D1.2: Current marine pressures and mechanisms driving changes in marine habitats

Marine Ecosystem Restoration in Changing European Seas MERCES

Grant agreement n. 689518

COORDINATOR: UNIVPM

LEAD BENEFICIARY: NUIG

AUTHORS:
Chris Smith, Thanos Dailianis, Nadia Papadopoulou, Vasilis Gerovasileiou, Katerina Sevastou (all HCMR), Anthony Grehan (NUIG), Dave Billett (DSES), Chris McOwen, (UNEP-WCMC), Teresa Amaro (CIIMAR), Tatjana Bakran-Petricioli (PMF-ZAGREB) Trine Bekkby, (NIVA), Meri Bilan (IMAR-UAz), Chris Boström (ÅAU), Marina Carriero-Silva (IMAR-UAz), Laura Carugati (UNIVPM), Emma Cebrian (UGIR), Carlo Cerrano (UNIVPM), Hartvig Christie (NIVA), Roberto Danovaro (UNIVPM), Elizabeth Grace Tunka Eronat (MCS), Dario Fiorentino (AWI), Simonetta Fraschetti (CONISMA), Karine Gagnon (ÅAU), Cristina Gambi (UNIVPM), Bernat Hereu (UB), Silvija Kipson (PMF-ZAGREB), Jonne Kotta (UTARTU), Cristina Linares (UB), Telmo Morato, (IMAR-UAz), Henn Ojaveer (UTARTU), Helen Orav-Kotta (UTARTU), Christopher Pham (IMAR-UAz), Eli Rinde (NIVA), Antonio Sarà (GAIA), Rachael Scrimgeour (UNEP-WCMC).

SUBMISSION DATE: 25/05/17

DISSEMINATION LEVEL
(e.g. Public)

PU	Public	X
CO	Confidential, only for members of the consortium (including the Commission Services)	

Typical coastal activities – aquaculture and oil and gas shore infrastructure in Saronikos Gulf, Greece. Photo by © Chris Smith.

Citation

Smith, C.J., Dailianis, T., Papadopoulou, K-N., Gerovasileiou, V., Sevastou, K., Grehan, A., Billett, B., McOwen, C., Amaro, T., Bakran-Petricioli, T., Bekkby, T., Bilan, M., Boström, C., Carriero-Silva, M., Carugati, L., Cebrian, E., Cerrano, C., Christie, H., Danovaro, R., Eronat, E.G.T., Fiorentino, D., Fraschetti, S., Gagnon, K., Gambi, C., Hereu, B., Kipson, S., Kotta, J., Linares, C., Morato, T., Ojaveer, H., Orav-Kotta, H., Pham, C.K., Rinde, E., Sarà, A., Scrimgeour, R. (2017) Current marine pressures and mechanisms driving changes in marine habitats. Deliverable 1.2, MERCES Project. 102 pp, incl. 2 Annexes.

Acknowledgments

The authors would like to thank James Aronson (CCSD, Missouri Botanical Garden), Steve Fletcher (UNEP-WCMC), Eleni Hatziyanni (Region of Crete), David Johnson (Seascape Consultants Ltd.) and Chiara Piroddi (ICM-CSIC), for commenting on and improving content of this report. This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 689518.

Summary

Human activities and the resultant pressures they place on the marine environment have been widely demonstrated to contribute to habitat degradation, therefore, their identification and quantification is an essential step towards any meaningful restoration effort. The overall scope of MERCES Deliverable 1.2 is to review current knowledge regarding the major marine pressures placed upon marine ecosystems in EU waters and the mechanisms by which they impact habitats in order to determine potential restoration pathways. An understanding of their geographical distribution is critical for any local assessment of degradation, as well as for planning conservation and restoration actions. This information would ideally be in the form of maps, which: (a) compile single or multiple activities and pressures over broad scales, integrating and visualizing available data and allowing direct identification of aggregations as well as gaps and (b) may be overlaid with habitat maps (or any other map layer containing additional information), thus combining different data levels and producing new information to be used for example when implementing EU policies. The deliverable also documents typical example habitat case studies, the prominent impacts and consequences of activities and pressures towards the identification of possible restoration or mitigation actions. Finally the deliverable discusses pressures, assessments, marine spatial planning and blue growth potential.

Activities and pressures are used in a strict sense, where marine activities are undertaken to satisfy the needs of societal drivers (e.g. aquaculture or tourism) and pressures are considered to be the mechanism through which an activity has an actual or potential effect on any part of the ecosystem (e.g. for demersal trawling activity, one pressure would be abrasion of the seabed). Habitats are addressed using a nested approach from large-scale geological features (e.g. shallow soft bottoms) to species-characterised habitats (e.g. *Posidonia* meadows) because of the way they are referred to in current policy documents which lack standard and precise definitions.

MERCES Pressure Catalogue

The MERCES Pressures catalogue was compiled from a semi-structured literature search using specific keywords and combinations. The catalogue consists of 264 entries, with 67 columns of associated data. Entries include published documents, web resources, and grey literature and are mostly in the form of simple images, but 5% of the entries concerned shapefiles where data can be directly shared for other applications. The majority of entries were for the Mediterranean Sea

and North-East Atlantic. The activity/pressure entries were mostly broad-scale (regional sea, national), with lesser numbers of entries for specific habitat classes. Map resources were screened for a total of 13 types of activities and 34 pressures. Fisheries, coastal marine infrastructure and transport were the most featured activities with respect to the broad scale maps and were consistent across the regional seas. Aquaculture and tourism ranked high for the sublittoral habitat and research/conservation for the deep-sea entries. Chemical pressures (inputs of various substances) and biological invasions ranked high at the broad scale, followed by litter, abrasion and extraction of species. These last three pressures seem to be the most frequently mapped pressures in deep-sea records.

Map availability depended on geographical area, research efforts and more obvious activities or pressures. The Black Sea had the least resources, but it is being supported in new projects towards spatial management; this applies to a lesser extent to southern Mediterranean Sea areas. Current EU directives and related research projects (e.g., MSFD, HD, MSP directives; EMODnet, BENTHIS, ADRIPLAN, MEDTRENDS) are driving the mapping process, as well as some national initiatives through the publication of marine atlases.

Maps vary in their use from positioning of point sources (aquaculture farm sites, oil platforms), continuous cables/pipelines, to general areas where an activity takes place (e.g., trawling/shipping maps) or might take place (e.g., MSP zoning/maps, oil and gas exploration blocks). Pressure maps may be more specific as an activity may not necessarily lead to a related pressure, however, many broad scale pressure maps may be interpolative/modelled (e.g., cumulative impacts maps), or the pressure map may just indicate where an incidence has been noted without information in other adjacent areas.

The limitations and gaps revealed by the review included; a large proportion of resources concerned static data (simple images, static in time, that have a limited use beyond that reference), spatial resolution (most maps are broad scale with unreliable information at the local scale – also containing modelled/interpolated data lacking validation), geographic coverage (under-representation in some regional and sub-regional areas and over-representation in others), and hard to find information (grey literature). It is recommended that future mapping initiatives should focus on: new georeferenced data (digital maps in open-access format), filling knowledge gaps (addressing geographical and temporal gaps and supporting regional/national initiatives) and gaining high levels of standardisation (through involvement of transnational/intergovernmental organisations).

Case Studies and Restoration Potential

The case study habitats included shallow soft bottoms (seagrass meadows), shallow hard bottoms (kelp and *Cystoseira* forests, coralligenous assemblages) and deep-sea areas (coral gardens, deep soft bottom communities). Activities and pressures were examined to produce extensive habitat-specific tables, listing pressure impacts and effects, consequences, and potential restoration or mitigations actions. The number of activities impacting each habitat differed significantly with the highest number of activities present in shallow soft areas, and the lowest number present in the deep-sea. At least one existing or future blue growth focus area (e.g. aquaculture, renewable energy generation or mining) and blue economy activity (e.g. fishing) was noted in all the cases. Additionally, numerous pressures were noted in all case studies acting as mechanisms of change and causing progressive state change effects from the population to the ecosystem level. The options for reducing impacts in the case studies were all similar and included: to eliminate, reduce or better regulate the activity, and where possible, conduct the activity in a region where the ecosystem has high recovery potential, whilst also making efforts to reduce inputs, ameliorate water quality, control harmful practices, reduce disturbance and ensure disturbance does not disrupt connectivity, create habitat connections, remove aliens and litter before restoration. Restoration should be performed away from problem areas and activities should be eliminated/reduced in restoration areas. In most of the cases mitigation is the recommended action with very few cases actually mentioning (additional) active restoration.

Pressures and Assessments

Activities and pressures are considered as important elements in the assessment of the status and health of ecosystems. The evolution of terminologies and listings from the Directives (HD, WFD, MSFD and MSP) and many related projects are examined, along with status assessments including Regional Sea assessments, cumulative effects assessments, and pressure assessments. These assessments are used to determine the level of environmental health (e.g., MSFD: Good Environmental Status) through the use of indicator thresholds and targets, and allowing measures/strategies for the implementation of protection measures after adverse effects, including restoration. Assessments often have data gaps, lack a temporal element or focus on a narrow range of activities or relatively “new” pressures (e.g. noise and litter). As they have evolved, different assessments may also concern factors such as persistence, resilience and recovery, but a common backbone beyond the methods is the need and use of spatial data on both pressure presence/intensity and habitat/species distribution/occurrences.

Potential for Restoration and Blue Growth

MSP provides a means of setting boundaries for spatially managed areas, for which it is essential to have a knowledge of the footprint of human activities and their pressures. It can also facilitate restoration initiatives by providing an appropriate zoning mechanism that will support continued economic activity while ensuring Good Environmental Status and thus sustainable 'Blue Growth'. Indeed, restoration areas may well be one of the tools in the 'toolkit' of managers tasked with maritime spatial planning. The identification of activities and pressure hot spots is crucial for planning future restoration actions. Mitigation of pressures and removal of their impacts at sites where restoration activities take place would also enable the quicker recovery of the given habitat.

Ecosystems provide us with goods and services that can be considered under the term Natural Capital. Their values can be monetised and integrated into a national accounting system to manage natural capital. Big business is beginning to adopt Corporate Natural Capital Accounting methods to balance business against environmental offsets, the latter through, for example, carbon sequestration, recreation or biodiversity. Biodiversity offsetting and habitat banking could potentially provide mitigation or compensation measures for impacts. The restoration of degraded marine ecosystems can often be seen as a cost in business planning, but recently greater awareness by businesses of ecosystem services has led to new business opportunities from restoration activities. Businesses, after Environmental Impact Assessments, are trying first to avoid pressures, devise civil and ecological engineering solutions to minimise adverse impacts, or where degradation cannot be avoided, to take direct restorative actions – this may be in the form of carbon trading initiatives (e.g. carbon sequestration by planting marine plants – which also offsets climate change), flood defence (coastal building/management) or Corporate Social Responsibility (deep sea mining and experimental restoration). There are business opportunities for knowledge-based companies and consultancies to assess ecosystem goods and services, plan for sustainable development and, where ecosystems have been degraded, invent simple and cost-effective solutions to kick start and speed up natural recolonisation processes. They can also advise on the role of marine ecosystem restoration for future carbon markets and carbon trading.

CONTENTS

1. Acronyms Used 7

2. Introduction 9
2.1. Scope of the Deliverable 9
2.2. Activities, Pressures and Mechanisms of Effect 9
2.3. Species, Habitats or Ecosystems? 15
2.4. Deliverable Objectives 16

3. Methods and Materials 17
3.1. The MERCES Pressures Catalogue compilation 17
3.1.1. Activity and Pressure Maps: Category Groups and Categories 17
3.2. The MERCES Pressures Systematic Review 20
3.3. The MERCES Key Habitats Pressure Activity Linkages 21

4. Results 21
4.1. The MERCES Pressures Catalogue compilation 21
4.1.1. Pressure/Activity Map Sources 21
4.1.2. Pressure/Activity Map Sources by Area 22
4.1.3. Pressure/Activity Map Resources by Key Habitat 23
4.1.4. Assessment of Activities 25
4.1.5. Assessment of Endogenous Pressures 28
4.1.6. Assessment of Exogenous Pressures 30
4.2. The MERCES Key Habitats Pressure Activity Linkages 31
4.2.1. Key Habitat Descriptions 31
4.2.1.1 Mediterranean Sea, Baltic Sea and North Atlantic Ocean - Shallow soft – Seagrass meadows 32
4.2.1.2 North-East Atlantic Ocean (Norway) – Shallow hard – Kelp forest 33
4.2.1.3 Mediterranean Sea – Shallow hard – Macroalgal forests: *Cystoseira* 33
4.2.1.4 Mediterranean Sea – Shallow hard – Coralligenous assemblages 34
4.2.1.5 Azores – Deep-sea – Coral Gardens 35
4.2.1.6 Deep-sea soft bottom communities 35
4.2.2. Case Studies: Habitats Responses to Activities and Pressures 38
4.2.2.1. Activities and Pressures 38
4.2.2.2. The case study examples, activities and pressures 40

5. Discussion 59
5.1. Conclusions from the Activities/Pressures Map Catalogue 59
5.2. Restoration Potential and Conclusions from the Case Studies 69
5.3. Pressures and pressure assessments 71
5.3.1. Pressures 71
5.3.2. Activity and Pressure Enigmas 78
5.3.3. Assessments 79
5.4. Potential for Restoration and Blue Growth 81
5.4.1. Restoration potential away from pressure hotspots 81
5.4.2. Enabling restoration: the MSP Directive and Natural Capital Accounting 82
5.4.3. Restoration and Blue Growth Opportunities 88

6. References 90

7. Annexes 100
7.1. Annex 1: Describing the MERCES Pressures Catalogue 101
A2.1. Category groups and categories 101
A2.3. Catalogue entries 102

1. Acronyms Used

Acronyms

AIS	Automatic Identification System
BALTIC	Baltic Sea
BLACK	Black Sea
CBD	Convention on Biological Diversity
CO_2	Carbon dioxide
CPIA	Cumulative pressure and impact assessments
CWC	Cold water coral
DPSIR	Driving Force-Pressure-State-Impact-Response framework
EC	European Commission
EEA	European Environmental Agency
EIA	Environmental Impact Assessment
EU	European Union
EUNIS	European nature information system
EEZ	Exclusive Economic Zone
EMODnet	European Marine Observation and Data Network
FAO	Food and Agriculture Organisation of the United Nations
GES	Good Environmental Status
GIS	Geographic Information System
HD	Habitats Directive
HELCOM	Helsinki Commission (Baltic Marine Environment Protection Commission)
IUCN	International Union for Conservation of Nature
MAP	Mediterranean Action Plan (UNEP)
MarLIN	Marine Life Information Network (UK)
MED	Mediterranean Sea
MSFD	Marine Strategy Framework Directive
MSP	Marine Spatial Planning Directive
NEA	North-East Atlantic
NIS	Non-indigenous species
NGO	Non-governmental organisation
OCEANA	Ocean Conservation non-governmental organisation set up by the Pew Trust
OSPAR	Oslo and Paris Commissions (Commission for the Protection of the Marine Environment of the North-East Atlantic)
OTHER	Other Regional Sea
pH	A figure expressing the acidity or alkalinity of a solution on a logarithmic scale.
RAC/SPA	Regional Activity Centre for Spatially Protected Areas (UNEP)
ROV	Remotely Operated Vehicle
RSC	Regional Sea Convention
SCOPUS	Abstract and citation database of peer-reviewed literature
SLR	Sea Level Rise
SME	Small and medium sized-enterprise
SST	Sea Surface Temperature
UNEP	United Nations Environment Programme
VMS	Vessel Monitoring System
WFD	Waters Framework Directive
WoS	Web of Science
WWF	World Wildlife Fund for Nature

Project Acronyms

ADRIPLAN	ADRiatic Ionian maritime spatial PLANning
BALANCE	Baltic Sea Management – Nature Conservation and Sustainable Development of the Ecosystem through Spatial Planning
BENTHIS	Benthic Ecosystem Fisheries Impact Studies
CoCoNet	Towards COast to COast NETworks of marine protected areas
DEVOTES	DEVelopment Of innovative Tools for understanding marine biodiversity and assessing good Environmental Status
MAES	Mapping and Assessment of Ecosystems and their Services
MARSPLAN-BS	Cross Border Maritime Spatial Planning in the Black Sea
Med-IAMER	Integrated Actions to Mitigate Environmental Risks in the Mediterranean Sea
MedPAN	Network Of Marine Protected Area Managers in the Mediterranean
MEDTRENDS	The Mediterranean Sea: trends, threats and recommendations
MISIS	MSFD Guiding Improvements In The Black Sea Integrated Monitoring System
MERCES	Marine ecosystem restoration in changing European Seas
MESMA	Monitoring and evaluation of spatially managed areas
ODEMM	Options for delivering ecosystem-based marine management
PERSEUS	Policy-oriented marine Environmental Research for the Southern European Seas
SIMCelt	Supporting Implementation of Maritime Spatial Planning in the Celtic Seas
THAL-CHOR	Cross-border Cooperation for Maritime Spatial Planning Development
VECTORS	VECTORS of Change in European Marine Ecosystems and their Environmental and Socio-Economic Impacts

2. Introduction

2.1. Scope of the Deliverable

Human activities and the resultant pressures they place on the marine environment have been widely demonstrated to contribute to habitat degradation (e.g. Halpern et al., 2008), therefore, their identification and quantification is an essential step towards any meaningful restoration effort. The overall scope of MERCES Deliverable 1.2 is to review current knowledge regarding the major marine pressures placed upon marine ecosystems in EU water and the mechanisms by which they impact habitats in order to determine potential restoration pathways.

The development of a comprehensive listing, comprising all recognised activities and pressures acting on marine habitats, is an important step in identifying potential drivers and their linkage patterns. Although a multitude of data linked to marine activities and pressures are available through various sources (e.g. the Marine Strategy Framework Directive (MSFD), recent EU projects, as well as published reviews) a understanding of their geographical distribution is critical for any local assessment of degradation, as well as for planning conservation and restoration actions. Hence, the information would ideally be in the form of maps, which: (a) compile single or multiple activities and pressures over broad scales, integrating and visualizing available data and allowing direct identification of aggregations as well as gaps and (b) may be overlaid with habitat maps (or any other map layer containing additional information), thus combining different data levels and producing new information to be used for example when implementing EU policies.

2.2. Activities, Pressures and Mechanisms of Effect

A great deal of work has been undertaken particularly within the EU, through the adoption of recent Directives to understand and categorise activities and pressures. The relationship between activities and pressures is incorporated within the DPSIR framework (Driving Force-Pressure-State-Impact-Response), where societal Drivers are those that cover basic human needs such as the need for food or recreation. The EU had adopted DPSIR as an overall mechanism for analysing environmental problems (EC, 1999) originating through the European Environmental Agency and Eurostat. In recent years, within the scope of the MSFD where marine monitoring aims to maintain good environmental status (GES), standardised activity and pressure lists were defined (EC, 2008), which have been refined further in the last few years in the DEVOTES, VECTORS and ODEMM research projects. Activities and Pressures have been defined as:

Activity: basic activities to satisfy the needs of societal drivers; e.g. aquaculture or tourism (Scharin et al., 2016)

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, one pressure would be abrasion of the seabed (Robinson et al., 2008).

Additional relevant definitions are given in Annex 3 of the MERCES Deliverable 1.1. (Bekkby et al., 2017)

Within the MERCES project the recently compiled standardised lists of activities and pressures of Smith et al. (2016) have been used as a basis of categorisation for the WP1 work: Table 1 shows the marine activities considered along with descriptions and examples. The list includes blue growth focus areas (such as aquaculture, renewable energy generation, coastal tourism and mining) and blue economy activities (such as fishing, oil/gas industry and transport) (COM, 2012 https://ec.europa.eu/maritimeaffairs/policy/blue_growth_en). Figure 1 illustrates some typical marine activities. Tables 2 and 3 show standardised list of marine pressures with descriptions and examples. Figure 2 illustrates some typical marine pressures. Distinguishing between endogenous and exogenous pressures is an import consideration when setting management plans - in the case of the endogenous pressures, management has to respond to the causes and consequences whereas for exogenic pressures it only responds to the consequences. In this study pressures have been divided into two types following the division of Elliot (2011): **Endogenous Pressures** are those emanating from within the system that we can control (manageable) e.g. abrasion on the seabed caused by trawling activities. **Exogenous Pressures** on the other hand are those emanating from outside the system that we cannot primarily control (unmanageable) and can be seen to be natural, e.g. change in seabed morphology from tectonic events. Both types of pressures can also be grouped into simple higher levels following on from Piroddi et al. (2015) and Teixera et al. (2016) and as can be seen in (Table 3) relating to physical impacts (damage caused by abrasion and other disturbances such as litter and noise), chemical (e.g. linked to eutrophication and organic enrichment), hydrological (e.g. changes in water flow due to man-made structures) and biological (e.g. introduction of non-indigenous species and extraction and mortality of species), used later in the catalogue analysis in this document.

Table 1. List of standardised Activities considered with description and examples (from Smith et al., 2016).

Activity	Examples and concerns from the activity leading to pressures
Production of living resources	Aquaculture: fin-fish set-up and operations, macro-algae set-up and operation, shellfish set-up and operations, predator control, disease control, stock enhancement methods
Extraction of living resources	Benthic trawling, scallop dredging, fishery wastes, netting (e.g. fixed nets, seine netting), pelagic trawling, potting/creeling, suction hydraulic dredging, bait digging, seaweed and saltmarsh vegetation harvesting, bird eggs and shellfish hand collecting, peels, curios, recreational fishing, extraction of genetic resources
Transport	Litter and debris (unauthorized dumping), mooring/beaching/ launching, shipping, steaming, shipping wastes, passenger ferries, transport of goods, navigation, dredged material disposal
Renewable energy generation	Renewable (tide/wave/wind) power station construction and operations
Non-renewable energy generation	Fossil fuel (coal, oil & gas) power stations, thermal discharge (cooling water), water abstraction, marine fracking, nuclear power, radioactive discharge and storage
Extraction of non-living resources	Inorganic mine and particulate waste, non-living maerl, rock/minerals (coastal quarrying), sand/gravel (aggregates), water for desalination, salt, navigational dredging, marine hydrocarbon extraction, capital dredging, maintenance dredging, substratum removal
Coastal and marine structure and Infrastructure	Artificial reefs, barrages, beach replenishment, communication infrastructure (cables), constructions, culverting lagoons, dock/port facilities, groynes, land claim, marinas, pipelines, removal of space and substrata, bathymetric/ topographic change, sea walls/breakwaters, urban buildings, cables/pipelines/ gas storage/carbon capture, cultural sites such as wrecks, foundations, sculptures
Land-based Industry	Industrial effluent treatment and discharge, industrial/urban emissions (air), particulate waste, desalination effluent, sewage and thermal discharge, power plant discharges
Agriculture	Coastal farming, coastal forestry, agricultural wastes, land/waterfront run-off
Tourism/ recreation	Angling, boating/yachting, diving/dive site, litter, littering/dumping, debris, bathing, public beach, tourist resort, water sports
Defense and national security	Military activities, hazardous material disposal areas, infrastructure (naval bases, ports, airports, degaussing stations), vessels, vehicles, sonars and munitions testing and use at sea, mooring/anchoring/beaching, dumping
Research and conservation	Animal sanctuaries, marine archaeology, marine research, physical sampling, physico-chemical and biological sample removal
Carbon Sequestration	Storage, exploration, construction, operational

Table 2a. List of standardised endogenous Pressures considered with description and examples (from Smith et al., 2016).

Pressure	Description
Abrasion	Physical interaction of human activities with the seafloor/seabed flora and fauna causing physical damage (e.g. trawling)
Aesthetic pollution	Visual disturbance, noise and odour nuisance
Barrier to species movement	Obstructions preventing natural movement of mobile species, weirs, barrages, causeways, wind turbines, etc. along migration routes
Change in wave exposure (local)	Change in size, number, distribution and/or periodicity of waves along a coast due to man-made structures.
Changes in siltation and light regime	Change in concentration of suspended solids in the water column (turbidity), deposition/accretion (dredging/run-off)
Collision	Caused by contact between biological components and moving parts of a human activity (ships, propellers, wind turbines).
Electromagnetic changes	Change in the amount and/or distribution and/or periodicity of electromagnetic energy from electrical sources (e.g. underwater cables)
Emergence regime change (local)	Change in natural sea level (mean, variation, range) due to man-made structures
Input of organic matter	Input of organic matter (e.g. industrial/sewage effluent, agricultural run-off, aquaculture, discards, etc.)
Introduction of microbial pathogens	Introduction of microbial pathogens
Introduction of non-indigenous species and translocations	Through fishing activity/netting, aquaculture, shipping, waterways, loss of ice cover, genetic modification
Introduction of non-synthetic compounds	Heavy metals, hydrocarbons, PAH, organometals
Introduction of other substances	Solids, liquids or gases not classed as synthetic/non-synthetic compounds or radionuclides
Introduction of radionuclides	Radioactivity contamination
Introduction of synthetic compounds	Pesticides, antifoulants, pharmaceuticals, organohalogens
Litter	Diffuse introduction of litter
Nitrogen and phosphorus enrichment	Input of nitrogen and phosphorus (e.g. fertilizer, sewage)
Noise	Underwater noise - Shipping, acoustic surveys; surface noise (including aesthetic disturbance)
pH changes (local)	Change in pH (mean, variation, range) due to run-off/change in freshwater flow, etc
Salinity regime change	Freshwater – seawater balance, seabed seepage
Selective extraction of non-living resources	Aggregate extraction/removal of surface substrata, habitat removal
Selective extraction of species	Removal and mortality of target (e.g. fishing) and non target (e.g. by catch, cooling water intake) species
Smothering	By man-made structures/ disposal at sea
Substratum loss	Sealing by permanent construction (coastal defenses/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)
Thermal regime change	Temperature change (average, range, variability) due to thermal discharge (local)
Water flow rate changes (local)	Change in currents (speed, direction, variability) due to man-made structures

Table 2b. List of standardised exogenous Pressures considered with description and examples (from Smith et al., 2016).

Pressure	Description
Thermal regime change	Temperature change (average, range, variability) due to climate change (large scale)
Salinity regime change	Salinity change (average, range, variability) due to climatological events (large scale)
Emergence regime change	Change in natural sea level (mean, variation, range) due to climate change (large scale) and isostatic
Water flow rate changes	Change in currents (speed, direction, variability) due to climate change (large scale)
pH changes	Change in pH (mean, variation, range) due to climate change (large scale), volcanic activity (local)
Change in wave exposure	Change in size, number, distribution and/or periodicity of waves along a coast due to climate change
Geomorphological changes	Changes in seabed and coastline changes due to tectonic events

Table 3. Pressure groups considered, by grouping of common pressures.

Pressure Group	Pressure
Physical damage	Smothering
	Substratum loss
	Changes in siltation and light regime
	Abrasion
	Selective extraction of non-living resources
Other physical	Litter
	Noise
	Aesthetic pollution
	Collision
	Barrier to species movement
	Electromagnetic changes
Chemical	Introduction of synthetic compounds
	Introduction of non-synthetic compounds
	Introduction of radionuclides
	Introduction of other substances
	Nitrogen and phosphorus enrichment
	Input of organic matter
Biological	Introduction of microbial pathogens
	Introduction of non-indigenous species
	Selective extraction of species
Hydrological	Thermal regime change (local)
	Salinity regime change (local)
	Emergence regime change (local)
	Water flow rate changes (local)
	pH changes (local)
	Change in wave exposure (local)

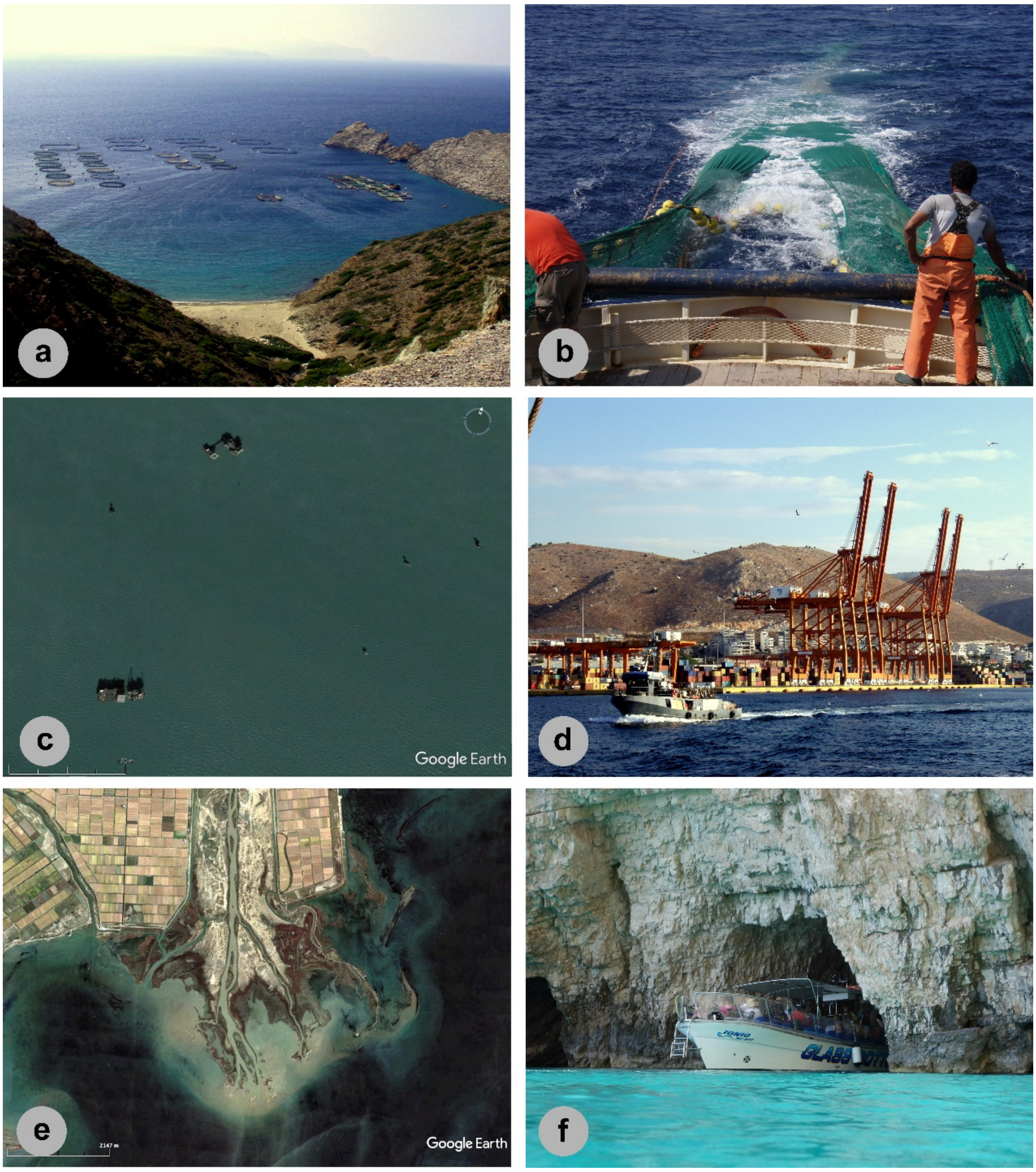

Figure 1. Typical marine activities; (a) Aquaculture (production of living resources); (b) demersal trawling (extraction of living resources); (c) Oil platforms (extraction of non-living resources); (d) Container terminal (coastal and marine structure and infrastructure); (e) river run-off from Agriculture; (f) Tourism/recreation. Photos by Chris Smith (a, b, d), Vasilis Gerovasileiou (f). Satellite images from Google Earth (c, e).

Figure 2. Typical pressures in the marine environments: (a) abrasion (trawl door scarring); (b) input of organic matter (aquaculture shore facility effluent); (c) introduction of non-indigenous species (*Caulerpa rachemosa*); (d) Litter (shore stranded floating litter); (e) Selective extraction of species (fish in a trawl cod-end); (f) Smothering (trammel net covering sponge garden). Photos by Chris Smith (a, d); Thanos Dailianis (b, f); Donat Petricioli (c); EPILEXIS/HCMR (e).

A pressure, through lethal or sub-lethal processes, may cause a physico-chemical and biological change in state affecting biological organization at many different levels (summarised in Figure 3). The mechanisms through which pressures cause a change in the state of a particular component of marine ecosystems are often very complex, for example, pressures may directly impact species/assemblages/habitats or may indirectly impact these components through changes in relationships/processes and rates. In order to effectively restore a degraded habitat actions need to be taken to remove the impacting pressures or at least reduce their severity, intensity, and/or duration through management of activities. The restorative action then needs to target or reverse state changes at whichever level they are affected, directly or through habitat replacement.

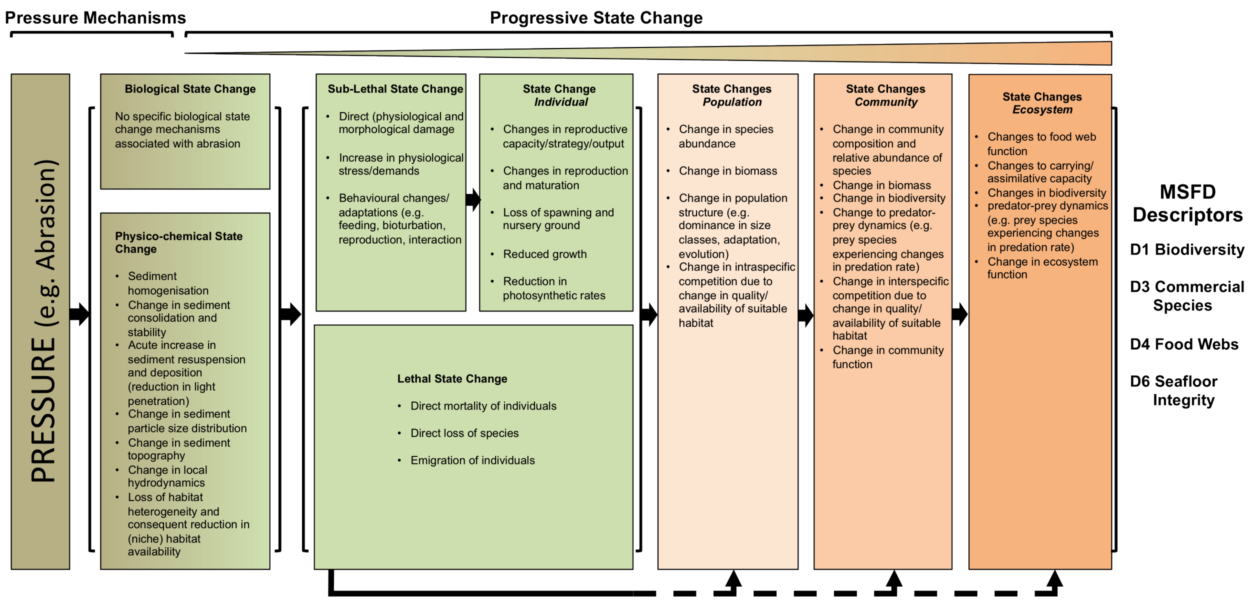

Figure 3. Conceptual model from Smith et al. (2016) showing the progression of Pressure related physico-chemical and biological induced State changes in marine ecosystems. Pressures can cause a biological State change at any level: either (1) progressively through a sub-lethal response at the individual level which, over time, can lead to State changes at higher biological organisation levels or (2) directly by acting at a higher level, leading to more immediate community and ecosystem State changes with respect to specific MSFD Descriptors

2.3. Species, Habitats or Ecosystems?

Typically, the targets of ecological restoration are degraded ecosystems (McDonald et al., 2016) but available mapping initiatives concern mainly particular habitats, communities or species. According to the EU Habitats Directive (92/43/EEC), natural habitats are defined as "terrestrial or aquatic areas distinguished by geographic, abiotic and biotic features, whether entirely natural or semi-natural" and its main aim is "to maintain or restore natural habitats at a favourable conservation status". The EUNIS defines habitat as "plant and animal communities as the characterising elements of the biotic environment, together with abiotic factors (soil, climate, water availability and quality, and others), operating together at a particular scale" (Davies and Moss, 2004). The EUNIS classification system is constantly evolving, with new habitat types added in an effort to include biological communities from different biogeographic regions.

