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RESPONSEABLE

Overview of Human-Ocean relationship and evaluation of key stories

Deliverable 1.1

Preliminary report presenting the framework for critical review of existing knowledge

WP1

March 1016

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1 Overview of Human-Ocean Relationship

In the past, the sea was for many inhabitants a remote place used mainly as a source of food and as a means of travel. The last centuries, however, have recorded a dramatic increase in the use of seas and oceans. The sea is now also a place where we explore for oil and gas, locate wind farms, develop aquaculture, relax during the summer or that support the transport of most of the goods consumed and produced in other continents. And more is to come as emerging maritime sectors present also important potential future benefits for human activities, as illustrated in the EU strategy for Blue Growth.

Consequently, the pressures on the sea have increased, which makes it more pressing to protect the seas from the consequences of human use. It is more important than ever that people know and care. However pressures exerted on the ocean have kept growing in parallel, these affecting the ocean health, the functioning of marine ecosystems and the ecosystem goods and services that these deliver or could deliver. The challenges faced by marine ecosystems of the different European seas, for example, are highlighted in the initial assessments carried out by European Union (EU) Member States (MS) in the context of the implementation of the Marine Strategy Framework Directive (MSFD) adopted in 2008. The need to better understanding oceans and the human-ocean relationships, be it for societal stakeholders of the ocean system and for citizens as a whole, is urging – if pressures on the marine ecosystems are to be reduced and the development opportunities offered by the ocean duly seized.

While the functioning of the oceans and the human-ocean relationship remain poorly understood, knowledge still has been improving over the last decades. At the same time, initiatives have been developed to gather all available knowledge on the oceans and improve the use of available knowledge. At the European level, for example, this takes place through or in parallel to the MSFD implementation. The focus of ResponSEAble is the understanding of the relationship between the ocean health and human activities, and how changes in behaviour can reduce pressures and ensure development opportunities offered by the ocean are seized. It focuses on the changes of behaviour of citizens (as consumers, users of ecosystem services, of different age/social groups), but also of all actors of the market economy/value chain.

The ocean offers for today's and future sustainable development – a key element of Blue Growth. In addition to addressing the human-ocean relationship in all its dimension, it provides the basis for a wider and positive message on everybody's role and responsibilities.

"The goal of WP1 is to produce a synthesis of the existing knowledge on the relationship between people and the oceans, building on the combination of the DPSIR and Ecosystem Goods and Services framework that help capturing both the pressures imposed by human activities on ocean ecosystems and the services and opportunities offered by the ocean to humans."

2 Existing knowledge

There is a vast amount of knowledge around human activities and the ocean. To sort through it and categorize it all would be impossible. It was crucial that this project develop a method for narrowing down the types of activities needed to focus on, as well as the types of information that could best be used to help support literacy on these topics. By examining the focus of the recent Marine Strategy Framework Directive as well as the EU Blue Growth Strategies, it was possible to determine, at a high level, key topics (or stories) that would be important to the citizens of the EU.

Once those topics were identified, a method of categorizing the data surrounding those topics needs to determined. The DPSIR framework was created by the European Environment Agency to help describe the relationship between the origin (driver) of an environmental issue and the related consequences. In doing so, the DPSIR creates causal network maps which is essential in understand the relationship among DPSIR categories.

While the DPSIR methodology is widely used, there are also criticisms including that may lead to the missing of connections between each category and that it is unable to identify future environmental impacts, rather focusing on past results.

Despite these criticisms, the DSPIR framework is still a valuable methodology to help highlight points along the value chain that could benefit from additional literacy to help reduce the impact. One of the added benefits to using DPSIR is that it helps highlight there were are gaps in the existing knowledge, which may be critical for understanding how and why increased literacy on a particular topic might result in behaviour change. The DSPIR model also provides a robust framework for critical review of existing knowledge on both the ecological status as well as human activities.

3 Adaptation of the DPSIR Framework

The DPSIR framework (Drivers-Pressures-State-Impact-Response framework) allows for developing a system-based approach expressing key relationships between society and the environment1. The dynamics of the relationships between all elements of the system are also integrated in this framework.

[1] Atkins *et a*l., 2011. Management of the marine environment: integrating ecosystem services and societal benefits with the DPSIR framework in a systems approach. Marine Pollution Bulletin 62 215-226.

Despite the many "DPSIR" existing frameworks (Smith et al. 2014), for the purpose of this project, the DAPSI(W)R approach (after Elliott 2014) has been selected and adapted to this project (ResponSEAble). The DAPSI(W)R approach considers that Drivers, which are the main social, demographic, economic and cultural developments in society (e.g. population growth), that lead to changes in life styles, overall levels of consumption and production patterns, require a set of Activities (e.g. extraction of living resources – fishing) to respond to these changes´ needs. The Activities may cause multiple pressures (e.g. trawling), which may lead to State changes (e.g. substrate abrasion) in the natural system. State changes may result on Impacts (on the environment (e.g. benthic community changes) and ultimately, on human Welfare (e.g. food provision changes), that will need addressing through Responses (e.g. involving economic, technological, legal etc. approaches) (e.g. trawling limitations or prohibited). Responses can tackle either part of the DAPSI(W)R approach, from modifying Drivers to technological developments focused to e.g. minimizing impacts (modified from Elliott 2014 with inputs from Patricio et al. 2014, DG Environment 2014, and ResponSEAble project). It needs to be highlighted that not all pressures lead to either environmental or welfare impacts. Furthermore, environmental impacts do not necessarily lead to welfare impacts or changes in the provision of ecosystem services.

Having the DAPSI(W)R approach as the basis for this project, the following ResponSEAble framework has been developed (Figure 1). This framework highlights the points below:

- Differences between global and specific drivers,
- Behind activities there are actors that carry out the different activities, and causal loops and value chains that can explain the way activities are carried out.
- State change can (but may not) lead to environmental impacts and consequently, impacts on ecosystem services. However, these are separated in the diagram, since not all impacts on the environment may have relevant impacts on ecosystem services.
- Responses can be directed to any part of the DAPSI(W)R approach.

Within this framework, the coverage of the different WPs have been defined to understand the overlaps between them for better coordination of the work.

