Application of a spatially explicit risk approach for multi-hazard assessment and management in marine environment

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Outline:

SECTION 1:

- Issues and challenges for marine planners and managers.
- Regulatory frameworks concerning management and planning of marine and coastal areas.
- Main objectives of the proposed research.

SECTION 2:

- Risk-based approach for multi-hazard assessment and management in marine environment:
  - ✓ methodological framework and operative steps.
  - ✓ application in the Adriatic sea case study.

SECTION 3:

- Lesson learnt and future challenges for risk assessment and management in marine areas.

Issues and challenges

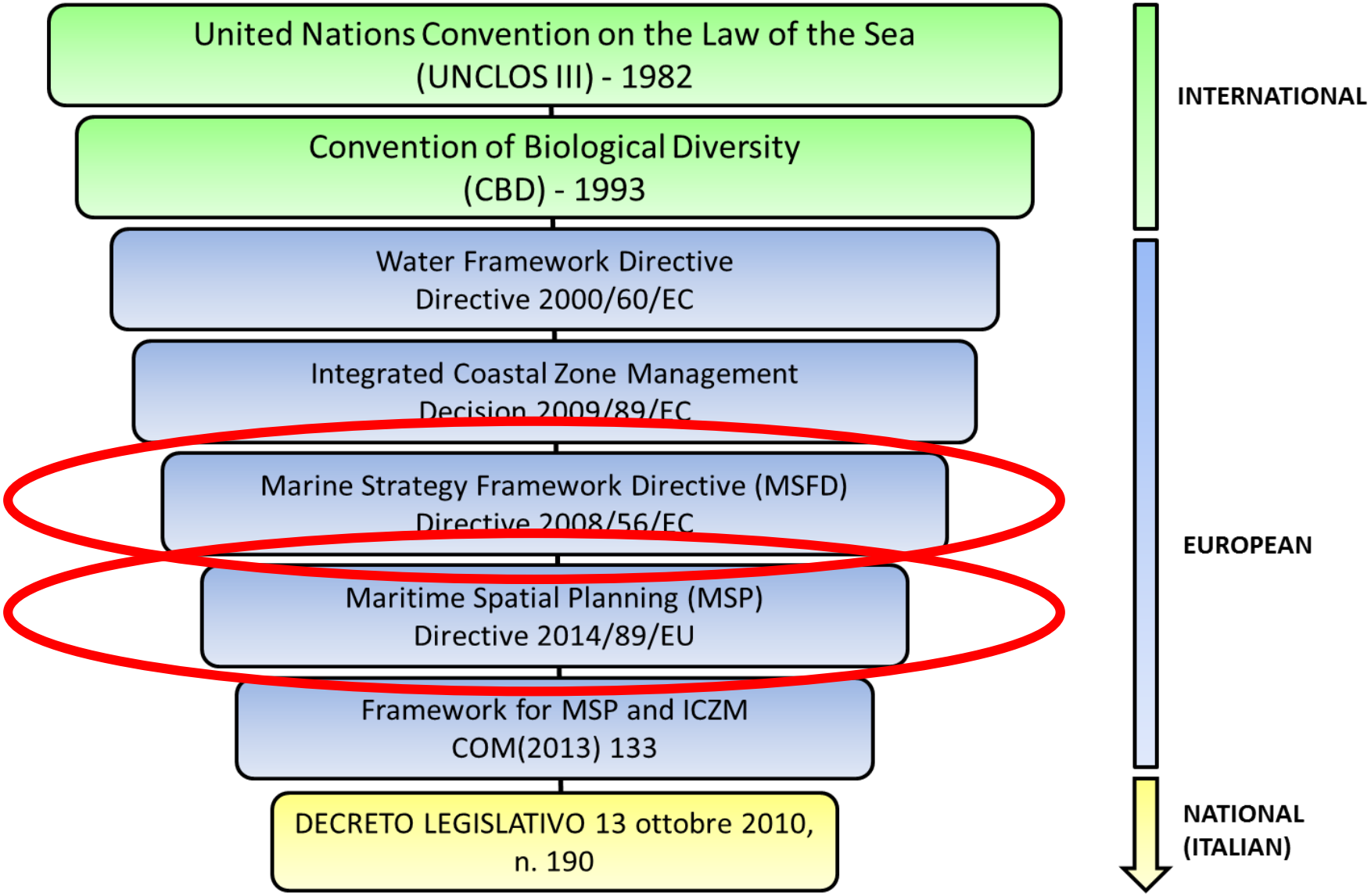
- Europe's seas are facing **increasing threats and degradation due to a range of human activities**, impairing marine ecosystems and their services for human wellbeing.

- A further complication is determined by **climate change** which is expected to exacerbate environmental impacts (e.g. temperature-induced changes are expected to interact with existing nutrient inputs).

- Need of **addressing conflicting objectives** of conservation and resource development and usage in marine spaces in order to achieve, restore or maintain the **Good Environmental Status** of marine areas.

It becomes important to develop assessment approaches and **methodologies** that are **integrated, cross-sectorial and adaptive** in order to **support science-based planning and management** of marine areas.

Regulatory frameworks concerning management and planning of marine areas



Key Messages – regulatory framework

UNCLOS:

better coordination of maritime affairs in order to resolve conflicts among both users and conflicts between and the environment which lead to relevant impacts on sensitive ecological areas.

CONFLICT MANAGEMENT

CBD:

application of an **Ecosystem based Approach** for a comprehensive look at all dimensions of environmental problems in order to support the sustainable development and management of human activities.

CUMULATIVE AND SYNERGIC IMPACTS

HOLISTIC APPROACH

MSFD:

