluate if there is sufficient and appropriate legislation in place to protect the marine environment and regulate activities/sectors. This helps identify any gaps or issues that need to be addressed through response measures.<br>• Assess if existing laws and policies are adequately implemented, enforced, and integrated. This can reveal where better management or enforcement of current rules may be needed.<br>• Understand the complexity of the governance system across sectors and levels (international, regional, national). Mapping this visually helps identify fragmentation, overlaps, or conflicts.<br>• Determine if the administration and institutions have the capacity and resources to effectively carry out marine management under the legislative frameworks. Gaps may point to the need for response measures.<br>• Facilitate coordination and information exchange between the entities involved in marine governance.<br>• Inform the development of streamlined and transparent governance systems that better integrate across sectors, laws, and jurisdictions. |
| **Q:** | **I am also a little confused about the Needs – Exercise 5 category sheet. Many societal needs are driving dynamics in the fishery through mechanisms such as ecolabeling and sustainability finance. But exercise 5 does not have an adjacency matrix.... can I custom design this section to be more dynamics and have feedbacks, for example with Goods and Benefits (through 'Income'). Then I think information in the last column of Exercise 5 would instead go into a BOT (?).** |
| **A:** | The Needs within the approach are the Drivers, so the last two pages of the ISA Excel document are the adjacency matrices of Activities -> Drivers and Drivers -> Goods and Benefits. Using the BOT graphs to understand the behaviour of the indicator of the need (Driver), you can complete this adjacency matrix to see how elements influence the SES. |
| **Q:** | **What is the difference between indicators for Drivers and Goods and Benefits?** |

**A:** When considering indicators of Drivers and Goods and Benefits, consider viewing the demand aspect as the Driver, while the Goods and Benefits provided represent the supply side.

**Drivers:**

*Definition:* The early work of Maslow (1943) proposed a range of basic human needs for an individual as a five-tier hierarchical structure, and it is proposed here that such needs reflect the Drivers within the DAPSI(W)R(M) framework. These are primarily socio-economic and demographic forces that provoke changes in levels of consumption and production, ultimately exerting pressure on the environment.




*Example:* A primary driver in the marine environment could be the increasing demand for fish as a primary protein source due to population growth and dietary preferences.

*Indicator:* Proportion and/or number of households located below 2m above sea level, which reflects the vulnerability to rising sea levels due to climate change, which is itself driven by human activities.

**Goods and Benefits:**

*Definition:* These refer to the outputs, outcomes, or advantages provided by the environment, often in response to the pressures or demands exerted by the drivers. They represent the 'supply' side of the equation.

*Example:* Marine ecosystems, such as coral reefs, provide numerous goods and benefits, including tourism opportunities, fish breeding grounds, and storm surge protection.

*Indicator:* The number of tourists visiting a marine protected area annually can indicate the recreational and economic benefits of a healthy marine ecosystem.

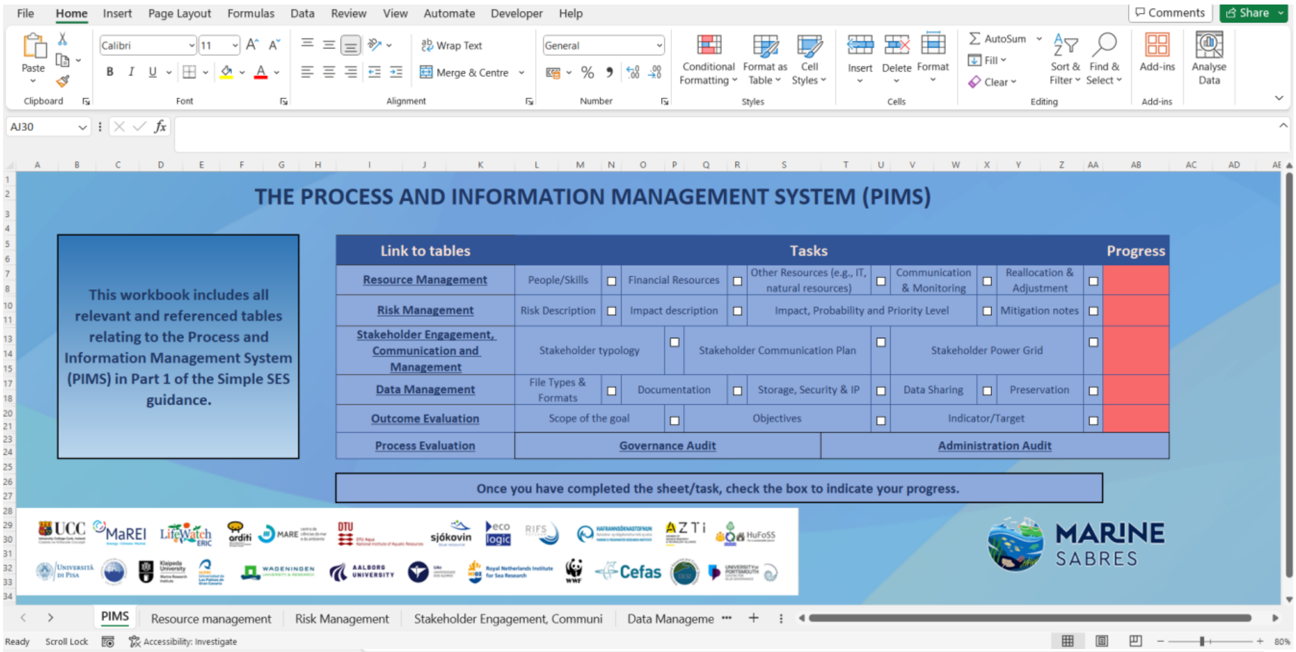
**The relationship between Drivers and Goods and Benefits**

Drivers are the causes; they represent the human-induced pressures or demands put on the environment due to societal behaviours and needs, whereas Goods and Benefits are the effects and products of the ecosystem services; they depict what the environment provides in return, either as a direct response to those Drivers which warrant Activities or as inherent products of ecosystem services. An example is that an increasing coastal population (Driver) demands more seafood. In return, through human Activities, the marine ecosystems provide fish as a resource, food for human consumption (Goods and Benefits). However, overfishing (Activities) might deplete fish stocks, reducing the ecosystem's capacity to provide this benefit in the long term.

For further information, see: Elliott, M., Burdon, D., Atkins, J. P., Borja, A., Cormier, R., de Jonge, V. N. & Turner, R. K. (2017) "And DPSIR begat DAPSI(W)R(M)!" - A unifying framework for marine environmental management. Mar Pollut Bull, 118(1-2), 27- , https://doi.org/10.1016/j.marpolbul.2017.03.049

## Appendix 3 – The Supporting Documents for the Simple SES

## Appendix 3(a) – The Process and Information Management System Excel Sheets




| | RESOURCE MANAGEMENT | | | HOME |
|---|---|---|---|---|
| People/Skills | *What are their roles and responsibilities?* | *Completed?* | *Date* | |
| | *Who is responsible for Filling in and updating the Excel sheets (PIMS and Data Sheet)/ Kumu interface/storage management of the different files?* | *Completed?* | *Date* | |
| | *What tasks are they to be undertaking and when?* | *Completed?* | *Date* | |
| | *Where is this information to be stored? Do all team members have access to this file?* | *Completed?* | *Date* | |
| | *How often will this information be reviewed?* | *Completed?* | *Date* | |
| | *Who is responsible for monitoring the financial resources?* | *Completed?* | *Date* | |
| Financial Resources | *What is the budget for the project? How is this to be spread among the phases of the project?* | *Completed?* | *Date* | |
| | *Where is this information to be stored? Do all team members have access to this file?* | *Completed?* | *Date* | |
| | *How often will this information be reviewed?* | *Completed?* | *Date* | |
| | *Who is responsible for monitoring the financial resources?* | *Completed?* | *Date* | |
| Other Resources (e.g., IT, natural resources) | *What other resources are essential to the undertaking of the project (for example, online data storage and computer software)?* | *Completed?* | *Date* | |
| | *Where is this information to be stored? Do all team members have access to this file?* | *Completed?* | *Date* | |
| | *How often will this information be reviewed?* | *Completed?* | *Date* | |
| | *Who is responsible for monitoring the financial resources?* | *Completed?* | *Date* | |
| Communication & Monitoring | *Where is this information to be stored? Do all team members have access to this file?* | *Completed?* | *Date* | |
| | *How often will this information be reviewed?* | *Completed?* | *Date* | |
| | *Who is responsible for monitoring overall resources, including reallocation and adjustment?* | *Completed?* | *Date* | |
| Reallocation & Adjustment | *Are any resources necessary to be reallocated?* | *Completed?* | *Date* | |
| | *Document here which resources are to be reallocated/adjusted.* | *Completed?* | *Date* | |
| | *When are these to be reviewed?* | *Completed?* | *Date* | |

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## RESOURCE MANAGEMENT

HOME

| | | | |
|---|---|---|---|
| People/Skills | *What are their roles and responsibilities?* | *Completed?* | *Date* |
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| | *How often will this information be reviewed?* | *Completed?* | *Date* |
| | *Who is responsible for monitoring the financial resources?* | *Completed?* | *Date* |
| Financial Resources | *What is the budget for the project? How is this to be spread among the phases of the project?* | *Completed?* | *Date* |
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| | *How often will this information be reviewed?* | *Completed?* | *Date* |
| | *Who is responsible for monitoring the financial resources?* | *Completed?* | *Date* |
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## STAKEHOLDER MANAGEMENT, COMMUNICATION AND ENGAGEMENT

HOME

| Type of Stakeholder | Stakeholder |
|---|---|
| Extractors (fishers, resource removers) | *List stakeholders here.* |
| Inputters (dischargers, polluters) | *List stakeholders here.* |
| Beneficiaries (those acquiring the benefits) | *List stakeholders here.* |
| Affectees (society, those paying the costs) | *List stakeholders here.* |
| Regulators (government, legislators, decision-makers) | *List stakeholders here.* |
| Influencers (expert groups, politicians, NGOs) | *List stakeholders here.* |

| Communication type | Stakeholders |
|---|---|
| Smaller communication methods; Sound bites, headlines, Tweets and one-page briefing notes. | *List stakeholders here.* |
| More in-depth and larger communication methods; Theses, reviews, scientific papers, and consultant reports. | *List stakeholders here.* |

| Interest | SUBJECTS | PLAYERS |
|---|---|---|
| | *List stakeholders here who are interested in the project, but have little influence over the outcomes (e.g. local individuals).* | *List stakeholders here who are interested in the project and have a high influence over the outcomes (e.g. large industry in the area, local environmental groups).* |
| | **CROWD** | **CONTEXT SETTERS** |
| | *List stakeholders here who currently exhibit neither interest nor power to influence the issue of concern (e.g. general public of the country).* | *List stakeholders here who may have a high degree of power over the future of the issue, particularly in terms of influencing the future context within which responses will need to operate (e.g. local governing bodies; marine planning authorities).* |
| | Power | |

PIMS | Resource management | Risk Management | Stakeholder Engagement, Communi | Data Manageme

## DATA MANAGEMENT PLAN

HOME

| Team member responsible for DMP | | *Name / Date* |
|---|---|---|
| **Category** | **Key Points** | **Data management actions** |
| File Types & Formats | What types of files will be created as part of the project? Will data be transformed and/or transferred as part of the process of analysis? Outlining all the types, sources, and estimated size of data being collected and analysed will help you identify potential issues relating to storage, sharing, and preservation. | *List the characteristics of the data to be collected (e.g. quantitative, text, audio, video, code, etc.)* |
| | | *Include the file formats/software and if they are open or proprietary. List relevant physical formats like lab notebooks here.* |
| | | *Outline the file types you'll be creating or transforming during collection and analysis.* |
| | | *What is the anticipated size of data? Will require additional resources?* |
| Documentation | It is important to document how files are being managed as you may want to or be expected to share your data, and someone may want to verify, replicate, or reuse your data. Describe the documentation and quality assurance strategies for each type of data during collection and analysis. Consider using a file naming convention and using built-in documentation capabilities, like taking notes in code scripts. | *Outline what documentation you will create here.* |
| | | *Describe workflows for systematic capture of study information.* |
| | | *How will you add, update, and maintain the data and documentation? Who will be responsible for this management?* |
| | | *How will you track multiple files or versions?* |
| | | *How will non-digital documentation be handled?* |
| | | *Establish if there is a relevant disciplinary standard for documentation and metadata* you could use.* |
| | | *Consider what documentation will be needed for shared/preserved data.* |
| | | Consider creating a README document for shared/preserved data you'll use during collection and analysis. Where will this be stored? |
| Storage, Security & IP | Storage location, data safety, and access control. In almost all cases, research data should be kept in secure storage (what does this mean in terms of this project?). Avoid using local hard drives, portable storage devices, laptops, and tablets for storage to reduce the risk of accidental loss. | *Describe where you will store your data at every stage of collection and analysis (be specific about the journey your data will take).* |
| | | *Determine how you will keep your data safe to prevent accidental loss and unauthorised access* |
| | | *Decide if you will transfer data from a collection tool to do your analysis, e.g. voice recorder, field measurements, or online survey*<br>*How and when will you do this? Every week? After data collection ends?* |
| | | *Describe how and when you will transfer data if necessary, including deleting data from collection tools/storage.* |
| | | *Identify any ethical, legal or commercial issues with your data, e.g. identifiable data, copyright materials, patents, etc. How will you protect the data? (This could include transforming, de-identifying, or anonymising the data).* |
| | | *Identify who will have access to the data. How will collaborators have access to the data?* |
| | | *Identify any special storage or computing requirements you may have.* |
| | | *Describe how you will securely store and maintain any non-digital data.* |
| Data Sharing | Data sharing for verification and reuse is an increasingly important marker of research integrity. Your plan should identify what data will or will not be shared from the project and, for data that can't be shared, you should include a justification for why not. For shareable data, you should outline where, when, and how others can access it. Often data is released following publication or at the close of a project. Be aware: some funders and publishers require data to be shared within specific timelines (what is the expectation on this project?). | *Make sure your consent forms don't prohibit sharing/retention and, even better, ensure that they mention that de-identified data will be shared in an open repository*<br>*If the data cannot be shared, explain why (e.g. don't own the data, national security, copyrighted)* |
| | | *Outline what parts of your data can and cannot be shared* |
| | | *Describe and justify any restrictions or terms of access (restricted, NDA, etc.)*<br>*When will the data be released?* |
| | | *Is there non-digital data that needs to be made available? How will people request access (e.g. a publicly discoverable metadata record)?* |
| | | *Will you transform the data? (e.g. de-identify or convert to an open format)* |
| | | *Identify how you will share your data, such as depositing in a repository*<br>Consider applying a Creative Commons license to your shared data or code<br>Check out the FAIR principles of data sharing (https://www.go-fair.org/fair-principles/) |
| | | *Best practice is to deposit the data into a suitable data repository. Repositories provide the best visibility, tracking, and safe keeping for your data (what is recommended for this project?).* |
| | | *Identify a suitable repository. Consider a discipline specific repository that is most appropriate for your data. Check out PLOS' list of recommended repositories (https://journals.plos.org/plosone/s/recommended-repositories) or Scientific Data's recommended data repositories (https://www.nature.com/sdata/policies/repositories).* |
| | Remember, sharing data isn't all or nothing. You can still engage in a culture of openness and transparency while appropriately protecting your data: | *Releasing some data publicly and restricting access to other parts* |
| | | *Transforming the data to share it more openly* |
| | | *Restricting access to bona fide researchers or on a case-by-case basis* |
| | | *Outlining terms of access and/or applying for a copyright licence* |
| | | *Only allowing access for verification of findings and subject to a non-disclosure agreement* |
| | | *Creating a public metadata record outlining what data is held and why it cannot be shared* |
| Preservation | Retaining data is an important part of the research process. Even if data cannot be shared now, it may still have important historical value for future researchers. You should identify what data will be retained, where it will be stored, and who will oversee its safekeeping in the longer term. | *Identify which data should be preserved. This should be anything that underpins the conclusions of your project and any published works* |
| | | *Identify what documentation you will include with the data to facilitate verification/reuse* |
| | | *Consider transforming your data to an open format for preservation* |
| | | *Identify where and who will be preserving the data and for how long* |
| | | *If you shared your data in a repository, it may have a preservation policy you can link/refer to.* |

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## OUTCOME EVALUATION

HOME

| **Site** | **The scope of the objectives** |
|---|---|
| | |

| **DA Sites** | **The broad scope of the goal** | **Objectives** | | **Indicator/Target** |
|---|---|---|---|---|
| The Tuscan Archipelago | Tourism and conservation of seagrass beds: We will restore seagrass beds by finding alternative mooring solutions. The recovery of seagrass beds from physical disturbance will be assessed by replicated diving surveys to assess the recovery rate in terms of biodiversity, protection from invasive species and carbon sequestration. Measures to promote more sustainable mooring and boat use across private users and commercial charter companies will be developed. | *Is this objective Specific, Measurable, Achievable, Realistic and Time-bound?* | *What is the scale of this objective (local, national, regional)?* | *The desired final state and the date at which it should be assessed, with appropriate intermediate assessments to check progress if appropriate, should be specified.* |
| | | *Is this objective Specific, Measurable, Achievable, Realistic and Time-bound?* | *What is the scale of this objective (local, national, regional)?* | *The desired final state and the date at which it should be assessed, with appropriate intermediate assessments to check progress if appropriate, should be specified.* |
| | | *Is this objective Specific, Measurable, Achievable, Realistic and Time-bound?* | *What is the scale of this objective (local, national, regional)?* | *The desired final state and the date at which it should be assessed, with appropriate intermediate assessments to check progress if appropriate, should be specified.* |
| | | *Is this objective Specific, Measurable, Achievable, Realistic and Time-bound?* | *What is the scale of this objective (local, national, regional)?* | *The desired final state and the date at which it should be assessed, with appropriate intermediate assessments to check progress if appropriate, should be specified.* |
| | | *Is this objective Specific, Measurable, Achievable, Realistic and Time-bound?* | *What is the scale of this objective (local, national, regional)?* | *The desired final state and the date at which it should be assessed, with appropriate intermediate assessments to check progress if appropriate, should be specified.* |
| | | *Is this objective Specific, Measurable, Achievable, Realistic and Time-bound?* | *What is the scale of this objective (local, national, regional)?* | *The desired final state and the date at which it should be assessed, with appropriate intermediate assessments to check progress if appropriate, should be specified.* |
| | | *Is this objective Specific, Measurable, Achievable, Realistic and Time-bound?* | *What is the scale of this objective (local, national, regional)?* | *The desired final state and the date at which it should be assessed, with appropriate intermediate assessments to check progress if appropriate, should be specified.* |
| | | *Is this objective Specific, Measurable, Achievable, Realistic and Time-bound?* | *What is the scale of this objective (local, national, regional)?* | *The desired final state and the date at which it should be assessed, with appropriate intermediate assessments to check progress if appropriate, should be specified.* |
| | | *Is this objective Specific, Measurable, Achievable, Realistic and Time-bound?* | *What is the scale of this objective (local, national, regional)?* | *The desired final state and the date at which it should be assessed, with appropriate intermediate assessments to check progress if appropriate, should be specified.* |
| | | *Is this objective Specific, Measurable,* | *What is the scale of this objective (local, national,* | *The desired final state and the date at which it should be assessed,* |

Risk Management | Stakeholder Engagement, Communi | Data Management | **Outcome evaluation** | Proce

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## Process Evaluation

HOME

**Focussing on the group option analysis session, to what extent do you agree or disagree with the following statements:**

| | | Strongly Disagree | Disagree | Agree | Strongly Agree | Neither Agree nor Disagree |
|---|---|---|---|---|---|---|
| **Communication** | a. There was a good exchange of ideas and viewpoints between participants | | | | | |
| | b. All participants contributed to the discussion | | | | | |
| | c. A shared language was being used | | | | | |
| | d. Some participants dominated discussions which prevented some other participants from contributing | | | | | |
| | e. Participants understood and were focussed on the options analysis task | | | | | |
| **Consensus** | a. Participants' opinions converged as they discussed options for their respective positions | | | | | |
| | b. Participants became aware that there were more options than they originally thought | | | | | |
| | c. Participants did not reach agreement on the analysis of the options | | | | | |
| | d. The approach to analysing options helped participants communicate their ideas to others | | | | | |
| **Commitment** | a. There was a strong belief and recognition of the value of the options analysis exercise | | | | | |
| | b. Participants' level of engagement with the analysis exercise was low | | | | | |
| | c. There was a strong desire to achieve an analysis of the options which was both correct and complete through the exercise | | | | | |

**Focussing on the process in its entirety, to what extent were the following delivered:**

| | | Fully | | | Not sure |
|---|---|---|---|---|---|
| **Take-Aways** | a. Understanding of opportunities for... | | | | |
| | b. Clarification of drivers and barriers to change | | | | |
| | c. An opportunity to engage in a discussion about... | | | | |
| | d. Greater appreciation of a range of stakeholder views on... | | | | |
| | e. Action to achieve... | | | | |

Stakeholder Engagement, Communi | Data Management | Outcome evaluation | Process Evaluation | Gove

| | A | B | C | D |
|---|---|---|---|---|
| 1 | **Governance Audit** | | | HOME |
| 2 | **BOX on Figure 1b** | **LEGISLATION** | **COMPLETE THIS COLUMN TO STATE YOUR NATIONAL IMPLEMENTATION & THE PROTECTION IT AFFORDS** | **Added to Figure 1b ✓** |
| 3 | ***Regional Sea Convention*** | | | |
| 4 | Box 1 | Insert your Regional Sea Convention in the central area (highlighted in yellow) e.g. OSPAR, HELCOM, Barcelona or Bucharest. | e.g. UK - OSPAR | |
| 5 | ***EU Marine Strategy Framework Directive (MSFD)*** | | | |
| 6 | Boxes 2a and 2b. | Under which piece of national legislation is the MSFD implemented? (If just one main act or regulation, then delete the second box). | e.g. UK – Marine Strategy Regulations; Environment Act | |
| 7 | Box 2c. | Do you have any nationally implemented legislation which also helps to achieve GES? | | |
| 8 | Box 2d | State what specific protection this legislation gives your Demonstration Area. | | |
| 9 | ***EU Marine Spatial Planning Directive (MSPD)*** | | | |
| 10 | Box 3 | Which piece(s) of national primary/enabling legislation implements the MSPD in your country? | | |
| 11 | Box 3a | State what components or sub-area this act/regulation specifically protects in the MarineSABRES Demonstration Area. | | |
| 12 | ***CBD COP9 - Ecologically or Biologically Significant Marine Areas (EBSAs)*** | | | |
| 13 | Box 4 | Do you use this term and if so, do you have any designated EBSAs? If so, name the area. | | |
| 14 | Box 4a | What specific protection does this concept/designation give to the Demonstration Area? | | |
| 15 | ***CBD Global Biodiversity Framework - Other Effective Area-Based Conservation Measures (OECMs)*** | | | |
| 16 | Box 5 | Do you use this term and do you have any designated OECMs? If so, name the area. | | |
| 17 | Box 5a | What specific protection does this concept/designation give to the Demonstration Area? | | |
| 18 | ***EU Habitats Directive*** | | | |
| 19 | Box 6 | List any national legislation implementing the Habitats Directive in your country. There may be other pieces of legislation which also fill that role which can be added to the additional boxes. Please delete any boxes that are not | | |
| 20 | Boxes 6a-f | What component(s) does each piece of legislation specifically give protection to in your Demonstration Area? | | |
| 21 | | e.g. protected areas, a certain species e.g. *Posidonia* , *Zostera* , fish sp. | | |
| 22 | ***AICHI targets through the EU Biodiversity Strategy*** | | | |
| 23 | Box 7 | State the main national legislation or actions used to implement the AICHI targets | | |
| 24 | Box 7a | What specific protection do these give to the Demonstration Area? | | |
| 25 | ***CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora)*** | | | |
| 26 | Box 8 | How is CITES implemented in your country? | | |
| 27 | Box 8a | What specific protection does it give to marine species? | | |
| 28 | ***UNESCO – World Heritage Sites (WHS)*** | | | |
| 29 | Box 9 | Do you have any coastal/marine WHS in your country and, if so, what is the main reason for designation? | | |
| 30 | Box 9a | What specific protection do these give to the Demonstration Area? | | |
| 31 | ***UNESCO – Protection of Underwater Cultural Heritage*** | | | |
| 32 | Box 10a | If your country is a signatory - how is this implemented in your country and what specific protection does it give? What components/aspects are protected? | | |
| 33 | Box 10b | If your country is not a signatory (as with the UK) how does your country give protection to marine archaeology? | | |
| 34 | ***EU Public Access to Environmental Liability Directive*** | | | |
| 35 | Box 11 | State how this Directive has been implemented in your | | |
| 36 | Box 11a | What protection is provided? | | |
| 37 | ***EC Regulation 1143/2014 on Invasive Alien Species (IAS)*** | | | |
| 38 | Box 12 | State how this has been implemented in your country. | | |
| 39 | Box 12a | What specific protection is provided? | | |
| 40 | ***IMO Ballast Water Convention*** | | | |
| 41 | Box 13 | If a signatory - how is this implemented in your country and what specific protection does it give? | | |
| 42 | Box 13a | If you have not ratified it, does your country provide equivalent protection? | | |
| 43 | ***MARPOL Annexes and Regulations*** | | | |
| 44 | Box 14 | What national legislation do you have to implement MARPOL Annexes and Regulations? | | |
| 45 | Box 14a | Does this provide any specific protection to marine habitats and species in your marine area? | | |
| 46 | ***IMO – Particularly Sensitive Sea Areas (PSSAs)*** | | | |
| 47 | Box 15 | Do you have any designated PSSAs? If so, name the area. | e.g. The Baltic Sea area, Denmark, Estonia, Finland, Germany, Latvia, Lithuania, Poland and Sweden | |
| 48 | Box 15a | What specific protection does this give to the Demonstration Area? | | |

| | | | | |
|---|---|---|---|---|
| 49 | ***IMO and Regional Sea Conventions - Oil and Gas Production and Decommissioning*** | | | |
| 50 | Box 16 | What are the main regulatory instruments relating to oil and gas extraction and decommissioning? | | |
| 51 52 53 | Box 16a | What kind of management/ protection do those instruments provide? | | |
| 54 | ***EU Bathing Waters Directive*** | | | |
| 55 | Box 17 | Which piece of national primary/enabling legislation implements the Bathing Waters Directive in your country? | | |
| 56 | Box 17a | State if and how this act/regulation specifically gives protection to your Demonstration Area. | | |
| 57 | ***EU Urban Waste Water Treatment Directive (UWWTD)*** | | | |
| 58 | Box 18 | Which piece(s) of national primary legislation and/or regulations implement the UWWTD? | | |
| 59 | Box 18a | State how these act(s)/regulation(s) specifically give protection to your Demonstration Area | | |
| 60 | ***EU Nitrates Directive*** | | | |
| 61 | Box 19 | Which piece(s) of national primary/enabling legislation implements the Nitrates Directive in your catchments? | | |
| 62 | Box 19a | State how these acts/regulations specifically give protection to your Demonstration Area. | | |
| 63 | ***EU Industrial Emissions Directive*** | | | |
| 64 | Box 20 | Which piece(s) of national primary/enabling legislation implements this Directive? | | |
| 65 | Box 20a | State how this act/regulation specifically gives protection to your Demonstration Area. | | |
| 66 | ***EU Waste Framework Directive*** | | | |
| 67 | Box 21 | Which piece(s) of national primary/enabling legislation implements this Directive? | | |
| 68 | Box 21a | State how this act/regulation specifically gives protection to your Demonstration Area. | | |
| 69 | ***EU Renewable Energy Directive*** | | | |
| 70 | Box 22 | Which piece(s) of national primary/enabling legislation implements this Directive? | | |
| 71 | Box 22a | State how this act/regulation specifically gives protection to your Demonstration Area. | | |
| 72 | ***Common Fisheries Policy (CFP) - Fisheries Management – Various regulations*** | | | |
| 73 | Box 23 | Which piece(s) of national primary/enabling legislation implements the CFP and Basic Fisheries Regs? | | |
| 76 | ***EU Contaminants in Food Regulations*** | | | |
| 77 | Box 24 | Which pieces of legislation are used to implement this Directive to ensure the safe consumption of shellfish? | | |
| 78 | Box 24a | What specific protection do these pieces of national legislation give to the Demonstration Area? | | |
| 79 | ***UNFAO Vulnerable Marine Ecosystems (VME)*** | | | |
| 80 | Box 25 | Do you have any VME designated areas? Please name the | | |
| 81 | Box 25a | What specific protection does this give to the Demonstration Area? | | |
| 82 | ***EU Strategic Environmental Assessment Directive (SEA)*** | | | |
| 83 | Boxes 26 | Which piece(s) of national primary/enabling legislation implements the EU SEA Directive? (delete/add boxes as | | |
| 84 | Box 26a | State how these acts/regulations specifically give protection to your Demonstration Area. | | |
| 85 | ***EU Environmental Impact Assessment Directive (EIA)*** | | | |
| 86 | Boxes 27 | Which piece(s) of national primary/ enabling legislation implements the EU EIA Directive? (delete/add boxes as | | |
| 87 | Box 27a | State how the act/regulation specifically gives protection to your Demonstration Area. | | |
| 88 | ***EU Flood Risk Management Directive (FRMD)*** | | | |
| 89 | Boxes 28 | Which piece(s) of national primary/enabling legislation implements the EU FRMD? (delete/add boxes as required) | | |
| 90 | Box 28a | State how this act/regulation specifically gives protection to your Demonstration Area. | | |
| 91 | ***EU Water Framework Directive (WFD)*** | | | |
| 92 | Box 29 | Which piece(s) of national primary/enabling legislation implements the EU WFD? | | |
| 93 | Box 29a | State how this act/regulation specifically gives protection to your Demonstration Area. | | |
| 94 | ***OTHER REGIONAL LEGISLATION SPECIFIC TO YOUR COUNTRY / DEMONSTRATION AREA NOT ALREADY CONSIDERED ABOVE*** | | | |
| 95 96 97 | | | | |
| 98 99 100 | | | | |
| 101 102 103 | | | | |
| 104 | | | | |
| 105 | | | | |

Data Management | Outcome evaluation | Process Evaluation | Governance Audit | Administration Audit

| Statutory Organisation | Hierarchy<br>If an agency/body – under which department do they operate | Overview<br>Describe the vision of the organisation | Responsibilities<br>Description of their specific role in relation to:<br>Maritime Spatial Planning (MSP) | Marine Protected Areas (MPAs) | Marine Strategy Framework Directive (MSFD) |
|---|---|---|---|---|---|
| e.g. Marine Management Organisation (MMO), England | Statutory.<br>Executive Non-Departmental Public Body working under the Department of Environment, Food and Rural Affairs (Defra) in England and Wales | Protecting and enhancing the marine environment and supporting UK economic growth by enabling sustainable marine activities and development. | Marine planning (planning and licensing functions for English waters and developing marine plans covering the English marine area);<br>Marine regulation & licensing (consenting process, harbour orders (HO), Sec 36 of Electricity Act (>1MW to 100MW) (also with responsibilities for Sec 36 and certain HOs in Welsh inshore waters));<br>Fisheries (regulate fishing outside territorial waters and outside MPAs, dispensations, monitoring & enforcement, quotas, statistics & vessels licenses). | Protecting the environment (marine pollution, nature conservation (MCZs) & wildlife licences). | Assists Defra to deliver the UK Marine Policy Statement by taking measures to improve the state of the UK's marine environment and achieve GES under the MSFD. |
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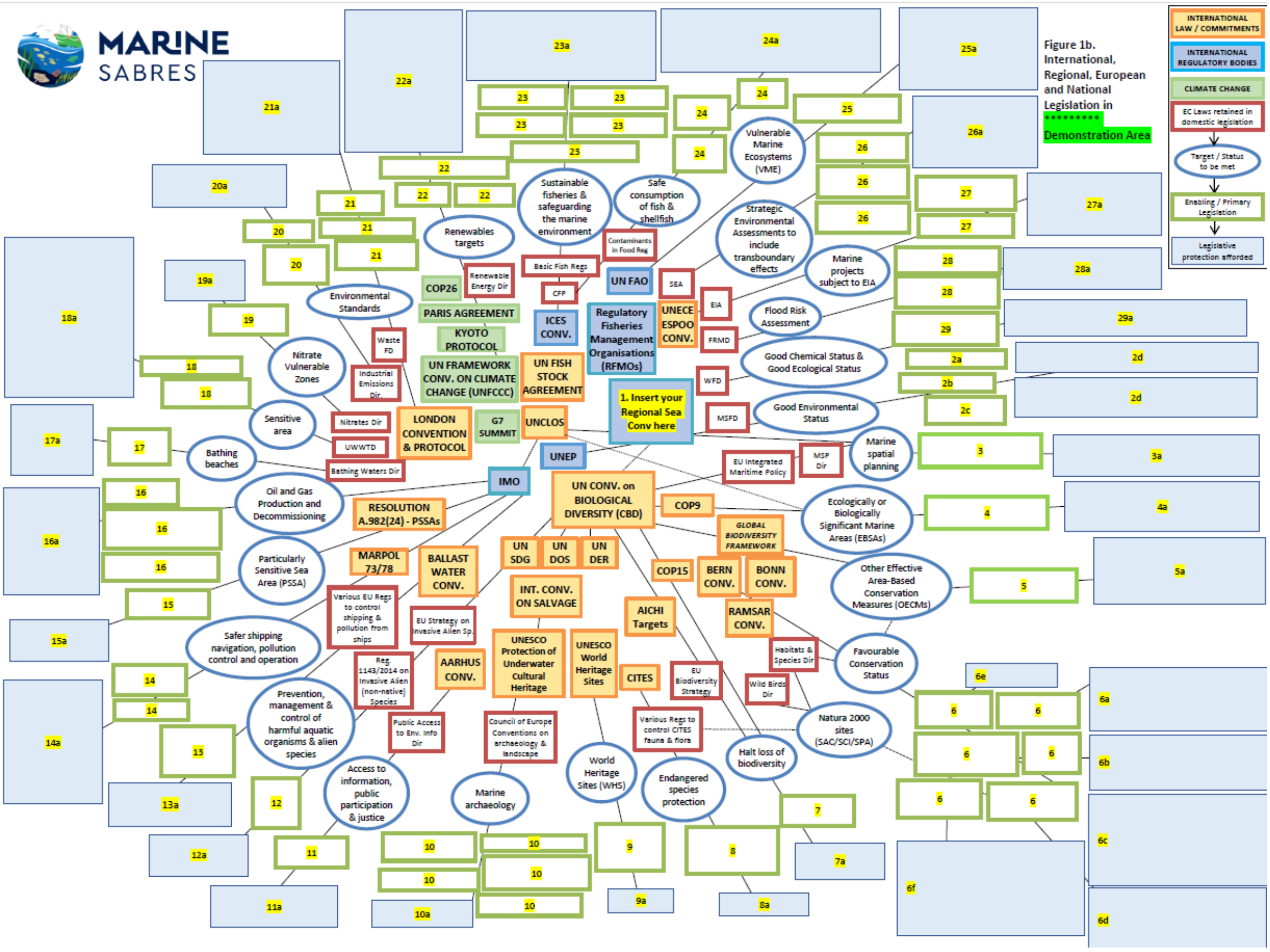
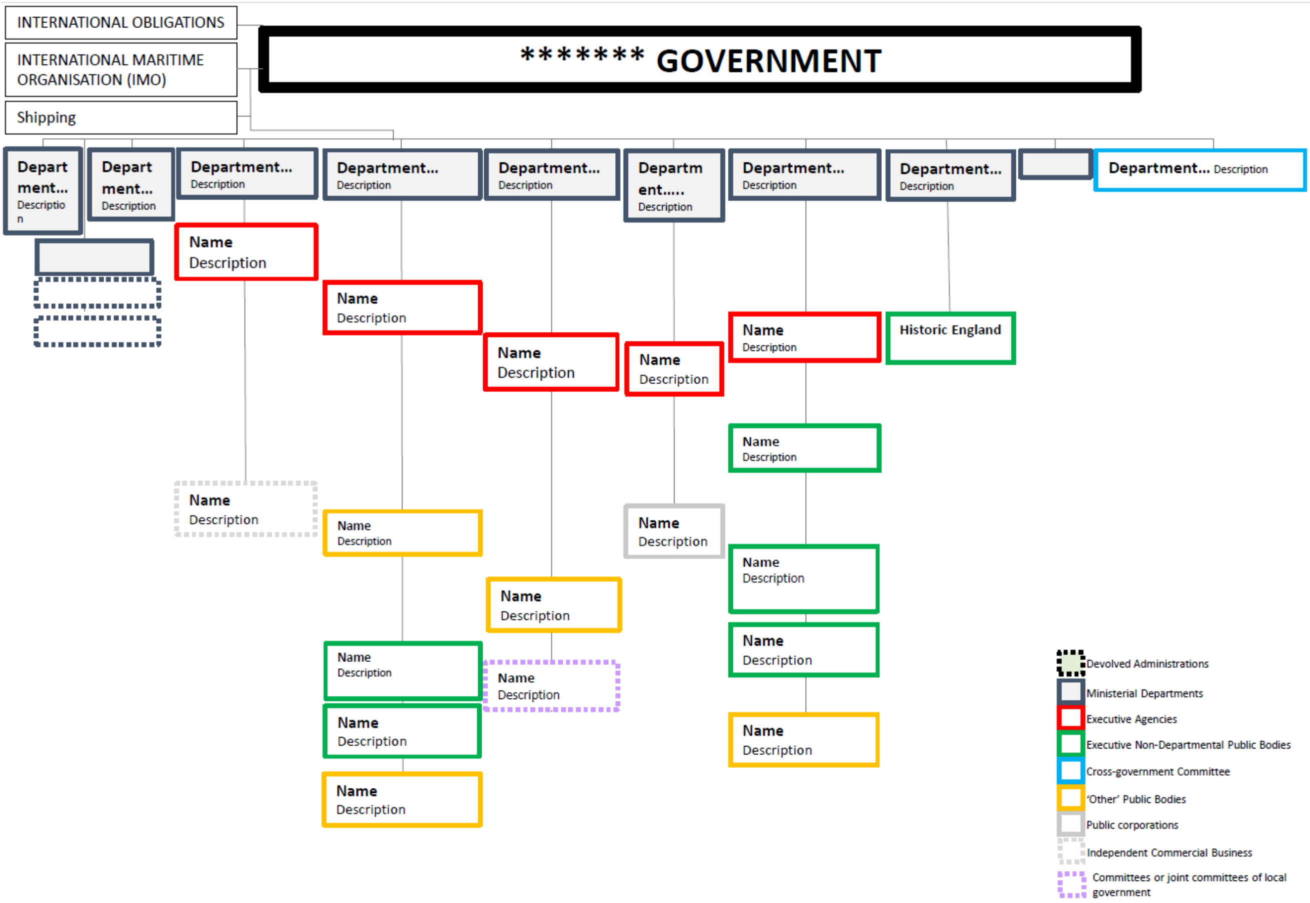
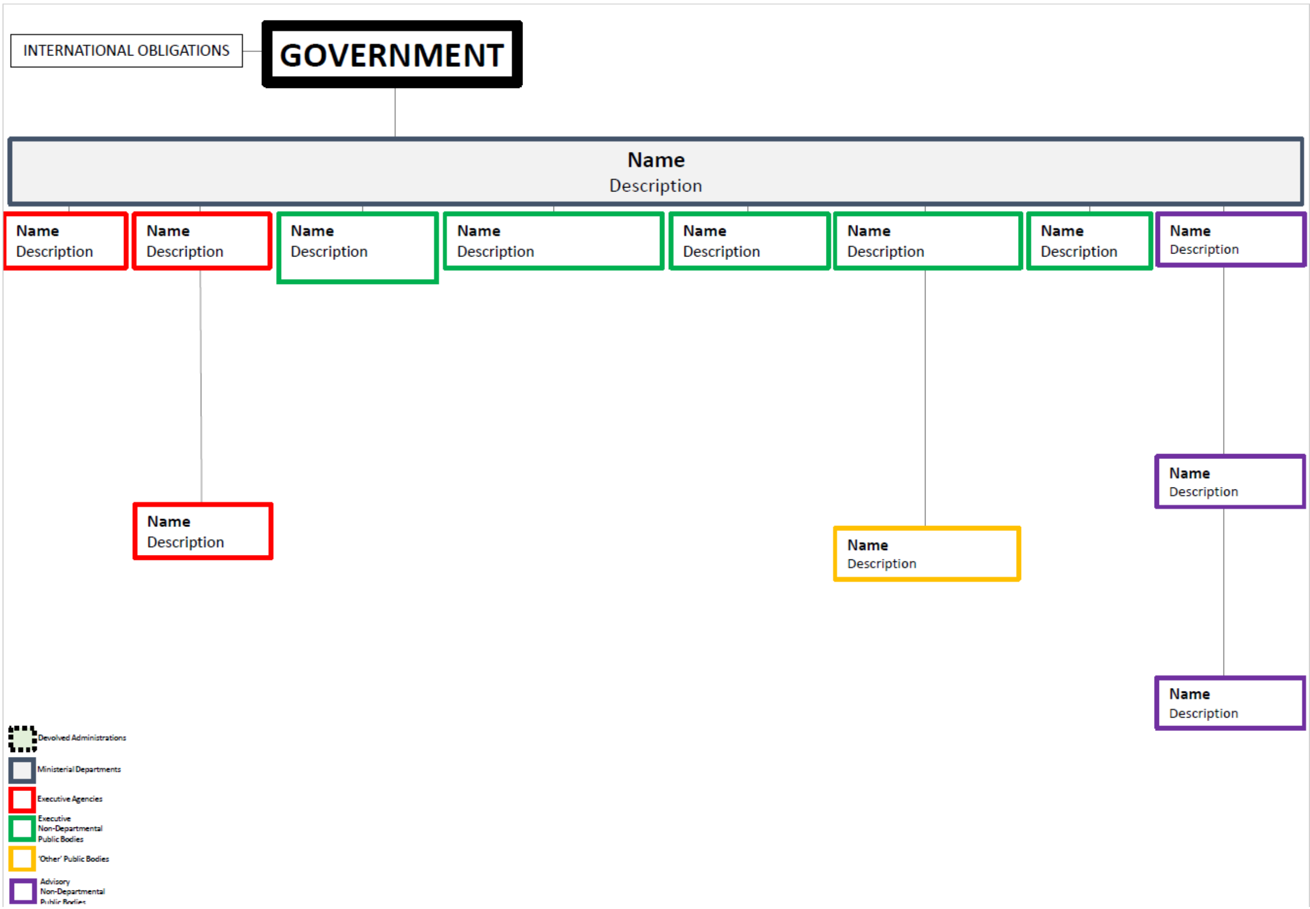
Administration Audit — HOME

Data Management | Outcome evaluation | Process Evaluation | Governance Audit | Administration Audit

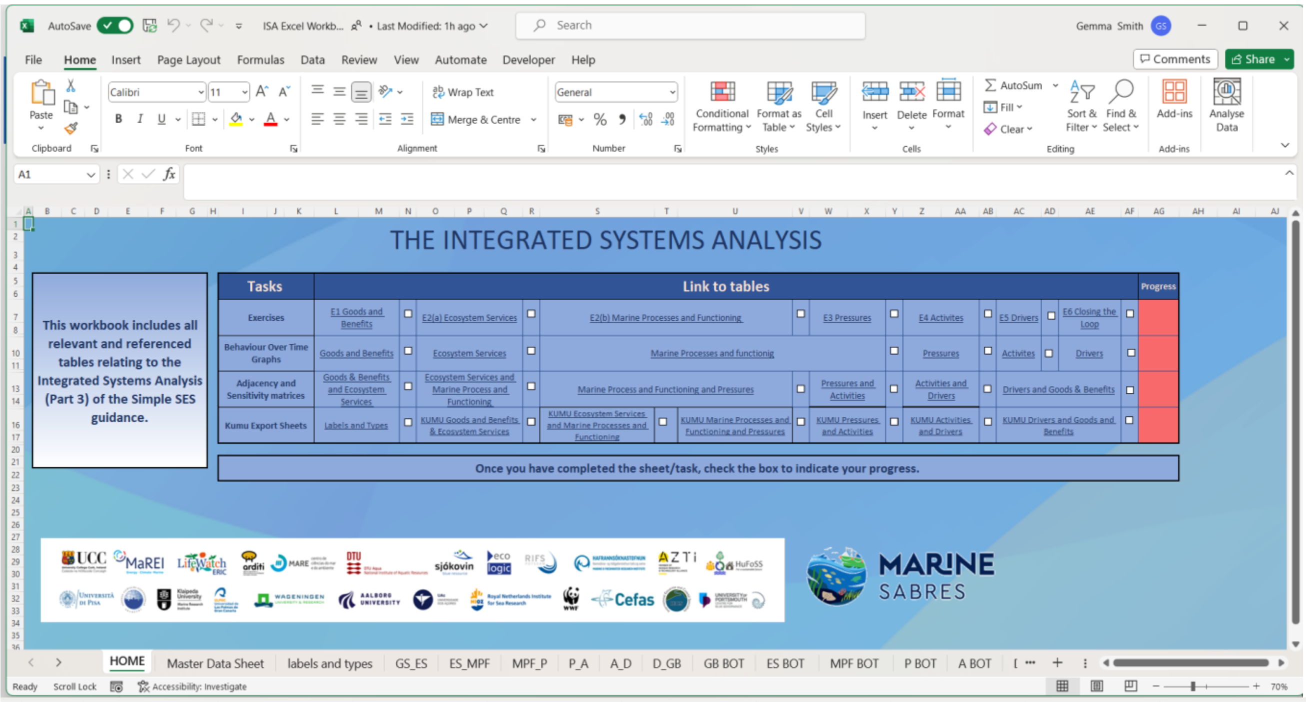
## Appendix 3(b)- The Governance Horrendogram and Administration Organogram Template Documents

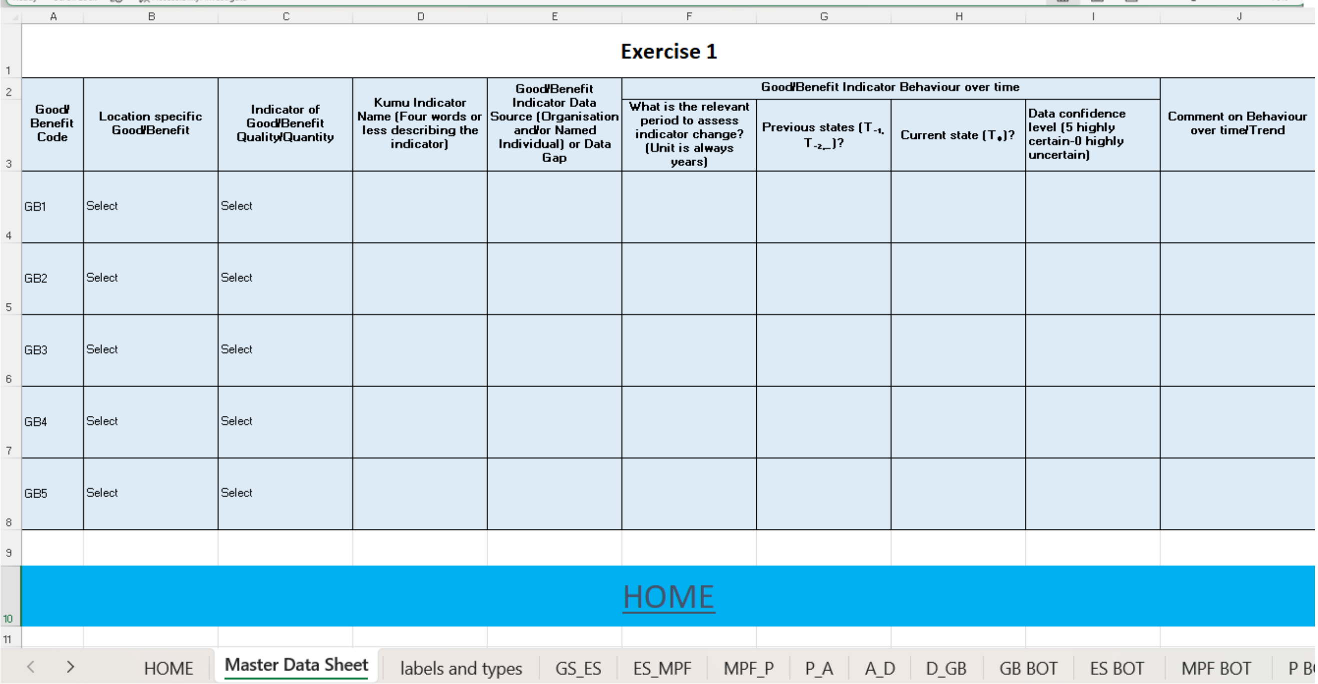



INTERNATIONAL OBLIGATIONS
INTERNATIONAL MARITIME ORGANISATION (IMO)
Shipping
******* GOVERNMENT
Department... Description
Department... Description
Department... Description
Department... Description
Department... Description
Department..... Description
Department... Description
Department... Description
Department... Description
Name Description
Historic England
Devolved Administrations
Ministerial Departments
Executive Agencies
Executive Non-Departmental Public Bodies
Cross-government Committee
'Other' Public Bodies
Public corporations
Independent Commercial Business
Committees or joint committees of local government


INTERNATIONAL OBLIGATIONS
GOVERNMENT
Name
Description
Name Description
Devolved Administrations
Ministerial Departments
Executive Agencies
Executive Non-Departmental Public Bodies
'Other' Public Bodies
Advisory Non-Departmental Public Bodies