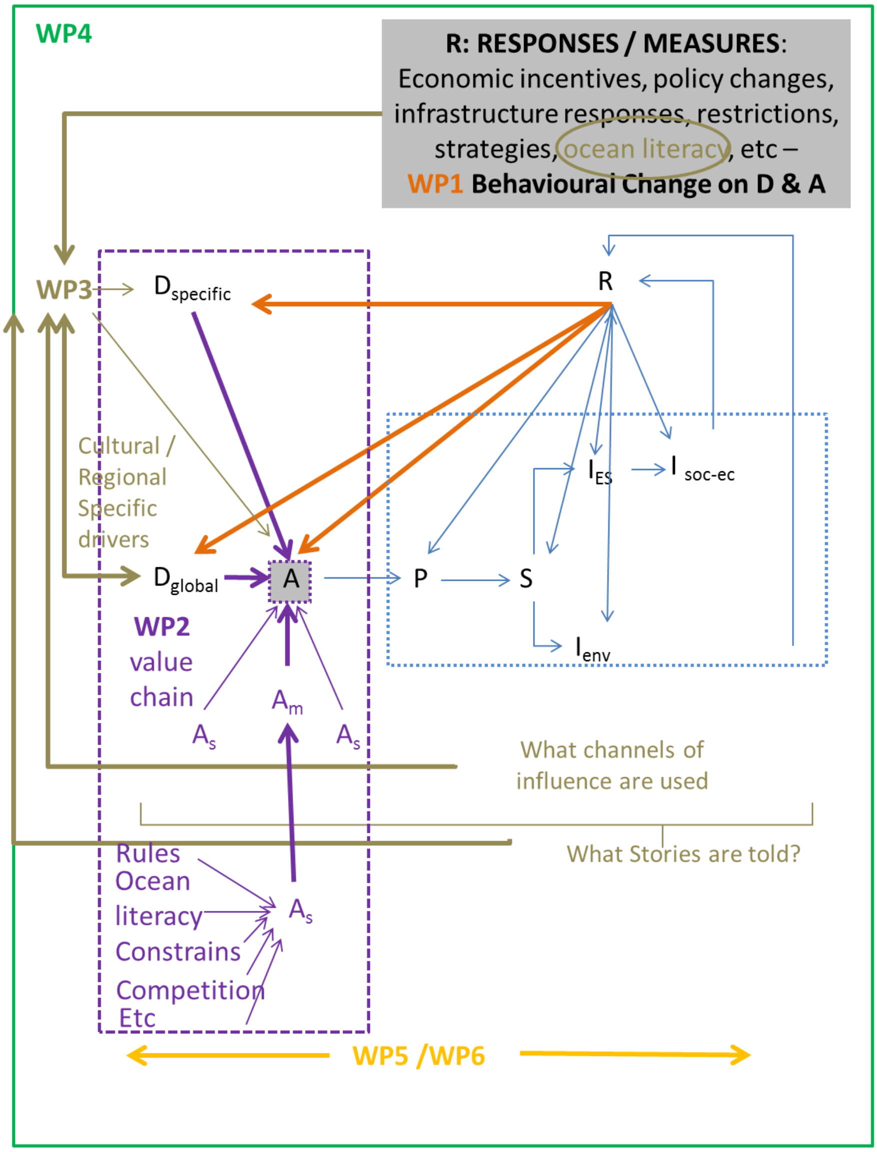


Figure 1. ResponSEAble framework based on an adaptation of the DAPSI(W)R approach, including the areas covered by the different WPs of ResponSEAble.

In order to have a common understanding of the framework as defined in ResponSEAble, the different concepts that are part of the DAPSI(W)R have been defined, taking into account existing definitions under different EU funded projects (i.e. DEVOTES, MARS, ODDEM), EU published documents (e.g. DG Environment, 2014), and relevant publications (e.g. Elliott 2015) For some of this concepts a series of examples have been provided (see Annex 1).

Drivers

Drivers are the social, demographic, economic and cultural developments in societies and the corresponding changes in life styles, overall levels of consumption and production patterns (DG Environment 2014).

Activity

A specific anthropogenic action or pursuit aimed at fulfilling the societal drivers (e.g. the need for food, space, transport) which ultimately have the potential to create the pressures leading to changes in both the natural state and human welfare (Patricio et al. 2014). Specific activities can be assigned to economic sectors. For a detailed list of sectors and related activities, refer to the following tables (see Annex 1).

Pressure

Pressure is considered as the mechanism through which an activity has an actual or potential effect on any part of the ecosystem (e.g. for demersal trawling activity "trawling", fish removal, could be pressures) (adapted from Borja et al. (2006), Robinson et al.(2008) and Atkins et al. (2011)).

State

The state can be defined as the level of health of marine ecosystems (or natural environment). As a result of pressures, the 'state' of the environment is affected; that is, the quality of the various environmental compartments (i.e. water, soil, etc.) in relation to the functions that these compartments fulfil. The 'state of the environment' is thus the combination of physical, chemical and biological conditions (DG Environment, 2014).

State change

State change refers to changes in the 'State' or 'Health' of the natural environment (marine ecosystems in this case), as a result of pressures, which cause state changes to ecological characteristics (e.g. abrasion may cause a decrease in macrofaunal diversity) (Smith et al. 2014).

Impact

The impact can be defined as the adverse consequences of the pressures caused by human activities and natural phenomena; the state change that occurs is different to that expected under natural condition. Often, they require to be detected by monitoring over and above natural and inherent variability (summarized as a 'signal' of an activity over the environmental 'noise'). The degree of state changes may determine whether the pressures lead to 'impacts' on the functioning of ecosystems, their life-supporting abilities (i.e. environmental impacts), and ultimately on human health and on the economic and social performance of society (i.e. human welfare) (adaptation and combination of DG Environment, 2014, Patricio et al. 2014 and Barnard et al. 2015). Despite the strict DPSIR only consider as impacts those that directly reflect changes in the environment (Gabrielsen & Bosch 2003), for the purpose of ResponSEAble, we consider both, environmental and human related impacts.

Response

Response is the societal reactions and measures implemented to stop drivers, activities and pressures having an effect on state and causing impacts on the ecosystem and on human welfare; They can be "legal", "economic", "social and behavioral", "technological" and "cognitive". These measures can be directed at any other part of the system (e.g. reduction in the number of bottom trawler licenses, the change to a less abrasive gear, or creation of no-fishing areas) (modified from Smith et al. 2014).