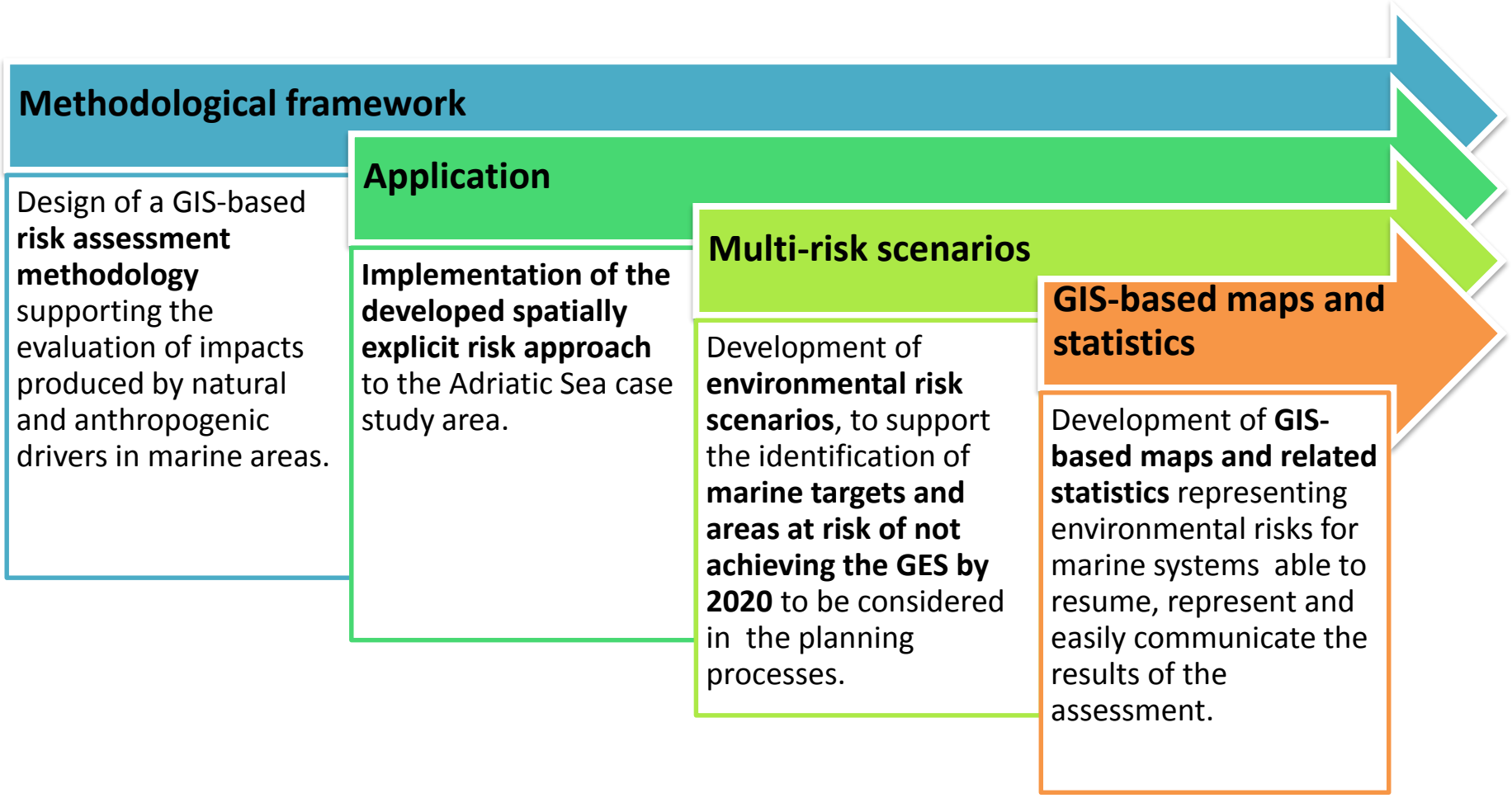
analysis of the predominant pressures and impacts, including human activity, on the **environmental status of marine ecosystems**, taking into account both cumulative and synergic effects and their transboundary features.

TRANSBOUNDARY FEATURES OF IMPACTS

MSP & ICZM:

integrated management of **sea–land interface** for the development of effective planning processes between MSP and ICZM. Ensure an holistic consideration of impacts, including cumulative ones, from various human activities since an early stage of the planning process.

Objectives of the analysis



Provide to local planners and decision makers useful information to set priorities in maritime spatial planning and management and defining effective measures and strategies to promote the sustainable valorization and preservation of the Adriatic region

PERSEUS

POLICY-ORIENTED MARINE ENVIRONMENTAL RESEARCH IN THE SOUTHERN EUROPEAN SEAS

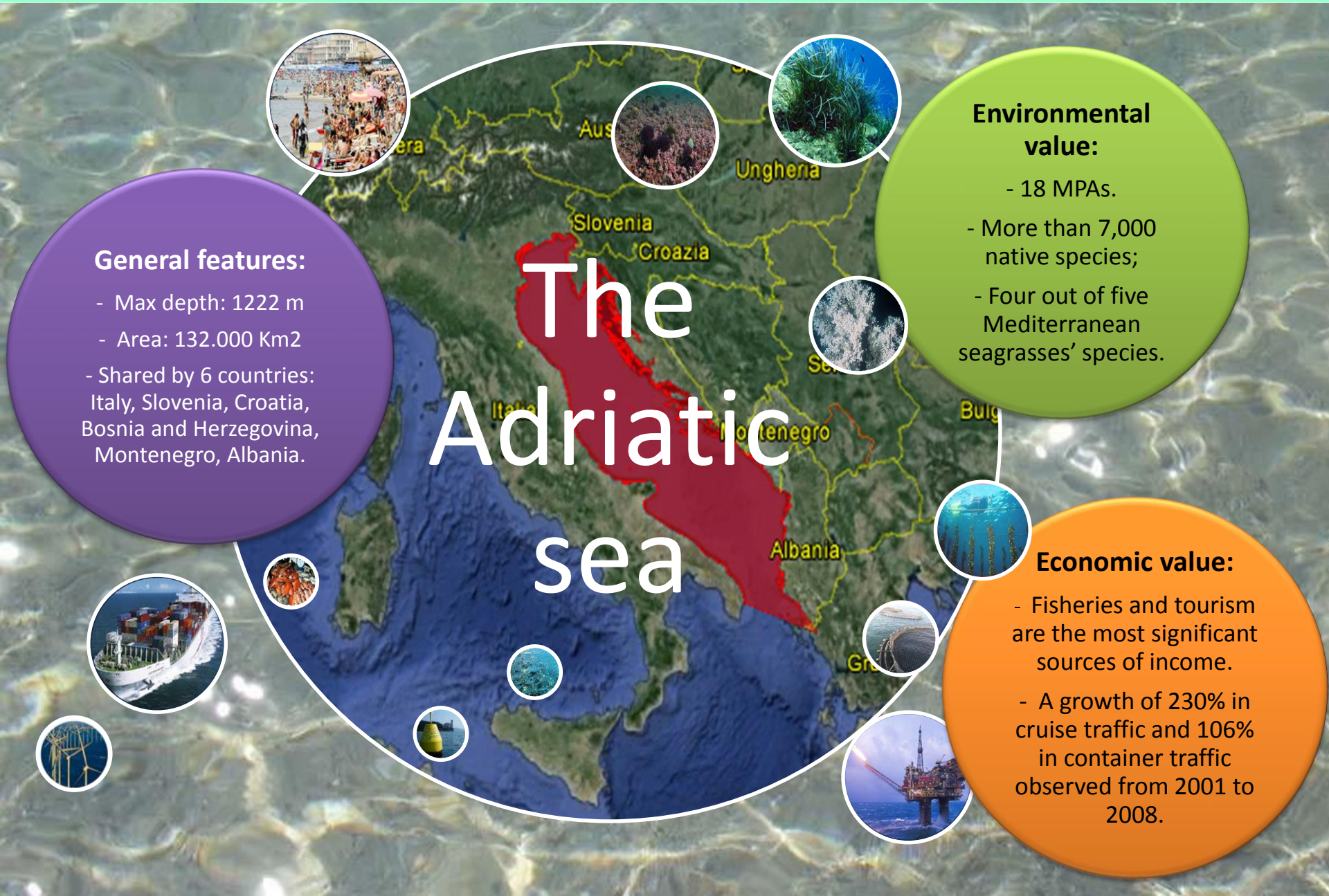
- FP7 Project
- Starting date: January 2012
  Ending date: December 2015
- www.perseus-net.eu/

Assess the **dual impact of human activity and natural pressures** on the Mediterranean and Black Seas.

Design an **effective and innovative research governance framework** for supporting policymakers to turn back the tide on marine life degradation.