# Appendix 3(c) – The Integrated Systems Analysis Excel Sheets.



**Exercise 1**

| Good/Benefit Code | Location specific Good/Benefit | Indicator of Good/Benefit Quality/Quantity | Kumu Indicator Name (Four words or less describing the indicator) | Good/Benefit Indicator Data Source (Organisation and/or Named Individual) or Data Gap | Good/Benefit Indicator Behaviour over time: What is the relevant period to assess indicator change? (Unit is always years) | Previous states ($T_{-1}$, $T_{-2}$...)? | Current state ($T_0$)? | Data confidence level (5 highly certain-0 highly uncertain) | Comment on Behaviour over time/Trend |
|---|---|---|---|---|---|---|---|---|---|
| GB1 | Select | Select | | | | | | | |
| GB2 | Select | Select | | | | | | | |
| GB3 | Select | Select | | | | | | | |
| GB4 | Select | Select | | | | | | | |
| GB5 | Select | Select | | | | | | | |

HOME

**Exercise 2(a)**

| Ecosystem Service Code | Ecosystem Service | Relevant Ecosystem Service Indicator(s) of Quantity and/or Quality | Kumu Indicator Name (Four words or less describing the indicator) | Ecosystem Service Indicator Data Source (Organisation and/or Named Individual) or Data Gap | Ecosystem Service Indicator Behaviour over time/Trend | | | | Behaviour over time/Trend |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | What is the relevant period to assess indicator change? | Previous states ($T_{-1}$, $T_{-2}$,...)? | Current state ($T_0$)? | Data confidence level (5 highly certain-0 highly uncertain) | |
| ES1 | Select | Select | | | | | | | |
| ES2 | Select | Select | | | | | | | |
| ES3 | Select | Select | | | | | | | |
| ES4 | Select | Select | | | | | | | |
| ES5 | Select | Select | | | | | | | |

HOME

**Exercise 2(b)**

| Marine Processes and Functioning Code | Marine Processes and Functioning | Relevant Marine Processes and Functioning Indicator(s) Quantity and/or Quality | Kumu Indicator Name (Four words or less describing the indicator) | Marine Processes and Functioning Indicator Data Source (Organisation and/or Named Individual) or Data Gap | Marine Processes and Functioning Indicator Behaviour over time/Trend | | | | Comment on Behaviour over time/Trend |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | What is the relevant period to assess indicator change? | Previous states (T-1, T-2,...)? | Current state (T0)? | Data confidence level (5 highly certain-0 highly uncertain) | |
| MPF1 | Select | Select | | | | | | | |
| MPF2 | Select | Select | | | | | | | |
| MPF3 | Select | Select | | | | | | | |
| MPF4 | Select | Select | | | | | | | |
| MPF5 | Select | Select | | | | | | | |

HOME

**Exercise 3**

| Pressure Code | Dominant Pressures | Dominant Pressures Indicator of Strength Quantity and/or Quality | Kumu Indicator Name (Four words or less describing the indicator) | Pressure Indicator Data Source (Organisation and/or Named Individual) or Data Gap | Local/Regional/National/International | Pressure Indicator Behaviour over time/Trend | | | | Comment on Behaviour over time/Trend | ExP/EnMP | Policies/laws/programmes relevant to the EnMP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | What is the relevant period to assess indicator change? | Previous states (T-1, T-2,...)? | Current state (T0)? | Data confidence level (5 highly certain-0 highly uncertain) | | | |
| P1 | Select | Select | | | Select | | | | | | | |
| P2 | Select | Select | | | Select | | | | | | | |
| P3 | Select | Select | | | Select | | | | | | | |
| P4 | Select | Select | | | Select | | | | | | | |
| P5 | Select | Select | | | Select | | | | | | | |

HOME

| Exercise 4 | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Dominant Activites | Indicators of Activity/ies Scope/Scale | Kumu Indicator Name (Four words or less describing the indicator) | Activity Indicator Data Source (Organisation and/or Named Individual) or Data Gap | Activity/ies Local (Individual, group/sector, national, international) | Activity Indicator Behaviour over time/Trend: What is the relevant period to assess indicator change? | Previous states (T-1, T-2,...)? | Current state (T0)? | Data confidence level (5 highly certain-0 highly uncertain) | Comment on Behaviour over time/Trend | Agreements/Laws/ Policies/ Programmes | Comment on Implementation, Monitoring and Evaluation |
| Select | Select | | | Select | | | | | | | |
| Select | Select | | | Select | | | | | | | |
| Select | Select | | | Select | | | | | | | |
| Select | Select | | | Select | | | | | | | |
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HOME | Master Data Sheet | labels and types | GS_ES | ES_MPF | MPF_P | P_A | A_D | D_GB | GB BOT | ES BOT | MPF BOT | P BOT | A BOT

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| Exercise 5 | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Need Code | Need(s) | Indicator of Strength of Need(s) | Kumu Indicator Name (Four words or less describing the indicator) | Ecosystem Service Indicator Data Source (Organisation and/or Named Individual) or Data Gap | Pressure Indicator Behaviour over time/Trend: What is the relevant period to assess indicator change? | Current state (T0)? | Previous states (T-1, T-2,...)? | Data confidence level (5 highly certain-0 highly uncertain) | Comment on Behaviour over time/Trend | Comment on the Need and any current ecological, economic and social trends affecting it |
| D1 | Select | Select | | | | | | | | |
| D2 | Select | Select | | | | | | | | |
| D3 | Select | Select | | | | | | | | |
| D4 | Select | Select | | | | | | | | |
| D5 | Select | Select | | | | | | | | |

HOME

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| 0 | Good and Benefit |
| 0 | Good and Benefit |
| 0 | Ecosystem Service |
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| 0 | Ecosystem Service |
| 0 | Ecosystem Service |
| 0 | Ecosystem Service |
| 0 | Marine Process and Function |
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| 0 | Marine Process and Function |
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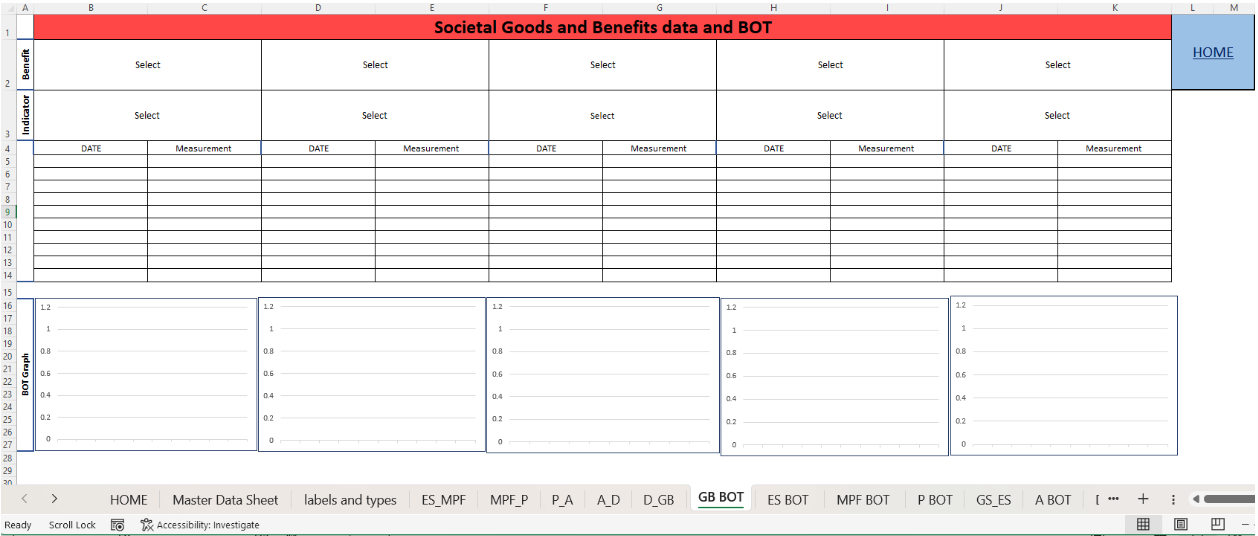
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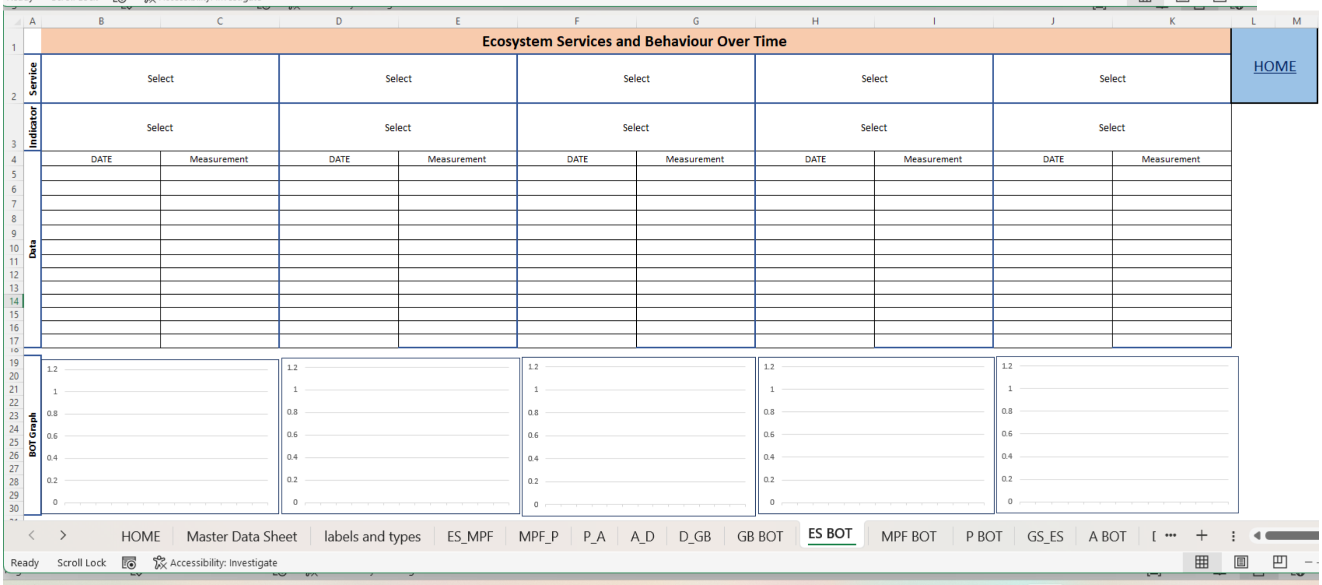
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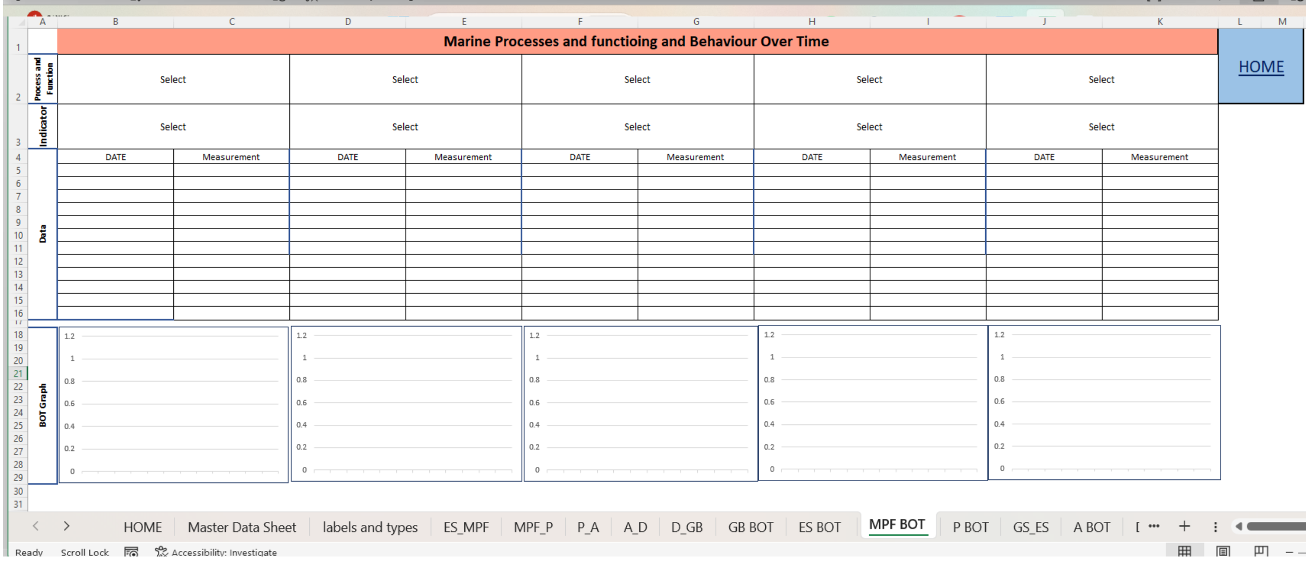
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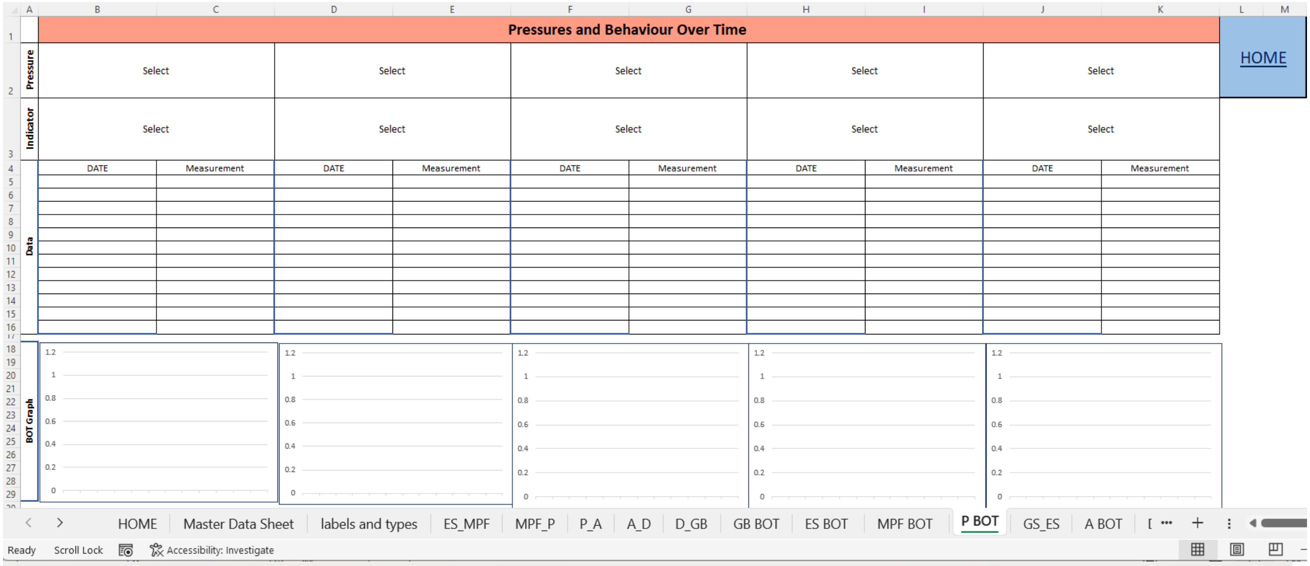
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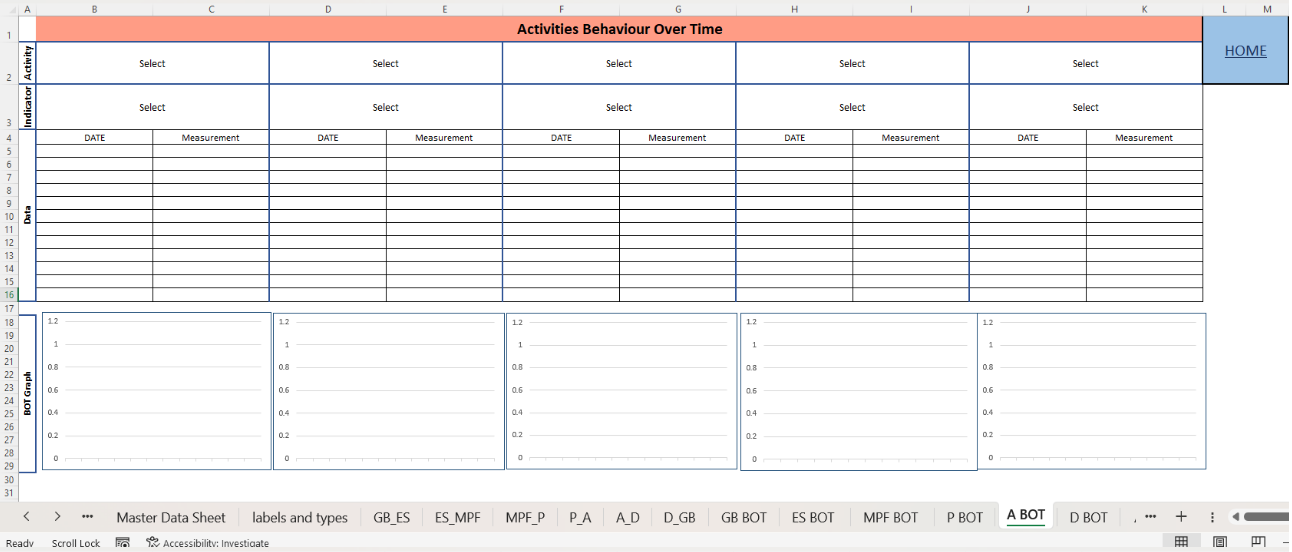
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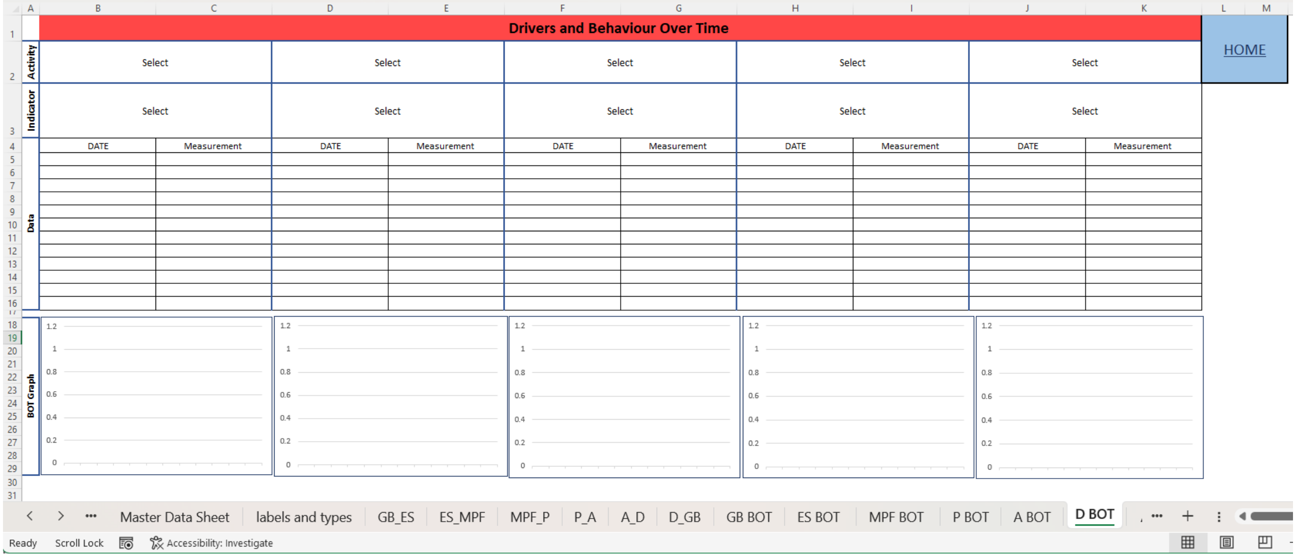
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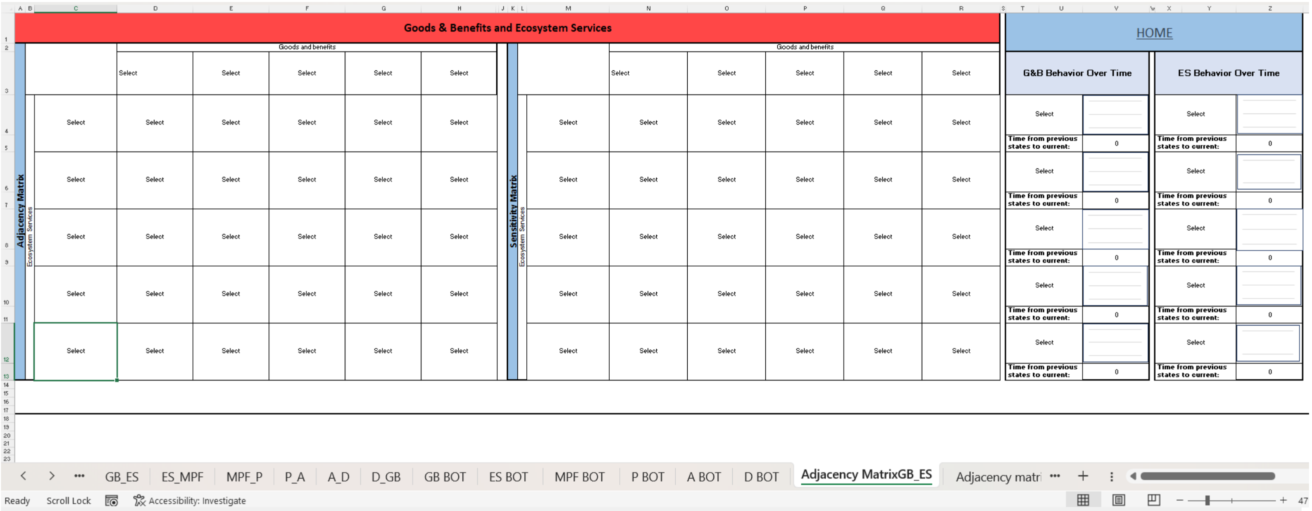
Goods & Benefits and Ecosystem Services
Goods and benefits
Adjacency Matrix
Ecosystem Services
Sensitivity Matrix
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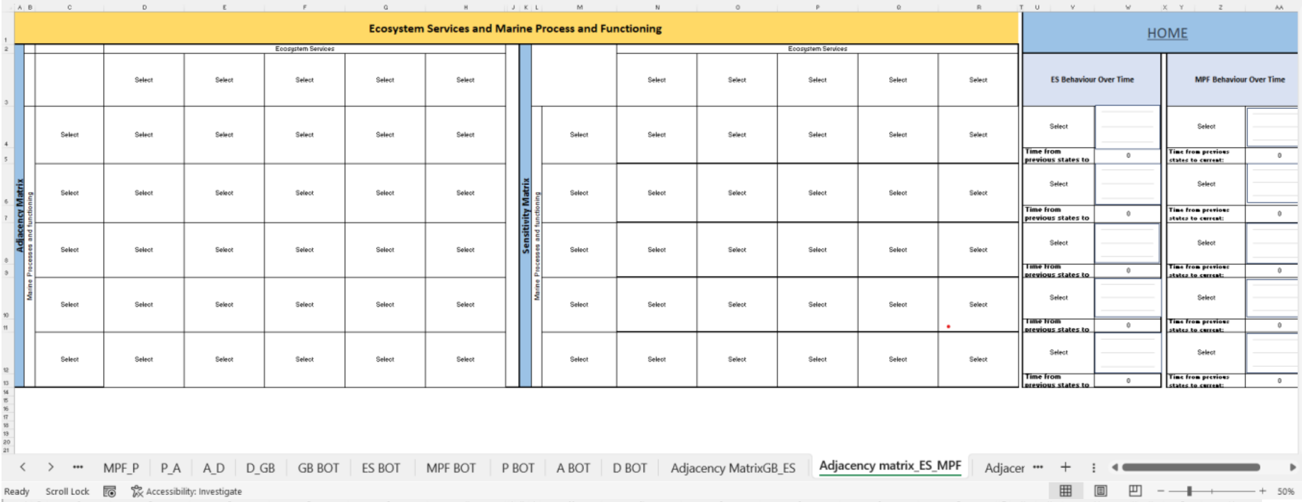
Ecosystem Services and Marine Process and Functioning
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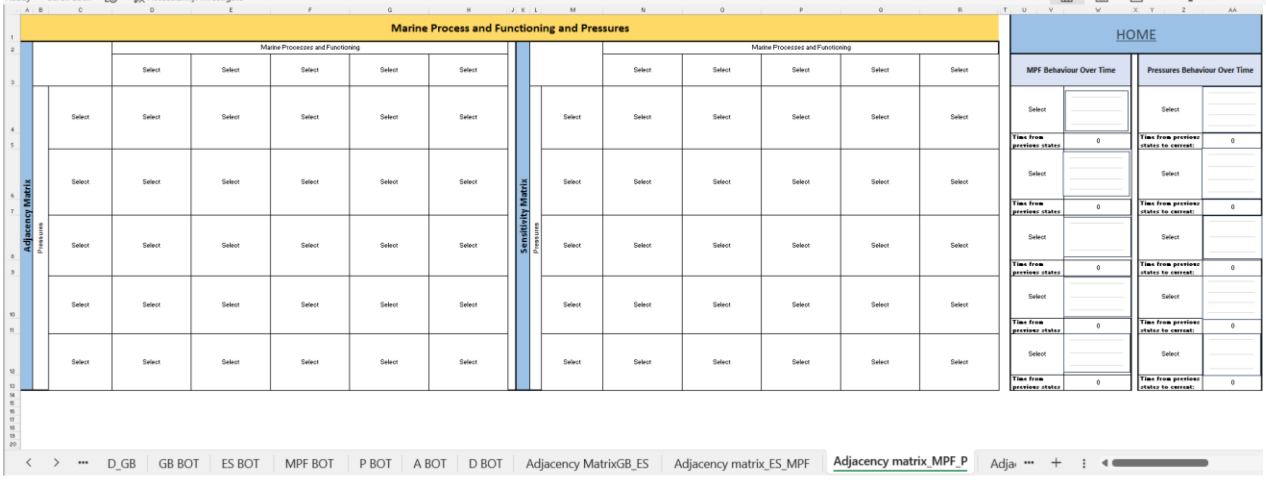
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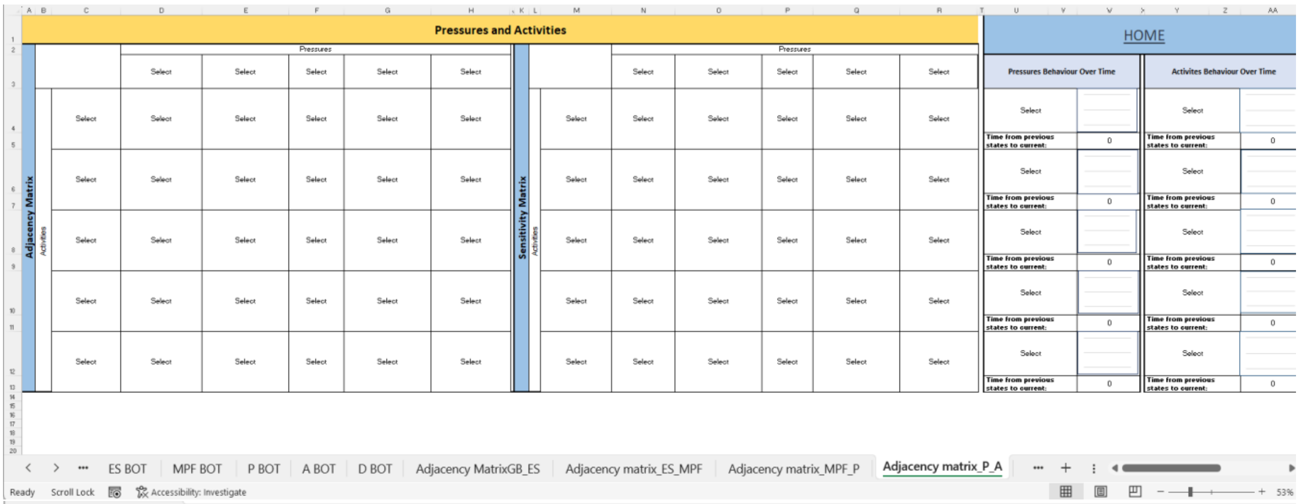
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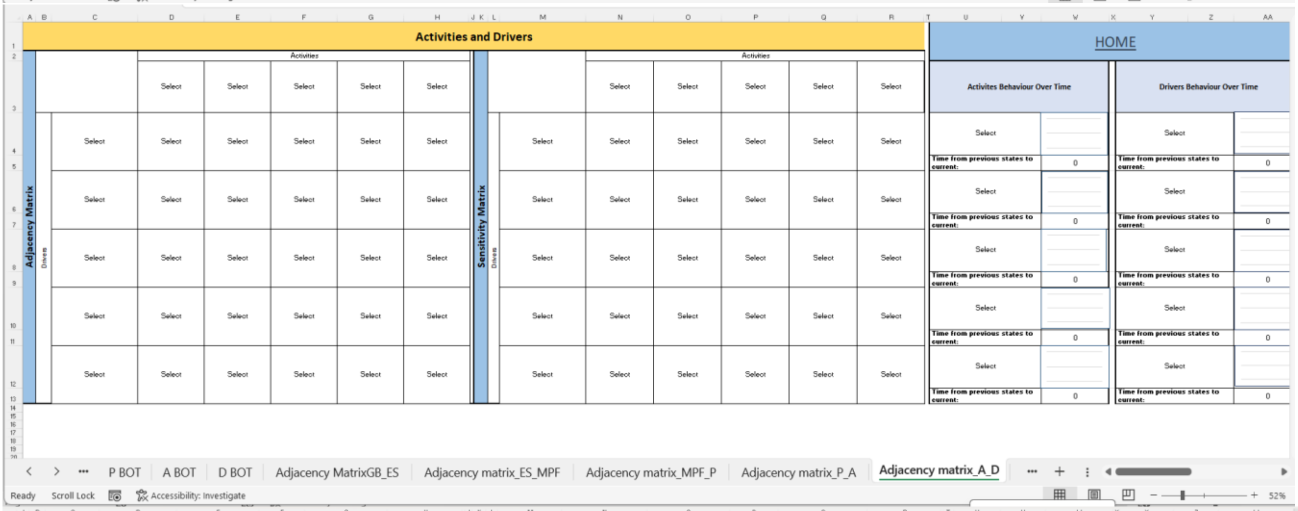
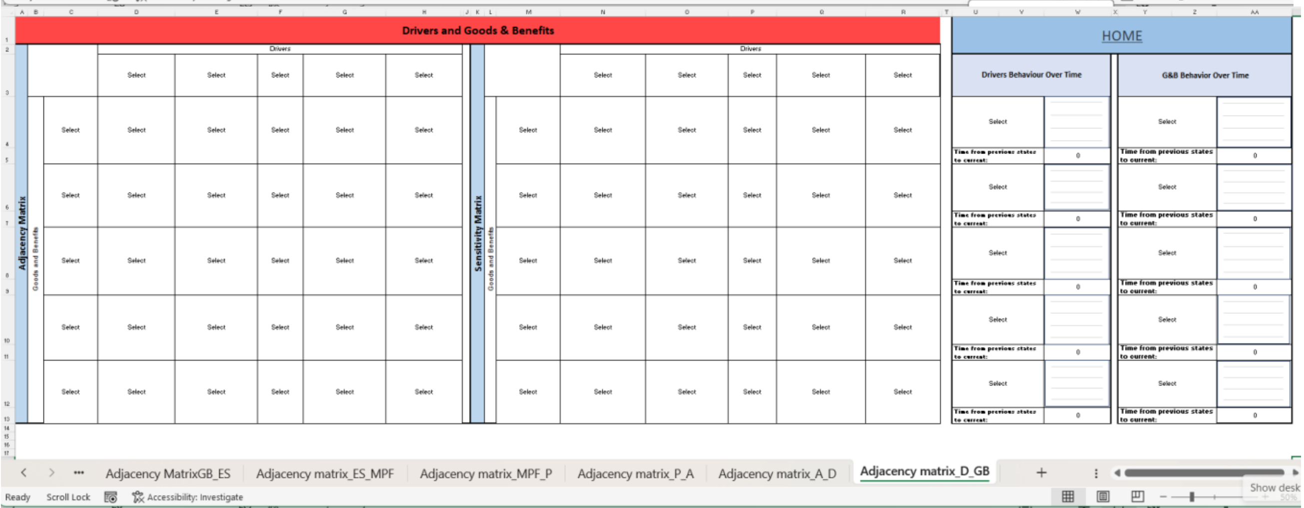
Adjacency MatrixGB_ES
Adjacency matrix_ES_MPF
Adjacency matrix_MPF_P
Adjacency matrix_P_A
Ready
Scroll Lock
Accessibility: Investigate


Activities and Drivers
HOME
Activities
Adjacency Matrix
Drivers
Sensitivity Matrix
Activites Behaviour Over Time
Drivers Behaviour Over Time
Select
Time from previous states to current:
P BOT
A BOT
D BOT
Adjacency MatrixGB_ES
Adjacency matrix_ES_MPF
Adjacency matrix_MPF_P
Adjacency matrix_P_A
Adjacency matrix_A_D
Ready
Scroll Lock
Accessibility: Investigate


Drivers and Goods & Benefits
HOME
Drivers
Adjacency Matrix
Goods and Benefits
Sensitivity Matrix
Drivers Behaviour Over Time
G&B Behaviour Over Time
Select
Time from previous states to current:
Adjacency MatrixGB_ES
Adjacency matrix_ES_MPF
Adjacency matrix_MPF_P
Adjacency matrix_P_A
Adjacency matrix_A_D
Adjacency matrix_D_GB
Ready
Scroll Lock
Accessibility: Investigate

## Appendix 1(d) – The Kumu Style Code

```
@settings {
  template: causal-loop;
}

@controls {
  bottom {
    filter {
      target: element;
      by: "element type";
      as: buttons;
      multiple: true;
      default: show-all;
    }
  }

  top {
    sna-dashboard {
      metrics: element-count, connection-count,
density, average-degree;
    }
  }
}

/* Goods and benefits */
element["element type"="good and benefit"] {
  color: #fff1a2;
  shape: triangle;
}

/* Ecosystem Service */
element["element type"="Ecosystem Service"]
{
  color: #313695;
  shape: square;
}

/* Marine Processes and Functioning */
element["element type"="Marine Process and
Function"] {
  color: #bce2ee;
  shape: pill;
}

/* Pressures */
element["element type"="Pressure"] {
  color: #fec05a;
  shape: diamond;
}

/* Activities */
element["element type"="Activity"] {
  color: #5abc67;
  shape: hexagon;
}

/* Drivers */
element["element type"="Driver"] {
  color: #776db3;
  shape: octagon;
}

connection["type"="+"] {
  color: #80b8d7;
}

connection["type"="-"] {
  color: #dc131e;
}

connection["strength"="strong positive"] {
  size: 30;
}

connection["strength"="medium positive"] {
  size: 15;
}

connection["strength"="strong negative"] {
  size: 30;
}

connection["description"="medium negative"] {
  size: 15;
}
```

MARINE SABRES

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## Marine SABRES Deliverable 3.2 Briefing Papers

# Cross-cutting theme Briefing Papers signposting document

Author: Frances Mynott

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UK Research and Innovation

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# 1. Overview - Briefing Papers signposting

To accompany the Simple Social-Ecological Systems (SES) Guidance (Gregory *et al.*, 2023) in the Marine SABRES project, a set of concise briefing papers has been produced. To support readers in cross-referencing between the briefing papers and the SES Guidance, the following table signposts to the briefing paper numbers and titles give a synopsis of the briefing papers individually and refer to linkages with the applicable section(s) of the SES Guidance Document. Signposting to relevant work packages (WP) in the project has also been included for clarity.

| Briefing Paper Number | Briefing Paper title | Briefing Paper synopsis | Links to SES Guidance Document section(s)/ wider project work packages. |
|---|---|---|---|
| 1 | Glossary of terms | This briefing paper outlines key terms related to the Simple SES guidance. | Throughout the Simple SES Guidance document (WP3). |
| 2 | Conservation and management | This briefing paper summarises the topics of management of impacts from human activities, marine nature conservation, protection and restoration (of marine habitats and species). | Throughout the Simple SES Guidance document (WP3). |
| 3 | Cause-Consequence-Response Chains – DAPSI(W)R(M) | This paper provides an overview of the DAPSI(W)R(M) framework and explains each element and associated benefits to managers within the Simple SES approach. | Part I of Simple SES Guidance (WP3) - Using the DAPSI(W)R(M) Framework for Issue Structuring.<br>Part II of Simple SES Guidance: Integrated Systems Analysis Part by Part. |
| 4 | Marine Processes and Functioning and Ecosystem Services | This paper details the concept of natural capital, marine processes and functioning, and the final ecosystem services. The paper includes background information on these elements, which are considered in the Simple SES. | Part II of the Simple SES Guidance (WP3): Integrated Systems Analysis Part by Part. |
| 5 | Societal Drivers, Benefits, Goods and Wellbeing | This briefing paper describes how Ecosystem Services (ES) become goods and benefits to society and the drivers affecting these goods and benefits. The briefing paper includes background information on these elements, which are considered in the Simple SES. | Part II of the Simple SES Guidance (WP3): Integrated Systems Analysis Part by Part. |
| 6 | Indicators | This briefing paper explains the concept of indicators and the role of indicators in the Simple SES approach. | Part II of the Simple SES Guidance (WP3): Integrated Systems Analysis Part by Part. |

| | | | |
|---|---|---|---|
| **7** | Ecosystem-based Management tools | This paper presents and summarises EBM tools, as linkage with the Simple SES approach. | Part II of the Simple SES Guidance (WP3): Integrated Systems Analysis Part by Part. |
| **8** | Scenario Testing | This briefing paper provides an overview of scenario testing within the context of the Simple SES approach. | Appendix 1 of the Simple SES Guidance (WP3). Also links with WP5 (5.1 Scenarios reporting) and WP4 reporting. |
| **9** | Systems thinking | This paper gives an overview and concepts of systems thinking, together with example modelling tools (mind maps, causal loop diagrams). | Part II of the Simple SES Guidance (WP3): Integrated Systems Analysis Part by Part. Visually Representing Complexity - DAPSI(W)R(M) and Causal Loop Diagramming. |
| **10** | Process and Information Management System (PIMS) | This briefing paper focusses on different aspects of managing the process, including information management, communication management, process management, and resource management. | Part I of the Simple SES Guidance (WP3) - Process and Information Management System (PIMS). |
| **11** | Marine Governance | This paper covers governance considerations and auditing within the context of the Simple SES approach. | Part I of the Simple SES Guidance (WP3) - Governance Sub-System. Also links with WP4. |
| **12** | Equity, Diversity and Inclusion | This paper highlights the principles of equality, diversity, including (EDI) and justice. The paper summarises how these can enhance decision-making and stakeholder engagement. | Part I of the Simple SES Guidance (WP3) - Stakeholder identification and engagement. Also links with WP2 of the project. |
| **13** | Stakeholders and stakeholder consultation | This briefing paper presents and discusses the role and importance of stakeholder engagement, together with the effective management of differing power relations and expectations. | Part I of the Simple SES Guidance (WP3) - Communication and impact management. Also links with WP2 of the project. |

MARINE SABRES

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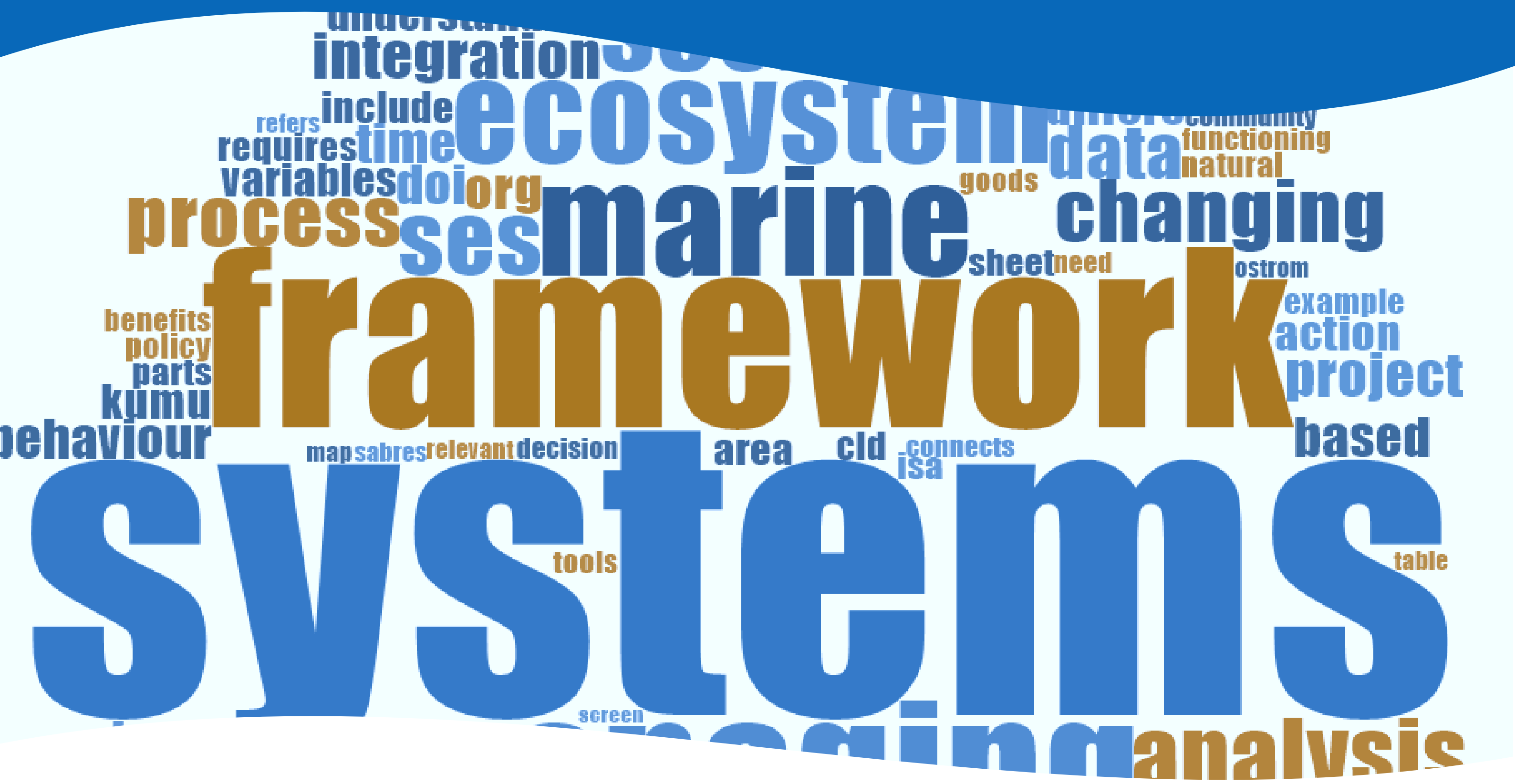
# Marine SABRES Deliverable 3.2 Briefing Paper 1

## Glossary of Terms

Authors: Gemma Smith and Michael Elliott




UCC University College Cork, Ireland · MaREI · LifeWatch ERIC · arditi · MARE · DTU · sjókovin · eco logic · RIFS Potsdam · Hafrannsóknastofnun · AZTI · HuFoSS · Università di Pisa · Klaipeda University · Wageningen University & Research · ULPGC · Aalborg University · UAc · NIOZ Royal Netherlands Institute for Sea Research · WWF · Cefas · IECS · University of Portsmouth

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| GES4SEAS Project | Grant Agreement 101059877 – GES4SEAS https://www.ges4seas.eu/ |
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This briefing note is one in a series of documents aimed at supporting the Simple Social-Ecological Guidance. For the complete set of briefing documents, please refer to the accompanying signposting document, which can be found here.

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## Contents

## 1. Introduction

This glossary of terms aims to promote clarity and consistency of implementation of the Simple SES guidance (Gregory et al. 2023), providing clear definitions of terms used. Moreover, this glossary serves as an accessible reference tool, particularly useful for anyone unfamiliar with certain jargon or technical terminology included within Marine ecosystem-based management.

Through a word cloud analysis to support the identification of frequently used terms, the below graphic illustrates the top 100 frequently used words in the Literature Review (Deliverable 3.1) and Guidance Document (Deliverable 3.2, Part A).