However, there has been a long debate on the definition of "habitat" among researchers (e.g. Fraschetti et al. (2010) wondering how many habitats are there, and where) and policy makers (e.g. in the requirement for assessments by broad habitat types for various EU directives, Galparsoro et al., 2012, 2014). Additionally environmental status assessments usually require integration of multiple ecosystem components such as species and broad scale habitats as well as spatially defined outputs (Borja et al., 2016). This often leads to a conflating and broad use of the term. This broad use of the term habitat is, for example, close to the definition of ecosystem provided by Clewell and Aronson (2007) as "the complex of living organisms and the abiotic environment with which they interact at a specified location".

In the current report, we have used a nested approach, starting from broad scale to fine scale. We have looked at very broad habitat types (e.g. A6 Deep sea, a level 2 EUNIS habitat) that are often seen in global maps or in initiatives mapping human activities. We considered various features, which correspond to different levels of the EUNIS habitat classification system, supporting communities of special conservation interest. We have included, for example, habitats from regional lists of threatened or declining habitats (e.g. OSPAR lists include Zostera beds and deep-sea sponge aggregations). Finally, we have also considered specific ecosystem-engineering taxa (e.g. *Posidonia* meadows, macroalgal/*Cystoseira* forests and coral/sponge gardens), and large physical/geological features such as seamounts and canyons and associated species communities, covering both levels 4 and 5 of the EUNIS habitat classification system.

2.4. Deliverable Objectives

Following on from the scope of the deliverable, the specific objectives of this report are:

(a) to inventory and assess available activity and pressure maps across the European regional seas (MERCES D1.2 Catalogue), as well as to perform a review and analyses that will allow identification of commonalities, and conclusions to be drawn;

(b) to showcase typical examples (case studies) to investigate activities and pressures acting on the selected MERCES habitats (habitats of focussed research efforts within the MERCES project, detailed in the following sections), their prominent impacts and consequences, as well as the identification and evaluation of possible restoration or mitigation actions.

3. Methods and Materials

3.1. The MERCES Pressures Catalogue compilation

The MERCES Pressures Catalogue was compiled from a semi-structured literature search on the internet using keywords and keyword combinations. Keywords included “map” and “marine” and “Europe” and types of activity (e.g. “aquaculture”, “trawling”, “aggregate extraction”, “hydrocarbons”, “renewable energy”, “shipping” etc.), or more general terms and major habitat types, such as “habitat” or “deep sea”, “seagrass” etc. in marine and coastal areas (excluding estuaries and lagoons). For all the above cases, the first 100 search results were scanned, (a) in order of relevance (browser derived) and (b) ranked by year (2016 - most recent). Specific web resources were also searched (including downloadable reports) of national/international organizations (including NGOs), commissions and agencies dealing with habitat conservation (e.g. EEA, IUCN, UNEP-MAP-RAC/SPA, HELCOM, OSPAR, FAO, OCEANA, MarLIN, Scotland’s Marine Atlas) and all the European projects registered in the European Marine Spatial Planning platform (e.g. MEDTRENDS, CoCoNet, MESMA, PERSEUS, ADRIPLAN, THAL-CHOR, BALANCE). In addition, MERCES participants were asked to provide entries based on their thematic and regional knowledge/expertise.

The catalogue was an Excel file with single row entries for pressure/activity map resources and column categories. Some categories permitted free-text entries; whilst others were restricted to specific lists of options (drop-down menus). The catalogue included a ‘Read me’ datasheet with instructions and clarifications for completion, a ‘List’ datasheet (for visualising the drop-down list options) and ‘Catalogue’ datasheet to be filled in. Additional sheets contained information helpful for the contributor, such as maps of the regional seas and their subdivisions, lists of habitat types and description of activities and pressures.

The catalogue entries were broken down into several broad category groups and then individual categories in single columns as described below.

3.1.1. Activity and Pressure Maps: Category Groups and Categories

The entries are broken down into 8 broad categories and then individual categories in single columns.

3.1.1.1. Data input identifier section

To identify the record and the record provider:

- ID: the unique entry number for this record (filled by the catalogue administrators)
- No.: the sequential number of the data entries starting from 1
- ID Partner: the acronym of the institution of the person providing the data
- Name: the name of the person providing the data
- E-mail: contact e-mail address of the person providing the data

3.1.1.2. Habitat Type

- Category: drop-down list with options (a) 'Broad scale' or (b) 'Particular Habitat'. 'Broad scale' referring to large area, actual or predicted seabed habitat maps or geomorphology maps for regional, sub-regional or country area. 'Particular Habitat' if a specific habitat type with more detail in next column.
- Type: only applicable if previous entry was 'Particular Habitat'. A drop-down list with options (a) 'sublittoral soft', (b) 'sublittoral hard', (c) 'deep sea' (>200 m depth), and (d) 'other' particular habitat.
- Main Feature: a drop-down list to specify habitat type, depending on category selected in the previous column. For 'Sublittoral soft': (a) *Posidonia*, (b) *Zostera*, (c) Other seagrass, (d) Other. For 'Sublittoral hard': (a) Maerl, (b) Coralligenous (including gorgonians), (c) Gorgonians, (d) Sponges, (e) *Cystoseira*/Macroalgal forests/beds, (f) Other. For 'Deep Sea' (a) Corals, (b) Sponges, (c) Mixed coral/sponge field, (d) Seamounts, (e) Hydrothermal vents, (f) Carbonate mounds, (g) Canyons, (h) Other. Not applicable for 'Broad scale' category.

3.1.1.3. Activities

For all activities explicitly mapped in the reference and matching the definitions provided. Free text information provided under each activity (Activity list taken from Smith et al., 2016, see Section 2.2.):

- 13 columns relating to activities shown in Table 1
- Activities comments: any extra or more detailed information on specific activities.

3.1.1.4. Endogenous (manageable) Pressures

For all pressures explicitly mapped in the reference and matching the definitions provided. Free text information provided under each pressure (endogenous pressure list taken from Smith et al., 2016, see Section 2.2.):

- 26 columns relating to endogenous pressures shown in Table 2a
- Endogenous Pressures Comments: any extra or more detailed information on endogenous pressures

3.1.1.5. Exogenous (unmanageable) Pressures

For all Pressures explicitly mapped in the reference and matching the definitions provided. Free text information provided under each pressure (exogenous pressure list taken from Smith et al., 2016, see Section 2.2.):

- 7 columns relating to exogenous pressures shown in Table 2b
- Exogenous Pressures comments: any extra or more detailed information on exogenous pressures

3.1.1.6. Information

- Other Maps: Drop-down list: chose one option, Yes or No, with any more detailed information added in the Comments in the next column.
- Comments: Free text, further details about the map source or finding of the paper/report, or any other useful information, e.g. human activities/impacts in the area.

3.1.1.7. Region

- Sea basins MSFD Regions: a drop-down list of MSFD Regions with options (a) Baltic Sea, (b) North-East Atlantic, (c) Mediterranean Sea, (d) Black Sea, (e) Other Regional Sea. The latter category ("other") refers to either sources at a global or European scale, or areas not included in the MSFD categories (such as Norwegian waters, or seafloor banks in the international waters of North-East Atlantic).
- MSFD sub-region: a drop-down list of MSFD sub-regions (applying only for the North-East Atlantic and the Mediterranean Sea). Options for the North-East Atlantic are (a)

Greater North Sea, including the Kattegat, and the English Channel, (b) Celtic Seas, (c) Bay of Biscay and the Iberian Coast, (d) Macaronesian biogeographic region (Azores, Madeira, Canary Islands). Options for the Mediterranean Sea are (a) Western Mediterranean Sea, (b) Adriatic Sea, (c) Ionian Sea and the Central Mediterranean Sea, (d) Aegean-Levantine Sea.

- Other Subdivisions: Free text for stating any further information or localised region e.g. ICES rectangles, GSA. A specification for non-MSFD regions (such as Norwegian waters, or seafloor banks in the international waters of the North-East Atlantic) is also included here, if "Other regional sea" is selected in the first column.

3.1.1.8. Sources

- Source: a drop-down list with options (a) on-line resource/site, (b) paper, (c) report, (d) conference paper, (e) expert/unpublished.
- Type: a drop-down list with options (a) Map image (raster or printed image from a paper or on-line), (b) Map viewer (interactive image on-line), (c) Shapefile (possibility to individually download GIS format shapefiles)
- Reference: Free text field, providing the full citation for the reference
- Reference Link: Free text field, providing a web link to the reference
- Multiple Entries: a drop-down list with options (a) Yes or (b) No, depending on how many rows have been added per reference. "Yes" indicates multiple entries for a single reference, as for example if a reference covers more than one regional area, or more than one habitat.

3.2. The MERCES Pressures Systematic Review

On receipt of the individual catalogues, an accession number was given to every entry. Once the catalogues had been collated and checked for duplicates and missing information, a systematic review of the data was undertaken to highlight the different data categories and the range of information by regional sea, habitat, etc.

3.3. The MERCES Key Habitats Pressure Activity Linkages

Marine habitats within the European Union are under pressure from a wide array of sources, hampering attempts to restore degraded areas. In order to explore this further, we investigated linkages between specific activities (e.g. the extraction of living resources), their resultant pressures (e.g. abrasion) and the implications for restoration efforts. First, following consultation with a number of experts, a generic table was constructed mapping 26 pressures derived from 13 human activities (Tables 1 and 2). Following this, several case studies were investigated in more detail. Case studies were selected at a WP1 MERCES workshop based on the presence of focal key habitats being investigated under MERCES (shallow soft bottom habitats – seagrass; shallow hard bottom habitats – kelp, macroalgal forests, coralligenous assemblages; deep sea habitats – coral gardens, deep-sea soft bottom communities (open slopes, submarine canyons, deep basins, seamounts). The review of the case studies included elements of the biology, ecology and relevant stressors and pressures. Full descriptions of the case studies including key important but generic features identified at the workshop (such as dynamics, connectivity and structural complexity) are given in Bekkby et al. (2017) MERCES D1.1. Deliverable. Short summaries of the selected habitats are given in this report (Section 4.2.1) with additional information provided here on relevant impacts and pressures. For each case study, tables were constructed whereby specific features were noted related to each of the generic feature topics to impacts (for example, on growth, patch size or on connectivity) as well as their consequence for restoration.

4. Results

4.1. The MERCES Pressures Catalogue compilation

The catalogue consists of 264 entries, resulting from the semi-structured search and contribution from 10 project partners.

4.1.1. Pressure/Activity Map Sources

Out of the 264 entries, 194 (73.5%) map activities, 147 (55.7%) map pressures, and 101 (38.3%) map both. Most of the information (49%) came from peer-reviewed journals, followed by project reports (27%) and web resources (19%) which consisted mainly of map viewers and other online inventories (Figure 4). Conference proceedings and unpublished records (expert opinion) represent a small percentage of the information gathered (3% and 1%, respectively). The substantial contribution of unpublished records (48% including project EEA reports, RSC reports, OSPAR reports, WWF reports, EU project deliverable reports, web resources, and unpublished records) underlines the importance of grey literature as a source of information for pressures maps.

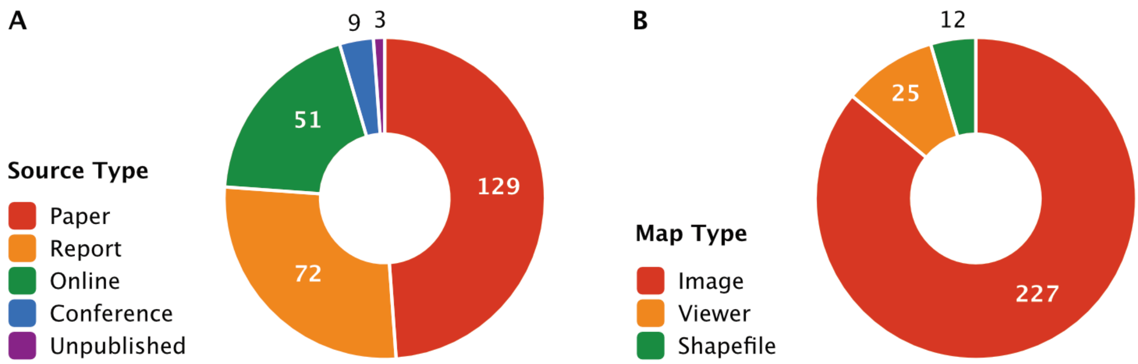

Figure 4. Sources and types of maps in the Pressures Catalogue. A) Proportion of the different types of sources, and B) Proportion of the types of maps.

The majority of maps are simple images (86%) with a further 9% relating to online map viewers, which often allowed multiple pressure and habitat layers to be viewed together, thereby facilitating inferences in relation to their spatial relationships. Only 5% of the entries were shapefiles, which represent the most useful sources of information for further work (Figure 4).

A large proportion of the entries report multiple activities and/or pressures (mostly physical and chemical, 48% of entries) impacting marine habitats, with three activities or endogenous pressures and two exogenous pressures were mapped on average per entry.

4.1.2. Pressure/Activity Map Sources by Area

Geographically, the majority of entries are from the Mediterranean Sea (39%) and the North-East Atlantic (27%), with the Baltic Sea and Black Sea represented to a much lesser extent (16% and 14%, respectively) (Figure 5).

At the sub-regional level, the North-East Atlantic is mostly represented by entries from the Greater North Sea and the Celtic Seas (54% and 31%, respectively; Figure 5), reflecting the extensive amount of references from UK waters and the OSPAR region. Regarding the Mediterranean Sea, all four MSFD sub-regions are represented, and a significant portion of entries (26%) includes maps of pan-Mediterranean scale. "Other" regions represent 3% of the total records and may either refer to sources with a global coverage, those covering the entire European continent, or sub-regions outside the EU or non MSFD-relevant (e.g. Norway, Hatton and Rockall Banks).

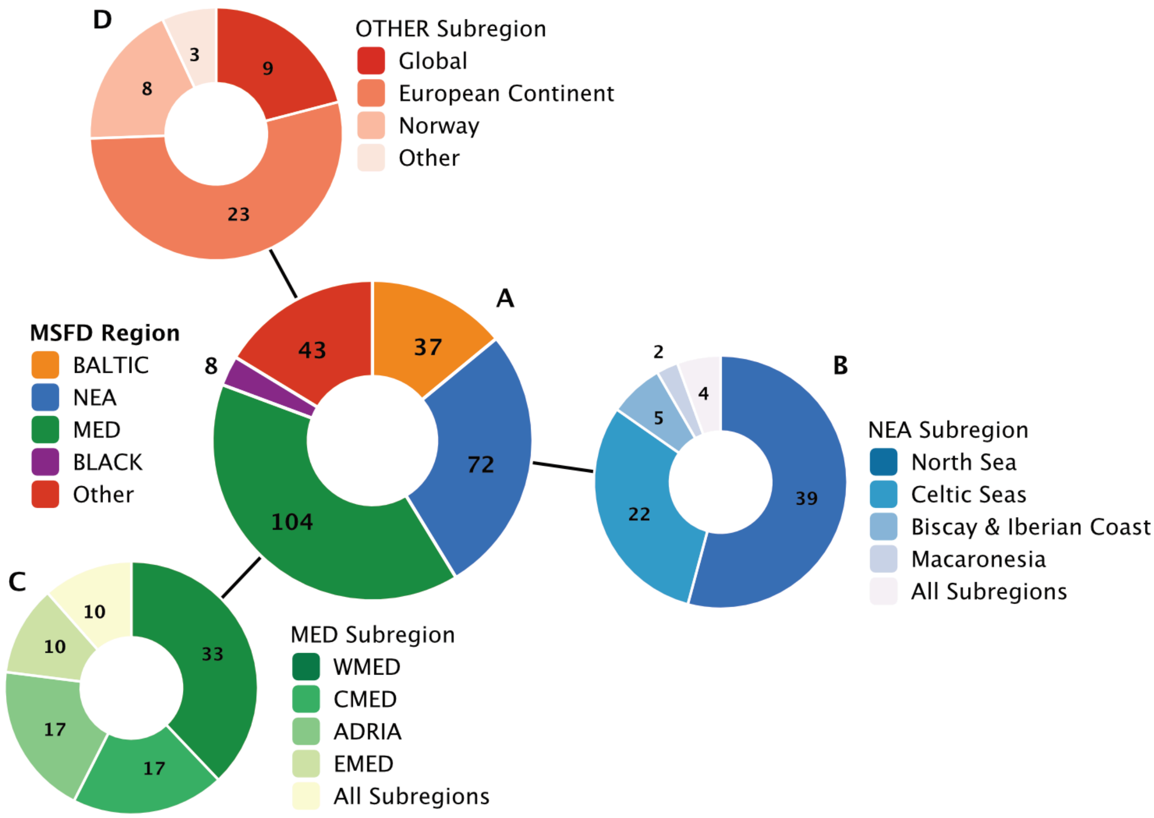

Figure 5. Number of records in the Pressures Catalogue for European regions and sub-regions. A) Regional seas (BALTIC: Baltic Sea; BLACK: Black Sea; MED: Mediterranean Sea; NEA: North-East Atlantic; Other: Other regional sea), B) North-East Atlantic sub-region, C) Mediterranean Sea sub-regions (WMED: Western Mediterranean; CMED: Central Mediterranean; ADRIA: Adriatic; EMED: Eastern Mediterranean), and D) Other sub-regions.

4.1.3. Pressure/Activity Map Resources by Key Habitat

Seventy-five percent of the entries refer to "broad scale" habitat categories, without an indication of specific habitat types. Those entries (25%) that do specify habitat type refer to either "sublittoral hard" and "soft bottoms", or "deep-sea" habitats (Figure 6).

The majority of "hard sublittoral" habitats where human activities information is catalogued refer to general rocky habitats, some dim-light coralligenous reefs (including gorgonians) and euphotic reefs with macroalgal forests (Figure 6B). On the other hand, "soft sublittoral" habitats simply refer to seagrass beds (Figure 6C). For "deep-sea" habitats, canyons and coral beds are the prominent features, with just one reference to seamounts (Figure 6D).

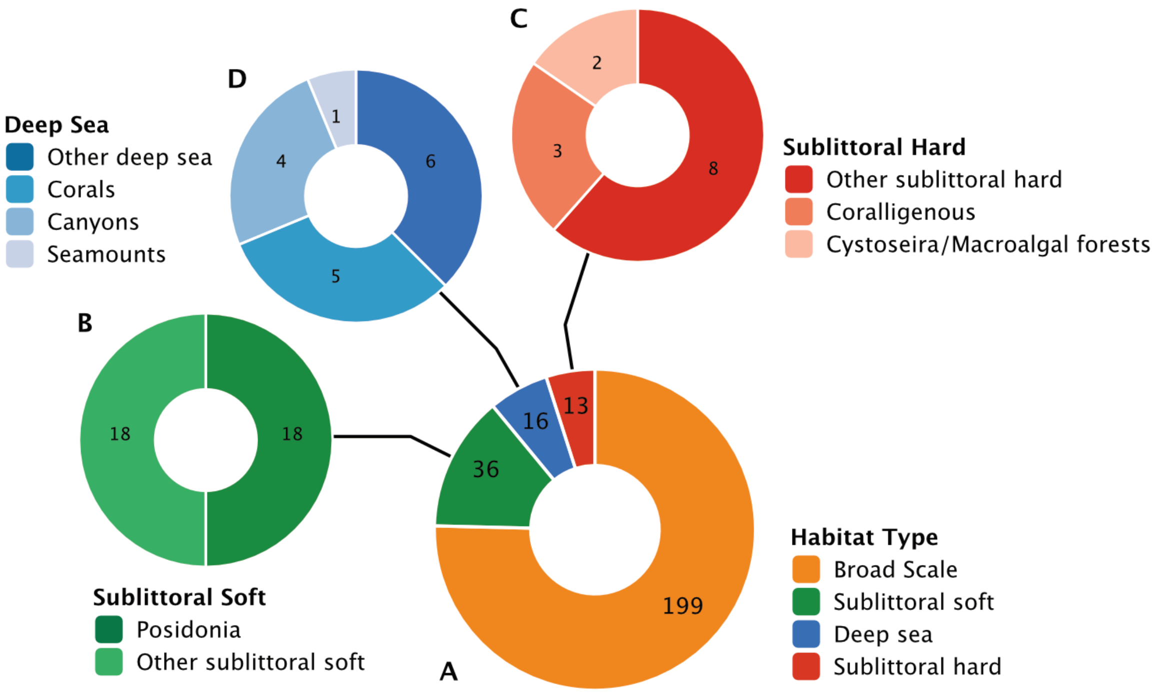

Figure 6. Habitat types for the Pressures Catalogue. A) Total entries, B) sublittoral soft habitats, C) sublittoral hard, and D) deep-sea habitats.

The paucity of information relating to the specific habitat type where a pressure occurs is not region specific, but it is consistent for all geographic subregions (Figure 7), although the relative percentages differ. For the Mediterranean region, 45% of entries refer to specific habitats, whilst the percentage is much smaller in the North-East Atlantic and "Other" (mainly global) regions, probably owing to the coarser scale of the studies. In the Baltic and the Black Sea, only "sublittoral soft bottom" habitats are identified.

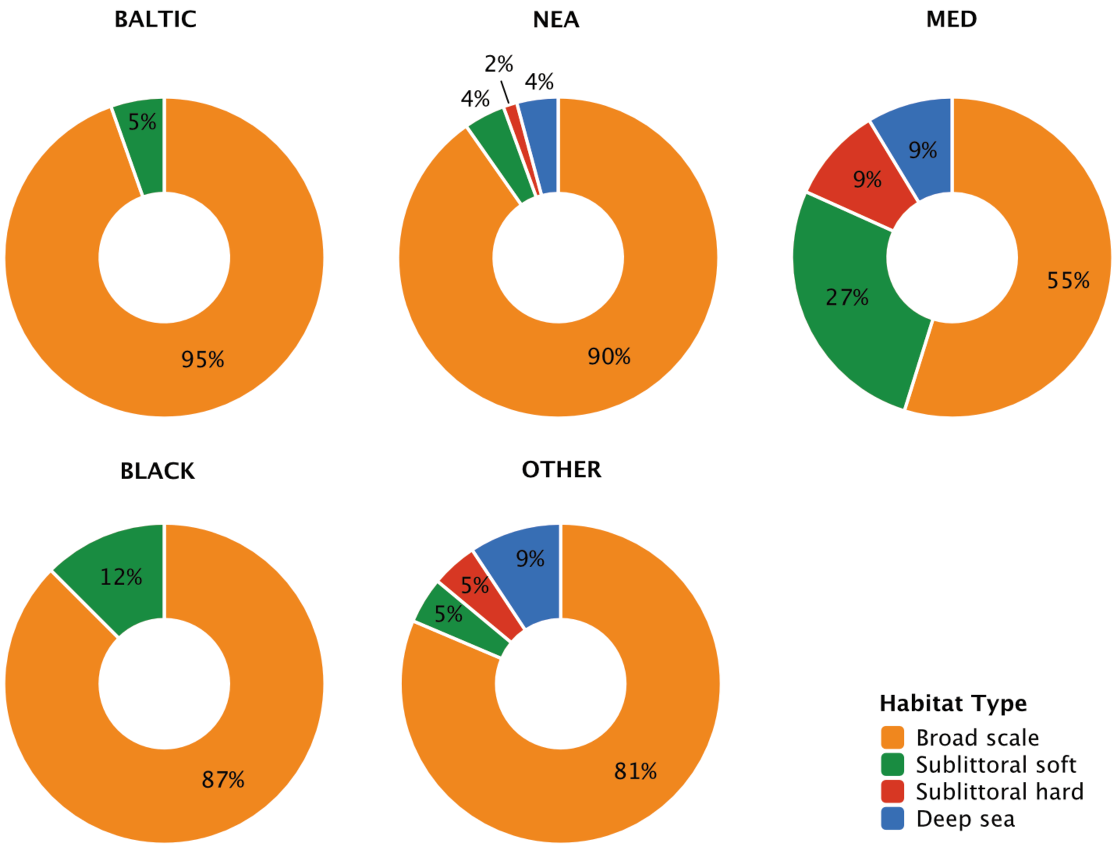

Figure 7. Proportion of habitat types according to geographic region (BALTIC: Baltic Sea; NEA: North-East Atlantic; MED: Mediterranean Sea; BLACK: Black Sea; OTHER: Other regional sea).

4.1.4. Assessment of Activities

Of the 264 entries, 191 included mapped activities. Their ranking by number of records is presented in Figure 8.

"Extraction of living resources" was the most frequently cited activity with 102 references. This category refers to fisheries in general, including trawling (bottom and pelagic); surrounding and seine nets; dredging; small-scale fishery, gillnets. It is usually expressed as cumulative swept area, amount of catch, size of fishing fleet, or fishing effort (usually derived from AIS/VMS signals). It also includes recreational fishing in some instances, in which case it is also relevant to tourism/recreation.

"Coastal and marine structure and Infrastructure", "Transport", and "Production of living resources" were the next most frequently cited activities, occurring in 77 (29%), 72 (27%), and 69 (26%) out of the total 264 references, respectively. The first one is a diverse category incorporating: (a) ports, harbours and marinas, (b) oil and gas pipelines (also relevant to "extraction of non-living resources"), (c) telecommunication cables and landing stations, (d) offshore wind farms (also relevant to “renewable energy production), (e) shipwrecks and submerged archaeological sites, (f) coastal urban development, etc.

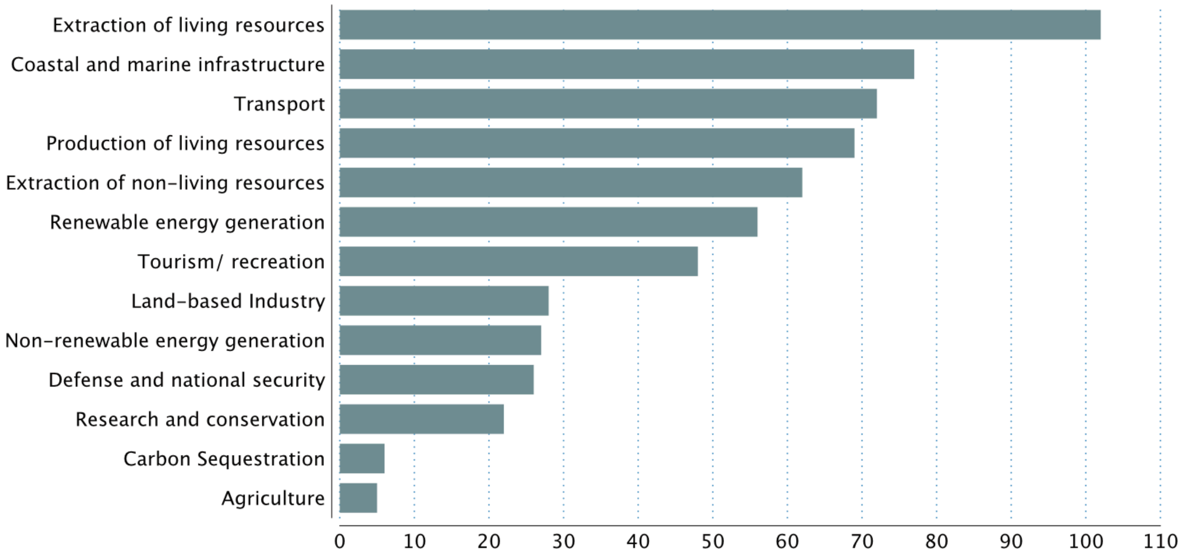

Figure 8. Mapped activities in the Pressures Catalogue, ranked in order of number of records.

“Coastal and marine structure and Infrastructure”, “Transport”, and “Production of living resources” were the next most frequently cited activities, occurring in 77 (29%), 72 (27%), and 69 (26%) out of the total 264 references, respectively. The first one is a diverse category incorporating: (a) ports, harbours and marinas, (b) oil and gas pipelines (also relevant to “extraction of non-living resources”), (c) telecommunication cables and landing stations, (d) offshore wind farms (also relevant to “renewable energy production), (e) shipwrecks and submerged archaeological sites, (f) coastal urban development, etc.

Activities relating to “Transport” are: (a) marine traffic (usually derived from AIS signals), as well as marine routes and motorways of the sea, (b) port traffic and location of ports and marinas (c) shipping accidents and locations of dumping or waste placement.

The “Production of living resources” category refers to aquaculture - mostly finfish (sometimes unspecified or mixed) and to a lesser extent shellfish. This predominantly documents the location of aquaculture sites and in a few instances illustrates densities.

"Research and conservation" is a rather under-represented category (only 22 (8%) out of 264 sources) that could be possibly expanded with a focused search for maps illustrating MPA distribution, or potentially locations where regulations apply.

"Carbon sequestration" and "agriculture" are the obviously under-represented categories in the Catalogue. The first is restricted to 6 sources citing offshore CO_2 storage and underground coal gasification, while the latter (with 5 entries) relates to mapped as agricultural land coverage proximal to the coast, or coastal population employed in agriculture.

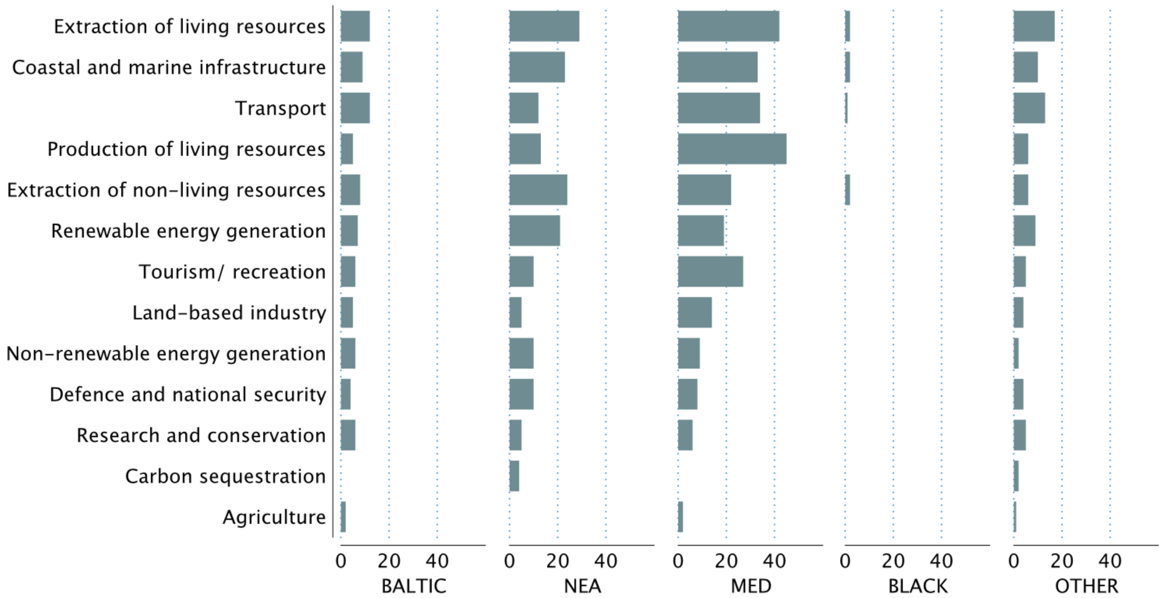

Figure 9. Mapped activities in the Pressures Catalogue per geographic region, ranked by number of total records (BALTIC: Baltic Sea; NEA: North-East Atlantic; MED: Mediterranean Sea; BLACK: Black Sea; OTHER: Other regional sea).

With the exception of "carbon sequestration" which only appears under "Other" regions (with documented cases in Norway), all other activities are found in the Baltic Sea, North-East Atlantic and Mediterranean Sea (Figure 9). "Transport", "extraction of living resources", and "coastal and marine structure and infrastructure" rank high in the Baltic Sea; and "extraction of living resources", "coastal and marine structure and infrastructure" and "extraction" of non-living resources rank high in the North-East Atlantic. "Production of living resources", "extraction of living resources" and "transport" rank high in the Mediterranean Sea, and the "extraction of living resources", "transport" and "renewable energy generation" under "Other" regions. Relatively few mapping resources are found in the Black Sea.

4.1.5. Assessment of Endogenous Pressures

Endogenous pressures are less frequently mapped than the activities that induce them. Out of the total 264 catalogued sources, 147 (56%) include mapped endogenous pressures (Figure 10).

Chemical pressures rank high in the list, with nitrogen and phosphorous enrichment, introduction of other substances, and input of organic matter occupying the three first positions, cited in 45, 40, and 35 (13-17%) out of a total of 264 sources, respectively.

Entries for “nitrogen and phosphorous enrichment” include mapping of point sources and actual (mainly bottom) concentrations. “Introduction of other substances” mainly includes mapped pollution sources or aggregations that are either not specified, or described in generic terms (e.g. land-based pollution, hazardous and noxious substances, chemical spills). Mapped “organic matter input” mainly includes riverine and urban runoffs, as well as chlorophyll concentrations.

Of those endogenous pressures present in more than 20% of the relevant entries, “abrasion”, “introduction of non-indigenous species”, and “litter” are notable. “Abrasion” is a physical pressure most commonly related to fishing activities (mainly trawling and dredging, but also physical contact with other fishing gear); in specific instances, it can be physical contact by sinking ships, infrastructure construction, and anchoring. “Introduction of non-indigenous species” is the most mapped biological pressure, with maps illustrating both the presence and the introduction vectors of species in the examined areas. Marine “litter” emerges as a well-mapped physical pressure, due to experimental trawling and ROV studies; maps of marine litter in our catalogue include (a) general waste, (b) abandoned, lost, or dismissed fishing gear, (c) mining waste dumping.

“Selective extraction of species”, although highly ranked, is seemingly under-represented in the catalogue (28 entries; 11%), considering the intensity of fisheries in the examined areas. When present, it is associated with general fisheries, in some instances being more specific (e.g. bycatch records of cetaceans and turtles, removal of kelp). The reason for the presumed under-representation is that, while fishing as an activity is widely assessed, the actual extraction of species is seldom explicitly put on a map, hence can be only assumed from fishing intensity maps or catch quotas per geographic areas.

Several endogenous pressures appear as seldom mapped, each one represented in less than 4% of the total entries. Most notable among these are local “thermal regime change”, “underwater noise”, “selective extraction of non-living resources”, and “barriers to species movement”. “Death by injury or collision” is not mapped in any of the examined sources.