Setting the scene for the design and implementation of **adaptive marine spatial plans and policies** toward the sustainable management of coastal and marine areas and the achievement of the Good Environmental Status.

The Adriatic sea case study



The Adriatic sea

General features:

- Max depth: 1222 m
- Area: 132.000 Km2
- Shared by 6 countries: Italy, Slovenia, Croatia, Bosnia and Herzegovina, Montenegro, Albania.

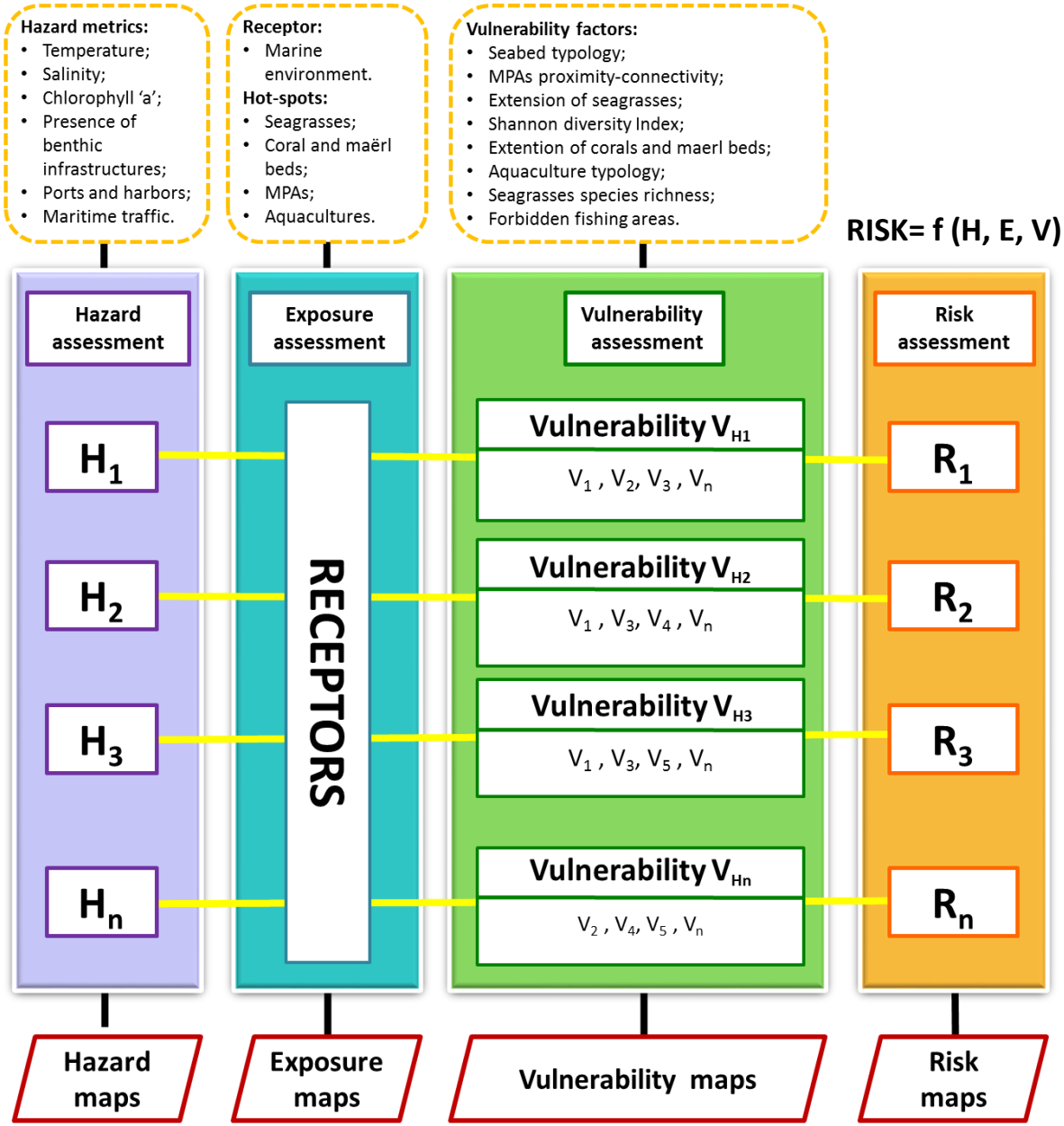
Environmental value:

- 18 MPAs.
- More than 7,000 native species;
- Four out of five Mediterranean seagrasses' species.

Economic value:

- Fisheries and tourism are the most significant sources of income.
- A growth of 230% in cruise traffic and 106% in container traffic observed from 2001 to 2008.

The risk methodology:



4-stages process

8 natural and anthropogenic pressures

1 main receptor and 5 hot-spot

Integration of MCDA and GIS techniques

Expert judgment

Regional coverage

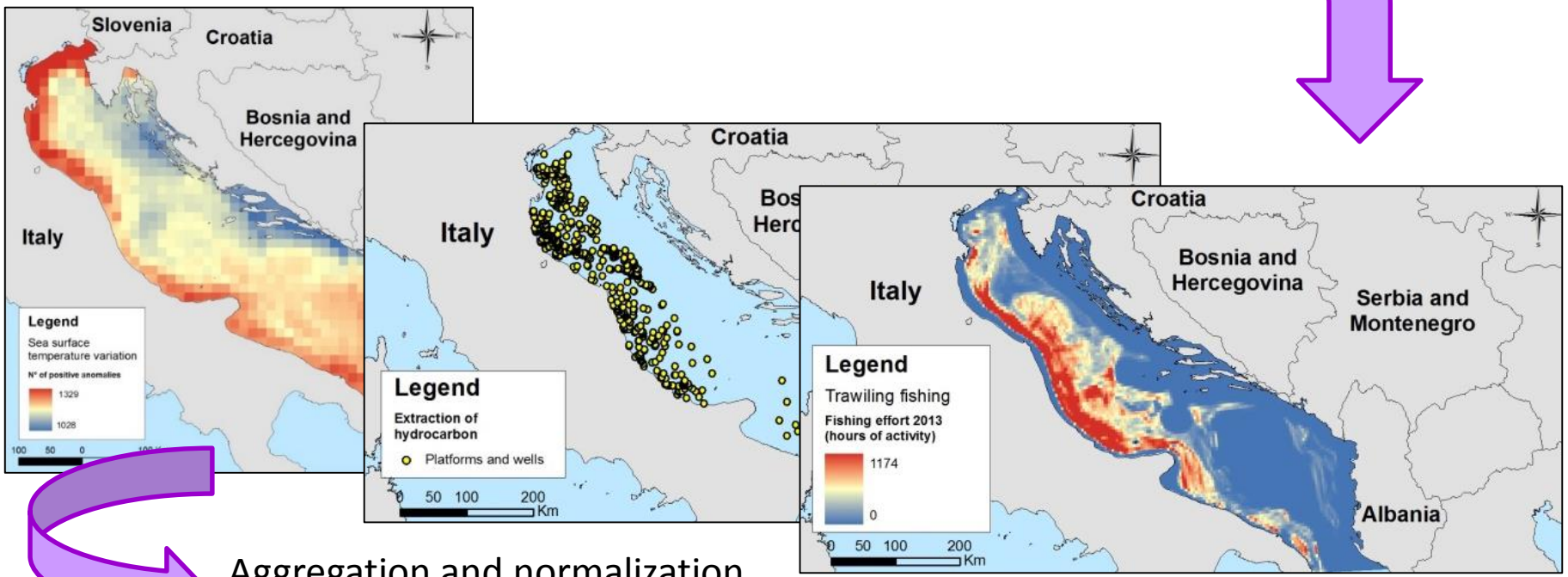
Phase 1: Hazard assessment

Aimed at identify and prioritize areas that could be affected by multiple natural and anthropogenic pressures in the baseline scenario

Methodological steps:

1. Select the hazards to be analysed.
2. Define the **temporal window** to be considered.
3. Analyze and spatially model the **single hazards**.
4. **Normalize** the results in a 0-1 range.