The response corresponds to actions, management measures, policies undertaken to prevent, compensate, ameliorate or adapt negative impacts of pressures caused by human activities and natural phenomena on the state of the ecosystems (e.g. economic incentives, information, ocean literacy, etc.). A 'response' can target either the start of the chain (at-source measures) or the end (end-of-pipe solutions) or at intermediate points of the DAPSI(W)R approach (e.g. reduction in the number of bottom trawler licenses, the change to a less abrasive gear, or creation of no-fishing areas) (adapted from DG Environment (2014) and Smith et al. (2014)).

Ecosystem services

Ecosystem services can be defined as the direct or indirect contributions from ecosystems to human wellbeing2 at present or in the future. Understanding the link between ecosystems and ecosystem service capacity may allow for better understanding of the functioning of ecosystem and therefore, potentially taking into account opportunities related to a healthy environment. The concept of "ecosystem goods and services" is synonymous with ecosystem services.

Human well-being

A context- and situation dependent state, comprising basic material for a good life, freedom, and choice, health and bodily well-being, good social relations, security, peace of mind, and spiritual experience (Millennium Ecosystem Assessment, 2005).

Measures (management measures)

Management measures are the actions that, if applied completely, they should ensure the prevention of, or provide adequate compensation or mitigation for, the state changes and impacts of the development or activity; they should cut across the following 10 tenets (Barnard and Elliott 2015):

- Ecologically sustainable
- Technologically feasible
- Economically viable
- Socially desirable / tolerable
- Ethically defensible (morally correct)
- Legally permissible
- Administratively achievable

[2] TEEB, 2010.

- Effectively communicable
- Politically expedient

4 Identification of Key Stories

Vast information exist on these different categories of DAPSI(W)R and collecting, classifying, organizing this knowledge on all marine issues is beyond the length and resources of the project. Thus, it was decided to focus on only selected key marine issues (key storylines).

In order to select which storylines to focus on the 11 MSFD Descriptors were reviewed and key stories were extracted from there. Overall, 40 key stories from 10 Descriptors (none were chose from Descriptor 9 – Contaminants in fish and other seafood). From there, the ResponSEAble consortium was asked to evaluate the potential key stories against 6 questions:

1. Can a "change in behaviour" by one (or more) stakeholder groups influence the issue raised in this key story? Rank 1 (yes), 2 (no). Comment (who and what)?
2. Is this a relatively old or new issue raised in this key story? If it is an established story, how can ResponSEAble add to the information around this. Rank 1 (new) - 3 (older) and comments as to what ResponSEAble can add to the story
3. Under which regional seas conventions has this issue also been identified as a priority? (Name of convention and comment)
4. Is this issue relatable by WP2? Rank 1 (yes) or 2 (no)
5. Is this issue relatable by WP3? Rank 1 (yes) or 2 (no)
6. Is there potential for innovation (media, arts, communication) in how the issue identified in the key story is presented that may affect behaviour change in the stakeholders involved. Rank 1 (least) - 5 (most).

The responses were tallied and the top 12 ranking stories were then evaluated further against the Regional Seas Programme Action Plans.
The Regional Seas Action Plans corresponding to the four regions of the ResponSEAble project (Black Sea, Baltic Sea, Mediterranean Sea, North-East Atlantic) were reviewed and evaluated as to if they referenced in specific environmental issues. The remaining12 stories were then evaluated as to how many Regional Seas Programme Action Plans contained their topic. The top 6 key stories (those that were referenced within 3 or 4 Action Plans) were evaluated further.

As a result of the evaluation, the key stories that have been chosen are listed below. They are currently being expanded to be more for specific each relevant region. These stories may be reduced further depending on the results from WP2 and WP3.

Key Storylines:

The fate of micro-plastics – from plastic pellets producers to the sea

Marine litter has become a global challenge due both the volume of litter as well due to the huge impacts it can have both on the environment and human well-being. A subset of marine litter that has been receiving growing attention is microplastics. Microplastics enter the marine environment directly (e.g. pre-production pellets and/or granules used as abrasives in cleaning products, cosmetics or toothpastes) or indirectly (fragmentation of larger plastic litter) which are described as secondary microplastics. This story will focus on all regions.

From food and water consumption to eutrophication

Eutrophication is an expanding problem globally as it can cause alter the biogeochemical cycling of nutrients and changing the benthic community, pushing benthic habitats in a hypoxic regime. There is a need to better understand and quantify the causes of eutrophication and to better understand them and how it relates to conserving marine biodiversity. This story will primarily focus on the Black and Baltic Sea regions.

Sustainable and "clean" fishing/fisheries

Heavy fishing pressures, such as overexploitation or overfishing, can have negative environmental impacts, resulting in the loss of significant potential yield of the stocks being fished and can even precede severe stock depletion and fisheries collapse. Because of overfishing, fish stocks can reduce dramatically to the point where they lose internal diversity and with it, their capacity to adapt to environmental changes. This story will focus on the Atlantic region. As well, fisheries will also incorporate the impacts of ghost nets on fish abundance within the North Sea and Black Sea.

From coastal development and engineering to morphological change of the sea

Development in the coastal areas is common feature throughout the world's oceans. From docks and piers that need to be built to accommodate shipping needs to the mining of gravel as substrate, these physical changes all have an impact on the species that inhabit the local region. These impacts result in lethal or sub-lethal effects and may result in the reduction in diversity (of genes, species, communities and habitats) or they may manifest as a general decline in species, or an increase in opportunistic taxa at the expense of others. There may also be temporary or permanent relocation of mobile species. Within each region, we will select one among coastal engineering, harbor development, material extraction depending on which is most relevant for that region.