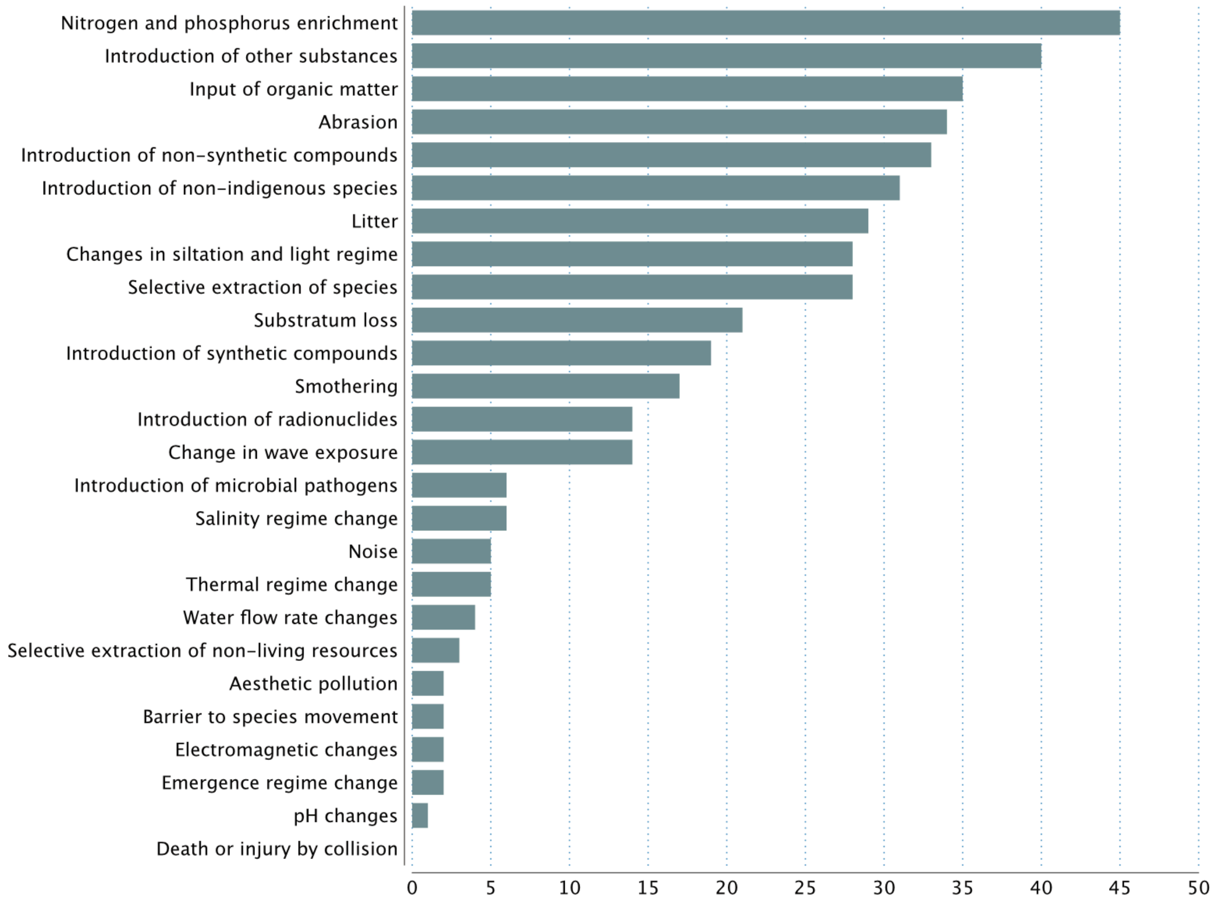

Figure 10. Mapped endogenous pressures in the Pressures Catalogue, ranked by number of records.

Most chemical and physical pressures are present and mapped in all the regions although not all of the pressures are mapped in each area (Figure 11). Hydrological and other physical disturbance pressures are much less frequently mapped mostly in the North-East Atlantic. From the biological pressures, “selective extraction of species” and “introductions of non-indigenous species” are mapped in all the regions.

Figure 11. Mapped endogenous pressures in the Pressures Catalogue per geographic region, ranked by number of total records (BALTIC: Baltic Sea; NEA: North-East Atlantic; MED: Mediterranean Sea; BLACK: Black Sea; OTHER: Other regional sea).

4.1.6. Assessment of Exogenous Pressures

Out of the 264 entries of the pressures catalogue, 52 (20%) included mapped exogenous pressures. Their ranking by number of records is presented in Figure 12. Most frequently mapped exogenous pressures are related to thermal and emergence regime change (in 62% and 42% of the records including mapped exogenous pressures, respectively).

“Thermal regime change” maps usually illustrate SST trends derived either from models or from actual measurements along temporal intervals. Heatwaves and extreme temperature events are also mapped. Similarly, “emergence regime change” illustrates SLR trends derived either from models or from actual measurements along temporal intervals. No maps of exogenous pressures were found among the queried sources to specifically address deep-sea habitats. The Mediterranean Sea, regions under "Other", and the Baltic Sea have some maps of various exogenous pressures, but this type of information is under-represented for the North-East Atlantic while missing for the Black Sea (Figure 13).

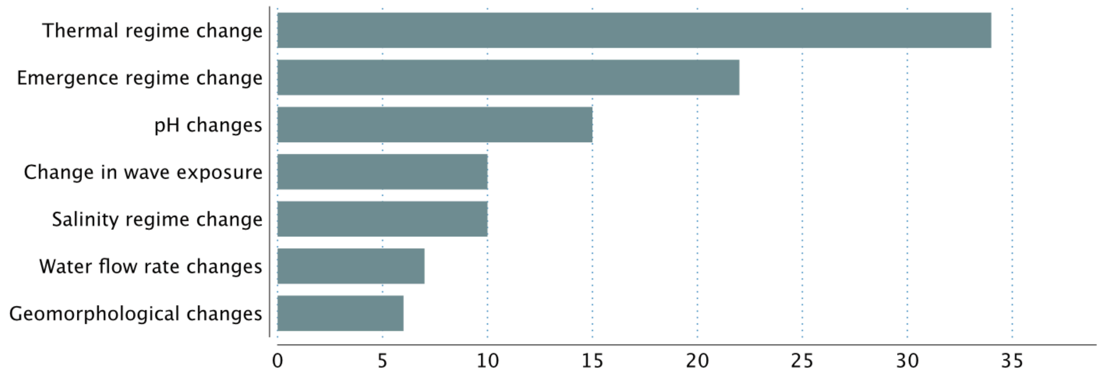

Figure 12. Mapped exogenous pressures in the Pressures Catalogue, in order of numbers of records.

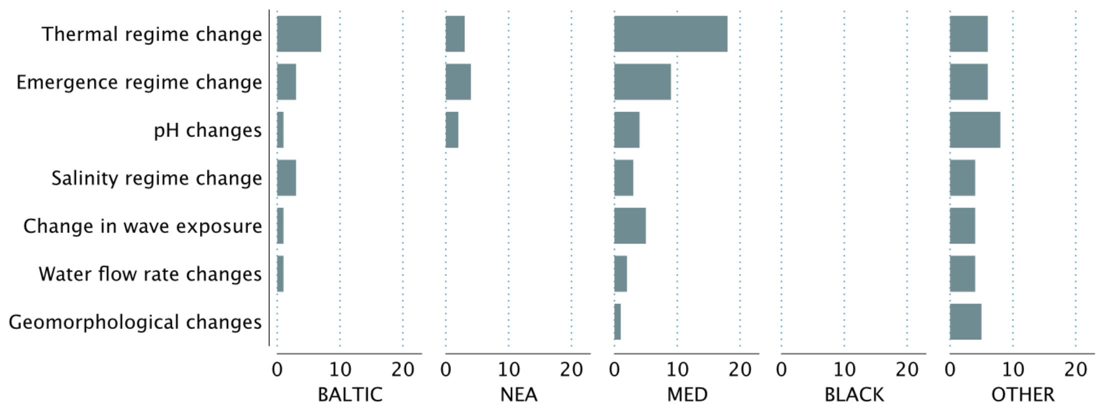

Figure 13. Mapped exogenous pressures in the Pressures Catalogue per geographic region, ranked by number of total records (BALTIC: Baltic Sea; NEA: North-East Atlantic; MED: Mediterranean Sea; BLACK: Black Sea; OTHER: Other regional sea).

4.2. The MERCES Key Habitats Pressure Activity Linkages

4.2.1. Key Habitat Descriptions

Full review descriptions for the case studies are given in Bekkby et al. (2017), MERCES D.1.1. Deliverable. In the following sections a short description of the case study habitats is given with focus on the reviewed activities, pressures and associated impacts acting on those habitats.

4.2.1.1 Mediterranean Sea, Baltic Sea and North Atlantic Ocean - Shallow soft – Seagrass meadows

Seagrass meadows are key ecosystems in soft-bottom coastal waters. Seagrasses depend on good environmental conditions such as clear waters, stable sediments, and suitable nutrients for successful growth, and are very vulnerable to anthropogenic pressures. Four native seagrass species are found in European waters: *Cymodocea nodosa, Posidonia oceanica, Zostera marina,* and *Zostera noltii.* They can be found both intertidally and subtidally up to 40 m depth and inhabit a wide range of salinity, ranging from the brackish waters (5‰) of the Baltic to 37‰ in Mediterranean waters. Seagrass play an important role in coastal ecosystems: they grow alongside algae and other plant species, support high associated biodiversity, and provide important ecological services. These include providing habitat and nursery areas for fish and invertebrates, as well as a food source for herbivores, contributing to the productivity of coastal areas by producing oxygen, supporting complex trophic networks, and playing a major role in carbon storage (Barbier et al., 2011; Cullen-Unsworth and Unsworth, 2013; Campagne et al., 2015; Nordlund et al., 2016). Seagrasses also filter freshwater discharges from land, reduce water movements thus stabilising sediments, and trap heavy metals and nutrient rich run-off, thus improving the water quality for the entire associated community.

Over their wide distribution range, seagrass meadows are prone to many pressures and activities, such as habitat loss, eutrophication, pollution, anchoring, invasive species, fishing, coastal development, aquaculture, dredging, energy generation including cables, transport, land-based industry, agriculture, tourism, defence (target shooting), natural disturbances, disease outbreaks, and climate change (Short and Wyllie-Echeverria, 1996; Short and Neckles, 1999; Milazzo et al., 2004; Orth et al., 2006; Boudouresque et al., 2009; Waycott et al., 2009; van der Heide et al., 2011), with seagrass experts agreeing that urban/industrial runoff, urban/port infrastructure development, agricultural runoff and dredging have the greatest impact on seagrasses (Grech et al., 2012). Seagrass losses have occurred around the world (approximately 30% of seagrasses have been lost globally; Waycott et al., 2009), and due to their important ecological role as ecosystem engineers, this has widespread repercussions for coastal ecosystems. Conservation measures, including protection of existent seagrass meadows, reduction of pressures, and restoration are necessary to ensure the continued existence of seagrass ecosystems (Orth et al., 2006).

4.2.1.2 North-East Atlantic Ocean (Norway) – Shallow hard – Kelp forest

Kelp forests are underwater forests formed by brown macroalgae in high densities/biomass. They have high production, biodiversity, functioning (e.g. Steneck et al., 2002; Smale et al., 2013) and ecosystem services (Gundersen et al., 2016), and provide food, shelter and habitat for many associated species, including sea mammals, seabirds, fish and invertebrates (e.g. Norderhaug et al., 2005; Christie et al., 2009). Kelp properties (e.g. growth, size, morphology) and the associated flora and fauna species vary with environmental conditions, such as wave exposure and ocean currents (Bekkby et al., 2014; Norderhaug et al., 2014). The kelp species *Laminaria hyperborea* and *Saccharina latissima* are amongst the habitat building species, building up the kelp forests dominating the shallow subtidal (down to ~30 m) rocky coasts of the North-East Atlantic. Kelp forests are extremely resilient to disturbances such as wave impacts and storm surges (Steneck et al., 2002). The resilience of kelp forests depends, amongst other things, on the biodiversity, contributing to robustness, stability and an ability to recover because enough species are available to "take over" if others are disturbed or lost. If an ecosystem's resilience is weakened due to pressures (e.g. over-fishing or eutrophication), a regime shift might happen, i.e. the ecosystem flips from one dynamic equilibrium level to another (Ling et al., 2009). Kelp forests are believed to be robust to human activities, such as *L. hyperborea* kelp harvesting in West Norway (Steen et al., 2016), but still large areas of *S. latissima* kelp have been lost in the southern part of Norway due to eutrophication effects (Bekkby and Moy, 2011; Moy and Christie, 2012), and various anthropogenic activities (aquaculture and fishing, renewable energy generation, transport, coastal development, agriculture, tourism). In other areas, *L. hyperborea* kelp forests are lacking due to pollution. The loss of kelp forests is a global phenomenon, occurring mainly due to destructive grazing by sea urchins in many areas (Steneck et al., 2002). In northern Norway, *L. hyperborea* has been impacted significantly by the grazing of sea urchins, though several areas are now recovering (Rinde et al., 2014), most likely due to a combination of temperature increase and increasing predatory pressure on the sea urchins (Fagerli et al., 2013, 2014).

4.2.1.3 Mediterranean Sea – Shallow hard – Macroalgal forests: Cystoseira

Macroalgal forests, such as kelps and fucoids, are dominant habitat-forming species in rocky intertidal and subtidal habitats around all the Mediterranean coasts. They are recognized hot spots of diversity, they provide food and habitat to diversified assemblages of understory species, and they enhance coastal primary productivity (Gianni et al., 2013; Gubbay et al., 2016; Cheminée et al., 2016). They are included in the EU Habitats Directive (92/43/EEC) under the generic habitat type "Reefs" (1180) and several Cystoseira species are protected according to the EU and Mediterranean legislation (i.e. Habitats Directive and Barcelona Convention). Macroalgal forests can thrive from the intertidal to the circalittoral (photosynthetic related limit) and they show a succession of different dominant species dwelling at each depth. Therefore, habitat features depend on the depth where macroalgae develop. Photophilic communities with canopy-forming algae in Mediterranean infralittoral and upper circalittoral rock were recently assessed as Endangered (EN) under the European Red List of Habitats (Gubbay et al., 2016).

In response to multiple stressors, pressures and activities, including urbanization and coastal development, eutrophication and increasing sediment loads in coastal areas, fishing, energy generation and other industries, transport, agriculture and tourism these habitats (shallow and deep) are being lost at alarming rates (Benedetti-Cecchi et al., 2001; Thibaut et al., 2005; Bermejo et al., 2016) and manipulative experiments have demonstrated that these systems may switch towards the dominance of algal turfs if the macroalgal canopy is removed or damaged (Benedetti-Cecchi, 1992a, b; Benedetti-Cecchi et al., 2015).

4.2.1.4 Mediterranean Sea – Shallow hard – Coralligenous assemblages

Coralligenous assemblages are hard bottoms of biogenic origin that are mainly produced by the accumulation of calcareous encrusting algae growing at low irradiance levels. Coralligenous assemblages harbour approximately 10% of Mediterranean marine species (Ballesteros 2007). Coralligenous assemblages extend around all Mediterranean coasts with a bathymetrical distribution ranging from 20 to 120 m depth depending on the local environmental variables, mainly light conditions (Ballesteros, 2007; Giakoumi et al., 2013; Martin et al., 2014). They are included in the EU Habitats Directive (92/43/EEC) under the generic habitat type "Reefs" (1170) and an Action Plan has been adopted by contracting parties of the Barcelona Convention specifically aiming at their conservation (UNEP-MAP-RAC/SPA, 2008). Infralittoral coralligenous bio-concretions were recently assessed as Near-Threatened (NT) under the European Red List of Habitats (Gubbay et al., 2016).

The main engineering key species involved in the construction of coralligenous concretions are long-lived with slow growth rates, including rhodophytes and sessile invertebrates, such as sponges, anthozoans, bryozoans and ascidians (Garrabou and Ballesteros, 2000; Ballesteros, 2006; UNEP-MAP-RAC/SPA, 2008; Teixidó et al., 2011).

Coralligenous assemblages are affected by several pressures, such as nutrient enrichment, invasive species, increase of sedimentation, mechanical impacts, climate change, and numerous anthropogenic activities including fishing, energy generation, transport, coastal and marine structure and infrastructure, land-based industry, agriculture, tourism, research and conservation activities (Ballesteros, 2006; Balata et al., 2007; Garrabou et al., 2009; Piazzi et al., 2012; Giakoumi et al., 2013; Martin et al., 2014; Gatti et al., 2015; Gubbay et al., 2016).

4.2.1.5 Azores – Deep-sea – Coral Gardens

Coral gardens are defined as dense single or multi-species aggregations of sessile, filter-feeding cold-water corals (CWC). CWCs include the anthozoan stony, soft and black corals and the hydrozoan hydrocorals (Roberts et al., 2009). Most species need a hard substratum for settlement and high currents to be able to find enough food input. They form structural habitats which include patches reefs, or carbonate mounds up to 380 m high (Mienis et al., 2006). CWCs can be found over a wide range of habitats and latitudes ranging from tropical to polar regions, and from shallow to the deep sea (Roberts et al., 2009). In the Azores, coral gardens are found in seamounts and island slopes, typically below 200 m depth, although the black coral *Antipathella wollastoni*, can occur at 20m deep (Braga-Henriques et al., 2013; Rakka et al., 2016). CWCs support high levels of biodiversity providing feeding, spawning and nursery areas for a wide range of organisms, including commercially important fish species (Buhl-Mortensen et al., 2010; Pham et al., 2015). Specific characteristics, particularly with regard to gorgonians and black corals, such as slow growth rates, long lifespan, low fecundity and larvae with potentially low dispersal capabilities (Roark et al., 2009; Watling et al., 2011) make them and the habitats they form vulnerable to impacts from human activities, such as fishing (bottom trawling and longlining), extraction of non-living resources (e.g. oil, gas and minerals), the potential development of Blue Growth activities, such as bio-prospecting and deep-sea mining, scientific research, marine litter, and the overall ocean warming and acidification (Freiwald et al., 2004, Roberts et al., 2009; Carreiro-Silva et al., 2013; Pham et al., 2014).

4.2.1.6 Deep-sea soft bottom communities

Open slopes

Slopes are the steep part of the continental margins connecting the continental shelf with the deep basins. The bathymetric gradient of slopes is characterised by sharp environmental gradients, such as temperature and food availability, high habitat heterogeneity and diverse communities (Levin and Sibuet, 2012). In spite of their restricted size (roughly 10 %, Ramirez-Llodra et al., 2010), slopes are very important ecosystems for the functioning of the oceans and the globe, offering important ecosystem goods and services, such as biological resources (finfish and shellfish), nutrient cycling, biodiversity, water circulation and exchange, energy transfer, and cultural services for educational and scientific point of views (Armstrong et al., 2010, 2012; Rogers et al., 2015). The most immediate threats for open slopes are related to several anthropogenic activities that include fishing, oil and gas exploitation, cable laying, pipeline construction, underwater noise and water pollution from shipping routes, waste dumping, drill cuttings from mining activities, and pollution from terrestrial sources (Armstrong et al., 2012, 2014; Benn et al., 2010; Ramirez-Llodra et al., 2011). The benthic responses to the effects of the disposal of litter and waste, fishing (trawling and longlining), oil and gas exploration and extraction have been documented at global ocean scale (Ramirez-Llodra et al., 2011), but also along the northern-western continental margins of the Mediterranean basin (Ramirez-Llodra et al., 2013; Pusceddu et al., 2014; Pham et al., 2014).

Submarine canyons

A submarine canyon is a steep-sided valley cut into the seabed of the continental slope, sometimes extending well onto the continental shelf, having nearly vertical walls. They are major and complex topographic systems that enhance the heterogeneity of continental slopes (Levin et al., 2010). Submarine canyons are major fast-track pathways for water, sediments, nutrients and pollutants passing from continental shelves to the deep ocean (Palanques et al., 2008, Pham et al., 2014, Puig et al., 2014, Amaro et al., 2015). Canyons show a wide variety of biodiversity levels, trophic interactions and ecosystem functions within each benthic components from microbes to megafauna (Ramirez-Llodra et al., 2013; Schlining et al., 2013; De Leo et al., 2014; Leduc et al., 2014; Ramalho et al., 2014; Amaro et al., 2015; Gambi and Danovaro, 2016). Submarine canyons offer different ecosystem goods and services, including biological resources (finfish and shellfish), habitat, nutrient cycling, enhance carbon sequestration and storage, biodiversity, water circulation and exchange, and cultural services for educational and scientific point of views (Epping et al., 2002; Canals et al., 2006; Masson et al., 2010; Armstrong et al., 2012, 2014; Rogers et al., 2015). Pressures from human activities include fishing, dumping of land-based mine tailings, and oil and gas extraction (Fernandez-Arcaya et al., 2017 and references therein). Moreover, hydrodynamic processes of canyons enhance the down-canyon transport of litter (Fernandez-Arcaya et al., 2017, and references therein).

Seamounts

Seamounts are mountains rising from the ocean seafloor that do not reach the water's surface. It is estimated that there are *ca.* 33,000 seamounts (with elevation >1000 m) and more than 138,000 knolls (elevation <1000 m) (Ramirez-Llodra et al., 2010; Harris and Whiteway, 2011; Yesson et al., 2011; Beaulie et al., 2015; Rogers et al., 2015). The percentage of seamounts investigated is very low (Rogers et al., 2015). The physical effects of the presence of seamounts have been summarized in the theory of ‘seamount effects’ that includes local, small- and mesoscale phenomena, turbulent mixing on the benthic boundary layers and regional up- or down-welling processes (Dieckman et al., 2006). All these factors may enhance local primary and secondary production, and community structure above the seamounts (Dower and Mackas, 1996). Seamounts are characterised by heterogeneous geophysical settings, hence, not all seamounts are expected to affect the surrounding ecosystems in the same way but because of their unique characteristics, seamounts may be viewed as ‘oases’ in the abyssal basins (Kvile et al., 2014). Seamounts offer important ecosystem goods and services such as biological resources, nutrient cycling, biodiversity, habitat, and cultural services for education and science (Rogers et al., 2015). Major existing and future human activities on seamount habitats are fishing, rock-drilling, gas and oil exploitation, deep-sea mining, and climate change. Trawling, in particular, physically destroys reef-building organisms (Williams et al., 2010), disturbs the filter feeding communities by sediment re-suspension (Clark et al., 2010), and selectively removes long-lived commercially valuable fish species (Pitcher, 2010) that are extremely vulnerable to heavy fishing (Morato et al., 2006).

Deep-sea Basins

Deep-sea basins are plains on the deep ocean floor, usually found at depths between 3000 and 6000 m, lying generally between the foot of a continental rise and a mid-ocean ridge. They represent the largest biome on our planet, covering 75% of the ocean floor (Danovaro et al., 2014). With less than 1% investigated (Rogers et al., 2015), this ecosystem is much more temporally and spatially variable than previously thought (Lampitt et al., 2010; Pusceddu et al., 2010, 2013; Rex and Etter, 2010). A global-scale study reports that deep-sea ecosystem functioning is positively exponentially related to deep-sea biodiversity, suggesting that a minor biodiversity loss in deep-sea ecosystems might be associated with exponential reductions of their functions (Danovaro et al., 2008a, b). Deep-sea ecosystems offer several benefits to human well-being (Armstrong et al 2012), including oil, gas, mineral, and living resources; chemical compounds for industrial, biotechnology, and pharmaceutical uses; carbon capture and storage; and cultural services such as education and scientific research (Van Dover et al., 2014). Deep-sea basins are subjected to several activities such as oil and gas exploitation, cable laying, pipeline construction, underwater noise, waste dumping, litter, drill cuttings from mining activities (Armstrong et al., 2014; Benn et al., 2010; Ramirez-Llodra et al., 2011, 2013). Many deep-sea activities are likely to increase globally over the next decades, such as mining activities for deep-sea resources like rare earth metals (e.g. gold, copper, zinc, and cobalt), and hydrocarbons (e.g. oil, gas, gas hydrates) (Kato et al., 2011; Ramirez-Llodra et al., 2011).

4.2.2. Case Studies: Habitats Responses to Activities and Pressures

4.2.2.1. Activities and Pressures

The 13 activities examined here are representative of the full spectrum of human uses of the marine and coastal environment and correspond to major societal needs and economic sectors. From the generic linkage table (Table 4) it is evident that the majority of those activities produce numerous pressures of different types (Table 5). At least 10 pressures are produced by all of the activities, while several activities produce multiple pressures. The top three activities in terms of numbers of linked pressures are “coastal and marine structure and infrastructure”, “land-based industry” and “tourism/recreation”. The activity with the lowest number of linked pressures is carbon sequestration. All examined activities produce physical pressures both causing damage and other disturbances, as well as chemical pressures with introductions and inputs of various substances and compounds (ranging from pesticides, to fertilizers and discards). However, a few activities are usually not expected to produce biological or hydrological pressures commonly or beyond a very local scale level. For example, energy generation and resource extraction do not produce many biological and hydrological pressures (such as introduction of microbial pathogens or water flow changes respectively) while producing many physical pressures. In a smaller fine scale application of this generic table there could be more pressures present at certain habitats (see section below). Smothering, introduction of synthetic and non-synthetic compounds and litter are the 4 pressures linked with all the examined activities. These 4 pressures along with the changes in siltation and light regime and the aesthetic pollution are the most frequently linked pressures to the activities examined.

Table 4. Generic linkage table showing expected pressures by activity, a matrix of 13 activities x 26 pressures. Pressures are grouped into 5 categories: physical damage (pink), other physical damage (yellow), chemical (lavender), biological (green) and hydrological (blue).

Pressure presence/absence - generic example	Physical damage					Other physical						Chemical						Biological			Hydrological					
Activity	Smothering	Substratum loss	siltation and light regime	Abrasion	extraction of non-living resources	Noise	Litter	Aesthetic pollution	Collision	Barrier to species movement	Electromagnetic changes	Introduction of synthetic	Introduction of non-synthetic	Introduction of radionuclides	Introduction of other substances	N and P enrichment	Input of organic matter	microbial pathogens	non-indigenous species	extraction of species	Thermal regime change	Salinity regime change	Emergence regime change	Water flow rate changes	pH changes	Change in wave exposure
Production of living resources	1	1	1	1	0	1	1	1	0	0	0	1	1	0	0	1	1	1	1	0	0	0	0	1	1	1
Extraction of living resources	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	1	0	1	1	0	0	0	0	0	0
Transport	1	1	1	1	0	1	1	1	1	0	0	1	1	0	0	0	1	1	1	0	0	0	0	0	0	0
Renewable energy generation	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	1	0	0	0	0	0	0	1	0	1
Non-renewable energy generation	1	1	1	1	1	1	1	1	0	0	1	1	1	1	0	0	0	0	0	0	1	1	0	0	0	1
Extraction of non-living resources	1	1	1	1	1	1	1	1	1	0	0	1	1	0	0	0	0	0	0	1	0	0	0	0	0	0
Coastal and marine structure and Infrastructure	1	1	1	1	1	1	1	1	0	1	1	1	1	0	0	0	0	0	1	0	0	1	1	1	1	1
Land-based Industry	1	0	1	0	0	0	1	1	0	1	0	1	1	0	1	1	1	1	1	0	1	1	0	1	1	1
Agriculture	1	0	1	0	0	0	1	1	0	0	0	1	1	0	0	1	1	1	0	0	1	1	0	0	1	0
Tourism/ recreation	1	1	1	1	1	1	1	1	1	0	0	1	1	0	0	1	1	1	1	1	0	0	0	0	0	1
Defense and national security	1	1	1	1	0	1	1	1	1	1	0	1	1	1	1	1	0	0	1	0	0	0	0	0	0	0
Research and conservation	1	1	1	1	1	1	1	1	1	0	0	1	1	1	1	0	1	0	1	1	0	0	0	1	0	0
Carbon Sequestration	1	1	0	1	1	1	1	0	0	0	0	1	1	0	1	0	0	0	0	0	0	1	0	0	1	0

Table 5. Types of pressures arising by each activity based on the generic linkage table (Table 4).

Activity	Type (group) of Pressures present at the generic example				
	physical	other physical	chemical	biological	hydrological
Production of living resources	1	1	1	1	1
Extraction of living resources	1	1	1	1	0
Transport	1	1	1	1	0
Renewable energy generation	1	1	1	0	1
Non-renewable energy generation	1	1	1	0	1
Extraction of non-living resources	1	1	1	1	0
Coastal and marine structure and Infrastructure	1	1	1	1	1
Land-based Industry	1	1	1	1	1
Agriculture	1	1	1	1	1
Tourism/ recreation	1	1	1	1	1
Defense and national security	1	1	1	1	0
Research and conservation	1	1	1	1	1
Carbon Sequestration	1	1	1	0	1

4.2.2.2. The case study examples, activities and pressures

From the case study habitat examples (Table 6 to Table 11) it is evident that the number of activities impacting each habitat differs significantly with the highest number of activities present in shallow soft areas and the lowest number present in the deep-sea habitats. All types (groups) of pressures are present as mechanisms of change, although not all activities produce all types (Table 5); whilst the physical pressures are always present, most activities produce only 2-3 types of pressure.

"Extraction of living resources", "transport", "coastal and marine structure and infrastructure" as well as "research and conservation" are present in all the studied key habitat examples, whilst, "land-based industry", "tourism/recreation", "renewable energy generation" and "agriculture" additionally operate in all the shallow soft and hard habitats. All of the key habitats examined feature at least one existing or future blue growth focus area (e.g. aquaculture, renewable energy generation or mining) and blue economy activity (e.g. fishing). Almost all of the pressures examined are present within shallow seagrass habitats, and several (e.g. smothering, changes in siltation and light, substratum loss, litter) appear to derive from multiple, often co-occurring, activities. Most pressures are produced by "coastal and marine structure and infrastructure" and "land based industry" and the least by "agriculture". All 5 types of pressures are present in seagrass habitats overall, although they do not always occur together, i.e. they are not produced by all the activities or concurrently. This is also true for the 3 shallow hard habitats, regardless of the lower number of activities and pressures operating there. "Changes in siltation and light regime", "introduction of synthetic and non-synthetic compounds" and "input of organic matter and litter" are the most frequent pressures for the shallow hard habitats algal forests and the coralligenous, whereas "changes in siltation and light regime", "smothering" and "litter" are present in the shallow hard kelp habitat example. "Abrasion", "substratum loss" and "litter" occur most often in the deep-sea example as they are generated by the majority of activities operating in that area (Table 10). All types of pressures are present overall, although most activities induce only 2-3 types, with the physical pressures always being present.

Table 6. Number of pressures arising by each activity as they operate in 5 habitat examples. Sh-soft seagr: shallow soft seagrass meadows, sh-hard kelp: NE Atlantic kelp forests, sh-hard corall: shallow hard coralligenous assemblages in the Mediterranean Sea, sh-hard Algal f: Mediterranean Sea macroalgal forests, shallow and deep *Cystoseria* species, deep sea: coral gardens of the Azores and Mediterranean deep-sea soft sediment communities.

Activity	No of Pressures/specific habitat example				
	sh-soft seagr	sh-hard kelp	sh-hard corall	sh-hard Algal f	deep-sea
Production of living resources	9	5			
Extraction of living resources	8	5	8	10	6
Transport	7	1	8	8	1
Renewable energy generation	7	5	7	8	
Non-renewable energy generation	7				6
Extraction of non-living resources	6				7
Coastal and marine structure and	12	10	8	11	4
Land-based Industry	12	10	11	14	
Agriculture	4	5	7	8	
Tourism/ recreation	9	7	8	11	
Defense and national security	8				1
Research and conservation	10	3	9	10	5
Carbon Sequestration					3
Pressures Total	21	17	18	19	14

Tables 7-11 provide a synthesis of expected pressure effects by major predominant activity operating in each of the selected habitat case study examples. Tables 7-11 also provide information on the resulting consequences for restoration while also advising on the required management of combined Activity x Pressure effects with specific reference to mitigation or restoration actions. Effects include numerous changes in the abiotic environment in ambient water and sediment parameters as well as numerous changes in biology, biotic processes and species interactions. Consequences include various forms of habitat degradation and damage to fauna and flora, impacts on key features such as dynamics, connectivity, loss of structural complexity and resilience and changes in species composition and ecosystem function.

Mitigation or restoration actions include; restriction of inputs (e.g. nutrients, organics, fertilizers, discharges, debris, other substances needed for example for disease control), spatio-temporal considerations for structures (such as those of fish farms) to reduce, remove or place elsewhere, carry out activities in areas that recover quickly, reduce barrier effects, reduce disturbances and ensure disturbances do not disrupt connectivity, reduction of impacts (through for example technical modifications reducing contact or application of best practices), removal of invasive species, regulate activity, reduce activity (spatio-temporal limitations, closures, bans), avoid overlap of activities with restoration projects, reduce, control or remove the pressure (e.g. for litter, sound, aliens), and finally eliminate activity is the answer in many cases. No restoration suggestions are given (e.g. restore a specific habitat/species with a particular method as it was not the aim of this deliverable), but spatial considerations are provided of where best to place restoration projects, i.e. away from almost all the activities and impacts such as from runoff areas, fish farms, cables, energy projects, mining sites, structures.

Table 7. The shallow soft seagrass case study example, showing expected pressures by activity operating in the habitat, expected impacts and effects on the ecosystem, consequences relevant to restoration and restoration and mitigation actions.