According to the MSFD requirements



Aggregation and normalization by means of MCDA

Hazard maps

Phase 1: Hazard assessment – input dataset

DATASET	SPATIAL DOMAIN AD RESOLUTION	UPDATE DATA	SOURCE
ENDOGENIC AND EXOGENIC DRIVERS			
Ports and harbours	Adriatic sea, 1:50000	2014	http://atlas.shape-ipaproject.eu/
Platform and wells for hydrocarbon extraction	Adriatic sea, 1:50000	2014	http://atlas.shape-ipaproject.eu/
	European seas, 1:100000		http://www.emodnet.eu/human-activities
Regasification terminals	Adriatic sea, 1:500000	2014	http://atlas.shape-ipaproject.eu/
Underwater pipelines and cables	Adriatic sea, 1:50000	2014	http://atlas.shape-ipaproject.eu/
Foul areas	Adriatic sea, 1:50000	2014	http://atlas.shape-ipaproject.eu/
Wrecks	Adriatic sea, 1:50000	2014	http://atlas.shape-ipaproject.eu/
Dumping disposal sites	Adriatic sea, 1:100000	2014	http://atlas.shape-ipaproject.eu/
Dumped munitions sites	European seas, 1:100000	2014	http://www.emodnet.eu/human-activities
Dredge spoil dumping	European seas, 1:100000	2015	http://www.emodnet.eu/human-activities
Offshore dredged areas	Adriatic sea, 1:100000	2014	http://atlas.shape-ipaproject.eu/
Offshore sand deposits	Adriatic sea, 1:100000	2015	http://adriplan.eu/
Map of spatio-temporal distribution of trawling fishing pressure based on Vessel Monitoring System data (2007-2010)	Adriatic sea, 3x3Km grid	2010	http://adriplan.eu/
Mineral titles	Adriatic sea, 1:50000	2015	http://adriplan.eu/
Shipping traffic	Global ocean 1:1.000.000	2008	https://www.nceas.ucsb.edu/globalmarine
Distributional map of alien species	Mediterranena sea, 10x10Km grid	2015	http://easin.jrc.ec.europa.eu/
Ship accidents points - oil spills (1977-2014).	Mediterranena sea, 1:100000	2014	http://accidents.rempec.org/
Coastal artificial protection	Adriatic sea, 1:25000	2014	http://atlas.shape-ipaproject.eu/
Military practice areas	Adriatic sea, 1:50000	2014	http://atlas.shape-ipaproject.eu/
Sea surface temperature (SST)	Mediterranena sea, 1/7 degree	2015	http://www.perseus-net.eu
Sea surface salinity (SSS)	Mediterranena sea, 1/7 degree	2015	http://www.perseus-net.eu
Chlorophyll 'a'	Mediterranena sea,	2015	http://adriplan.eu/

Shape Project

Adriplan Project

PERSEUS Project

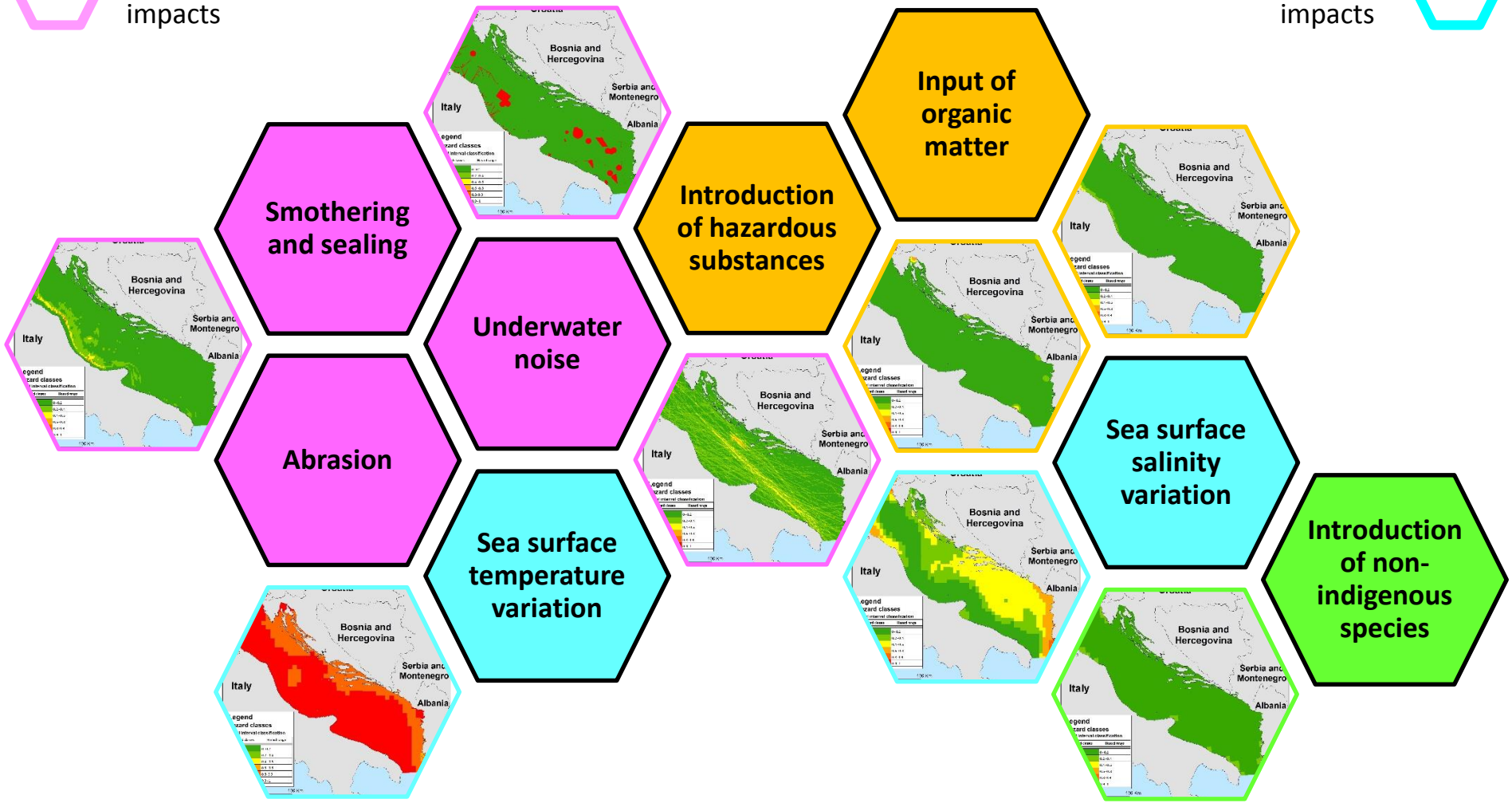
Phase 1: Hazard assessment - selected hazard