*Figure 1: Wordcloud of the SES Literature Review and Simple SES Guidance (created in NVivo © 2023 Lumivero).*

# 2. Glossary

This glossary is compiled of the definitions relating to the Simple SES explored in the literature review (Deliverable 3.1), combined with the GES4SEAS/ MARBEFES/ Marine Plan glossaries of key terms to aid harmonisation across the Horizon Europe sister projects.

| *Term* | *Definition* |
|---|---|
| **Activities** | Actions (potentially positive or negative) by society in an area orglobally - what we do in the natural and built environment to give us the Drivers; actions throughout all stages including creating, operating, using, and removing infrastructure; creating an energy supply; obtaining food and water; being cognitive; using material by our presence (air), etc. (Elliott et al., 2022a). |
| **Activity Footprint** | The area, and/or time, based on the duration, intensity and frequency of an activity which ideally, has been legally sanctioned by a regulator in an authorisation, licence, permit or consent, and which should be so clearly defined and mapped in order to be legally-defendable; it should be both easily observedand monitored and attributable to the proponent of the activity (Cormier et al., 2020). |
| **Alien species** | Any live specimen of a species, subspecies or lower taxon of animals, plants, fungi or micro-organisms introduced outside its natural range; it includes any part, gametes, seeds, eggs or propagules of such species, as well as any hybrids, varieties or breeds that might survive and subsequently reproduce (EU, 2014). |
| **Behaviour Over Time** | Similar to a time series, behaviour over time refers to a visual trend for understanding the temporal dynamics of specific system variables (Kopainsky et al., 2015). |
| **Baseline data** | Fundamental units of basic inventory information that are crucial for biodiversity conservation planning and management. These are both biotic and abiotic and usually include: (1) the presence and/or abundance of species and other units; (2) other dependent biotic data (e.g., plant cover for macro-arthropods); (3) the appropriate influential abiotic variables, and (4) human variables[1]. |
| **Boundary** | A border enclosing the parts of the system structure needed to generate the behaviour of interest. The system boundary excludes all components not relevant to the problem behaviour of concern (Ford, 2019). A system identified by a boundary will have inputs and outputs, which may be physical or abstract. |
| **Causal Loop** | A circular chain of causation that either reinforces or balances a change in the system (Garrity, 2018). |
| **Causal Loop Diagram** | Causal Loop Diagrams are rooted in systems thinking and are designed to visually represent the intricate interrelations between system variables (Senge, 1990). |
| **Coherence** | Coherence is the quality of being logical and consistent and/or the quality of being regarded as forming a whole; that there is a clear relationship between the parts, that the whole is greater than the sum of the individual parts; that there is a similarity in marine aspects in adjoining transboundary areas; that similar actions and features occur |

[1] Glossary — European Environment Agency (europa.eu))

| Term | Definition |
|---|---|
| | either side of a boundary; i.e. actions are the same on each side of a boundary (Elliott et al., 2023). |
| Complexity | Complexity refers to the intricate interconnections and interdependencies among the system components, which lead to emergent behaviours and non-linear outcomes that are often unpredictable (Kauffman, 1993; Lovelock, 2007). |
| Connectivity | Connectivity is the state of being or being able to be connected; marine features that are linked and contiguous in some way, either naturally by ecology and hydrodynamics or by management measures (human interventions and actions); i.e. elements are joined/linked across boundaries (Elliott et al., 2023). |
| Cumulative pressures | Aggregated, collective, accruing, and (or) combined pressures acting at the same space and/or time (GES4SEAS, 2023) |
| Cumulative effect | Aggregated, collective, accruing, and (or) combined ecosystem changes that result from a combination of human activities and natural processes. (Scherer, 2011). They can be antagonistic, synergistic and additive (Birk et al., 2020). |
| Drivers | Societal basic needs – the qualities and their quantities that humans need from the natural and built environment for health and well-being, e.g., space, food, water, clean air, shelter, energy, comfort, employment, enjoyment and relaxation, education, good mental and physical health (Elliott et al. 2022a). |
| Ecosystem | The interaction between the biotic and the abiotic components, functioning as a whole in a particular location (Dolbeth and Arenas, 2021) |
| Ecosystem Services | "functions and products from nature that can be turned into benefits with varying degrees of human input" (Natural Capital Committee, 2019, p.3). |
| Ecosystem- based approach (to management) | An 'ecosystem-based approach' or 'ecosystem-based management' is an integrated approach to management of human activities that considers the entire ecosystem including humans. The goal is to maintain ecosystems in a healthy, clean, productive and resilient condition, so that they can provide humans with the services and goods upon which we depend. It is a spatial approach that builds around a) acknowledging connections, b) cumulative impacts and c) multiple objectives. In this way, it differs from traditional approaches that address single concerns e.g., species, sectors or activities. (CSWD, 2020). |
| Effect | Human activities exert pressures which have effects which may lead to impacts on receptors. So, pressure and effect are always coupled so that every pressure has an effect, but not every pressure necessarily leads to an impact (Judd et al., 2015). |

| *Term* | *Definition* |
|---|---|
| **Effects Footprint** | The spatial (extent), temporal (duration), intensity, persistence and frequency characteristics resulting from (a) a single pressure from a marine activity, (b) all the pressures from that activity, (c) all the pressures from all activities in an area, or (d) all pressures from all activities in an area or emanating from outside the management area. They will have adverse consequences on the natural ecosystem components, but also are likely to affect the ecosystem services from which society gains goods and benefits. Hence, the determination of the effects-footprint needs to include the near-field and far-field effects and near- and far-time effects because of the dynamics and characteristics of marine areas and the uses and users of the area. Similarly, the effects-footprints may be larger in extent and more persistent than the causing activity-footprint and the resulting pressures-footprints. They also need to encompass the effects of both endogenic and exogenic pressures operating in that area (Cormier et al., 2020). |
| **Element** | An element is a variable that is liable to vary or change (Oxford English Dictionary). |
| **Emergence** | The generation of novel properties or functionalities that cannot be explained by their constituting elements alone, e.g., outcomes that are more than the sum of their parts (Moore et al. 2018; Page 2015). |
| **Endogenous / Endogenic managed pressure** | Anthropogenic pressures which originate within the management system, i.e. the causes of change can be controlled and their consequences addressed (Borja et al. 2010). |
| **Environmental Impact** | Environmental impact is an alteration from natural conditions, whether permanent or temporary, in a physical, chemical or biological aspect of environment state that is considered undesirable (an adverse effect). In applying the GES Decision, this undesirable state (for a GES criterion) is distinguished from the desirable state by a threshold value (CSWD, 2020). |
| **Environmental Target** | A qualitative or quantitative statement on the desired condition of the different components of, and pressures and impacts on, marine waters in respect of each marine region or subregion (EU, 2008). |
| **Equivalence** | Equivalence is that a relationship exists between two (or more) entities (e.g., national marine areas), and the relationship is described as one of likeness/sameness/similarity/equality in terms of one or more potential qualities; that the same and comparable outputs and outcomes occur either side of a boundary even if the methods used differ; i.e. actions have the same outcome on each side of a boundary irrespective of the methods used. |
| **Exogenous / Exogenic unmanaged pressure** | Causes of change which have their origin outside of a management system and cannot be controlled by local measures whereas the consequences which occur in the management site are subject to management measures (Borja et al., 2010) |
| **Exposure** | A measure of the degree to which a receptor is subjected to a pressure to which it is sensitive (Hiscock et al., 1999). |
| **Feedback** | When the effect of a causal impact comes back to influence the original |

| *Term* | *Definition* |
|---|---|
| **loop** | cause of that effect. A feedback loop is a sequence of variables and causal links that creates a closed ring of causal influences (Ford, 2019). |
| **Framework** | Frameworks are described as an organisational and prescriptive tool to identify and order elements and relationships between them (Ostrom, 2011; Elliott et al., 2020b). |
| **DA Process Management** | Refers to the oversight of the Demonstration Area (DA) activities, ensuring that each phase of the project corresponds with its intended objectives. In the wider context of marine EBM, this consideration ensures that the specific goals of ecosystem conservation, sustainable resource use, and stakeholder engagement are integrated and managed (Smith et al., 2023; Gregory et al., 2023). |
| **Good Environmental Status (GES)** | The environmental status of marine waters where these provide ecologically diverse and dynamic oceans and seas which are clean, healthy and productive within their intrinsic conditions, and the use of the marine environment is at a level that is sustainable, thus safeguarding the potential for uses and activities by current and future generations (under the Marine Strategy Framework Directive) (EC, 2008). |
| **Governance** | The structures and processes in which people in societies make decisions and share power, create the conditions for ordered rule and collective power (Folke et al., 2005); more specifically, the sum of the policies, politics, administration and legislation required in adaptive environmental management (Cormier et al., 2022). |
| **Holism** | Holism in this context refers to systems and their properties should be viewed as interconnected entities, not merely as a collection of individual parts (Capra, 1996). |
| **Homeostasis** | The tendency of organisms to preserve their equilibrium conditions. Control through the operation of negative feedback loops — homeostasisis is reached when the goal is attained and a stable equilibrium achieved (Ford, 2019). Environmental homeostasis is the ability of the environment to absorb environmental pressures with minimal overall change in status (Elliott and Quintino, 2007). |
| **Impacts on human Welfare** | Changes affecting wealth creation, quality of life required to satisfy the Drivers; changes in the results of the provisioning ecosystem services and cultural benefits; positive and negativeinfluences on the human complementary assets/capital to extract societal goods and benefits from ecosystem services (Elliott et al., 2022a). |
| **Indicator** | In general, an indicator consists of one or several parameters chosen to represent (indicate) a certain situation or aspect and to simplify a complex reality CSWD (2020). |
| **Intensity** | The magnitude of a pressure, resulting effect or impact (ICES, 2019). |
| **Invasive alien species** | An alien species whose introduction or spread has been found tothreaten or adversely impact upon biodiversity and related ecosystem services (EU, 2014). |
| **Loop Polarity** | A characteristic of feedback loops represented by a positive (+) or negative (−) sign that indicates whether a loop is a reinforcing (positive) or balancing (negative) one. Loop polarity is found by the algebraic product of all signs around a loop (Ford, 2019). |

| Term | Definition |
|---|---|
| **Management Response-Footprint** | The area and time covered by the governance means of monitoring, assessing and controlling the causes and consequences involved in the use of the marine environment through public policy-making, marine planning and regulatory processes. The policies, marine plans and technical measures produced by these processes indicate the means of determining if legal controls are satisfied, and of providing information and data to national and supra-national bodies. They focus on the area and/or time covered by the marine management actions and measures (e.g., Programme of Measures), including the distribution and range of a species (Elliott et al., 2022a) |
| **Marine Processes and Functioning** | All the ways in which marine biota and ecosystems control or modify the biotic and abiotic parameters defining the environment of people (i.e. all aspects of the 'ambient' environment). These marine ecosystem outputs are not consumed, but they affect the performance of individuals, communities and populations (Haines-Young and Potschin, 2018). Ecologically, this is taken to include the natural system as well as the 'environment of people'. |
| **Persistence** | The period over which a pressure continues to cause impact following cessation of the activity introducing that pressure (Knights et al., 2015) |
| **Physical Disturbance** | Abrasion, removal and deposition result in physical disturbances and may lead to physical loss depending on the intensity and/or persistence of the pressure. Sealing automatically implies physical loss. Any other physical pressures on the seabed that do not correspond to physical loss should be classified as physical disturbance. Such pressures do not induce permanent change since natural recovery, once the pressure has ceased, may be expected without human intervention (EC, 2022) |
| **Physical Loss** | Physical loss is defined as a permanent change of one of the following types (EC, 2022):<br>1. Sealing of natural substrate by an artificial structure or other allochthonous material.<br>• Loss of biogenic substrate.<br>• Seabed change at EUNIS level 2 (e.g., from sand to mud), or morphology or sediment changes at a more detailed level if significant and documented.<br>2. A permanent change is defined if one of the following conditions is true:<br>• When reversal is only possible by active human intervention (e.g., by coral, seagrass and kelp transplantations, by removal of artificial structures, by sand capping, etc.).<br>• When natural recovery rates exceed 12 years (such as the recovery time of some coral reefs or seagrass beds or the long-lasting effect of hydrographical or substrate change), or<br>• When natural recovery rates are unknown or undocumented but suspected to exceed 12 years. |
| **Pressure** | Resulting from [human] activities - defined as the mechanisms (as rate processes) of change, in the way in which activity will change the natural and societal systems, by modifying the structure and functioning of the systems (Elliott et al., 2022a). |

| Term | Definition |
|---|---|
| **Pressures Footprint** | The area and time covered by the mechanism(s) of change resulting from a given activity or all the activities in an area once avoidance and mitigation measures have been employed (the endogenic managed pressures). It does not necessarily coincide with the activity-footprint and may be larger or smaller. It also needs to include the influence and consequences of pressures emanating from outside the management area (the exogenic unmanaged pressures); given that these are caused by wide- scale events (and even global developments) then these are likely to have larger scale (spatial and temporal) consequences (Cormier et al., 2020) |
| **Programme of Measures** | The suite of measures which need to be taken by Member States in order to achieve or maintain GES. These include: input controls, output controls, Spatial and distribution controls, measures to improve traceability, economic incentives, mitigation and remediation tools, communication, stakeholder involvement and raising public awareness (EC, 2008). |
| **Recovery** | A return to a normal state of health, mind, or strength. The recovery of populations or ecosystems can be as simple increase, standardized or scaled increase, increase towards a specified target, increase to historical or pristine level or recovery of former structure or function (Lotze et al., 2011). |
| **Resilience** | The ability of an ecosystem or component, such as a habitat, to return to its original state after being disturbed. The recovery period (often measured in months and years) is used to assess sensitivity (to pressures or activities) for management purposes (CSWD, 2020). |
| **Resistance** | The ability of a receptor to absorb disturbance or stress without changing character (Hollings, 1973). Can be a synonym of intolerance. |
| **Resource Management** | Centered on the strategic distribution and use of resources, this element ensures the process operates within its stipulated budget and time constraints, efficiently utilising resources, from scientific tools to human expertise, ensuring that marine EBM projects are cost-effective and impactful (Smith et al., 2023; Gregory et al., 2023). |
| **Response (using management Measures)** | Using management measures (ecology/environment, technological, economic, societal behavior, governance (politics/policies, administration, legislation), culture, ethics/morals and communication, using stakeholders) as ways of influencing the Drivers and controlling the activities and pressures as the causes of change in order to prevent the consequences of state changes and impacts on welfare; to respond to both the exogenic and endogenic causes and consequences (Elliott et al., 2017, 2022a). |
| **Scenario** | A plausible description of how the future may develop, based on a coherent and internally consistent set of assumptions about key relationships and driving forces (e.g., rate of technology changes, prices). Note that scenarios are neither predictions nor forecast[2] |
| **Sensitivity** | Susceptibility of an ecosystem component to a specific pressure. The concept of sensitivity accounts for the ecosystem components recovery potential, resistance and resilience with respect to a certain pressure and |

[2] Glossary — European Environment Agency (europa.eu))

| Term | Definition |
|---|---|
| | related effects (Stelzenmüller et al., 2018). |
| **Shared Socio-Economic Pathways (SSP)** | Shared socio-economic pathways (SSP) are a set of narratives developed by a group of climate researchers to describe "plausible alternative trends in the evolution of society and natural systems over the 21st century at the level of the world and large world regions" (O'Neill et al., 2014). |
| **Simple** | "Comprising those basic elements necessary to achieve the objectives in an easily conducted and understood manner through the minimum complexity necessary." (Collins, 2023; Beer, 1984). |
| **Social-Ecological System** | "A social-ecological system consists of a bio-geo-physical unit and its associated social actors and institutions. Social-ecological systems are complex and adaptive and delimited by spatial or functional boundaries surrounding particular ecosystems and their problem context." (Glaser et al., 2012) |
| **Societal Benefits, including material Goods (often termed Societal Goods and Benefits)** | Those qualities and quantities satisfying human health and well-being and the economy which are derived from ecosystem services after inputting capital (built, human and social), including the human assets of energy, time, money, skills, knowledge and an ability to be sentient. |
| **Stakeholder Identification, Engagement and Communication** | Involves surfacing and actively involving all relevant people in the process, as well as seeking to create a dialogue that addresses their insights and reservations. This approach includes taking a critical perspective to who and how you are involving stakeholders in the process, ensuring this is done in a meaningful way. In the marine context, this could imply the involvement of everyone from fishermen to policymakers, ensuring that the diverse voices and concerns of all stakeholders are acknowledged in marine management decisions (Smith et al., 2023; Gregory et al., 2023a). |
| **State** | The term 'state' refers to the quality/condition of species/habitat/ecosystem elements. This can be determined through measurements in the environment of relevant parameters for such elements; such measurements, by definition, will reflect any impacts (individual and cumulative) to which the element has been subjected (CSWD, 2020). |
| **State Change** | Change on the natural system (as the ecology and its supporting physico-chemical aspects) – the resultant spatial and temporal changes in the environmental and ecological structure (situation at one time) and functioning (rate processes), the changes in the natural aspects of the supporting and regulating ecosystem services (Elliott et al., 2022a). |
| **Storyline** | A narrative description of a scenario, which highlights its main features and the relationships between the scenario's driving forces and its main features[3]. (Glossary — European Environment Agency (europa.eu)) |
| **Stressor** | A type of direct or indirect, natural or human related driver that causes undesired change in an ecosystem to any physical, chemical, or biological entity that can induce adverse effects on ecosystems or human health (Selkoe et al., 2015). |

[3] Glossary — European Environment Agency (europa.eu))

| Term | Definition |
| --- | --- |
| **System** | A system is a whole, encompassing interconnected elements which are networks of interactions, which together work to create the achievement of a common goal or purpose (Jackson, 2019; Elliott et al., 2020b). |
| **Systems Thinking** | Reynolds and Holwell (2020) describe 'systems' as being constructs for "engaging with and improving situations of real-world complexity", hence, in this context systems thinking can refer to any approach that adopts a holistic approach to analysis (Reynolds and Holwell, 2020). |
| **Threshold value** | A value or range of values that allows for an assessment of the quality level achieved for a particular criterion, thereby contributing to the assessment of the extent to which GES is being achieved (EU, 2017a). |
| **Tipping point** | Zones of rapid change in a nonlinear relationship between the state of an ecosystem or ecosystem component and intensity of a driver, human activity or pressure. This leads to abrupt transitions beyond a critical level, in which the system is unable to return to the precedent stable stage (Selkoe et al., 2015; Stelzenmüller et al., 2018). |
| **Tolerance** | The ability of an organism to endure unfavourable environmental conditions (EEA, 2001). |
| **Worldviews** | Worldviews are the system of values and beliefs shared by groups of people. They use them to make sense of the world they live in, and they represent the human bias for understanding nature and the individual's participation in social life. These perspectives represent the lens through which people see the future (Oliveira, 2022). |

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MARINE SABRES

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# Marine SABRES Deliverable 3.2 Briefing Paper 2

# Marine Management, Conservation and Restoration Briefing Note

Author: Michael Elliott

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# Table of Contents

# 1. Introduction

Marine management has a central and fundamental aim: to maintain and enhance the natural system, by ensuring that its physico-chemical structure and functioning lead to a sustainable ecological structure and functioning and the production of ecosystem services, while ensuring that society gains the goods and benefits necessary for its welfare and well-being (Elliott, 2011) (see Briefing Paper 4: *Marine Processes and Functioning and Ecosystem Services; and* Briefing Paper 5: *Societal Drivers, Benefits, Goods and Wellbeing*). The integrated management of marine areas requires the human activities, the resulting pressures, effects and ecological components to be managed, not least within a system of maritime spatial planning (MSP). The management has to be carried out within a system of legislation and by those administrative bodies charged with implementing that legislation (see Briefing Paper 11: *Governance*). Once management has determined that there are likely adverse effects of human activities, then Programmes-of-Measures are required to effect solutions, such as mitigation and/or compensation.

Maintaining and protecting species, habitats and habitat mosaics requires conservation measures. These may include designating particular areas or species as conservation zones and again bringing in management measures to ensure that new or existing activities do not adversely affect those components. Degraded systems, habitats, areas or species as the result of human activities then either need restoring or society should accept or tolerate that degraded state. However, there is a duty on all maritime states to restore degraded habitats either by removing the pressures and allowing recovery (passive restoration) or active restoration, by manipulating the habitats and species such as through geoengineering or ecoengineering (now commonly termed nature-based solutions) (Lepage et al., 2022).

This briefing paper covers each of these aspects – the management, conservation and restoration of marine areas; to add context and support the Simple SES guidance (Gregory et al., 2023).

# 2. Management of impacts from human activities

The coasts and seas support many activities, each of which has the potential to create pressures, defined as the mechanisms of effects which may be on both the natural and social systems. Hence, those natural and social systems and the activities, pressures and effects all need managing. As a degree of further complexity, the area of one maritime nation state adjoins adjacent maritime states such that transboundary issues of connectivity, coherence and equivalence in the assessment and management of those areas have to be considered (Figure 1) (see Elliott et al., 2023).

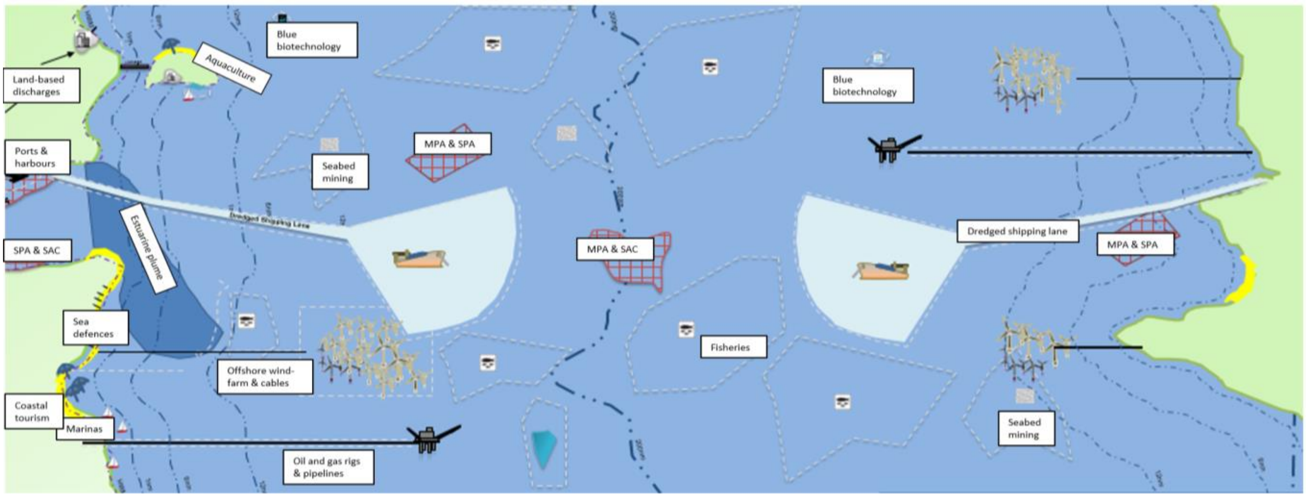

*Figure 1. A hypothetical multi-user transboundary area showing the area of influence (as a white dashed line) of each activity (From Elliott et al., 2023)*

Marine management requires an underlying philosophy and strategy. While marine management requires the same actions and has the same approaches and constraints worldwide, the European Marine Strategy is an example particularly relevant for Marine SABRES and its features have been adopted in countries outside the EU. This Strategy consists of two main pillars - the EU Marine Strategy Framework Directive (MSFD) and the Maritime Spatial Planning Directive (MSPD) which between them aim to create a coherent strategy for managing the features and activities in European marine areas (non-EU countries also have equivalent legislation). In essence, the implementation of such marine strategies aims to determine the status of an area, the effects of activities and their pressures, and the means of controlling and/or removing such pressures and effects (Figure 2). All maritime countries have created a plethora of marine governance (defined as policies, politics, administration and legislation) thereby including both the legal instruments and the bodies charged with carrying out the legislation (Boyes and Elliott, 2014, 2015; see Briefing Paper 11: *Governance*).

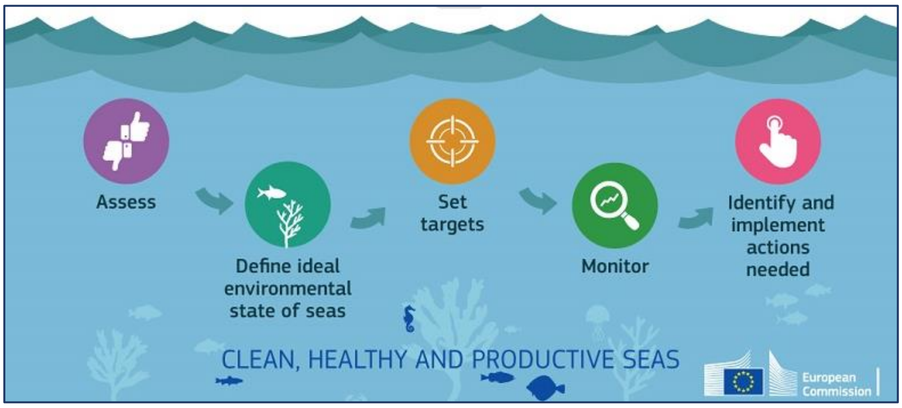


*Figure 2. Recommendation of the way to develop a Marine Strategy (note that this sequence is then repeated at 6-year intervals) (https://ec.europa.eu/environment/marine/eu-coast-and-marine-policy/implementation/reports_en.htm)*

Marine management and governance have progressed from managing the environment sectorally, i.e. by controlling each sector (fisheries, navigation, sea disposal, conservation, etc.) separately, to adopting a holistic system in which all areas are managed in order to achieve the Ecosystem Approach. The latter is defined as *an integrated approach to the management of human activities that considers the entire ecosystem including humans. The goal is to maintain ecosystems in a healthy, clean, productive and resilient condition, so that they can provide humans with the services and goods upon which we depend. It is a spatial approach that builds around a) acknowledging connections, b) cumulative impacts and c) multiple objectives. In this way, it differs from traditional approaches that address single concerns e.g. species, sectors or activities* (CSWD 2020).

As a pre-eminent example of the Ecosystem Approach, the MSFD had the aim, firstly, to protect and preserve the marine environment, prevent its deterioration or, where practicable, restore marine ecosystems in areas where they have been adversely affected. Secondly, it aimed to prevent and reduce inputs in the marine environment, with a view to phasing out pollution in order to ensure that there are no significant impacts on or risks to marine biodiversity, marine ecosystems, human health or legitimate uses of the sea.

For each country within the European Union, and for those countries outside the EU which still follow the Directive, the MSFD covers from the High Water mark out to the 200 nautical miles (or the mid-line between adjacent countries) limit and so overlaps with the Water Framework Directive operating out to 1 nm. The MSFD requires Member States to achieve Good Environmental Status (GES) while the WFD requires attaining Good Ecological and Chemical Status. Furthermore, with regard to conservation, the Habitats and Species and Wild Birds Directives require an area to be designated for its conservation objectives (names species or habitats) and then maintained in Favourable Conservation Status (see Boyes and Elliott 2014 for details). For each area, the MSFD requires an initial assessment, the development of a GES goal for each of 11 descriptors, the establishment of targets, the development of a monitoring programme and a Programme of Measures to be drawn up to achieve GES (Figure 3) (Borja et al., 2010, 2013). The descriptors are named in Figure 4 and can be regarded as being hierarchical in which D1 (biodiversity) and D4 (foodwebs and functioning) are paramount, i.e. if these are in GES then by definition, there should not be problems with the others Descriptors and vice versa.

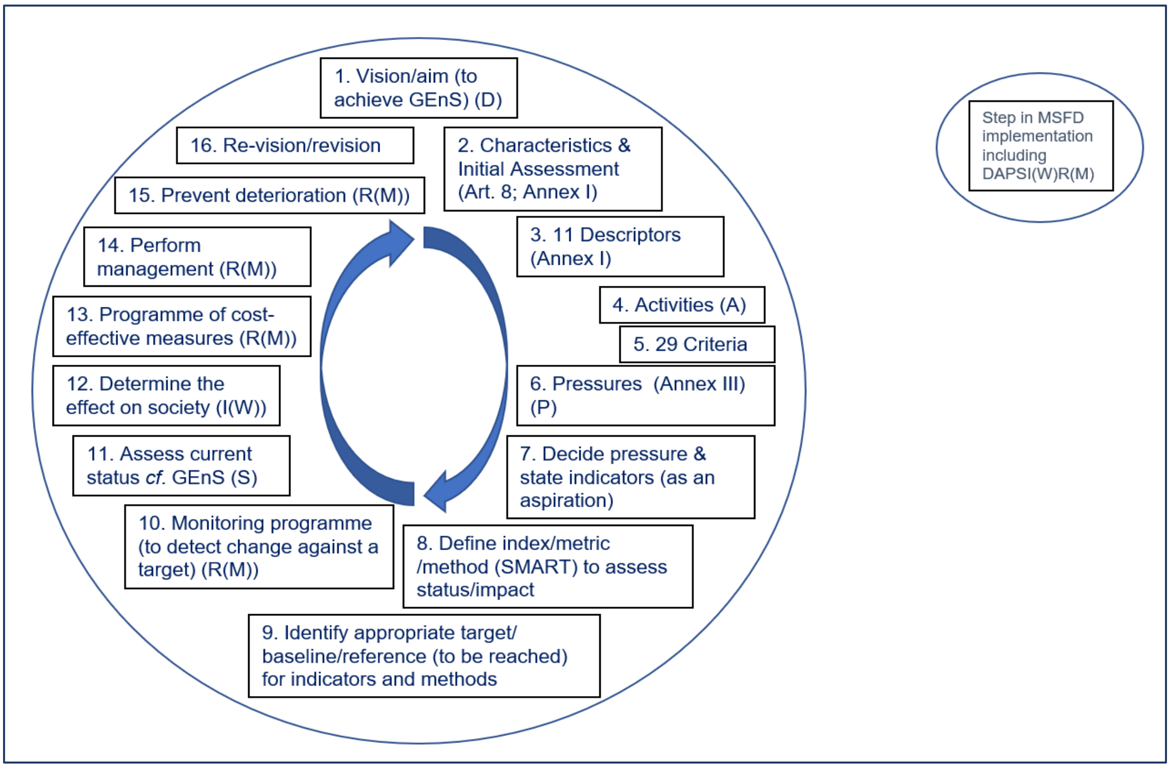


*Figure 3. A conceptual model of the implementation of the MSFD, with the cause-consequence-response model DAPSI(W)R(M) superimposed (see Briefing Paper 3: Cause-Consequence-Response Chains – DAPSI(W)R(M)) (from Elliott et al., 2015).*

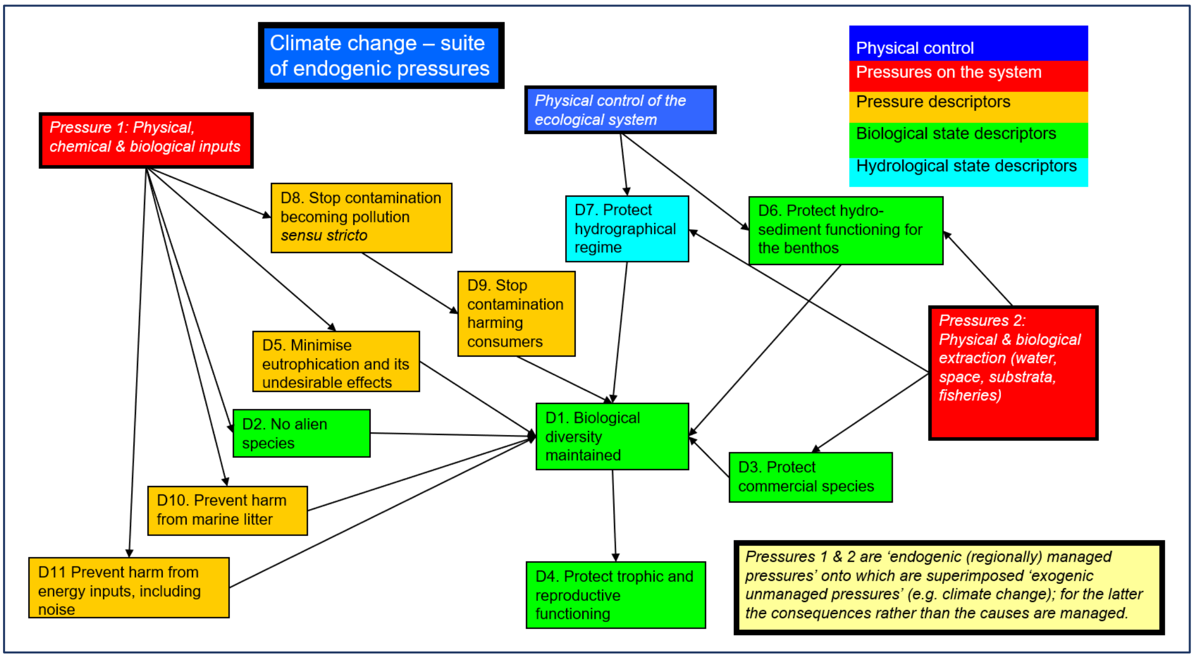


*Figure 4. The EU MSFD linkages between the 11 Descriptors, whether they relate to state or pressures and their relationship to endogenic and exogenic pressures, including climate change (modified from Borja et al., 2010).*

Under the subsidiarity principle, the MSFD is implemented by national agencies and in tandem with the European Regional Seas Conventions, thereby showing vertical integration from the local to the global. Marine management also requires horizontal integration across all sectors (fishing, aquaculture, navigation, etc.). The European Regional Seas Conventions (RSC) are for the Baltic (HELCOM), Mediterranean Sea (Barcelona Convention), the North-East Atlantic (OSPAR) and the Black Sea (Bucharest Convention). The aim for the MSFD was to work closely, and be implemented, with the RSC and so the RSCs have produced guidance and data relevant to the MSFD implementation. The RSC also produce Quality Status Reports showing the overall characteristics of their areas. As a further complication and area of overlap, the International Council for the Exploration of the Sea (ICES) also performs ecosystem reviews and a marine environmental characterisation.

The descriptors are linked and cover the adverse effects of activities as pressures and state changes to the system (as defined under the cause-consequence-response chain DAPSI(W)R(M)) (see Briefing Paper 3: *Cause-Consequence-Response Chains – DAPSI(W)R(M)*). Good Environmental Status requires to be determined by the monitoring and assessment programme and any remediation required is in actions under the Programme of Measures (PoM). Whereas the MSFD is regarded as the quality assessment directive, its counterpoint the EU Maritime Spatial Planning Directive (MSPD) is regarded as the means of achieving an integrated planning for the seas and so is linked to the European Blue Economy strategy; the MSPD is regarded as an integral part of the PoM. The MSPD aim is to achieve: '*the sustainable growth of maritime and coastal economies and the sustainable use of marine and coastal resources*'. Maritime Spatial Planning (MSP) focuses on planning when and where human activities take place at sea – to ensure these are as efficient and sustainable as possible. The MSP Directive then ensures a coordinated approach to MSP throughout Europe; it enables the efficient and smooth application of MSP in cross-border marine areas; it favours the development of maritime activities, and leads to the protection of the marine environment based on a common framework.

A sea area can be regarded as having a capacity to support and assimilate human activities, what may be termed the carrying capacity and the assimilative capacity (Elliott et al., 2018) (Figure 5). In essence, a sea will have a high environmental quality until activities are permitted, after which that quality will degrade with each activity; quality may be recovered with mitigation but eventually the capacity of the sea to assimilate those human uses will be exceeded, thereby exceeding the threshold for Good Environmental Status as required under the MSFD, i.e. a failure to attain GES (Elliott et al., 2018). Hence, marine management will be required to ensure that the seas can still support those activities for societal benefit while at the same time not being degraded regarding their natural habitats and species.

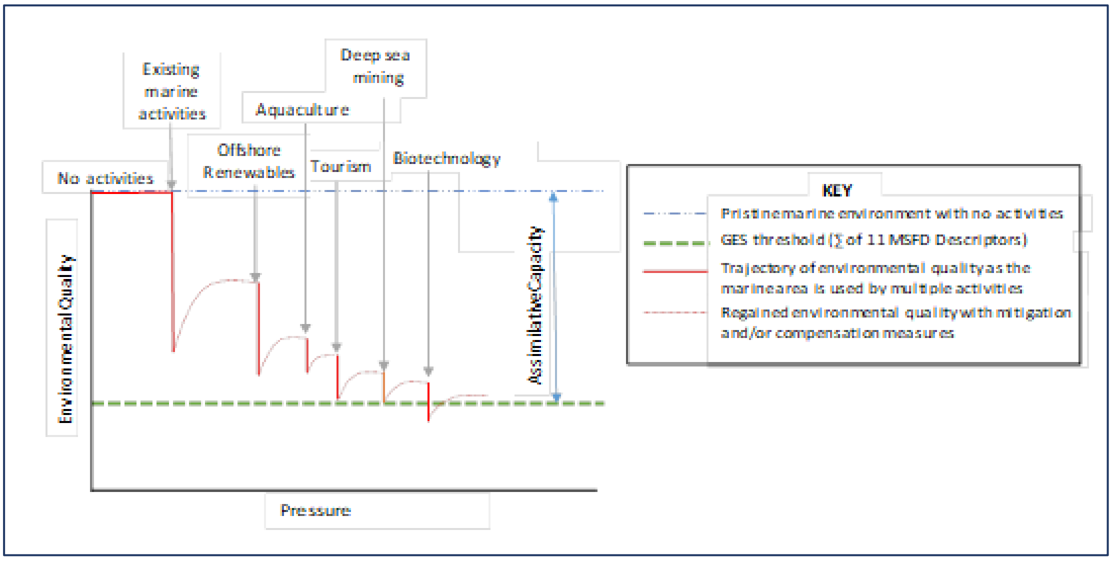


*Figure 5. A marine assimilative capacity conceptual model (see text for explanation) (Elliott et al., 2018).*

# 3. Activity-, Pressures-, Effects- and Management Response-Footprints

The plethora of marine human activities and their pressures and effects on natural and societal features require managing at local, national, regional and international scales. This requires management responses to determine (a) the time and area in which the human activities take place; (b) the time and area covered by the pressures generated by the activities on the prevailing habitats and species (in which pressures are defined as the mechanisms of change), and (c) the time and area over which any adverse effects (and even benefits) occur to both the natural and human systems.

These durations and extents of influence can be regarded as footprints and hence the spatial and temporal scales of these leads to the concepts of *activity-, pressures-, effects- and management responses-footprints* (Elliott et al, 2020a; Cormier et al., 2022) (Table 1). These footprints cover areas from tens of $m^2$ to millions of $km^2$, and, in the case of management responses, from a large number of local instruments to a few global instruments thereby giving rise to what is termed the management response-footprint pyramids (Figures 6a and b). This pyramid may operate from either bottom-up or top-down directions, whether as the result of local societal demands for clean, healthy, productive and diverse seas or by diktat from national, supranational and global bodies such as the United Nations (see Cormier et al., 2022, for further details). The developer of an activity, via an Environmental Impact Assessment, will be required to determine and control the activity footprint and its pressures and effects leading from that footprint (see Elliott and Wither, 2023). In turn, the regulators permitting that activity should understand the wide range of environmental control regulations, i.e. their footprint, both spatially and temporally. Figure 7 indicates the types of marine management authority likely to be created in each country as well as some of the instruments used by those bodies; it is emphasised that horizontal integration is required across these bodies.

*Table 1. Definitions for activity-, pressures-, effects- and management response-footprints (adapted from Elliott, et al. 2020; Cormier et al, 2022).*

| Footprint | Definition |
|---|---|
| **Activity-footprint** | The area and/or time, based on the duration, intensity and frequency of an activity which ideally has been legally sanctioned by a regulator in an authorisation, licence, permit or consent, and which should be clearly defined and mapped in order to be legally-defendable; it should be both easily observed and monitored and attributable to the proponent of the activity. |
| **Pressures-footprint** | The area and time covered by the mechanism(s) of change resulting from a given activity, or all the activities in an area, once avoidance and mitigation measures have been employed (the endogenic managed pressures). It does not necessarily coincide with the activity-footprint and may usually be larger but could be smaller. It also needs to include the influence and consequences of pressures emanating from outside the management area (the exogenic unmanaged pressures); given that these are caused by wide-scale events (and even global developments) then these are likely to have larger scale (spatial and temporal) consequences. |
| **Effects-footprint** | The spatial (extent), temporal (duration), intensity, persistence and frequency characteristics resulting from (a) a single pressure from a marine activity, (b) all the pressures from that activity, (c) all the pressures from all activities in an area, or (d) all pressures from all activities in an area or emanating from outside the management area. They include both the adverse and positive consequences on the natural ecosystem components and on the ecosystem services and societal goods and benefits. They need to include the near-field and far-field effects and near- and far-time effects because of the dynamics and characteristics of marine areas and the |

| | |
|---|---|
| | uses and users of the area. They may be larger in extent and more persistent than the causing activity-footprint and the resulting pressures-footprints. They also need to encompass the effects of both endogenic and exogenic pressures operating in that area. |
| **Response-footprints** | The area and time covered by the governance methods and approaches of monitoring, assessing and controlling the causes and consequences involved in the use of the marine environment through public policy-making, marine planning and regulatory processes. The policies, marine plans and technical measures produced by these processes indicate the means of determining if legal controls are satisfied, and of providing information and data to national and supra-national bodies. They focus on the area and/or time covered by the marine management actions and measures (e.g., programme of measures), including the distribution and range of a species. |

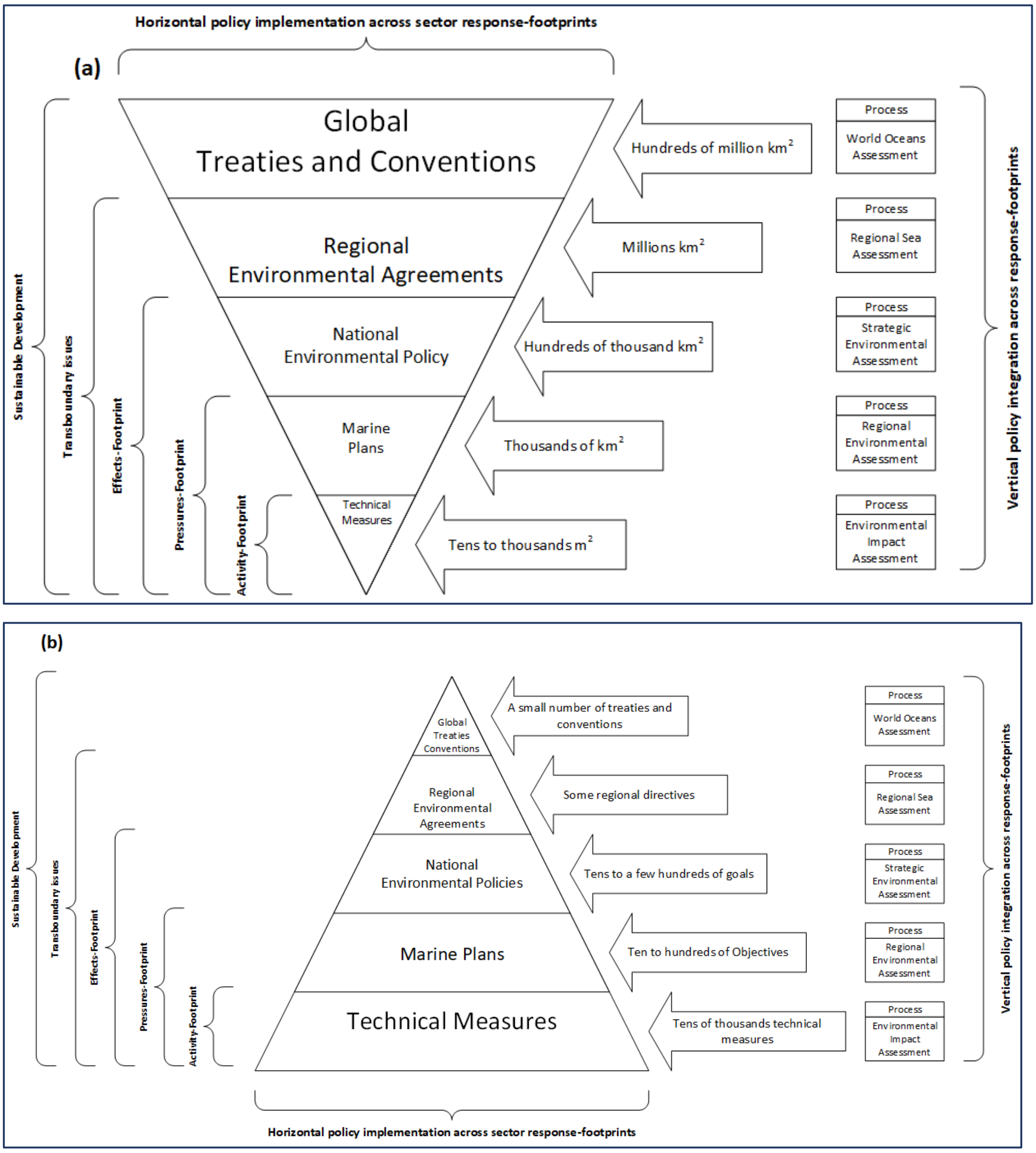


*Figure 6. The management response-footprint pyramids showing (a) the area covered by the management measures, and (b) the number of measures of each type; the height of the pyramids*

*indicates vertical integration whereas each horizontal slice of the pyramid will include all sectors (fisheries, navigation etc.) which must be horizontally integrated (after Cormier et al., 2022).*

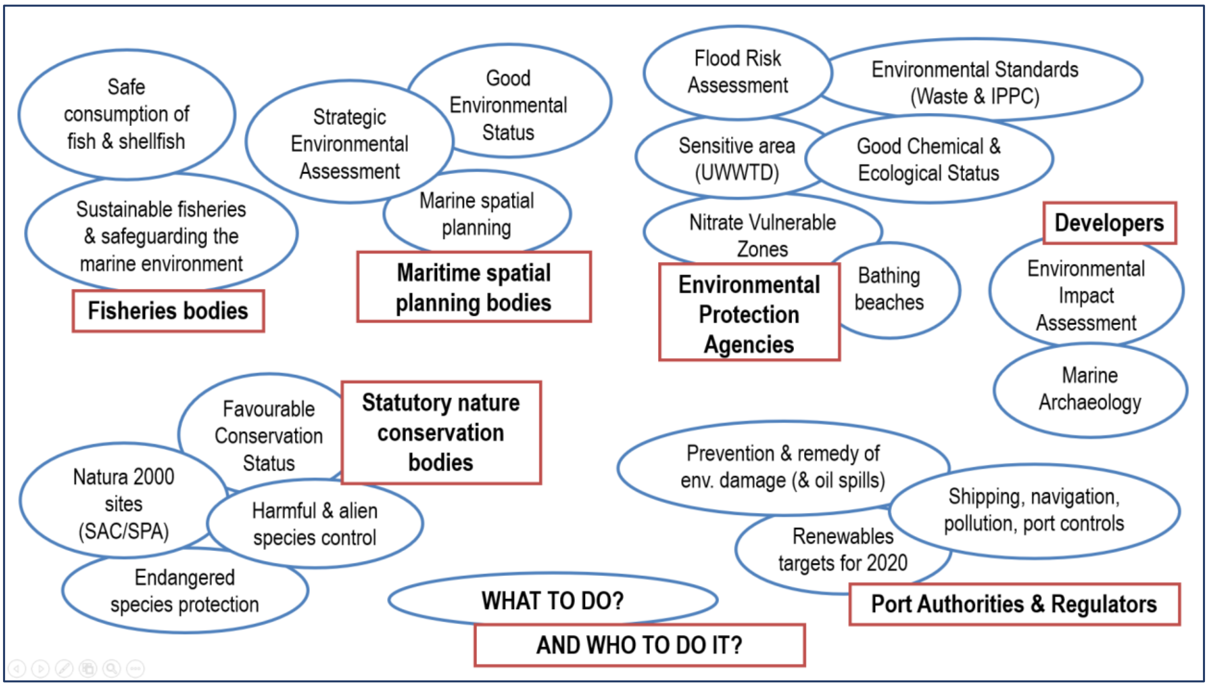


*Figure 7. The types of management bodies and examples of their instruments*

As exemplified by the Marine SABRES project, the complexity of the marine environment and the complexity of its assessment and management and governance system requires a systems approach (Elliott et al., 2020b; Gregory et al., 2023). At its most simple, this can be regarded as having three parts – setting the priorities and determining the issues in an area as well as the vision for the area (Part A), obtaining the relevant natural and social data (Part B) and using those data amongst stakeholders, the administrators enacting the legislation (Part C) (Figure 8). The analysis of these features shows that there are many tools and approaches in managing areas, that management covers from the small to the large scale, and that the management measures can be presented as an ordered list (Table 2).

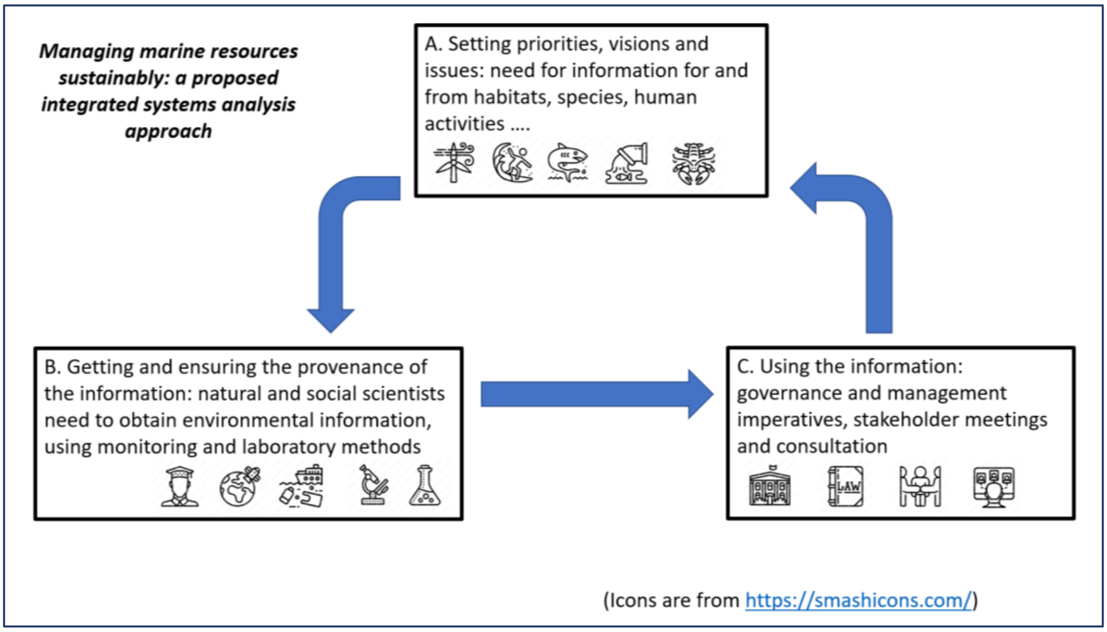


*Figure 8. An underpinning systems analysis approach (from Elliott et al., 2020b)*

*Table 2. How and where are we managing activities and what is the recipe for integrated marine management? (modified from Elliott and Wither, 2023, and references cited within this briefing paper)*

| How are we managing activities? | Where are we managing? | Recipe Leading to Integrated Marine Management: |
|---|---|---|
| By management action;<br>By developing programmes of measures;<br>By developing monitoring schemes;<br>By linking monitoring to SMART indicators (indicators which are Specific, Measurable, Achievable, Realistic, and Timebound);<br>By feedback to check if management is working;<br>By implementing laws;<br>By having many management bodies;<br>By making industry get their house in order;<br>By realizing the management footprint;<br>By having visions, objectives, policies;<br>By using good and fit for purpose science. | A small area (the activity footprint);<br>A middle-sized area (pressures footprints);<br>Middle to large areas (effects footprints);<br>Whole estuaries;<br>Whole catchments/ river basins;<br>Catchment-estuary-coastal areas;<br>Seas and sea regions;<br>Regional seas;<br>Areas Beyond National Jurisdictions;<br>The globe. | Need to understand how our activities lead to which pressures;<br>Need to understand which pressures are within and outside our control;<br>Need to understand ecological structure and functioning;<br>Need to understand what state changes on the natural system occur from those pressures;<br>Lead to describing the impact on human welfare as effects on Ecosystem Services and Societal Goods and Benefits;<br>Lead to defining the appropriate responses as management measures;<br>Require implementation of governance (policies, politics, administration and legislation);<br>Within a multiuser system requiring resolution of conflicts amongst users;<br>Communicate by working with stakeholders. |

## 4. Marine Nature Conservation and Protection

Marine activity managers will be charged with ensuring that their activities do not affect designated nature conservation sites irrespective of whether the industry is in, adjacent to or further away from the site. Therefore, they will be required to consult with and get permission from the local environmental protection agency, the marine licensing agency and the local statutory nature conservation body (Figure 7). Many marine areas are designated for their conservation value (e.g., Table 3 gives the plethora of nature conservation designations), each emanating from a particular piece of legislation (a regulation or Directive in the case of a country or European designation) or an agreement (in the case of local, regional and global designations). The sites will be designated to protect specific and designated features (named species and habitats, these may be termed the conservation objectives) from plans or projects (the industrial and urban activities).

The regulatory body will then require an assessment of the potential effects of the activity; this may be an Appropriate Assessment in the case of the EU Natura 2000 Directives (the Habitats & Species and Wild Birds Directives), a Habitats Regulations Assessment (HRA) or an Environmental Impact Assessment (EIA) (Lonsdale et al., 2017; Elliott & Wither, 2023) and including a cumulative effects assessment (Lonsdale et al., 2020). It is emphasised that while the statutory body is not required to demonstrate that there will be an adverse environmental effect by the activity, the developer will be asked to demonstrate that there will not be an adverse environmental effect. However, demonstrating a negative effect is challenging and may not always be possible. An adverse environmental effect although demonstrated may still be allowed if it is decided by the competent authority that there are good reasons for this and the effects cannot be mitigated, the designation of so-called IROPI – Imperative Reasons of Overriding Public Interest.

Some nature designated sites will allow activities as long as they are shown not to adversely affect the designated features; more usually these require either prevention or mitigation measures, or, where these are not possible, then by creating new habitats, the practice of ecoengineering (now often termed nature-based solutions) or geoengineering (e.g., Wolanski and Elliott, 2015). Under some designations, activities are not allowed, for example no-take zones or no-trawl zones in which fishing will be prohibited. Some of the designations allow recreational activities but not commercial ones.