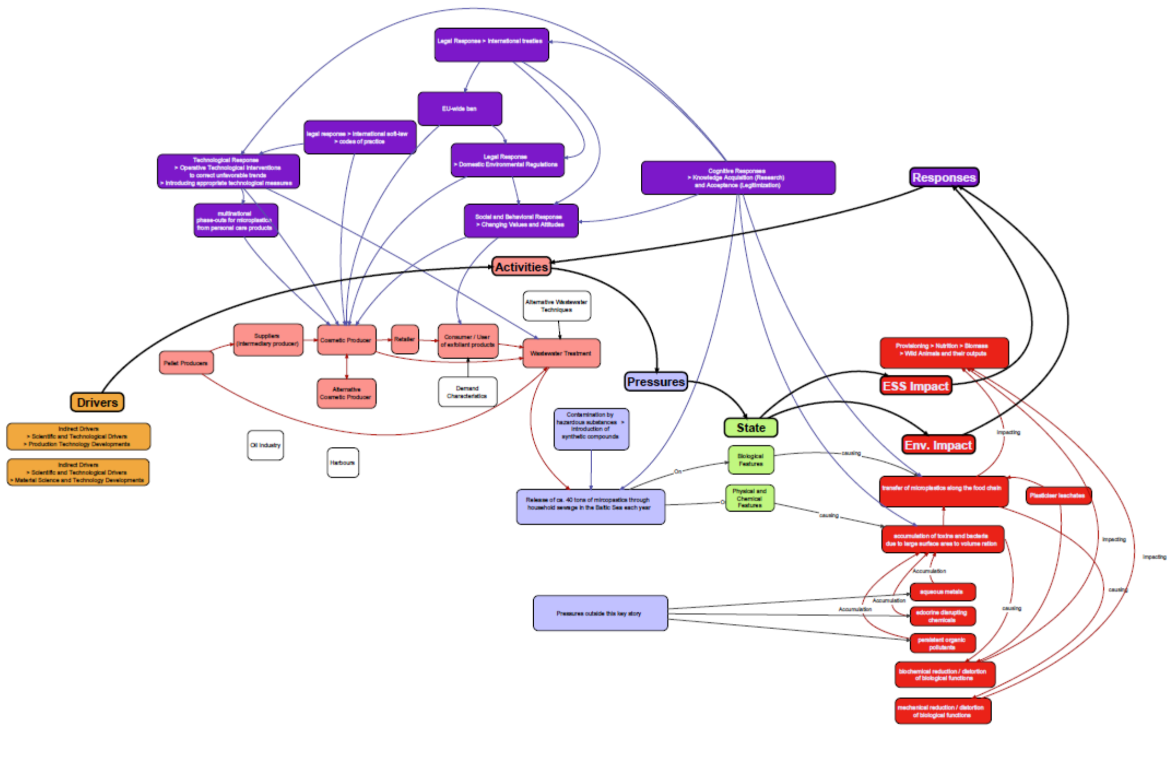
Integrating (marine) reneawable energy development into sustainable "sea-land" territorial development

Marine renewable energy is one of the fastest growing sectors of Blue Growth within the EU. From tidal power to wave power, communities are attempting to understand how they might benefit from
Similar to other physical changes, the placement marine renewable energy technology often has an impact on the local ecosystem, both benthic as well as pelagic. These impacts may include positive impacts such as an increase in habitats due to additional structures on the seafloor but they may also include negative impacts such as loss of local biodiversity and change in migration patterns for fish or marine mammals. This story will be evaluated for all regions.

Changing homes: the issue of ballast water and invasive species

Invasive species, or non-indigenous species, have the ability to have an adverse effect on the communities and ecosystems they inhabit. The increasing amount of movement of global goods by sea has been a primary driver of the spread of invasive and non-native species with the transfer of harmful aquatic organisms and pathogens through ballast water and sediments of ships as well as on the hulls of the vessels being one of the primary methods. This story will focus on all regions.

For each of the stories, a causal map will be produced to enable the development of the Knowledge Base. Below is an example casual map created for microplastics.



5 Knowledge Base

Knowledge Base (KB) will be developed to include the knowledge for each of the key storylines, where knowledge described in the previous chapters is described.

The Knowledge Base will:

- Allow marine scientists, ocean literacy experts, domain experts in general, to create rich integrated models representing the *human-ocean relationship, ocean economy* and related *knowledge on ocean literacy.*

- Support the incorporation of the DPSIR and EGS frameworks into the models. (as it will follow DAPSI(W)R.

- Build complex models of specific marine topics, incorporating links to knowledge (evidence) associated with particular topics or causal links.

- Search for available knowledge on the human-ocean relationships that can help developing “ocean literacy” products

In the short term, KB will be used by ResponSEAble partners for developing the Key Stories, understanding the current state of knowledge, developing specific Ocean Literacy products.

In the longer term (end of ResponSEAble project) it is envisaged that the KB will be used as a resource by:

- those wishing to continue the work of developing key stories using the DAPSIR framework, and attaching relevant knowledge in order to build out the scope and depth of the knowledge base. IT
- by developers of Ocean Literacy tools
- researchers investigating topics or stories within the knowledge base.

Future development of the KB should consider how we can “live”? i.e. that any new knowledge produced in Europe on the human-ocean relation can be “integrated”, or even automatically trawled from the internet, research libraries etc., and incorporated into the knowledge base.