Biological impacts

Physical impacts

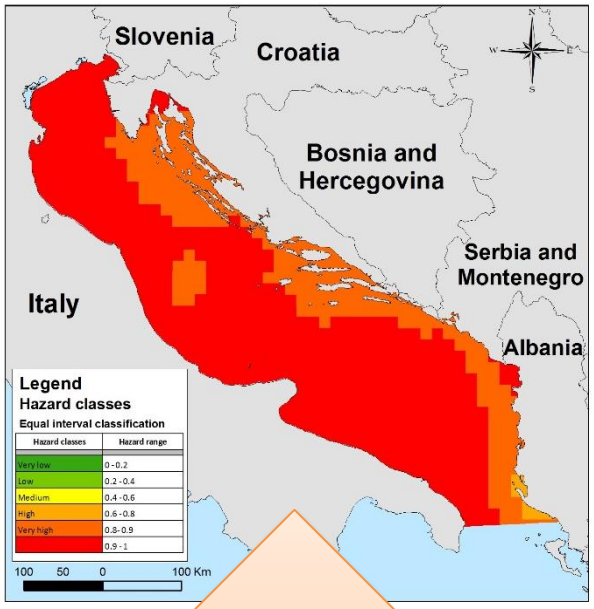
Chemical impacts

Climatic impacts



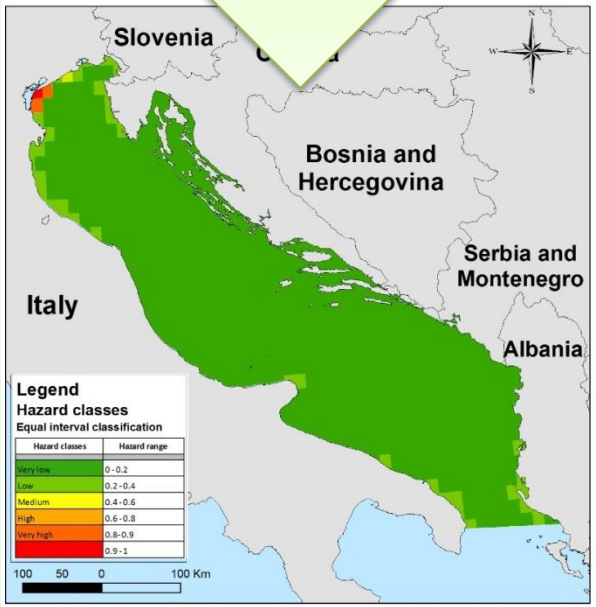
Phase 1: Hazard assessment - outputs

SST variation



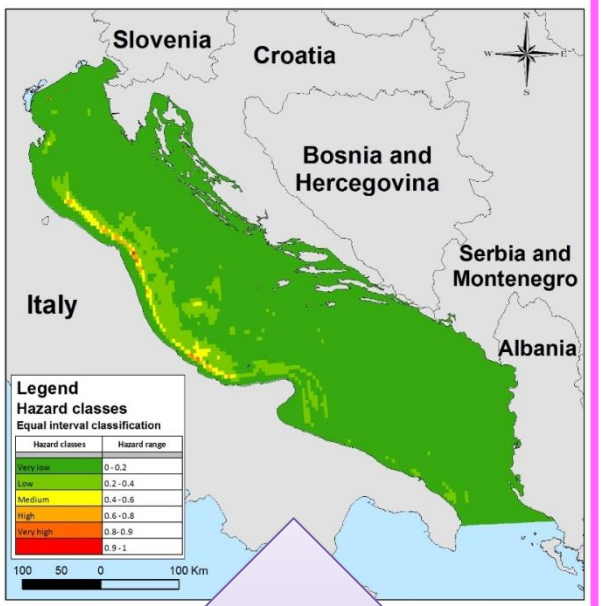
Very high hazard scores in the whole case study area (0.8-1) due to high occurrence of unusually warm sea surface temperatures

Higher hazard scores (0.8-1) in the North Adriatic sea due to many aquaculture activities and the massive maritime traffic in the area



Introduction of NIS

Abrasion



Higher hazard scores (0.4-1) in the western-central part of the Adriatic Sea due to high exploitation of the area for trawling fishing activities

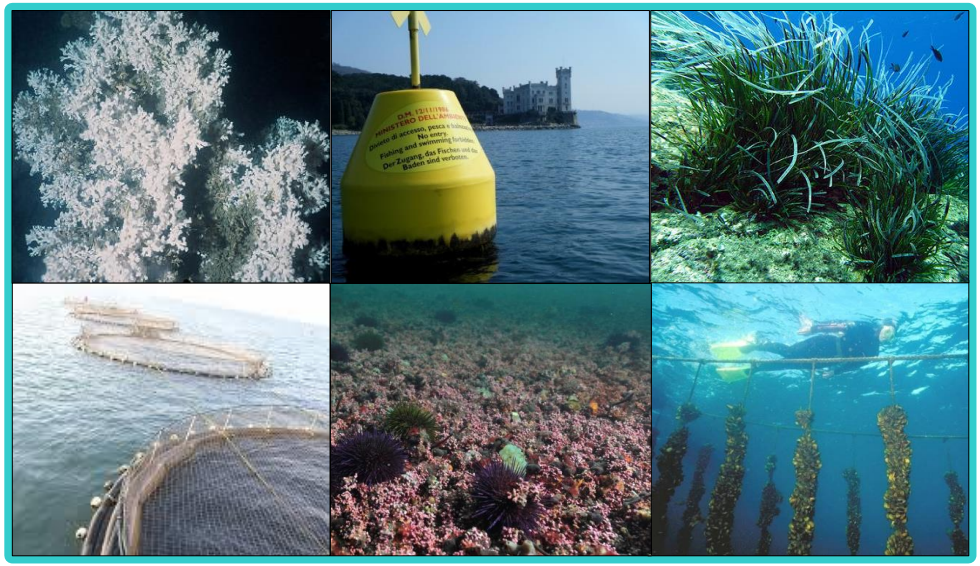
HAZARD MAPS: represent potentially significant hazard scenarios, against which a system needs to adapt in order to maintain its ecological functions. They support the development of future marine spatial plans avoiding hazard-prone areas.

Phase 2: Exposure assessment

Aimed at identify, select and localize receptors (i.e. elements at risk) that could potentially be in contact with the considered hazard.

$$E = \begin{cases} 0 & \text{if no receptor is present in the investigated cell} \\ 1 & \text{presence of one or more receptors} \end{cases}$$

E= exposure score of the union of the geographic area of the receptors.