The prevailing laws or adopted procedures will ensure that the nature designated areas or species are maintained or restored to a given status and hence activities will be controlled to restrict the pressures and effects. Any causes of actual or potential degradation will then have to be removed, reduced or mitigated or, failing that, compensated. The latter is of three types to compensate: the users of an area (e.g., economic compensation for fishermen affected), the resource affected (e.g., by restocking with fish or replanting seagrasses), or the habitat affected (e.g., by re-creating habitats elsewhere, such as by wetland creation) (Wolanski & Elliott, 2015).

The 2022 Convention on Biological Diversity agreed that countries would aim for 30% of their areas to be protected for nature and biodiversity by 2030 with a third of that being strictly protected, i.e. where activities are greatly (strictly or strongly) controlled; this is described as the '30x30 +10' approach. Hence it is expected that in the coming years the designated areas will increase in size.

It is also emphasised that some areas will have more than one designation. For example, many European Marine Sites (EMS) will be designated both for their bird populations and other species and habitats; hence they may be an EMS, SAC, SPA and Ramsar Site (Table 3). As such, the protected areas may range in size from very localise areas to large areas as in the case of EBSAs (Ecologically and/or Biologically Sensitive Areas) covering large ocean areas. In addition, each country will have its own nature protection designations, many of which may be for terrestrial areas which could include terrestrial coastal areas, possibly up to high water tide mark or even including intertidal areas.

*Table 3. Examples of Marine Nature Conservation designations (modified from Elliott and Wither, 2023)*

| Acronym | Title | Originator |
|---|---|---|
| **PSSA** | Particularly Sensitive Sea Areas | global, International Maritime Organisation |
| **SAC** | Special Areas of Conservation | EU Habitats & Species Directive |
| **SPA** | Special Protected Areas | EU Wild Birds Directive |
| **MPA** | Marine Protected Areas | EU Maritime Spatial Planning Directive, etc. global |
| **SSSI** | Sites of Special Scientific Interest | UK |
| **OECM** | Other Effective Conservation Measures | global |
| **EBSA** | Ecologically and/or Biologically Sensitive Areas | global |
| **HPMA** | Highly Protected Marine Areas | UK |
| **MCZ** | Marine Conservation Zones | UK |
| **NTZ** | No-Take Zones | global |
| **EFH** | Essential Fish Habitat | US, UK, etc |
| **BSH** | Broad Scale Habitats | UK etc. |
| **HSCI** | Habitats and Species of Conservation Importance | UK etc. |
| **EMS** | European Marine Sites | EU Natura 2000 Directives |
| **FOCI** | Feature of Conservation Importance | UK etc. |
| **VMEs** | Vulnerable Marine Ecosystems | FAO |

| Ramsar | Sites under the Ramsar Wetlands Convention | global |
|---|---|---|

## 5. Habitat and Species Restoration

Once a marine area has been degraded through human activities, then restoration measures will need to be implemented in order to return the site to an acceptable nature conservation status. Such a restoration may be passive, i.e. by removing the pressures and allowing the system and its species and habitats to recover, or active, by supporting/enhancing the habitats and species (Lepage et al., 2022). The conceptual model (Figure 9) indicates that an ecosystem (or one of its habitats or species) will degrade through human activities but that degradation may be reduced through prevention and mitigation of pressures. The system may recover once the pressures are removed (the red arrow) or if that is not successful then habitat rehabilitation or restoration will be required. Failing that, habitat recreation, creation, replacement or compensation will be required (for definitions of these terms see Elliott et al., 2007). Restoration may include geoengineering, i.e. changing the physical shape and structure of the area, and ecoengineering, now often termed nature-based solutions.

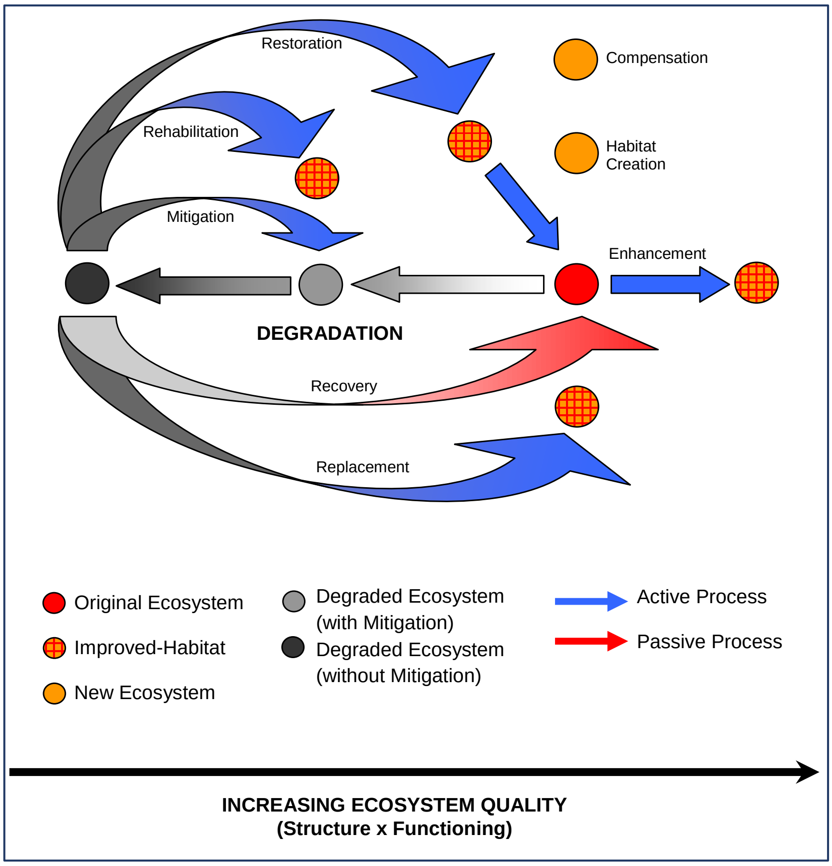


*Figure 9. A conceptual model showing the options for habitats degraded by human activities (from Elliott et al., 2007)*

The Programmes of Measures (see above) required by the MSFD and other Directives and legislation requires the prevention of degrading activities and the reversal of the adverse effects. Central to this is the use of ecoengineering to restore, recreate or replace habitats and to help species to recover. Ecoengineering (also termed Nature-based Solutions), which is to be used after the after pressures have been removed or controlled, or even if the pressures cannot be removed, is of two types (Elliott et al., 2016; Lepage et al., 2022). Ecoengineering Type A in which management changes the physics of the area, including changing the physiography and manipulating, where relevant, the freshwater flows from the catchment, to produce the ecological niches which in turn lets the ecology and habitats develop, especially if the colonising species are ecological engineers; this is on the basis that organisms will then recolonise the area with natural recruitment patterns.

If Type A ecoengineering is not successful, and habitat-forming and other species are not returning, then Type B Ecoengineering will aim to enhance and restore the ecology, by restocking, reseeding or replanting, in turn creating habitats or letting the ecological engineer species modify habitats, thus enhancing the physical-biological links. Ecoengineering initiatives often aim to accelerate natural rehabilitation and sometimes harness dynamic variability. However, they often only achieve establishing a static system (the desired state) even if this does not include all natural successional processes and stages. The success of ecoengineering requires an understanding of ecohydrology, the links between the biota, especially the habitat-forming species, and the hydrophysical environment (Wolanski & Elliott, 2015).

Table 4 indicates why systems degrade and how this can be reversed. It is emphasised that whereas active restoration and ecoengineering are potentially more successful in coastal and estuarine/lagoonal areas, they are less so (or even not possible) in offshore areas where often the only alternative is to remove the pressures and let the area recover naturally. For example, while a degraded beach or estuarine wetland can be recreated or restored in the same place or even elsewhere, a subtidal, offshore sandbank changed by siting a wind farm cannot be recreated elsewhere as it would require changing the hydrodynamic and sedimentary regime.

Finally, it is of note that in 2023, the European Commission proposed a Nature Restoration Law as a key element of the EU Biodiversity Strategy. Although greater details are not yet available, the Law proposes 'binding targets to restore degraded ecosystems, in particular those with the most potential to capture and store carbon and to prevent and reduce the impact of natural disasters'. The law will need to integrate the Marine Strategy and the implementation of the Natura Directives for Habitats and Species and Wild Birds.

Table 4. Management for what needs restoring, why and how? (from Wolanski and Elliott, 2015; Elliott et al., 2016).

| What? | Cause? | Reverse? |
|---|---|---|
| Land-claim | Wetland removal/dyke construction | Restocking with vegetation, reconnection, resculpting |
| DO sag | Waste discharges | Reduction/treatment of inputs, reoxygenation, bubbling |
| Bivalve biogenic reef loss | Siltation, overharvesting, | Adaptation, flushing, regulation, restocking |
| Eutrophication | Poor flushing, excess nutrients | Reconnection, regulation |
| Biota kills | Toxin input, WQ problems | Regulation, industry removal |
| Coral reef loss | Siltation, direct damage, bleaching | Run-off controls, re-creation, global rethinking, |
| Loss of fish | Overharvesting, climate change, hydrodynamic barriers | Restocking, rethinking, adaptation, regulation |
| Salinity change | Upstream abstraction, impediments to flow | Removal, reconnection |

| | | |
|---|---|---|
| Loss of seagrass | Smothering, nutrient excess, disease, hydrographic change | Reduction, removal, reconnection, replanting |
| Loss of flow | Diversion, abstraction, structures | Reconnection, reallocation |
| Seabed extraction | Aggregate removal, loss of sediment fraction | Reseeding, regulation, reallocation |
| Taxonomic changes | Non-indigenous species influx | Removal, eradication, prevention |

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## Marine SABRES Deliverable 3.2 Briefing Paper 3

# Cause-Consequence-Response Chains – DAPSI(W)R(M)

Authors: Michael Elliott, Jonathan Atkins and Gemma Smith

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# DISCLAIMER

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# 1. Introduction

Environmental management, and especially that for marine and coastal areas, is essentially a risk assessment and risk management process which implicitly or explicitly involves a cause-consequence-response framework (Cormier et al., 2019; Elliott et al., 2020a, b). In this, the natural and anthropogenic causes of hazards to the natural environment and the resulting risks to society are determined and then management measures determined to either prevent, mitigate or compensate those adverse effects. In the case of EU marine management legislation, such as the Marine Strategy Framework, Water Framework, Habitats and Species, and Wild Birds Directives, the sum of the management responses are termed Programmes of Measures.

# 2. The DPSIR Framework and its evolution

Those consequences are regarded as effects on both the natural system and the way society uses the natural system, which then need management actions to alleviate, reduce or remove those consequences (Elliott and Wither, 2023). This approach has long been proposed (since the early 1990s) as the Driver-Pressure-State-Impact-Response (DPSIR) framework to link development and its pressures and impacts on the environment (Patricio et al., 2016) (Figure 1). The aim of the approach is to link human needs for the marine and estuarine systems, the consequences of those needs and the means of tackling any problems resulting from those needs and consequences. This cyclical framework considers the *Drivers* (human activities and economic sectors responsible for the pressures); *Pressures* (particular stressors on the environment); *State* (the characteristics and conditions of the environment); *Impacts* (changes in the natural and human system and the way in which we use the marine area), and *Responses* (the creation of different policy options and economic instruments to overcome the state changes and impacts). Hence, the five elements of DPSIR framework produce a valuable philosophy for tackling and communicating our methods of marine management (McLusky & Elliott, 2004; Patricio et al., 2016;Elliott 2011; Atkins et al., 2011).

To the DPSIR acronym we may also add Recovery (a reduction in the state changes as the result of these actions) this giving a 6th element in the DPSIRR framework (Elliott et al., 2007; Borja et al., 2010). Subsequently, the EU project KNOWSEAS replaced the I for Impact with W for Welfare (hence DPSWR), both to avoid the long-standing confusion and separate impacts on the natural system (the state changes) from impacts on the human system and also to reinforce the societal-ecosystem links.

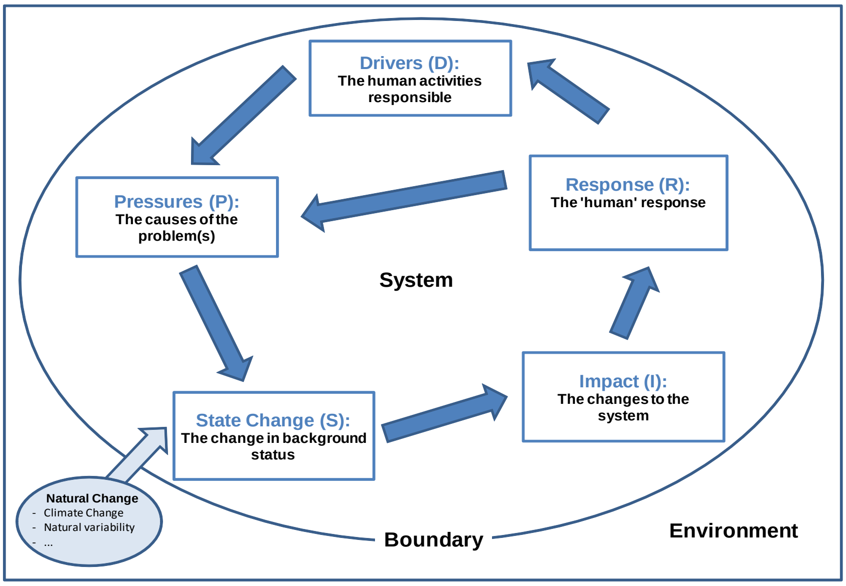



*Figure 1. The DPSIR Cycle (from Atkins et al., 2011)*

Earlier iterations then showed that there will be a single DPSIR cycle for each major driver (e.g., power generation is one cycle) but this interacts with cycles for wild capture fisheries, recreational fisheries, tourism, other industry etc. These ideas were expanded to require a set of 15 DPSIR-ES&SB (Ecosystem Services & Societal Benefits) postulates (see Atkins et al., 2011; Elliott 2011). As an example, a power station development fulfils the need for power by society (D) which in turn will lead to loss of space, requirement for cooling water and aggregates (P) which could change the ecological health of the benthos and the fish community (S). If not checked, these changes on the natural system would lead to a loss of amenity and fisheries (I). To prevent the latter then requires economic and legal instruments (R).

## 3. The DAPSI(W)R(M) Framework

Patricio et al. (2016) showed the evolution of the DPSIR approach and its many iterations and so, over time, various areas of confusion have developed in the use of DPSIR not least with social scientists using the elements in one way and natural scientists in another way. For example, a driver could be a human need, an activity, a sector of activities, or a stressor; a pressure could be an activity, a sector or a mechanism of change; state could be the characteristics of a system or the changes to those; impacts could be on the natural and/or social system, and responses were poorly defined. Hence DPSIR has been modified and refined into the most recent, and arguably a more complete, approach - the DAPSI(W)R(M) (pronounced *dap-see-worm*) framework (Figures 2 and 3) (Patrício et al., 2016; Elliott et al., 2017). The approach has now been used in many applications and areas (e.g., Lovecraft and Meek, 2019; Izar et al., 2022) as well as being merged with similar frameworks such as that produced by the AQUACROSS project (Elliott and O'Higgins, 2020).

The DAPSI(W)R(M) framework was designed to overcome anomalies and confusion in the previous iterations of the framework, especially the DPSIR approach (Table 1). In this, *Drivers* of basic human needs and values (such as the need for food and recreation) need to be fulfilled by *Activities* (e.g., fishing, tourism) that create *Pressures* (e.g., seabed abrasion, pollution); in turn, those Pressures, as the mechanisms of change, lead to *State changes* on the natural system (e.g., turbidity increase, oxygen depletion) and *Impacts (on human Welfare)* on the human system (e.g., biodiversity loss, ecosystem services provision depletion). The *Response (using management Measures)*, i.e. a policy response, then implies that society responds to those environmental and societal consequences, not least using a Programme of Measures, as defined in the EU Water Framework Directive and the EU Marine Strategy Framework Directive (Elliott et al., 2017). Those responses then need to range across the set of ecological, economic, technological, governance and other measures, summarised as the so-called 10-tenets (e.g., Cormier et al., 2022).

*Table 1. The rationale for modifying the DPSIR framework to the DAPSI(W)R(M) framework (extracted from Patricio et al., 2016; Elliott et al., 2017)*

| Element | Differences in DAPSI(W)R(M) from DPSIR |
|---|---|
| **Drivers** | The original framework did not restrict drivers to high level human needs thereby making it difficult to link to the welfare aspects; this also confused overall drivers and activities; this led to the concept of sectoral drivers (such as fisheries, oil, and gas, etc.). |
| **Activities** | In the original framework, activities were merged *inter alia* with drivers and pressures, thereby adding confusion; drivers were not explicitly restricted to high level human needs |
| **Pressures** | In the original, pressures and activities were merged (e.g., fisheries was a pressure rather than an activity creating pressures). They were not defined as mechanisms of change. |

| | |
|---|---|
| **State change** | In DPSIR this was regarded by social scientists as State Change on the natural system whereas natural scientists regarded it as State of the natural system (as a condition at one time) so that Impact was then the change on both the natural and social aspects. |
| **Impacts (on human Welfare)** | Originally social scientists regarded this as changes to the societal system whereas natural scientists regarded it as changes to both the natural and social systems. It has only recently been linked to ecosystems services. The new system then separates ecosystem services from societal goods and benefits by addressing them in State Change and Impact (on Welfare) respectively. |
| **Responses (using management Measures** | In DPSIR, these were regarded as ways to respond but little detail was given. The inclusion of management Measures then harmonised the framework with legislation such as EU Directives which require countries to define 'Programmes of Measures'. The definition then explains what type of measures are possible to get a holistic response. |
| **Links between the elements** | The original framework had a simpler cycle with fewer linkages. |

As with DPSIR, the DAPSI(W)R(M) framework can be presented as a set of interlinked cycles within a management area, each cycle for a major sector (fisheries, energy production, etc.), and where the activities produce the endogenic managed pressures (EnMP); the latter require management of both their causes and consequences within the management area (Figure 4). That management area, however, is also subject to exogenic unmanaged pressures (ExUP) in which the causes, such as of climate change, require management outside the management areas whereas the consequences and their management (such as sea-level rise) occur within the management area (Figure 4). The overall marine, coastal and estuarine system and their catchment can be shown as a set of interlinked DAPSI(W)R(M) cycles (Figure 5), thereby showing the complexity of the environmental management system, which requires the need for systems analysis and the development of a multifaceted Simple social-ecological system (Gregory et al., 2023). Briefing Paper 4 on Marine Processes and Functioning and Ecosystem Services presents an integrated ecosystem model based on DAPSI(W)R(M) (from Elliott, 2023).

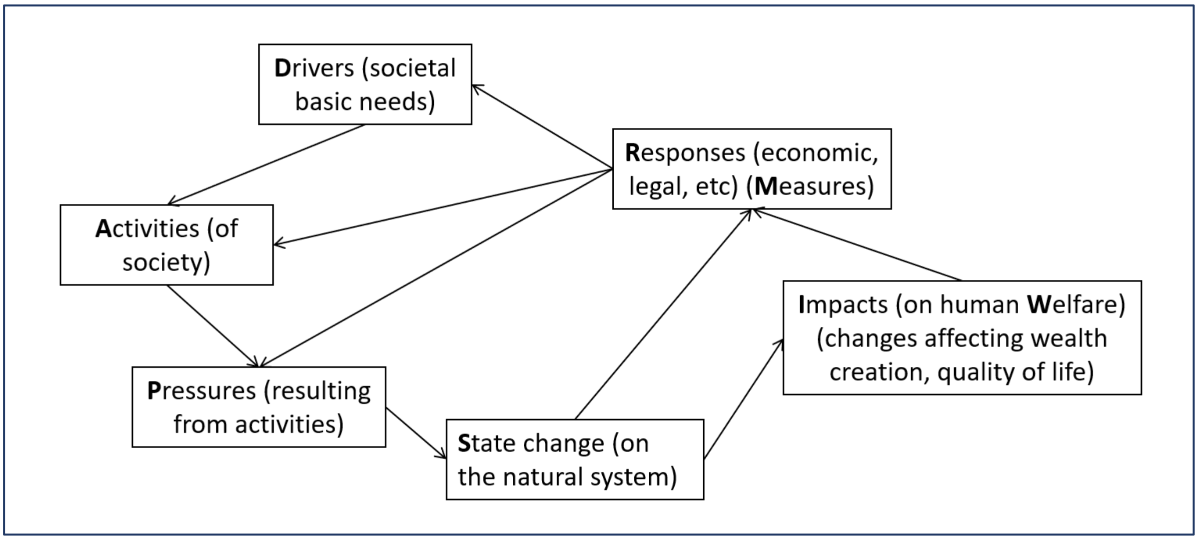



*Figure 2. The DAPSI(W)R(M) Framework*

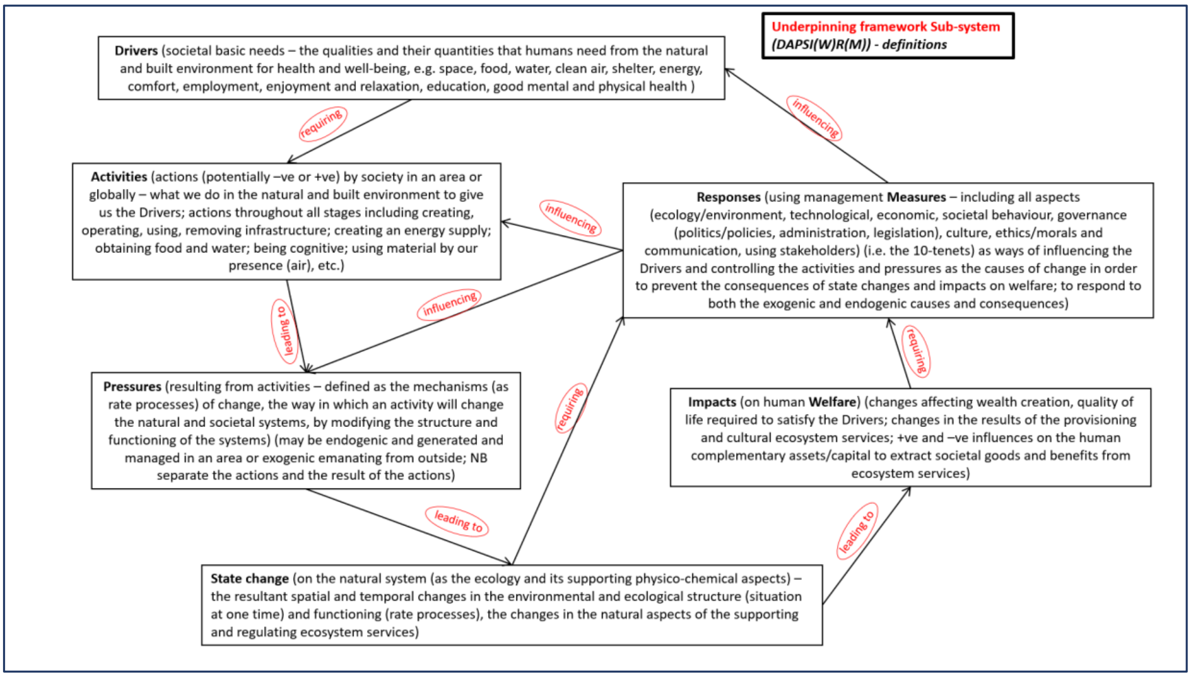
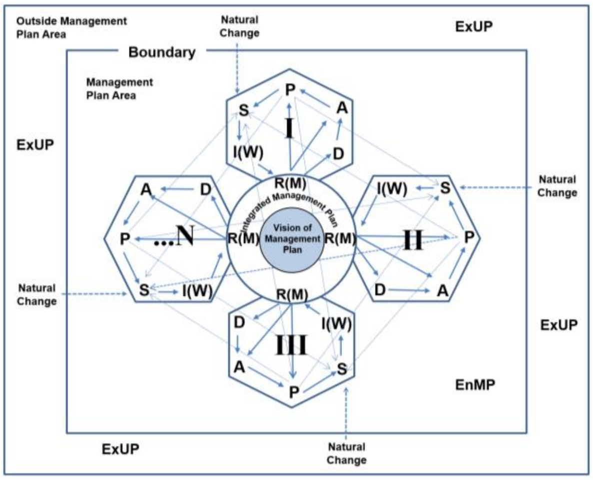



*Figure 3. The DAPSI(W)R(M) Framework - the description of each element and the links between them*



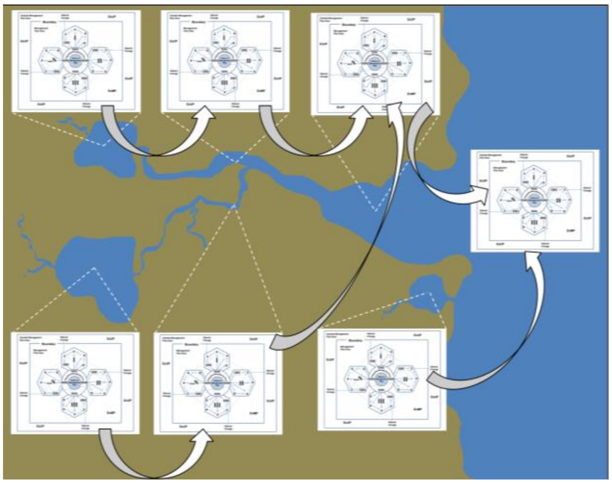



*Figure 4. (Left). The DAPSI(W)R(M) cycles for each sector of endogenic managed pressures within a management area (the inner box) and surrounded by the exogenic unmanaged pressures and natural change (the outer box) (from Elliott et al., 2017)*

*Figure 5. (Right). The DAPSI(W)R(M) framework (Figure 4) shown for each area within a catchment and at sea showing the connectivity links between them.*

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# Marine SABRES Deliverable 3.2 Briefing Paper 4

# Marine Processes and Functioning and Ecosystem Services

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# 5. Introduction

The marine system and its relationship with human uses and abuses can be visualised as an integrated model (Figure 1, Elliott 2023) in which a central spine from physico-chemical structure and functioning creates the conditions for ecological structure, biodiversity and functioning and ecosystem services. The latter then lead to societal benefits, including material goods, and wellbeing after adding human capital and assets (see Briefing Paper 5: *Societal Drivers, Benefits, Goods and Wellbeing*). Those natural science aspects (in green in Figure 1) and human aspects (in blue) are then affected by human activities and their resulting pressures (see Briefing paper 3: *Cause-Consequence-Response Chains-DAPSI(W)R(M)*) which can lead to a degraded system (denoted as the grey bar in Figure 1). Adaptive management, restoration, governance and planning are then required to prevent degradation or restore the degraded system as shown by the surrounding side and lower blue boxes in Figure 1.

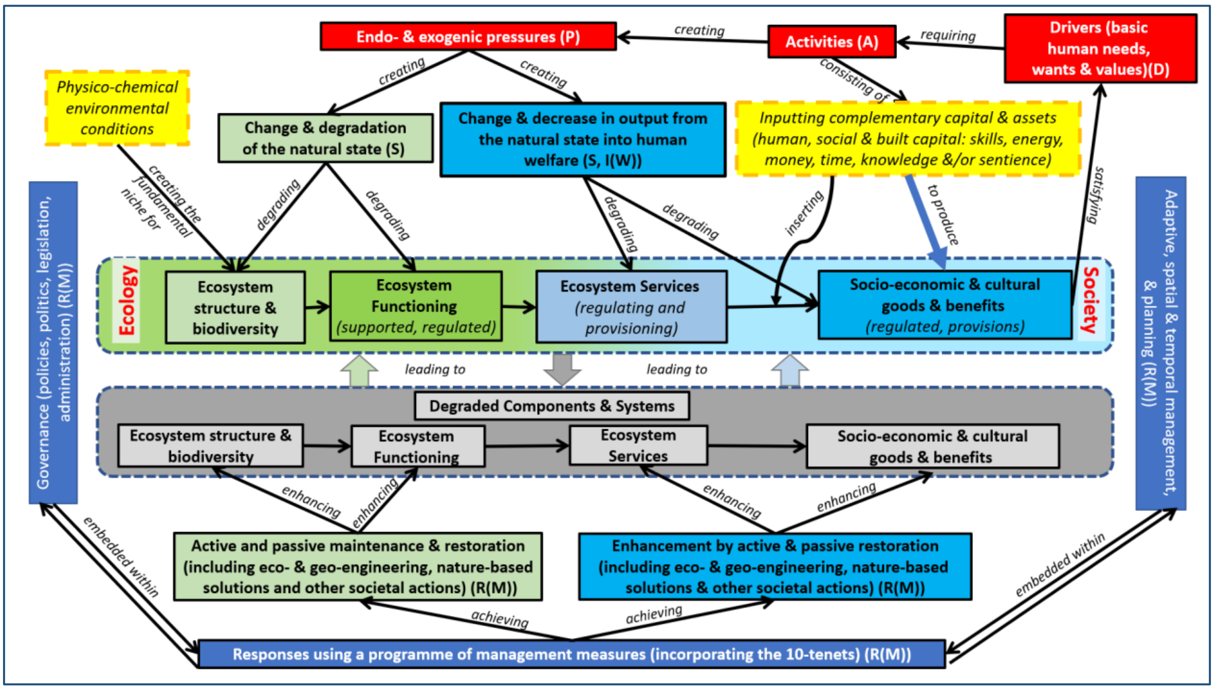


*Figure 1. The integrated socio-ecological system aiming to unify the DAPSI(W)R(M) framework, the means of degrading the natural system and recovery management measures, and the ecological structure and functioning to ecosystem services and societal goods and benefits continuum (from Elliott, 2023).*

In the Marine SABRES Simple SES approach (Gregory et al., 2023), an understanding of the terms 'marine processes and functioning' and ecosystem services is essential to determining the nature of the State Changes to the natural environment and then the adverse effects on the social system (the Impacts (on human Welfare)) as part of the DAPSI(W)R(M) underpinning framework (Elliott et al., 2017). For this we regard these terms as:

<u>Ecosystem Services</u> - *"functions and products from nature that can be turned into benefits with varying degrees of human input"* (UK Natural Capital Committee, 2019).

<u>Marine Processes and Functioning</u> – *"All the ways in which marine biota and ecosystems control or modify the biotic and abiotic parameters defining the environment of people (i.e. all aspects of the 'ambient' environment)* (Haines-Young and Potschin, 2018). However, in the use here, this should be extended to include the environment for nature as well as people.

## 6. Marine Processes and Functioning

Determining marine environmental sustainability requires evaluating the way in which human activities affect both the human and natural environment, as well as how the environment impacts society; this requires knowledge of the behaviour of human activities in the area, their footprints together with their pressures- and effects-footprints and the features and behaviour of the natural environment (Gray and Elliott, 2009; Elliott et al., 2020; Elliott and Wither, 2023). Coastal and marine ecosystems are complex and diverse, consisting of a variety of natural components such as habitats, species and ecological processes, all of which are both influence by, and the result of, the physico-chemical structure and processes. These elements form the basis of the natural capital, which provides a wide range of ecosystem services (Stuart and Davison-Smith, 2021; Elliott 2023; Burdon et al., 2024).

The term Natural Capital is defined as *"the elements of nature that directly or indirectly produce value to people, including ecosystems, species, freshwater, land, minerals, the air and oceans, as well as natural processes and functions"* (UK Natural Capital Committee, 2019). This recognises that coastal and marine ecosystems contain a range of components (e.g., habitats and species) and processes (e.g., food webs and ecological dynamics), which are the marine processes and functions from which Ecosystem Services flow (UK Natural Capital Committee, 2019). Understanding and managing this natural capital is essential for ensuring the sustainable use of our oceans and coasts (Stuart and Davison-Smith, 2021).

While it is not the aim of this Briefing Paper to explain the different marine processes and functioning in each habitat and ecosystem studied in the MarineSABRES project, general underlying principles can be given which can then be applied to those different habitats and ecosystems. Ecosystems are formed by the interconnected nature of physico-chemical and biological structural components (where structure equates to the features at one time) which are then modified by key rate processes, the resultant ecosystem functioning (Gray and Elliott, 2009). The Convention on Biological Diversity defines an ecosystem as "*a dynamic complex of plant, animal, and microorganism communities, along with their non-living environment, interacting as a functional unit*" (CBD, 2000). In the context of the marine environment, these critical processes relate to the inter-relationships between the physico-chemical (abiotic) and biological (biotic) attributes, as shown in Table 1 and Figures 1-4. However, natural phenomena and anthropogenic activities will then affect the structure and functioning of these ecosystems by impacting these fundamental processes and functions. Healthy marine environments are necessary to provide the full range of ecosystem services and societal benefits that enhance society's well-being.

The natural marine environment interacts with human systems through fundamental processes; these processes can be broadly categorised into three distinct groups: physico-chemical, ecological, and anthropogenic. The physico-chemical processes can be separated into the water column and the bed processes (respectively left-hand and right-hand sides in Figure 2, from Gray and Elliott 2009). It is emphasised here that such physico-chemical features can be defined as a suite of interlinked regimes and that the ecological structure and function cannot be understood or interrogated without a good understanding of these regimes and features. Figure 2 shows the cascade in those features from global and long-term scales at the top to more local and short-term scales lower in the figure.

Summarised as 'environment-biology interactions', the physico-chemical system creates a habitat, i.e. the fundamental niches in the water column or substrata, colonised by organisms and so creating the community structure, according to the environmental tolerances of the organisms (Gray and Elliott, 2009; Solan and Whiteley, 2016). (There are also interactions between the physico-chemical features – termed the 'environment-environment relationships'.) The organisms then interact with each other at the individual, population and community levels, for example with competition and predator-prey interactions; these constitute the inter- and intra-specific 'biology-biology interactions' that lead to ecological functioning (i.e. rate processes) (Figure 3). Such interactions occur across the trophic levels, from producers to top consumers, in which a lower layer may produce the biomass to support an upper layer and the upper layers act as population controls on the lower trophic levels. There is likely to be competition for available resources within and between such trophic levels and ultimately all biological material will be recycled through detrital food chains and the microbial system.

Following this, the biological components (as levels of biological organisation from the individual and population to communities and ecosystems) can create a feedback mechanism and influence the physico-chemical system, which is then termed the 'biology-environment relationships' (Gray and Elliott, 2009). In essence, the physical system sets up the conditions for relevant colonising organisms, which then modify the system via feedback loops. It is important to note that these natural processes are influenced by anthropogenic processes and features. The impact of these features and processes on the natural environment is a matter of increasing concern as marine processes and functions and the resulting ecosystem services ultimately produce societal benefits (see Briefing Paper 5).

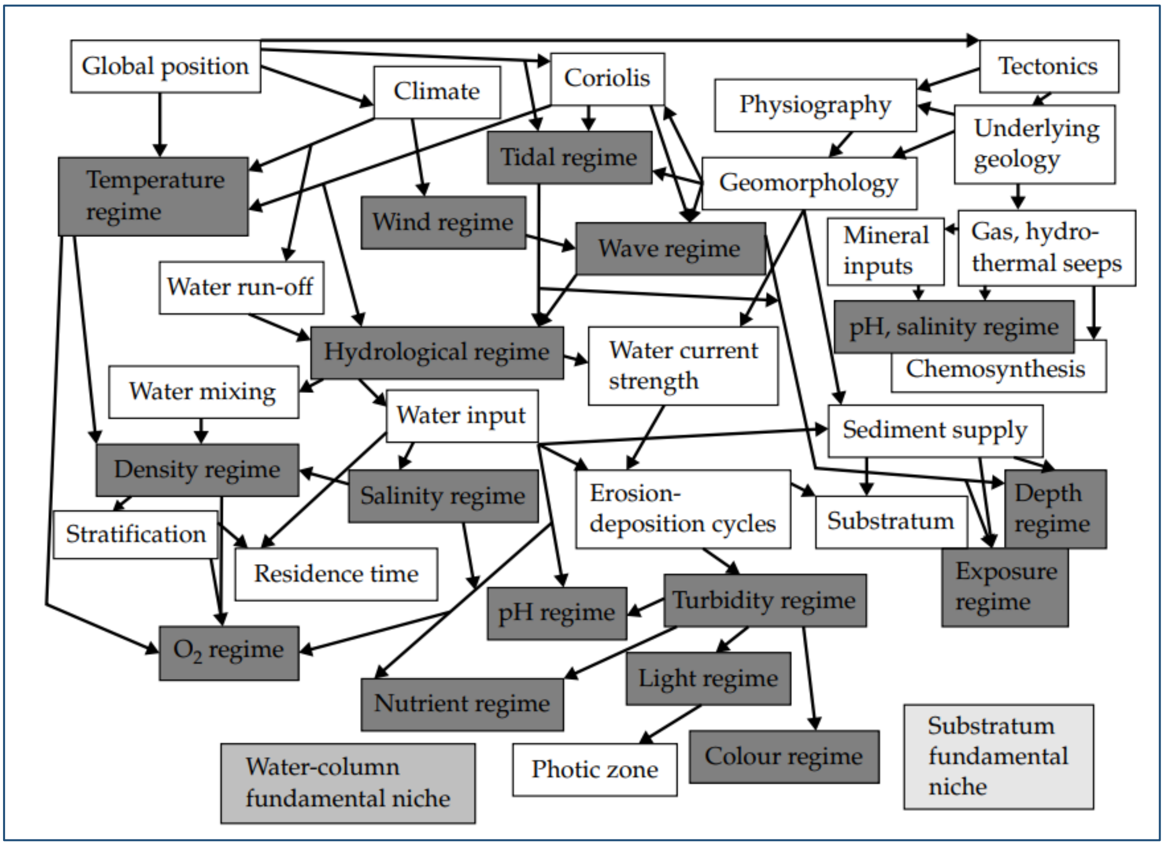


*Figure 2. The links between the physico-chemical regimes and features resulting in the two main fundamental and overarching niches, for the water column and substratum; the darkened boxes are the main regimes (from Gray and Elliott, 2009).*

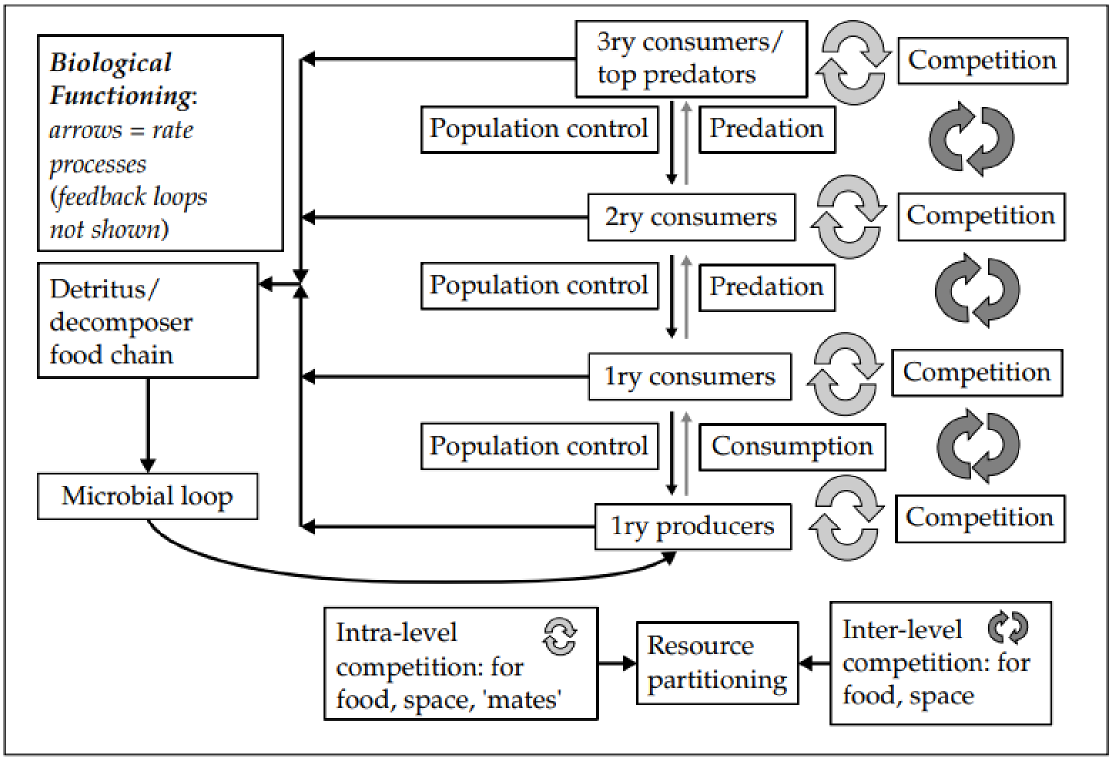


*Figure 3. Ecosystem Functioning: the main ecological processes (from Gray and Elliott, 2009).*

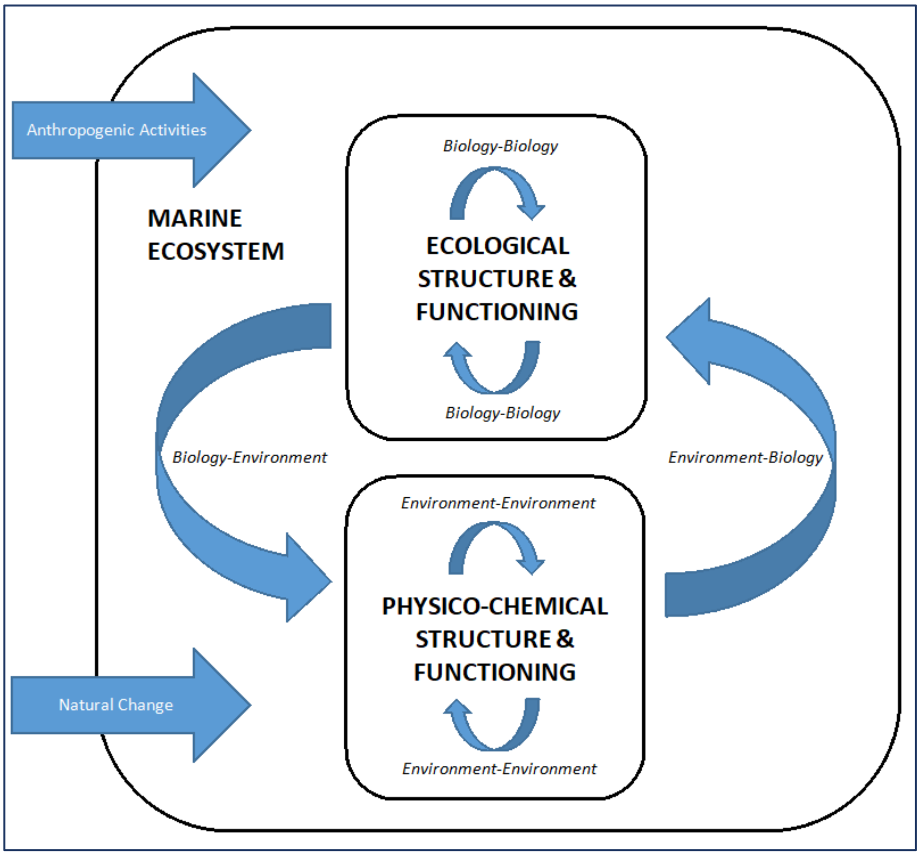


*Figure 4. A conceptual model indicating the linking and feedback between abiotic and biotic attributes of the marine ecosystem; the model denotes the main four sets of interrelated processes – 'environment-environment', 'environment-biology', 'biology-biology' and 'biology-environment' (Burdon, 2016; modified from Gray and Elliott, 2009).*

*Table 7: Estuarine and coastal processes and inter-relationships (Table modified from Burdon, et al., 2024; based upon Atkins et al., 2014 and Gray and Elliott, 2009).*

| Processes | Meaning | Examples |
|---|---|---|
| 'Environment–biology' | The physico-chemical system (e.g., salinity, temperature, sediment, geology, hydrography, etc.) creates the fundamental niches for colonisation by organisms, where that colonisation depends on the environmental tolerances of each species. | Reduced water currents will allow the development of muddy substrata which will be colonised by deposit-feeding organisms; biogeographic regimes and physico-chemical oceanographic processes and gradients will thus create the conditions likely to be colonised by organisms. |
| 'Biology–biology' | The resultant community is modified by biological processes and interactions such as predator–prey relationships, competition, and recruitment processes such as propagule supply and settlement. | The mud-dwelling invertebrates then compete with each other for space but also provide food for wading birds and fish. |
| 'Biology–environment' | The biology may influence the physico-chemical system and the import and export of materials into and out of the system. | Benthic invertebrates bioturbate and alter the sedimentary regime, leading to biogeochemical changes; water column oxygen demand is created by a large number of organisms occurring together. |
| 'Environment–environment' | One or more elements of the physicochemical system impact upon other elements of the physico-chemical system. | Changes in the hydrographic regime (e.g., currents, tides, etc.) result in changes to the sediment structure on the seabed. |

# 7. Ecosystem Services and their Interconnectedness with Marine Processes and Functioning

Marine processes and functioning underpin the production of ecosystem services and all of these constitute the natural domain and interact with the human domain. As indicated above, marine processes and functioning provide the fundamental physico-chemical and biological conditions that create and sustain diverse ecosystems which deliver a range of ecosystem services. After inputting human capital and assets, these services contribute significantly to human well-being and the economic vitality of coastal and marine communities (see Briefing Paper 5: *Societal Drivers, Benefits, Goods and Wellbeing*). However, it is important to manage and mitigate the impacts of human activities on these natural processes to ensure the sustainability, resistance and resilience of both the marine environment and the human benefits derived from it.

The concept of ecosystem services has been presented and debated for several decades (e.g. Daily, 1997; Constanza, et al., 1997; De Groot, et al., 2002). Despite this, there is no consensus on the definition of Ecosystem Services and the term is often both conflated and confused with the term Societal Benefits (Burdon et al., 2024; Elliott, 2023). Figures 5 and 6 illustrate this link between the natural environment and the human domain, which is explained below and especially in the Briefing paper 5: *Societal Drivers, Benefits, Goods and Wellbeing*).

In the context of identifying, defining and quantifying goods and services provided by marine biodiversity alone, the UN 2005 Millennium Ecosystem Assessment (MEA 2005) described four types of ecosystem services:

- Production services which involve products and services obtained from the ecosystem;
- Regulating services which are the benefits obtained from the regulation of ecosystem processes;
- Cultural services which are the non-material benefits people obtain from ecosystems;
- Supporting services which are those that are necessary for the production of all other ecosystem services, but do not yield direct benefits to humans.

Beaumont et al. (2007) then introduced a further category of 'Option use values which are associated with safeguarding the option to use the ecosystem in an uncertain future'. As a successive iteration, the generic term 'goods and services' was more recently been modified to indicate that a fully functioning ecosystem maintains a set of ecosystem services and that these are separated into fundamental services or characteristics (the physico-chemical environment) and final services (the biological elements and processes resulting from the fundamental services which will lead to the benefits for society) (Potschin et al., 2016). That fundamental structure (the natural capital and the ecosystem structure and functioning) and final ecosystem services then produce societal benefits although these require the introduction of human capital and assets to be obtained (see Briefing Paper 5: *Societal Drivers, Benefits, Goods and Wellbeing*). The societal benefits, and material goods, can then be valued both as TEV (Total Economic Value) and TSV (Total System Value) in which the latter may include components for which it is difficult to derive a monetary value (use/non-use, tangible/non-tangible, material/non-material and 'feel-good' values) (Elliott et al., 2017).

For example, the natural system can maintain the hydrographic processes which create the conditions for invertebrates as food for fishes and then harvesting the fishes requires boats and harbours, and the skills to use those fish. As another example, the natural processes can deliver marine sands and gravels but these become marine aggregates for construction when the vessels and infrastructure are created to exploit them. As a further example, the natural system can produce a blue whale but human capital is required for society to confer a greater value to that animal than just if it was yet another animal.

While there are various iterations of this model, the most recent versions (see Elliott and Wither, 2023; Burdon et al., 2024), modify this ecosystem services classification and further emphasise the separation of the marine system into the natural and human domains (Figures 5 and 6). These emphasise that the term ecosystem services only refers to the central part of the model and should always be distinguished from societal benefits, including material goods. Secondly, the model suggests that supporting services are no different from ecosystem structure and functioning and so the term has been dropped. Thirdly, Figure 5 maintains the classification of regulating, provisioning and cultural services, whereas Figure 6 emphasises only provisioning aspects and regulating processes occur and suggests that the term cultural services is a misnomer as the natural environment does not recognise 'culture' which is a human construct. Both figures indicate that the left-hand side of the models relates to the natural domain whereas the right-hand sides relate to the human domain. Finally, these recent models further indicate that ecosystem services are an intermediate step giving flows from ecosystem structure and functioning (natural capital) to societal benefits.