Activity	Pressure	Impact and effect on the ecosystem	Consequences	Restoration or Mitigation actions
Production of living resources	Smothering	loss of seagrass from installation of anchors and structures	loss of seagrass, increased patchiness and decreased patch size, decreased connectivity	focus restoration on areas away from fish farms, or move fish farms away from seagrass meadows to bare sand areas.
	Substratum loss	loss of seagrass from installation of anchors and structures	loss of seagrass, increased patchiness and decreased patch size, decreased connectivity	focus restoration on areas away from fish farms, or move fish farms away from seagrass meadows to bare sand areas.
	Changes in siltation/light	decreased growth due to shading from fish farms or bivalve lines	shading causes decreased growth and primary production of meadows	focus restoration on areas away from fish farms, or move fish farms away from seagrass meadows to bare sand areas.
	Litter	debris from farms or lines	debris can cause local damage to seagrass plants or associated species	reduce debris from boats and farms, move restoration efforts away from immediate area. clean litter up before restoration.
	N and P enrichment	nutrient enrichment from fertilizers used in fish farms leads to algal blooms	overgrowth of algae can decrease seagrass growth and primary production, and cause mortality, while phytoplankton blooms can reduce turbidity	reduce nutrient inputs from fish farms by using more modern and efficient farming techniques, different fertilizers,
	Input of organic matter	enrichment from fertilizers in fish farms and fecesfrom fish and bivalves	organic matter can stimulate algal overgrowth and phytoplankton blooms	reduce nutrient inputs from fish farms by using more modern and efficient farming techniques, different fertilizers,
	Intr. of microbial pathogens	pathogens from fish or bivalves could infect those in seagrass meadows	loss of fish species could alter trophic levels and create trophic cascades	more efficient farming techniques to reduce disease
	Intr. of non-indigenous species	introduction of fish and bivalves could affect native species in seagrass meadows	invasive species could outcompete important native species and cause shifts in trophic netowkrs	restore near fish farms raising native fish only
	Water flow rate changes (local)	installations can affect water movement and local currents	modified currents can either increase sedimentation or increase erosion	move fish farms, or concentrate restoration efforts away from the immediate area
Extraction of living resources	Smothering	sedimentation due to trawling, traps on bottom	smothering by sediment can reduce growth and cause loss of seagrass	fishing bans in restoration areas
	Substratum loss	seagass loss due to bottom trawling, bottom fishing, or anchor lines	loss of seagrass, increased patchiness and decreased patch size, decreased connectivity	fishing bans in restoration areas
	Changes in siltation/light	sedimentation due to trawling, traps on bottom	increases sedimentation decreases light availability and growth/primary productivity	fishing bans in restoration areas
	Abrasion	seargass loss due to dredging, bottom fishing, or anchor lines	loss of seagrass, increased patchiness and decreased patch size, decreased connectivity	fishing bans in restoration areas
	Litter	debris falling from fishing boats, ghost lines and traps, etc.	debris can cause local damage to seagrass plants or associated species	fishing bans in restoration areas. clean litter up before restoration.
	Intr. of non-synthetics	oil spills from fishing boats	oil or fuel spills can affect mobile species living in seagrass meadows such as fish or birds, as well as benthic organisms in the substrate	
	Input of organic matter	fish bycatch or waste from fishing boats	organic matter can stimulate algal overgrowth and phytoplankton blooms	fishing bans in restoration areas
	Selective extraction of species	removal of predatory fish or important invertebrate species	removal of species alters food webs and can cause trophic cascades	fishing bans in restoration areas
Transport	Substratum loss	loss of seagrass from dredging	loss of seagrass, increased patchiness and decreased patch size, decreased connectivity	fishing bans in restoration areas
	Changes in siltation/light	sedimentation from dredging	increased turbidity from sedimentation leads to decreased growth of seagrass	fishing bans in restoration areas
	Abrasion	loss of seagrass from dredging	loss of seagrass, increased patchiness and decreased patch size, decreased connectivity	fishing bans in restoration areas
	Noise	noise in shipping lanes may affect seagrass associated species	loss of some higher trophic level species may cause trophic cascades	fishing bans in restoration areas

Table 7. The shallow soft seagrass case study example (continued)

Activity	Pressure	Impact and effect on the ecosystem	Consequences	Restoration or Mitigation actions
	Intr. of non-synthetics	oil spills from boats	oil or fuel spills can affect mobile species living in seagrass meadows such as fish or birds, as well as benthic organisms in the substrate	fishing bans in restoration areas
	Litter	debris falling from boats	debris can cause local damage to seagrass plants or associated species	clean litter up before restoration.
	Intr. of non-indigenous species	introduction of invasive species on ship hulls and ballast waters may affect seagrass-associated species	invasive species could outcompete important native species and cause shifts in trophic netowrks	fishing bans in restoration areas
Renewable energy generation	Smothering	loss of seagrass from installation of structures (wind/tidal turbines)	loss of seagrass, increased patchiness and decreased patch size, decreased connectivity	ensure energy projects are located away from existing seagrass meadows, and concentrate restoration areas away from energy projects
	Substratum loss	loss of seagrass from installation of structures (wind/tidal turbines)	loss of seagrass, increased patchiness and decreased patch size, decreased connectivity	ensure energy projects are located away from existing seagrass meadows, and concentrate restoration areas away from energy projects
	Changes in siltation/light	shading from structures	shading causes decreased growth and primary production of meadows	ensure energy projects are located away from existing seagrass meadows, and concentrate restoration areas away from energy projects
	Abrasion	loss of seagrass from installation of structures (wind/tidal turbines)	loss of seagrass, increased patchiness and decreased patch size, decreased connectivity	ensure energy projects are located away from existing seagrass meadows, and concentrate restoration areas away from energy projects
	Barrier to species movement	structures may impede migrating and spawing fish in seagrass meadows	decreased fish abundance in meadows can cause trophic cascades	ensure passages for species and connectivity between habitats (e.g. by placing structures further apart, or constructing artificial passages)
	Water flow rate changes (local)	structures may cause changes in local currents	increased or decreased currents may increase sedimentation or increase erosion	conduct restoration away from immediate area of structures
	Change in wave exposure (local)	structures may cause changes in currents and waves	increased wave exposure could increase erosion and disturbances, while decreased wave exposure could cause increased sedimentation	conduct restoration away from immediate area of structures
Non-renewable energy generation	Smothering	loss of seagrass from structures near power stations (piers, pipes, etc.)	loss of seagrass, increased patchiness and decreased patch size, decreased connectivity	ensure any new structures are located away from seagrass meadows, and place restoration projects away from existing structures
	Substratum loss	loss of seagrass from structures near power stations (piers, pipes, etc.)	loss of seagrass, increased patchiness and decreased patch size, decreased connectivity	ensure any new structures are located away from seagrass meadows, and place restoration projects away from existing structures
	Changes in siltation/light	shading from power station structures	shading causes decreased growth and primary production of meadows	ensure any new structures are located away from seagrass meadows, and place restoration projects away from existing structures
	Thermal regime change	warm water runoff from power plants	increased or decreased growth of seagrass or filamentous algae	locate restoration projects away from runoff areas
	Salinity regime change	freshwater runoff from power plants	decreased growth of marine seagrasses but increased growth of estuarine plants	locate restoration projects away from runoff areas
	Change in wave exposure (local)	changes in waves from structures	increased wave exposure could increase erosion and disturbances, while decreased wave exposure could cause increased sedimentation	locate restoration projects away from structures
Extraction of non-living resources	Smothering	seagrass loss from dredging and/or mining	loss of seagrass, increased patchiness and decreased patch size, decreased connectivity	ban mining or dredging within restoration areas, locate restoration projects away from active mining sites
	Substratum loss	seagrass loss from dredging and/or mining	loss of seagrass, increased patchiness and decreased patch size, decreased connectivity	ban mining or dredging within restoration areas, locate restoration projects away from active mining sites

Table 7. The shallow soft seagrass case study example (continued)

Activity	Pressure	Impact and effect on the ecosystem	Consequences	Restoration or Mitigation actions
	Changes in siltation/light	increased sedimenation from dredging	increased turbidity from sedimentation leads to decreased growth of seagrass	ban mining or dredging within restoration areas, locate restoration projects away from active mining sites
	Abrasion	seagrass loss from dredging and/or mining	loss of seagrass, increased patchiness and decreased patch size, decreased connectivity	ban mining or dredging within restoration areas, locate restoration projects away from active mining sites
	Selective extraction of non-living resources	loss of sand substrate	loss of seagrass, increased patchiness and decreased patch size, decreased connectivity	ban mining or dredging within restoration areas, locate restoration projects away from active mining sites
	Water flow rate changes (local)	changes in depth from dredging cause changes in currents and hydrodynamics	depth changes can affect local currents, which control sedimentation and erosion	ban mining or dredging within restoration areas, locate restoration projects away from active mining sites
Coastal and marine structure and infrastructure	Smothering	loss of seagrass from installation of structures	loss of seagrass, increased patchiness and decreased patch size, decreased connectivity	limit development and structure building in seagrass meadows and restoration areas
	Substratum loss	loss of seagrass from installation of structures	loss of seagrass, increased patchiness and decreased patch size, decreased connectivity	limit development and structure building in seagrass meadows and restoration areas
	Changes in siltation/light	shading from structures	shading causes decreased growth and primary production of meadows	limit development and structure building in seagrass meadows and restoration areas
	Abrasion	loss of seagrass from installation of structures	loss of seagrass, increased patchiness and decreased patch size, decreased connectivity	limit development and structure building in seagrass meadows and restoration areas
	Selective extraction of non-living resources	loss of substrate from dredging	loss of seagrass, increased patchiness and decreased patch size, decreased connectivity	limit development and structure building in seagrass meadows and restoration areas
	Noise	noise could affect species living in seagrass meadows	changes in species composition could affect trophic networks	limit development and structure building in seagrass meadows and restoration areas
	Litter	debris from piers, boats, docks	debris can cause local damage to seagrass plants or associated species	limit development and structure building in seagrass meadows and restoration areas. clean litter up before restoration and at regular intervals.
	Barrier to species movement	structures prevent fish spawning or migration	decreased fish abundance in meadows can cause trophic cascades	create connections between habitats (either natural or artificial)
	Intr. of non-synthetics	runoff and oil spills	oil or fuel spills can affect mobile species living in seagrass meadows such as fish or birds, as well as benthic organisms in the substrate	limit development and structure building in seagrass meadows and restoration areas
	Emergence regime change (local)	artificial islands, filling, and dredging changing depths	changing depths can alter intertidal regimes for intertidal species, increasing or decreasing their emergence stress	limit development and structure building in seagrass meadows and restoration areas
	Water flow rate changes (local)	breakwaters, piers and dredging changing hydrodynamics and local currents	changing currents can alter sedimentation and erosion	locate restoration areas away from immediate area
	Change in wave exposure (local)	breakwaters, piers, and dredging modifying wave exposure	altered wave regimes can affect sedimentation and erosion	locate restoration areas away from immediate area
Land-based industry	Smothering	industrial building discharges can contain suspended organic matter	smothering of seagrass can cause death of meadows	reducing discharges, restoring areas away from discharge water, preventing building in areas close to seagrass meadows
	Changes in siltation/light	industrial building discharges can limit light	light limitation can cause weakening and decreased growth	reducing discharges, restoring areas away from discharge water, preventing building in areas close to seagrass meadows
	Litter	will limit light, result in habitat lost smother	local damage and smothering to seagrass	clean litter up before restoration.

Table 7. The shallow soft seagrass case study example (continued)

Activity	Pressure	Impact and effect on the ecosystem	Consequences	Restoration or Mitigation actions
	Intr. of synthetics	industrial building discharges full of synthetic compounds effects the physiology of the meadow.	can limit reproductive success, slow growth, increase stress and mortality	reducing discharges, restoring areas away from discharge water, preventing building in areas close to seagrass meadows
	Intr. of non-synthetics	industrial building discharge full of non-synthetic compounds	can limit reproductive success, slow growth, increase stress and mortality	reducing discharges, restoring areas away from discharge water, preventing building in areas close to seagrass meadows
	N and P enrichment	inductrial discharge full of n and p will result with plankton blooms	plankton blooms will limit light, change the biochemical parameters. may increase the growth rate for a while but in the long run will harm seagrass through shading and overgrowth	reducing discharges, restoring areas away from discharge water, preventing building in areas close to seagrass meadows
	Input of organic matter	plankton blooms increase which limits light	plankton blooms will limit light, change the biochemical parameters. may increase the growth rate for a while but in the long run will harm seagrass through shading and overgrowth	reducing discharges, restoring areas away from discharge water, preventing building in areas close to seagrass meadows
	Thermal regime change	cooling water discharge will change local temperature	can limit reproductive success, slow growth, increase stress and mortality	reducing discharges, restoring areas away from discharge water, preventing building in areas close to seagrass meadows
	Salinity regime change	industrial building discharges rich in ions changes salinity	can limit reproductive success, slow growth, increase stress and mortality	reducing discharges, restoring areas away from discharge water, preventing building in areas close to seagrass meadows
	Water flow rate changes (local)	structures affect currents	shift in erosion or sedimentation rates	restore areas away from structures, prevent building near seagrass meadows
	Change in wave exposure (local)	structures can affect wave exposure	shift in erosion or sedimentation rates, damage to leaves	restore areas away from structures, prevent building near seagrass meadows
Agriculture	Changes in siltation/light	run off water from over irrigation can high amounts of silt	light limitation can cause weakening and decreased growth	reducing discharges, restoring areas away from discharge water.
	Litter	debris from runoff	local damage and light limitation	clean litter up before restoration.
	N and P enrichment	n and p (fertilizers) from contaminated run off water from over irrigation can result in planktonand filamentous algal blooms blooms	plankton blooms will limit light, change the biochemical parameters. may increase the growth rate for a while but in the long run will harm seagrass through shading and overgrowth	reducing discharges, restoring areas away from discharge water, reduce the amount of fertilizers used in farmlands
	Input of organic matter	organic matter from runoff water with high nutrient content	plankton blooms will limit light, change the biochemical parameters. may increase the growth rate for a while but in the long run will harm seagrass through shading and overgrowth	reducing discharges, restoring areas away from discharge water, reduce the amount of fertilizers used in farmlands
Tourism/ recreation	Smothering	clearing activities	silt and substrate can smother meadows, cause seagrass habitat loss.	reduce activites in seagrass meadows. enact protection measures reducing access
	Substratum loss	substratum destruction due to clearing or building structures	loss of seagrass habitat	reduce activites in seagrass meadows. enact protection measures reducing access
	Changes in siltation/light	floating decks or platforms, clearing activities	clearing activities change the siltation, limit light availability. floating platforms also limit light avaliablity. these will limit growth and reproduction, increase stress.	reduce activites in seagrass meadows. enact protection measures reducing access
	Abrasion	clearing activities	continues clearing damages the meadows	reduce activites in seagrass meadows. enact protection measures reducing access
	Litter	littering by tourists and recreational activities from boat tours, at beaches	can smother and damage meadows	clean litter up before restoration and at regular intervals.
	N and P enrichment	excessive use of detergents, cleaning agents and sewer systems by hotels and recreational places	nutrient enrichment causes algal blooms, decreases seagrass growth.	reduce discharges in seagrass meadows. restore in areas away from discharges

Table 7. The shallow soft seagrass case study example (continued)

Activity	Pressure	Impact and effect on the ecosystem	Consequences	Restoration or Mitigation actions
	Input of organic matter	organic matter input by hotels and recreational places increases the nutrient levels in water	increases phytoplankton blooms, inhibits light penetration thus photosynthesis	reduce discharges in seagrass meadows. restore in areas away from discharges
	Selective extraction of species	recreational fishing, marine aquariums, scuba diving	decreased biodiversity, shifts in trophic structure	fishing bans in restoration areas.
	Change in wave exposure (local)	clearing activities, construction of structures	lost in natural wave barriers, exposing meadows to erosion. changes sedimentation and erosion	restore areas away from structures, prevent building near seagrass meadows
Defense and national security	Smothering	using underwater weaponry	can damage and weaken meadows	reduce activities in seagrass meadows.
	Substratum loss	destruction due to explosions	use of explosives will damage and destroy softbottom substratum	reduce activities in seagrass meadows.
	Noise	excessive ship traffic	can affect species living in seagrass	restore in undisturbed areas.
	Intr. of synthetics	pollution, e.g. chemical spills	damage to seagrass meadows and associated species	better prevention of spills
	Intr. of non-synthetics	pollution, e.g. oil spills	damage to seagrass meadows and associated species	better prevention of spills
	N and P enrichment	nitrogen or phosphorus based weaponry	excess nitrogen or phosphorus will cause blooms and limit photosynthesis, growth, increase stress	redice discharges. restore in areas away from discharges.
	Litter	litter from ships	damage seagrass habitat	clean litter up before restoration and at regular intervals.
	Barrier to species movement	construction of structures	blocks seagrass dispersal, migration of associated species	reduce activities in seagrass meadows. create connections between habitats (natural or artificial)
Research and conservation	Smothering	substratum smothering for experimental purposes	loss of seagrass habitat	reduce disturbances and ensure disturbances do not disrupt connectivity. do not perform destructive sampling in newly restored areas.
	Substratum loss	substratum destruction for experimental purposes	during destructive samplings sustratum loss will effect seagrass and weaken, result in barren patches	reduce disturbances and ensure disturbances do not disrupt connectivity. do not perform destructive sampling in newly restored areas.
	Changes in siltation/light	during experimental activities light limitation	light limitation can cause weakening and stress, inhibits photosynthesis	reduce disturbances and ensure disturbances do not disrupt connectivity. do not perform destructive sampling in newly restored areas.
	Abrasion	abrasions due to sampling	destructive sampling will weaken, vulnerable to diseases	reduce disturbances and ensure disturbances do not disrupt connectivity. do not perform destructive sampling in newly restored areas.
	Selective extraction of non-living resources	removal of substrate for experimental purposes	can destroy some seagrass habitat	reduce disturbances and ensure disturbances do not disrupt connectivity. do not perform destructive sampling in newly restored areas.
	Intr. of synthetics	Intr. of synthetics for experimental activities	synthetic compound introduction for experimental proposes might have effects in the long run.	ensure proper clean up and removal of substances in the field.
	Litter	leftover experiment material or structures	can damage seagrass, decrease light availability and growth.	clean litter up before restoration and at regular intervals.
	Selective extraction of species	collection of specific species from the environment for research purposes (lab/aquarium research, transplantion, etc.). removal of invasive species.	removal of native species in large numbers could affect trophic networks. removal of invasive species is beneficial for the meadow.	pulling out invasive species prior to restoration.
	Water flow rate changes (local)	structures may limit flow	changes in erosion and sedimentation	remove structures after the end of experiments. limit the amount of structures, especially in restored meadows.

Table 8. The shallow hard kelp case study example, showing expected pressures by activity operating in the habitat, expected impacts and effects on the ecosystem, consequences relevant to restoration and restoration and mitigation actions.

Activity	Pressure	Impact and effect on the ecosystem	Consequences	Restoration or Mitigation actions
Production of living resources	Changes in siltation/light	aquaculture facilities may impose a shadowing effect	reduces lower growth limit	eliminate activity, place facility in none-kelp areas
	N and P enrichment	nutrient enrichment from fertilizers used in fish farms leads to algal blooms	overgrowth of turf algae can decrease kelp growth and primary production, cause mortality, may reduce the lower growth limit	reduce nutrient inputs from fish farms by using improved methods for feeding and farming
	Input of organic matter	enrichment from fertilizers in fish farms and faeces from fish and bivalves	organic matter can stimulate algal overgrowth of kelp, ocean darkening	reduce nutrient inputs from fish farms by using improved methods for feeding and farming
	Intr. of microbial pathogens	pathogens from fish or bivalves could infect those in kelp forests	loss of fish species may create trophic cascades	more efficient farming techniques to reduce disease
	Intr. of non-indigenous species	introduction of non-indigenous species or farming them in an area they normally do not live could affect native species in the kelp forest	foreign species could outcompete important native species and cause shifts in trophic netwokrs	raising native species only
Extraction of living resources	Smothering	damaging kelp and associated flora and fauna (from e.g. fish trawling)	total and partial mortality of organisms, loss of density and cover, loss of diversity	eliminate activity, carry out the activity in areas that recover quickly
	Changes in siltation/light	altering environmental characteristics, impacting growth	regrowth of a more homogenous kelp forest (because of kelp trawling removing the whole canopy)	eliminate activity
	Abrasion	removing/destroying the kelp forest (kelp trawling)	total removal of kelp, loss of associated flora and fauna species, both abundance and diversity, reducing genetic connectivity, loss of structural complexity;	eliminate activity, carry out the activity in areas that recover quickly, reduce barrier effects
	Selective extraction of species	predation removal (e.g. sea urchins), removal of kelp	incresing kelp growth and recovery when removng urchins, loss of kelp as associated flora and faune when kelp trawling	regulate activity
	Barrier to species movement	reducing connectivity between kelp forest areas and between kelp forest and other habitats (such as seagrass meadows inside of kelp forests)	loss of genetic connectivity, loss of resilience (ability to recover from disturbances)	eliminate activity, reduce barriers, carry out the activity in areas that recover quickly
Transport	Smothering	mooring, dredging etc. may removing/destroy kelp forests	loss of associated flora and fauna species, both abundance and diversity, reducing genetic connectivity, loss of structural complexity	eliminate activity, carry out the activity in areas that recover quickly
Renewable energy generation	Smothering	constructions may destroy kelp forests	loss of associated flora and fauna species, both abundance and diversity, reducing genetic connectivity, loss of structural complexity	eliminate activity, carry out the activity in areas that recover quickly
	Substratum loss	removing/destroying habitat	loss of associated flora and fauna species, both abundance and diversity, reducing genetic connectivity, loss of structural complexity	eliminate activity, carry out the activity in areas that recover quickly
	Barrier to species movement	reducing connectivity between kelp forest areas and between kelp forest and other habitats (such as seagrass meadows inside of kelp forests)	loss of genetic connectivity, loss of resilience (ability to recover from disturbances)	eliminate activity, reduce barriers, carry out the activity in areas that recover quickly
	Water flow rate changes (local)	change in water flow characteristics	change in kelp growth and species composition (of kelp and associated flora and fauna species)	eliminate activity or place it in order to impact the water flow as little as possible
	Change in wave exposure (local)	change in wave exposure level	change in kelp growth and species composition (of kelp and associated flora and fauna species)	eliminate activity or place it in order to impact the wave exposure as little as possible

Table 8. The shallow hard kelp case study example (continued)

Activity	Pressure	Impact and effect on the ecosystem	Consequences	Restoration or Mitigation actions
Coastal and marine structure and Infrastructure	Smothering	constructions may destroy kelp forests	loss of associated flora and fauna species, both abundance and diversity, reducing genetic connectivity, loss of structural complexity	eliminate activity, carry out the activity in areas that recover quickly
	Substratum loss	adding artifical sediment (for beaches etc), removal of space by constructions	loss of associated flora and fauna species, both abundance and diversity, reducing genetic connectivity, loss of structural complexity	eliminate activity
	Changes in siltation/light	constructions altering environmental characteristics, impacting growth	reduced growth of kelp and associated species, with impact on associated fauna, reduced lower growth limit	eliminate activity
	Salinity regime change	coastal construction and river outflow change circulation and environmental characteristics, such as salinity, possibly impacting kelp forests and grazing sea urchins	change on species composition of kelp and associated species.	eliminate activity or keep salinity levels and vairation as natual as possible
	Intr. of synthetics	damaging kelp and associated flora and fauna	lethal or sublethal effects on many species	eliminate activity, ameliorate water quality
	Intr. of non-synthetic compounds	damaging kelp and associated flora and fauna	lethal or sublethal effects on many species	eliminate activity, ameliorate water quality
	Litter	damaging kelp and associated flora and fauna	lethal or sublethal effects on many species	eliminate activity, ameliorate water quality
	Barrier to species movement	reducing connectivity between kelp forest areas and between kelp forest and other habitats (such as seagrass meadows inside of kelp forests)	loss of genetic connectivity / loss of resilience (ability to recover from disturbances)	eliminate activity, reduce barriers, carry out the activity in areas that recover quickly
	Water flow rate changes (local)	change in water flow characteristics due to constructions	change in kelp growth and species composition (of kelp and associated flora and fauna species)	eliminate activity or place it in order to impact the water flow as little as possible
	Change in wave exposure (local)	change in wave exposure level due to constructions	change in kelp growth and species composition (of kelp and associated flora and fauna species)	eliminate activity or place it in order to impact the wave exposure as little as possible
Land-based Industry	Changes in siltation/light	altering environmental characteristics for species through discharges	mortality of and reduces growth and survival of species	reduce activity, control harmful practiques, reduce discharges,
	Thermal regime change	altering environmental characteristics for species through thermal discharges	mortality of and reduces growth and survival of species	reduce activity, control harmful practiques, reduce discharges,
	Salinity regime change	altering environmental characteristics for species	mortality of and reduces growth and survival of species	reduce activity, control harmful practiques, reduce discharges,
	Intr. of synthetics	damaging kelp and associated flora and fauna	lethal or sublethal effects	eliminate activity, improve water quality
	Intr. of non-synthetic compounds	damaging kelp and associated flora and fauna	lethal or sublethal effects	eliminate activity, improve water quality
	Intr. of other substances	damaging kelp and associated flora and fauna	lethal or sublethal effects	eliminate activity, improve water quality
	N and P enrichment	damaging kelp and associated flora and fauna	lethal or sublethal effects	eliminate activity, improve water quality
	Litter	damaging kelp and associated flora and fauna	lethal or sublethal effects	eliminate activity, improve water quality
	Input of organic matter	damaging kelp and associated flora and fauna	lethal or sublethal effects	eliminate activity, improve water quality

Table 8. The shallow hard kelp case study example (continued)

Activity	Pressure	Impact and effect on the ecosystem	Consequences	Restoration or Mitigation actions
	Intr. of microbial pathogens	damaging kelp and associated flora and fauna	lethal or sublethal effects	eliminate activity, improve water quality
Agriculture	Changes in siltation/light	altering environmental characteristics for species through discharges	mortality of and reduces growth and survival of species	reduce activity, control harmful practiques, reduce discharges,
	Intr. of synthetic compounds	damaging kelp and associated flora and fauna	lethal or sublethal effects	eliminate activity, improve water quality
	N and P enrichment	damaging kelp and associated flora and fauna	lethal or sublethal effects	eliminate activity, improve water quality
	Litter	damaging kelp and associated flora and fauna	lethal or sublethal effects	eliminate activity, improve water quality
	Input of organic matter	damaging kelp and associated flora and fauna	lethal or sublethal effects	eliminate activity, improve water quality
Tourism/ recreation	Smothering	tourist resorts, anchoring etc may lead to smothering of kelp forests	loss of kelp and associated flora and fauna species, both abundance and diversity, reducing genetic connectivity, loss of structural complexity;	eliminate activity
	Substratum loss	tourist resorts may lead to adding of artifical sediment (for beaches etc), removal of space by constructions	loss of kelp and associated flora and fauna species, both abundance and diversity, reducing genetic connectivity, loss of structural complexity;	eliminate activity
	Changes in siltation/light	tourist resorts may lead to constructions altering environmental characteristics, impacting growth	reduced growth of kelp and associated species, with impact on associated fauna.	eliminate activity
	N and P enrichment	tourist resorts may lead to nutrient added that damage kelp and associated flora and fauna	lethal or sublethal effects on many species	eliminate activity, ameliorate water quality
	Litter	tourist resorts may lead to litter added that damage kelp and associated flora and fauna	lethal or sublethal effects on many species	eliminate activity, ameliorate water quality
	Input of organic matter	tourist resorts may lead to organic matter added that damage kelp and associated flora and fauna	lethal or sublethal effects on many species	eliminate activity, ameliorate water quality
	Change in wave exposure (local)	tourist resorts may lead to constructions that change the wave exposure level due to constructions	change in kelp growth and species composition (of kelp and associated flora and fauna species)	eliminate activity or place it in order to impact the wave exposure as little as possible
Research and conservation	Substratum loss	adding permanents construction and removing kelp forests	loss of associated flora and fauna species, both abundance and diversity, reducing genetic connectivity, loss of structural complexity;	eliminate/reduce the activity, carry out the activity in areas that recover quickly
	Abrasion	removing/destroying areas of kelp forest	total removal of kelp, loss of associated flora and fauna species, both abundance and diversity, reducing genetic connectivity, loss of structural complexity;	eliminate/reduce the activity, carry out the activity in areas that recover quickly
	Intr. of non-indigenous species	change on species interactions and ecosystem functioning by doing fiels experiments on non-indigenous species	simplification of ecosystem functioning and diversity	eliminate or reduce the activity
	Selective extraction of species	removing and thereby damaging flora and fauna and removing predators (e.g. sea urchins)	partial and total mortality of sampled organisms, regrowth of kelp forests	some restrictions and control are needed if sampling is important

Table 9. The shallow hard coralligenous case study example, showing expected pressures by activity operating in the habitat, expected impacts and effects on the ecosystem, consequences relevant to restoration and restoration and mitigation actions.

Activity	Pressure	Impact and effect on the ecosystem	Consequences	Restoration or Mitigation actions
Extraction of living resources	Smothering	damaging fauna and flora	total and partial mortality of organisms, loss of density and cover, loss of diversity	eliminate activity
	Substratum loss	removing/destroying habitat	total mortality of organisms, loss of diversity, reducing genetic connectivity, loss of structural complexity	eliminate activity
	Changes in siltation/light	altering environmental characteristics for species	mortality of algae, symbiotic organisms and suspension feeders	eliminate activity
	Abrasion	damaging fauna and flora, loss of habitat	total or partial mortality of organisms, loss of diversity, reducing genetic connectivity, loss of structural complexity	eliminate activity
	Litter	damaging fauna	lethal or sublethal effects on suspension feeders	eliminate activity
	Input of organic matter	damaging fauna and flora	simplification of communities	eliminate activity
	Intr. of non-indigenous species	reducing substrata availability	reducing the recruitment of native species, changes in community composition	eliminate activity
	Selective extraction of species	damaging fauna and flora	loss of structural complexity, simplification of communities, changes in community composition, changes in functional properties	eliminate, regulate activity
Transport	Substratum loss	removing/destroying habitat	total mortality of organisms, loss of diversity, reducing genetic connectivity, loss of structural complexity	eliminate activity
	Changes in siltation/light	altering environmental characteristics for species	mortality of algae, reduce photosynthetic capacity, recruit viability	eliminate activity
	Intr. of synthetics	damaging flora and fauna	impairment on organisms biology	eliminate activity
	Intr. of non-synthetics	damaging flora and fauna	impairment on organisms biology	eliminate activity
	Litter	damaging fauna	lethal or sublethal effects on suspension feeders	reduce activity, control harmful practiques, communication
	Input of organic matter	damaging flora and fauna	simplification of communities, changes in community composition, changes in functional properties	eliminate activity, ameliorate water quality
	Intr. of microbial pathogens	damaging flora and fauna	lethal or sublethal effects on species,	reduce activity, control harmful practiques
	Intr. of non-indigenous species	reducing substrata availability	reducing the recruitment of native species, changes in community composition & functional properties	reduce activity, control harmful practiques
Renewable energy generation	Substratum loss	removing/destroying habitat	total mortality of organisms, loss of diversity, reducing genetic connectivity, loss of structural complexity	eliminate activity
	Changes in siltation/light	altering environmental characteristics for species	mortality of algae, reduce photosynthetic capacity, recruit viability	eliminate activity
	Intr. of synthetics	damaging flora and fauna	impairment on organisms biology	eliminate activity
	Intr. of non-synthetics	damaging flora and fauna	impairment on organisms biology	eliminate activity
	Litter	damaging fauna	lethal or sublethal effects on suspension feeders	reduce activity, control harmful practiques
	Input of organic matter	damaging flora and fauna	simplification of communities, changes in community composition, changes in functional properties	eliminate activity, ameliorate water quality
	Barrier to species movement	reducing connectivity among habitats	loss of genetic connectivity, loss of resilience (ability to recover from disturbances)	eliminate activity

Table 9. The shallow coralligenous case study example (continued)

Activity	Pressure	Impact and effect on the ecosystem	Consequences	Restoration or Mitigation actions
Coastal and marine structure and Infrastructure	Substratum loss	removing/destroying habitat	total mortality of organisms, loss of diversity, reducing genetic connectivity, loss of structural complexity	eliminate activity
	Changes in siltation/light	altering environmental characteristics for species	mortality of algae, symbiotic organisms and suspension feeders	eliminate activity
	Intr. of synthetics	damaging flora and fauna	impairment on organisms biology	eliminate activity
	Intr. of non-synthetics	damaging flora and fauna	impairment on organisms biology	eliminate activity
	Litter	damaging fauna	lethal or sublethal effects on suspension feeders	reduce activity, control harmful practiques
	Intr. of non-indigenous species	damaging flora and fauna	simplification of communities, changes in community composition, changes in functional properties	eliminate activity,
	Barrier to species movement	reducing connectivity among habitats	loss of genetic connectivity, loss of resilience (ability to recover from disturbances)	eliminate activity
	pH changes (local)	change in environmental characteristics	change on species compòsition	eliminate activity
Land-based Industry	Changes in siltation/light	altering environmental characteristics for species	mortality of algae, symbiotic organisms and suspension feeders	reduce activity, control harmful practiques
	Thermal regime change	change in environmental characteristics	change in species composition	eliminate activity
	Salinity regime change	change in environmental characteristics	change in species composition	eliminate activity
	Intr. of synthetics	damaging flora and fauna	impariment on organisms biology	eliminate activity, ameliorate water quality
	Intr. of non-synthetics	damaging flora and fauna	impariment on organisms biology	eliminate activity, ameliorate water quality
	Intr. of other substances	damaging flora and fauna	impariment on organisms biology	eliminate activity, ameliorate water quality
	Litter	damaging fauna	lethal or sublethal effects on suspension feeders	eliminate activity, ameliorate water quality
	Input of organic matter	damaging flora and fauna	simplification of communities	eliminate activity, ameliorate water quality
	Intr. of microbial pathogens	damaging flora and fauna	lethal or sublethal effects on vulnerable species	eliminate activity, ameliorate water quality
	Intr. of non-indigenous species	change on species interactions and ecosystem functioning	simplification of ecosystem functioning and diversity	eliminate activity, ameliorate water quality
	pH changes (local)	change in environmental characteristics	change in species composition	eliminate activity
Agriculture	Changes in siltation/light	altering environmental characteristics for species	mortality of algae, symbiotic organisms and suspension feeders	reduce activity, control harmful practiques
	Thermal regime change	change in environmental characteristics	change on species composition	eliminate activity
	Salinity regime change	change in environmental characteristics	change on species composition	eliminate activity
	Intr. of synthetics	damaging flora and fauna	impariment on organisms biology	eliminate activity, ameliorate water quality
	Intr. of non-synthetics	damaging flora and fauna	impariment on organisms biology	eliminate activity, ameliorate water quality
	Litter	damaging fauna	lethal or sublethal effects on suspension feeders	eliminate activity, ameliorate water quality

Table 9. The shallow coralligenous case study example (continued)

Activity	Pressure	Impact and effect on the ecosystem	Consequences	Restoration or Mitigation actions
	Input of organic matter	altering environmental characteristics for species	mortality of some vulnerable species	reduce activity, control harmful practiques
Tourism/ recreation	Smothering	damaging fauna and flora	total and partial mortality of organisms, loss of density and cover, loss of diversity	establishment appropiate carrying capacity, transplants of damaged species in local areas where the activity is reduced
	Substratum loss	removing/destroying habitat	total mortality of organisms, loss of diversity, reducing genetic connectivity, loss of structural complexity	eliminate activity
	Abrasion	damaging fauna and flora, loss of habitat	total or partial mortality of organisms, loss of diversity, reducing genetic connectivity, loss of structural complexity	establishment appropiate carrying capacity, transplants of damaged species in local areas where the activity is reduced
	Intr. of synthetics	damaging flora and fauna	impariment on organisms biology	eliminate activity, ameliorate water quality
	Intr. of non-synthetics	damaging flora and fauna	impariment on organisms biology	eliminate activity, ameliorate water quality
	Litter	damaging fauna	lethal or sublethal effects on suspension feeders	eliminate activity, ameliorate water quality
	Input of organic matter	altering environmental characteristics for species	mortality of some vulnerable species	reduce activity, control harmful practiques
	Intr. of non-indigenous species	change on species interactions and ecosystem functioning	simplification of ecosystem functioning and diversity	eliminate activity, ameliorate water quality
Research and conservation	Substratum loss	removing/destroying habitat	total mortality of organisms, loss of diversity, reducing genetic connectivity, loss of structural complexity	eliminate activity
	Changes in siltation/light	altering environmental characteristics for species	mortality of some vulnerable species	reduce activity, control harmful practiques
	Intr. of synthetics	damaging flora and fauna	lethal or sublethal effects on vulnerable species	eliminate activity, ameliorate water quality
	Intr. of non-synthetics	damaging flora and fauna	lethal or sublethal effects on vulnerable species	eliminate activity, ameliorate water quality
	Intr. of other substances	damaging flora and fauna	lethal or sublethal effects on vulnerable species	eliminate / regulate the activity
	Litter	damaging flora and fauna	lethal or sublethal effects on vulnerable species	eliminate activity
	Input of organic matter	damaging flora and fauna	lethal or sublethal effects on vulnerable species	eliminate activity, ameliorate water quality
	Intr. of non-indigenous species	damaging flora and fauna	simplification of ecosystem functioning and diversity	eliminate / regulate activity
	Selective extraction of species	damaging flora and fauna	partial and total mortality of sampled organisms	some restrictions needed if sampling is at large scale (100's kilometers)

Table 10. The shallow hard algal forests case study example, showing expected pressures by activity operating in the habitat, expected impacts and effects on the ecosystem, consequences relevant to restoration and restoration and mitigation actions.