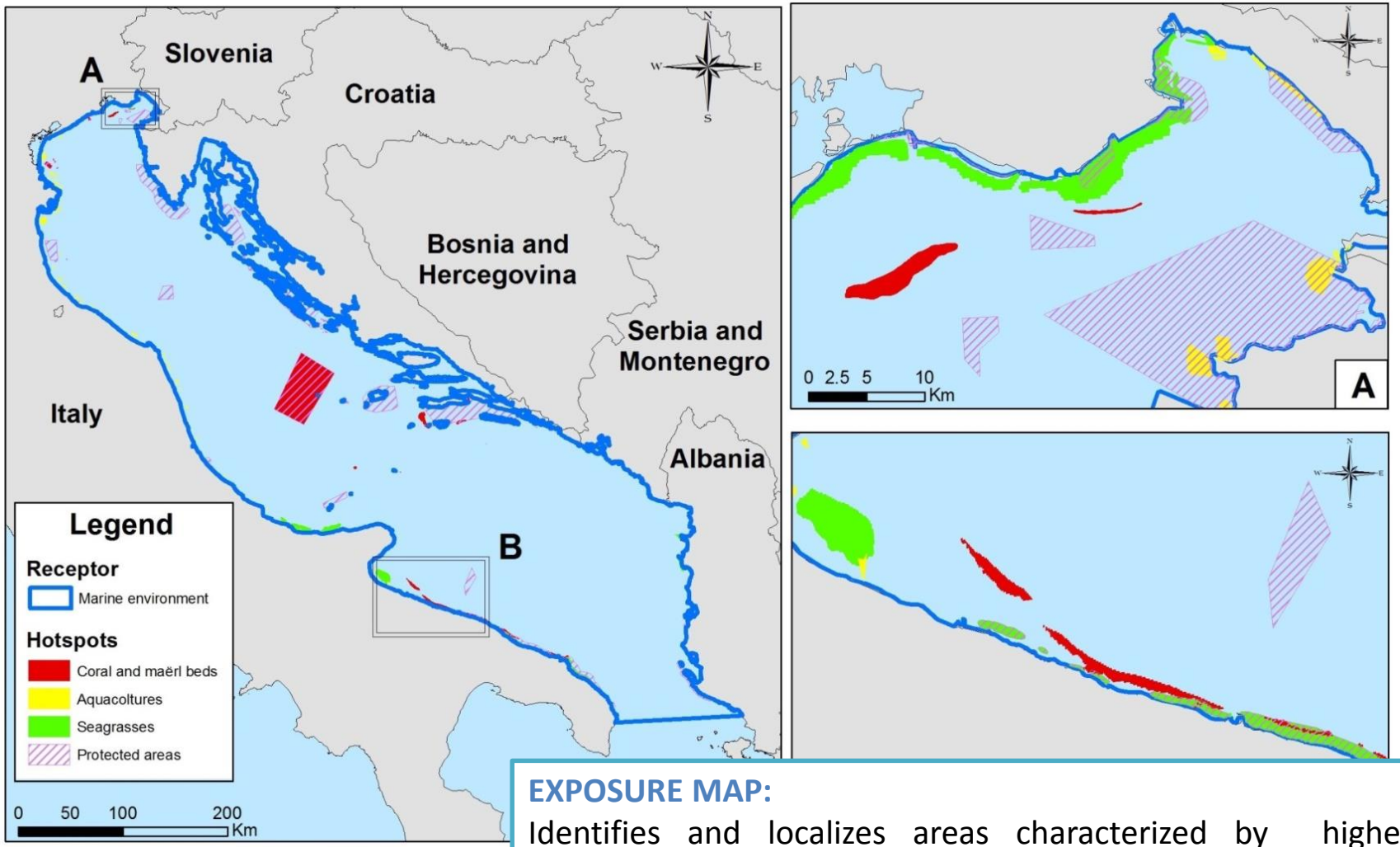
Selected receptor:

- Marine environment

Hot-spot with high environmental and economic value:

- Seagrasses
- Coral and maërl beds
- Marine protected areas
- Aquacultures

Phase 2: Exposure assessment - outputs



EXPOSURE MAP:

Identifies and localizes areas characterized by higher environmental and socio-economic values that can be subject to potential losses or damages in the case study area due to not sustainable use of the marine environment.

Phase 3: Physical and environmental vulnerability assessment

Aimed at evaluating the degree to which the receptors could be adversely affected by the considered hazard based on site-specific physical and environmental information.

Methodological steps:

1.Identification of physical and environmental vulnerability factors based on site-specific information.

2.Classification and normalization of vulnerability factors in vulnerability classes by environmental risk expert team.

3.Aggregation and normalization in a 0-1 range of vulnerability factors through a Multi-Criteria Decision Analysis (MCDA) for all the considered hazards.

Vulnerability factor	Vulnerability class	Vulnerability score
MPAs proximity-connectivity (km)	0 - 25.63	0,2
	25.64 - 48.33	0,4
	48.34 - 70.58	0,6
	70.59 - 95.54	0,8

Vulnerability factor	Vulnerability class	Abrasion and extraction	Introduction of non-indigenous species and translocations	Inputs of organic matter	Introduction of hazardous substances	SST variation	SSS variation
	Mediterranean coralligenous communities moderately exposed to or sheltered from hydrodynamic action	1	1	1	1	1	0,8
	Shallow sublittoral rock and						

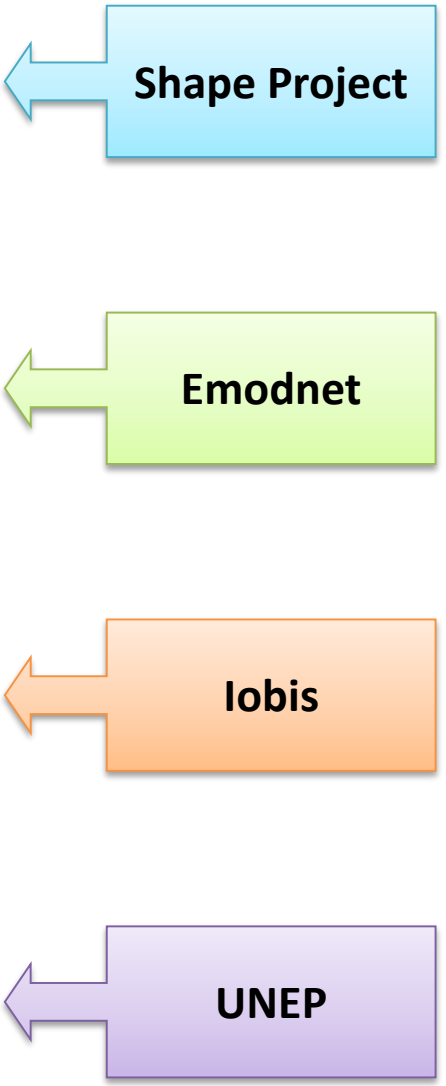
$$V = f(vf_i)$$

V= physical and environmental vulnerability score, representing the predisposition of the territory to be affected by the considered pressures.

$vf_i = i^{th}$ physical and environmental vulnerability factor.