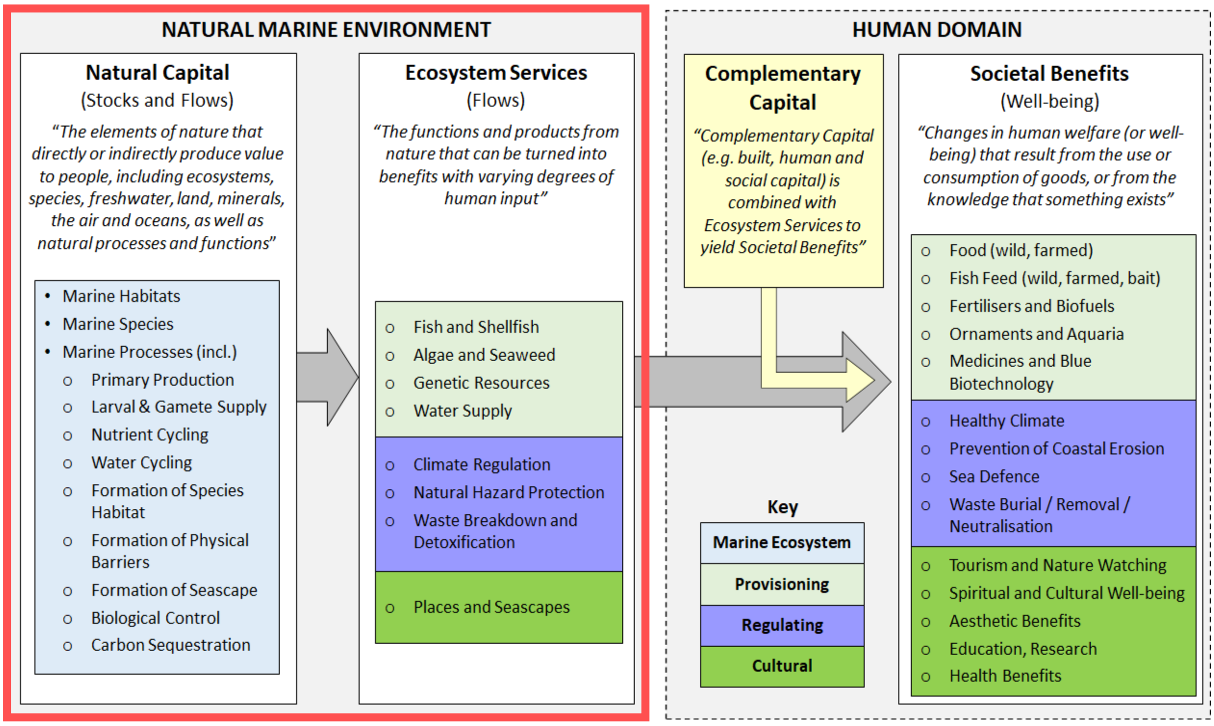


*Figure 5: The Ecosystem Services and Societal Benefits Model with the Natural domain (Marine Processes and Functioning and Ecosystem Services) highlighted by a red box (Burdon et al., 2024).*

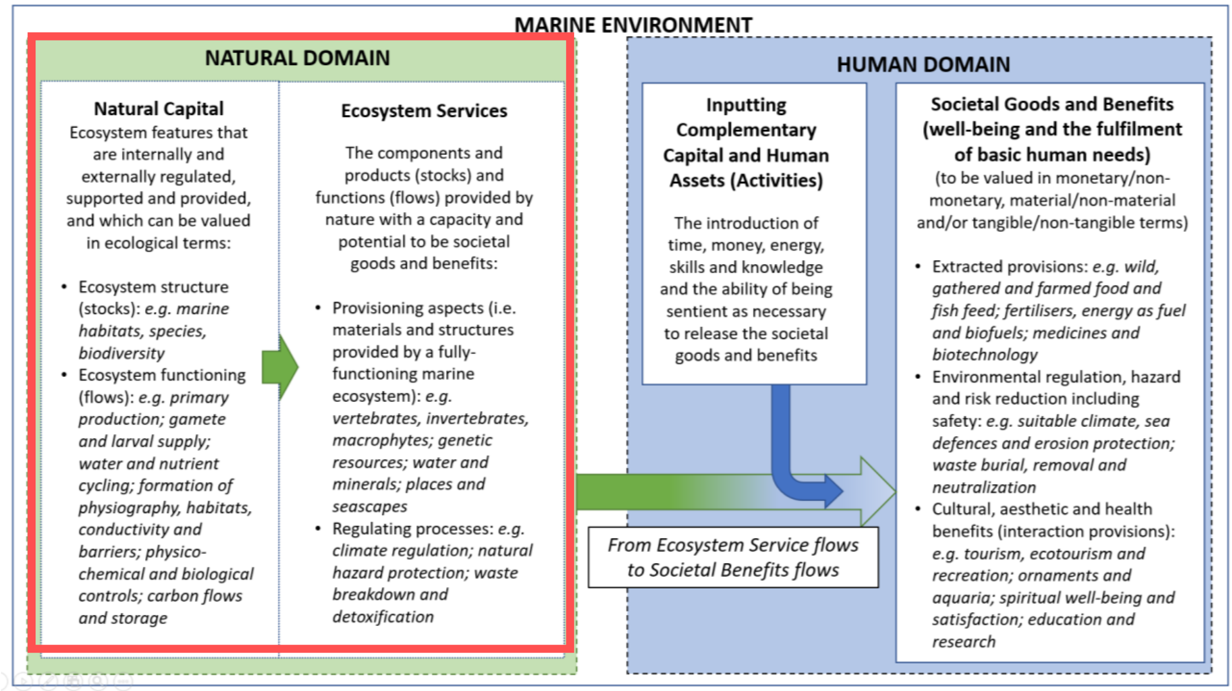


*Figure 6. The revised Ecosystem Services and Societal Goods and Benefits Model (from Elliott 2023)*

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MARINE SABRES

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# Marine SABRES Deliverable 3.2 Briefing Paper 5

# Societal Drivers, Benefits, Goods and Wellbeing

Authors: Jonathan Atkins, Michael Elliott, Gemma Smith, Daryl Burdon and Amanda Gregory

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This briefing note is one in a series of documents aimed at supporting the Simple Social-Ecological Guidance. For the complete set of briefing documents, please refer to the accompanying signposting document, which can be found here.

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# Table of Contents.

# 1. Introduction

The term societal benefits can have various interpretations and definitions (Potschin et al., 2016) but in the Marine SABRES project the term 'societal benefits' refers to:

*'those qualities and quantities satisfying human health and well-being and the economy which are derived from ecosystem services after inputting capital (built, human and social), including the human assets of energy, time, money, skills, knowledge and an ability to be sentient.'*

This expanded definition is consistent with the brief definition of societal benefits from the UK Natural Capital Committee (2019): '*Changes in human welfare (or well-being) that result from the use or consumption of goods, or from the knowledge that something exists*'. The term benefits is used here as being synonymous with the term 'goods and benefits' used elsewhere (Turner et al., 2014, 2015; Marcos et al., 2021; Elliott, 2023) in which all goods (as materials) are benefits but not all benefits may be material goods; this may differ from a purely economic view of a human good as a term for all benefits.

This briefing paper introduces the above concept in the context of the marine environment and it shows the linkages with the concepts of natural capital, ecosystem services, the complementary role of capital and human assets, as these are central to our understanding of societal benefits. The relationships between these concepts are depicted in Figure 1 which places societal benefits, including material goods, at the right-hand side (RHS, the human domain) of a continuum resulting from the structure and functioning of the natural domain (the left-hand side). Securing those benefits is necessary to satisfy 'Drivers', as basic human needs as an element of the DAPSI(W)R(M) framework (Elliott et al., 2017), which is the underpinning framework of the Simple Social-Ecological System being designed and tested in Marine SABRES (Gregory et al., 2023); thus, it is emphasised that drivers motivate the need to carry out activities in order to secure societal benefits, including material goods.

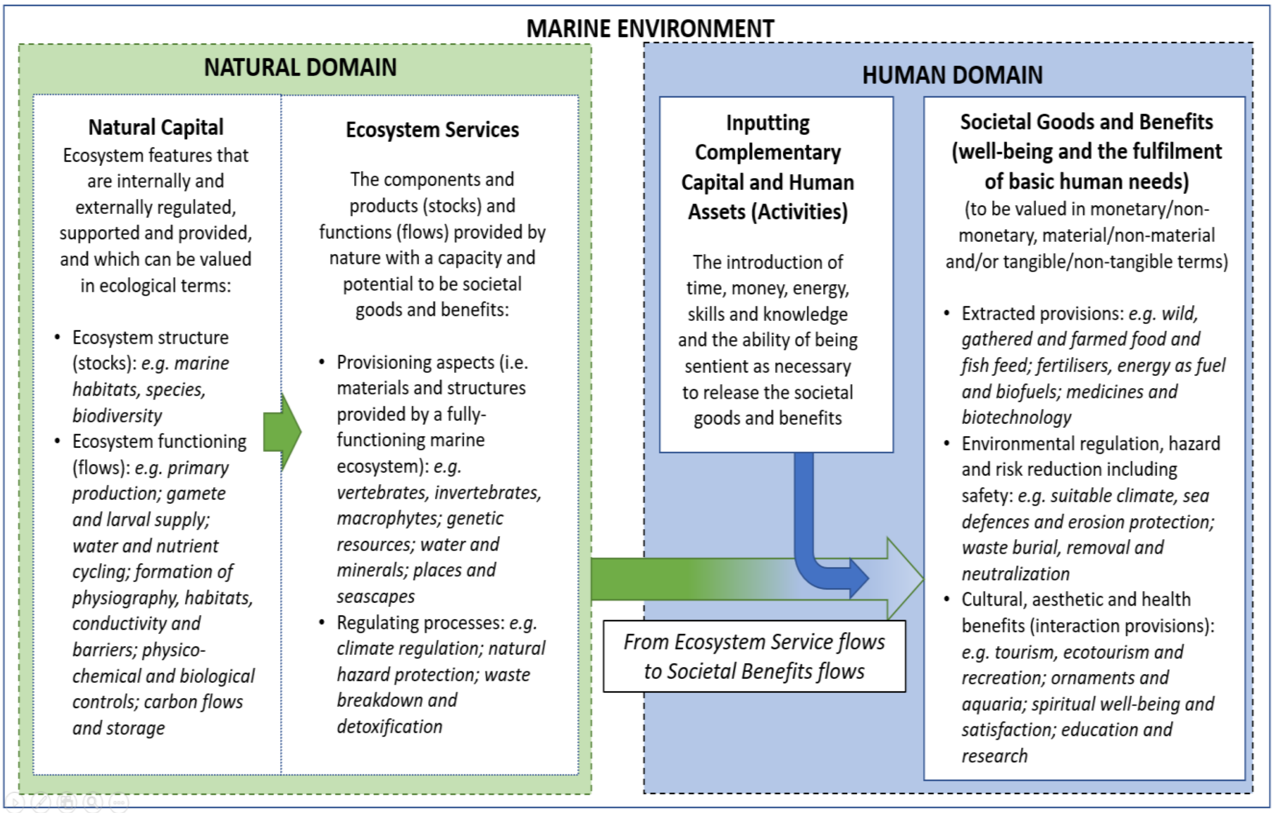


*Figure 1: Natural capital, ecosystem services and societal benefits, including material goods, provided by marine ecosystems (Elliott, 2023).*

## 2. Societal Benefits, Human Health and Wellbeing and the Economy

**Societal benefits**

Table 1 gives examples of 14 benefits derived from the marine environment (based on Turner et al, 2015). Consequently, the term societal benefits aims to be all-embracing by including, firstly, material 'goods', such as fertilisers and biofuels and food for consumption, and their monetised value can be measured by a price using an exchange value, i.e. such goods are frequently bought and sold in markets. Secondly, the term includes 'benefits' which constitute a more diverse set of entities, e.g. flood control and aesthetic and cultural benefits, both of which contribute to human welfare but their value may be less amenable to monetisation, i.e. they may not necessarily be traded. Although the term 'societal benefits' refers to the benefits to human health and wellbeing and economy derived from the natural environment, we might also refer to dis-benefits if impacts are detrimental.

The societal benefits are grouped into three types here on the RHS of Figure 1 but modified from the ecosystem services categorisation used by the Millennium Ecosystem Assessment (MEA, 2005), namely:

- Extracted provisions (called *provisioning* services in MEA (2005), which refers to these as the products obtained from the ecosystem);
- Environmental regulation, hazard and risk reduction including safety (called *regulating* services in MEA (2005), which refers to these as the benefits obtained from the regulation of ecosystem processes);
- Cultural, aesthetic and health benefits (interaction provisions) (called *cultural* services in MEA (2005) which refers to these as the non-material benefits people obtain from ecosystems; also including research and education).

The terminology has been changed given that the definitions used by the MEA (2005) appear to conflate both services and benefits (see Elliott, 2023). It is emphasised that by separating societal benefits (including material goods) from ecosystem services then the former can be used for the human aspects in marine ecosystem functioning and the cause-consequence-response relationships inherent in the social-ecological system; in contrast, the term ecosystem services is then reserved for the natural physico-chemical and ecological aspects. The term ecosystem services then implicitly includes so-called supporting services (sometimes referred to as intermediate services (Turner et al., 2015)), which are those services that are necessary for the production of all other ecosystem services but which do not yield direct benefits to humans; these have been identified as processes within the marine natural capital in Figure 1.

*Table 8: Examples of societal goods and benefits from the marine and coastal environment (Burdon et al., 2024, and Turner et al., 2015).*

| **Provisioning Goods/Benefits: Products obtained from the ecosystem** | |
|---|---|
| **Fertilisers and biofuels** | Materials (biota) sourced from coastal and marine biota for consumption or industrial uses. |
| **Food for human consumption** | Extraction of coastal and marine biota (plants and animals) for human consumption. |
| **Food not for human consumption** | Extraction of biota not for human consumption e.g., animal fodder. |
| **Genetic resources** | Extraction of coastal and marine biota for genetic purposes. |
| **Medicines and biotechnology** | Extraction of biota to produce medicines, pharmaceuticals, etc. |
| **Ornaments, aquaria and aquaculture** | Extraction for decoration, fashion, handicraft, souvenirs, etc. |

| | |
|---|---|
| **Materials** | Materials used in the manufacture of goods. |
| **Regulating Goods/Benefits: Benefits obtained from the regulation of ecosystem processes** | |
| **Drinking water** | Supply of water sufficient quality for humans to consume. |
| **Healthy climate** | Maintenance to human well-being as a result of a healthy climate. |
| **Flood control** | Reduction in flooding related hazards. |
| **Erosion control** | Reduction in hazards from the prevention of coastal erosion. |
| **Waste burial/removal/neutralisation** | Contribution of biota to achieving policy standard related to waste levels in water by natural waste burial, removal, and neutralisation. |
| **Cultural Goods/Benefits: Non-material benefits people obtain from ecosystems** | |
| **Aesthetic benefits** | Appreciation of natural landscapes and seascapes. |
| **Education, Research** | Benefits for formal education, research and science. |
| **Leisure, recreation, tourism** | Benefits from recreation, leisure, and tourism driven by natural landscapes. |
| **Spiritual and cultural well-being** | Appreciation of culture, heritage, folklore, etc. |
| **Human health** | Human physical and psychological health benefits. |

**Ecosystem services (also see Briefing Paper *BP4: Marine Processes and Functioning and Ecosystem Services*)**

Although ecosystem services have been long discussed in the literature (e.g., Daily, 1997; Constanza et al., 1997; De Groot et al., 2002; Elliott, 2023, and references therein), there is no agreed definition of the term ecosystem services, which can lead to confusion over the distinction between ecosystem services and societal benefits (Burdon et al, 2024). Here it is emphasised that by separating these terms, as in having separate Briefing Papers, then this confusion is eliminated. Consequently, as a working definition, ecosystem services can be simply regarded as:

*"functions and products from nature that can be turned into benefits with varying degrees of human input"* (UK Natural Capital Committee, 2019).

This definition emphasises that ecosystem services are different to societal benefits in referring to naturally occurring processes in the natural environment, i.e. in the absence of humans, ecosystem services would still be present in the natural environment. In contrast, societal benefits are secured from ecosystem services through the complementary input of capital (built, human and social) and human assets (an input of energy, time, money, skills, knowledge and the ability of being sentient) (Elliott, 2023) and are therefore associated with the human domain (as in Figure 1). Hence, ecosystem service flows act as the link between the Natural Capital that comprise the marine and coastal ecosystem and the benefits, and material goods, obtained by society that are valued through their impact on human health and wellbeing and on the economy.

Figure 1, and Elliott (2023) and Burdon et al (2024), place ecosystem services and societal goods and benefits within a modified version of the so-called cascade produced by the CICES framework (Haines-Young and Potschin, 2018; Potschin et al., 2016). This emphasises that there is a central continuum (i.e. a cascade) from environmental physico-chemical structure and processes, through ecological structure and functioning, to ecosystem services and then to societal goods and benefits after inputting human capital and assets. Burdon et al. (2024) emphasises that individual societal benefits will depend upon an array of ecosystem services rather than being attributable to any single one, as interdependencies and backward linkages are characteristics of complex coastal and marine systems (Gregory et al., 2013). Secondly, that ecosystem services associated with one broad habitat type can be affected by changes in other habitats, and thirdly, that the interconnected nature of spatially separate components of the wider environment, highly mobile species and the role of the water column are particularly important considerations in coastal and marine habitats.

**Complementary roles of capital and human assets**

'Natural Capital' is regarded here as "*the elements of nature that directly or indirectly produce value to people, including ecosystems, species, freshwater, land, minerals, the air and oceans, as well as natural processes and functions*" (UK Natural Capital Committee, 2019). This recognises that coastal and marine ecosystems contain a range of components (e.g., habitats and species) and processes (e.g., food webs and ecological dynamics) which form the natural capital from which ecosystem services flow. These are shown as stocks and flows in Figure 1. However, given the above definition of societal benefits, and material goods, the use of 'indirectly or directly' implicitly refers to the input of human capital and assets. The literature commonly uses the terms human, built and social capital although this may be regarded as tautological as 'built' and 'social' are by definition related to humans – an example of the need for the language of this field to be standardised. For example, Shittu et al. (2021) combine all of these types of capital into human capital, whereas Berkes and Folke (1992) regard the roles of three types of capital (natural, human-built and cultural) as being complementary. Schuller (2001), in discussing the complementary roles of human, social and cultural capital, considers the anomalies and ambiguity (and even tautology) in the terms. Furthermore, it is of note that the literature does not use the term 'complementary capital' but rather indicates that the different types of capital have complementary roles.

Despite the varying terms used in the literature, here and in essence, the complementary types of capital can be taken to comprise: **built capital** - the material goods or fixed assets which contribute to the production process rather than being the output itself – e.g. fuel, tools, machines and buildings; **human capital** - the accumulated knowledge, skills and experience embodied in agents along with their motivations, health and commitment of time, and **social capital** – networks, norms and trust, and the way these allow agents and institutions to be more effective in achieving common objectives. The latter helps us maintain and develop human capital in partnership with others, e.g. families, communities, businesses, trade unions, schools, and voluntary organisations. The terms built, human and social capital have also included, respectively, physical capital, seed capital and cultural capital (Potschin et al., 2016).

As emphasised here, societal benefits, and material goods, are secured only by inputting these types of capital, including the human assets of time, energy, money, skills, knowledge and the ability to be sentient (Elliott 2023). However, in some cases, there are indirect relationships between such inputs and the realisation of benefits; for example, in carbon sequestration and storage in shelf sea sediments, and water storage and regulation in wetlands. In the model presented above (Figure 1), these are ecosystem services provided by the natural domain which only result in societal goods and benefits to humans inhabiting an area; however, it can be argued that ecosystem services such as carbon sequestration benefit humans worldwide if it reduces the adverse effects of climate change. As shown by Elliott (2023), adding capital and human assets constitute the range of human activities in the environment whereby these activities also generate employment opportunities and contribute to value added within the wider economy.

Using the example activity of fishing, the built capital is the trawler, gear, fuel, ice and port infrastructure employed to catch and preserve fish for processing which have all been manufactured and/or involve processing and hence require inputting time, money and energy. Technological change is likely to alter the characteristics of the employed built capital over time. Without these elements of built capital, a trawled catch of fish would not be fit at the time of landing for processing for, say, human consumption despite there being an abundance of fish in the sea.

An example of human capital and assets to secure benefits, and material goods, is the fisher such as the captain of a trawler choosing when, where and for how long to fish, the type of gear to employ, how to organise the crew, and so forth, where the captain draws from their accumulated knowledge, skills and experience, and decides their expenditure of time and energy to the activity.

Continuing the example relating to trawling, an example of social capital is the relationships between the trawler captain and the crew which, to function effectively, is based on trust and adherence to authority, or the cooperative relationships between members of the crew pursuing a collective endeavour. This example of fishing indirectly also includes the last of the list of human assets given above, the ability to be sentient, in the fisher and their customers being able to appreciate the benefits of fishing.

A more extensive list of complementary roles of capital may include **financial capital** as this enables the other types of capital to be owned, employed and traded (see UK Natural Capital Committee, 2019). Financial capital is exemplified by shares and banknotes (Forum for the Future, n.d.) although if insurance is included in this category then it has an important role in safeguarding the value of owned built capital and human capital against particular risks e.g., to protect the value an owner's investment in, say, a physical asset such as a fishing trawler from physical damage or loss, or to protect a worker (or their dependents) financially where there is potential for injury or death. Without the availability of such insurance, investment in the sector may be more difficult to secure and workers may be less willing to undertake more hazardous activities. If not distinguished separately, financial capital is subsumed within the term built capital.

The level of complementary application of capital can indicate sustainable levels of ecosystem services and thereby sustainable levels of societal benefits. For example, capital in the form of fishing effort can be at a level that sustains societal benefits associated with a fishery over time. However, if fishing effort exceeds the levels necessary to sustain the fishery, some societal benefits may be enhanced in the short term (for example, fish for human consumption and recreational fishing) but applying this level of capital may be detrimental to those same societal benefits in the longer term. Controlling those levels of application by regulatory bodies has been termed **institutional capital** (Platje, 2008).

**Drivers (see also *BP3: Cause-Consequence-Response Chains – DAPSI(W)R(M)*)**

The Drivers in the DAPSI(W)R(M) framework (Elliott et al., 2017) are "*related to basic human needs such as the need for food, energy, space, movement of goods, security or recreation*" and this definition informed the design of the Marine SABRES Social-Ecological System (Gregory, et al., 2023) and in turn the recommended indicators for the drivers. Drivers are important here as they require to be satisfied by activities employing human capital and assets to secure societal goods and benefits from ecosystem services. In the Marine SABRES Social-Ecological System, this is the justification for 'closing the loop' between 'impacts on welfare (goods and benefits)' and 'drivers' in the causal loop diagrams (Gregory et al., 2023).

The interpretation of drivers in Marine SABRES, including the choice of SMART indicators (Indicators which are Specific, Measurable, Achievable, Realistic and Timebound), is informed by Maslow's hierarchy of needs (Maslow, 1943). This hierarchy is typically depicted as a pyramid as in Figure 2, reflecting the universal needs of individuals in society as its base (levels 1 and 2 in Figure 2) and more acquired emotions at higher levels (levels 3, 4 and 5 in Figure 2).

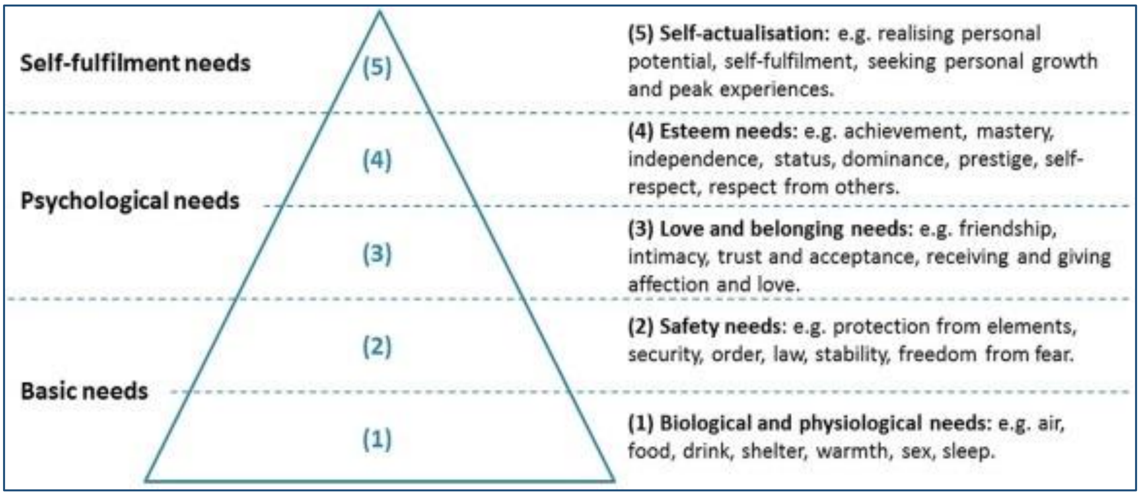


*Figure 2: Maslow's hierarchy of needs and human welfare (from Elliott et al. (2017) adapted from Maslow, (1943)).*

A further influence on our understanding, and representation through choice of indicators, of Drivers is the non-hierarchical taxonomy of fundamental human needs, and the ways in which these needs can be satisfied, given by Max-Neef (1989) with key aspects summarised in Table 2.

*Table 9: A non-hierarchical scheme of Drivers (based on Max-Neef, 1989).*

| Human Needs | Being (Qualities) | Having (Things) | Doing (Actions) | Interacting (Settings) |
|---|---|---|---|---|
| **Subsistence** | Physical and mental health | Food, shelter, work | Feed, clothe, rest, work | Living environment, social setting |
| **Protection** | Care, adaptability, autonomy | Social security, health systems, work | Co-operate, plan, take care of, help | Social environment, dwelling |
| **Affection** | Respect, sense of humour, generosity, sensuality | Friendships, family, relationships with nature | Share, take care of, make love, express emotions | Privacy, intimate spaces of togetherness |
| **Understanding** | Critical capacity, curiosity, intuition | Literature, teachers, policies, educational | Analyse, study, meditate, investigate | Schools, family, communities |
| **Participation** | Receptiveness, dedication, sense of humour | Responsibilities, duties, work, rights | Cooperate, dissent, express opinions | Associations, parties, churches, neighbourhoods |
| **Leisure** | Imagination, tranquillity, spontaneity | Games, parties, peace of mind | Daydream, remember, relax, have fun | Landscapes, intimate spaces, places to be alone |
| **Creation** | Imagination, inventiveness, curiosity | Abilities, skills, work, techniques | Invent, build, design, work, compose, interpret | Spaces for expression, workshops |
| **Identity** | Sense of belonging, self-esteem, consistency | Language, religions, work, customs, values, norms | Get to know oneself, grow, commit oneself | Places one belongs to, everyday settings |
| **Freedom** | Autonomy, passion, self-esteem, open-mindedness | Equal rights | Dissent, choose, run risks, develop awareness | Anywhere |

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MARINE SABRES

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# Marine SABRES Deliverable 3.2 Briefing Paper 6

# Indicators for the Simple SES approach

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# Contents

## 1. Introduction

How do we know if a pressure on the marine environment has reduced or an environmental state has changed? How do we know whether the drivers for change, and the intensity of activities within the marine system are lessening or strengthening? Do the impacts of changes in the state of the marine environment affect human health, wellbeing, and the economy (societal benefits)?' 'You cannot manage something unless you can measure it', and hence, good management requires effective monitoring (Elliott, 2023). Quantitative measurements using standards, indicators, and objectives support decision-makers in determining what management may be required and the success of management actions (Cormier and Elliott, 2017). Objectives and targets can be very specific or more ambiguous and aspirational; for example, the target of '30x30' (the 30% of area protected by 2030, OECD, 2019) is more far-reaching and ambiguous than the target of Good Ecological Status (European Commission, 2008) in a particular river basin. If targets are subjective and ambiguous, then it is difficult to determine if they have been effectively achieved, so if the target is to reduce levels of phosphate in a water body, and this is reduced by a small amount but not enough to counteract the negative results, then this objective is achieved, but the outcome is not effective.

An indicator is an 'observed value representative of a phenomenon to study' (European Commission, 2017). In addition, indicators are tools 'to monitor and assess the state of the marine environment and to manage human activities having an impact upon it' (European Commission, 2008). Atkins et al. (2015) argues that environmental indicators serve three primary functions: to simplify the components of an ecosystem to allow for the characterisation of the state of the ecosystem; to quantify elements so they can be analysed alongside reference values; and to be in a form to easily communicate state changes in reference to targets and objectives with stakeholders. In general, an indicator consists of one or more parameters chosen to represent ('indicate') a certain situation or aspect and to simplify a complex reality (CSWD, 2020).

In Marine SABRES, indicators are being defined as quantitative measures associated with elements of the DAPSI(W)R(M) framework which underpins the Simple Social-Ecological System (SES) as indicators are a tool for reducing the challenge of understanding the whole complexity of an Social-Ecological System and to support management decisions.

## 2. SMART Indicators

Previous literature (Doran, 1981; Cormier and Elliott, 2017) refer to the selection of indicators to be based on criteria reflecting operational, value, and success criteria (Atkins, et al., 2015). These criteria require indicators to be SMART, that is

- Specific – what exactly is the indicator of success?
- Measurable – can you quantitatively measure this indicator?
- Achievable - Do the objectives describe a state of the ecosystem, including the position and activities of humans within it, which accurately reflects the values and desires of a majority of stakeholders?
- Realistic – Are the objectives implementable using the resources (research, monitoring, and assessment and enforcement tools) available to developers, managers and stakeholders? 'Good objectives should reflect the aspirations of stakeholders, such that the majority of stakeholders will strive to achieve them and ensure sustainable development' (Cormier, 2017).
- Time-bounded – is there a clearly defined time scale for meeting objectives?

Further explored by Elliott (2011), these SMART characteristics were expanded to include 18 attributes specifically for marine management and are embedded within the DAPSI(W)R(M) framework underpinning the Simple Social Ecological System in Marine SABRES. The additional attributes include 'anticipatory; biologically/environmentally important; broadly applicable and integrative over space and time; giving continuity over time and space; cost-effective in monitoring; grounded in theory/relevant and appropriate; interpretable; low redundancy; non-destructive; responsive feedback to management; sensitive to a known stressor or stressors; and socially relevant' (Atkins, et al., 2015; Elliott, 2011). Identification and assessment of indicators relating to social, economic, and cultural qualities are relevant at multiple stages of the DAPSI(W)R(M) framework and the ISA approach. Drivers of the activities are inherently social, economic, and cultural, as they are the reason societal benefits are sought from coastal and marine environments. Furthermore, in order to be effective in marine management, indicators and monitoring should fulfil, as a minimum, the SMART criteria (Cormier and Elliott, 2017).

## 3. Key Indicators supporting the Integrated Systems Analysis Approach: The DAPSI(W)R(M) elements

As noted above, the Integrated Systems Analysis approach (ISA) of Elliott et al. (2020), including the DAPSI(W)R(M) framework as the underpinning framework, was selected as the basis for the Marine SABRES Simple SES (Gregory et al., 2023). The use of the underpinning DAPSI(W)R(M) framework logically structures problems from the Drivers, Activities, and Pressures, which cause State changes leading to Impacts on human Welfare, which may warrant Response Measures (DAPSI(W)R(M)) (Elliott et al., 2017) (For further information on this framework see Briefing Paper 3: *'Cause-Consequence-Response Chains – DAPSI(W)R(M)'*). This approach is being used increasingly in climate change reports and in marine studies; for example, the EU Marine Strategy Framework Directive (MSFD) and Water Framework Directive (WFD), the UK Marine Strategy, and the Regional Seas Conventions Quality Status Reports (such as OSPAR, the Oslo and Paris Convention) are all focusing attention on such a method (see; Ducommun et al., 2020; OSPAR, 2023; Gregory et al., 2022).

Through the use of the DAPSI(W)R(M) framework, which can be considered a problem structuring method (Gregory et al, 2013), key indicators will be specified for each element of the framework in the Demonstration Areas and support reviews of progress associated with measures implemented, policy and response evaluations, and provide a benchmark of standards to communicate with stakeholders. Specifying indicators for the elements of the framework facilitates understanding of how response measures affect the coastal or marine system in focus. The DAPSI(W)R(M) framework is for use within the Simple SES approach, it is noted that linkages can be examined conceptually, qualitatively, or quantitatively and promote forward thinking to the process (Teixeira et al., 2016). Therefore, indicators for various aspects of the problem structuring framework can provide insight into the status of the component about the management objectives (Elliott, 2011); highlighting the necessity of indicators when making informed management decisions on which response measures are appropriate. A non-exhaustive list of indicators relating to different elements of the DAPSI(W)R(M) framework are given in Annex 1.

## 4. Further reading


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## 5. Summary Diagram

Link to online resource pictured in the summary diagram: https://0630f3fe-3d89-4a18-bd3e-e74fbefeb169.usrfiles.com/ugd/0630f3_b75ee66f5b5a458ba077460d625546c2.pdf

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## Annex 1 – A non-exhaustive list of indicators relating to the various DAPSI(W)R(M) elements (adapted from Atkins, et al., 2015).

| Element | Indicators | DAPSI(W)R(M) type |
|---|---|---|
| Cleaner water | Days x miles of shoreline closed due to sewage, biotoxins or pollution | Driver |
| | (quantitative policy target) for (households with fresh water) in the region for the period ('X -Y' in terms of years/months) | Driver |
| | (quantitative policy target) for (provisions for safely managed water) in the region for the period ('X' Years/Months)' | Driver |
| | Total population in a named region (‘000) | Driver |
| | Population growth rate (%) | Driver |
| | Number of people living within X km of the area (‘000) | Driver |
| Cultural wellbeing | % of shoreline that is publicly accessible or owned | Driver |
| | (quantitative policy target) for (cultural engagement) in the region for the period ('X -Y' in terms of years/months) | Driver |
| | Total population in a named region (‘000) | Driver |
| | Population growth rate (%) | Driver |
| | Number of people living within X km of the area (‘000) | Driver |
| Equality Diversity and Inclusion | Proportion of adults encountering barriers which prevent them from experiencing particular cultural activities (%) | Driver |
| | (quantitative policy target) for (EDI) in the region for the period ('X -Y' in terms of years/months) | Driver |
| | Total population in a named region (‘000) | Driver |
| | Population growth rate (%) | Driver |
| | Number of people living within X km of the area (‘000) | Driver |
| Food security and improved nutrition | (quantitative policy target) for (nutrition) in the region for the period ('X -Y' in terms of years/months) | Driver |
| | Proportion of population that do not satisfy current regional government (or UN SDG) target nutrition levels (%) | Driver |
| | Total population in a named region (‘000) | Driver |
| | Population growth rate (%) | Driver |
| | Number of people living within X km of the area (‘000) | Driver |
| Healthier climate | (quantitative policy target) for (Sea level rise risk) in the region for the period ('X' Years/Months)' | Driver |
| | Total population in a named region (‘000) | Driver |
| | Population growth rate (%) | Driver |
| | Number of people living within X km of the area (‘000) | Driver |
| | Total population in a named region (‘000) | Driver |

| | | |
|---|---|---|
| | Population growth rate (%) | Driver |
| | Number of people living within X km of the area ('000) | Driver |
| Identity and belonging | (quantitative policy target) for (community based initiatives) in the region for the period ('X' Years/Months)' | Driver |
| | Total population in a named region ('000) | Driver |
| | Population growth rate (%) | Driver |
| | Number of people living within X km of the area ('000) | Driver |
| Safer places | Area of land in the coastal region below 2 metres above sea level | Driver |
| | (quantitative policy target) for (amount of at-risk properties) in the region for the period ('X' Years/Months) | Driver |
| | Total population in a named region ('000) | Driver |
| | Population growth rate (%) | Driver |
| | Number of people living within X km of the area ('000) | Driver |
| Pipelines | Capacity in a (given period) in a (given geographical area) of (given activity) using (given technique) | Activity |
| | Number/ total length of pipeline(s) in a (given period) in a (given geographical area) | Activity |
| Telecommunication cables | Number/ total length of telecommunication cable(s) in a (given period) in a (given geographical area) | Activity |
| | Capacity in a (given period) in a (given geographical area) of (given activity) using (given technique) | Activity |
| Vessel anchorages | Capacity in a (given period) in a (given geographical area) of (given activity) using (given technique) | Activity |
| | Number of within the geographical area | Activity |
| Vessel moorings | Capacity in a (given period) in a (given geographical area) of (given activity) using (given technique) | Activity |
| | Number of within the geographical area | Activity |
| Oil and gas infrastructure | Capacity in a (given period) in a (given geographical area) of (given activity) using (given technique) | Activity |
| Cargo operations and landward transportation | Capacity in a (given period) in a (given geographical area) of (given activity) using (given technique) | Activity |
| Aerial military activity | Capacity in a (given period) in a (given geographical area) of (given activity) using (given technique) | Activity |
| Sea surface military activity | Capacity in a (given period) in a (given geographical area) of (given activity) using (given technique) | Activity |
| Port and harbours Operation | Capacity in a (given period) in a (given geographical area) of (given activity) using (given technique) | Activity |
| Vessel movements and maintenance | Capacity in a (given period) in a (given geographical area) of (given activity) using (given technique) | Activity |

| | | |
|---|---|---|
| Powerboating or sailing with an engine | Capacity in a (given period) in a (given geographical area) of (given activity) using (given technique) | Activity |
| Dredging (Capital, aggregate and maintenance) | Capacity in a (given period) in a (given geographical area) of (given activity) using (given technique) | Activity |
| | Number of sites within an area | Activity |
| Beach sand extraction | Capacity in a (given period) in a (given geographical area) of (given activity) using (given technique) | Activity |
| | Number of sites within an area | Activity |
| Exploratory drilling | Capacity in a (given period) in a (given geographical area) of (given activity) using (given technique) | Activity |
| | Number of sites within an area | Activity |
| | The area sites use (in hectares or square kilometres) in a given period | Activity |
| Water abstraction | Capacity in a (given period) in a (given geographical area) of (given activity) using (given technique) | Activity |
| | Number of sites within an area | |
| Deep sea mining | Capacity in a (given period) in a (given geographical area) of (given activity) using (given technique) | Activity |
| | Number of sites within an area | Activity |
| | The area sites use (in hectares or square kilometres) in a given period | Activity |
| Demersal seine netting | Capacity in a (given period) in a (given geographical area) of (given activity) using (given technique) | Activity |
| Demersal trawling | Capacity in a (given period) in a (given geographical area) of (given activity) using (given technique) | Activity |
| Dredging shellfish | Capacity in a (given period) in a (given geographical area) of (given activity) using (given technique) | Activity |
| Extraction of genetic resources | Capacity in a (given period) in a (given geographical area) of (given activity) using (given technique) | Activity |
| Harvesting - seaweed and other sea-based food | Capacity in a (given period) in a (given geographical area) of (given activity) using (given technique) | Activity |
| Line fishing | Capacity in a (given period) in a (given geographical area) of (given activity) using (given technique) | Activity |
| Pelagic fishing | Capacity in a (given period) in a (given geographical area) of (given activity) using (given technique) | Activity |
| Purse Seining | Capacity in a (given period) in a (given geographical area) of (given activity) using (given technique) | Activity |
| Set net fishing | Capacity in a (given period) in a (given geographical area) of (given activity) using (given technique) | Activity |

| | | |
|---|---|---|
| Shellfish aquaculture Bottom culture | Capacity in a (given period) in a (given geographical area) of (given activity) using (given technique) | Activity |
| Finfish aquaculture | Capacity in a (given period) in a (given geographical area) of (given activity) using (given technique) | Activity |
| Seaweed Shellfish aquaculture, Suspended rope net culture and Trestle culture | Capacity in a (given period) in a (given geographical area) of (given activity) using (given technique) | Activity |
| Coastal flood and erosion risk management schemes | Capacity in a (given period) in a (given geographical area) of (given activity) using (given technique) | Activity |
| | The area (in hectares or square kilometres) in a given period | Activity |
| Piling_Port and Harbours Coastal flood and erosion risk management schemes | Capacity in a (given period) in a (given geographical area) of (given activity) using (given technique) | Activity |
| | The area (in hectares or square kilometres) in a given period | Activity |
| Offshore coastal defence structures | Capacity in a (given period) in a (given geographical area) of (given activity) using (given technique) | Activity |
| | The area (in hectares or square kilometres) in a given period in a (given geographical area) | |
| Managed realignment | The area (in hectares or square kilometres) in a given period | Activity |
| Leisure e.g. swimming, rock pooling | Capacity in a (given period) in a (given geographical area) of (given activity) using (given technique) | Activity |
| Cultural and heritage sites e.g. wrecks, sculptures, foundations etc. | Capacity in a (given period) in a (given geographical area) of (given activity) using (given technique) | Activity |
| Marine and Coastal Research and teaching | Capacity in a (given period) in a (given geographical area) of (given activity) using (given technique) | Activity |
| Surveys | Capacity in a (given period) in a (given geographical area) of (given activity) using (given technique) | Activity |
| Marine archaeological research | Capacity in a (given period) in a (given geographical area) of (given activity) using (given technique) | Activity |
| Offshore wind | Capacity in a (given period) in a (given geographical area) of (given activity) using (given technique) | Activity |
| Tidal lagoon impoundment | Capacity in a (given period) in a (given geographical area) of (given activity) using (given technique) | Activity |

| | | |
|---|---|---|
| | The area (in hectares or square kilometres) in a given period | Activity |
| Power cable | Capacity in a (given period) in a (given geographical area) of (given activity) using (given technique) | Activity |
| Thermal and nuclear Powerstation | Capacity in a (given period) in a (given geographical area) of (given activity) using (given technique) | Activity |
| Shoreside industry and operations | Capacity in a (given period) in a (given geographical area) of (given activity) using (given technique) | Activity |
| Input or spread of nonindigenous species | Amount of non-indigenous species (Abundance in the area) | Pressure |
| | Presence of non-indigenous species (Number of species per area) | Pressure |
| Input of microbial pathogens | Levels of E. coli (cfu/mL) | Pressure |
| | Levels of Enterococci (cfu/mL) | Pressure |
| | Species distribution (number of species per hectare) | Pressure |
| Input of genetically modified species and translocation of native species | Species abundance (number of) | Pressure |
| Loss of or change to natural biological communities due to cultivation of animal or plant species | Total biomass of surveyed species (kg/m²) | Pressure |
| | Area loss of habitat type in the area (% of the area lost) | Pressure |
| Disturbance of species due to human presence | Area of habitat disturbed or lost (km²) | Pressure |
| | Frequency and duration of disturbance events (e.g., number of events per year) | Pressure |
| | Proportion of critical habitats (breeding grounds, nursery areas, etc.) impacted | Pressure |
| | Spatial distribution of disturbance events (e.g., distance from critical habitats) | Pressure |
| Extraction mortality or injury to wild species | Individuals killed or injured per activity or per year (number of) | Pressure |
| | Fishing effort e.g., number of fishing vessels, fishing days, gear type per year (number of) | Pressure |
| Physical disturbance to | Change in topography and bathymetry of the seabed | Pressure |
| | Area of seabed cover (km²) | Pressure |

| | | |
|---|---|---|
| seabed temporary or reversible | Change from sedimentary or soft rock substrata to hard rock or artificial substrata or vice-versa. | Pressure |
| Physical loss due to permanent change of seabed substrate or morphology and to extraction of seabed substrate | Change in topography and bathymetry of the seabed | Pressure |
| | Area of existing habitats ($km^2$) | Pressure |
| Changes to hydrological conditions | Velocity | Pressure |
| | Upwelling | Pressure |
| | Wave Exposure | Pressure |
| | Mixing characteristics | Pressure |
| | Turbidity | Pressure |
| | Residence | Pressure |
| | Time, spatial and temporal distribution of salinity | Pressure |
| | Spatial and temporal distribution of nutrients (DIN, TN, DIP, TP, TOC) | Pressure |
| | Oxygen, pH, pCO2 profiles | Pressure |
| | Equivalent information used to measure marine acidification | Pressure |
| Input of nutrients diffuse sources | Discharge of total Phosphates in the waterbody | Pressure |
| | Levels of Biological Oxygen Demand (BOD) | Pressure |
| | Chemical Oxygen Demand (COD) | Pressure |
| | Total Organic Carbon (TOC) | Pressure |
| | pH levels | Pressure |
| | Discharge of total Nitrates in the waterbody | Pressure |
| Input of other substances | Input of: Oily waste (Gallons | Pressure |
| | Garbage (Tonnes) | Pressure |
| | Sewage (Gallons) | Pressure |
| | Total amount of liquids released into the marine environment area (Gallons) | Pressure |
| | Oil spill incidents: The number and severity of oil spills resulting from offshore activities, typically measured using satellite imagery or field monitoring. | Pressure |
| Input of litter | Median total number of littered items per $100m^2$ | Pressure |
| Input of anthropogenic sound | Sound Exposure Level (in dB re 1 µPa 2 .s); peak sound pressure level (in dB re 1 µPa peak) at one metre, measured over the frequency band 10 Hz to 10 kHz (11.1.1); | Pressure |
| | Trends in the ambient noise level within the 1/3 octave bands 63 and 125 Hz (centre frequency) (re | Pressure |

| | | |
|---|---|---|
| | 1µPa RMS; the average noise level in these octave bands over a year) | |
| Input of other forms of energy | The temperature of the water | Pressure |
| | Light emitting structures in the area (Number of) | Pressure |
| | Cable characteristics and power transmitted determine the sources and intensity of the EMFs emitted (volts per meter (V/m) | Pressure |
| Input of waterpoint sources | Input of water (Gallons) | Pressure |
| | the temperature of inputted water | Pressure |
| | velocity of inputted water | Pressure |
| | BOD contents of inputted water | Pressure |
| Habitats and species | Abundance (number) | Marine processing and functioning |
| | Biomass (g, kg) | Marine processing and functioning |
| | Species diversity (Shannon Wiener Index) | Marine processing and functioning |
| | % cover of habitat | Marine processing and functioning |
| | Area of habitat (ha) | Marine processing and functioning |
| | Gene pool | Marine processing and functioning |
| | Biotope matrix | Marine processing and functioning |
| | AMBI (marine biotic index) | Marine processing and functioning |
| | Phytoplankton index | Marine processing and functioning |
| Sea space | Area of surface (ha) | Marine processing and functioning |
| | Volume (m 3) | Marine processing and functioning |
| | Tidal range (m) | Marine processing and functioning |
| | Depth (m) | Marine processing and functioning |
| | Bathymetry | Marine processing and functioning |
| | Topography | Marine processing and functioning |
| Sea water | Depth (m) | Marine processing and functioning |
| | Volume (m 3) | Marine processing and functioning |
| | pH | Marine processing and functioning |

| | | |
|---|---|---|
| | Salinity | Marine processing and functioning |
| | Turbidity (mg/l) | Marine processing and functioning |
| Substratum | Area (ha) and depth (m) by type (mud, sand, gravel, etc.) | Marine processing and functioning |
| Production | Community production (kcal) | Marine processing and functioning |
| | Net productivity by species (kcal/ha/yr) | Marine processing and functioning |
| | P:B (productivity: biomass) ratios | Marine processing and functioning |
| Decomposition | Amount and number of decomposers (n/ha) | Marine processing and functioning |
| | Decomposition rate (kg/ha/yr) | Marine processing and functioning |
| Food web dynamics | Changes over time in community composition (abundance (number) | Marine processing and functioning |
| | Biomass (g, kg); species diversity (diversity indices)) | Marine processing and functioning |
| | Population dynamics (age classes, male: female ratios) | Marine processing and functioning |
| Ecological interactions | Competition for food and space | Marine processing and functioning |
| | Resilience and resistance (predator: prey, adults: juveniles, etc.) | Marine processing and functioning |
| Hydrological processes | Current speed (m/s) and direction | Marine processing and functioning |
| | Wave height | Marine processing and functioning |
| | Changes in temperature (°C) | Marine processing and functioning |
| | Changes in salinity | Marine processing and functioning |
| | Changes in turbidity (mg/l) | Marine processing and functioning |
| | NAO (North- Atlantic Oscillation) cycles | Marine processing and functioning |
| Geological processes | Sediment accumulation rates | Marine processing and functioning |
| | Beach slopes and gradients | Marine processing and functioning |
| | Seabed form | Marine processing and functioning |
| | Channel depths | Marine processing and functioning |
| | Erosion- deposition cycles | Marine processing and functioning |

| | | |
|---|---|---|
| Evolutionary process | Changes in genetic diversity | Marine processing and functioning |
| | Mutation rates | Marine processing and functioning |
| | Influx/efflux of species (number) | Marine processing and functioning |
| Primary production | Quality of primary production (e.g., efficiency of converting sunlight to carbon) | Marine processing and functioning |
| | Quantity of primary production (g C per unit area/ volume) | Marine processing and functioning |
| Larval and Gamete supply | Quantity of larvae/gametes supplied to a particular location (number per m 3) | Marine processing and functioning |
| | Quality of larvae/gametes supplied to a particular location (% affected by disease; mortality rates) | Marine processing and functioning |
| Nutrient cycling | Changes (output of the system less input to the system) in the amount of nitrates, phosphates, silica (g per unit area/ volume) | Marine processing and functioning |
| | Denitrification (kg N/ha/yr) | Marine processing and functioning |
| Water cycling | Changes (output of the system less input to the system) in the amount of water (m 3 ) | Marine processing and functioning |
| Formation of species habitat | Change in area of habitat (per ha); change in quality of habitat | Marine processing and functioning |
| | Change in number of juveniles | Marine processing and functioning |
| Formation of physical barriers | Change in amount of natural barriers e.g., saltmarsh, reefs, sand dunes, reed beds etc. (% cover, ha) | Marine processing and functioning |
| Formation of seascape | Changes in area by scenic type (ha, % cover, visual range (m, km)) | Marine processing and functioning |
| Biological control | Quantity of pest/disease/predator-control species (number) | Ecosystem Services |
| | Quality of pest-control species (prevalence) | Ecosystem Services |
| Natural hazard regulation | Width or area (and volume if applicable) of saltmarsh, reed bed, mudflat, sand dunes etc. (m, % cover, ha, m 3 ) absorbing energy | Ecosystem Services |
| Waste breakdown and detoxification | Water quality indicators (N mg/l, P mg/l, bacterial levels mg/l etc.) | Ecosystem Services |
| | Total dissolved solids (mg/l) | Ecosystem Services |
| | Water volume | Ecosystem Services |
| | Assimilative capacity | Ecosystem Services |
| Carbon sequestration | Amount of carbon dioxide sequestered (tonnes of CO 2 per m 2 or m 3 ) | Ecosystem Services |
| | Assimilative and recycling capacity, net carbon burial (tonnes per ha per year) | Ecosystem Services |
| Coastal and marine biota | Fish and shellfish population size (biomass of fish/ shellfish in tonnes) | Ecosystem Services |
| | Quality of the fish, shellfish (age profile; length profile; % affected by disease; mortalit rates) | Ecosystem Services |