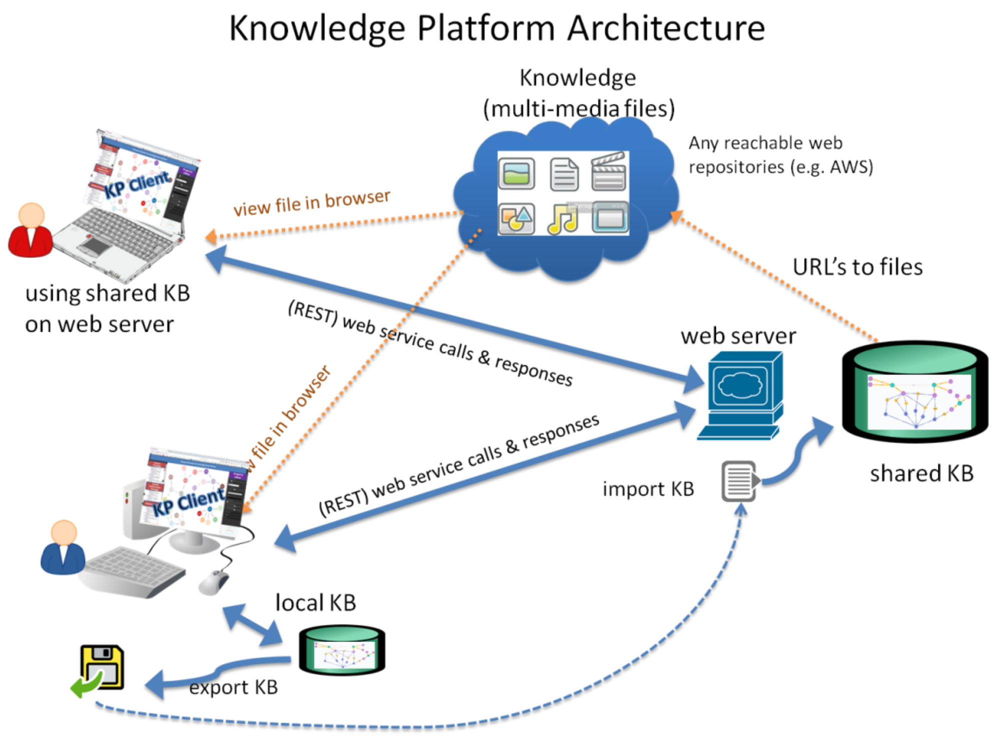
Knowledge Base Architecture

The knowledge base must be a means of storing information on things and causal relationships between them. In addition, it must be capable of storing knowledge on these things and on the relationships. In essence, it must be capable of storing causal maps (the DAPSIR stories), and all of the knowledge incorporated in those stories, which will be a variety of documents and media related to either the individual Drivers, Pressures, etc., or to the relationships (e.g. D-P).

KB provides a truly flexible approach will allow domain experts to model complex issues such as marine litter, and include related knowledge on the economic and ocean literacy models.

The KB should allow domain experts to build such models, and users to navigate and query them, both via graphical, text and API interfaces. The types of knowledge to be supported by the knowledge base can be any type media. The knowledge base itself will only hold links to the relevant knowledge.

The KB itself will be composed of a Client Application, and a Server Application. The Client Application will run on the users web browser, and will be the primary interface for users. The Server Application will manage connections to the database by multiple clients, and ensure security and concurrency. It will also be the portal through which ultimately, clients could connect to a choice of databases, should multiple teams create their own instance of the KB and make it accessible.



Knowledge Base Technology

The actual storage of the causal maps and related knowledge will be supported by a graph database, OrientDB. Other graph databases should be usable in future, as we are focusing on using the Tinkerpop graph database API to interface with the database. Rather than storing the actual documents such as reports, graphs, multimedia, etc., inside the database, we will use a document server to store them, and only store the URL in the graph database. Where we do not have permissions to (or don't want to) maintain our own copies of documents, we will just use the URL to the actual resource.

Access to the knowledge base

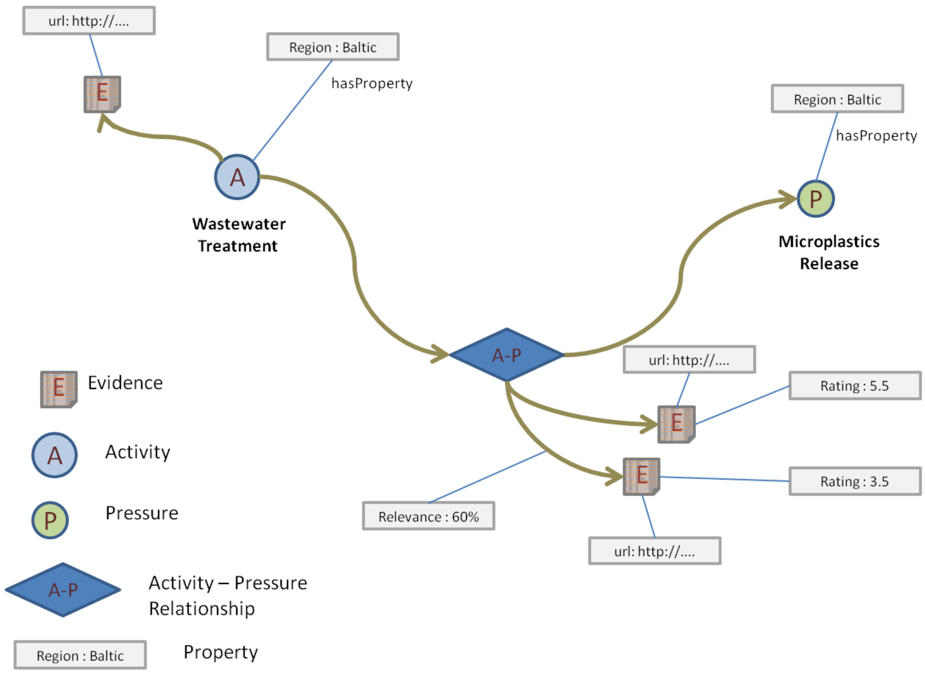
A user interface to support the domain expert to build the knowledge graphs for specific topics (e.g. Marine Litter) will be developed. The KB Client is developed using common browser development tools such as javascript, HTML and query. The graphing functionality is being developed using the rapid (http://www.jointjs.com/rappid/tour) library.

The KB Server Application is developed using Java Enterprise technology. Interaction with the client is implemented using RESTful Web Services, and JSON as the data exchange format.

Representing DAPSIR in the graph database

The stories (DAPSIR causal maps) will be stored in the graph database as nodes and relationships. Both the nodes and the relationships can themselves have any number of properties. The following diagram illustrates the concept for the storage of a Activity-Pressure relationship.