Activity	Pressure	Impact and effect on the ecosystem	Consequences	Restoration or Mitigation actions
Extraction of living resources	Smothering	damaging flora and associated fauna	total and partial mortality of organisms, loss of density and cover, loss of diversity	eliminate activity
	Substratum loss	removing/destroying habitat	total mortality of organisms, loss of density and cover, loss of diversity, reducing genetic connectivity, loss of structural complexity	eliminate activity
	Changes in siltation/light	altering environmental characteristics for species	mortality of algae, reduce photosynthetic capacity, recuit viability	eliminate activity
	Abrasion	damaging flora and associated fauna, loss of habitat	total or partial mortality of organisms, loss of density and cover, loss of diversity, reducing genetic connectivity, loss of structural complexity	eliminate activity
	Intr. of synthetics	damaging flora and associated fauna	impairment on organisms biology	eliminate activity
	Intr. of non-synthetics	damaging flora and associated fauna		
	Litter	damaging flora and associated fauna	lethal or sublethal effects on many algal species (structural Cystoseira species)	eliminate activity
	Input of organic matter	damaging flora and associated fauna	simplification of communities	eliminate activity, ameliorate water quality
	Intr. of non-indigenous species	reducing substrata availability, changes in composition of assemblages	reducing the recruitment of native species	eliminate activity
	Selective extraction of species	predation removal (e.g. sea urchins), assemblage recovery	increasing growth and recruitment	regulate activity
	Barrier to species movement	reducing connectivity among habitats	loss of genetic connectivity, loss of resilience (ability to recover from disturbances)	eliminate activity
Transport	Substratum loss	removing/destroying habitat	total mortality of organisms, loss of diversity, reducing genetic connectivity, loss of structural complexity	eliminate activity
	Changes in siltation/light	altering environmental characteristics for species	mortality of algae, reduce photosynthetic capacity, recruit viability	eliminate activity
	Intr. of synthetics	removing/destroying habitat	total mortality of organisms, loss of diversity, reducing genetic connectivity, loss of structural complexity	eliminate activity
	Intr. of non-synthetics	damaging flora and associated fauna	impariment on organisms biology	eliminate activity
	Litter	damaging flora and associated fauna	lethal or sublethal effects on many algal species (structural Cystoseira species)	eliminate activity
	Input of organic matter	damaging flora and associated fauna	simplification of communities	eliminate activity, ameliorate water quality
	Intr. of microbial pathogens	damaging flora and fauna	lethal or sublethal effects on species,	reduce activity, control harmful practiques
	Intr. of non-indigenous species	reducing substrata availability, changes in composition of assemblages, interaction and ecosystem functioning	reducing the recruitment of native species	reduce activity, control harmful practiques
Renewable energy generation	Substratum loss	removing/destroying habitat	total mortality of organisms, loss of diversity, reducing genetic connectivity, loss of structural complexity	eliminate activity
	Changes in siltation/light	altering environmental characteristics for species	mortality of algae, reduce photosynthetic capacity, recruit viability	eliminate activity
	Intr. of synthetics	damaging flora and associated fauna	lethal or sublethal effects on many algal species (structural Cystoseira species)	eliminate activity, ameliorate water quality
	Intr. of non-synthetics	damaging flora and associated fauna	lethal or sublethal effects on many algal species (structural Cystoseira species)	eliminate activity, ameliorate water quality

Table 10. The shallow hard algal forests case study example (continued)

Activity	Pressure	Impact and effect on the ecosystem	Consequences	Restoration or Mitigation actions
	Litter	damaging flora and associated fauna	lethal or sublethal effects on many algal species (structural Cystoseira species)	eliminate activity, ameliorate water quality
	Input of organic matter	damaging flora and associated fauna	simplification of communities	eliminate activity, ameliorate water quality
	Barrier to species movement	reducing connectivity among habitats	loss of genetic connectivity, loss of resilience (ability to recover from disturbances)	eliminate activity
	Change in wave exposure (local)	change in environmental characteristics	change in species composition	eliminate activity
Coastal and marine structure and Infrastructure	Substratum loss	removing/destroying habitat	total mortality of organisms, loss of diversity, reducing genetic connectivity, loss of structural complexity	eliminate activity
	Changes in siltation/light	altering environmental characteristics for species	mortality of algae, symbiotic organisms and suspension feeders	eliminate activity
	Salinity regime change	change in environmental characteristics, increasing vulnerability of some algal species	change in species composition	eliminate activity
	Intr. of synthetics	damaging flora and associated fauna	lethal or sublethal effects on many algal species (structural Cystoseira species)	eliminate activity, ameliorate water quality
	Intr. of non-synthetics	damaging flora and associated fauna	lethal or sublethal effects on many algal species (structural Cystoseira species)	eliminate activity, ameliorate water quality
	Litter	damaging flora and associated fauna	lethal or sublethal effects on many algal species (structural Cystoseira species)	eliminate activity, ameliorate water quality
	Intr. of non-indigenous species	change in species composition, interactions and ecosystem functioning	simplification of ecosystem functioning and diversity	eliminate activity, ameliorate water quality
	Barrier to species movement	reducing connectivity among habitats	loss of genetic connectivity, loss of resilience (ability to recover from disturbances)	
	Water flow rate changes (local)	change in environmental characteristics	change in species composition	eliminate activity
	pH changes (local)	change in environmental characteristics	change in species composition	eliminate activity
	Change in wave exposure (local)	altering environmental characteristics for species	mortality of algae, change in species composition	reduce activity, control harmful practiques
Land-based Industry	Changes in siltation/light	altering environmental characteristics for species	mortality of algae, symbiotic organisms and suspension feeders	reduce activity, control harmful practiques
	Thermal regime change	change in environmental characteristics	change in species composition	eliminate activity
	Salinity regime change	change in environmental characteristics	change in species composition	eliminate activity
	Intr. of synthetics	damaging flora (specially species of genus Cystoseira)	lethal or sublethal effects on many algal species	eliminate activity, ameliorate water quality
	Intr. of non-synthetics	damaging flora (specially species of genus Cystoseira)	lethal or sublethal effects on many algal species	eliminate activity, ameliorate water quality
	Intr. of other substances	damaging flora and changing associated fauna	lethal or sublethal effects on many algal species	eliminate activity, ameliorate water quality
	N and P enrichment	damaging flora and changing associated fauna	lethal or sublethal effects on many algal species	eliminate activity, ameliorate water quality
	Litter	damaging flora and associated fauna	lethal or sublethal effects on suspension feeders	reduce activity, control harmful practiques

Table 10. The shallow hard algal forests case study example (continued)

Activity	Pressure	Impact and effect on the ecosystem	Consequences	Restoration or Mitigation actions
	Input of organic matter	damaging flora and associated fauna	lethal or sublethal effects on many algal species	eliminate activity, ameliorate water quality
	Intr. of microbial pathogens	damaging flora and associated fauna	lethal or sublethal effects on many algal species	eliminate activity, ameliorate water quality
	Intr. of non-indigenous species	change on species interactions and ecosystem functioning	simplification of ecosystem functioning and diversity	eliminate activity, ameliorate water quality
	Water flow rate changes (local)	change in environmental characteristics	change in species composition	eliminate activity
	pH changes (local)	change in environmental characteristics	change in species composition	eliminate activity
	Change in wave exposure (local)	change in environmental characteristics	change in species composition	eliminate activity
Agriculture	Changes in siltation/light	altering environmental characteristics for species	mortality of algae, symbiotic organisms and suspension feeders	reduce activity, control harmful practiques
	Thermal regime change	change in environmental characteristics	change in species composition	eliminate activity
	Salinity regime change	change in environmental characteristics	change in species composition	eliminate activity
	Intr. of synthetics	damaging flora and associated fauna	lethal or sublethal effects on many algal species (structural Cystoseira species)	eliminate activity, ameliorate water quality
	Intr. of non-synthetics	damaging flora and associated fauna	lethal or sublethal effects on many algal species (structural Cystoseira species)	eliminate activity, ameliorate water quality
	N and P enrichment	damaging flora and changing associated fauna	lethal or sublethal effects on many algal species (structural Cystoseira species)	eliminate activity, ameliorate water quality
	Litter	damaging flora and changing associated fauna	lethal or sublethal effects on many algal species (structural Cystoseira species)	eliminate activity, ameliorate water quality
	Input of organic matter	altering environmental characteristics for species, damaging flora and associated fauna	mortality of some vulnerable species	reduce activity, control harmful practiques
Tourism/ recreation	Smothering	damaging fauna and flora	total and partial mortality of organisms, loss of density and cover, loss of diversity	establishment of appropiate carrying capacity, transplants of damaged species in local areas where the activity is reduced
	Substratum loss	removing/destroying habitat	total mortality of organisms, loss of diversity, reducing genetic connectivity, loss of structural complexity	eliminate activity
	Abrasion	damaging fauna and flora, loss of habitat	total or partial mortality of organisms, loss of diversity, reducing genetic connectivity, loss of structural complexity	establishment of appropiate carrying capacity, transplants of damaged species in local areas where the activity is reduced
	Intr. of synthetics	damaging flora and associated fauna	lethal or sublethal effects on many algal species (structural Cystoseira species)	eliminate activity, ameliorate water quality
	Intr. of non-synthetics	damaging flora and associated fauna	lethal or sublethal effects on many algal species (structural Cystoseira species)	eliminate activity, ameliorate water quality
	N and P enrichment	damaging flora (specially species of genus Cystoseira)	lethal or sublethal effects on many algal species (structural Cystoseira species)	eliminate activity, ameliorate water quality
	Litter	damaging flora (specially species of genus Cystoseira)	lethal or sublethal effects on many algal species (structural Cystoseira species)	eliminate activity, ameliorate water quality

Table 10. The shallow hard algal forests case study example (continued)

Activity	Pressure	Impact and effect on the ecosystem	Consequences	Restoration or Mitigation actions
	Input of organic matte	damaging flora (specially species of genus Cystoseira)	lethal or sublethal effects on many algal species (structural Cystoseira species)	eliminate activity, ameliorate water quality
	Intr. of non-indigenous species	change on species interactions and ecosystem functioning	simplification of ecosystem functioning and diversity	eliminate activity, ameliorate water quality
	Selective extraction of species	predation removal (e.g. sea urchins), assemblage recovery	increasing growth and recruitment	regulate activity
	Change in wave exposure (local)	altering environmental characteristics for species	mortality of some vulnerable species	reduce activity, control harmful practiques
Research and conservation	Substratum loss	removing/destroying habitat	total mortality of organisms, loss of diversity, reducing genetic connectivity, loss of structural complexity	eliminate, regulate activity
	Changes in siltation/light	altering environmental characteristics for species	mortality of some vulnerable species	reduce activity, control harmful practiques
	Intr. of synthetics	damaging flora and associated fauna	lethal or sublethal effects on many algal species (structural Cystoseira species)	eliminate activity, ameliorate water quality
	Intr. of non-synthetics	damaging flora and associated fauna	lethal or sublethal effects on many algal species (structural Cystoseira species)	eliminate activity, ameliorate water quality
	Intr. of other substances	damaging flora and associated fauna	lethal or sublethal effects on many algal species (structural Cystoseira species)	eliminate activity, ameliorate water quality
	Litter	damaging flora and associated fauna	lethal or sublethal effects on many algal species (structural Cystoseira species)	eliminate activity, ameliorate water quality
	Input of organic matter	damaging flora and associated fauna	lethal or sublethal effects on many algal species (structural Cystoseira species)	eliminate activity, ameliorate water quality
	Intr. of non-indigenous species	change on species interactions and ecosystem functioning	simplification of ecosystem functioning and diversity	eliminate activity,
	Selective extraction of species	damaging flora and fauna	partial and total mortality of sampled organisms	some restrictions and control are needed if sampling is important (also in term of scale)
	Water flow rate changes (local)	change in environmental characteristics	change in species composition	eliminate activity

Table 11. The deep sea case study example, showing expected pressures by activity operating in the habitat, expected impacts and effects on the ecosystem, consequences relevant to restoration and restoration and mitigation actions

Activity	Pressure	Impact and effect on the ecosystem	Consequences	Restoration or Mitigation actions
Extraction of living resources	Smothering	trawling-induced sediment displacement and removal from fishing grounds causes the morphology of the deep sea floor to become smoother over time, reducing its original complexity	reduced species diversity by regulating levels of competition, predation and physiological stress	reduce the activities and consider undisturbed adjacent areas as source of species
	Substratum loss	habitat destruction due to trawling activities	loss of species, decreased connectivity and ecosystem functioning	reduce the activities and consider undisturbed adjacent areas as source of species
	Changes in siltation/light	plume generated by trawling activities and deposition/burial	decreased biodiversity, connectivity and ecosystem functioning	reduce the activities and consider undisturbed adjacent areas as source of species
	Abrasion	loss of substratum due to trawling activities, trawling-induced sediment displacement and removal from fishing grounds causes the morphology of the deep sea floor to become smoother over time, reducing its original complexity	loss of species, decreased connectivity and ecosystem functioning	reduce the activities and consider undisturbed adjacent areas as source of species
	Litter	burial due to the loss of net and sampling devices	loss of species and decreasing of ecosystem fucntioning	remove the litter
	Selective extraction of species	removal of non-target species (bycatch)	loss of species and alter food webs	reduce bycatch by using specific nets
Non-renewable energy generation	Smothering	loss of subtratum due to the installation of oil&gas platforms	loss of species,decreased connectivity	ensure any new structures are located away from restoring areas and place restoration projects away from existing structures
	Substratum loss	loss of substratum due to the installation of oil&gas platforms	loss of species, decreased connectivity	ensure any new structures are located away from restoring areas and place restoration projects away from existing structures
	Abrasion	loss of substratum due to the installation of oil&gas platforms	loss of species, decreased connectivity	ensure any new structures are located away from restoring areas and place restoration projects away from existing structures
	Selective extraction of non-living resources	loss of benthic habitats due to the installation of oil&gas platforms	loss of species, decreased connectivity and ecosystem functioning	ensure any new structures are located away from restoring areas and place restoration projects away from existing structures
	Introduction of radionuclides	contamination of benthic habitats and organisms	radioactivity contamination	reducing radionuclide discharges and place restoring areas away from discharge
	Introduction of other substances	contamination of benthic habitats and organisms	toxic chemicals contamination	reducing toxic chemical discharges and place restoring areas away from discharge
Extraction of non-living resources	Substratum loss	loss of substratum due to mining activities	loss of species, decreased connectivity and ecosystem functioning	reduce the activities and consider undisturbed adjacent areas as source of species
	Changes in siltation/light	plume generated by mining activities and burial after its deposition	decreased biodiversity, connectivity and ecosystem functioning	reduce the activities and consider undisturbed adjacent areas as source of species
	Abrasion	loss of substratum due to mining activities; changing the substrate characteristics (e.g., porosity, particle size distribution, mineralogy)	loss of species, decreased connectivity and ecosystem functioning	reduce the activities and consider undisturbed adjacent areas as source of species
	Selective extraction of non-living resources	loss of benthic habitats due to mining activities	loss of species, decreased connectivity and ecosystem functioning	reduce the activities and consider undisturbed adjacent areas as source of species
	Noise	disturbance to megafauna; produced at surface vessel's engine and machinery, at bottom machinery, crushing activities, and pumping	changes in behaviour; attraction to the source, avoidance from the source at some range, masking of signals of interest, induce stress for animals which linger in the area	remove the pressure, reducing the noise with new technologies
	Intr. of non-synthetics	disturbance to pelagic and benthic species	change in species composition	reduce the use of non-synthetic compounds

Table 11. The deep-sea case study example (continued)

Activity	Pressure	Impact and effect on the ecosystem	Consequences	Restoration or Mitigation actions
	Litter	burial	loss of species and decreasing of ecosystem fucntioning	remove debris
Coastal and marine structure and Infrastructure	Smothering	loss of substratum due to installation of cable lays for telecommunications	loss of species, decreased connectivity	limit installation of cables near restoration areas; restoring areas away from cables
	Substratum loss	loss of substratum due to installation of cable lays for telecommunications	loss of species, decreased connectivity	limit installation of cables near restoration areas; restoring areas away from cables
	Abrasion	loss of substratum due to installation of cable lays for telecommunications	loss of species, decreased connectivity	limit installation of cables near restoration areas; restoring areas away from cables
	Selective extraction of non-living resources	loss of benthic habitats due to installation of cable lays for telecommunications	loss of species, decreased connectivity and ecosystem functioning	limit installation of cables near restoration areas; restoring areas away from cables
Research and conservation	Smothering	substratum smothering for experimental purposes	loss of substrate and species	reduce disturbances and ensure disturbances do disrupt connectivity. do no perform destructive sampling in newly restored areas.
	Substratum loss	loss of substrate due to sediment samples collection	removal of benthic species with consequences on the ecosystem fucntioning	reduce disturbances and ensure disturbances do disrupt connectivity. do no perform destructive sampling in newly restored areas.
	Abrasion	abrasions due to sampling: dreadging	removal of benthic species and consequences on biodiversity and ecosystem functioning	reduce disturbances and ensure disturbances do disrupt connectivity. do no perform destructive sampling in newly restored areas.
	Litter	burial	loss of species	remove debris
	Selective extraction of species	collection of specific species (deep-water corals) for research purposes (lab/aquarium research, transplantion, etc.)	removal of a large numbers of organisms could affect trophic networks and the fauna associated to these key species	limit the collection to avoid any negative effects on their behaviour and survival
Carbon Sequestration	Substratum loss	substrate loss due to creation of co2 lakes on the sea floor	changes in abundance and diversity of benthic species and consequences on biodiversity and ecosystem functioning	avoid carbon sequestration near restoration areas
	Abrasion	substrate loss due to creation of co2 lakes on the sea floor	changes in abundance and diversity of benthic species and consequences on biodiversity and ecosystem functioning	avoid carbon sequestration near restoration areas
	pH changes (local)	ph reductions, reduction in the productivity of calcifying organisms leading to higher ratios of non-calcifiers over calcifiers (when co2 is released in the water column)	biodiversity loss, variation of food webs, decreased ecosystem functioning	avoid carbon sequestration near restoration areas

5. Discussion

5.1. Conclusions from the Activities/Pressures Map Catalogue

The activities and pressures that impact marine ecosystems are relatively well-documented in available sources at the European level. The MERCES Activities/Pressures Catalogue contains entries from all MSFD regions, with the majority of records (67%) coming from the Mediterranean Sea and North-East Atlantic presumably relating to the extensive research effort those areas attract as well as their multi-national nature. Similar to these regions, the Baltic Sea which, although geographically restricted, but surrounded by 9 countries, attracts significant research interest, however, there were a smaller number of entries for this region. This is probably the result of having to choose the most synthetic and/or most representative between the many available resources, see for example the HELCOM site (http://maps.helcom.fi/website/mapservice/index.html) featuring literally hundreds of different maps. In addition to specific regions, a substantial portion of entries is of global or European scale, as well as some sources documenting activities and pressures outside the strict EU- or non MSFD-relevant borders (e.g. Norway, Hatton and Rockall Banks).

Within the Mediterranean Sea, there is a west-to-east trend regarding the reported availability of sources, resulting in activities and pressures in the eastern basin being relatively less documented in general. A potential knowledge gap is identified for the Black Sea, which represents a very small share (3%) of the total records. Taking into account its size (30% larger than the Baltic Sea) and multi-national status (6 countries of which only 2 are EU Member States), this is rather surprising and could be attributed to a reduced research effort and/or limited communication/publication of study results. Nevertheless, this may change in the future as several initiatives have recently been launched aiming to incorporate maritime spatial planning into policy making in the region in order to facilitate cooperation between EU countries in the management of maritime space, for example by funding research, e.g. MARSPLAN-BS, MISIS, CoCoNet, PERSEUS. Furthermore, the European Commission is also supporting research institutes and public stakeholders from all Black Sea countries to pool together existing data in order to create a single digital map of the Black Sea seabed, including its geology, habitats and marine life. A first version of the map is expected in 2017. An additional knowledge gap, linked to a similar issue (i.e. a lack of EU countries committed to EU policy drives), although not directly highlighted by the results, is the lack of mapped activities/pressures data for the southern Mediterranean Sea coastline. As regional cooperation is of paramount importance (for example in the case of shared stocks between EU and non-EU countries or as a shared sea invaded by aliens crossing administrative borders), the European Commission supports various activities, initiatives (e.g. European Neighbourhood Policy), and maritime projects (e.g. MedPAN South Project, ADRIPLAN, PERSEUS).

The maps relating to activities and pressures are mostly broad-scale in nature, seldom indicating the presence of or impact on specific habitats. While this is expected due to the underlying aims of the initial query (i.e. to look for maps documenting activities/pressures at the regional or national level), it is not desirable since mapped features cannot be evaluated according to their impact on key habitats and assemblages. Certainly, some activities are connected to specific habitats in the broad sense, e.g. trawling and dredging to soft bottoms, and the same applies for certain pressures (e.g. abrasion). However, no specific feature of key importance (e.g. coral gardens, seagrass beds) is identified by this approach. In the case of map viewers or available shapefiles this limitation can be overcome when habitat and key feature data are available, by simply overlaying distinct layers. In the case of image maps, potential workarounds could be found by linking to the habitat and degraded habitat maps catalogued in Bekkby et al. (2017) MERCES D1.1 Deliverable. Deep-sea habitats are also rarely identified in activities/pressures maps (6% of the total records) and are mainly associated with deep-sea fishing (activity) and litter (pressure).

A lack of accessible shapefiles is evident in the Catalogue (5% of the total records) a similar percentage to the habitats/degraded habitats catalogue (Bekkby et al., 2017), with the majority of entries coming in the form of image. The lack of shapefiles reduces the potential for the extraction and manipulation of the data contained in the maps, impeding their usability for further synthesis, analysis and conservation planning.

At the EU level, several regulatory bodies and initiatives have been driving forward the mapping of activities and pressures impacting marine habitats. For example, the European Environmental Agency (EEA) has aggregated and made publicly available a substantial amount of mapped data, mainly regarding fishing and tourism activities, renewable energy infrastructure and management of natural resources. Regular updates of these, feature in the EEA state of Europe's seas reports (e.g. EEA, 2015, with a new assessment being prepared for 2020). Additionally, through the WFD and MSFD significant progress has been made in relation to basic research and the mapping of activities and pressures, whilst further maps are expected as a result of the implementation of the MSP Directive, with outputs being incorporated into the European Commission's European Atlas of the Seas as a result of national or regional initiatives e.g. the

SIMCelt cross-border project involving partners from the UK, Ireland and France, and supporting the implementation of the Maritime Spatial Planning Directive in the Celtic Seas.

In addition, the EU have led or funded a number of research projects with pan European (e.g. EMODnet, PERSEUS, and BENTHIS) and more restricted, sub-regional coverage (e.g. ADRIPLAN and Med-IAMER). At the regional or regional sea level, the extensive production and aggregation of mapped environmental data has been coordinated by OSPAR and HELCOM, two major international commissions governing policies in the North-East Atlantic and the Baltic Sea, respectively. The OPAR Quality Status Report of 2010 is perhaps the most comprehensive of these (including, for example, detailed factsheets on threatened and/or declining species and habitats (OSPAR, 2010)) and OSPAR has an Intermediate Assessment due in 2017 leading to another QSR in 2020. Within the Mediterranean Sea, MEDTRENDS (WWF project funded by EU through the European Development Fund, Piante and Ody, 2015) has produced a substantial repository of multi-parametric maps of activities and pressures, although its focus is the eight Mediterranean countries of the EU. Finally, at the national level, there are a number of initiatives which have generated comprehensive collections of mapped activities/pressures mainly at the EEZ level, for example, the Marine Atlases of Scotland and Ireland.

Regarding the mapping of activities, variation was observed in relation to the degree to which the activities are quantified, often in relating to the nature of the activity (i.e. fixed or mobile). Specifically, some activities are mapped as geographic points indicating the presence of an activity (such as locations of mining or hydrocarbon extraction and pipeline contiguous presence, locations of ports, shipping routes, locations of fish farms), while others indicate concentrations of activities over wide areas (such as fishing effort, density of marine traffic, intensity of tourism, and so on) (Figure 14).

The most frequently mapped activity in the MERCES Activities/Pressures Map Catalogue was the extraction of living resources which is generally expressed as cumulative swept area, amount of catch, size of fishing fleet, or fishing effort (usually derived from AIS/VMS signals). The latter, especially, makes the activity easy to track and quantify, resulting in the availability of relevant maps at varying scales (Figure 15). It should be noted though, that the coverage may be incomplete, due to the absence of information from specific fleets.

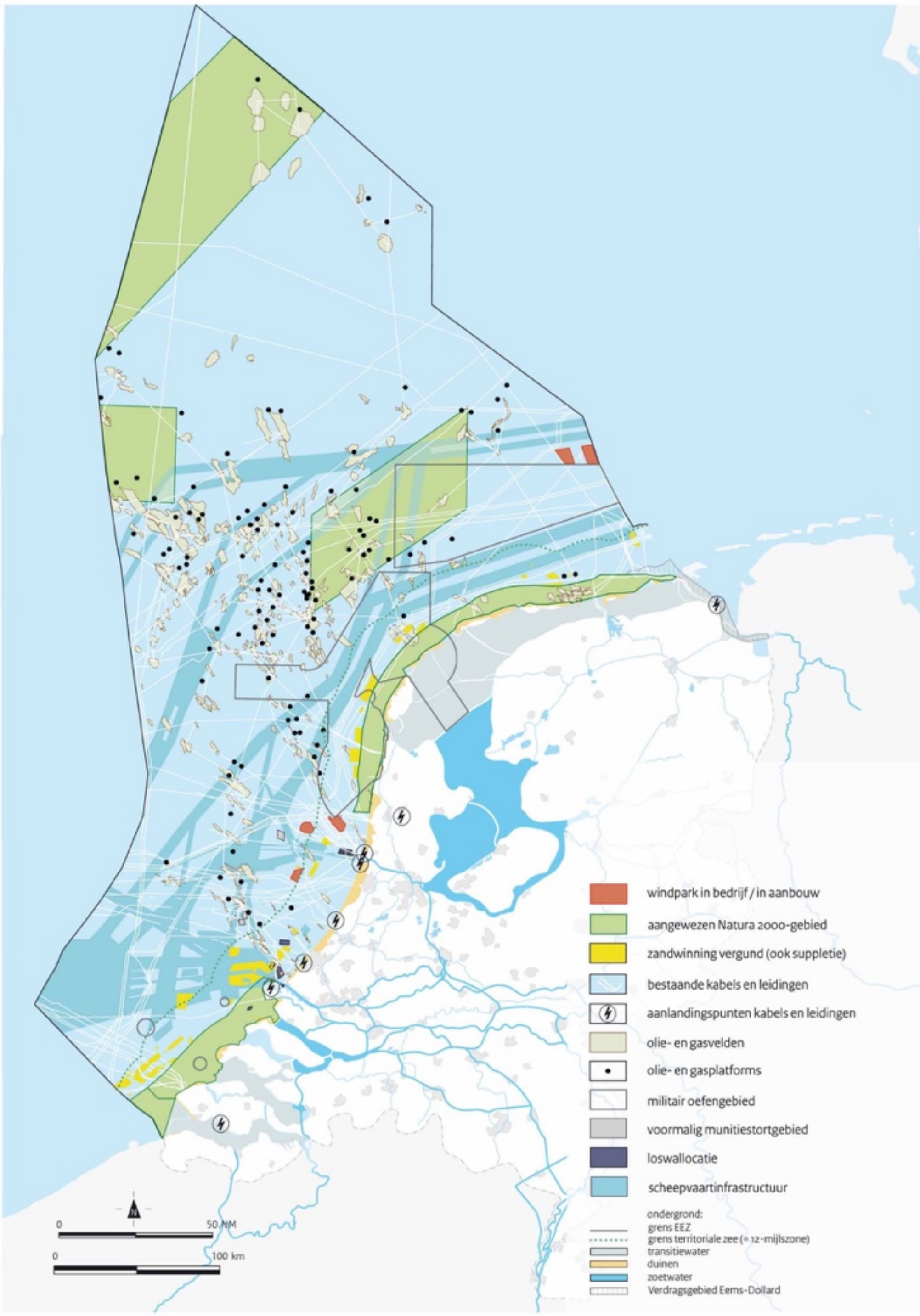

Figure 14. Current uses (activities) in the Dutch North Sea waters. Some activities are represented as points (e.g. oil and gas platforms, black dots) and others as areas where the activity takes place (e.g. sand mining, yellow areas). Also, some activities are currently present (e.g. cable landing points, lightning symbols), while others are planned or permitted (e.g. sand extraction permissions, orange areas). Image from Anonymous, 2015.

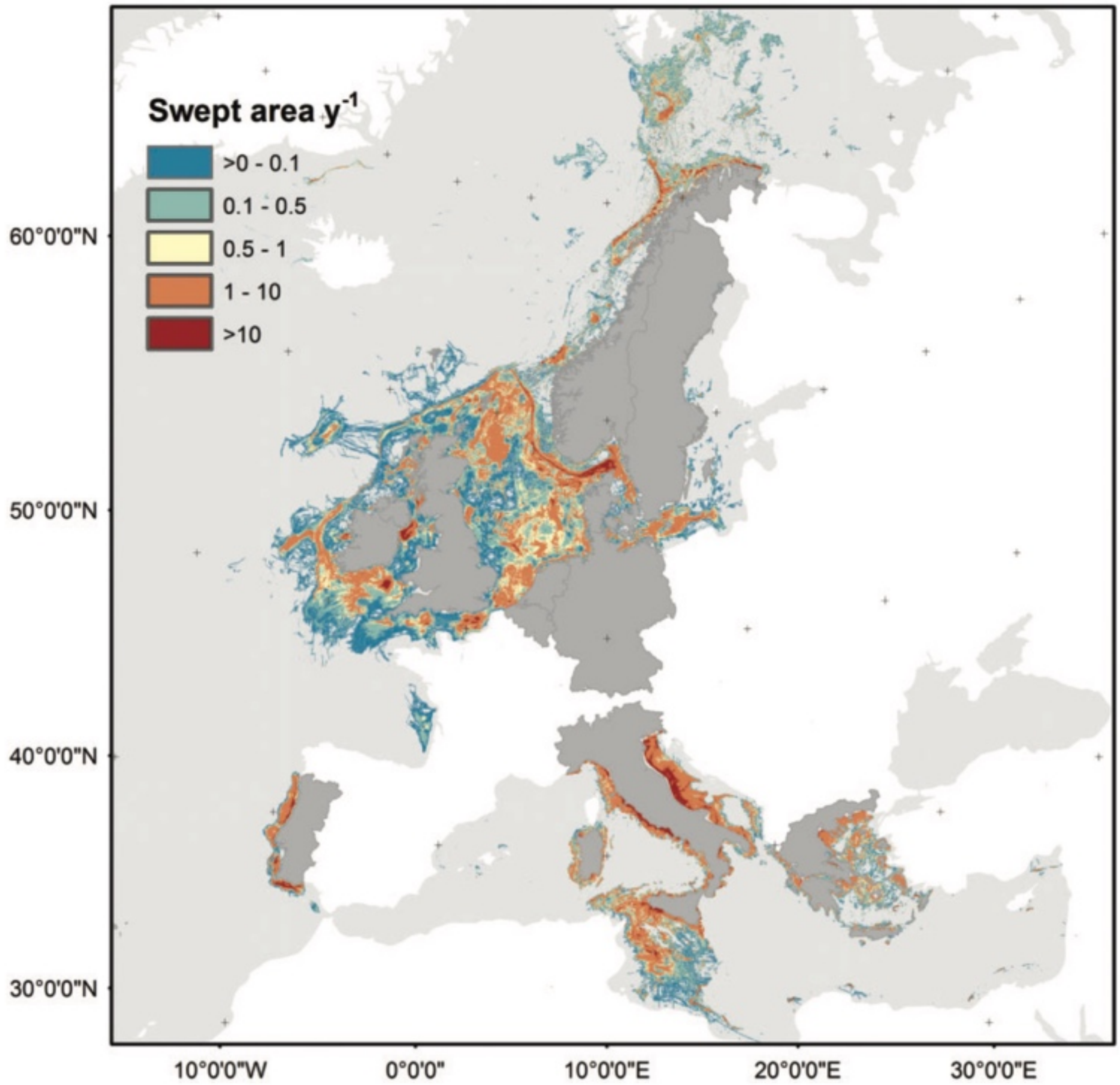

Figure 15. Mean annual trawling intensity at the surface level (sediment abrasion < 2 cm). The intensity is estimated from VMS and logbook data of bottom trawl fleets as the total area swept yearly in grid cells of 1 x 1 min divided by grid cell size. Countries marked dark grey provided data. Image from Eigaard et al. (2016).

Oil and gas exploitation and exploration is another commonly mapped activity, in the form of "extraction of non-living resources" and the "coastal and marine structure and infrastructure", the latter relating to the deployment of pipelines and landing points in the marine sector. The activities may be either existing (in the case of current exploitation), or potentially present in the future (in the case of exploration and licensing). This information is mapped as a mixture of points and contiguous points/lines, as well as broad areas (exploration or licensed fields) (Figure 16).

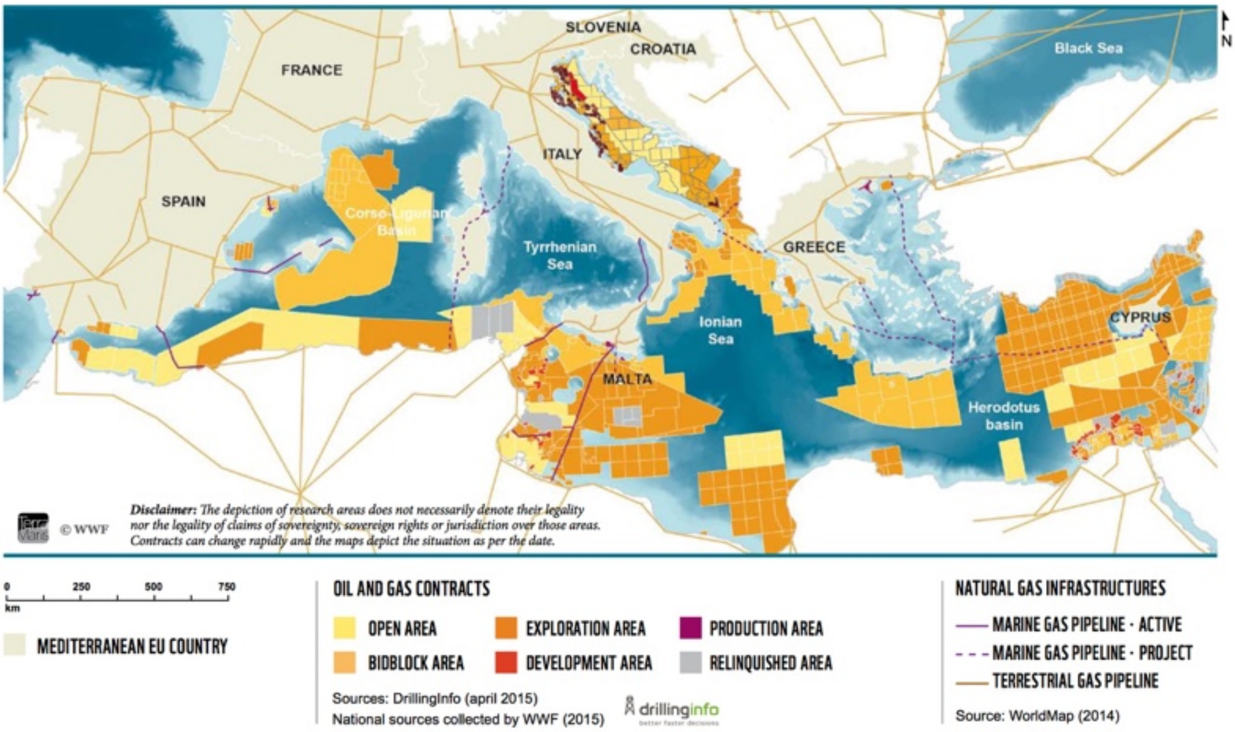

Figure 16. Current offshore oil and gas exploration and production contracts in the Mediterranean Sea (depicted as broad areas), and active and projected gas pipelines (depicted as lines). Image from Piante and Ody (2015).

The production of living resources is another major activity in the catalogue which captures aquaculture and fish farming activities. This tends to be relatively well-documented and mapped at the national level, generally taking the form of point locations (presence of farming units), although sometimes it can also be quantified (either through production levels or incorporated in pressure indices) (Figure 17).