Phase 3: Physical and environmental vulnerability assessment

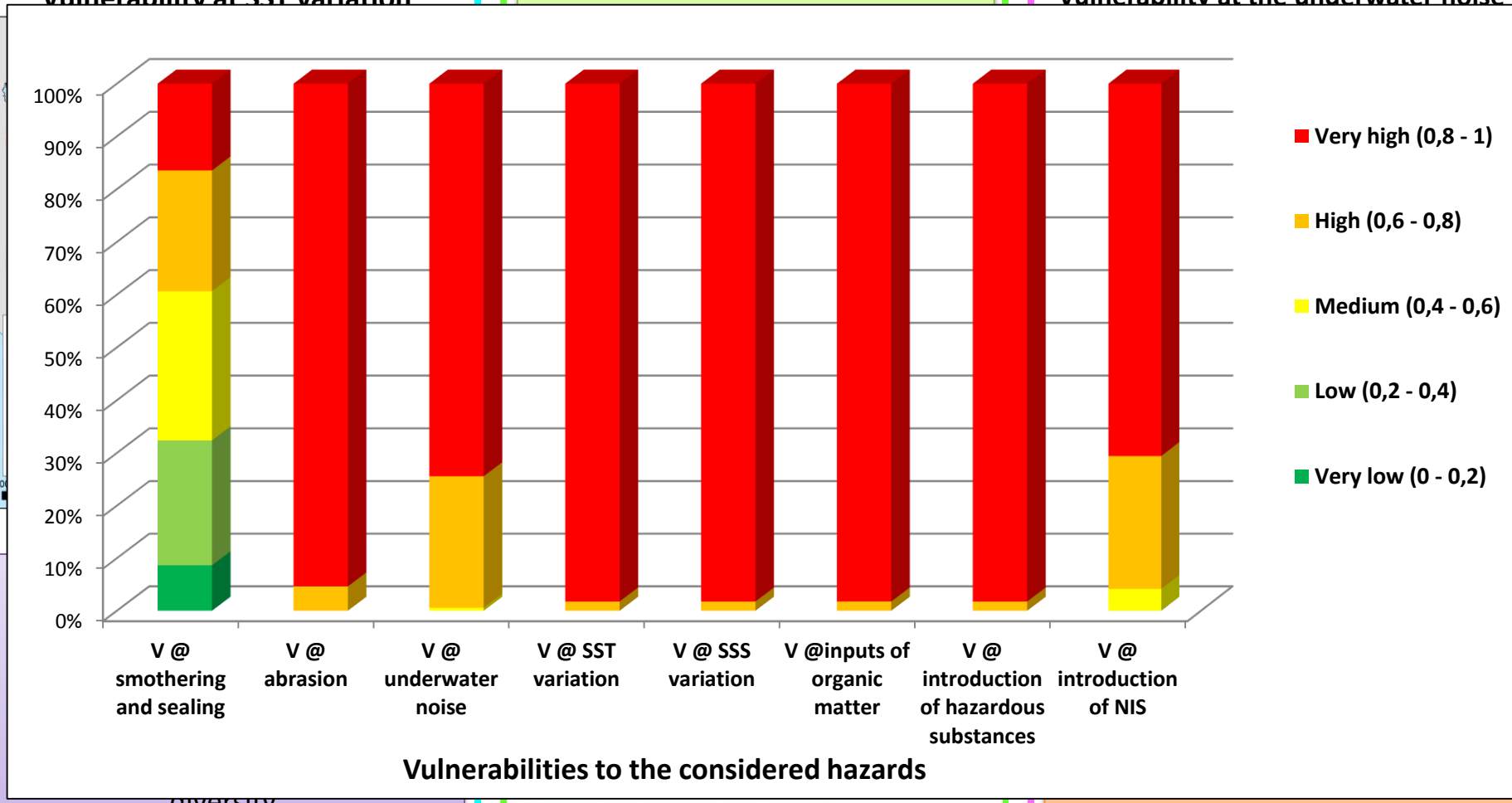
DATASET	SPATIAL DOMAIN AD RESOLUTION	UPDATE DATA	SOURCE
PHYSICAL AND ENVIRONMENTAL DATA			
Adriatic basin boundary	Adriatic sea, 1:50000	2013	http://atlas.shape-ipaproject.eu/
Marine administrative zones	Adriatic sea, 1:50000	2013	http://atlas.shape-ipaproject.eu/
Marine Protected areas (MPAs)	Global ocean 1: 1.000.000	2014	www.protectedplanet.net
	Adriatic sea, 1:50000	2013	http://atlas.shape-ipaproject.eu/
Sites of Community Importance (SCI), Zone of Special Protection (ZSP)	Adriatic sea, 1:50000	2013	http://atlas.shape-ipaproject.eu/
Nationally designated areas	Adriatic sea, 1:25000	2013	http://atlas.shape-ipaproject.eu/
Biologic protection zones (BPZ)	Adriatic sea, 1:10000	2013	http://atlas.shape-ipaproject.eu/
Fishing regulated areas	Adriatic sea, 1:1000000	2013	http://atlas.shape-ipaproject.eu/
EUSeaMap -seabed habitat map-	Adriatic sea, 1: 1.000.000	2014	http://www.emodnet.eu/seabed-habitats
Biodiversity Shannon's Index	Global scale, hex grid	2014	http://www.iobis.org/mapper/
Seagrass species richness	Global ocean 1: 1.000.000	2003	http://data.unep-wcmc.org/



Phase 3: Physical and environmental vulnerability assessment: outputs

Vulnerability at SST variation

Vulnerability at the underwater noise



diversity.

Vulnerability at the introduction of NIS

VULNERABILITY MAPS: identify which are the environmental and biological factors that mainly contribute to increase the vulnerability of a specific area and to select appropriate adaptation measures and policies to rise the resilience of the marine environment as a whole.

Phase 4: Risk assessment

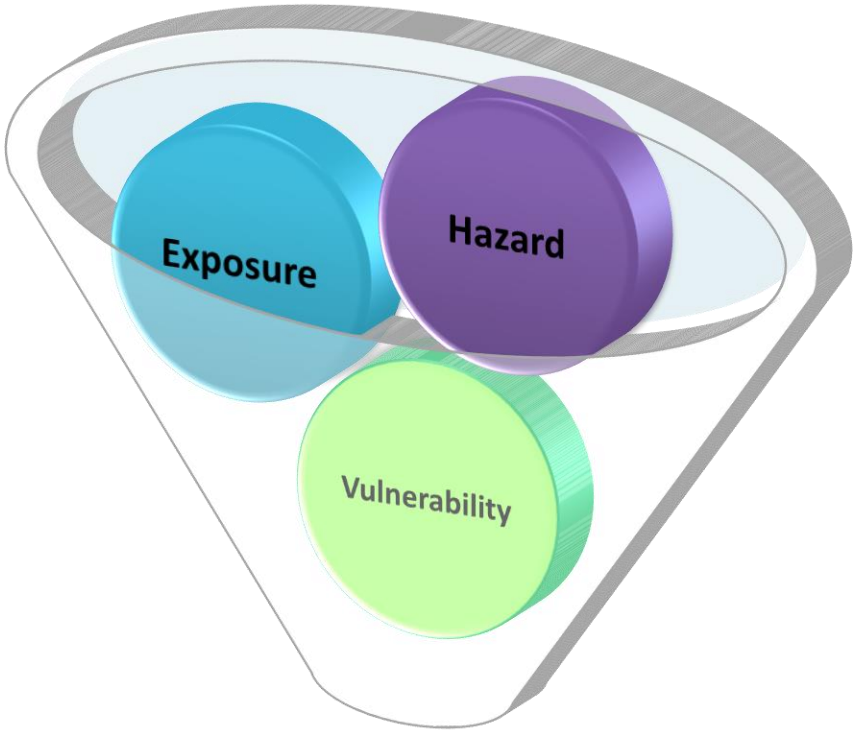
Aimed at integrating information about the hazard with the environmental exposure and vulnerability assessments in order to identify and ranking areas at risk of not achieving GES due to multiple pressures.