Creation of casual relationship between Activity and Pressure in Knowledge Base

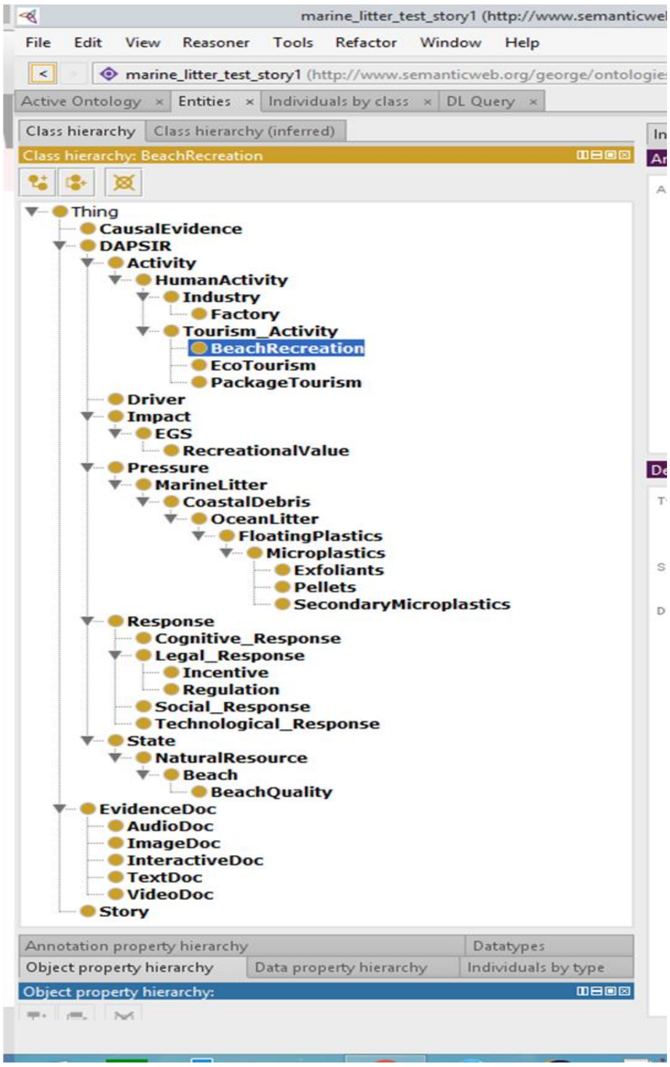


The Activity and the Pressure are represented as nodes in a directed graph. The relationship between them is also implemented as a node. The actual "knowledge" relating to specific nodes, including relationship nodes, is itself represented as nodes. It is necessary to implement the DAPSIR relationships as nodes in their own right, in order to be able to link knowledge nodes to them. In this diagram we call them "Evidence", as we see them as being the evidence relating to the nodes and relationships in the DAPSIR causal map. Each Evidence node should have a URL by which we can retrieve the actual document relating to it. Other properties will also be needed, such as audience, year, region, year, publication, etc.. The Evidence may be completely devoted to a specific topic, or only refer to it briefly. We will therefore use properties, such as relevance to fully specify such relationships.

Likewise, it may be desirable to rate publications according to their authority or citation rating, so this will be implemented as a property of the evidence node itself. Where we need to specify in more detail other nodes we can also use properties. For example, in the diagram above, this A-P relationship may only be relevant to a specific region, for example the Baltic.

The DAPSIR Classification Scheme

In collaboration with WP2 and WP3, we are developing an ontology/classification scheme which will provide a starting point for modelling stories using DAPSIR. Effectively we will provide a set of domain-relevant topics and subtopics, such as the classification of Economic Activities, Responses, etc.. The actual classification scheme and related ontology is still under development.

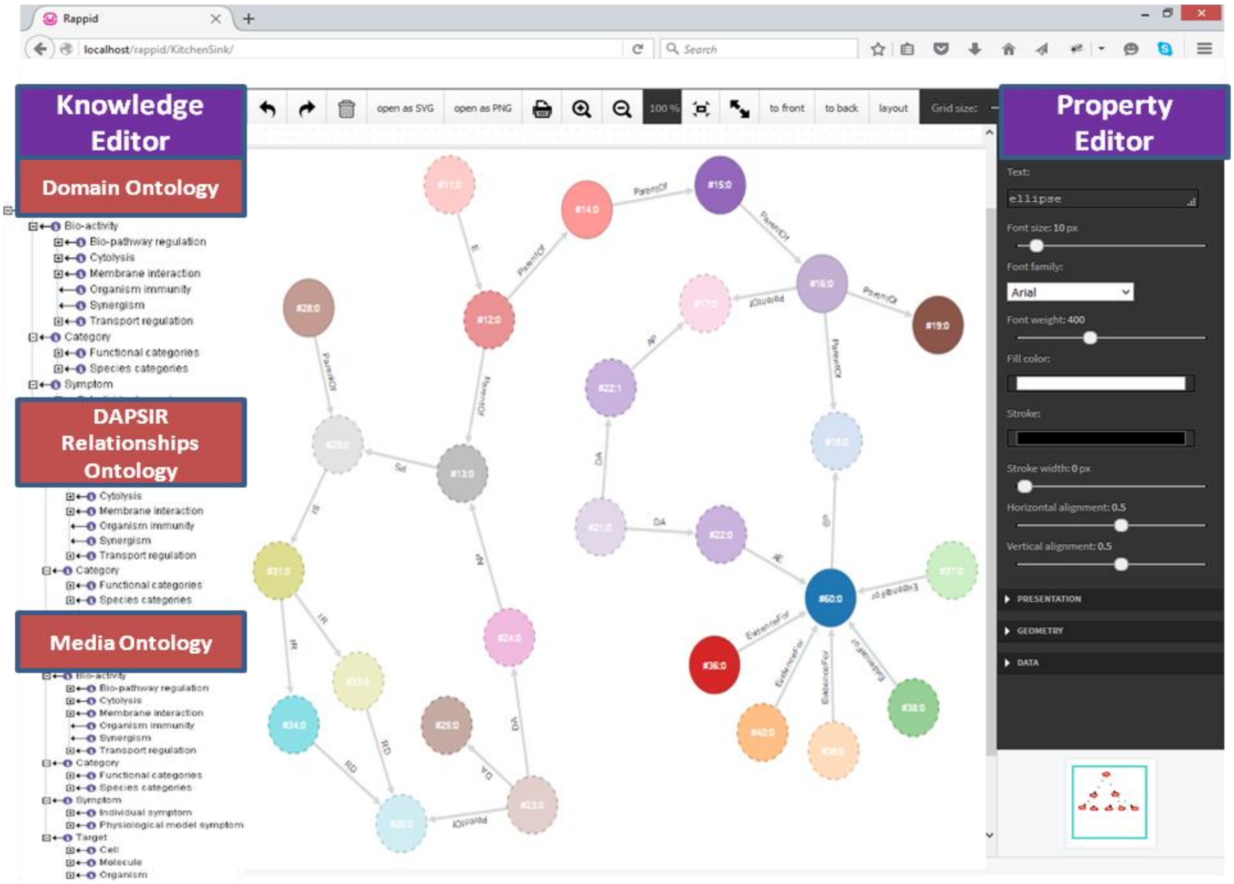


The ontology or ontologies will themselves be stored in the OrientDB database as classes and subclasses, and we intend to provide users (with sufficient permissions) to edit this ontology within the KB Client itself, including adding and deleting properties of the classes within the ontology.