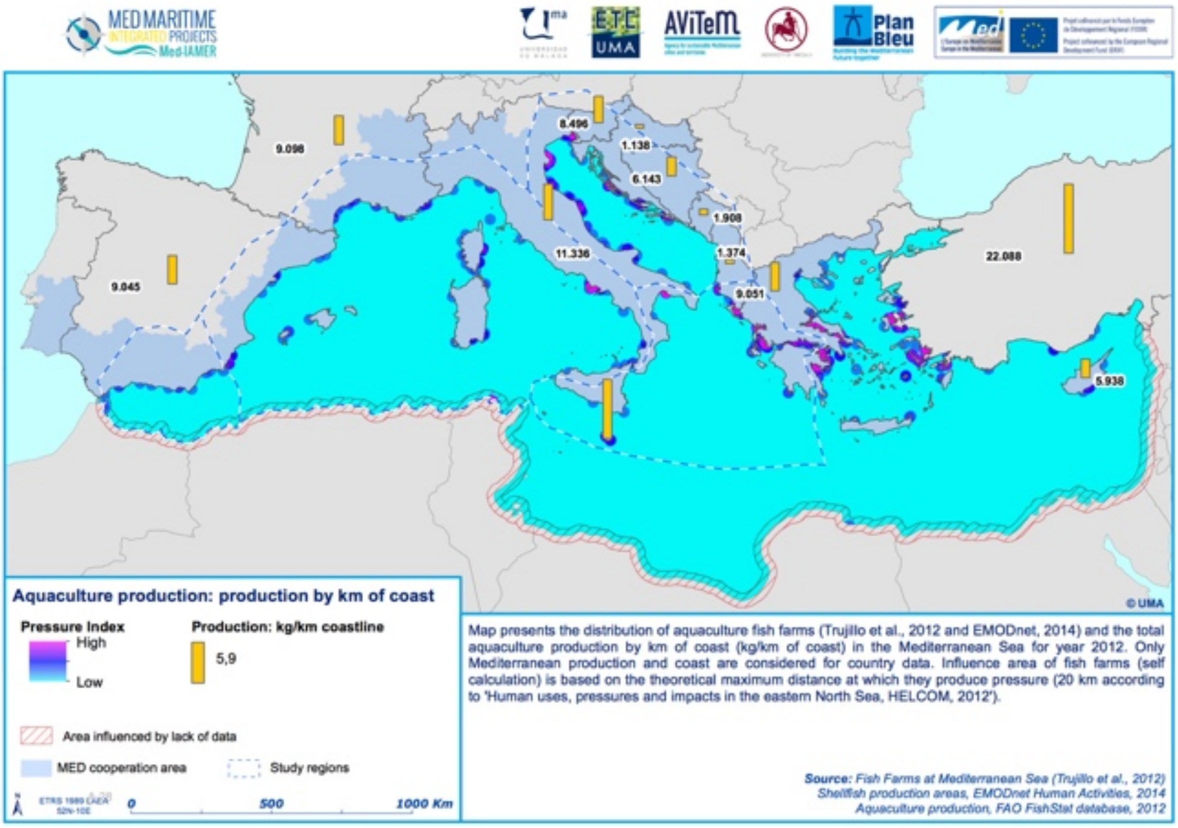

Figure 17. Aquaculture distribution in the Mediterranean and visualisation of intensity derived from production data. Image from Med-IAMER (2014).

Some activities appear in just a small portion of the records, a (e.g. land-based industry, non-renewable energy generation, agriculture, carbon sequestration) and are likely underrepresented in the catalogue, presumably being either too new (for example currently there are only very few carbon sequestration sites/projects), not so widespread (e.g. there are less wind farms than aquaculture farms or something else) or too broad and coast based to assess at large-scale.

As far as pressures are concerned, many endogenous (i.e. manageable within a local management system/unit) pressures appear well mapped, such as the introduction of chemicals and compounds (Figure 18), marine litter (Figure 19) and abrasion (usually directly linked to trawling patterns and intensity, e.g. see Figure 15). However, others are either under-represented (e.g. underwater noise, change in wave exposure, emergence regime change, thermal regime change), or absent (death by collision). This may be related to the fact that these pressures are either not assessed at all, or assessed locally and not mapped on a broad scale. The same applies for exogenous (i.e. unmanageable with local measures) pressures, with water flow rate changes being under-represented, and geomorphological changes absent. Clearly, warming trends and sea-level rise are the most frequently mapped exogenous pressures, followed by acidification.

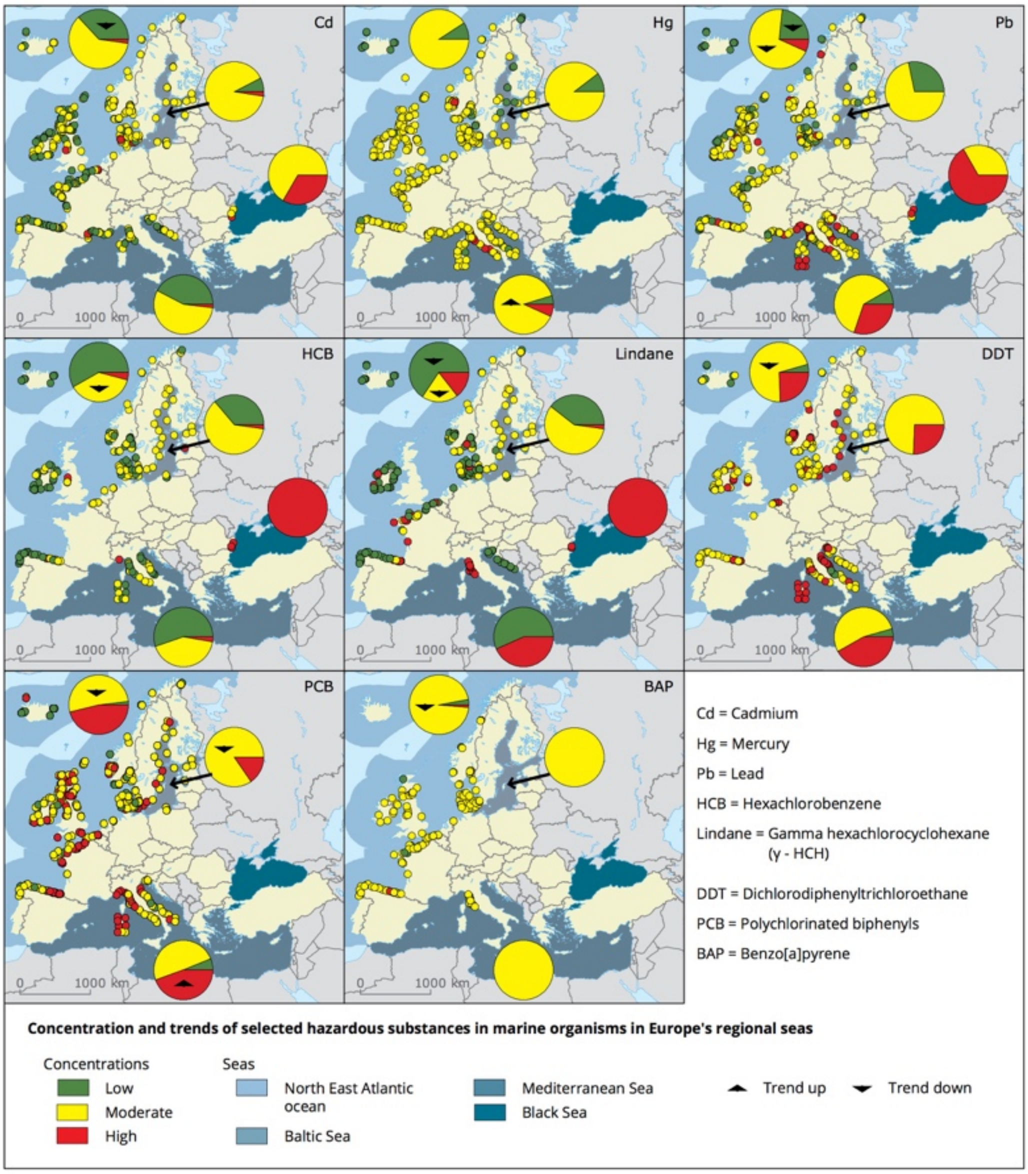

Figure 18. Aggregated assessment of hazardous substances in biota measured in the North-East Atlantic, Baltic Sea and the Mediterranean Sea. Image from EEA (2015).

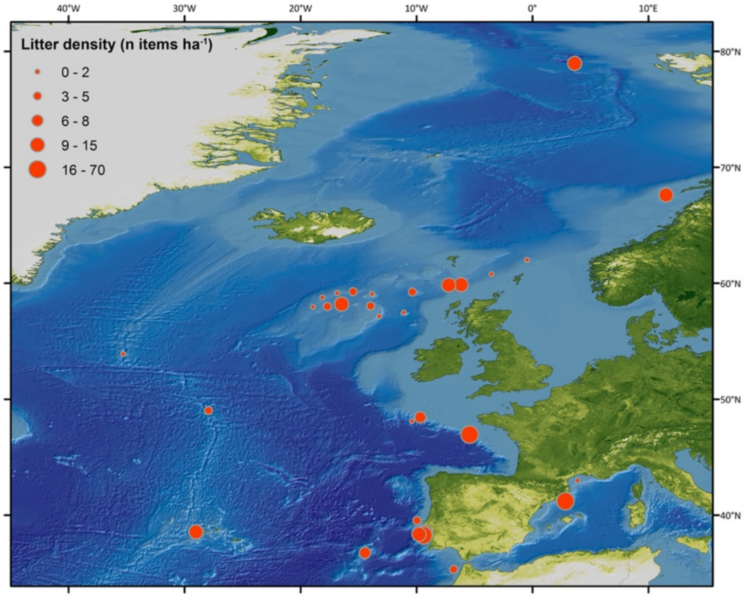

Figure 19. Litter densities (number of items per hectare) in different locations across some European waters obtained with ROVs, towed camera systems, manned submersible and trawls. Image from Pham et al. (2014).

Nevertheless, whilst an activity has the potential to cause multiple pressures, it may not necessarily be realised in practice in a particular space/habitat, for example, shipping only causes abrasion by anchoring or grounding in shallow waters rather than along an entire shipping route/track and might not actually ever happen if the vessels tie-up alongside in port. Furthermore, even if an activity does take place its resultant pressure upon the marine environment will vary as a function of its frequency/intensity/duration and footprint. For example, many pressures may be accidental (shipping: abrasion from grounding, contamination from oil spills) and therefore infrequent, but others may be a major part of the activity and for the large part match the action/footprint of the activity (fishing: abrasion from trawling activities). Furthermore, whist activities are shown as points of presence or areas of concentration, their pressures may go beyond the actual footprint of the activity, for example smothering caused by dredging/trawling impacts areas outside the actual footprint of the activity, as does contamination by hydrocarbons following an oil spill. Therefore, whilst maps of activity are useful indicators of its location they do not necessarily translate into maps of pressures (and vice versa) and as such care needs to be taken when interpreting them.

A limitation with a number of the maps in the catalogue is their applicability at small spatial scales. Whilst VMS data have highly accurate initial vessel geo-positioning (10 m accuracy) by the time they are processed they are often at 2000 m accuracy based on an intensity derived from the proportion of an area swept per year. The same is also true for interpolated maps based on modelled data, which is often relatively coarse. If the resolution is low, the possibility of having accurate data within that area is also low, making it difficult to infer activity extent at local levels. In addition, such “footprints” of activity often lack actual details on intensity, temporal scales, actual duration and in the case of a pressure, how long the impact may last.

The comprehensive review undertaken in this report highlights several limitations and gaps concerning the resolution, data availability and format and geographical coverage of mapped pressure and activates occurring in European Seas as well as their geographic coverage:

- **Static data**: A clear majority of the available activities/pressure maps are simple images greatly reducing their usability since they cannot be accurately overlaid with other complimentary maps nor can the underlying data be easily extracted. Moreover, images are static in time (in contrast to digital media which can be easily updated with newer data), while activities and pressures in marine habitats are temporally dynamic.
- **Spatial resolution**: Available activities/pressure maps are usually broad-scale and low-resolution. This has considerable implications for precision and accuracy, further enhanced by the fact that broad-scale coverage for non-point data is usually inferred by interpolation. While low resolution may be sufficient for setting conservation priorities (see Giakoumi et al., 2015) it cannot be considered appropriate for actual conservation and for restoration actions.
- **Modelled data**: Related to the previous bullet; a number of the available maps may contain a high level of modelled/predicted data (using a variety of data proxies) with a high degree of interpolation between actual data points. Validation of spatial analysis, that may cover complete regional seas, is an issue and this leads to high levels of uncertainty and the limitation of broad scale map utilisation only for broad scale use.
- **Geographic coverage**: Geographic under-representation is an issue, both at the regional level (Black Sea) and sub-basin level (Eastern Mediterranean Sea). This reflects geographical research efforts, but may also reflect the lesser degree of local project expertise in some areas.
- **Over-representation**: some specific habitats have more information than others (e.g. seagrass meadows). This is most likely due to their multi-use, perceived or legislative importance, or simple “accessibility”.
- **Hard to find information**: Grey literature (e.g. dissemination publications, technical and project reports) is a significant source for useful activities/pressure maps; however, these sources are not directly visible or searchable through standard literature platforms (e.g. SCOPUS, WoS).

Based on the above, it is recommended that future mapping initiatives should focus on the following:

- **Generating georeferenced data**: The generation of digital maps based on georeferenced information, preferably in open-access formats. The ideal solution would be to create and support universal web platforms to serve as data repositories and visualizers to allow the interrogation of multiple sources of information at varying spatial and temporal scales.
- **Increased needs in assessments**. Open access georeferenced data on habitats, degraded habitats and activities/pressures are in high demand for status and health assessments, cumulative effects assessments, EU directives, EIA and EEA assessments and for planning for MSP. They are also needed for threatened and special places in the world's oceans such as the IUCN Red Lists assessments and the work of the Convention of Biological on Ecologically or Biologically Significant Areas respectively. All these assessments need to one degree or another ecological, biological and pressures data layers - overlaying multiple layers of information is becoming a necessity (see examples for vulnerability, fragility and naturalness and high/low level of human induced habitat degradation, in the Global Ocean Biodiversity Initiative that builds on the scientific criteria adopted by the Parties to the Convention on Biological Diversity (CBD) www/gobi.org)
- **Filling gaps in knowledge**: Filling the aforementioned geographical and temporal gaps (by digitization of old/historical maps) and supporting regional and national mapping initiatives. National or regional atlases are often valuable resources since they integrate state-of-the-art knowledge over broad components of the environment and relevant human activities and induced pressures.
- **Gaining high-level standardization**: The role of transnational and intergovernmental organizations such as the EU but also UNEP-MAP, OSPAR, HELCOM and the Black Sea Commission can be crucial towards the production, standardization, and integration of data with universal approaches and balanced geographical representativeness.

5.2. Restoration Potential and Conclusions from the Case Studies

For the shallow soft substrate seagrass example, the effects (Table 7) of the mix of activities and pressures operating there include changes in sediment biogeochemistry, changes in hydrology, changes in light and ambient water biochemical parameters. Negative changes in biology and species include effects of native and alien species, micro and macroalgal overgrowth and blooms. Consequences include impacts on key features: population and spatial dynamics, reduced growth, primary production, habitat complexity, general diversity, dispersion and migration of species, reproductive success, increased stress and mortality, smother and damage, loss of seagrass and bare patches, increased habitat fragmentation (decreased patch size, increased isolation and decreased connectivity) as well as shifts in trophic structure.

For the three shallow hard substrate examples effects and consequences include removing and destroying the habitat (e.g. by mooring/dredging and trawling in the kelp), damaging flora and associated fauna, altering environmental characteristics for species, shadowing and enrichment effects, hydrological changes, predation removal, reducing connectivity among habitats, mortality of organisms, loss of diversity, loss of density and cover, reducing genetic connectivity, loss of structural complexity, loss of resilience (ability to recover from disturbances), impairment on organisms biology, lethal or sub-lethal effects on many algal species (specially structural *Cystoseira* species), change in species composition, simplification of communities.

Existing and potential effects on deep-sea habitats (Table 11) include changes in substrate characteristics such as porosity, particle size distribution and mineralogy biogeochemistry, loss and change of substratum due to mining activities, oil-gas platforms, cables lays and the creation of CO_2 lakes on the sea floor, changes in sediment topography and complexity (e.g. sediment displacement due to trawling causing flattening of the sea floor, plumes generated by trawling and mining activities leading to deposition, burial and clogging of suspension feeding (including water column gelatinous zooplankton), changes in hydrology (in the case of the carbon sequestration activity with pH reductions and reduction in the productivity of calcifying organisms leading to higher ratios of non-calcifiers over calcifiers when CO_2 is released in the water column), changes in biodiversity and species composition (including removal of various species such as fish and corals for commercial interest and scientific/research purposes (lab/aquarium research, transplantation, etc.), as well as changes in physical properties with introduction of litter and noise, changes in nutrient conditions, changes in pH, changes in temperature and salinity and release of toxic metals. The main consequences are the loss of species, decreased biodiversity, changes in behaviour and species composition, alterations of food webs, decreased connectivity and ecosystem functioning.

As expected, numerous pressures are recorded in all case studies acting as mechanisms of change and causing progressive state change effects from the population to the ecosystem level in agreement with Smith et al. (2016) (see below for cumulative pressure assessments). The options recorded in the case studies are all similar in nature offering the same advice and conclusions. These include: to eliminate, reduce or better regulate the activity, and where possible, conduct the activity in a region where the ecosystem has high recovery potential, whilst also making efforts to reduce impacts and inputs, ameliorate water quality, control harmful practices, reduce disturbance and ensure disturbance does not disrupt connectivity, create habitat connections, remove alien species and litter before restoration. Restoration should be performed away from problem areas, activities should be eliminated/reduced in restoration areas, and destructive sampling should not be allowed in newly restored areas. In most of the cases mitigation is the recommended action with very few cases actually mentioning (additional) active restoration (e.g. transplanting). In these latter cases emphasis is given to the prevailing pre-conditions and the biological and environmental features that could compromise the restoration efforts in the absence of suitable factors to support spontaneous regeneration and restoration.

In this deliverable/section, six key habitats were reviewed listing pressures, impacts, consequences and restoration or mitigation actions. Restoration practices themselves, and/or differences between the key habitats in terms of resilience and receptiveness to restoration are discussed in terms of six major ecosystem features (including diversity, vulnerability, connectivity and structural complexity) and presented in detail in MERCES D1.1 Deliverable (Bekkby et al., 2017). In summary, based on ecosystem features and logistical considerations, deep-sea coral habitats are likely to be the most challenging to restore due to their slow growth rates and high vulnerability while, kelp forests, among the shallow hard-bottom habitats, are probably the easiest to restore owing to their fast growth rates and high levels of connectivity.

5.3. Pressures and pressure assessments

5.3.1. Pressures

The Habitats Directive, one of the oldest EU policies and of fundamental importance in assessing the status and trends of species and habitats of the European Seas, has been using for its reporting and assessment needs a comprehensive list of pressures and threats based on hierarchical system of over 400 threats and pressure codes (http://bd.eionet.europa.eu/activities/Reporting/Article_17/reference_portal). These include a variety of activities and an extensive list of pressures ranging from agriculture and forestry to disturbances due to human activities, pollution, invasive and introduced species to geological events and natural catastrophes (see Table 12, 13, 14).

Table 12. Habitat Directive listed activities, pressures and threats

HD Pressures for Reporting
Agriculture
Silviculture, forestry
Mining, extraction of materials and energy production
Transportation and service corridors
Urbanisation, residential and commercial development
Biological resource use other than agriculture & forestry
Human intrusions and disturbances
Pollution
Invasive, other problematic species and genes
Natural System modifications
Natural biotic and abiotic processes (without catastrophes)
Geological events, natural catastrophes
Climate change
Unknown threat or pressure
No threats or pressures
Threats and pressures from outside the EU territory
Threats and pressures from outside the Member State

Table 13. Habitat Directive listed pressures under Mining, extraction of materials and energy production, includes various levels as seen by the code (part of the hierarchical system)

code	HD Pressures Under Mining, extraction of materials and energy production
C	Mining, quarrying & energy production
C01	Mining and quarrying
C01.01	Sand and gravel extraction
C01.01.01	sand and gravel quarries
C01.01.02	removal of beach materials
C01.02	Loam and clay pits
C01.03	Peat extraction
C01.03.01	hand cutting of peat
C01.03.02	mechanical removal of peat
C01.04	Mines
C01.04.01	open cast mining
C01.04.02	underground mining
C01.05	Salt works
C01.05.01	abandonment of saltpans (salinas)
C01.05.02	conversion of saltpans
C01.06	Geotechnical survey
C01.07	Mining and extraction activities not referred to above
C02	Oil and gas exploitation
C02.01	exploration drilling
C02.02	production drilling
C02.03	jack-up drilling rig
C02.04	semi-submersible rig
C02.05	drill ship
C03	Production of renewable energy (abiotic)
C03.01	geothermal power production
C03.02	solar energy production
C03.03	wind energy production
C03.04	tidal energy production

Table 14. Habitat Directive listed Pressures under Human intrusions and disturbances, includes various levels as seen by the code (part of the hierarchical system)

code	HD Pressures Under Human intrusions and disturbances
G	Disturbances due to human activities
G01	Outdoor sports, leisure and recreational activities
G01.01	nautical sports
G01.01.01	motorized nautical sports
G01.01.02	non-motorized nautical sports
G01.02	walking, horse riding and non-motorised vehicles
G01.03	motorised vehicles
G01.03.01	regular motorized driving
G01.03.02	off-road motorized driving
G01.04	mountaineering, rock climbing, speleology
G01.04.01	mountaineering & rock climbing
G01.04.02	speleology
G01.04.03	recreational cave visits
G01.05	gliding, delta plane, paragliding, ballooning
G01.06	skiing, off-piste
G01.07	Scuba diving, snorkelling
G01.08	other outdoor sports and leisure activities
G02	Sport and leisure infrastructures
G02.01	golf course
G02.02	skiing complex
G02.03	stadium
G02.04	circuit, track
G02.05	hippodrome
G02.06	attraction park
G02.07	sports pitch
G02.08	camping and caravans
G02.09	wildlife watching
G02.10	other sport / leisure complexes
G03	Interpretative centres
G04	Military use and civil unrest
G04.01	Military manoeuvres
G04.02	abandonment of military use
G05	Other human intrusions and disturbances
G05.01	Trampling, overuse
G05.02	shallow surface abrasion/ mechanical damage to seabed surface
G05.03	penetration/ disturbance below surface of the seabed
G05.04	Vandalism
G05.05	intensive maintenance of public parks /cleaning of beaches
G05.06	tree surgery, felling for public safety, removal of roadside trees
G05.07	missing or wrongly directed conservation measures
G05.08	closures of caves or galleries
G05.09	fences, fencing
G05.10	overflying with aircrafts (agricultural)
G05.11	death or injury by collision

The Habitats Directive also considers pressures originating from outside EU waters as well as threats (defined as future pressures expected to occur in the not too distant future e.g., around 10 years) and climate change. This information is used in the regular status assessments to elucidate the factors affecting the status of the habitats in question. In the most recent such State of Nature report (COM, 2015) the main reported threats and pressures for marine systems include the use of living resources (primarily fishing and harvesting of aquatic resources), pollution, modification of natural conditions (dredging, hydrological modifications and coastline management) and disturbances due to human activities (Figure 20) which is in agreement with the findings of this report.

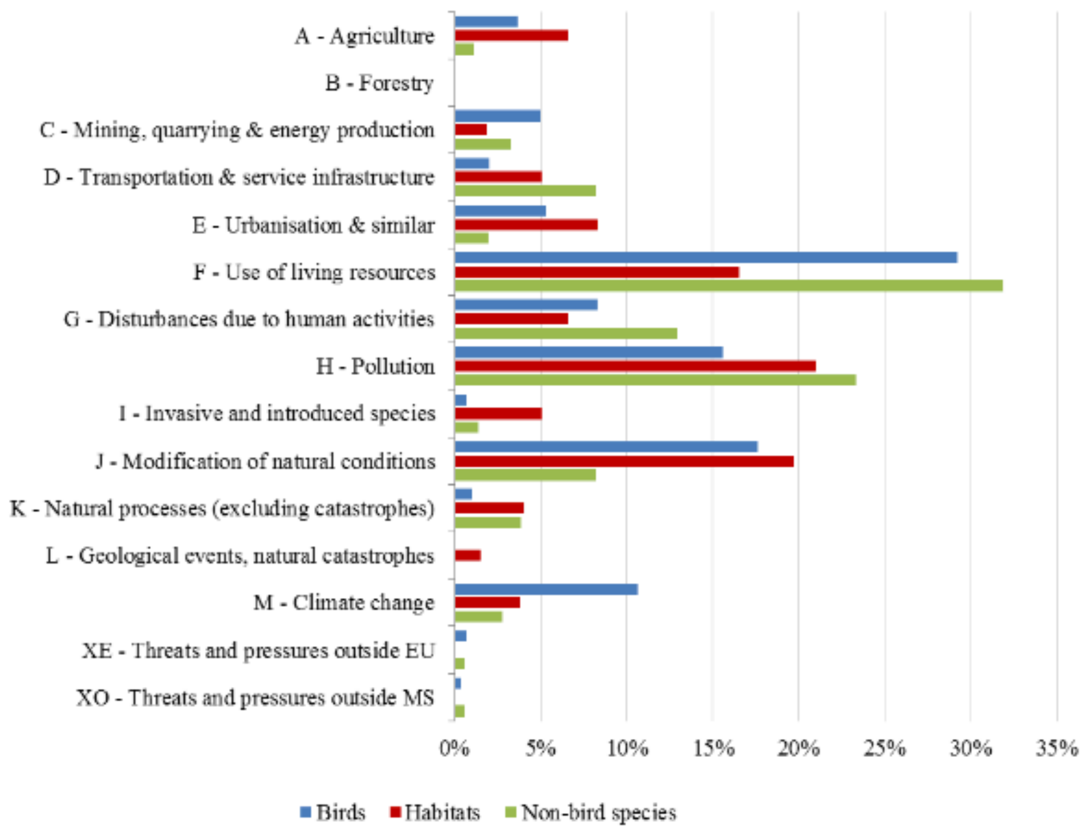

Figure 20. Frequency (percentage) of high ranked level 1 pressures and threats (together). COM (2015).

In a similar approach, the Water Framework Directive (Article 5) calls for the identification of driving forces or sectors of activities that might exert pressures on the water bodies under assessment. The driving forces include, among others, diffuse (e.g., urban drainage and agriculture diffuse), point (e.g., wastewater, industry, mining, aquaculture), and morphological sources (e.g., flow regulation, river, transitional and coastal management). Activities and related pressures are grouped under pollution, water regime, morphology and biology (Figure 21, IMPRESS, 2003: Table 3.5 and 3.6, page 30).

Table 3.5 Example hydromorphological pressures and their impacts.

Activity or Driving force	Pressure	Possible change in state or impact
Dredging	Sediment disposal	Smothering of bed, alteration of invertebrate assemblage
	Removal of substrate	Loss of habitat
	Change in water level	Change in water table, loss of wetlands, loss of spawning areas.
Physical barriers (dams, weirs etc.)	Variation in flow characteristics (e.g. volume, velocity, depth) both up and downstream of barrier.	Altered flow regime and habitat.
Channel modification (e.g. straightening)	Variation in flow characteristics (e.g. volume, velocity, depth)	Altered flow regime and habitat.

Table 3.6 Example biological pressures and their impacts.

Activity or Driving force	Pressure	Possible change in state or impact
Fisheries	Fishing	Reduced fish fauna, especially on migratory and amphibiotic fish
	Fish stocking	Genetic contamination of wild populations
Introduction of alien species	Competition with indigenous species	Substitution of populations, destruction of habitats, food competition

Figure 21. Examples of pressures and impacts from the Water Framework Directive, (IMPRESS, 2003)

In addition to the Habitats and Water Framework Directives, the Marine Strategy Framework Directive - the aim of which is to protect more effectively the marine environment across Europe - requires member states to define what constitutes "good environmental status" and establish a comprehensive set of targets and associated indicators to track progress towards the desired state. Article 8 in particular supports the assessment of predominant pressures on the marine environment with the ultimate aim of bringing a pressure or an impact to a level that achieves the environmental target that is consistent with GES definition or allows the recovery of marine systems towards GES. In order to facilitate this process, the MSFD produced an indicative list of pressures and impacts (Annex III, Table 2), which builds upon earlier attempts to categorize pressures (e.g. DEFRA, 2005, 2010; Eastwood et al., 2007).

The extended lists of activities and pressures used in this report (Tables 1-2) were compiled from several recent FP7 projects including ODEMM, VECTORS and DEVOTES (e.g. Robinson et al., 2013; Smith et al., 2016). This work was focused on the MSFD lists and terminology (Annex III, Table 2) while looking at adding clarity in the definitions (e.g., Patricio et al., 2014, 2016; Smith et al., 2016) and consistency in the assessments. In most cases, proxies and groupings are necessary. The choice of pressure groupings (or themes) is important but as the majority of EU policy instruments call for the same main groupings, it is fairly standardised (biological change, physical change (including, or not, hydrological modifications) and chemical changes related to pollution, eutrophication and various inputs of substances, litter and energy). For example, physical pressures, such as changes in siltation due to sediment plumes or even seabed abrasion, are very difficult to measure and monitor and often the activities themselves are used as proxies (e.g. fishing footprint from VMS vessel tracks to represent abrasion). Although grouping is often the only practical solution, it is important to note here that the footprint and longevity of the siltation and abrasion pressures would not be the same; sediment clouds would be more ephemeral than trawl tracks and they would spread further than the measured trawl path by VMS technology. But very rarely there will be data for separate pressures or pressure components (but see an exception in Eigaard et al. (2016) who give surface and subsurface abrasion maps).

A note on consistency: as it obvious from the examples presented here (Tables 12-14, Figures 21-22) and the analysis of the Catalogue entries, a “pressure” is not always a pressure, and the terms “driver”, “activity”, “sector”, “pressure”, “stressor” and “threat” have been used interchangeably or in a variety of inconsistent ways (see for example, Halpern et al., 2008; Coll et al., 2012; Micheli et al., 2013; Korpinen and Andersen, 2016; Knights et al., 2015). Further examples of discrepancies in the definition and use of the elements of the DPSIR cycle in marine assessments are given by Elliot (2014), Borja et al. (2006) for the WFD, Smith et al. (2016), Patricio et al. (2016), both for the MSFD and Borja et al. (2016) for integrative assessments. These discrepancies include also the “Impact” element of the DPSIR cycle where impacts can be considered impacts or state changes, while impacts and effects (of pressures) can be used interchangeably or be considered a different step in the process (Judd et al., 2015; Korpinen and Andersen, 2016; Patricio et al., 2016; Smith et al., 2016). A major challenge is defining “significant impacts”, “adverse effects” and/or “significant adverse effects” that can cause “serious harm” (see Korpinen et al., 2013, for a Habitats Directive-MSFD example and Levin et al., 2016, for a deep-sea example). Article 1 of the MSFD calls for marine strategies to be developed and implemented in order to protect the marine environment, prevent its deterioration or, where practicable, restore marine ecosystems in areas where they have been “adversely” affected. In the revised MSFD (based on documents endorsed by the MSFD common implementation groups) Member states will be required to assess the spatial extent of any adversely affected habitats and to provide thresholds of the adverse effects by physical disturbance through regional cooperation. These thresholds will be linked to GES and the risk of failing to achieve it, in which case measures will be required and implemented. These could range from activity reduction (reduce fishing effort) to active interventions (eradication of invasive alien species) and ecosystem restoration. Depending on the degree of degradation and the type of ecosystem in question, it is likely that repeated policy cycles and long monitoring of restored sites (Bayraktarov et al., 2016) will be necessary to match the restoration time scale, as full recovery may take decades to centuries (Clewell and Aronson, 2007)

5.3.2. Activity and Pressure Enigmas

Whilst marine activities are all to the benefit of society, they create pressures that are generally perceived to be negative to the environment. A few activities that have been recently received attention and large-scale investment are as a result of societies "worries" including carbon sequestration and renewable energy activities (wind turbines, tidal and wave energy generating systems). There are, however, a few enigmas to this thought and some pressures/activities may have mitigative or restorative abilities. Carbon sequestration has localised impacts in the area of sequestration, but a far wider area of pressure reduction from containment of carbon dioxide. Renewable energy activities may also create local pressures, but energy generated and distributed widely leads to a reduction in more wasteful (non-renewable resources – oils, gas and coal) or polluting (production of CO_2, other contaminants or nuclear waste) energy generation activities. Structures in the sea associated with marine renewable energies may also provide hard substrates that will allow hard substrate communities and local biodiversity hotspots to develop, or lead to closed areas where other activities are no longer allowed to operate (e.g. fishing and dredging), thus creating *de-facto* protected areas (albeit with potential displacement activity consequences too). Another enigma relating to activities and pressures concerns litter. Lost fishing gears (classified under litter) may ghost-fish for some time after loss, but in time will provide hard substrates for colonisation of hard substrate fauna. Such objects on the bottom may also baffle seabed currents and allow settlement of larvae and colonisation in the lee of the objects (Matsuoka et al., 2005).

5.3.3. Assessments

Numerous policies call for preservation/restoration of habitats, minimization of loss/reduction of impacts and holistic ecosystem health assessments.

Structured linkage frameworks (matrices of Pressures x Activities), like those produced for the case study examples in this deliverable, are the base of many integrated pressure or cumulative pressure and impact assessments (CPIA). OSPAR, for example has regular assessments of certain human activities and Intersessional Correspondence Group working on cumulative effects. Numerous such pressure assessments have been performed in Europe and elsewhere in the last decade (Halpern et al., 2008; Korpinen et al., 2013; Korpinen and Andersen, 2016; Knights et al., 2015; Goodsir et al., 2015; Giakoumi et al., 2015; UK Charting Process assessments http://www.marlin.ac.uk/habitats/SNCB-benchmarks, http://www.marlin.ac.uk/species/sensitivity_rationale , http://www.marlin.ac.uk/habitats/detail/1142/deep_water_lophelia_reefs, Borja et al., 2016). A recent review of 40 assessments (Korpinen and Andersen, 2016) concludes that activities were included in the majority of the studies, pressures were commonly linked to activities and pressure categories were used often according to the MSFD. Impacts, often cumulative, were assessed based on the sensitivity of the habitats/ecosystem components, their resistance to damage (Eno et al., 2013), or the severity of the pressures. However, very few studies have included a full array of pressures in their assessments, or have looked at more than a few ecosystem components.

Due to lack of information or data gaps, few studies incorporated the element of time, assuming that many pressures are long lasting. However, some pressures and impacts can be short-lived (e.g. noise). One of the assessments attempted to assess and incorporate the recovery potential by looking at the pressure persistence, i.e. time (years) the pressure continues to cause impact after cessation of the activity working at the broad habitat level (e.g., littoral or sub-littoral sediments). Using expert judgment and published information, over 4000 potential activity-pressure-species/habitats-impact chains were evaluated for this assessment (see details in Knights et al., 2013, 2015). Four persistence categories and four resilience categories were used in the assessment (i.e. recovery time of the ecological characteristic to return to pre-impact conditions). The resulting recovery lag (based on the persistence of a pressure and the resilience of a habitat/species group) was found to be highly dependent on the pressure type. Relatively short minimum recovery times (between 1 and 11 years) were associated with physical pressures (e.g., abrasion, noise) while biological (e.g. NIS) contaminant and hydrological pressures were characterized by long RL times of >100 years. For some pressure types, there were no differences in recovery lag between regions/seas (e.g., non-synthetic or synthetic contaminants), but for others such as recovery following nitrogen and phosphorus enrichment were region specific (estimated to take a minimum of 11 years in the Baltic Sea but only 2–3 years in all other regions (Knights et al., 2015, Figure 22 from his Figure 4).

In agreement with findings in this Deliverable and Bekkby et al. (2017) MERCES Deliverable D.1.1., most of the assessments worked at the broad habitat types as these are often the only available mapped habitats (Korpinen and Andersen, 2016).