| | | |
|---|---|---|
| | Quantity of seaweed stock (biomass in tonnes, area of seaweed ha) | Ecosystem Services |
| | Quality of seaweed stock (% affected by disease; mortality rates) | Ecosystem Services |
| | Quantity of raw material (tonnes) | Ecosystem Services |
| | Quality of raw material (concentration) | Ecosystem Services |
| | Quantity of species with potential/actual useful genetic raw material (tonnes) | Ecosystem Services |
| | Gene bank composition (e.g., number of species and subspecies) | Ecosystem Services |
| | Quality of species with potential/ actual useful genetic raw material (tonnes equivalent if variation in quality) | Ecosystem Services |
| | Quality of species with potential/ actual useful genetic raw material (tonnes equivalent if variation in quality) | Ecosystem Services |
| Climate regulation | Greenhouse gas balance especially carbon sequestration (g C) | Ecosystem Services |
| | Quantity of greenhouse gases fixed and/or emitted | Ecosystem Services |
| | Effect on climate parameters (temperature, rainfall, wind, etc.) | Ecosystem Services |
| Natural hazard protection | Width or area of saltmarsh, reed bed, mudflat, sand dunes etc. providing natural hazard protection (m, % cover, ha) | Ecosystem Services |
| | Sediment stabilisation properties | Ecosystem Services |
| | Water retention capacity (m 3 ) | Ecosystem Services |
| | (wave) energy dissipation capacity (joules/m 2) | Ecosystem Services |
| Clean water and sediments | Amount of waste that can be recycled or immobilised (tonnes) | Ecosystem Services |
| | Biological oxygen demand (mg O 2 /litre/day) | Ecosystem Services |
| | Amount of organic matter in water and sediment (mg/l) | Ecosystem Services |
| | Amount of heavy metals in water and sediment (mg/l) | Ecosystem Services |
| | Amount of bacteria in water and sediments (mg/l) | Ecosystem Services |
| | Heavy metal (and other pollutant) content in marine organisms (concentration) | Ecosystem Services |
| | Bathing water quality status under WFD (physicochemical parameters (mineral oils, surface-active substances and phenols). | Ecosystem Services |
| Places and seascapes | Designated sites (number of) | Ecosystem Services |
| | Number/area of specific seascape features (% of total natural seascape) | Ecosystem Services |
| Aesthetic benefits | Number and/or area of marine features of given stated appreciation | Goods and Benefits |
| | Length of heritage coast (km) | Goods and Benefits |
| Clean water and sediments | Amount of waste that can be recycled or immobilised (tonnes) | Goods and Benefits |
| | Biological oxygen demand (mg O 2 /litre/day) | Goods and Benefits |
| | Amount of organic matter in water and sediment (mg/l) | Goods and Benefits |

| | | |
|---|---|---|
| | Amount of heavy metals in water and sediment (mg/l) | Goods and Benefits |
| | Amount of bacteria in water and sediments (mg/l) | Goods and Benefits |
| | Heavy metal (and other pollutant) content in marine organisms (concentration). | Goods and Benefits |
| Education and Research | Field trips (number and number of people involved) | Goods and Benefits |
| | Classes (numbers and number of people involved) | Goods and Benefits |
| | Total number of publications in all forms | Goods and Benefits |
| | Scientific studies (number of research papers, subscriptions, library borrowing, on-line downloads) | Goods and Benefits |
| | Books (number, print run, library usage, e-book downloads); | Goods and Benefits |
| | Other publications including newspaper articles (circulation including on-line accessing) | Goods and Benefits |
| | works of art (number of works, number of people viewing work) | Goods and Benefits |
| Equality Inclusion and Diversity | Proportion of people living below 50 percent of median income, by sex, age, race, and persons with disabilities the geographical area (%) | Goods and Benefits |
| | Changes in the gender pay gap in geographical area (%) | Goods and Benefits |
| Fertilisers and biofuels | Mineral and other content used (e.g. N concentration in g, tonnes) | Goods and Benefits |
| | Quantity of biomass harvested for energy production | Goods and Benefits |
| Food for human consumption | Nutrition from seafood consumption (g protein/year or g protein/year/head or per household) | Goods and Benefits |
| | Fish landed for human consumption (landings data at particular times and places in tonnes) | Goods and Benefits |
| Food not for human consumption | Nutrition from non-human seafood consumption (g protein/year) | Goods and Benefits |
| | Fish landed not for human consumption (landings data at particular times and places in tonnes) | Goods and Benefits |
| | Bait landed for angling (tonnes) | Goods and Benefits |
| | Quantity of bait collected by type | Goods and Benefits |
| Healthy climate | Physical damage avoided through net GHG sequestration and effects on climate parameters | Goods and Benefits |
| | Bodily harm avoided (lives saved and injuries not incurred) through net GHG sequestration and effects on climate parameters | Goods and Benefits |
| Housing | Proportion of the population who are homeowners in the geographical area (%) | Goods and Benefits |
| | Average rent cost (£) ratio to the average income in the geographical area | Goods and Benefits |
| Human health benefits | % cover of coastal and marine environments | Goods and Benefits |
| | % cover of designated coastal and marine spaces (SACs, SPAs, EMS, MPAs, MCZs) | Goods and Benefits |
| | Time spent in the coastal/marine environment (hours) | Goods and Benefits |
| | Participation in particular activities in the coastal/marine environment (type and duration) | Goods and Benefits |

| | | |
|---|---|---|
| Human wellbeing | Sites with cultural heritage/well-being (usage rates by people, degree of importance) | Goods and Benefits |
| | Sites with spiritual and/or religious significance/well-being (number of people who attach significance, degree of significance attached) | Goods and Benefits |
| Income and Employment | Changes in the gender pay gap (%) | Goods and Benefits |
| | Trends in job role dominance between marine sectors by sex, age, race, and persons with disabilities in the geographical area (%) | Goods and Benefits |
| | The difference in part-time and full-time workers between sectors by sex, age, race, and persons with disabilities in the geographical area (%) | Goods and Benefits |
| Medicines and blue biotechnology | Contribution to medicines (number of medicines, improvements in mortality rates and quality of life, etc.) | Goods and Benefits |
| | Total amount of useful substances that can be extracted (kg/ha) | Goods and Benefits |
| | Quantity of specific blue biotechnologies (e.g., biocatalysts) | Goods and Benefits |
| Movement of goods and services | Imports of goods and services (% of GDP) | Goods and Benefits |
| | Exports of goods and services (% of GDP). | Goods and Benefits |
| Ornaments aquaria and aquaculture | Ornamental use (tonnes) by type | Goods and Benefits |
| | Number of people/ businesses who rely on ornamental artefacts (no.) | Goods and Benefits |
| Use of places and seascapes | Number of designated sites the geographical area | Goods and Benefits |
| | Number/area of specific seascape features the geographical area | Goods and Benefits |
| | % of total natural seascape. | Goods and Benefits |
| Prevention of coastal erosion | Number of prevented hazards (number per yr) | Goods and Benefits |
| | Quantity of risk prevention (quantity of assets affected adjusted for risk) | Goods and Benefits |
| | Amount of man-made infrastructure not required (length/width/height in m) | Goods and Benefits |
| Sea defence and Flood control | Number of natural disaster-related casualties and economic losses | Goods and Benefits |
| | Amount of man-made infrastructure no longer required | Goods and Benefits |
| | Businesses and people protected from flooding | Goods and Benefits |
| | Number of households/Number of people protected from flooding | Goods and Benefits |
| | Number of flood related mortalities | Goods and Benefits |
| | Flooding days per year (combined with rainfall indicator) | |
| | Quantity of degradable waste deposited (tonnes by type) | Goods and Benefits |

| | | |
|---|---|---|
| Waste burial removal and neutralisation | Quantity of non-degradable waste deposited (tonnes by type) | Goods and Benefits |
| | Pollution damage avoided by not disposing degradable and non- degradable waste elsewhere (type and extent) | Goods and Benefits |
| | Treatment and engineering works not required (type and capacity) | Goods and Benefits |
| | Changes in activity not implemented due to capacity to immobilise waste (quantity and/or other characteristics of activity) | Goods and Benefits |

MARINE SABRES

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# Marine SABRES Deliverable 3.2 Briefing Paper 7

# Ecosystem Based Management Tools

Authors: Frances Mynott, Julie Bremner

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# Table of Contents

## 2. Definition

Ecosystem-Based Management (EBM) can be defined as: "*Ecosystem-based approach (to management), an 'ecosystem-based approach' or 'ecosystem-based management' is an integrated approach to management of human activities that considers the entire ecosystem including humans"* (European Commission Staff Working Document, 2020). The goal with EBM is to "*maintain ecosystems in a healthy, clean, productive and resilient condition, so that they can provide humans with the services and goods upon which we depend. It is a spatial approach that builds around a) acknowledging connections, b) cumulative impacts and c) multiple objectives*" (European Commission Staff Working Document, 2020)[4].

Other variants of the EBM term in available literature include the Ecosystem Approach (EA or EcAp) or the Ecosystem-Based Approach.

There are various EBM methods/tools available that link to the EBM phases of planning, implementation, reviewing and evaluation. A summary of the different EBM tools is provided in Section 3 of this paper.

## 3. EBM and EBM tools

The Ecosystem Approach was first developed by the UN Convention for Biological Diversity (CBD, 2000, 2004) as a set of 12 principles (CBD, 1992). Annex 1 of this document lists the 12 principles. Long *et al*. (2015) started from the 12 CBD principles and undertook a literature review of EBM principles (up to 2010, across marine and terrestrial environments) and selected the 15 more important/commonly cited principles from a list of 26 principles. The Fifteen Key Principles were identified (in descending frequency of appearance in the literature): **Consider Ecosystem Connections**, **Appropriate Spatial and Temporal Scales, Adaptive Management, Use of Scientific Knowledge**, **Integrated Management**, **Stakeholder Involvement**, **Account for Dynamic Nature of Ecosystems**; **Ecological Integrity and Biodiversity**; **Sustainability**, **Recognise Coupled Social-Ecological Systems**; **Decisions reflect Societal Choice**, **Distinct Boundaries**, **Interdisciplinarity**, **Appropriate Monitoring**, and **Acknowledge Uncertainty**.

EBM implementation it is not a 'one size fits all'. Therefore, the operationalisation of EBM approaches can be diversely shaped, including, from local to global scale, and in view of levels of uncertainty, knowledge available, diversity of human pressures and stakeholder engagement. Examples of EBM implementation/application include, for example, within The CBD, regional seas conventions and associated strategies, assessments, action plans e.g., Oslo-Paris Convention, The Barcelona Convention, and Integrated Ecosystem Assessments (Levin, 2009; 2014).

There are several scientific tools/methods that have been developed to date for EBM. EBM tools include software and methods that can be used by decision-makers/marine managers to support the operational implementation of EBM, including conceptual models, spatial mapping tools, species models, and assessment indices.

[4] Definition also highlighted in the GES4SEA project Marine Strategy Framework Directive Terminology Definitions and Lists (Smith *et al*. 2022).

EBM tools vary in terms of focussing on a specific part of a marine ecosystem, or taking a whole ecosystem view, or may involve EBM applied in a specific context e.g., marine spatial planning or commercial fisheries management.

The Good Environmental Status for Seas (GES4SEAS) project that is a 'sister project' to Marine SABRES, undertook a process to identify EBM components that align with the GES4SEAS project needs and subsequently identified and reported a range of EBM methodological approaches/tool groups. A narrative of each method/approach/tool was produced within the various tools. Given the comprehensive nature of the existing review, the tools lists and information have been adapted for the purposes of this Marine SABRES briefing paper.

The EBM tools in this briefing paper have not been grouped into a hierarchy but are set out roughly in order from more qualitative approaches (e.g., conceptual models) to more complex quantitative modelling (e.g., ecosystem models) as well as marine spatial planning tools. It is recognised that several of these EBM tools are linked and they may be used in concert to pursue EBM objectives.

# 4. EBM tools summary

## Conceptual models

**Description:** Conceptual models are graphical representations or models that are abstract and aim to represent a system and components. Examples of conceptual models include argument mapping, mind-mapping, 'horrendograms' and organograms.

**Application:** Conceptual models are usually created using drawing packages or using software packages for computer-aided argument mapping, e.g., KUMU analytics and visualisation platform to create relationships maps. Conceptual models have been used in a variety of marine environmental management studies to date. Notably, in the Marine SABRES there are the creation of the governance 'horrendograms' for each Demonstration Area, the DAPSI(W)R(M) framework and use of Kumu software. These are described in Marine SABRES Briefing Papers 1, 2 and 8.

## Knowledge Graphs

**Description:** A knowledge graph is a structured representation of knowledge that encapsulates information on entities, their attributes, and the relationships between them. It consists of 'nodes' (representing entities) and 'edges' (representing the relationships between them). A knowledge graph can be visualized as a network or a graph.

**Application:** Knowledge graphs can be used for integrating data, analytics and sharing information. For example, Fotopoulou *et al*. (2022) conceptualised and developed a knowledge graph to track information related to the progress towards achievement of targets defined in the United Nations Sustainable Development Goals (SDGs), at both national and regional levels. The high-level map from Fotopoulou *et al*. (2022) is shown in Figure 1.

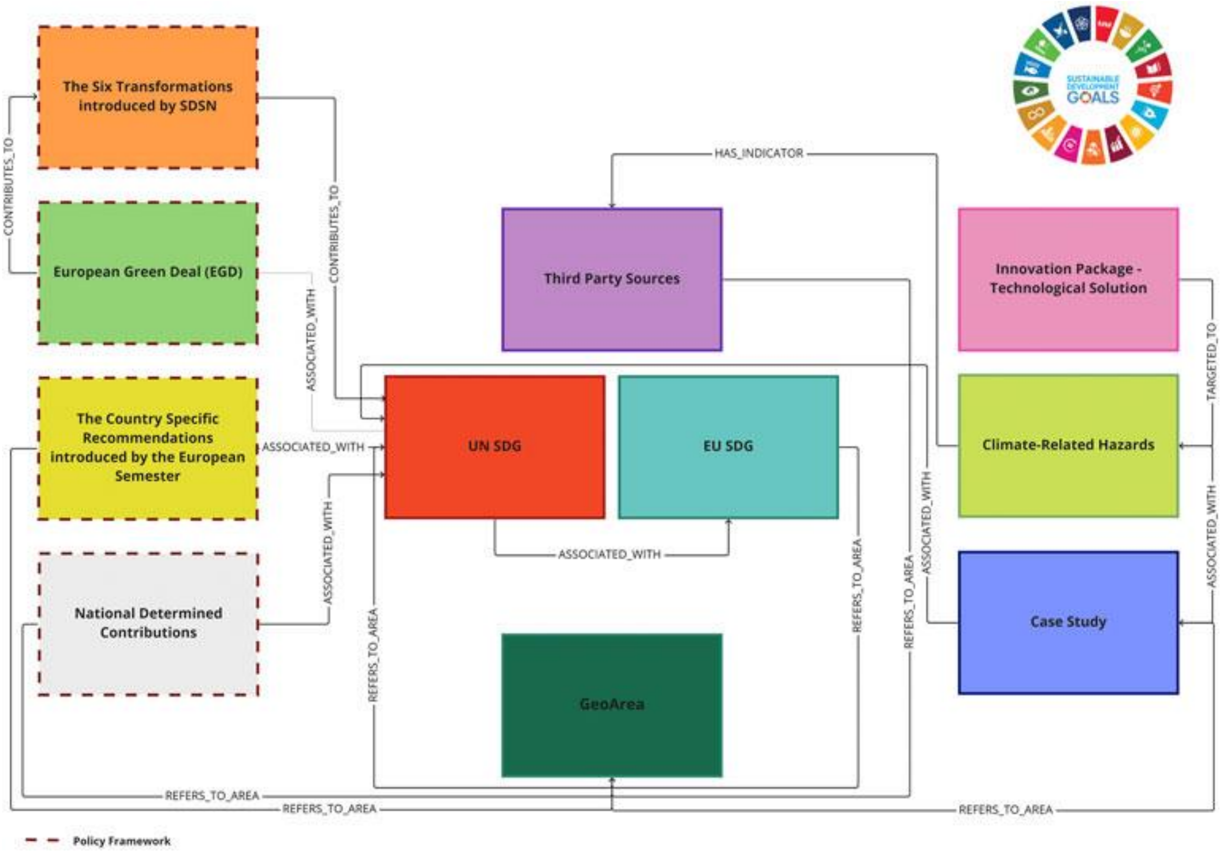

Figure 1: High level view of the SustainGraph, sourced from Fotopoulou et al. (2022).

## Bayesian Belief Networks

**Description**: Bayesian Belief Networks (BBNs) are models that graphically and probabilistically represent correlative and causal relationships among variables and which account for uncertainty (McCann *et al*. 2006). BBN nodes or vertices represent variables which can include observed or unobserved quantities, expert opinion, model outputs, or unknown parameters. There are links or edges joining parent nodes to child nodes[5]. In this way, BBNs can incorporate both empirical, quantitative data and narrative evidence, providing a way to link across the natural and social sciences.

**Application:** BBNs have been used in a variety of studies on marine and coastal environmental management and fisheries management studies. For example, considering management of coral reefs (e.g., Carriger *et al*. 2019), and extracted figure shown in Figure 2 example; management of fishery interventions (e.g., Underwood *et al*., 2016); support tool for marine spatial planning (e.g., Stelzenmüller *et al*. 2010), and linking natural capital to maritime activities (e.g., Gacutan *et al*. 2019), among others.

[5] Bayesian Belief Networks | IPBES secretariat

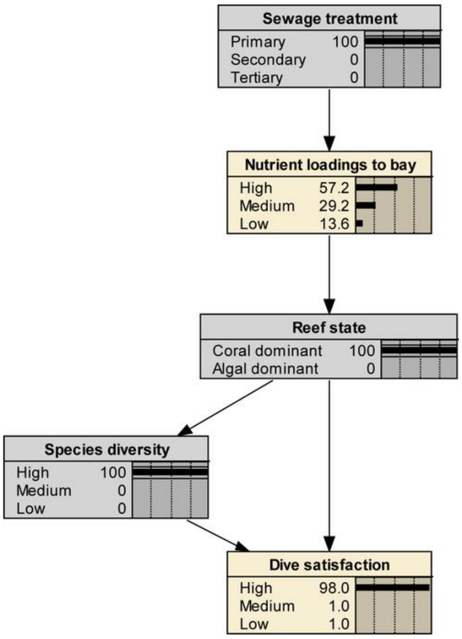


*Figure 2: Bayesian network displaying probability distributions for dive satisfaction and nutrient loadings given that primary sewage treatment is implemented, the reef state is observed to be dominated by coral, and species diversity is high. Gray nodes indicate that new evidence has been entered into the node's state(s) (e.g., 100% probability of primary sewage treatment). From: Carriger et al. (2019).*

## Semi-quantitative mental models (e.g., Fuzzy Cognitive Mapping)

**Description:** Mental models are another name for a conceptual model and consist of a graphical representation of a system e.g., natural ecosystem, socio-economic system, socio-ecological system. In mental models, the linkages are documented, and the direction and strength of interaction can be specified, which allows for simple scenario investigation. An example of a Fuzzy Cognitive Mapping (FCM) tool is Mental Modeler (Gray *et al*., 2012, 2013a, 2013b).

**Application:** Semi-quantitative models can help with identifying what elements are relevant/should be included/prioritised in an otherwise extremely complex system. It highlights which elements are related to each other and how they are connected. FCM has been used in a variety of marine environmental management studies to date. For example, Olsen *et al*. (2023) used FCM (with stakeholder input), in an Integrated Ecosystem Assessment. This was to help evaluate the present and future status of the marine ecosystems in the sub-regions of the North Sea, due to modelled changes.

## Risk-based approaches exposure-effect-hazard-vulnerability (e.g., bow-ties)

**Description:** Bow-Tie diagrams are a visual tool describing and analysing the pathways of a risk, from hazards to outcomes and reviewing controls (preventative and mitigation/compensation methods, the so-called Programmes of Measures). The approach shows the causes of a problem (to the left of the knot of a bow-tie), the hazard and element of main concern (the knot of a Bow-Tie) and the consequences of a hazard happening (to the right of the knot). Various controls can be placed on the left of the hazard to prevent the hazard from occurring, or on the right to reduce/mitigate/compensate for the magnitude of any consequences (Cormier *et al*., 2019).

Bow-tie diagrams can incorporate multiple causes and consequences of a given event, to analyse existing and possible controls that are used to prevent the causes of the event, both individually and collectively and to mitigate and recover from consequences of the event (Cormier *et al*., 2019). Bow-ties are an industry-standard ISO-31000 compliant method and an accepted conceptual model for analysing legislation and policies for managing the environmental risks of human activities (Cormier *et al*., 2019).

**Application:** Bow-tie analysis has been used in many industrial applications and recently used in relation to fisheries and aquaculture (Elliott *et al*., 2020b) and offshore windfarms (Burdon *et al*., 2018). Figure 3 shows an example of a generic bow-tie diagram for marine spatial planning, from the BALTSPACE project[6]. In BALTSPACE, the bow-tie analysis has been used to analyse and evaluate the spatial and temporal management options to either prevent environmental effects, health and safety incidents or user conflicts as well as mitigate the environmental impacts, socio-economic consequences, or legislative repercussion.

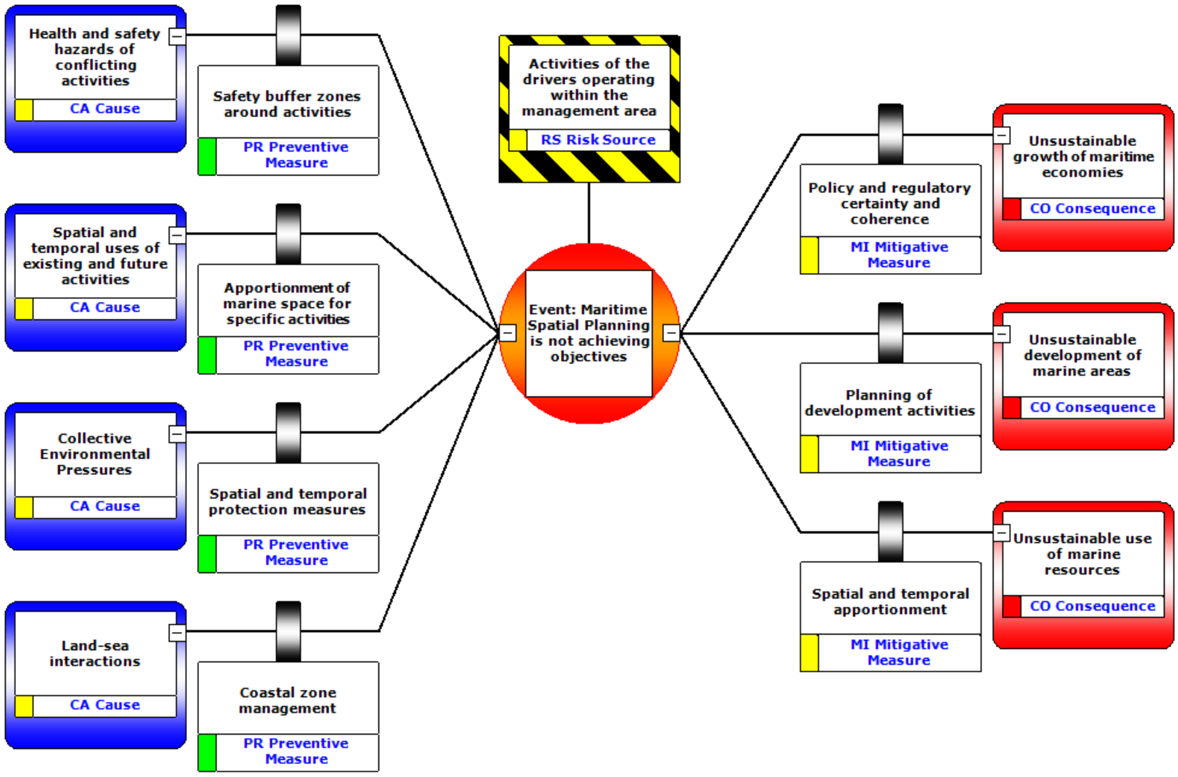


*Figure 3: Generic Bow-tie for maritime spatial planning. From: BALTSPACE - Bow-tie approach.*

## Impact risk ranking through linkage-chain-frameworks

**Description:** Impact risk ranking through linkage-chain-frameworks can be used as assessment methodology for tracing sector–pressure–ecosystem component pressure pathways. The methods have been developed in the Options for Delivering Ecosystem-Based Marine Management (ODEMM) project and AQUACROSS projects. In general, the approach consists of identifying where linkages exist (mapping in a 'linkage matrix') and then scoring each linkage that does occur for several attributes (e.g., spatial overlap, temporal overlap, degree of impact, resilience or resistance, although there are variations on these).

[6] https://www.baltspace.eu/

**Application:** The methodology has been adapted and evolved, including for use in Ecosystem Overviews produced by the International Council for the Exploration of the Sea (ICES). An example of The Azores Ecosystem Overview is shown in Figure 4.

Impact risk ranking through linkage-chain-frameworks has been adapted and used, for example, in the Integrated Ecosystem Assessment in the Mission Atlantic project, linking to management objectives such as the EU Marine Strategy Framework Directive descriptors and criteria, and to better account for cumulative impacts (see ICES WGCEAM, ICES 2019a). There are several existing integrated ecosystem assessments, e.g., for four European regional seas (see Knights *et al*., 2015) and for the Irish Sea (see Pedreschi *et al*., 2019).

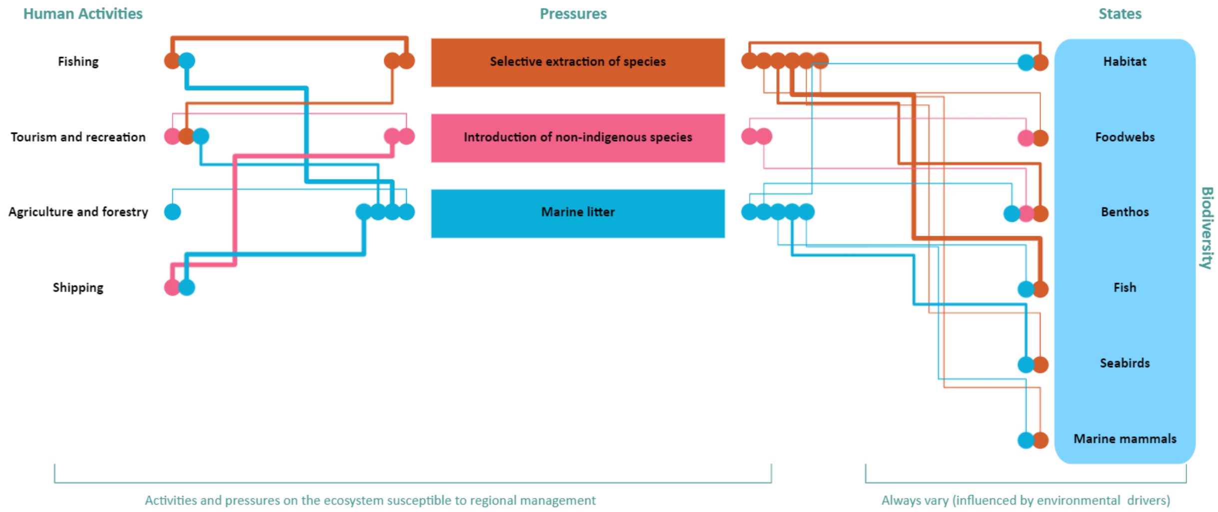


*Figure 4: Azores Ecosystem Overview.*
*From: https://www.ices.dk/advice/ESD/Pages/Azores_ecosystem_overview.aspx?diagramid=48.*

## Cumulative impact spatial mapping

**Description:** A method for Cumulative Impact Assessment (CIA) that is based on a geospatial index describing the relative impact of multiple human pressures on the marine environment.
The main features of the global human impact assessment (Halpern *et al*., 2008) are (i) a grid of selected resolution for all the spatial data, (ii) spatial layers of pressures which are quantified and then normalized between 0-1 inside a grid cell, (iii) spatial layers of ecosystem components (e.g., species, species groups, habitats) which are similarly quantified and then normalized between 0-1 inside a grid cell, and (iv) weight scores representing the sensitivity of the ecosystem components to each of the pressures. Depending on the application, the three scores are summed, or a mean of impacted ecosystem components is taken (e.g., Stock and Micheli, 2016). There are also various ways in determining the weight scores (Halpern *et al*., 2007; Korpinen and Andersen, 2016).

**Application:** Following the first global assessment (Halpern *et al*., 2008), several regional and pan-European development processes were established and published. These include the HELCOM holistic assessment in 2010 (CEA; HELCOM, 2010; Korpinen *et al*., 2012), the Mediterranean and the Black Sea (Micheli *et al*., 2013) and the North Sea (Andersen and Stock, 2013).

## Single species models (life cycle, stock assessment)

**Description:** Single-species models are mathematical representations used to study and understand the dynamics of a particular species within an ecosystem. The models focus on the population size, growth and interactions of a single species, while often considering the species' interactions with its environment and other factors that influence its population dynamics. These models can incorporate limited ecosystem or multispecies information. Examples of types of single-species models are dynamic energy budget models, metapopulation models, dynamic population models and individual-based models (Papadopoulou *et al*. 2023).

**Application:** Single-species models encompass a large variety of models that differ in the level of complexity and the amount of data required.

## Habitat suitability models (species predictive distribution)

**Description:** Habitat suitability models (HSM) are used to predict the spatial distribution of species based on their observed relationship with environmental conditions. These are also referred to as species distribution models (SDM) or predictive habitat distribution models (Guisan and Zimmermann, 2000).

**Application:** Examples of applying HSM include use in mapping Essential Fish Habitats for fish and shellfish species, or to identify geographical regions suitable for different cetacean species, seagrass, seabirds, and elasmobranchs. HSM models may also be applied to identify potential important marine areas where to prioritise conservation, restoration or to support spatial planning and project level assessment.

## Food web models (e.g., multispecies models, Ecopath with Ecosim)

**Description:** As described in Papadopoulou *et al*. (2023), Marine Ecosystem Models (MEMs) are of different types and include a variety of assumptions, such as size based, food-web based and individual based processes. Ecosystem models frequently describe the interactions between at least two ecosystem components (e.g., populations, species, functional groups), whereby the interactions are real ecological processes (e.g., predator–prey interactions, mediation, size relationships) and are driven by ecological dynamics, including movement, and perturbations (both natural and anthropogenic). Some of the most frequently used MEMs are food web models, which are often visualized as networks, where nodes denote interacting ecological components, and the causal relationships between them are shown by edges (Geary *et al*., 2020).

**Application:** Food web models have been applied in a variety of studies, with the use of EwE models to analyse (among others) the ecosystem functioning and the impacts of fisheries; trophic functioning in marine systems; the effects of pollution, aquaculture and Marine Protected Areas on a wide variety of ecosystems (including polar regions and terrestrial systems). Also, to investigate the impacts of climate change or cumulative impacts (Colléter *et al*., 2015; Stock *et al*., 2023). Other applications for food web models include evaluating the trade-offs among alternative fishing strategies (e.g., discard policy); evaluating relative impacts of fisheries and climate effects, evaluation of closed area management, and studying the feasibility for ecosystem-based management.

## Biogeochemical models

**Description:** Biogeochemical models capture two-way interactions between the biology and geochemistry of ecosystems. They are used to simulate how abiotic and biotic variables interact through time and across space and provide a means to explore management scenarios in relation to climate change and change in the flow of nutrients from land into the ocean. Typically, biogeochemical models are used to study nutrient cycling (nitrogen, phosphorus, oxygen, silicon, and iron) and impacts on planktonic communities due to events such as eutrophication and oxygen depletion) (from Papadopoulou *et al*. 2023).

**Application:** Examples of biogeochemical models include The European Regional Seas Ecosystem Model (ERSEM), which is a plankton functional type model; ECOSMO (ECOSystem MOdel) is a coupled physical-biogeochemical model (Schrum *et al*., 2006a, 2006b), and with the hydrodynamics based on the HAMSOM (HAMburg Shelf Ocean Model, Schrum and Backhaus, 1999). There is also the BALTSEM, the 'Baltic Sea Long-Term Large-Scale Eutrophication Model' (Savchuk *et al*., 2012).

## Ecosystem models (e.g., End2End)

**Description:** As described in Papadopoulou *et al*. (2023), End-to-end (E2E) models are one type of ecosystem models. They are a mathematical representation of an entire ecosystem and a single modelling framework that integrates physico-chemical oceanographic descriptors, and organisms, and links to the marine socio-economic aspects. E2E models are used to describe and understand the current ecosystem and forecast/hindcast scenarios, and often also to make decisions on management actions. They are able to incorporate multiple spatial scales and account for temporally dynamics.

**Application:** Examples of E2E models are Atlantis and STRATH E2E. Atlantis is an E2E ecosystem model that considers all parts of marine ecosystems, including the biophysical, economic and social systems (Fulton, 2010; Fulton *et al*., 2011). An example of the Baltic Atlantis model–biological structure is shown in Figure 5, from Bossier *et al*. (2018).

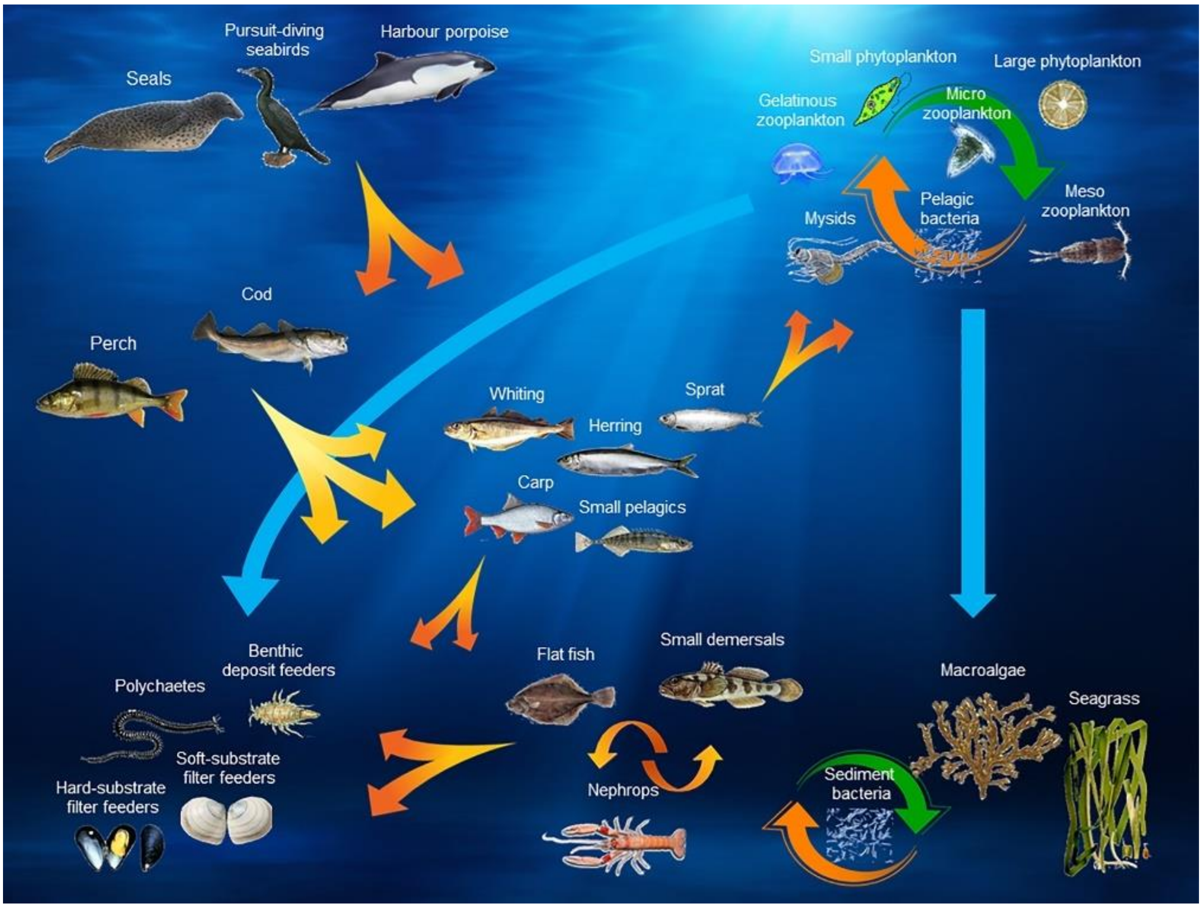


*Figure 5: Main interactions focussed upon in the Baltic Atlantis model–biological structure. From: Bossier et al. (2018).*

STRATH E2E is geared towards marine ecosystem-based management. STRATH E2E model couples an ecological model with either a fishing fleet model or a fishers' behaviour model and thus creating feedback between ecological state and properties of the fishing fleet. The model is designed for application in the North Sea, West of Scotland, Celtic Sea and English Channel (from Papadopoulou *et al.*, 2023).

## Natural capital accounting; ecosystem services valuation

**Description:** Natural capital can be defined as "*another term for the stock of renewable and non-renewable resources (e.g., plants, animals, air, water, soils, minerals) that combine to yield a flow of benefits to people*"[7]. The natural capital approach to policy and decision-making considers the value of the natural environment for people and the economy. The Natural Capital Approach provides a tool to support the protection and management of the natural environment and to facilitate the engagement of stakeholders into decision making within the marine environment.

Natural capital accounting is an "*umbrella term covering efforts to use of an accounting framework to provide a systematic way to measure and report on stocks and flows of natural capital"*[8]. Natural capital accounting *"covers accounting for individual environmental assets or resources, both biotic and abiotic (such as water, minerals, energy, timber, fish), as well as accounting for ecosystem assets (e.g. forests; wetlands), biodiversity and ecosystem services*"[5].

[7] Capitals Approach – Capitals Coalition

[8] Natural Capital and Ecosystem Services FAQ | System of Environmental Economic Accounting

The United Nations System of Environmental Economic Accounting-Ecosystem Accounting (SEEA-EA) is the "*accepted international standard for environmental-economic accounting, providing a framework for organizing and presenting statistics on the environment and its relationship with the economy*"[5].

Natural capital accounts are developed to assess and monitor the contribution of natural resources to economic activity. Physical accounts tables provide basic information on the state of the environment (the stock and the flows of the natural capital, analogous to ecological structure and functioning) in a specific geographical area. When a condition table is also populated, this information can indicate at what level of the ecosystem an impact of economic activities is occurring. Natural capital accounting provides information that is used in decision support tools to support planning decisions, particularly in bio-economic and socio-economic models (from Papadopoulou *et al*. 2023).

**Application:** Natural Capital accounts for different geographic areas has been prepared to date (e.g., Northeast Atlantic, for the UK, and for sea basins of the Baltic and Mediterranean Sea *etc*).

## Bio-economic models, socio-economic models (cost-benefit analysis), societal goods and benefits valuation

**Description:** Bio-economic models are integrated economic-ecological models. Cost-benefit analysis (CBA) is a systematic process of calculating the benefits and costs, expressed in monetary units, of policy options and projects. Environmental CBA is the application of CBA to projects or policies that "*have the deliberate aim of environmental improvement or actions that somehow affect the natural environment as an indirect consequence*" (Atkinson and Mourato, 2008). Societal goods and benefits valuation covers consideration of ecological value, economic value, and socio-cultural value. The concept of 'total social value' (covering all these values), can be used to incorporate value preferences of society associated with natural capital into decision making (from Papadopoulou *et al*. 2023).

**Application:** Bio-economic modelling is applied to resource management and sustainable resource use, such as in fisheries management e.g., anchovy fishery studied in Maravelias *et al*. (2010). A suite of economic valuation methods, including market and non-market approaches, are available which can be applied to value the flow and changes in the flow of ecosystem services. The approach to the monetary valuation of costs and benefits includes assessment based on opportunity costs (defined by the value which reflects the best alternative use a good or service could be put to), and valuation may include data based on market prices and non-market monetary valuation where market prices are not available. Data on all relevant costs and benefits requires data on a range of variables including those associated with natural capital, health and risks to life (Papadopoulou *et al*., 2023).

## Spatial planning tools

**Description:** Marine spatial planning tools are used to help planners and policymakers make informed decisions about the use of marine space, and coastal and marine resources (examples see UNESCO-IOC/European Commission, 2021). Marine spatial planning models, as an example of tools, are designed to provide insights into the potential impacts of different planning scenarios, and to help identify the most effective strategies for achieving specific planning goals (Stelzenmuller *et al*. 2013). There are several different types of spatial planning models, each of which is suited to different types of planning challenges. Geographic Information Systems (GIS) are computer-based tools used to store, analyse, and visualize spatial or geographic data, and present geographic data in a variety of ways, including as maps, charts, and 3-D models,

**Application:** GIS-based spatial planning tools have been used in a variety of studies, including applications in marine environmental monitoring and management, fisheries and resource management, development of marine renewable energy projects, and marine environmental emergency responses, among others (e.g., PlanWise4Blue, Kotta *et al*., 2020).

## Systematic conservation planning tools

**Description:** A subset of spatial planning tools, these conservation-specific decision support tools have been developed to facilitate systematic conservation planning, with the most widely used being MARXAN and ZONATION (See Portman, 2016 for further information). These tools tend to include a suite of different applications used together to provide a range of information to underpin planning decisions.

**Application:** Wider applications of conservation planning tools include use in designing new MPA networks, new MPA sites, zonation within MPAs, prioritise management actions (amongst others). Notably, conservation planning tools are considered relevant for the implementation of the spatial targets of the EU Biodiversity Strategy for 2030.

**Other EBM tools** include the following: **simple assessment index** (e.g., multimeric index M-AMBI); and **descriptor or theme-specific combination of indices and models** (e.g., HEAT for eutrophication, BEAT for biodiversity, and CHASE for hazardous substances), and **overarching assessment tools** (e.g., Nested Environmental status Assessment Tool and Ocean Health Index (for more details see Borja *et al.* 2016).

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# Annex 1 – The 12 CBD Principles

The 12 original principles from the CBD are considered complementary and interlinked [9]:

*Principle 1: The objectives of management of land, water and living resources are a matter of societal choices.*

*Principle 2: Management should be decentralized to the lowest appropriate level.*

*Principle 3: Ecosystem managers should consider the effects (actual or potential) of their activities on adjacent and other ecosystems.*

*Principle 4: Recognizing potential gains from management, there is usually a need to understand and manage the ecosystem in an economic context. Any such ecosystem-management programme should:*

*a. Reduce those market distortions that adversely affect biological diversity;*

*b. Align incentives to promote biodiversity conservation and sustainable use;*

*c. Internalize costs and benefits in the given ecosystem to the extent feasible.*

*Principle 5: Conservation of ecosystem structure and functioning, in order to maintain ecosystem services, should be a priority target of the ecosystem approach.*

*Principle 6: Ecosystem must be managed within the limits of their functioning.*

*Principle 7: The ecosystem approach should be undertaken at the appropriate spatial and temporal scales.*

*Principle 8: Recognizing the varying temporal scales and lag-effects that characterize ecosystem processes, objectives for ecosystem management should be set for the long term.*

*Principle 9: Management must recognize the change is inevitable.*

*Principle 10: The ecosystem approach should seek the appropriate balance between, and integration of, conservation and use of biological diversity.*

*Principle 11: The ecosystem approach should consider all forms of relevant information, including scientific and indigenous and local knowledge, innovations and practices.*

*Principle 12: The ecosystem approach should involve all relevant sectors of society and scientific disciplines.*

[9] Principles (cbd.int)

MARINE SABRES

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# Scenarios Briefing Paper

Authors: Julie Bremner, Bruno Meirelles de Oliveira

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## 6. What are scenarios?

Scenarios are descriptions of plausible and coherent societal or policy trajectories, which can be used to guide strategy, policy-making and environmental management (IPBES, 2016; Goudeseune et al., 2020). They focus on societal and environmental drivers of change and what the outcomes of those drivers might be. Scenarios are mainly narratives of what the future might look like, although they can include quantitative information and they can also be defined retrospectively. Scenarios are not predictions or forecasts and they are 'possible' not 'likely' futures.

It is unlikely that the 'real' future for a nation will be described by any single scenario, it is more likely that it will be a combination of elements from several scenarios and that individual countries will follow different trajectories at different times.

Scenarios are used in many different contexts, including global applications such as the United Nations Intergovernmental Panel on Climate Change (IPCC) 6th Assessment Report and the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) activities, as well as local, national and regional initiatives on shared human-environment challenges (e.g. Biosphere Futures – Welcome to our global collection of place-based social-ecological scenario case studies.). Due to their broad usage for a variety of purposes, scenarios can mean different things to different people and there is no one comprehensive and unambiguous definition.

There is also no one overall set of 'true' scenarios. According to IPBES (2016) "*No single combination of scenarios, models and decision-support tools can address all policy and decision contexts…..no single set of scenarios and models can address all pertinent spatial and temporal scales*". There are general scenario frameworks (see sections 2 and 3), but each project can create its own scenarios by tailoring them to project priorities and geographic, societal and environmental conditions. Scenarios do not need to be static and can be updated as knowledge grows or opinions change.

Selecting which aspects of the human-nature relationship are relevant is a value-driven action, taken independently or collectively by society. These value-driven actions (or priorities) are culturally biased, built on shared values and beliefs, and can be explained by the use of worldviews (Ney, 2012; Thompson, 1997). Worldviews describe the bias society has while framing human-nature relations and how they unfold in the future. Plausible future states can, therefore, be enhanced by investigating these worldviews in the local context.

## 7. Types of scenarios

The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) describe three broad families of scenario related to the policy cycle - exploratory scenarios, intervention scenarios and policy evaluation scenarios (IPBES, 2016). Intervention scenarios have two subsets - target-seeking scenarios and policy-screening scenarios. Biodiversa and the Belmont Forum have refined these to simplify the language and provide further guidance for biodiversity decision-making (Goudeseune et al., 2020). The scenario types are visualised in Figure 1 and described in Table 1.

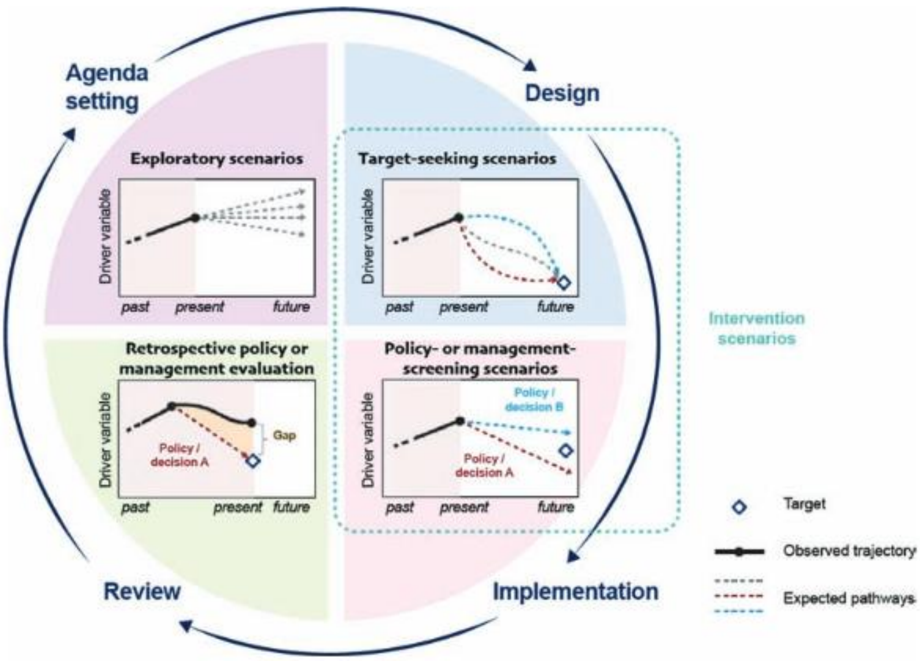


*Figure 1: The four types of scenario relevant to policy making according to IPBES and the Biodiversa/Belmont Forum. In **exploratory scenarios** the dashed lines represent different plausible futures, often based on storylines. In **target-seeking scenarios**, the diamond represents an agreed-upon future target and the coloured dashed lines indicate scenarios that provide possible pathways for reaching this target. In **policy/management-screening scenarios**, the dashed lines represent various policy options under consideration. In **policy evaluation scenarios** (retrospective policy evaluation), the observed trajectory of a policy implemented in the past (black lines) is compared to scenarios that would have achieved the intended target (dashed line). Adapted from Goudeseune et al. (2020).*

*Table 1. The four biodiversity scenario types according to IPBES. Adapted from Goudeseune et al. (2020).*

| | Use | Explanation |
|---|---|---|
| **Exploratory scenarios** | **Awareness-raising, problem identification and agenda-setting** Answer questions such as: *What could happen to biodiversity under future societal and environmental changes?* | They stimulate creative thinking to examine a range of plausible futures, based on potential trajectories of direct (e.g. climate change, pollution) or indirect (e.g. demographic factors, technology developments) biodiversity drivers. |
| **Target-seeking scenarios** | **To design interventions to reach specific goals** Answer questions such as: *What are the possible pathways to reach our goal?* | They focus on pathways for achieving a clearly defined future goal. They are valuable for examining the viability and effectiveness of alternative pathways to a desired outcome. |
| **Policy- or management-screening scenarios** | **To implement interventions** Answer questions such as: *What would happen if other intervention options were considered?* | They consider various policy or management options and are used to forecast the effects of alternative policy or management interventions on biodiversity outcomes. |
| **Policy evaluation scenarios** | **To evaluate previous interventions** Answer questions such as: *Have the interventions achieved the anticipated outcomes and goals?* | The trajectory of a past policy is compared to scenarios that would have achieved the intended goal. The outcomes of previously adopted policies/practices are compared to |

| | | |
|---|---|---|
| | | hypothetical or alternative policies/practices. |

## 8. The SSP-RCPs

Shared socio-economic pathways (SSP) are a set of narratives developed by a group of climate researchers to describe "*plausible alternative trends in the evolution of society and natural systems over the 21st century at the level of the world and large world regions*" (O'Neill et al., 2014). Although they were originally designed with challenges to climate mitigation in mind, they have broad use as agenda-setting tools because they take us from the present through a set of plausible futures.