The KB Client

The KB client is currently under development. It will provide the user with a knowledge editor, which the user can use to create the nodes and relationships of the DAPSIR causal map for a story. Nodes will be grouped, or clustered, to form stories, as multiple stories (DAPSIR causal maps) will be stored in a single database.

The user will drag items from the relevant ontology on the left hand side into the central graph area to create new nodes and relationships. Nodes and relationships can be selected and their properties edited on the right hand side of the page.

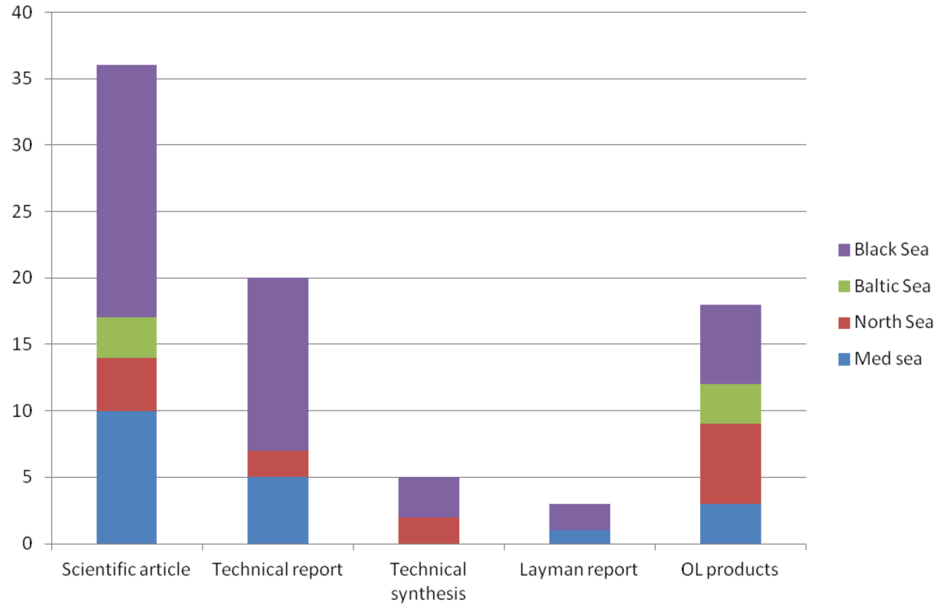


Querying the Knowledge Base

The KB client will provide users with the ability to query the knowledge base, in a variety of ways:

- The user will be able to query the list of available stories.
- The user will be able to retrieve and view the graphs for specific stories.
- The user will be able to use key words for searching and filtering the (nodes and relationships in the) knowledge base.
- The user will be able to search the knowledge (evidence) using their properties.

Outputs must be available both in graphical and tabular form. When retrieving knowledge (evidence) from the database, the user should be able to specify which subset of the evidence nodes properties they are interested in retrieving. We must also support production of graphical outputs, for example the following figure, depicting the number and types of knowledge which exists in the DB for a specific region.



Interfacing with the Server Application

As the server interface is implemented using RESTful web services, and input / output is sent via JSON, it will be possible to allow other applications to be developed around the knowledge base, for example geographical reporting tools, analytics tools, etc..

Importing Ontologies

While the main client and application development is being undertaken by NUIG, ITIA have also developed a module for importing ontologies into the OrientDB database. This will allow future users to develop their own domain-specific ontologies, including their own versions of DAPSIR, and create their own knowledge bases using them from the client application.

Knowledge Base – current status

We are currently working towards having the first key story (Microplastics) stored in the knowledge base and accessible via the client application for the partners meeting in May 2016 in Athens. At this time we will also have the ability to create new stories using the DAPSIR framework, including knowledge (evidence) nodes and their properties. Refinement of the KB, including the querying functionality, will take place after the Athens meeting.

6 Conclusion

This preliminary report presented the framework which will be used for structuring the knowledge on ocean literacy that it will be collected over the course of the project for selected keys storylines. As a result KB will be populated with the knowledge on these storylines and the final report will present the results to public.

The human-ocean relationship is vast, intricate and essential to our everyday lives, whether we live next to the sea or not. By providing EU citizens the opportunity to become more literate around a number of timely and oft-poorly understood topics, ResponSEAble is providing tools and products that will allow better decisions to be made, both at the individual citizen level as well as national policy level, resulting in positive behaviour change which benefits both the ocean and us.

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8 Appendix 1

DAPSIR Examples

Activity

A specific anthropogenic action or pursuit aimed at fulfilling the societal drivers (e.g. the need for food, space, transport) which ultimately have the potential to create the pressures leading to changes in both the natural state and human welfare (Patricio et al. 2014). Specific activities can be assigned to economic sectors. For a detailed list of sectors and related activities, refer to the following tables:

Table 1: List of marine activities (and related pressures)– modified from Koss et al. (2011), Patricio et al. (2014), Barnard et al. (2015)

Activities	*Pressure*
Fishing- Extraction of living resources	**Benthic trawls and dredges - operation**
	Benthic trawls and dredges - mooring/anchoring
	Benthic trawls and dredges - general
	Nets (fixed/set/gillnets/other nets/lines) - set up/recovery
	Nets (fixed/set/gillnets/other nets/lines) - operational
	Nets (fixed/set/gillnets/other nets/lines) - general
	Pelagic trawls - operations
	Pelagic trawls - mooring/anchoring
	Pelagic trawls - general
	Potting/creeling - set up/recovery
	Potting/creeling - operational
	Potting/creeling - general
	Suction/hydraulic dredges - operations
	Suction/hydraulic dredges - mooring/anchoring
	Suction/hydraulic dredges - general
Harvesting / collecting	**Bait digging**
	Seaweed and saltmarsh vegetation harvesting
	Bird eggs
	Shellfish hand collecting
	Peeler crabs (boulder turning)
	Curios
Production of living resources - aquaculture (including marine biotechnology based on aquaculture)	**Fin-fish - construction/installation of infrastructure**
	Fin-fish - operational
	Macro-algae - construction/installation of infrastructure
	Macro-algae - operational
	Shellfish - construction/installation of infrastructure
	Shellfish – operational
Renewable energy	**Wind farms - construction - installation/decommissioning of turbines on seafloor**
	Wind farms - operational (active cables laying on seafloor, moving turbines)
	Wave energy - construction, cable laying, decommissioning
	Wave energy - operational
	Tidal sluices - construction