Spatial and temporal uncertainty and uncertainty in measurements (e.g. objective measurements versus estimated or modelled values) is an issue that is increasingly addressed systematically by some of the assessments (Borja et al., 2016). Despite the simplicity involved in these assessments, for example the relationship between pressure and state change is often assumed to be linear, and the interaction between co-occurring activities and pressures is ignored or assumed to be additive (when it could be, synergistic or antagonistic) they are very useful as risk based frameworks for prioritization of management (Judd et al., 2015; Knights et al., 2015).

The common backbone to all these assessments, beyond methods for assessing impacts and recovery from damage, is the need and use of spatial data on both pressure presence/intensity and habitat/species distribution/occurrences. Korpinen and Andersen (2016) promote the open access to geospatial data and free sharing of tools and codes such as the open access EcoImpactMapper (Stock, 2016) used by the widely adopted Halpern et al. (2008) assessment.

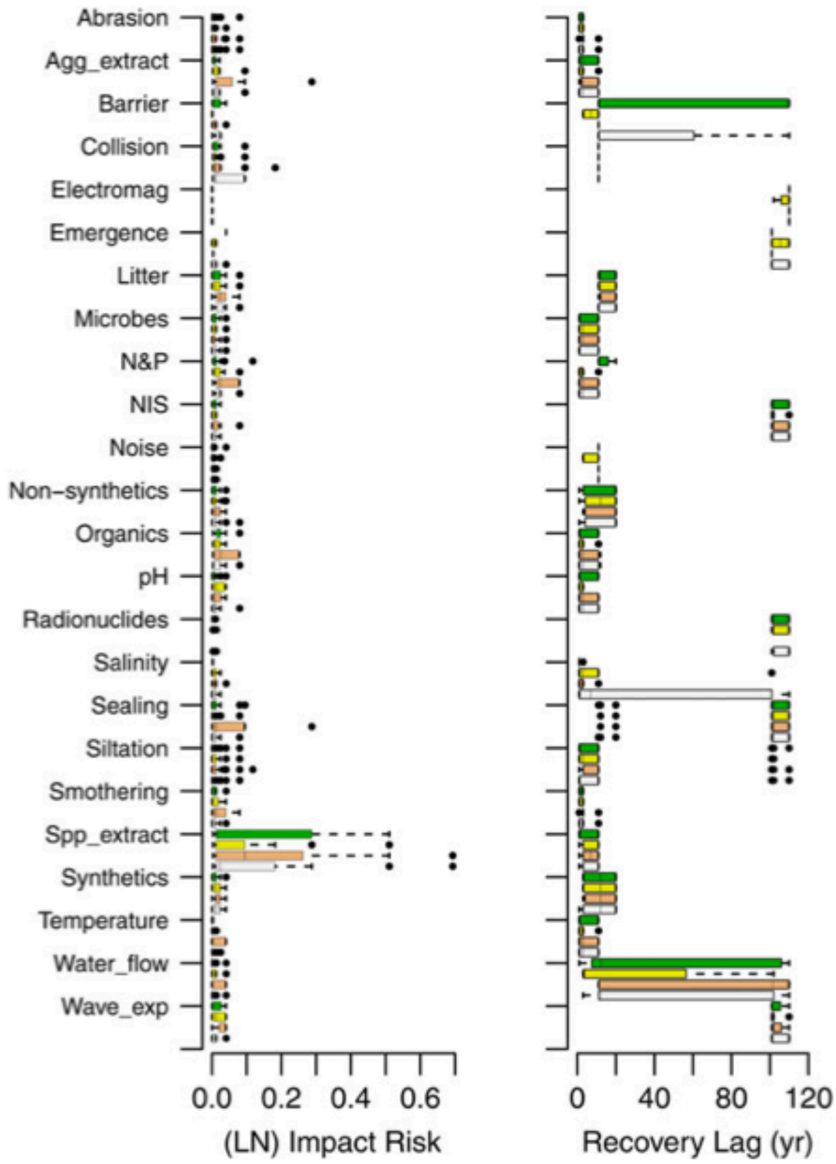

Figure 22. Distribution of Impact Risk and Recovery Lag scores grouped by pressure type in each of the 4 European regional seas (bars: Baltic Sea (green), Black Sea (yellow), Mediterranean Sea (orange) and North-East Atlantic (white)). The maximum IR and RL score for any chain is 0.7 and 1.0 respectively. No bar indicated the absence of the pressure in the region. Middle lines of boxplots represent the median values; hinge lengths (end of box) represent the 25% quartiles from the median; whiskers represent the 1.5 times the interquartile range (IQR) beyond the hinge. Outliers are shown as black dots (from Knights et al., 2015, Figure 4)

5.4. Potential for Restoration and Blue Growth

5.4.1. Restoration potential away from pressure hotspots

The identification of activities and pressure hot spots (as seen in the catalogue maps and the case studies examples, Results section, Tables 6-10) is crucial for planning future restoration actions. Highly degraded sites harbouring habitats which suffer intense anthropogenic impacts are usually more difficult to restore (Abelson et al., 2016). Therefore, restoration activities taking place in these hotspot areas are likely to require more intense restoration efforts as well as greater costs. Mitigation of pressures and removal of their impacts at sites where restoration activities take place could also enable the quicker recovery of the given habitat, as highlighted in the aforementioned case studies. Notable measures which apply to most – if not all – of the examined habitats include the elimination and/or regulation of particular detrimental activities (e.g. harmful fishing practices), the reduction and/or removal of specific pressures (e.g. removal of litter, reduction of nutrient input) and the amelioration of water quality.

Different types of activities and pressures differ in the level and type of degradation inflicted on different habitats. The systematic review regarding degraded habitat map resources (Bekkby et al., 2017, MERCES D1.1. Deliverable) revealed that most map sources reported multiple activities and pressures (mostly physical and chemical) causing habitat degradation in all regions and major habitat types. However, very few of the mapped sources include information on the recovery restoration potential of the examined habitats. Mitigation and/or removal of pressures causing habitat degradation (e.g., restrictions to fishing activities and MPAs) were highlighted as important components of habitat restoration (see discussion in Elliot et al., 2007). Alternative restoration actions were suggested only in a few cases, due to (a) the logistical constraints and cost of applying active restoration at large scales, or (b) the lack of mapping initiatives suitable for planning restoration actions. Therefore, the detailed mapping and assignment of "habitat-specific" activities and pressures causing degradation, could aid recovery potential increasing the chances for effective restoration.

5.4.2. Enabling restoration: the MSP Directive and Natural Capital Accounting

Blue Growth is the European Union's long-term strategy to support sustainable growth in the marine and maritime sectors (COM, 2012). Maintaining healthy seas and oceans are considered vital to Blue Growth. The MSFD, adopted in 2008, establishes the policy framework to address the challenges facing Europe's marine environment and to work towards a sustainable use of its marine resources. With the Birds and Habitats Directives (EC, 2009; EEC, 1992 respectively), this Directive forms the environmental pillar of the maritime policy and is at the heart of the EU's contribution to international efforts to protect the marine environment (SWD, 2017). Within the MSFD, the marine environment is considered "a precious heritage" and Member States should adopt an ecosystem approach to the management of human activities, put emphasis on the health of the ecosystem alongside the sustainable use of marine goods and services and take measures to achieve GES by 2020 to prevent further deterioration and/or restore marine ecosystems in areas where they have been adversely affected.

The European Biodiversity Strategy 2020 (COM, 2011) promotes the restoration of degraded ecosystems and their services and is intended to contribute to the Union's sustainable growth and help mitigate and adapt to climate change (SWD, 2017). Indeed, the Biodiversity Strategy has the longer term goal that by 2050, European Union biodiversity and the ecosystem services it provides, its ‘natural capital’ will be protected, valued and appropriately restored for biodiversity's intrinsic value and for their essential contribution to human wellbeing and economic prosperity, and so that catastrophic changes caused by the loss of biodiversity are avoided (COM, 2011). The recently amended Environmental Impact Assessment (EIA) Directive (2014/52/EU), simplifies the rules for assessing the potential effects of projects on the environment. If projects are likely to cause significant adverse effects on the environment, developers are obliged to do the necessary to avoid, prevent or reduce such effects.

The Maritime Spatial Planning (MSP) Directive (Directive 2014/89/EU) is considered a key enabler of Blue Growth. Spatial planning should lead to an increase in the efficiency of licensing offshore activities whilst protecting the marine environment. The Directive requires Member States to develop national marine spatial plans before March 2021. Together with the MSFD, the MSP Directive is a foundation stone for the sustainable development of the EU's seas and oceans (SWD, 2017). The main purpose of the MSP Directive is to promote sustainable development and to identify the utilisation of maritime space for different sea uses as well as to manage spatial uses and conflicts in marine areas. In so doing, the Directive will contribute to achieving the aims of several Directives and initiatives including MSFD, the Habitats Directive and the EU Biodiversity Strategy.

A common information need, shared by MSP and a number of the Directives and initiatives it will support, is the collation and mapping of existing information to provide an inventory of ecosystem components, and major human pressures and impacts, in a given area (cf. Stelzenmüller et al. 2013) although differences do exist between Directives (e.g. MSP specifies a minumum number of human activities to be considered explicitly mentioning several Blue growth activities, the maritime dimension of coastal uses as well as nature conservation and research (Boyes et al. 2016)). As well as informing zoning decisions required under MSP, knowledge of the extent of ecosystem components is required to support mapping and assessment and valuation of ecosystem goods and services (MAES, 2013, 2014); while spatial and temporal data on pressures and impacts can be used to assist the determination of GES in the

MSFD and the future prospects of attaining/maintaining ecosystem integrity in Special Areas of Conservation (cf. Article 17 reporting, Habitats Directive, (EIONET, 2017)).

Almost all economic activities in the sea cause some environmental impact. The degree of impact depends on the severity/frequency of the activity and the resistance/recoverability of the receiving environment. The 'concept' of sensitivity has been developed over many decades and applied in coastal and marine habitats with numerous approaches, applied at a range of spatial scales, and to a variety of management questions (see Roberts et al., 2010). Sensitivity assessments typically employ a variety of standardized thresholds, categories and ranks (MarLIN, 2017) including:

1. standard categories of human activities and natural events, and their resultant 'pressures' on the environment;
2. descriptors of the nature of the pressure (i.e., type of pressure, e.g., temperature change or physical disturbance);
3. descriptors of the pressure (e.g. magnitude, extent, duration and frequency of the effect) termed the pressure benchmark (or Impact Risk sensu Knights et al. 2015);
4. descriptors of resultant change/damage (intolerance/resistance) (i.e. proportion of species population lost, area of habitat lost/damaged);
5. categories or ranks of recovery (recoverability/resilience) thought to be significant; and
6. resultant ranks of sensitivity and/or vulnerability.

Thresholds used to assess GES under the MSFD will facilitate an 'acceptable' level of environmental degradation provided key ecosystem components and functions are maintained. Prins et al. (2014) and Borja et al. (2014) state that one of the key issues when evaluating GES will be choosing the appropriate spatial scale for the assessment of multiple criteria and indicators. They state that assessments need to be done at spatial scales that are ecologically relevant, to provide information on the environmental status which is relevant to ecosystem-based management. The assessments have to support management of human activities and pressures in the marine environment, in order to achieve GES in line with the ecosystem-based approach. They also state that from a management perspective, the definition of spatial scales can be linked to the risk-based approach which should assess the link between Pressure-State-Indicator criteria/indicators. From this perspective, issues like the spatial scale of pressures and impacts, the impacts of one single pressure on various indicators/descriptors, the cumulative impacts of pressures, trans-boundary problems and time scales of impacts need to be considered. While, the MSFD requires that GES is determined at the level of European marine region or sub-region, Prins et al. (2014) recommend that a further system of nested spatial scales is required to reconcile the large number of assessment scales required for each specific assessment while maintaining an acceptable monitoring and reporting effort.

The MSP Directive requires setting boundaries for areas managed by spatial plans. Knowledge of the footprint of human activities (e.g. in the form of pressure maps, *cf.* Andersen et al., 2013) is required both for GES assessments and to facilitate area-based management. Combining pressure maps with maps assessing ecosystem services (see above), can provide useful information to managers required to implement maritime spatial planning adopting an ecosystem approach. Maritime spatial planning can also facilitate restoration initiatives by providing an appropriate zoning mechanism. Obviously to succeed, all impacting activities should cease in the area chosen for habitat restoration. Maritime spatial planning can be used to identify locations for potential restoration within a managed area that will allow continued economic activity while ensuring GES and thus sustainable 'Blue Growth'. Indeed, restoration areas may well be one of the tools in the 'toolkit' of managers tasked with maritime spatial planning.

Other potential tools that can be used in a maritime spatial planning context are biodiversity offsetting and habitat banking to ensure no net loss of biodiversity (see points 1, 2 and 3 in Box 1) from planned marine developments. A recent feasibility study in the UK (Cook and Clay, 2013) attempted to identify potential biodiversity offsetting and habitat banking options for use in UK waters. Biodiversity offsetting and habitat banking could potentially provide mitigation or compensation measures for impacts on Natura 2000 sites. The mitigation or compensation could be located in a different location to the impact and would be considered an 'offsite mitigation'.

Biodiversity offsetting and habitat banking options considered by Cook and Clay (*loc cit.*) fall under the following categories (adapted from Eftec, 2013) of: Restoration, Creation, Averted risk, Preservation and Research. Restoration is considered as the manipulation of the physical, chemical, or biological characteristics of a degraded site, with the goal of enhancing natural functions or species communities in an existing habitat. While the authors concluded that offsetting was a viable proposition, they drew attention to the considerable uncertainty regarding the financial viability of marine biodiversity offsetting; in particular whether the cost of creating and/or managing an offset scheme would be prohibitive with respect to the ability of developers to fund the scheme or to purchase credits. They also drew attention to the need to manage or exclude fisheries if any of the offsetting options were to be successful.

While EU directives have created a second driver in MSP to identify areas of high biological value (Olsen et al., 2014), a possible criticism of the MSP Directive is that while it should contribute to the EU Marine Biodiversty Strategy, it does not explicitly mention the need to conserve natural capital. A stronger integration of the natural capital 'mindset', would ensure a more holistic understanding of the environmental trade-offs of human activity and better inform strategic business and investment decisions, for example, by factoring in the need to take measures to mitigate/adapt to climate change.

The concept of Natural Capital (see point 4 in Box 1) has gained currency in recent years as a means to highlight the finite nature of our planet's living resources and how ecosystem goods and services make life possible on the planet. In the past, natural capital has been considered a 'free' commodity but increasingly economists and scientists are calling for politicians and the public to recognise nature's value to the economy. Integrating these values into national accounting systems can therefore help us manage our scarce and dwindling natural capital (Constanza and Daly, 1992; Aronson et al., 2007; Blignaut et al., 2014).

A rapidly-evolving method for properly recognising the value of nature is 'natural capital accounting'. This involves attributing a measurable value to our natural capital in monetary terms (such as euros or dollars) and/or in ecological terms (such as the number of species in an area). Natural capital accounting is something that all EU member States have to do by 2020, through the Mapping and Assessment of Ecosystem Services project (MAES, 2013). Increasingly, big business is beginning to adopt Corporate Natural Capital Accounting methods as a means to integrate financial values for carbon sequestration and recreation, and non-financial values for biodiversity, into a natural capital asset index and in their financial reports (*cf.* Greenhouse Gas Protocol, 2001; Eftec, 2015). Habitat restoration as part of biodiversity offsetting and habitat banking initiatives can help business 'grow' their natural capital assets. The recently developed Natural Capital Protocol (Natural Capital Coalition, 2016) is a framework designed to help generate trusted, credible, and actionable information that business managers need to inform decisions. It aims to support better decisions by including how we interact with nature, or more specifically natural capital, in decision making.

Box 1. Natural capital and loss mitigation tools

1: Biodiversity offsets can be defined as "measurable conservation outcomes resulting from actions designed to compensate for significant residual adverse biodiversity impacts arising from project development after appropriate mitigation measures have been taken" (BBOP, 2013). They are distinguished from other forms of ecological compensation by the requirement for measurable outcomes.

2: No net biodiversity loss lies at the heart of biodiversity offsetting. No net loss, in essence, refers to the point where biodiversity gains from targeted conservation activities match the losses of biodiversity due to the impacts of a specific development project, so that there is no net reduction overall in the type, amount and condition (or quality) of biodiversity over space and time. A net gain means that biodiversity gains exceed a specific set of losses (BBOP, 2012).

3: Habitat banking provides a route through which those seeking to offset residual impacts on biodiversity can finance offsetting activities. This is achieved by the creation of a market in which developers can purchase biodiversity credits. The term habitat bank can also be used in reference to private or publicly owned land managed for its biodiversity value or to the delivering body, which brokers arrangements between developers seeking biodiversity credits and the land owners/managers which provide them).

4: Natural capital is a concept that unites the economy and the environment as allies for a sustainable future. It comprises the world's stocks of physical and biological resources, including air, water, minerals, soils, fossil fuels and biodiversity. Natural capital is an economic metaphor for the limited stocks of physical and biological natural elements found on Earth, some of which are of direct use to society (then called resources) and some of which are not. According to Rees (1995, 1996) and the Millennium Ecosystem Assessment (2005), there are four, partially overlapping types: renewable (living species and ecosystems), non-renewable (subsoil assets, e.g. petroleum, coal, and diamonds), replenishable (e.g. the atmosphere, potable water, and fertile soils) and cultivated (e.g., heritage lines of crop plants and livestock, and traditional agricultural knowledge).

5.4.3. Restoration and Blue Growth Opportunities

The restoration of degraded marine ecosystems can often be seen as a cost in business planning, but recently greater awareness by businesses of ecosystem services has led new business opportunities from restoration activities. By working methodically through a mitigation hierarchy businesses are first trying to avoid pressures, then devising civil and ecological engineering solutions to minimise adverse impacts. Where substantial impacts are inevitable, businesses are then taking direct actions to restore degraded portions of marine environments, using creative and cost-effective solutions that are of direct benefit to the environment, the reputation of industries and a business's the bottom line. Examples of restoration actions (described below) might be seen for instance, in 1) 'Building with Nature' in coastal management, such as for flood defence, 2) carbon sequestration by salt marshes, seagrass beds and mangroves (and the sediments they accrete) as an element in new carbon trading initiatives, and 3) experimenting with restoration measure by oceans mining companies as part of their Corporate Social Responsibility.

Short term planning in the coastal zone can often lead to unsustainable economic activities that have unintended consequences on local populations, such as the clearing of mangroves for aquaculture. Within the last 50 years, clearing of mangroves for shrimp culture has contributed to 38% of global mangrove loss, with other aquaculture accounting for another 14% (Barbier and Cox, 2004; Polidoro et al., 2010). Shrimp farms can become polluted with wastes, fertilizers and antibiotics (e.g. Thuy et al., 2011). The coasts in some cases, such as in the Asia-Pacific region, have become prone to erosion which in turn exposes coastal communities to increased risk from flooding and storm surges (DasGupta and Shaw, 2017). Longer-term planning is now evident recognising the value of a wider array of ecosystem services such as coastal protection and carbon sequestration. This requires the accurate mapping and quantification of habitats and pressures. There are business opportunities for knowledge-based companies and consultancies to assess all ecosystem services and their benefits, plan for sustainable coastal development and, where ecosystems have been degraded, invent simple and cost-effective engineering solutions to kick start and speed up natural recolonisation processes. Coastal engineers are now 'Building with Nature' to provide sustainable coastal management practices. In European waters this includes using salt marshes as natural coastal defence reducing wave erosion, binding pollutants, sequestering carbon and providing nursery grounds for fish.

Recently, the importance of salt marsh, seagrass and mangrove ecosystems in sequestering significant amounts of carbon from the atmosphere and the ocean has been recognised (e.g.

McLeod et al., 2011; Röhr et al., 2016). Restoring marine environments is now good business in mitigating climate change. For instance, although seagrasses account for less than 0.1% of sea areas, they account for approximately 10-18% of total oceanic carbon burial (Fourqurean et al., 2012; Greiner et al., 2013). The sediments associated with mangroves, tidal marshes, and seagrass meadows capture and store between 50 and 99% of the carbon in these systems, storing the carbon for exceptionally long times (http://thebluecarboninitiative.org/blue-carbon/#mitigation, Duarte et al., 2005). Key to assessing the value of restoring salt marshes, seagrasses (Greiner et al., 2013) and mangroves for carbon sequestration is accurate mapping of habitats and pressures worldwide, including the large-scale losses that have occurred in recent times. Knowledge-based SMEs have the capacity to advise on the role of marine ecosystem restoration for future carbon markets and carbon trading to address climate actions and sustainable development.

The growing need for 'technology metals' in electrical and communication goods upon which we all depend is driving greater activity in the exploration of minerals in the deep ocean (SPC, 2013). The seabed of the equatorial eastern Pacific Ocean between Hawaii and Central America alone has some 21 billion tons of polymetallic nodules lying on the surface of the abyssal seabed sediment (http://worldoceanreview.com/en/wor-3-overview/mineral-resources/manganese-nodules/). In addition, exploration is occurring on mid ocean ridges and in back-arc basins on deposits associated with hydrothermal activity and many seamounts (undersea mountains) are coated in a layer of cobalt rich crust up to 25 cm thick, especially in the western equatorial Pacific Ocean (https://www.isa.org.jm/sites/default/files/files/documents/ia6_eng6.pdf). While engineering solutions are being devised to minimise impacts, such as sediment compaction and the effects of near-bed plumes, large-scale impacts from mining are still inevitable. In addition, it is known that deep-sea ecosystems will take a long time to recover owing to long generation times (Thiel, 2003). There is therefore growing interest in what restoration measures might be undertaken to speed up natural recolonisation processes. It is likely that in order to obtain 'a social licence' to operate businesses will have to develop novel restoration solutions for the different ecosystems that might be impacted by mining. Mapping and modelling of species distributions and ocean habitats, and the scale, intensity and duration of mining impacts, are required in order to determine what proportion of the seabed can be disturbed, and over what time, without affecting natural ecosystem services and values.

6. References

Abelson A, Nelson PA, Edgar GJ, Shashar N, Reed DC, Belmaker J, Krause G, Beck MW, Brokovich E, France R, Gaines SD (2016) Expanding marine protected areas to include degraded coral reefs. Conservation Biology 30:1182–1191

Amaro T, de Stigter H, Lavaleye M, Duineveld G (2015) Organic matter enrichment in the Whittard Channel (northern Bay of Biscay margin, NE Atlantic); its origin and possible effects on benthic megafauna. Deep-Sea Research Part I 102:90–100

Andersen JH, Stock A (eds), Mannerla M, Heinanen S, Vinthe, M (2013) Human uses, pressures and impacts in the eastern North Sea. Aarhus University, DCE – Danish Centre for Environment and Energy, Technical Report from DCE – Danish Centre for Environment and Energy, No 18

Anonymous (2015) Ontwerp Beleidsnota Noordzee 2016-2021

Armstrong CW, Foley N, Tinch R, van den Hove S (2010) Ecosystem goods and services of the deep sea. Deliverable D62 HERMIONE Project

Armstrong CW, Foley N, Tinch R, van den Hove S (2012) Services from the deep: steps towards valuation of deep sea goods and services. Ecosystem Services 2:2–13

Armstrong CW, Foley NS, Kahui V, Grehan A (2014) Cold water coral reef management from an ecosystem service perspective. Marine Policy 50:126–134

Aronson J, Milton SJ, Blignaut J (eds) (2007) Restoring natural capital: science, business and practice. Island Press, Washington DC

Ballesteros E (2006) Mediterranean coralligenous assemblages: a synthesis of present knowledge. Oceanography and Marine Biology - An Annual Review 44:123–195

Barbier EB, Cox M (2004) Introduction: global mangrove loss and economic development. In: Barbier EB, Sathirathai S (eds) Shrimp Farming and Mangrove Loss in Thailand. Edward Elgar Publishing, Cheltenham, p 1-22

Barbier EB, Hacker SD, Kennedy C, Koch EW, Stier AC, Silliman BR (2011) The value of estuarine and coastal ecosystem services. Ecological Monographs 81:169–193

Bayraktarov E, Saunders MI, Abdullah S, Mills M, Beher J, Possingham HP, Mumby PJ, Lovelock CE (2016) The cost and feasibility of marine coastal restoration. Ecological Applications 26:1055–1074

BBOP - Business and Biodiversity Offsets Programme (2012) Resource Paper: No net loss and loss- gain calculations in biodiversity offsets. BBOP, Washington DC, Forest Trends

BBOP - Business and Biodiversity Offsets Programme (2013) To no net loss and beyond: an overview of the Business and Biodiversity Offsets Programme (BBOP). BBOP, Washington DC, Forest Trends

Beaulieu S, Joyce K, Cook J, Soule SA (2015) Woods Hole Oceanographic Institution

Bekkby T, Gerovasileiou V, Papadopoulou K-N, Sevastou K, Dailianis T, Fiorentino D, McOwen C, Smith CJ, Amaro T, Bakran-Petricioli T, Bilan M, Boström C, Carreiro-Silva M, Carugati L, Cebrian E, Cerrano C, Christie H, Danovaro R, Eronat EGT, Fraschetti S, Gagnon K, Gambi C, Grehan A, Hereu B, Kipson S, Kizilkaya I, van de Koppel J, Kotta J, Linares C, Milanese M, Morato T, Ojaveer H, Orav-Kotta H, Rinde E, Sarà A, Scharfe M Srimgeour R (2017) State of the knowledge on European marine habitat mapping and degraded habitats. Deliverable 1.1, MERCES Project, p 137

Bekkby T, Moy FE (2011) Developing spatial models of sugar kelp (Saccharina latissima) potential distribution under natural conditions and areas of its disappearance in Skagerrak. Estuarine, Coastal and Shelf Science 95:477–483

Bekkby T, Rinde E, Gundersen H, Norderhaug KM, Gitmark J, Christie H (2014) Length, strength and water flow - the relative importance of wave and current exposure on kelp Laminaria hyperborea morphology. Marine Ecology Progress Series 506:61–70

Benedetti-Cecchi L, Cinelli F (1992a) Canopy removal experiments in Cystoseira dominated rockpools from the Western coast of the Mediterranean (Ligurian Sea). Journal of Experimental Marine Biology and Ecology 155:69–83

Benedetti-Cecchi L, Cinelli F (1992b) Effects of canopy cover, herbivores and substratum type on patterns of Cystoseira spp settlement and recruitment in littoral rockpools. Marine Ecology Progress Series 90:183–191

Benedetti-Cecchi L, Pannacciulli F, Bulleri F, Moschella PS, Airoldi L, Relini G, Cinelli F (2001) Predicting the consequences of anthropogenic disturbance: large-scale effect of loss of canopy algae on rocky shores. Marine Ecology Progress Series 214:137–150

Benedetti-Cecchi L, Tamburello L, Maggi E, Bulleri F (2015) Experimental perturbations modify the performance of early warning indicators of regime shift. Current Biology 25:1867–1872

Benn AR,Weaver PP, Billet DSM, van den Hove S, Murdock AP, Doneghan GB, Le Bas T (2010) Human activities on the deep seafloor in the North East Atlantic: an assessment of spatial extent. PLoS ONE 5 (9): e12730, https://doi.org/10.1371/journal.pone.0012730

Bermejo R, de la Fuente G, Ramírez-Romero E, Vergara JJ, Hernández I (2016) Spatial variability and response to anthropogenic pressures of assemblages dominated by a habitat forming seaweed sensitive to pollution (northern coast of Alboran Sea). Marine Pollution Bulletin 105:255–64

Blignaut JN, Aronson J, de Groot RS (2014) Restoration of natural capital: a key strategy on the path to sustainability. Ecological Engineering 65:54–61

Borja A, Elliott M, Andersen JH, Berg T, Carstensen J, Halpern BS, Heiskanen A-S, Korpinen S, Lowndes JSS, Martin G, Rodriguez-Ezpeleta N (2016) Overview of integrative assessment of marine systems: the Ecosystem Approach in practice. Frontiers in Marine Science 3(20), https://doi.org/10.3389/fmars.2016.00020

Borja A, Galparsoro I, Solaun O, Muxika I, Tello EM, Uriarte A, Valencia V (2006) The European Water Framework Directive and the DPSIR, a methodological approach to assess the risk of failing to achieve good ecological status. Estuarine Coastal and Shelf Science 66:88–96

Borja A, Prins T, Simboura N, Andersen JA, Berg T, Marques JC, Neto JM, Papadopoulou N, Reker J, Teixeira H, Uusitalo L (2014) Tales from a thousand and one ways to integrate marine ecosystem components when assessing the environmental status. Frontiers in Marine Science 1(72), https://doi.org/10.3389/fmars.2014.00072

Boyes SJ, Elliott M, Murillas-Maza A, Papadopoulou N, Uyarra MC (2016) Is existing legislation fit-for-purpose to achieve Good Environmental Status in European seas? Marine Pollution Bulletin 137:105–119

Braga-Henriques A, Porteiro FM, Ribeiro PA, De Matos V, Sampaio Í, Ocaña O, Santos RS (2013) Diversity, distribution and spatial structure of the cold-water coral fauna of the Azores (NE Atlantic). Biogeosciences 10:4009–4036, doi:10.5194/bg-10-4009-2013

Buhl-Mortensen L, Vanreusel A, Gooday AJ, Levin LA, Priede IG, Buhl-Mortensen P, Gheerardyn H, King NJ, Raes M (2010) Biological structures as a source of habitat heterogeneity and biodiversity on the deep ocean margins. Marine Ecology 31:21–50

Campagne CS, Salles J-M, Boissery P, Deter J (2015) The seagrass Posidonia oceanica: ecosystem services identification and economic evaluation of goods and benefits. Marine Pollution Bulletin 97:391–400

Canals M, Danovaro R, Heussner S, Lykousis V, Puig P, Trincardi F, Calafat A, Durrieu de Madron X, Palanques A (2009) Cascades in Mediterranean submarine grand canyons. Oceanography 22:26–43

Canals M, Puig P, de Madron XD, Heussner S, Palanques A, Fabres J (2006) Flushing submarine canyons. Nature 444:354–357

Carreiro-Silva M, Andrews AH, Braga-Henriques A, De Matos V, Porteiro FM, Santos RS (2013) Variability in growth rates of long-lived black coral Leiopathes sp from the Azores. Marine Ecology Progress Series 473:189–199

Cheminée A, Sala E, Pastor J, Bodilis P, Thireiet P, Mangialajo L, Cottalorda JM, Francour P (2013) Nursery value of Cystoseira forests for Mediterranean rocky reef fishes. Journal of Experimental Marine Biology and Ecology 442:70–79

Christie H, Norderhaug KM, Fredriksen S (2009) Macrophytes as habitat for fauna. Marine Ecology Progress Series 396:221–233

Clark MR, Rowden AA, Schlacher T, Williams A, Consalvey M, Stocks KI, Rogers AD, O'Hara TD, White M, Shank TM, Hall-Spencer JM (2010) The ecology of seamounts: structure, function, and human impacts. Annual Review of Marine Science 2:253–278

Clewell AF, Aronson J (2013) Ecological restoration: principles, values, and structures of an emerging profession. 2nd Edition. Island Press, Washington DC

Coll M, Piroddi C, Albouy C, Lasram FBR, Cheung WWL, Christensen V, Karpouzi VS, Guilhauman F, Mouillot D, Paleczny C, Palomares ML, Steenbeek J, Trujillo P, Watson R, Pauly D (2012) The Mediterranean Sea under siege: spatial overlap between marine biodiversity, cumulative threats and marine reserves. Global Ecology and Biogeography 21:465–480

COM (2011) Communication from the Commission to the European Parliament, the Council, the Economic and Social Committee and the Committee of the Regions "Our life insurance, our natural capital: an EU biodiversity strategy to 2020". COM(2011)244

COM (2012) Communication from the Commission to the European Parliament, the Council, the Economic and Social Committee and the Committee of the Regions "Blue growth: opportunities for marine and maritime sustainable growth". COM(2012)494

COM (2015) Report of the Commission to the Council and the European Parliament “The state of nature in the European Union: report on the status of and trends for habitat types and species covered by the Birds and Habitats Directives for the 2007-2012 period as required under Article 17 of the Habitats Directive and Article 12 of the Birds Directive”. COM(2015)219

Cook D, Clay N (2013) Marine biodiversity offsetting and habitat banking feasibility study. The Crown Estate

Costanza R, Daly HE (1992) Natural capital and sustainable development. Conservation Biology 6:37–46

Cullen-Unsworth L, Unsworth R (2013) Seagrass meadows, ecosystem services, and sustainability. Environment: Science and Policy for Sustainable Development 55:14–28

Danovaro R, Gambi C, Dell’Anno A, Corinaldesi C, Fraschetti S, Vanreusel A, Vincx M, Gooday AJ (2008b) Exponential decline of deep-sea ecosystem functioning linked to benthic biodiversity loss. Current Biology 18:1–8

Danovaro R, Gambi C, Lampadariou N, Tselepides A (2008a) Deep-sea biodiversity in the Mediterranean Basin: testing for longitudinal, bathymetric and energetic gradients. Ecography 31:231–244

Danovaro R, Snelgrove PVR, Tyler P (2014) Challenging the paradigms of deep-sea ecology. Trends in Ecology & Evolution 29:465–475

DasGupta R, Shaw R (2017) Mangroves in Asia-Pacific: a review of threats and responses. In: DasGupta R, Shaw R (eds) Participatory Mangrove Management in a Changing Climate. Springer, p 1-16

Davies CE, Moss D, Hill MO (2004) EUNIS habitat classification revised 2004. Report to European Environmental Agency and European Topic Centre on Nature Protection and Biodiversity

De Groot RS, Blignaut J, van der Ploeg S, Aronson J, Elmqvist T, Farley J (2013) Benefits of investing in ecosystem restoration. Conservation Biology 27:1286–1293.