There are five SSPs, named using terminology on roads to emphasise that they describe development trends over time not a static snapshot at a particular time (O'Neill et al., 2017; Figure 2:igure 2*):*

- *SSP1: Sustainability – taking the green road*
  The world shifts gradually, but pervasively, toward a more sustainable path, emphasising more inclusive development that respects perceived environmental boundaries.
- *SSP2: Middle of the road*
  The world follows a path in which social, economic, and technological trends do not shift markedly from historical patterns.
- *SSP3: Regional rivalry – a rocky road*
  A resurgent nationalism, concerns about competitiveness and security, and regional conflicts push countries to increasingly focus on domestic or, at most, regional issues.
- *SSP4: Inequality – a road divided*
  Highly unequal investments in human capital, combined with increasing disparities in economic opportunity and political power, lead to increasing inequalities and stratification both across and within countries.
- *SSP5: Fossil-fuelled development – taking the highway*
  Driven by the economic success of industrialised and emerging economies, this world places increasing faith in competitive markets, innovation and participatory societies to produce rapid technological progress and development of human capital as the path to sustainable development.

There are full descriptions of the scenarios in O'Neill et al. (2017). The SSP scenarios can be down-scaled to produce social and environmental scenarios for individual nations or shared oceanic areas.

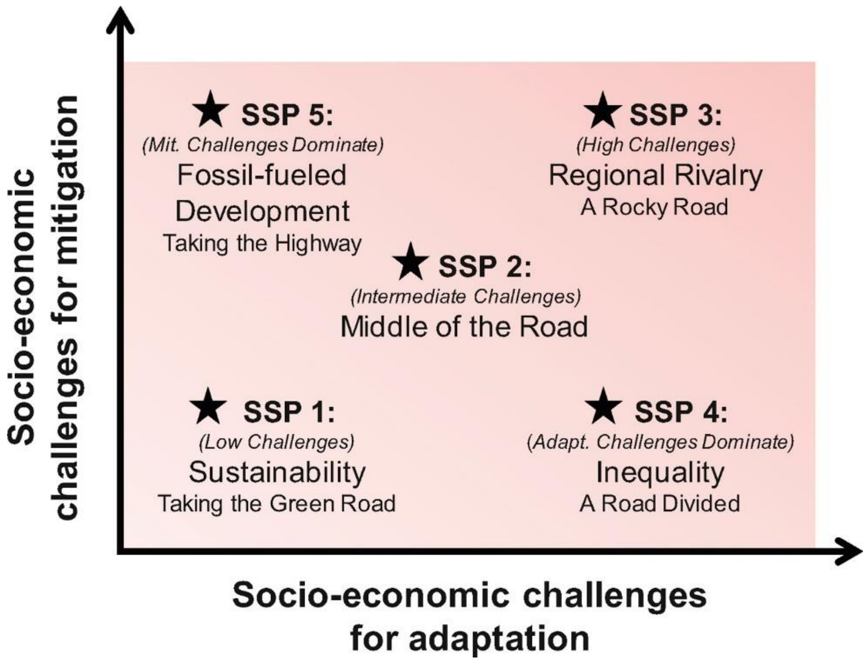


*Figure 2: The five shared socio-economic pathways (SSPs) designed to consider different combinations of challenges to climate mitigation and adaptation. From O'Neill et al., (2017)*

Representative concentration pathways (RCP) were developed by the IPCC as part of their climate assessment process. They describe greenhouse gas concentrations, aerosol emissions and land-use pattern time-series derived from models to the year 2021 (IPCC, 2021 Table 1.4).

The RCP used in the IPCC's 6th assessment are (from IPCC, 2023 Cross-section Box 2):

- RCP 1.9: very low greenhouse gas emissions
- RCP 2.6: low greenhouse gas emissions
- RCP 4.5: intermediate greenhouse gas emissions
- RCP 7: high greenhouse gas emissions
- RCP 8.5: very high greenhouse gas emissions

In their 6th assessment, the IPCC has combined the greenhouse gas concentrations, aerosol emissions and land-use patterns from the RCP with the socio-economic futures from the SSPs (IPCC, 2021). These are known as the 'SSP-RCPs'. The SSP-RCPs replace older climate emissions and social change scenarios developed by the IPCC in the Special Report on Emissions Scenarios (known as the 'SRES scenarios' or the 'SRES storylines'; Nakicenovic et al., 2000)).

## 9. How are scenarios created?

There are two main approaches to scenario development and these are *expert-based approaches* and *participatory approaches* (see IPBES, 2016). Participatory approaches involve a group of stakeholders sharing ideas and collectively developing scenarios via meetings and workshops. Expert-based approaches use (formal) expert opinion to derive the scenarios, based on individual knowledge in a particular subject area and/or empirical data. Techniques for collating the expert knowledge include 'informed qualitative ranking through expert opinion' and the 'Delphi technique' (Perveen et al., 2017).

The PESTLE (or PESTEL) conceptual framework can be used to help develop the scope of scenarios (Pinneger et al., 2021). This involves describing the possible *political*, *economic*, *social*, *technological*, *legal* and *environmental* conditions in the future. When used with the SSP scenarios described in Section 3, the scenario writers - either individually or in groups - imagine what the political, economic, social, technological, legal and environmental conditions might be in nations/regions in the future for one or more of five scenarios of (SSP1) sustainability, (SSP2) middle of the road, (SSP3) regional rivalry, (SSP4) inequality and (SSP5) fossil-fuelled development.

Another approach for framing scenarios is to apply the 10-tenets concept, which considers (1) social desirability, (2) ecological sustainability, (3) economic viability, (4) technological feasibility, (5), legal permissibility, (6) administrative achievability, (7), political expediency, (8), cultural inclusivity, (9) ethical defensibility and (10) communicability (Barnard and Elliott, 2015). This approach lends itself well to target-seeking and policy-screening scenarios that aim to identify pathways to achieve a desired environmental goal.

## 10. Using worldviews in scenario creation

Worldviews are the system of values and beliefs shared by groups of people. They use them to make sense of the world they live in, and they represent the human bias for understanding nature and the individual's participation in social life. These perspectives represent the lens through which people see the future (Figure 3). These four perspectives vary through two axes: the axis 'group' defines the degree to which individual choice is bounded by the group and 'grid' describes the degree to which an individual life is limited by externally imposed conditions, and thus the degree to which it is open to individual negotiation (Thompson, 1997).

Broadly, the four worldviews are:

In an **egalitarian perspective** people understand nature as fragile, an entity that needs attention and caution; any mistake can lead the ecosystem to an undesired state or collapse. They usually consider the precautionary principle as a good solution to human-nature problems.

The **individualist's perspective** sees nature as benign in meaning that it can take care of itself, independent of human use or abuse. If free markets (unrestricted competition between privately owned businesses) could operate with minimal restrictions, prices would control scarcity and environmental degradation, and the surplus would provide the economic capital necessary to solve environmental challenges.

The **hierarchist perspective** sees nature as fragile or tolerant depending on thresholds that must be managed properly by qualified personnel. It is crucial to have trained specialised people to investigate the limits of nature, as wise guidance can show the path towards a desired future.

The **fatalist perspective** sees nature as without rhyme or reason. As for this group a lack of understanding of mechanisms and lack of power to take decisions and participate in the management of the social life are blatant, they cope when change there is a change in their environment.

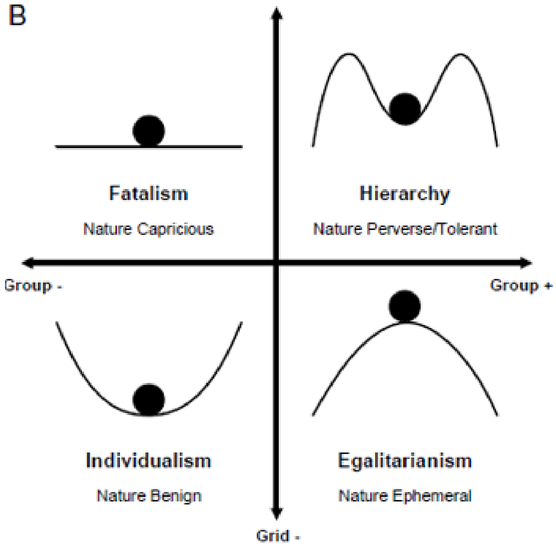


*Figure 3: Worldviews typology. Hierarchy, Individualism and Egalitarianisms are the most politically active types; Fatalism is not active. From Chuang et al., (2020).*

Incorporating worldviews into marine research has revealed the relevance of perspectives when pursuing social goals in ecosystem-based management (Oliveira, 2022) and in developing co-management options that incorporate conflicting perspectives on marine protected area management (Halik et al., 2018). Taking these worldviews into account during scenario development can maximise the chance of the resulting scenarios representing a future with which everyone can identify.

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# Marine SABRES Deliverable 3.2 Briefing Paper 9

## Systems Thinking

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# 1. Systems Thinking: Overview and Some Core Concepts

**Overview**

Systems thinking is a powerful tool for understanding and addressing complex, interconnected problems and issues. It provides methodologies and techniques that can be used to help deepen understanding of an issue or problem, develop more considered decision-making, create more sustainable solutions, and improve and amplify the positive impact of actions. This makes it an appropriate approach for making a significant difference in complex systems, such as the marine environment as such an approach can help develop more effective policy and management strategies to address marine environmental issues and promote sustainable development.

It was in the 1940s and 1950s that systems thinking emerged as a transdiscipline in its own right i.e. separate from any particular discipline but applicable to them all. The founding fathers of systems thinking as a transdiscipline were von Bertalanffy (a biologist), who established 'general system theory', and Wiener (a control engineer), who established cybernetics. Von Bertalanffy (1968) was concerned with the complexity of entire organisms. In an attempt to deal with this complexity, he believed that organisms must be studied as 'complex wholes'. The name 'cybernetics' was first applied to a field of study by Wiener (1948) which he defined as the "science of control and communication in the animal and the machine". Cybernetics, Wiener argued, had application to many different disciplines because it dealt with general laws which governed control processes whatever the nature of the system under governance.

**Some Core Concepts**

In this briefing paper, the aim is to develop a conception of a system, informed by the ideas of von Bertalanffy, Wiener and other systems theorists, which will have general applicability. The central concepts of such a system are shown in Figure 1.

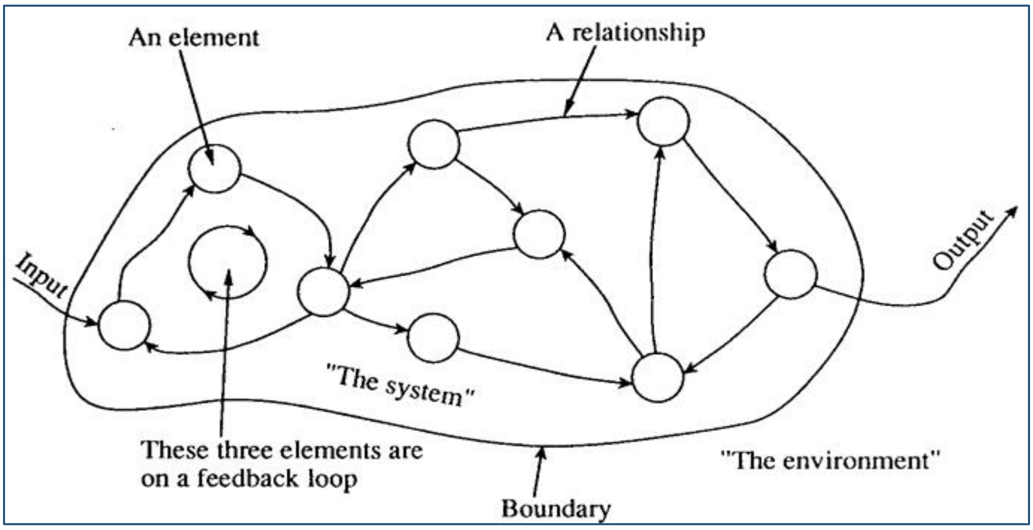


Figure 1. A general conception of a system (from Flood and Jackson, 1991a)

The terms used in this Figure 1 are: element, relationship, boundary, input and output, environment and feedback. However, we need some further notions to describe the complete concept, these are:

attributes, transformation, purpose, open system, homeostasis, emergence, communication, control, identity and hierarchy. Let us expand on these ideas.

A system consists of a number of elements and the relationships between the elements. A richly interactive group of elements can be separated from those in which few and/or weak interactions occur. This can be achieved by drawing a boundary around the richly interactive group. The system identified by a boundary will have inputs and outputs, which may be physical or abstract. The system does the work of transforming inputs into outputs. The processes in the system are characterised by feedback, whereby the behaviour of one element may feed back, either directly from another element by way of their relationship, or indirectly via a series of connected elements, to influence the element that initiated the behaviour. We give attributes to elements and relationships according to how we measure them (e.g., for an element we might use size, weight, colour, number, volume; and, for relationships, measurements might be in terms of intensity, flow, strength).

A system so described is separated by its designated boundary from its environment. It is termed an open system if the boundary is permeable and allows inputs from and outputs to the environment. A system is able to sustain an identity by maintaining itself in a dynamic steady state in the face of and using its changeable environment (we label this homeostasis). That does not mean that nothing is happening in the system; all the constituent parts may themselves have to adapt and/or change in the process of continuing essential transformation processes. A system that maintains an identity and stable transformation processes over time, in changing circumstances, is said to be exhibiting some form of control. Essential to this is the communication of information between the elements. A system can be said to be purposive if it is carrying out a transformation, and is termed purposeful if its purpose is internally generated.

A system stabilised by its control mechanisms, and possessing an identity, can be further understood through its emergent properties. These are properties relating to the whole system but not necessarily present in any of the parts. The term "synergy" refers to the increased value of parts working together as a whole. Emergent properties arise where a complex interconnected network exhibits synergy such that "the whole is greater than the sum of the parts".

Systems are generally understood to occur in hierarchies, so that a system we are considering may also be considered as a sub-system of a wider system. And, if we "blow up" any of the parts of the system of concern, we may usefully conceive of them as sub-systems which exhibit all the characteristics of a system as set out above. We say that these sub-systems are identifiable at a higher level of resolution than the system of which they are part. Sub-systems may themselves be considered in terms of parts, or sub-subsystems, at an even higher resolution level.

## 2. Systems Approaches and Example Modelling Tools

Here we consider how different thinkers started to use systems these concepts, in different ways.

**Systems Approaches**

Some of the early approaches in the systems discipline, often referred to as hard systems thinking, regarded systems as real-world entities. As such the focus was on capturing and understanding these systems through expert modellers creating, often large-scale, representations of all the parts and interrelationships to understand given the behaviour of the system and its emergent properties. The fundamental assumption of such an approach is of a hard external reality that can be captured by an expert modeller who can manipulate the model to derive some kind of optimal solution to whatever problem or issues is faced and then (re)engineering the system, based on the learning from the modelling effort, for optimal achievement. Approaches based on this kind of logic include Systems Analysis (see for example, Miser and Quade, 1985, 1988). Adopting a similar line of realist thought were approaches that looked to understand the structures that underlie complex situations such as System Dynamics (see for example, Forrester, 1961).

In such hard or realist approaches, people were often regarded as rule-following, deterministic parts of the system being modelled rather than self-conscious actors who can change their purposes (Ackoff, 1979). Recognition of the negative effects of the dehumanising of the human parts of a system by hard systems approaches (Checkland, 1985) led to the creation of new systems approaches, which recognised that systems are always seen from the perspective of an observer/participant (Churchman, 1979). These approaches looked to promote stakeholder participation, surface different perspectives through facilitated qualitative modelling, and dialogue for collaborative learning. Such approaches were based on the assumption that different stakeholder positions offered partial perspectives on the complex whole and hence it is necessary to bring stakeholders together to bring about the kind of mutual understanding that can provide the basis for some kind of accommodation and agreement of a way forwards.

Often referred to as soft systems thinking, these approaches include soft systems methodology (Checkland, 1981), strategic assumption surfacing and testing (Mason and Mitroff, 1981), interactive planning (Ackoff, 1981) and interactive management (Warfield, 1994). In addition, some of the earlier hard or structuralist approaches were reinterpreted to address the challenges revealed from a soft perspective, such as to become more participatory, such as system dynamics (e.g. Vennix and Vennix, 1996; Lane and Oliva, 1998) and organisational cybernetics (e.g. Espejo and Harnden, 1989).

The fundamental assumption of the soft approaches is of an ideal speech situation in which everyone is able and willing to contribute and the force of the best argument will out but the naivity of such an assumption with respect to the use of power led to the emergence of approaches associated with a more critical perspective (see for example, Ulrich, 1983, 1987, 1994). Ulrich's key idea is that, as everyone's view of a system is partial, boundaries are inevitably set with reference to the purposes and values of decision makers. However, boundary judgements are often presented as definitive and imposed without being subject to question about whose purposes are being served. From a critical perspective, boundary judgements regarded as subjective and value-laden reflecting decisions about whose voices should and should not be heard. Ulrich encourages dialogue about implicit boundary decisions on the key assumptions upon which that project should be based. However, when dialogue is avoided by decision makers, those affected by their ideas have the right to make a 'polemical' case to compel decision makers to engage in dialogue. The key principle is preventing powerful stakeholders (decision makers and experts) from simply taking their boundaries and values for granted and imposing them on others.

Around about the same time as the emergence of critical approaches focussed on the use of power, systems thinking took a critical term in another way. This other critical turn was based on methodological pluralism: drawing creatively from hard, soft and critical methodologies, and reinterpreting methods through new frameworks or guidelines for choice (e.g., Jackson and Keys, 1984; Jackson, 1991; Mingers and Gill, 1997). Much of the work on methodological pluralism was developed under the banner of 'critical systems thinking' (Flood and Jackson, 1991b; Flood and Romm, 1996; Jackson, 2000, 2003, 2019).

Methodological pluralism makes good sense in the context of marine and coastal management, as some approaches are particularly useful for evolving stakeholder perspectives (e.g., Checkland, 1981), others support intervention in organisational and institutional structures (e.g., Beer, 1966, 1981) and other ask important questions about which stakeholder voices are being considered (e.g., Ulrich, 1987, 1995). Please refer to the BP on Stakeholders and Stakeholder Communication for further information. Work from a pluralist position on cultural theory may also be considered relevant (e.g., Thompson et al., 1990; Thompson, 1997).

Having provided a summary overview of the development of systems thinking, let us now, for the sake of illustration, describe a couple of modelling methods offered by this discipline.

**Example Modelling Methods**

*Mind Maps*

Mind maps (Buzan, 1974) are a simple fast form of individual brainstorming. Although relatively unstructured whether you are creating them by hand or using a software package such as xmind[10], there are some guidelines that can help in their construction (Open University, n.d.):

- Express the focal idea you wish to explore as a keyword or phrase and put it in a circle near the centre of the page to allow the diagram to grow in any direction necessary.
- Capture related ideas, expressed in one or a few words, and write them down around the central idea. Link related ideas to the focal idea with a straight line (note, the lines do not show directional links). Keep going by considering each line or branch to see if further branches (ideas) link to it.
- Start by working fairly freely and then look at the map to see whether any of the strands are effectively the same idea and also to check whether you are creating a single-layer map with ideas attached to the focal idea or issue, or a multiple-layered map with secondary circles creating fans.
- Different colours can be used to group or highlight particular fans or clusters of ideas.
- If you get stuck or lose the thread, start with a new focal keyword or phrase and create a subsidiary map rather than clutter up the original. Alternatively, leave your mind map for a while to allow fresh thinking before adding to it or redrawing it, combining or grouping similar ideas.

See Figure 2 for an example of a mind map.

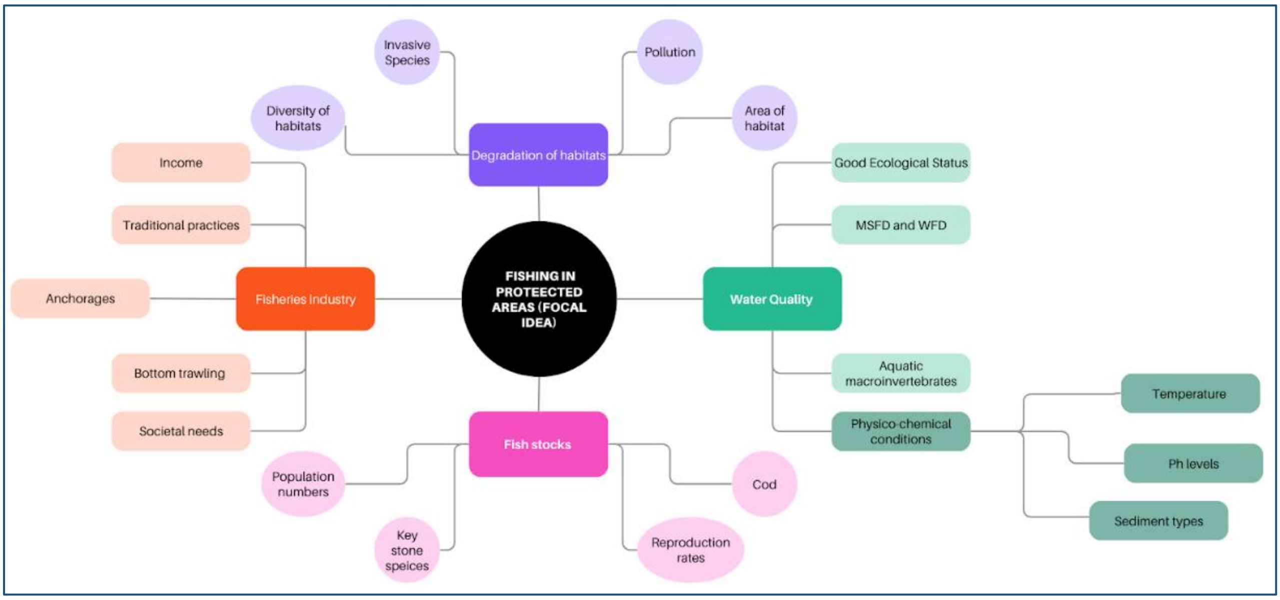


Figure 2. Mind Map on Fishing in Protected Areas

[10] https://xmind.app/

For collaborative idea mapping, the whiteboard tool in Canva[11] allows multiple people to add and link ideas.

*Causal Loop Diagrams*

A causal loop diagram (CLD) is a qualitative systems-based model that shows the relationships between a set of elements that are variables (factors liable to change e.g., indicators) operating in a system (Barbrook-Johnson & Penn, 2022) . The basic premise of causal loop diagramming is that the structure of a system ought to fully explain its behaviour and the process of developing CLDs can help stakeholders converge on a shared understanding of system behaviour and also how to intervene in a system, through the identification of root causes and manipulation of leverage points, to bring it closer to a desired state (Meadows, n.d.). This type of systems approach was discussed in the 1960s (Forrester, 1961) and has been widely used and further since (e.g., Senge, 1990 and Sterman, 2000). Causal Loop Diagramming with stakeholders has already been used extensively in marine management (e.g., Videira, 2012).

A CLD can also provide the basis for quantitative modelling techniques e.g. system dynamics, which can provide a more robust exploration of system behaviours and testing of policy and practice options before final decision making and implementation. See Figure 3 for a diagram portraying the process of CLD based investigation and modelling.

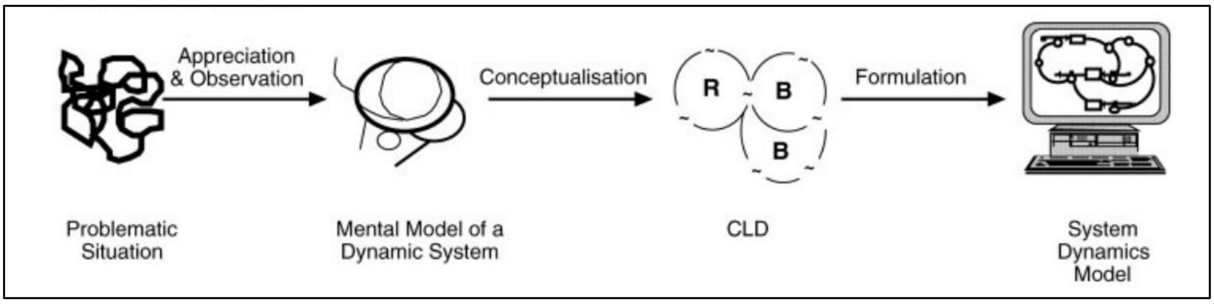


Figure 3. A Causal Loop Diagram (CLD) based process for issue conceptualisation and formulation[3][12] (Lane, 2008)

The creation of a CLD focusses on the identification of key of elements and the relationships between them and it is important to be clear about exactly what we are referring to here.

<u>On Elements</u>

An element is a variable that has two attributes: a name and a level which can be expressed quantitatively, e.g. size of a population, or qualitatively, e.g. population well-being. In addition, we can distinguish between endogenous variables, both influencing and influenced by other variables within the CLD, and exogenous variables, influencing but not being influenced. In a complex system there are many variables, and we can (in principle) describe the state of the whole system by reporting the levels of all of these variables but this might not be possible due to lack of data or even desirable given the amount of resource that assessing the state of all variables would absorb. It is important to be pragmatic and focus attention on just those elements that are relevant to the issue of concern.

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[11] https://www.canva.com/

[12] R=Reinforcing Loop; B=Balancing Loop

Elements should be named using nouns or noun phrases. It is important that the name given to an element makes it clear that the thing or characteristic referred to is capable of change:

- Use clear language to describe elements in a neutral way that does not have any positive or negative connotations.
- Use a name that allows for variation and does not tie the level of the variable to an end point of its range.

On The Level of Detail or Abstraction

Sometimes, to ensure a consistent level of abstraction in a CLD, elements need to be aggregated or disaggregated. Aggregation involves identifying related elements and expressing them as a single element that captures their overall effect (see Table 1). Aggregation is sometimes necessary when excessive detail and too many elements detracts from the understanding of the system's behaviour.

*Table 10: Examples of Element (Variable) Aggregation (Proust and Newell, 2020)*

| Related variables needing Aggregation | Example of Aggregated Variable |
|---|---|
| Rainfall, Humidity, Wind speed | Suitability of Climate |
| Level of pollution, Area of public green space, Air quality, Extent of tree canopy | Healthiness of urban environment |

In some instances, an element needs to be disaggregated because it expresses a concept that is too high-level or too abstract to be meaningful (see Table 2).

*Table 11: Examples of Element (Variable) Dis-aggregation (Proust and Newell, 2020)*

| Original Variable | Possible components of disaggregated form |
|---|---|
| Water quality | Concentration of pathogens<br>Concentration of suspended sediments<br>pH |
| Worldviews | Level of concern for the environment<br>Level of belief in anthropogenic climate change |

The process of aggregation and disaggregation is essential to achieve a level of abstraction and detail appropriate to the issue being addressed. In looking to portray complex systems in simple ways, detailed knowledge of the underlying sub-systems and elements may not just be unnecessary but counter-productive in inhibiting our ability to 'see' the structures that are driving the behavior of the system. With this and keeping it simple in mind, it is recommended that the number of elements in a CLD should be limited to about 15 to 20 in order to maintain overview and coherence (Haraldsson, 2004). It is likely that the process of creating an issue based composite CLD will lead you to exceed this recommendation but it is good to keep it in mind so that you simplify and aggregate to improve clarity and simplicity where possible.

On Connections in CLDs

Causal relationships onnections between linked elements are shown as connecions in CLDS (uni-directional arrows). Connections are either:

- reinforcing–denoted by a '+' or an 's' as the elements (variables) move in the same direction, an increase or reduction in one element causes an increase or reduction in the element it influences
- opposing–denoted by a '–' or an 'o' as the elements move in opposite directions, an increase one element causes a decrease in the element it influences.

See Figure 6 for further description of the connections between elements. When working with others on the construction of a CLD then it is important to agree the labelling convention that will be used consistently and this is especially important if multiple CLDs are to be constructed by multiple teams.

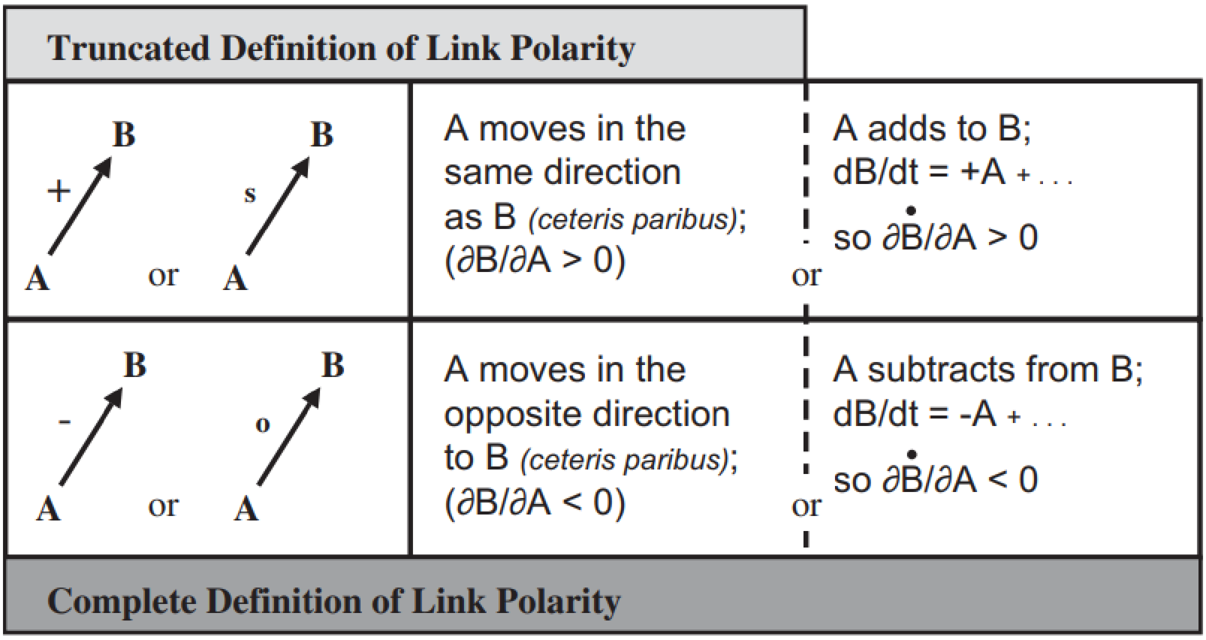

Figure 6. Polarity signs in Causal Loop Diagrams (Lane, 2008)

When there are multiple connections between elements, they can form causal loops, also known as feedback loops. A feedback loop is a closed sequence of causes and effects, that are either reinforcing (vicious or virtuous circles that act as the engine for the growth or decline of a system) or balancing, where self-correction occurs which enables the system to maintain a steady state. See Figure 7 for an example of a simple CLD.

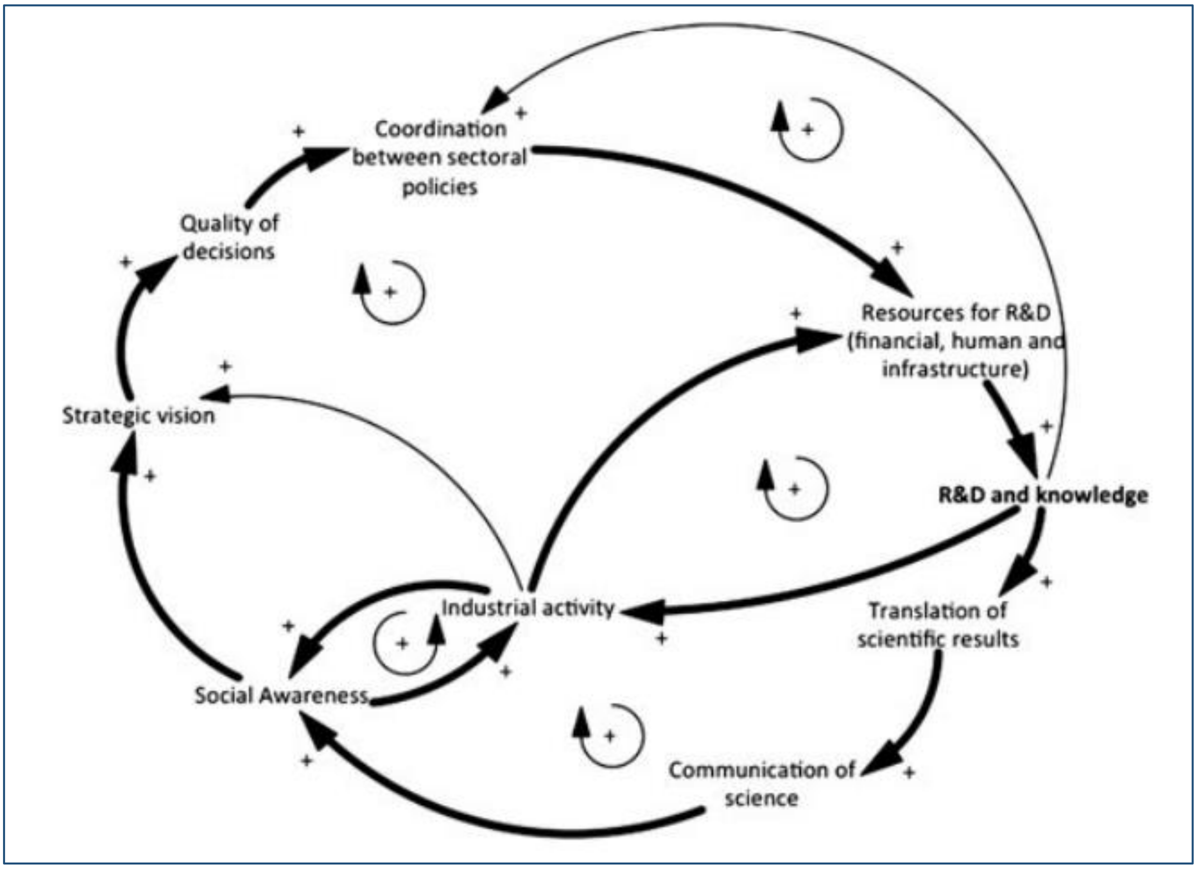


Figure 7. Causal Loop Diagram for issue of 'R&D awareness and dissemination of ocean-related activities (Videira, 2012)

On System Levels and Scales

It has already been mentioned that, when constructing CLDs, it is essential to achieve a level of abstraction and detail appropriate to the issue being addressed but it is also important to recognise that an issue can manifest at different system levels so it is important to identify the level at which the impacts of concern are being realized. The process of unfolding complexity, involving the definition of distinct system levels and interactions between levels, is important as it helps clarify the system-in-focus, the sub-systems that constitute it and the meta-system of which it is a part (see Figure 8). The process of identifying different system levels is essentially a process of defining boundaries and whilst we often defer to familiar definitions (e.g., city, state, country) these can and should be made problematic so that systems levels are defined that are meaningful to stakeholders and appropriate for supporting understanding given the issue being addressed (Jackson, 2019). For example, stakeholders may determine that it is more meaningful to define a particular system level based on common geographical features rather than institutional arrangements. It is important, though, to give a meaningful label to each systems level, should one not already exists, and at each system level there should be a consistent level of abstraction and detail.

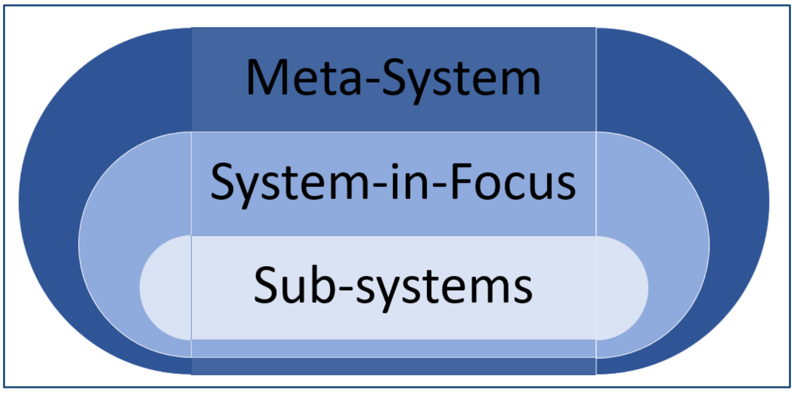


Figure 8. Unfolding Complexity across System Levels

As well as system levels it is also relevant to consider the relevant scale of each level and there are different ways of thinking about scale:

- Temporal scale - This is defined by the time feedback mechanisms in the system take (this might also be thought of as a 'delay' or 'lag' in the effect of one variable on another). If we are focussed on an issue that has a short time-frame then we might not include feedback loops with very long delays as the impacts of these will not be realized over the period we are concerned with. That said, this requires careful consideration to ensure that important slow changes are not disregarded and that the potential for the speed of change to change is recognized.
- Physical scale - This is the physical size of the system. The pace of change in smaller systems tends to be quicker than in larger ones.

Simple CLDs are often drawn by hand but sometimes the number of elements and connections get difficult to present on a hand-drawn model, as it is often necessary to move them about so that connecting arrows do not cross, and there are a range of data visualisation software packages that are available to support the building of CLDs.

Kumu and Gephi are data visualization and analysis packages and templates (e.g. causal loop modelling and social network analysis) to support a range of modelling processes. Kumu[13] is free to join and public projects can be created for free (an overview of Kumu can be found here[14]).

CLDs are useful for capturing and sharing basic insights on the causal relationships that are driving the behaviour of a system. These basic models can be further developed and software packages (e.g. Vensim, iThink) provide enhanced analysis and simulation capability (see for example, Maani and Cavana, 2007).

[13] https://kumu.io
[14] https://kumu.io/tour

## 3. Summary

This briefing paper provides a summary overview of systems thinking. As a transdiscipline, the approaches and core concepts of systems thinking have been applied usefully across a diverse range of disciplines. In summary, key principles include:

- Respecting the complementary nature of different paradigmatic approaches within systems thinking as each offers something valuable when dealing with complex problem situations.
- Identifying the different parts of a system (e.g., elements, relationships, boundaries, inputs, outputs, feedback loops) and understanding how different parts of a system interact to create structures that drive system behaviour.
- Considering systems to be adaptive, with the ability to maintain dynamic stability through feedback and control mechanisms. Systems are also seen as purposive, meaning they have a function or goal, often defined by their structure and the interactions between their parts.
- Making the definition of boundaries problematic as they determine which elements, relationships, and interactions to include within the system under study, thereby shaping the scope of analysis and ensuring that key components relevant to the issue are considered without overcomplicating the model.

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## Marine SABRES Deliverable 3.2 Briefing Paper 10

# The Process and Information Management System

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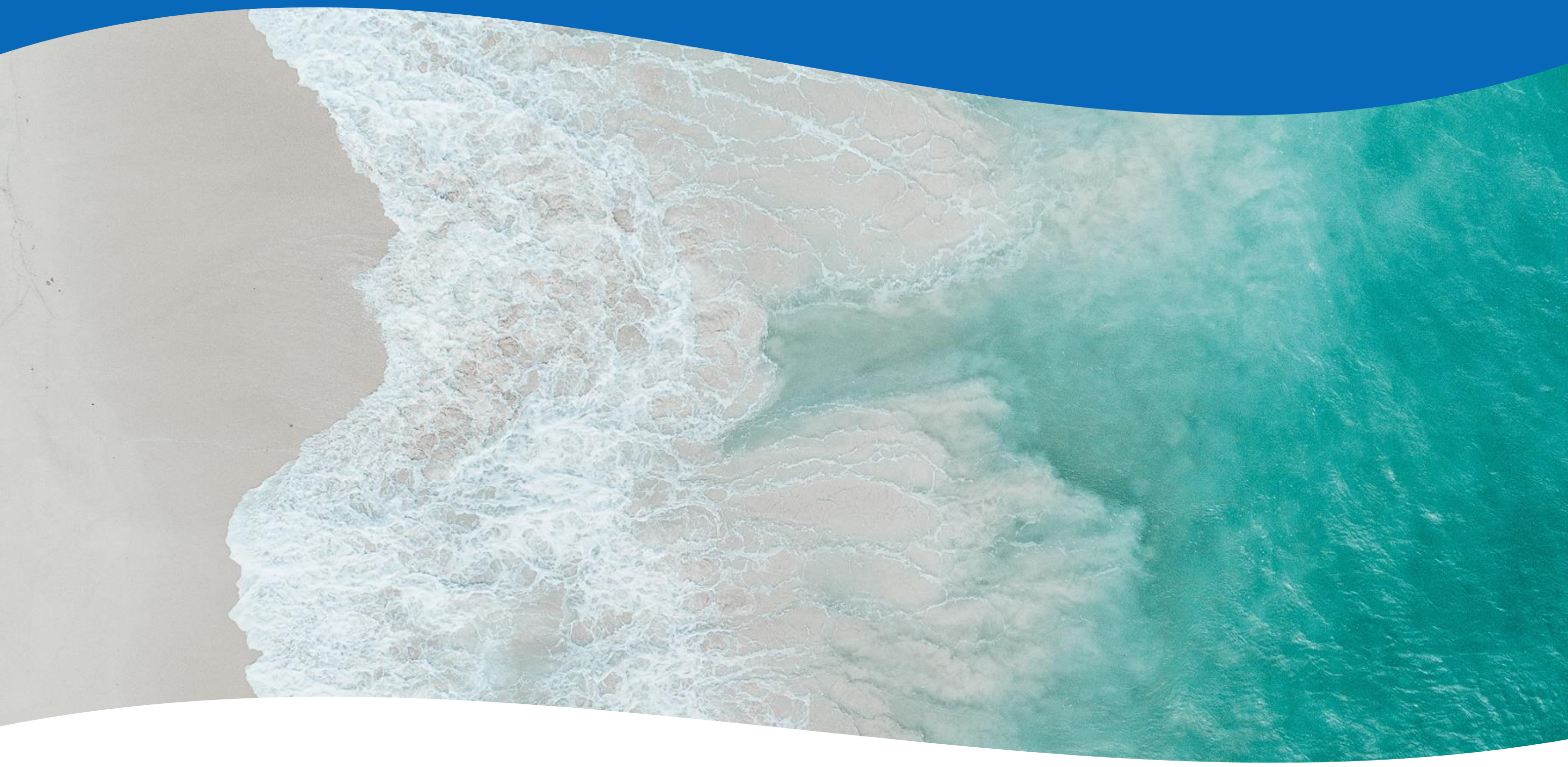

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## Contents

# 1. Why do we need a Process and Information Management System?

In the context of Marine Ecosystem-Based Management (EBM), the Process and Information Management System (PIMS) is a comprehensive framework designed to support the holistic management and conservation of marine ecosystems (Gregory et al., 2023). It serves as a tool to guide the integration of data, stakeholder perspectives, and governance in marine EBM projects, ensuring their success and sustainability. Marine EBM is a multifaceted approach that aims to balance ecological, societal, and economic goals in marine environments. Given the management of the marine environment's complexity, there's a need for a structured system like PIMS to manage the myriad of processes, information, and stakeholders involved (Ritchie & Ellis, 2010). PIMS, with its emphasis on good governance, information provenance, and systematic management, ensures that marine EBM projects are not only scientifically rigorous but also transparent, inclusive, and adaptive to changes. It recognises the dynamic nature of marine ecosystems and the diverse stakeholders involved, ensuring that decisions are evidence-based, equitable, and reflect the interconnectedness of marine socio-ecological systems.

Within the core of PIMS is the Integrated Systems Analysis (ISA) (Elliott, 2020). ISA is regarded as an action learning cycle, and PIMS, especially in marine EBM, ensures that each iteration of this cycle is well-documented, evidence-based, and reflects the dynamic nature of marine ecosystems. Using PIMS in conjunction with ISA ensures that marine EBM projects are not just iterative but also adaptive, transparent, and inclusive, leading to better outcomes for both marine ecosystems and the stakeholders dependent on them (see *Briefing Paper 12: Equity, Diversity and Inclusion*). The PIMS is a crucial component of an Action Learning Cycle (Zimmer, 2001) because it plays a vital role in maintaining good governance and ensuring information provenance and management throughout the process.

# 2. The PIMS elements

**DA Process Management** - Refers to the oversight of the Demonstration Area (DA) activities, ensuring that each phase of the project corresponds with its intended objectives. In the wider context of marine EBM, this consideration ensures that the specific goals of ecosystem conservation, sustainable resource use, and stakeholder engagement are integrated and managed.

**Resource Management** - Centred on the strategic distribution and use of resources, this element ensures the process operates within its stipulated budget and time constraints, efficiently utilising resources, from scientific tools to human expertise, ensuring that marine EBM projects are cost-effective and impactful.

**Stakeholder Identification, Engagement and Communication** - Involves surfacing and actively involving all relevant people in the process, as well as seeking to create a dialogue that addresses their insights and reservations. This approach includes taking a critical perspective to who and how you are involving stakeholders in the process, ensuring this is done in a meaningful way. In the marine context, this could imply the involvement of everyone from fishermen to policymakers, ensuring that the diverse voices and concerns of all stakeholders are acknowledged in marine management decisions. More information can be found in the briefing paper 'Stakeholders and stakeholder consultation'.

**Data Provenance and Management** - Underscores the importance of data integrity and traceability. It entails a structured approach to managing data in line with a Data Management Plan (DMP) and respecting data protection standards like GDPR (Regulation 2016/679). This is especially vital in marine EBM, where data from various sources, including traditional knowledge, satellite imagery, and field studies, needs to be integrated, verified, and managed.

**Evaluation** – This should comprise a continuous appraisal process that compares the project's progression with predefined standards, enabling timely modifications to enhance outcomes. Assessing the health of marine ecosystems, the effectiveness of management actions, and the satisfaction of stakeholders allows for timely adjustments in strategies.

**Governance** - Pertains to the establishment and enforcement of clear protocols, rules, and decision-making processes, ensuring the project is conducted ethically, transparently, and efficiently (Boyes & Elliott, 2014). By establishing clear marine governance structures, we ensure that EBM decisions are ethical, legal, and in line with international marine conservation goals.

## 3. Overview diagram

The various elements of the PIMS will not relate to any specific part of the ISA process; rather, it is an encompassing system which is key in the beginning and throughout to support action learning processes using the DAPSI(W)R(M) Framework (Figure 1).

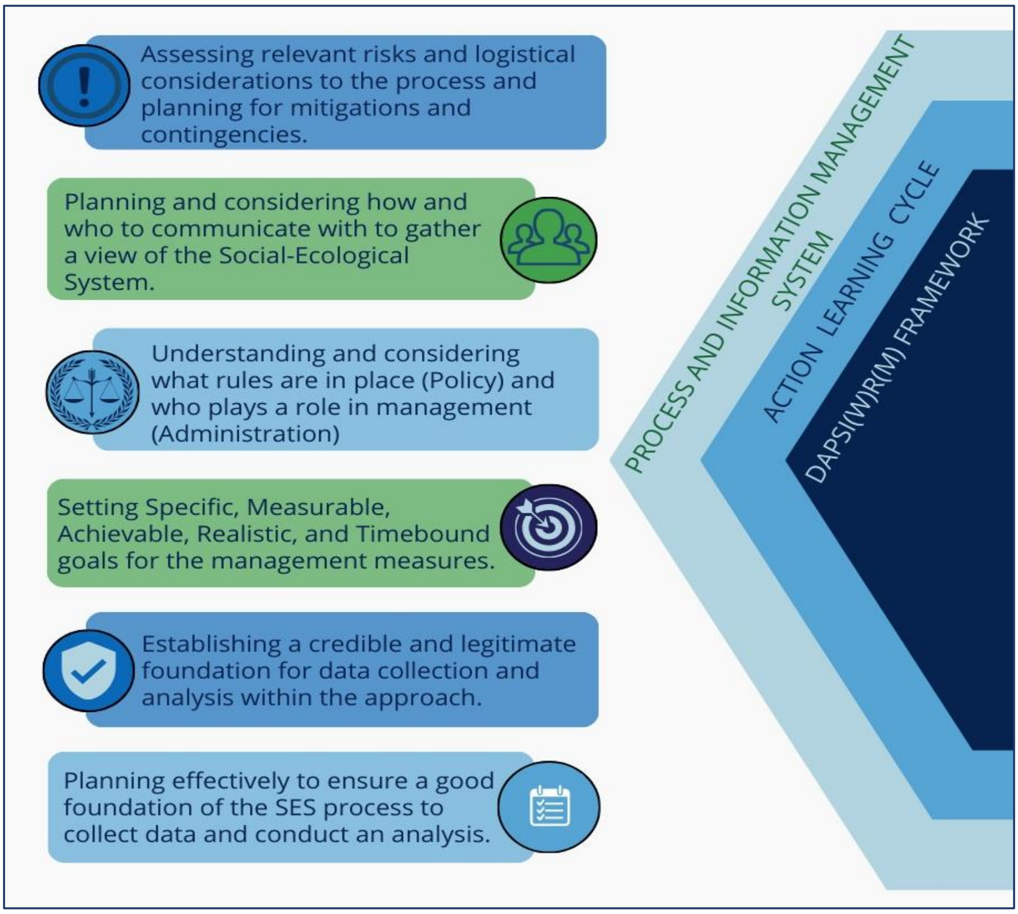


*Figure 1: The key PIMs actions encompassing the Learning and action cycle and the DAPSI(W)R(M) framework.*

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# Marine SABRES Deliverable 3.2 Briefing Paper 11

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# 1. Marine Governance Overview

Marine governance includes legislation, policy, politics, administration, and the interplay among them (Boyes & Elliott, 2014). Governance has also been defined as structures and processes that are designed to ensure accountability, transparency, responsiveness, rule of law, stability, equity and inclusiveness, empowerment, and broad-based participation (UNESCO, 2021). Managing the marine environment to protect its ecological function and sustainability is carried out using a complexity of governance strategies. Countries are bound firstly by national policies, laws and agreements, and secondly by external agreements and laws which address regional, transboundary and international concerns by being signatories to global initiatives such as the United Nations Convention on the Law of the Sea (UNCLOS) and the Convention on Biological Diversity (CBD).