	Tidal sluices - operational
	Tidal barrages - construction
	Tidal barrages – operational
Non-renewable energy (oil, gas and hydro)	Oil and Gas -exploration, construction, decommissioning
	Oil and Gas - operational
	Hydro - operational
	Power stations (land-based, but coastal) - construction
	Power stations (land-based, but coastal) – operational
Non-renewable energy (nuclear)	Power stations (land-based, but coastal) - construction
	Power stations (land-based, but coastal) – operational
Telecommunications	Communication cables - laying cables
	Communication cables - active/operational
Shipping	Mooring/anchoring/beaching/launching
	General
Navigational dredging	Capital dredging - extraction of substrate
	Capital dredging - disposal of spoil/waste
	Maintenance dredging - extraction of substrate
	Maintenance dredging - disposal of spoil/waste
Aggregate extraction	Maerl - extraction of substrate
	Maerl - disposal of spoil/waste
	Rock/Minerals - coastal quarrying - extraction of substrate
	Rock/Minerals - coastal quarrying - disposal of spoil/waste
	Sand/gravel aggregates - extraction of substrate
	Sand/gravel aggregates - disposal of spoil/waste
Coastal infrastructure development	Artificial reefs - construction
	Artificial reefs - operational
	Beach replenishment - operational
	Culverting lagoons - construction
	Culverting lagoons - operational
	Marinas and dock/port facilities - construction
	Marinas and dock/port facilities - operational
	Land claim - construction
	Land claim - operational
	Coastal defence - sea walls/breakwaters/groynes - construction
	Coastal defence - Sea walls/breakwaters/groynes – operational
Tourism / recreation	Recreational angling
	Boating/yachting/diving/water sports - mooring/anchoring/beaching/launching
	Boating/yachting/diving/water sports - general
	Public beach - general
	Tourist resort - construction
	Tourist resort – operational
Desalinization	Operational
Waste water treatment	Operational
Defense and security	Operations (specific to activity but can include: seismic activities, sonar)
	Mooring/anchoring/beaching/launching
	General

Research	**Operations**
	Mooring/anchoring/beaching/launching
	General
Land based industry	**Industry with discharges into rivers and coastal waters – operational**
Agriculture	**Deforestation**
	General

State change

State change refers to changes in the 'State' or 'Health' of the natural environment (marine ecosystems in this case), as a result of pressures, which cause state changes to ecological characteristics (e.g. abrasion may cause a decrease in macrofaunal diversity) (Smith et al. 2014).

Table 2. List of potential state changes that can result from acting pressures (modified from Barnard et al. 2015).

STATE CHANGE	Description	In MSFD Annex 3- T2
Smothering **(physical damage)**	By man-made structures/ disposal at sea	?
Substratum loss **(physical damage)**	Sealing by permanent construction (coastal defences/wind turbines), change in substratum due to loss of key physical/biological features, replacement of natural substratum by another type (e.g. sand/gravel to mud)	?
Changes in siltation and light regime **(physical damage)**	Change in concentration of suspended solids in the water column (turbidity), deposition/accretion (dredging/run-off)	?
Abrasion **(physical damage)**	Physical interaction of human activities with the seafloor/seabed flora and fauna causing physical damage (e.g. trawling)	?
Selective extraction of non-living resources	Aggregate extraction/removal of surface substrata, habitat Removal	?
Noise **(other physical pressures)**	Underwater noise - Shipping, acoustic surveys; surface noise (including aesthetic disturbance)	?
Thermal regime change	Temperature change (average, range, variability) due to thermal discharge (local)	?
Salinity regime change	Freshwater – seawater balance, seabed seepage	?
Introduction of synthetic compounds **(contamination)**	Pesticides, antifoulants, litter (plastics), pharmaceuticals, organohalogens	?
Introduction of non-synthetic compounds **(contamination)**	Heavy metals, hydrocarbons, PAH, organometals, litter	?
Introduction of radionuclides **(contamination)**	Radioactivity contamination	?
Introduction of other substances **(contamination)**	Solids, liquids or gases not classed as synthetic/non-synthetic compounds or radionuclides, litter	?
Nitrogen and phosphorus enrichment **(contamination)**	Input of nitrogen and phosphorus (e.g. fertiliser, sewage)	?
Litter	Diffuse introduction of solid wastes, garbage (also see other relevant entries)	?

Input of organic matter	Input of organic matter (e.g. industrial/sewage effluent, agricultural run-off, aquaculture, discards, etc.)	⍰
Introduction of microbial pathogens **(biological contaminant)**	Introduction of microbial pathogens	⍰
Introduction of non-indigenous species and translocations **(biological contaminant)**	Through fishing activity/netting, aquaculture, shipping, waterways, loss of ice cover, genetic modification	⍰
Selective extraction of species	Removal and mortality of target (e.g. fishing) and non target 20 (e.g. by catch, cooling water intake) species	⍰
Aesthetic pollution	Visual disturbance, litter, noise and odour nuisance	X
Death or injury by collision **(other physical pressures)**	Caused by impact with moving parts of a human activity (ships, propellers, wind turbines)	X
Barrier to species movement **(other physical pressures)**	Obstructions preventing natural movement of mobile species, weirs, barrages, causeways, wind turbines, etc. along migration routes	X
Emergence regime change **(local hydrological change)**	Change in natural sea level (mean, variation, range) due to man-made structures (local)	X
Water flow rate changes **(local hydrological change)**	Change in currents (speed, direction, variability) due to manmade structures (local)	X
pH changes **(local hydrological change)**	Change in pH (mean, variation, range) due to run-off/changein freshwater flow, etc (local)	X
Electromagnetic changes	Change in the amount and/or distribution and/or periodicity of electromagnetic energy from electrical sources (e.g. underwater cables)	X
Change in wave exposure **(local hydrological change)**	Change in size, number, distribution and/or periodicity of waves along a coast due to man-made structures (local) or climate change (large scale)	X
Geomorphological changes	Changes in seabed and coastline changes due to tectonic events	