De Leo FC, Vetter EW, Smith CR, Rowden AA, McGranaghan M (2014) Spatial scale-dependent habitat heterogeneity influences submarine canyon macrofaunal abundance and diversity off the Main and Northwest Hawaiian Islands. Deep-Sea Research Part II 104:267–290

DEFRA (2005) Charting progress: an integrated assessment of the state of UK seas. DEFRA, London, http://wwwmcciporguk/media/1405/charting-progresspdf

DEFRA (2010) Charting progress 2: an assessment of the state of UK seas. DEFRA, London, http://catalogipbesnet/system/assessment/180/references/files/482/original/CP2-Full_reportpdf?1363944877)

Diekmann R, Nellen W, Piatkowski U (2006) A multivariate analysis of larval fish and paralarval cephalopod assemblages at Great Meteor Seamount. Deep-Sea Research Part I 53:1635–1657

Dower J F, Mackas DL (1996) Seamount effects in the zooplankton community near Cobb Seamount. Deep-Sea Research Part I 43:837–858

Duarte CM, Middelburg JJ, Caraco N (2005) Major role of marine vegetation on the oceanic carbon cycle. Biogeosciences 2:1–8, doi:10.5194/bg-2-1-2005

Eastwood PD, Mills CM, Aldridge JN, Houghton CA, Rogers SI (2007) Human activities in UK offshore waters: an assessment of direct, physical pressure on the seabed. ICES Journal of Marine Science 64:453–463

EC (1999) Towards Environmental Pressure Indicators for the EU. 1st Edn. Luxembourg: Office for Official Publications of the European Communities

EC (2008) Directive 2008/56/EC of the European Parliament and of the Council of 17 June 2008 establishing a framework for community action in the field of marine environment policy (Marine Strategy Framework Directive). Official Journal of the European Union 164:19–40

EC (2009) Directive 2009/147/EC of the European Parliament and of the Council of 30 November 2009 on the conservation of wild bird. Official Journal of the European Union 20:7–25

EC (2014) Directive 2014/89/EU of the European parliament and of the council of 23 July 2014 establishing a framework for maritime spatial planning. Official Journal of the European Union 257:135–145

EEA (2015) State of Europe's seas. European Environment Agency, Luxembourg

EEC (1992) Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora. Official Journal of the European Union 206:7–50

Eftec - Economics for the Environment Consultancy Ltd (2013) Marine Biodiversity Offsetting – UK scoping study, available at: http://wwwthecrownestatecouk/media/397708/marine-biodiversity-offsetting-uk-scoping-studypdf

Eftec - Economics for the Environment Consultancy Ltd (2015) Developing corporate natural capital accounts - Final Report for the Natural Capital Committee, UK, p 1–80, available at: https://www.cbd.int/financial/values/uk-corporatenatural.pdf

Eigaard OR, Bastardie F, Hintzen NT, Buhl-Mortensen L, Buhl-Mortensen P, Catarino R, Dinesen GE, Egekvist J, Fock HO, Geitner K, Gerritsen HD, Marín González M, Jonsson P, Kavadas S, Laffargue P, Lundy M, Gonzalez-Mirelis G, Nielsen JR, Papadopoulou N, Posen PE, Pulcinella J, Russo T, Sala A, Silva C, Smith CJ, Vanelslander B, Rijnsdorp AD (2016) The footprint of bottom trawling in European waters: distribution, intensity, and seabed integrity. ICES Journal of Marine Science 74:847–86

EIONET (2017) Reporting under Article 17 of the Habitats Directive (period 2007-2012). Introduction to assessment of conservation status of habitats and species of Community interest. European Topic Centre on Biological Diversty, http://ec.europa.eu/environment/nature/knowledge/rep_habitats/index_en.htm

Elliott M (2011) Marine science and management means tackling exogenic unmanaged pressures and endogenic managed pressures - a numbered guide. Marine Pollution Bulletin 62:651–655

Elliott M (2014) Integrated marine science and management: wading through the morass. Marine Pollution Bulletin 86:1–4

Elliott M, Burdon D, Hemingway KL, Apitz SE (2007) Estuarine, coastal and marine ecosystem restoration: confusing management and science - A revision of concepts. Estuarine, Coastal and Shelf Science 74:349–366

Eno NC, Frid CLJ, Hall K, Ramsay K, Sharp RAM, Brazier DP, Hearn S, Dernie KM, Robinson KA, Paramor OAL, Robinson LA (2013) Assessing the sensitivity of habitats to fishing: from seabed maps to sensitivity maps. Journal of Fish Biology 83:826–846

Epping E, van der Zee C, Soetaert K, Helder W (2002) On the oxidation and burial of organic carbon in sediments of the Iberian margin and Nazaré Canyon (NE Atlantic). Progress in Oceanography 52:399–431

Fagerli CW, Norderhaug KM, Christie H (2013) Lack of sea urchin settlement may explain kelp forest recovery in overgrazed areas in Norway. Marine Ecology Progress Series 488:119–132

Fagerli CW, Norderhaug KM, Christie H, Pedersen MF, Fredriksen S (2014) Predators of the destructive sea urchin Strongylocentrotus droebachiensis on the Norwegian coast. Marine Ecology Progress Series 502:207–218

Fernandez-Arcaya U, Ramirez-Llodra E, Aguzzi J, Allcock AL, Davies JS, Dissanayake A, Harris P, Howell K, Huvenne VAI, Macmillan-Lawler M, Martín J, Menot L, Nizinski M, Puig P, Rowden AA, Sanchez F, van den Beld IMJ (2017) Ecological role of submarine canyons and need for canyon conservation: a review. Frontiers in Marine Science 4(5), https://doi.org/10.3389/fmars.2017.00005

Fourqurean JW, Duarte CM, Kennedy H, Marba N, Holmer M, Mateo MA, Apostolaki ET, Kendrick GA, Krause-Jensen D, McGlathery KJ, Serrano O (2012) Seagrass ecosystems as a globally significant carbon stock. Nature Geoscience 5:505–509

Fraschetti S, Terlizzi A, Boero F (2008) How many habitats are there in the sea (and where)? Journal of Experimental Marine Biology and Ecology 366:109–115

Freiwald AJH, Fosså SJH, Grehan A, Koslow A, Roberts JM (2004) Cold-water coral reefs: out of sight – no longer out of mind. UNEP-WCMC, Cambridge

Galparsoro I, Borja A, Uyarra MC (2014) Mapping ecosystem services provided by benthic habitats in the European North Atlantic Ocean. Frontiers in Marine Science 1(23), https://doi.org/10.3389/fmars.2014.00023

Galparsoro I, Connor DW, Borja A, Aish A, Amorim P, Bajjouk T, Chambers C, Coggan R, Dirberg G, Ellwood H, Evans D, Goodin KL, Grehan A, Haldin J, Howell K, Jenkins C, Michez N, Mon G, Buhl-Mortensen P, Pearce B, Populus J, Salomidi M, Sánchez F, Serrano A, Shumchenia E, Tempera F, Vasquez M (2012) Using EUNIS habitat classification for benthic mapping in European seas: present concerns and future needs. Marine Pollution Bulletin 64:2630–2638

Gambi C, Danovaro R (2016) Biodiversity and life strategies of deep-sea meiofauna and nematode assemblages in the Whittard Canyon (Celtic margin, NE Atlantic Ocean). Deep-Sea Research Part I 108:13–22

Garrabou J, Ballesteros E (2000) Growth of Mesophyllum alternans and Lithophyllum frondosum (Corallinales, Rhodophyta) in the northwestern Mediterranean. European Journal of Phycology 35:1–10

Garrabou J, Coma R, Benssousan N, Bally M, Chevaldonne P, Cigliano M, Diaz D, Harmelin J-G, Gambi M-C, Kersting DK, Ledoux J-B, Lejeusne C, Linares C, Marschal C, Pérez T, Ribes M, Romano JC, Serrano E, Teixidó N, Torrents O, Zabala M, Zuberer F, Cerrano C (2009) Mass mortality in Northwestern Mediterranean rocky benthic communities: effects of the 2003 heat wave. Global Change Biology 15:1090–1103

Gatti G, Bianchi CN, Parravicini V, Rovere A, Peirano A, Montefalcone M, Massa F, Morri C (2015) Ecological change, sliding baselines and the importance of historical data: lessons from combing observational and quantitative data on a temperate reef over 70 years. PLoS ONE 10 (2): e0118581, https://doi.org/10.1371/journal.pone.0118581

Giakoumi S, Halpern BS, Michel LN, Gobert S, Sini M, Boudouresque C-F, Gambi M-C, Katsanevakis S, Lejeune P, Montefalcone M, Pergent G, Pergent-Martini C, Sanchez-Jerez P, Velimirov B, Vizzini S, Abadie A, Coll M, Guidetti P, Micheli F, Possingham HP (2015) Towards a framework for assessment and management of cumulative human impacts on marine food webs. Conservation Biology 29:1228–1234

Giakoumi S, Sini M, Gerovasileiou V, Mazor T, Beher J, Possingham H, Abdulla A, Cinar ME, Dendrinos P, Gucu AC, Karamanlidis A, Rodic P, Panayotidis P, Taskin E, Jaklin A, Voultsiadou E, Webster C, Zenetos A, Katsanevakis S (2013) Ecoregion-based conservation planning in the Mediterranean: dealing with large-scale heterogeneity. PLoS ONE 8 (10): e76449, https://doi.org/10.1371/journal.pone.0076449

Gianni F, Bartolini F, Airoldi L, Ballesteros E, Francour P, Meinesz A, Thibaut T, Mangialajo L (2013) Conservation and restoration of marine forests in the Mediterranean Sea and the potential role of Marine Protected Areas. Advances in Oceanography and Limnology 4:83–101

Goodsir F, Bloomfield HJ, Judd AD, Kral F, Robinson LA, Knights AM (2015) A spatially-resolved pressure-based approach for the identification and management of combined effects arising from multiple human activities. ICES Journal of Marine Science 72:2245–2256

Grech A, Chartrand-Miller K, Erftemeijer P, Fonseca M, McKenzie L, Rasheed M, Taylor H, Coles R (2012) A comparison of threats, vulnerabilities and management approaches in global seagrass bioregions. Environmental Research Letters 7:024006, doi:101088/1748-9326/7/2/024006

Greenhouse Gas Protocol (2001) A Corporate Accounting and Reporting Standard (Corporate Standard), http://www.ghgprotocol.org/about-ghgp

Greiner JT, McGlathery KJ, Gunnell J, McKee BA (2013) Seagrass restoration enhances “Blue Carbon” Sequestration in coastal waters. PLoS ONE 8(8): e72469, https://doi.org/10.1371/journal.pone.0072469

Gubbay S, Sanders N, Haynes T, Janssen JAM, Rodwell JR, Nieto A, García Criado M, Beal S, Borg J, Kennedy M, Micu D, Otero M, Saunders G, Calix M (2016) European Red List of Habitats – Part 1. Marine habitats. European Commission

Gundersen H, Bryan T, Chen W, Moy FE, Sandman AN, Sundblad G, Schneider S, Andersen JH, Langaas S, Walday MG (2015) Ecosystem Services in the Coastal Zone of the Nordic Countries. TemaNord 2016:552

Halpern BS, Walbridge S, Selkoe KA, Kappel CV, Micheli F, D'Agrosa C, Bruno JF, Casey KS, Ebert C, Fox HE, Fujita R, Heinemann D, Lenihan HS, Madin EM, Perry MT, Selig ER, Spalding M, Steneck R, Watson R (2008) A global map of human impact on marine ecosystems. Science 319:948–52

Harris PT, Whiteway T (2011) Global distribution of large submarine canyons: geomorphic differences between active and passive continental margins. Marine Geology 285:69–86

IMPRESS (2003) Analysis of pressures and impacts. Guidance document No3 - Common implementation strategy for the Water Framework Directive (2000/60/EC). IMPRESS Working Group 21. Office for Official Publication of the European Communities, Luxembourg

Judd AD, Backhaus T, Goodsir F (2015) An effective set of principles for practical implementation of marine cumulative effects assessment. Environmental Science and Policy 54:254–262

Kato Y, Fujinaga K, Nakamura K, Takaya, Y, Kitamura K, Ohta J, Toda R, Nakashima T, Iwamori H (2011) Deep-sea mud in the Pacific Ocean as a potential resource for rare-earth elements. Nature Geoscience 4:535–539

Knights AM, Koss RS, Robinson LA (2013) Identifying common pressure pathways from a complex network of human activities to support ecosystem-based management. Ecological Applications 23:755–765

Knights AM, Piet GJ, Jongbloed RH, Tamis JE, White L, Akoglu E, Boicenco L, Churilova T, Kryvenko O, Fleming-Lehtinen V, Leppanen J-M, Galil BS, Goodsir F, Goren M, Margonski P, Moncheva S, Oguz T, Papadopoulou K-N, Setälä O, Smith CJ, Stefanova K, Timofte F, Robinson LA (2015) An exposure-effect approach for evaluating ecosystem-wide risks from human activities. ICES Journal of Marine Science 72:1105–1115

Korpinen S, Andersen JH (2016) A global review of cumulative pressure and impact assessments in marine environments. Frontier in Marine Science 3(153), https://doi.org/10.3389/fmars.2016.00153

Korpinen S, Meidinger M, Laamanen M (2013) Cumulative impacts on seabed habitats: an indicator for assessments of good environmental status. Marine Pollution Bulletin 74:311-319

Kvile KØ, Taranto GH, Pitcher TJ, Morato T (2014) A global assessment of seamount ecosystems knowledge using an ecosystem evaluation framework. Biological Conservation 173:108–120

Lampitt RS, Billett DSM, Martin AP (2010) The sustained observatory over the Porcupine Abyssal Plain (PAP): insights from time series observations and process studies. Deep-Sea Research Part II 57:1267–1271

Leduc D, Rowden AA, Nodder SD, Berkenbusch K, Probert PK, Hadfield MG (2014) Unusually high food availability in Kaikoura Canyon linked to distinct deep-sea nematode community. Deep-Sea Research Part II 104:310–318

Levin LA, Mengerink K, Gjerde KM, Rowden AA, Van Dover CL, Clark MR, Ramirez-Llodra E, Currie B, Smith CR, Sato KN, Gallo N, Sweetman AK, Lily H, Armstrong CW, Brider J (2016) Defining serious harm to the marine environment in the context of deep-seabed mining. Marine Policy 74:245–59

Levin LA, Sibuet M (2012) Understanding continental margin biodiversity: a new imperative. Annual Review of Marine Science 4:79–112

Levin LA, Sibuet M, Gooday AJ, Smith CR, Vanreusel A (2010) The roles of habitat heterogeneity in generating and maintaining biodiversity on continental margins: an introduction. Marine Ecology 31:1–5

Ling SD, Johnson CR, Frusher SD, Ridgway KR (2009) Overfishing reduces resilience of kelp beds to climate-driven catastrophic phase shift. Proceedings of the National Academy of Sciences of the United States of America 106:22341–22345

MAES (2013) Mapping and assessment of ecosystems and their services - An analytical framework for ecosystem assessments under action 5 of the EU biodiversity strategy to 2020. Technical Report 067. Publications office of the European Union, Luxembourg

MAES (2014) Mapping and assessment of ecosystems and their services - Indicators for ecosystem assessments under Action 5 of the EU Biodiversity Strategy to 2020. Technical Report 080. Publications office of the European Union, Luxembourg

MarLIN (2017) Marine evidence based sensitivity assessment (MarESA). Marine Life and Information Network, http://www.marlin.ac.uk/species/sensitivity_rationale

Martin CS, Giannoulaki M, De Leo F, Scardi M, Salomidi M, Knittweis L, Pace ML, Garofalo G, Gristina M, Ballesteros E, Bavestrello G, Belluscio A, Cebrian E, Gerakaris V, Pergent G, Pergent-Martini C, Schembri PJ, Terribile K, Rizzo L, Souissi J Ben, Bonacorsi M, Guarnieri G, Krzelj M, Macic V, Punzo E, Valavanis V, Fraschetti S (2014) Coralligenous and maërl habitats: predictive modelling to identify their spatial distributions across the Mediterranean Sea. Scientific Reports 4:5073, doi:101038/srep05073

Masson DG, Huvenne VAI, de Stigter HC, Wolff GA, Kiriakoulakis K, Arzola RG, Blackbird S (2010) Efficient burial of carbon in a submarine canyon. Geology 38:831–834

Matsuoka T, Nakashima T, Nagasawa N (2005) A review of ghost fishing: scientific approaches to evaluation and solutions. Fisheries Science 71:691–702

McDonald T, Gann GD, Jonson J, Dixon KW (2016) International standards for the practice of ecological restoration – including principles and key concepts. Society for Ecological Restoration, Washington DC

Mcleod E, Chmura GL, Bouillon S, Salm R, Bjork M, Duarte CM (2011) A blueprint for blue carbon: toward an improved understanding of the role of vegetated coastal habitats in sequestering CO2. Frontiers in Ecology and the Environment 9:552–560

Med-IAMER (2014) Med-IAMER project: activities, outputs and results

Micheli F, Halpern BS, Walbridge S, Ciriaco S, Ferretti F, Fraschetti S, Lewison R, Nykjaer L, Rosenberg AA (2013) Cumulative human impacts on Mediterranean and Black Sea marine ecosystems: assessing current pressures and opportunities. PLoS ONE 8(12): e79889, https://doi.org/10.1371/journal.pone.0079889

Mienis F, van Weering T, de Haas H, de Stigter H, Huvenne VAI, Wheeler AJ (2006) Carbonate mound development at the SW Rockall Trough margin based on high resolution TOBI and seismic recording. Marine Geology 233:1–19

Milazzo M, Badalamenti F, Ceccherelli G, Chemello R (2004) Boat anchoring on Posidonia oceanica beds in a marine protected area (Italy, western Mediterranean): effect of anchor types in different anchoring stages. Journal of Experimental Marine Biology and Ecology 299:51–62

Millennium Ecosystem Assessment (2005) Ecosystems and human well-being: biodiversity synthesis. World Resources Institute, Washington DC

Morato T, Watson R, Pitcher TJ, Pauly D (2006) Fishing down the deep. Fish and Fisheries 7:24–34

Moy FE, Christie H (2012) Large-scale shift from sugar kelp (Saccharina latissima) to ephemeral algae along the south and west coast of Norway. Marine Biology Research 8:357–369

Natural Capital Coalition (2016) Natural Capital Protocol, www.naturalcapitalcoalition.org/protocol

Norderhaug KM, Christie H (2009) Sea urchin grazing and kelp re-vegetation in the NE Atlantic. Marine Biology Research 5:515–528

Norderhaug KM, Christie H, Fosså JH, Fredriksen S (2005) Fish-macrofauna interactions in a kelp (Laminaria hyperborea) forest. Journal of the Marine Biological Association UK 85:1279–1286

Norderhaug KM, Christie H, Rinde E, Gundersen H, Bekkby T (2014) Importance of wave and current exposure to fauna communities in Laminaria hyperborea kelp forests. Marine Ecology Progress Series 502:295–301

Nordlund LM, Koch EW, Barbier EB, Creed JC (2016) Seagrass ecosystem services and their variability across genera and geographical regions. PLoS ONE 11(10): e0163091, https://doi.org/10.1371/journal.pone.0163091

Olsen E, Fluharty D, Hoel AH, Hostens K, Maes F, Pecceu E (2014) Integration at the round table: marine spatial planning in multi-stakeholder settings. PLoS ONE 9(10): e109964, https://doi.org/10.1371/journal.pone.0109964

Orth RJ, Carruthers TJB, Dennison WC, Duarte CM, Fourqurean JW, Heck KLJ, Hughes AR, Kendrick GA, Kenworthy WJ, Olyarnik S, Short FT, Waycott M, Williams SL (2006) A global crisis for seagrass ecosystems. BioScience 56:987–996

OSPAR (2010) Quality Status Report. OSPAR Commission, London

Palanques A, Masqué P, Puig P, Sanchez-Cabeza JA, Frignani M, Alvisi F (2008) Anthropogenic trace metals in the sedimentary record of the Llobregat continental shelf and adjacent Foix Submarine Canyon (northwestern Mediterranean). Marine Geology 248:213–227

Patrício J, Elliott M, Mazik K, Papadopoulou K-N, Smith C (2016) DPSIR - two decades of trying to develop a unifying framework for marine environmental management? Frontiers in Marine Science 3(177), doi:103389/fmars201600177

Patrício J, Teixeira H, Borja A, Elliott M, Berg T, Papadopoulou N, Smith C, Luisetti T, Uusitalo L, Wilson C, Mazik K, Niquil N, Cochrane S, Andersen JH, Boyes S, Burdon D, Carugati L, Danovaro R, Hoepffner N (2014) DEVOTES recommendations for the implementation of the Marine Strategy Framework Directive. Deliverable 1.5 DEVOTES project. JRC92131

Pham CK, Ramirez-Llodra E, Alt CHS, Amaro T, Bergmann M, Canals M, Company JB, Davies J, Duineveld G, Galgani F, Howell KL, Huvenne VAI, Isidro E, Jones DOB, Lastras G, Morato T, Gomes-Pereira JN, Purser A, Stewart H, Tojeira I, Tubau X, Van Rooij D, Tyler PA (2014) Marine litter distribution and density in European Seas, from the shelves to deep basins. PLoS ONE 9(4): e95839, https://doi.org/10.1371/journal.pone.0095839

Pham CK, Vandeperre F, Menezes G, Porteiro F, Isidro E, Morato T (2015) The importance of deep-sea vulnerable marine ecosystems for demersal fish in the Azores. Deep-Sea Research Part I 96:80–8

Piante C, Ody D (2015) Blue Growth in the Mediterranean Sea: the challenge of Good Environmental Status. MedTrends Project. WWF-France

Piazzi L, Gennaro P, Balata D (2012) Threats to macroalgal coralligenous assemblages in the Mediterranean Sea. Marine Pollution Bulletin 64:2623–2629

Piroddi C, Teixeira H, Lynam CP, Smith C, Alvarez MC, Mazik K, Andonegi E, Churilova T, Tedesco L, Chifflet M, Chust G, Galparsoro I, Garcia AC, Kämäri M, Kryvenko O, Lassalle G, Neville S, Niquil N, Papadopoulou N, Rossberg AG, Suslin V, Uyarra MC (2015) Using ecological models to assess ecosystem status in support of the European Marine Strategy Framework Directive. Ecological Indicators 58:175–191

Pitcher TJ (2010) BOX 8: Eight Major Target Species in World Seamount Fisheries. Oceanography 23:130–131

Polidoro BA, Carpenter KE, Collins L, Duke NC, Ellison AM, Ellison JC, Farnsworth EJ, Fernando ES, Kathiresan K, Koedam NE, Livingstone SR, Miyagi T, Moore GE, Ngoc Nam V, Ong JE, Primavera JH, Salmo SG, Sanciangco JC, Sukardjo S, Wang Y, Yong JWH (2010) The loss of species: mangrove extinction risk and geographic areas of global concern. PLoS ONE 5(4): e10095, https://doi.org/10.1371/journal.pone.0010095

Prins TC, Borja A, Simboura N, Tsangaris C, Van der Meulen MD, Boon AR, Menchaca I, Gilbert AJ (2014) Coherent geographic scales and aggregation rules for environmental status assessment within the Marine Strategy Framework Directive: towards a draft guidance. Deltares/AZTI/HCMR, Report 1207879-000-ZKS-0014 to the European Commission, Delft, p 56 + annexes

Puig P, Palanques A, Martín J (2014) Contemporary sediment-transport processes in submarine canyons. Annual Review of Marine Science 6:53–77

Pusceddu A, Bianchelli S, Canals M, Sanchez-Vidal A, Durrieu De Madron X, Heussner S, Lykousis V, de Stigter H, Trincardi F, Danovaro R (2010) Organic matter in sediments of canyons and open slopes of the Portuguese, Catalan, Southern Adriatic and Cretan Sea margins. Deep-Sea Research Part I 57:441–457

Pusceddu A, Bianchelli S, Martin J, Puig P, Palanques A, Masque P, Danovaro R (2014) Chronic and intensive bottom trawling impairs deep-sea biodiversity and ecosystem functioning. Proceedings of the National Academy of Sciences of the United States of America 111:8861–8866

Pusceddu A, Mea M, Canals M, Heussner S, Durrieu De Madron X, Sanchez-Vidal A, Bianchelli S, Corinaldesi C, Dell'Anno A, Thomsen L, Danovaro R (2013) Major consequences of an intense dense shelf water cascading event on deep-sea benthic trophic conditions and meiofaunal biodiversity. Biogeosciences 10:2659–2670, doi:10.5194/bg-10-2659-2013

Rakka M, Orejas C, Sampaio I, Monteiro J, Parra H, Carreiro-Silva M (2017) Reproductive biology of the black coral Antipathella wollastoni (Cnidaria: Antipatharia) in the Azores (NE Atlantic). Deep-Sea Research Part II in press

Ramalho SP, Adão H, Kiriakoulakis K, Wolff GA, Vanreusel A, Ingels J (2014) Temporal and spatial variation in the Nazaré Canyon (Western Iberian margin): inter-annual and canyon heterogeneity effects on meiofauna biomass and diversity. Deep-Sea Research Part I 83:102–114

Ramirez-Llodra E, Brandt A, Danovaro R, De Mol B, Escobar E, German CR, Levin LA, Martinez Arbizu P, Menot L, Buhl-Mortensen P, Narayanaswamy BE, Smith CR, Tittensor DP, Tyler PA, Vanreusel A, Vecchione M (2010) Deep, diverse and definitely different: unique attributes of the world's largest ecosystem. Biogeosciences 7:2851–2899, doi:10.5194/bg-7-2851-2010

Ramirez-Llodra E, De Mol B, Company JB, Coll M, Sardà F (2013) Effects of natural and anthropogenic processes in the distribution of marine litter in the deep Mediterranean Sea. Progress in Oceanography 118:273–287

Ramirez-Llodra E, Tyler PA, Baker MC, Bergstad OA, Clark MR, Escobar E, Levin LA, Menot L, Rowden AA, Smith CR, Van Dover CL (2011) Man and the last great wilderness: human impact on the deep sea. PLoS ONE 6(7): e22588, https://doi.org/10.1371/journal.pone.0022588

Rees W (1995) Achieving sustainability: reform or transformation? Journal of Planning Literature 9:343–361

Rees W (1996) Revisiting carrying capacity: area-based indicators of sustainability. Population and Environment 17:195–215

Rex MA, Etter RJ (2010) Deep-sea biodiversity: pattern and scale. Harvard University Press

Rinde E, Christie H, Fagerli CW, Bekkby T, Gundersen H, Norderhaug KM, Hjermann DØ (2014) The influence of physical factors on kelp and sea urchin distribution in previously and still grazed areas in the NE Atlantic. PLoS ONE 9(6): e100222, https://doi.org/10.1371/journal.pone.0100222

Roark EB, Guilderson TP, Dunbar RB, Fallon SJ, Mucciarone DA (2009) Extreme longevity in proteinaceous deep-sea corals. Proceedings of the National Academy of Sciences 106:5204–5208

Roberts C, Smith C, Tillin H, Tyler-Walters H (2010) Review of existing approaches to evaluate marine habitat vulnerability to commercial fishing activities. Report to the Environment Agency from the Marine Life Information Network and ABP Marine Environmental Research Ltd. Environment Agency Evidence Report: SC080016/R3. Environment Agency, Peterborough, http://publications.environment-agency.gov.uk/PDF/SCHO1110BTEQ-E-E.pdf

Roberts JM, Wheeler A, Freiwald A, Cairns S (2009) Cold-Water Corals: the biology and geology of deep-sea coral habitats. Cambridge University Press, UK

Roberts JM, Wheeler AJ, Freiwald A (2006) Reefs of the deep: the biology and geology of cold-water coral ecosystems. Science 312:543–547

Robinson LA, Rogers S, Frid CLJ (2008) A marine assessment and monitoring framework for application by UKMMAS and OSPAR – Assessment of Pressures and Impacts Phase II: Application for Regional Assessments. (Contract No: C-08-0007-0027for the Joint Nature Conservation Committee). University of Liverpool, Liverpool and Centre for the Environment, Fisheries and Aquaculture Science, Lowestoft

Rogers AD, Brierley A, Croot P, Cunha MR, Danovaro R, Devey C, Hoel AH, Ruhl HA, Sarradin P-M, Trevisanut S, van den Hove S, Vieira H, Visbeck M (2015) Delving deeper: critical challenges for 21st century deep-sea research. Larkin KE, Donaldson K, McDonough N (eds) Position Paper 22 of the European Marine Board, Ostend

Röhr ME, Boström C, Canal-Vergès P, Holmer M (2016) Blue carbon stocks in Baltic Sea eelgrass (Zostera marina) meadows. Biogeosciences 13:6139–6153, doi:105194/bg-13-6139-2016

Scharin H, Ericsdotter S, Elliott M, Turner RK, Niiranen S, Blenckner T, Hyytiäinen K, Ahlvik L, Ahtiainen H, Artell J, Hasselström L, Söderqvist T, Rockström J (2016) Processes for the sustainable stewardship of marine environments. Ecological Economics 128:55–67

Schlining K, von Thun S, Kuhnz L, Schlining B, Lundsten L, Jacobsen Stout N, Chaney L, Connor J (2013) Debris in the deep: using a 22-year video annotation database to survey marine litter in Monterey Canyon, central California, USA. Deep-Sea Research Part I 79:96–105

Short FT, Neckles H (1999) The effects of global climate change on seagrasses. Aquatic Botany 63:169–196

Short FT, Wyllie-Echeverria S (1996) Natural and human-induced disturbance of seagrasses. Environmental Conservation 23:17–27

Smale DA, Burrows MT, Moore P, O'Connor N, Hawkins SJ (2013) Threats and knowledge gaps for ecosystem services provided by kelp forests: a northeast Atlantic perspective. Ecology and Evolution 3:4016–4038

Smith CJ, Papadopoulou K-N, Barnard S, Mazik K, Elliott M, Patrício J, Solaun O, Little S, Bhatia N, Borja A (2016) Managing the marine environment, conceptual models and assessment considerations for the European Marine Strategy Framework Directive. Frontiers in Marine Science 3(144), doi:103389/fmars201600144

SPC (2013) Deep sea minerals: Deep sea minerals and the green economy. Baker E, Beaudoin Y (eds) Vol. 2, Secretariat of the Pacific Community

Steen H, Moy FE, Bodvin T, Husa V (2016) Regrowth after kelp harvesting in Nord-Trøndelag, Norway. ICES Journal of Marine Science 73:2708–2720

Stelzenmüller V, Breen P, Stamford T, Thomsen F, Badalamenti F, Borja A, Buhl-Mortensen L, Carlstöm J, D'Anna G, Dankers N, Degraer S, Dujin M, Fiorentino F, Galparsoro I, Giakoumi S, Gristina M, Johnson K, Jones PJS, Katsanevakis S, Knittweis L, Kyriazi Z, Pipitone C, Piwowarczyk J, Rabaut M, Sørensen TK, van Dalfsen J, Vassilopoulou V, Vega Fernández T, Vincx M, Vöge S, Weber A, Wijkmark N, Jak R, Qiu W, ter Hofstede R (2013) Monitoring and evaluation of spatially managed areas: a generic framework for implementation of ecosystem based marine management and its application. Marine Policy 37:149–164

Steneck RS, Graham MH, Bourque BJ, Corbett D, Erlandson JM, Estes JA, Tegner MJ (2002) Kelp forest ecosystems: biodiversity, stability, resilience and future. Environmental Conservation 29:436–459

Stock A (2016) Open source software for mapping human impacts on marine ecosystems with an additive model. Journal of Open Research Software 4(1), p.e21, doi:http://doi.org/10.5334/jors.88

SWD (2017) Report on the Blue Growth Strategy Towards more sustainable growth and jobs in the blue economy. Commission Staff Working Document, SWD (2017), Brussels

Teixeira H, Berg T, Uusitalo L, Fürhaupter K, Heiskanen A-S, Mazik K, Lynam CP, Neville S, Rodriguez JG, Papadopoulou N, Moncheva S, Churilova T, Kryvenko O, Krause-Jensen D, Zaiko A, Veríssimo H, Pantazi M, Carvalho S, Patrício J, Uyarra MC, Borja A (2016) A catalogue of marine biodiversity indicators. Frontiers in Marine Science 3(207), doi:103389/fmars201600207

Teixido N, Garrabou J, Harmelin J-G (2011) Low dynamics, high longevity and persistence of sessile structural species dwelling on Mediterranean coralligenous outcrops. PLoS ONE 6(8): e23744, https://doi.org/10.1371/journal.pone.0023744

Thibaut T, Pinedo S, Torras X, Ballesteros E (2005) Long-term decline of the populations of Fucales (Cystoseira spp and Sargassum spp) in the Alberes coast (France, North-western Mediterranean). Marine Pollution Bulletin 50:1472–1489

Thiel H (2003) Anthropogenic impacts on the deep sea. In: Tyler PA (ed) Ecosystems of the deep oceans. Ecosystems of the World. Vol 28. Elsevier, Amsterdam, p 427–471

Thuy HTT, Nga LP, Loan TTC (2011) Antibiotic contaminants in coastal wetlands from Vietnamese shrimp farming. Environmental Science and Pollution Research 18:835–841

UNEP-MAP-RAC/SPA (2008) Action plan for the conservation of the coralligenous and other calcareous bio-concretions in the Mediterranean Sea Tunis: RAC/SPA

van der Heide T, van Nes EH, van Katwijk MM, Olff H, Smolders AJP (2011) Positive feedbacks in seagrass ecosystems – Evidence from large-scale empirical data. PLoS ONE 6(1): e16504, https://doi.org/10.1371/journal.pone.0016504

Van Dover CL, Aronson J, Pendleton L, Smith S, Arnaud-Haond S, Moreno-Mateos D, Barbier E, Billett D, Bowers K, Danovaro R, Edwards A, Kellert S, Morato T, Pollard E, Rogers A, Warner R (2014) Ecological restoration in the deep sea: desiderata. Marine Policy 44:98–106

Watling L, France SC, Pante E, Simpson A (2011) Biology of Deep-Water Octocorals. Advances in Marine Biology 60:41–122

Waycott M, Duarte C, Carruthers T, Orth B, Dennison B, Olyarnik S, Calladine A, Fourqurean J, Heck K, Hughes R, Kendrick G, Kenworthy J, Short F, Williams S (2009) Accelerating loss of seagrasses across the globe threatens coastal ecosystems. Proceedings of the National Academy of Science 106:12377–12381

White LJ, Koss RS, Knights AM, Eriksson A, Robinson LA (2013) ODEMM Linkage Framework Userguide (Version 2). ODEMM Guidance Document Series No.3. EC FP7 project (244273) 'Options for Delivering Ecosystem-based Marine Management'. University of Liverpool

Williams A, Schlacher TA, Rowden AA, Althaus F, Clark MR, Bowden DA, Stewart R, Bax NJ, Consalvey M, Kloser RJ (2010) Seamount megabenthic assemblages fail to recover from trawling impacts. Marine Ecology 31:183–199

Yesson C, Clark MR, Taylor M, Rogers AD (2011) The global distribution of seamounts based on 30-second bathymetry data. Deep-Sea Research Part I 58:442–453

7. Annexes

Annex 1 – *Describing the MERCES Pressures Catalogue*

Contained within this document

Annex 2 – *The Catalogue (MERCES_WP1_D1.2_Catalogue_Activities&Pressures_v10.xlsx)*

A separate downloadable Excel file

7.1. Annex 1: Describing the MERCES Pressures Catalogue

A.1. Introduction

The purpose of Annex 1 is to physically describe Annex 2, which is the MERCES Pressures Catalogue database.

The data catalogue is a simple Excel file entitled:

MERCES_WP1_D1.2_Catalogue_Activities&Pressures_v10.xlsx

The file consists of 7 separate sheets

Sheet 1_Cover page: cover page for the Catalogue and Deliverable D1.2

Sheet 2_Read me & DoW: description of work and instructions for the contributing partners of the catalogue

Sheet 3_Catalogue_Pressures: the Pressures Catalogues entries and associated data/information

Sheet 4_Lists: data entry options and lists of preselected options for various categories of data entries

Sheet 5_Regional Seas: regional and sub-regional maps with information on regional seas, their subdivisions, management units, or assessment areas for defining geographical categories entries

Sheet 6_ EUNIS & EUSEAMAP: European Nature Information System (EUNIS) habitat types hierarchical view and seabed habitats according to EMODNET (European Marine Observation and Data Network) for defining habitat type/feature categories entries

Sheet 7_Press_Activ: lists of pressures and activities leading to pressures/concerns with descriptions and examples.

A.2. Catalogue Pages

The Catalogue worksheet contains the single row entries of all activities and pressures map source entries (264 rows in total) with various categories of associated information (67 columns).

7.1.1. A2.1. Category groups and categories

The entries are broken down into 8 broad categories and then individual categories in single columns.

- Data Input identifier section: to identify who added data information, including institution name and contact
- Habitat Type: identifying the habitats by category, type and main feature
- Activities: checklist of 13 major categories of activities explicitly mapped in the reference entry, with any comments provided in a separate column
- Endogenous (manageable) pressures: checklist of 26 major pressures explicitly mapped in the reference entry, with any comments provided in a separate column
- Exogenous (unmanageable) pressures: checklist of 7 major pressures explicitly mapped in the reference entry, with any comments provided in a separate column
- Information: additional information on any other types of maps provided by the reference entry and general comments
- Region: information on the MSFD region, subregion or other subdivision covered by the source entry
- Source: source/type of the data entry, including full reference and the reference link.

7.1.2. A2.3. Catalogue entries

There is a total of 264 entries in the Catalogue with data/information given for most of the categories for each entry. The catalogue also cites 164 references.