Within the European Union (EU), many thematic initiatives have been developed and implemented by Member States to ensure integration between the management of regional seas, including spatial planning to ensure human activities are managed in a sustainable manner to achieve ecological, economic, and social objectives; the protection of vulnerable marine habitats; encouraging cross border cooperation; and the need for integrated marine governance in EU Member States. Particular attention must be taken to accomplish the goals of the Directive 2014/89/EU establishing a framework for Maritime Spatial Planning (MSP).

Governance systems set the parameters under which management and administrative systems will operate to achieve the desired results, and to ensure stakeholders are held accountable for their actions (UNESCO, 2021). It is common in most countries that the plethora of marine activities are managed by numerous statutory and competent authorities, departments, and administrative agencies (Boyes and Elliott, 2015). These bodies are bound by national and international law to protect and manage the marine area through International or European initiatives such as MSP, and the protection of important conservation features through networks of protected areas. In most countries, there is no one single government department or agency which manages and coordinates the management of the marine environment, and usually different economic sectors (e.g. fisheries, energy, transport) are all managed under different ministries. Many countries apparently have many government departments or agencies with differing priorities which can lead to overlapping jurisdictions, duties and competencies and in some cases gaps in management (Elliott et al., 2006, 2022).

Marine management can be regarded as a pyramid moving from the local to the global aspects and vice versa, what may be termed vertical integration, and in which the governance and management of all sectors (navigation, fisheries, etc) need to be managed together (termed horizontal integration) (Cormier et al., 2022; Figure 1). Each stratum in the pyramid has a differing number of statutory instruments, from the large number of Environmental Impact Assessments (EIA) covering each activity in an area, to the few global instruments and agreements. Similarly, the instruments may cover a small area, such as an activity footprint covered by an EIA (see Elliott et al., 2020) to the large areas covered by MSPs and the even larger areas covered by regional and global instruments (Figure 1). Accordingly, MSP is required to encompass that horizontal and vertical integration.

Each Demonstration Area within Marine SABRES will carry out an audit of the marine governance framework, including an interrogation of the complex governance framework and also map the organisations and agencies responsible for implementing and enacting those legislative instruments and agreements (see Simple SES guidance document for instructions (Gregory et al., 2023)). All acronyms used in this working document can be found in Annex 1.

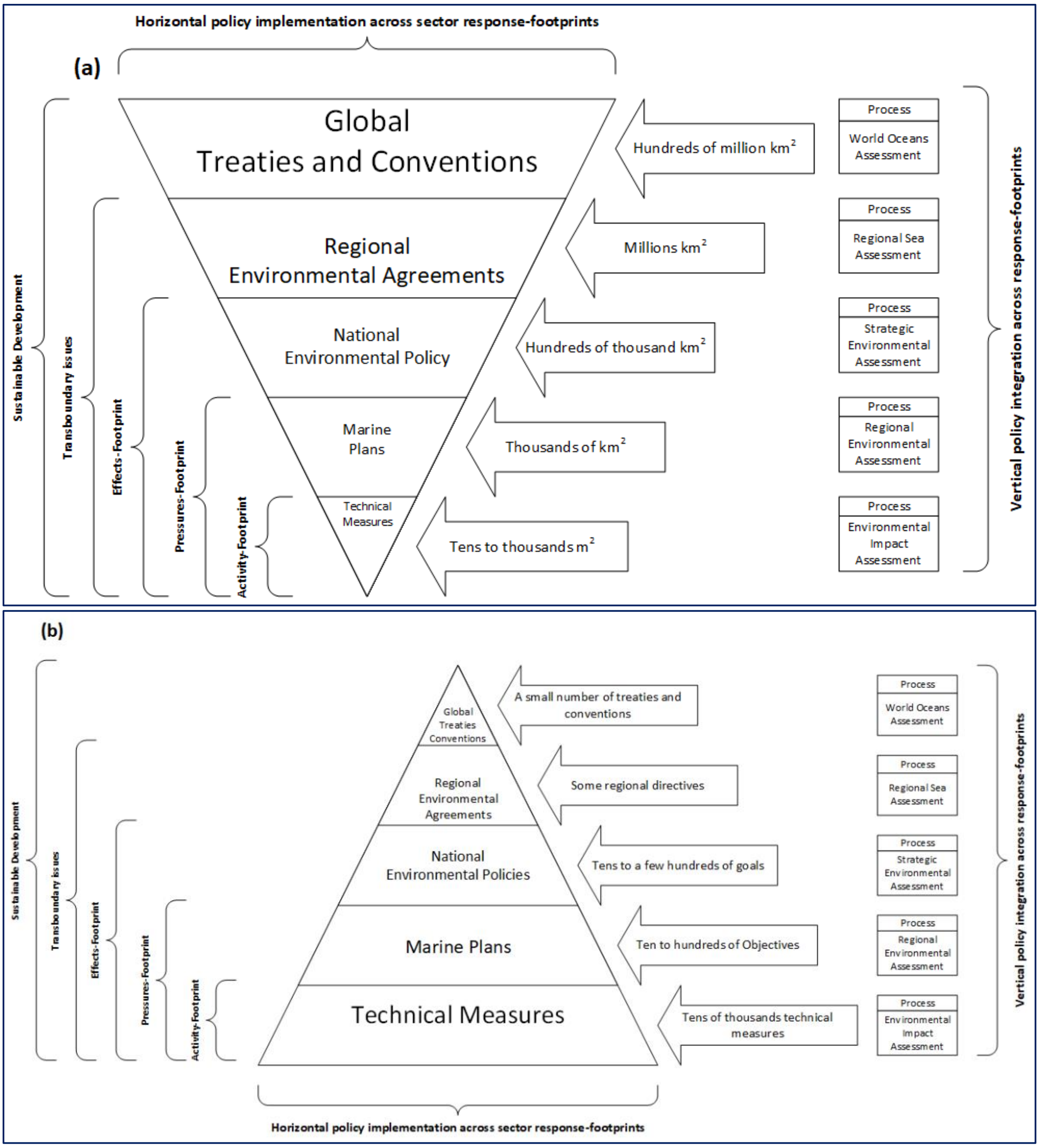


Figure 1. The 'management response-footprint pyramid' – showing both (upper) the areas covered by management response-footprints and (lower) the number of policy instruments; horizontal and vertical policy integration is also denoted (Cormier et al., 2022)

The management response footprint elements can then be represented as a site-specific framework for each marine area and maritime state. A legislation figure (horrendogram) showing the existing environmental legislation in the UK (Boyes & Elliott, 2014, updated post Brexit by Elliott et al., 2022) will be adapted and used as a template for providing insight into the marine environmental legislation frameworks of the 3 Demonstration Areas in Marine SABRES (Figure 2). This has been successfully used as a tool by other researchers to map marine legislation in several other countries worldwide (see Monwar et al., 2020) and within the EU projects MarinePlan and MARBEFES. From the centre moving outwards, the horrendogram maps the vertical governance levels from the international (e.g., United Nations), regional (e.g., European Union) and national laws (e.g., country specific implementation) related to marine management which encompasses all activities required to be factored into marine spatial planning management. Sectors, as the types of marine use, have also been grouped into segments on the horrendogram based on their management through national legislation (although there are obvious connections made between different sectors to ensure targets are being met). These groups include ecological protection, fisheries, water quality, flood and risk assessment, marine spatial planning, climate change, strategic environmental assessment (SEA), environmental impact assessment (EIA), shipping and general ocean management.

Within the SES, the Demonstration Area partners will identify and characterise the number of statutory organisations and agencies that have a strategic role in MSP, MSFD and managing and designating MPAs within the Demonstration Areas. This will assist in the creation of organograms for each Demonstration Area as demonstrated in Figure 3a which gives an example of the UK Government marine organogram (predominantly for England) indicating the main bodies within each government department and their principal competencies (Elliott et al., 2015, 2022). As a subset, because of its importance for the marine environment, Figure 3b shows the dominant lead marine body in the UK (Department for Environment, Food and Rural Affairs (Defra)) and its associated agencies for marine management.

The figures indicate that a country can have many government departments with a marine competency, not only the more obvious ministries and departments such as environment and trade, but also defence, foreign affairs and transport. Each Demonstration Area may have to indicate department/ministries that have joint responsibility, for example with a remit for climate change and the environment. The governance section of the ISA Process and Information System (BP 10: *Process and Information Management System (PIMS)*) will provide the guidelines and set of instructions and templates for each Demonstration Area to complete both a legislation and administration audit to determine the governance of the Demonstration Area, particularly in relation to the protection and management of Marine Protected Areas (MPAs), Maritime Spatial Planning (MSP) aims and the Marine Strategy Framework Directive (MSFD) objectives. This information will then be mapped graphically in a horrendogram and an organogram.

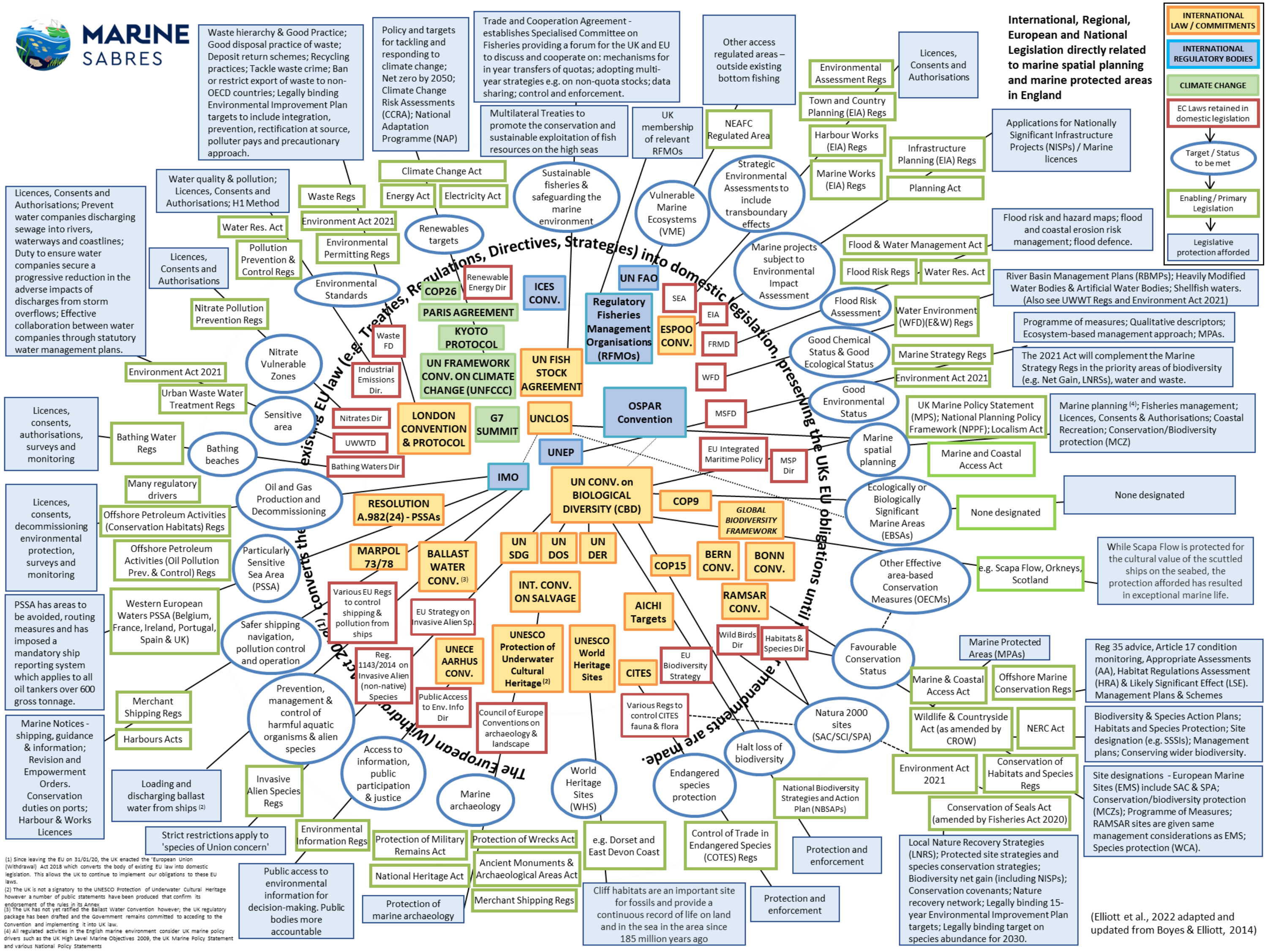


Figure 2: Current UK Marine Governance (expanded and modified from Boyes and Elliott, 2014, 2016) relating to the post-Brexit changes and the implementation of new UK Acts (Elliott et al., 2022).

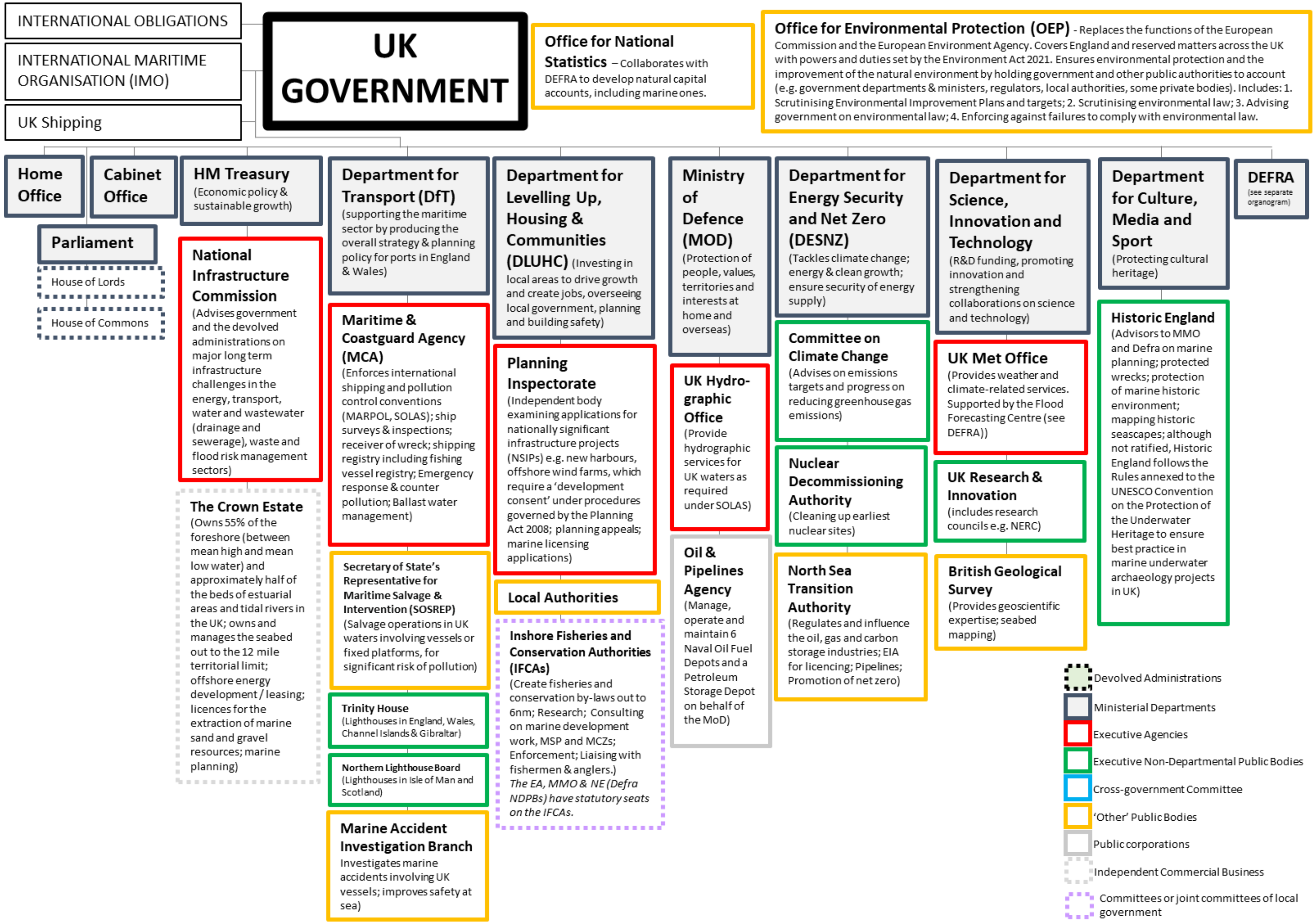


Figure 3a: The UK Government marine organogram (predominantly for England) indicating the main bodies and their predominant competencies (updated from Elliott et al., 2022).

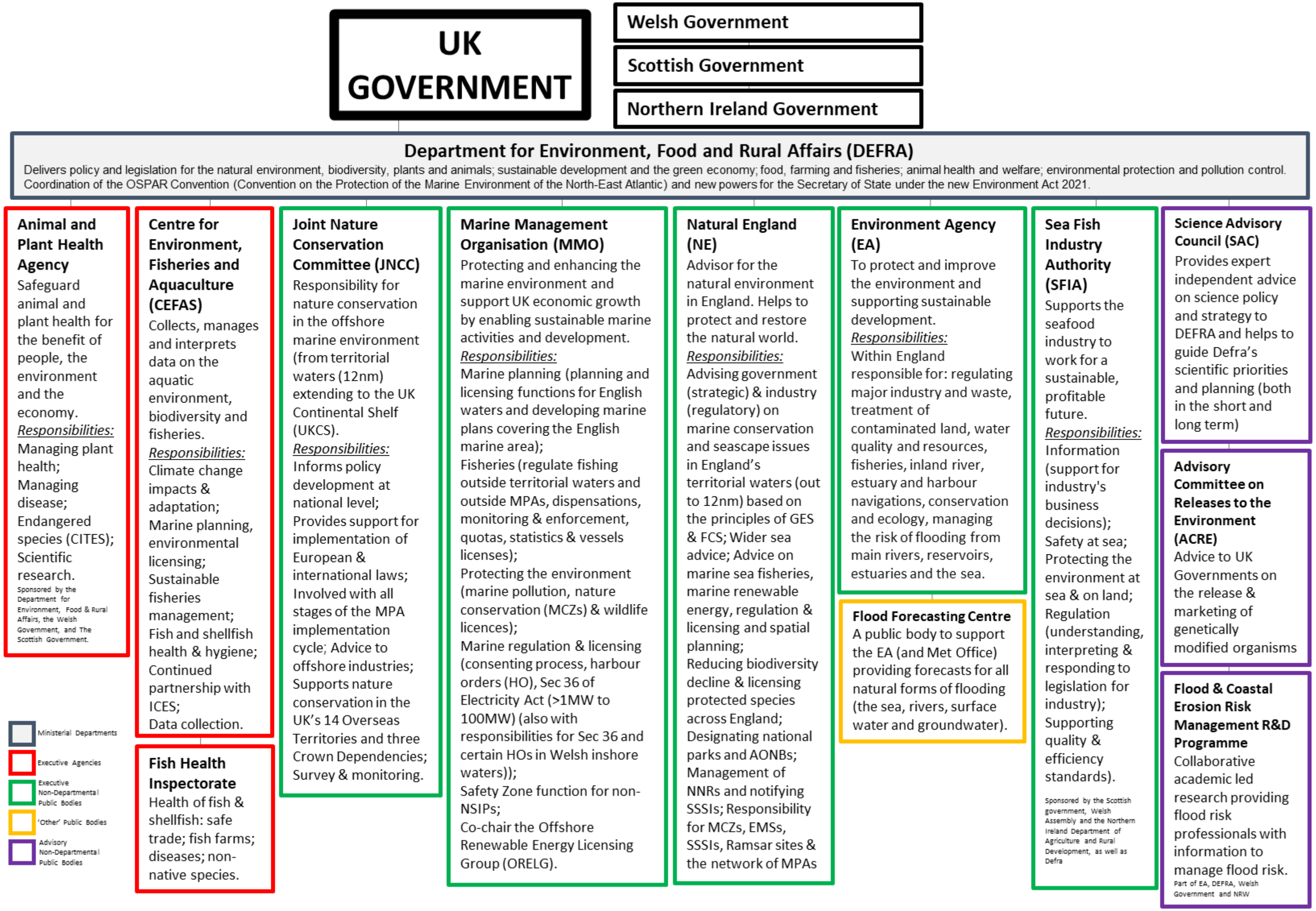


Figure 3b: Organogram specially detailing the agencies and bodies under DEFRA (updated from Elliott et al., 2022).

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# Annex 1 - ACRONYMS

| | |
|---|---|
| AA | Appropriate Assessments |
| AARHUS Conv. | UNECE Convention on Access to Information, Public Participation in Decision-Making and Access to Justice in Environmental Matters |
| AICHI Targets | 20 biodiversity targets to help reach 6 main goals of the CBD |
| BERN Conv. | Conservation of European Wildlife and Natural Habitats (1979) |
| BONN Conv. | The Convention on the Conservation of Migratory Species of Wild Animals |
| BWD | Bathing Waters Directive |
| BWM | Ballast Water Management Convention |
| CBD | Convention on Biological Diversity |
| CITES | Convention on International Trade in Endangered Species of Wild Fauna **and** Flora |
| Conv. | Convention |
| COP | Conference of the Parties |
| COP9 | 9th meeting of the Conference of the Parties to the Convention on Biological Diversity 2008, adopted the scientific criteria for **identifying EBSAs** |
| COP15 | 15th UN Biodiversity Conference, Canada 2022 |
| COP26 | 26th UN Climate Change Conference of the Parties (COP26), Glasgow 2021; similarly COP27 for Egypt 2022 |
| COTES | Control of Trade in Endangered Species Regulations |
| EIA | Environmental Impact Assessment |
| EMS | European Marine Sites |
| EBSAs | **Ecologically or Biologically significant Marine Areas in need of protection in open-ocean waters and deep-sea habitats** |
| ESPOO | Convention on Environmental Impact Assessment in a Transboundary Context |
| FCS | Favourable Conservation Status |
| FRMD | Flood Risk Management Directive |
| GES | Good Environmental Status |
| HMWBs | Heavily Modified Water Bodies |
| HPMA | Highly Protected Marine Area |
| HRA | Habitat Regulations Assessments |
| HSD | Habitats and Species Directive |
| ICES | International Council for the Exploration of the Seas |
| IMO | International Maritime Organisation |
| Kyoto Protocol | Operationalises the United Nations Framework Convention on Climate Change |
| MARPOL | International Convention for the Prevention of Pollution by Ships |
| MCZs | Marine Conservation Zones |
| MSFD | Marine Strategy Framework Directive |
| MSP Dir | Maritime Spatial Planning Directive |
| Natura 2000 | A network of nature protection areas made up of SACs and SPAs |
| NSIPs | Nationally Strategic Infrastructure Projects |
| OECD | Convention on the Organisation for Economic Co-operation and Development – OECD Country |
| OECMs | Other Effective area-based Conservation Measures |
| OSPAR | The Convention for the Protection of the Marine Environment of the North East Atlantic |
| PSSA | Particularly Sensitive Sea Area – designated under IMO Resolution A.982(24) |
| RAMSAR Conv. | Intergovernmental treaty that provides the framework for the conservation and wise use of wetlands and their resources, Ramsar 1971 |
| RBMP | River Basin Management Plans |
| RFMOs | Regional Fisheries Management Organisations |
| Reg(s) | Regulations |
| SAC | Special Area of Conservation |

| | |
|---|---|
| SEA | Strategic Environmental Assessment |
| SPA | Special Protection Area |
| UN | United Nations |
| UNCLOS | United Nations Convention on the Law of the Sea |
| UN DER | United Nations Decade of Ecosystem Restoration 2021-2030 |
| UN DOS | United Nations Decade of Ocean Science for Sustainability 2021-2030 |
| UNECE | United Nations Economic Commission for Europe |
| UNEP | United Nations Environment Programme |
| UNGA | United Nations General Assembly |
| UN FAO | United Nations Food and Agriculture Organisation |
| UNFCCC | United Nations Framework Convention on Climate Change |
| UN SDG | United Nations Sustainable Development Goals |
| UWWTD | Urban Waste Water Treatment Directive |
| VME | Vulnerable Marine Ecosystems (UN FAO) |
| WBD | Wild Birds Directive |
| WFD | Water Framework Directive |
| WHS | World Heritage Site |

MARINE SABRES

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## Marine SABRES Deliverable 3.2 Briefing Paper 12

# Equity, Diversity and Inclusion Briefing Paper

Authors: Josefin Ekstedt, Maila Paisano Guilhon e Sá, Bruno Meirelles de Oliveira, Catherine Chambers, Furqan Asif

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# 1. Introduction and theoretical overview

Concepts of justice, equality, equity, diversity, and inclusion in marine governance are increasingly in focus in academic and practitioner circles. EDI (equality/equity; diversity; inclusion) is a common phrase used to highlight the importance of considering these aspects in marine governance and marine science, but the definitions and implementation plans are often unclear. The objective of the Equity, Diversity, and Inclusion Briefing Paper (EDI-BP) is to provide Marine SABRES consortium researchers and stakeholders from the Demonstration Areas (DAs) with an overview of the main principles associated with EDI in the context of marine management.

Acknowledging and addressing EDI is a fundamental step in achieving sustainability goals and objectives. In the 3”e” model of sustainability, “equity” is a fundamental pillar of truly sustainable social-ecological systems and sustainable development. In fact, some authors argue that social equity should be at the core of all ocean governance policies and practices as this may lead to more effective and long-term outcomes (Bennett et al. 2021).

Issues of EDI in the ocean context have been tackled by several contributions (Bennett et al., 2021; Bennet 2022; Crosman et al., 2022; Johri et al., 2021). For example, EDI is important in maritime spatial planning (Gurney et al 2021; Saunders et al 2020), in decision-making in general (Bennett 2022; Österblom et al 2020), in Indigenous Environmental Justice (Parsons et al 2021), and in how marine science is produced (Johri et al 2021).

Important ways to ensure EDI is practiced as part or organisations, policies and practices include: developing awareness of past EDI issues in the marine policy sphere where an organisation works; exploring different avenues for the operationalisation of EDI in ocean policy and practice; mainstreaming EDI in organisational policies, practices, programs and portfolios; and organisations taking actions internally to ensure diverse representation, genuine inclusion, and equitable treatment (Bennet, 2022). Issues of justice and equity have been identified in academic literature covering various dimensions of ocean related topics, these have been categorised and defined by Bennett (2022) and can be seen in Figure .


*Figure 1: Ocean equity (Bennet, 2022)*

For diversity, measures include having diversity as part of organisation's staff and in leadership roles, including members of the community affected by the decisions of such organisations (Bennett et al., 2022). Inclusivity will ensure that individuals feel welcomed and well during workshops and other activities. Actions toward inclusivity include conducting bias and anti-discriminatory training, ensuring that effective harassment policies and responses are in place, and embracing diverse identities and opinions.

## 2. Equity, Diversity, and Inclusion (EDI) Principles

**Equity**

The 'E' in EDI has often been interpreted as equality. Equality means providing the same opportunities to all people. The classic examples are related to gender, ethnicity, income level to name a few, but in the marine context this can also mean different stakeholders. As discussed by Legg et al. (2023) it would be more appropriate to consider the word equity, meaning fairness between groups (gender in the original) - while recognizing that some groups start from places of disadvantage, with imbalances that must be addressed. In addition, it is necessary to recognize gender as an inclusive construct that embraces all non-binary and Indigenous identities and roles, and its intersectionality with other marginalized groups, usually those identified by race, ethnicity, economic class, and nationality (Legg et al., 2023).

In the marine context, a concept that has gained popularity is "blue justice" (tracing its origins to the 2018 during the 3rd World Small-Scale Fisheries Congress) (Blythe et al, 2023). The focus on a "blue" justice was in reaction to increasing support of a "blue" economy. Specifically, the anticipated and real uneven distribution of social and environmental costs and benefits of blue economy initiatives (Bennett et al. 2021).

**Diversity**
Diversity acknowledges the presence of various perspectives, experiences, and backgrounds within the stakeholder community. It recognizes that these differences enrich discussions and offer a broader pool of potential solutions.

**Inclusion**
Inclusion refers to creating an environment where all voices are heard, valued, and actively engaged in the decision-making process. It is about being open-minded and inviting and respecting different viewpoints. This principle also encompasses the notion of the different ways of knowing and understanding the natural world, i.e. considering traditional ecological knowledge (TEK), e.g. indigenous knowledge.

## 3. Justice as an overarching theoretical background

Justice has been academically studied for a long time. A useful understanding of the main concepts around justice theory comes from the works of John Rawls (1971). To the author distribution is an important dimension of justice, responsible for the attribution of rights, duties, benefits, and burdens among people. Schlossberg (2007) diversifies this idea, moving beyond distribution in at least three other aspects: recognition, participation (or procedure), and capability.

From the distributional aspect of justice, other questions emerged, such as those related not only to how the resources were distributed among the beneficiaries, but why they were distributed among that group of beneficiaries. For Young (1990), the main cause that determines distributional injustices comes from the lack of recognition of social differences among groups, or individuals, and consequent practices of oppression and domination. Recognition, therefore, comes to admit that people have different identities and histories; and that policies and institutions should not only divide the benefits in fair shares but among the full diversity of groups of that society, towards which historical asymmetries must be acknowledged and compensated (Young, 1990).

People and groups, once recognized, must have the right to have their voices and necessities heard in decision-making arenas. Participation (or procedure) therefore is about the roles that different social groups take during the decision-making process (Schlosberg, 2007), that govern the distribution benefits and duties. Participation is relevant because representatives channel the influence that those being represented. For example, women activists from all over the world claim that legislatures formed by a majority of men cannot properly represent women (Young, 2000).

Capabilities come from a different school of justice. Capabilities mean the freedom to live different types of life (Sen, 1993). It represents the real opportunities for one person to do and to be in the context of a determined society. Capabilities represent something fundamental to each human being: “core human entitlements that should be respected and implemented by the governments of all nations, as a bare minimum of what respect for human dignity requires” (Nussbaum, 2007).

Building on the theoretical underpinnings of justice, recent scholarship has emerged specifically using the concept of blue justice, which directly links marine systems to theories of justice (Figure ). As a specific reaction to ideas of blue growth or blue economy, concepts of blue justice focus on under-represented voices in blue growth activities such as small-scale fisheries, aquaculture, coastal development, and even blue carbon markets and oil and gas development (Bennett et al 2021; Blythe et al 2023).


*Figure 2 Ten key considerations to advance blue justice in blue growth initiatives (Bennett et al, 2021)*

## 4. Focus on gender

Gender is a socially and culturally defined role and behavior of girls, boys, men, women, and minorities. Different from sex, which is biologically and physiologically defined as male, female, and intersex, gender is a social construct, a non-binary cultural differentiation role between people (Legg et al., 2023). Historical socially-driven processes created and perpetuated differences in the way people of different genders access many aspects of social life. These differences reveal negative patterns in access to education, payment and pensions, employment, power, and the victimization of violence, driven by gender-related differences. In Europe, the gap between genders in the possibilities of realization of a plentiful life persists (EC, 2020), and the development of policies and practices to address this inequality problem is crucial.

The EU Commission's communication on gender and equality (EC, 2020) brings an overall progressive statement regarding the gender gap in Europe and is apparently permeated by a perspective of capabilities while referring to gender justice. The dual approach of this strategy, meaning not only calling attention to the topic but also proposing targets to be reached, is remarkable. Considering intersectionality as a crosscutting issue in all policies increases the credibility and the reach of the strategy. But, although the communication is permeated by statements such as "Gender equality is considered nowadays, a core value of the EU, a fundamental right, and a key principle of the European Pillar of Social Rights" (EC, 2020) which might serve as a reference for gender-related policies and programs, some issues remain untouched. These include a vague and binary understanding of gender, the apparent disregard for the necessity to reverse historical inequalities (represented by the use of the word equality in the text instead of equity), and a disproportionate focus on the economic values of gender equality, rather than intrinsic ethical obligations

The gender dimension in Marine SABRES is consistent with the European Gender Equality Strategy 2020-2025 (EC, 2020), which includes objectives to: end gender-based violence; challenge gender stereotypes; close gender gaps in the labour market; achieve equal participation across different sectors of the economy; address the gender pay and pensions gaps; close the gender care gap and achieve gender balance in decision-making and politics. More specifically, gender is a cross-cutting issue in Marine SABRES and is expected to be reflected in the collection of baseline data, development of pathways for transformation, scenarios, behavioural change, and governance and as an aspect for responsible research and innovation.

# 5.Implementation: EDI in Marine SABRES

As reviewed above, EDI is an important area of study in marine governance and also in terms of how marine science is produced. Overall, the dimensions of EDI are important when working with coastal communities and questions relating to the oceans. These dimensions can form the backbone of the Marine SABRES project and its activities within the demonstration areas (DA). As the DAs differ in several aspects both generally and within the project's objectives, the ocean equity dimensions might apply to DAs more or less.

Two of the DAs, Tuscany and Macaronesia, work in a local context with tourism and conservation, subjects that are highly related to the dimensions of recognitional, procedural and environmental equity. The Arctic Northeast Atlantic DA might have a closer relation to contextual, distributional and management equity as it looks at commercial fishing within the region, the impact of climate change and how there needs to be a change in human behaviour. However, as previously stated, all dimensions of ocean equity can be tied to each DA and should be considered during the projects work. Asking the following questions (based on Crossman et al 2022) when planning Marine SABRES activities can ensure that EDI aspects are embedded in the project:

- Where – in what places and contexts is EDI being examined and addressed?
  - What is the history behind the issue you are focusing on? How has it evolved through time?
  - Who were/are the leading players?
  - Were/are there existent conflicts within or between groups which affect the issue in question?
- Why is EDI being examined or considered in this work?
  - Why is it essential to consider EDI aspects in the DA? How does EDI relate to the issue of focus for your DA?
- EDI for or amongst whom?
  - Who are/should be the subjects of EDI?
  - Which voices are currently not taking part in the issue of focus in the DA?
- What is being distributed?
  - What are the benefits of the issue of focus?
  - Who are the primary beneficiaries of the current context? And who should be included as beneficiaries of such?
  - Who has a say on how benefits are distributed?
- When – in what stage – in governance or research processes is EDI being forwarded or considered?
  - In what step of the process have/will EDI aspects be acknowledged and addressed?
- How do (or might) governance structures mediate, create, or undermine EDI?
  - Do governance institutions/regulations address EDI issues? How?
  - Do they favour any specific groups? Which ones? How?
  - Are the processes transparent and inclusive? Is the communication with stakeholders and the broader community transparent and inclusive?

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# Stakeholders and Stakeholder Communication

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# 1. Stakeholder Identification and Boundary Critique

Much stakeholder theory has its roots in the need to adopt a strategic approach to 'managing' stakeholders in the interests of improving the functioning of systems and performance (see for example, Freeman, 1994). However, it has also been suggested that there is a moral principle associated with stakeholder engagement. Those who will be affected by decision making, but are not (initially) involved in it, ought to have a meaningful input into what is decided, not only because they have relevant knowledge, but also because it is empowering and combats alienation when people have a reasonable amount of collective control of what happens in their own lives and communities (Ulrich, 1983). Ulrich's work is informed by both systems theory about the boundaries of who counts as a stakeholder (building on Churchman, 1970, 1979) and a critical social theory of why the involvement of citizens in deliberative democracy is important (Habermas, 1976). The democratic rationale for stakeholder engagement has been influential in the social sciences (e.g., Cohen & Arato, 1992), and the need for such an approach in marine governance is being increasingly recognised.

In a very general way, we can define various different types of stakeholders in the marine environment. Firstly, there are those creating the marine pressures (the 'inputters' and the 'extractors' – respectively those who put waste, structures, land-claim, etc., into the sea, and those who remove resources such as space, fish and shellfish, seabed and water, from the sea). Next, the 'regulators' include those who have a duty to control these potentially-damaging activities. The 'affectees' are the parts of society affected by these activities and regulations, either positively or negatively, and the 'beneficiaries' are those who benefit from the uses and users of the seas. Finally, the 'influencers' are the policy makers, politicians, educators, researchers and lobbying groups (e.g. environmentalists, conservationists) who attempt to control the behaviours of the other stakeholders (Newton & Elliott, 2016). It is of note that some bodies, such as a port authority or fishing cooperative, can be included in all of these types of stakeholder.

In the latter decades of the twentieth century, ocean and coastal area planning and policies were formed mainly in governmental arena (Burroughs, 2011). As such, their formation and implementation reflected a traditional top down approach to power, legitimacy, and authority among the diverse levels and institutions involved (Nobre et al., 2017). Consequently, the need for a more dynamic approach that took into account different stakeholder priorities and looked to balance social and ecological needs was proposed by Costanza et al. (1998) and Burroughs (2011). Sytnik et al. (2019, p.289) suggest such an approach is based on four key principles:

1. stakeholders should be involved in formulating and implementing policies, and those policies should be ecologically sustainable and socially equitable;
2. institutional scales for decision-making should match ecological inputs;
3. potentially damaging activities should be approached with caution, and there should be ample opportunity to adapt and improve policies;
4. sustainable governance of the ocean rests on full allocation of social and ecological costs and benefits.

Whilst the statement of these principles is a step in the right direction, Sytnik et al. (2019) recognise that their realisation in practice is not without issue:

1. How can challenges related to existing discrepancies/conflicts among stakeholders involved in ocean governance processes be addressed, and how can a common vision be built?
2. How can a constructive, inclusive, and proactive dialogue among policymakers, scientists, and communities for well-informed decision-making be ensured?

Hummel et al. (2017) provide an example of the first issue in recognizing differences between scientists and the managers of Protected Areas identification and scoring of the perceived importance of environmental and socio-economic variables and go on to conclude that 'differentiation between scientists and practitioners about their perceptions of important variables can thus be rather common' (p. 6).

The importance of addressing issues in stakeholder engagement processes was highlighted by Hummel et al. (2022) who found that the causes of 'bad management' of Protected Areas included, amongst other issues, the 'disproportional influence of divergent stakeholders' (p. 11). Clearly there is an evident need for an approach to not only identifying but also managing stakeholder engagement and, for this, we look to systems theory.

In considering any system, it is impossible to comprehend the whole relevant system, hence we are compelled to make boundary decisions. By boundary decisions we mean defining what or who is relevant and included as inside the boundary and relegating that or those considered irrelevant and excluded to the environment. Obviously, this is an important practical issue as the wider the boundaries then the more time and cost is entailed in the analysis but the greater the benefit, particularly in terms of the knowledge base, hence there is a need to balance the costs and benefits in a defensible and transparent way. Such accountability is important because who is involved (defined as being within the boundary for inclusion) gets a voice and to influence decision making and the values served.

An almost inevitable implication of being aware of boundaries is the need to adopt a multi-stakeholder perspective. Clearly here we are being critical about who the client for any project or intervention is, going beyond any singular commissioning group, and also not relying on generic stakeholder lists or profiles but rather asking difficult questions about who the stakeholders really are in the specific situation or context. Hence, we are not merely seeking to perpetuate existing relations in terms of who is involved but to ask the more critical question of who ought to be involved with due consideration to equality, diversity and inclusion (EDI). Our approach to stakeholder engagement is critical and based on a set of principles (see Table 1) that require reflection and discussion of what constitutes both justifiable and pragmatic boundaries of engagement. To be clear, boundary critique does not suggest that everyone must be involved but rather that where stakeholders are excluded this is recognised, discussed and justified on a credible basis.

In multi-stakeholder settings, conflicts of interest are addressed, ideally, through procedures considered fair by all, while recognising that there may be no quick solution to the focal issue. Various approaches in the systems discipline can help not only identify different stakeholder perspectives but also to help bring about an accommodation that provides the basis for a way forwards. See for example Soft Systems Methodology based on the work of Checkland (1981).

*Table 12: Stakeholder principles and implications (Gregory et al., 2020 based on Pouloudi et al., 2016).*

| Stakeholder principles recognise that: |
|---|
| 1. The set and number of stakeholders are context and time-dependent |
| 2. Stakeholders may have multiple roles |
| 3. Different stakeholders, even within the same group, may have different values and perspectives, which may be explicit, implicit or hidden |
| 4. Stakeholder roles, perspectives and alliances may change over time |
| 5. Stakeholders' relations and power matter in the shifts in their roles, perceptions and alliances |

| | |
|---|---|
| 6. | The definition of stakeholder groups for inclusion also represents boundaries of exclusion and marginalisation |
| 7. | Causes and issues from which stakeholders derive a sense of identity from may affect trust, co-operation and value creation in an issue-based stakeholder network |
| 8. | Researchers and funders are stakeholders too, and they may be surrounded by other stakeholder groups with associated interests |

## 2. Communication and Stakeholder Management

Taking stakeholders seriously implies more than merely giving attention to how stakeholders are identified; it also means giving appropriate consideration to what information is disseminated, to whom and in what form, and about recognising political/power alliances and identity impact on the construction of understandings of the context, focal issues and stakeholder interactions.

When considering stakeholders, it important to recognise that different stakeholder groups may have different communication traditions and preferences. The general public, policy-makers and politicians may want very brief information (sound-bites, headlines, tweets and one-page briefing notes). In contrast, specialists may create a large amount of (often unsuitable) material (theses, reviews, scientific papers, consultant reports) which then needs 'interpreting' and usually summarising for the public and politicians (the so-called 'dissemination diamond', Elliott et al., 2017). It is frequently argued that different disciplines and different sectors are 'not talking the same language' (Ostrom, 2009), so a stakeholder-based communication strategy is necessary to enable understanding between stakeholders and support, if relevant, conflict resolution. Stakeholders should be included in as many aspects of the creation of the communication strategy as possible, with justification being explicit for where they are not. There should also be feedback loops to ensure that they can receive information, act on it and have an influence, as, in theory, should be the case in all Environmental Impact Assessments (Glasson & Therivel, 2019).

Ackerman and Eden (2011) suggest the need for stakeholder management strategies that specify "*when* and *how* it is appropriate to intervene to alter or develop the basis of an individual stakeholder's significance" (p.180). For this purpose, Ackermann and Eden (2011) suggest the use of a power/interest grid (see Figure 1). The four quadrants of the grid can be seen as defining four categories of stakeholder. Stakeholders in the upper two categories are those with most stake (i.e., most 'interest') in the issue but with varying degrees of power: those to the right-hand side enjoy more power, i.e. they have 'influence', but may or may not actually be concerned about the issue. 'Players' are those interested stakeholders who also have a high degree of power to support (or to sabotage) the outcome, whereas 'Subjects', while interested, have less influence. The two lower categories can perhaps be seen more as 'potential' stakeholders, who have not (yet) displayed much interest in the issue. 'Context setters' may have a high degree of power over the future of the issue particularly in terms of influencing the future context within which responses (plans, policies, etc) will need to operate. The last quadrant, the 'Crowd', (currently) exhibit neither interest in or power to influence the issue of concern.

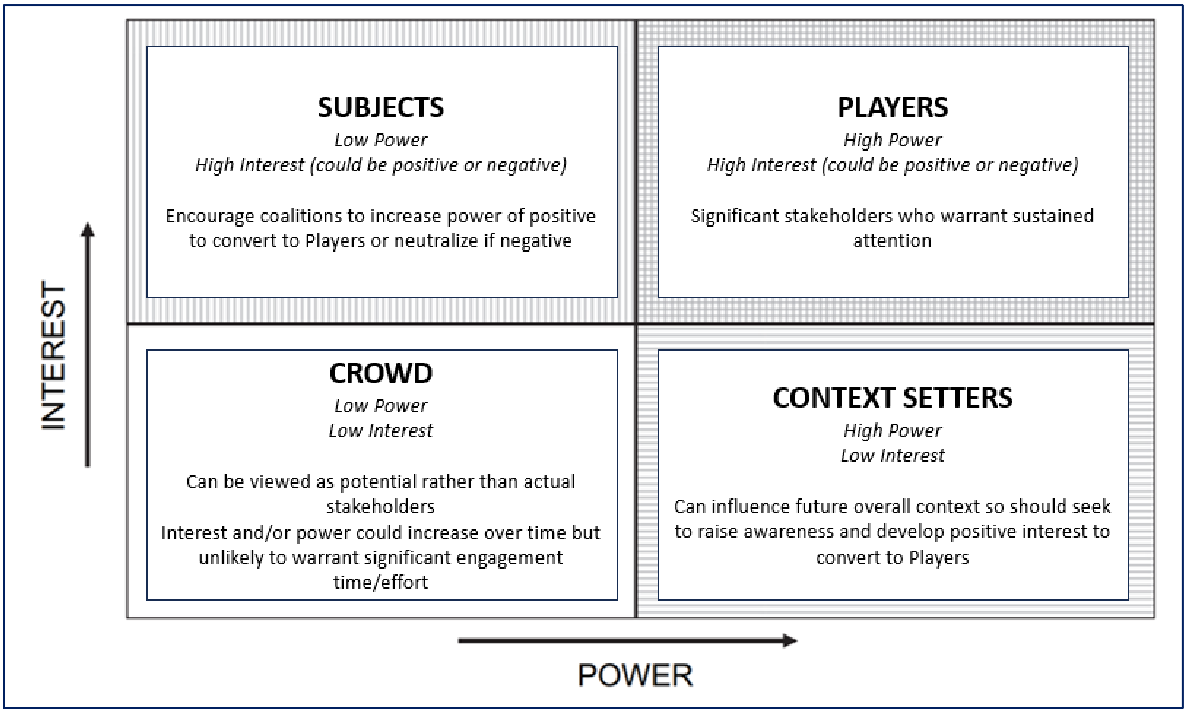

*Figure 1: Stakeholder Power-Interest Grid (based on Ackermann and Eden, 2011)*

When stakeholders respond to a particular action they may do so with reference to other stakeholders and how they might respond. Exploring the impact of stakeholder relationships stems from the extensive literature on social networks. One stakeholder's actions can generate a dynamic of responses across a range of other stakeholders. Indeed, Fliaster and Kolloch (2017, p.698) suggest that "stakeholders are likely to orchestrate their activities and thus develop a much stronger bargaining power. Furthermore, some stakeholders do actively search for coalition partners that can help promote their particular agenda and exert additional impact". In the same way a stakeholder's power can often be described in relation to their position in the network of other stakeholders. This interactional aspect of stakeholder analysis can be depicted as a 'Stakeholder Influence Network Diagram' which aims to surface both the formal and informal relationships that are the bases of such social networks (a software package such as Kumu can be used for social network analysis). Taking stakeholder disposition (positive or negative) into account reveals potential opportunities and dangers. A centrally-located stakeholder, with many links both in and out, who is perceived as being negatively disposed towards the intervention can have a significant detrimental impact (via their influence over others), so it is critical that they are successfully managed. In this case, the obvious options are to attempt to change their negative disposition and/or to reduce their power. However, it is recognised that care needs to be taken to ensure that any attempt to change power relationships is appropriately reflected with due consideration for ethics and to avoid accusations regarding the manipulation of stakeholders and related interests

It is clear from the above that stakeholder identification, engagement, communication and management are complicated and often complex tasks that need to be approached in a considered and planned way.

## 3. Summary

This briefing paper outlines an approach to stakeholder identification, engagement and communication, which respects the complexity and fluidity of stakeholder identities and relationships within marine governance. In summary, for best practice, we recommend to:

- Recognise that stakeholders are diverse and may assume various roles across different contexts, impacting their relevance to the marine environment.
- Define the boundaries of the SES and focal issue clearly from the outset. This serves to ensure a transparent and justifiable process for stakeholder inclusion, thus minimising the risk of marginalising less powerful groups and ensuring the scope of the approach is manageable.
- Adopt a multi-stakeholder perspective that is informed by principles of equality, diversity, and inclusion, enabling a broad range of inputs and fostering collective learning, ownership and control.
- Develop a communication strategy that acknowledges and reflects the diverse traditions and preferences of different stakeholder groups, from concise formats for policymakers to detailed reports for specialists. Such an approach should be mindful of the fundamentals of the information obtained from questioning the various stakeholders. To ensure this information can be harmonised and remains comparable in order to allow for valid (scientific) analyses.
- Strategically manage stakeholders, if necessary to ensure a meaningful process and outcomes, by assessing their power and interest through tools such as a power/interest grid.

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