Methodological steps:

1. Consider **risk** as a function of hazard, exposure and vulnerability.
2. **Aggregate** and **normalize risk in a 0-1 range**, by means of MCDA, in order to obtain risk indicators.
3. **Visualize** risks by means of spatial maps and tabular results summarizing key risk metrics.

$$R = f(H, E, V)$$

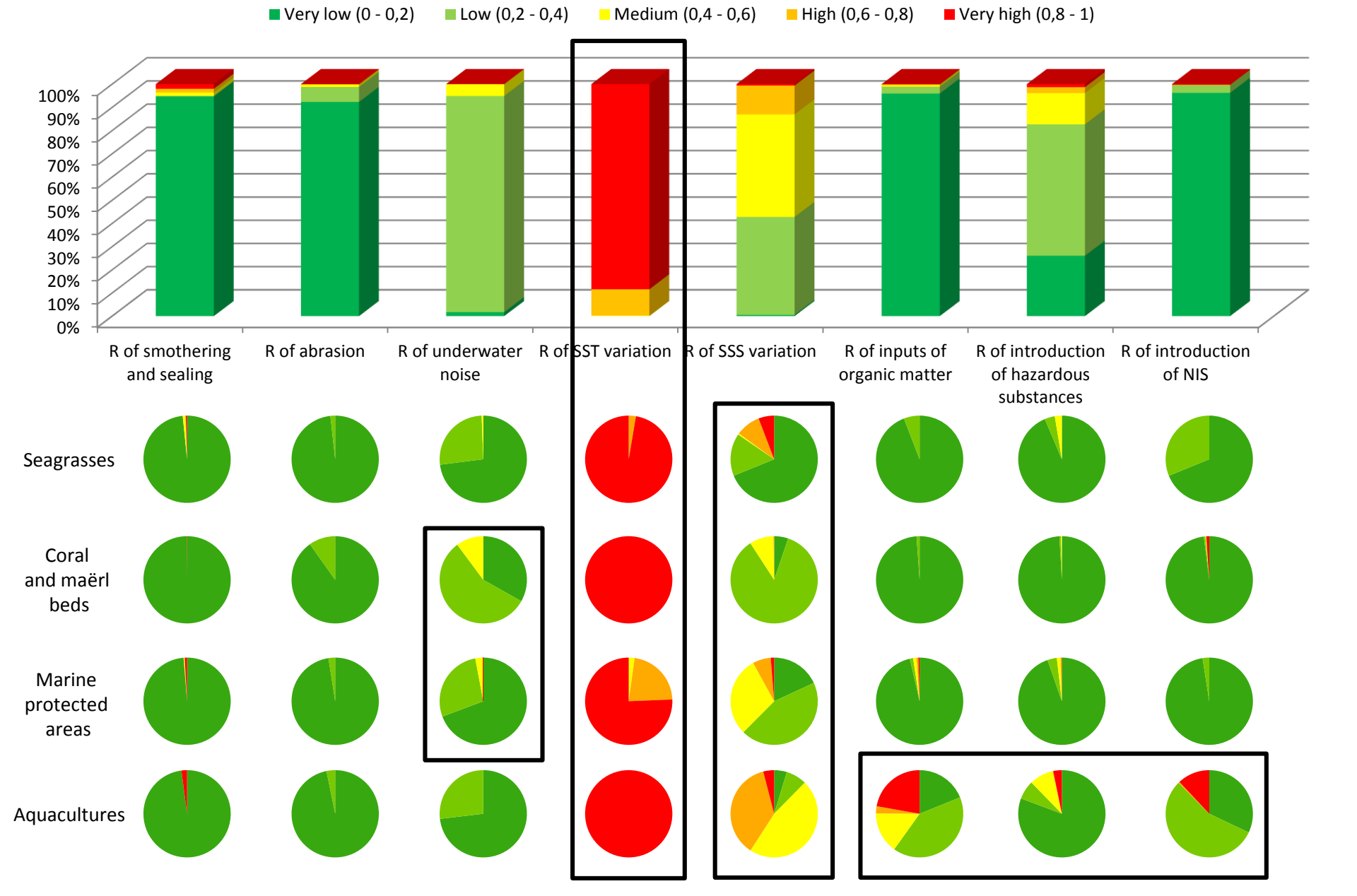
R= risk index;
H = hazard scores.
E= exposure score.
V= biophysical and environmental vulnerability score.



MCDA

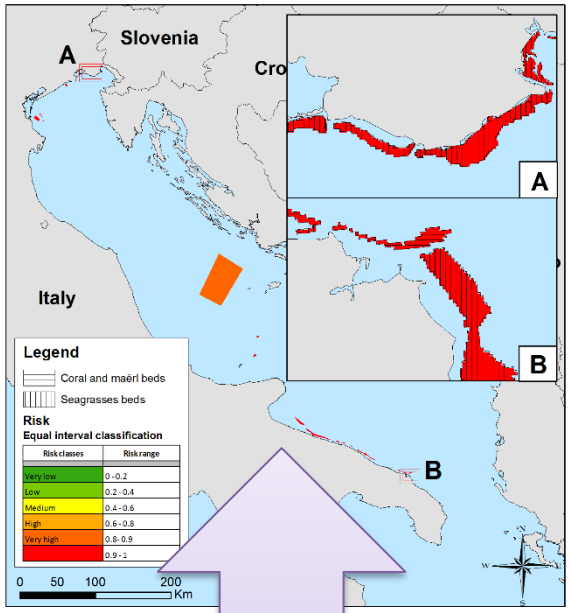
Risk

Phase 4: Risk assessment: outputs



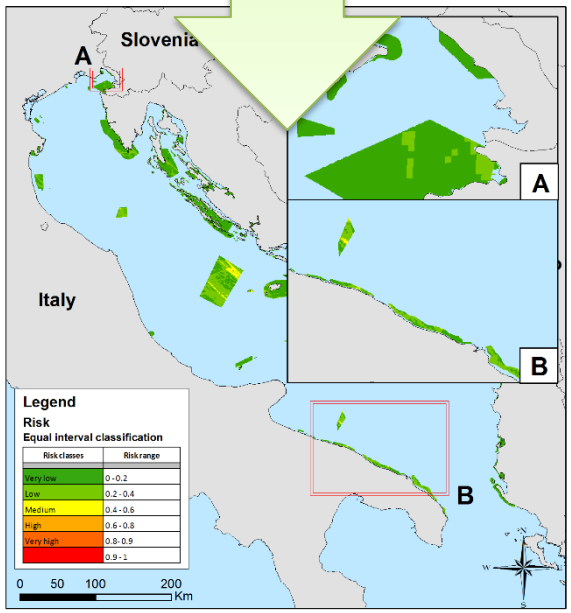
Phase 4: Risk assessment: outputs

Risk at SST variation for seagrasses and coral and maërl beds



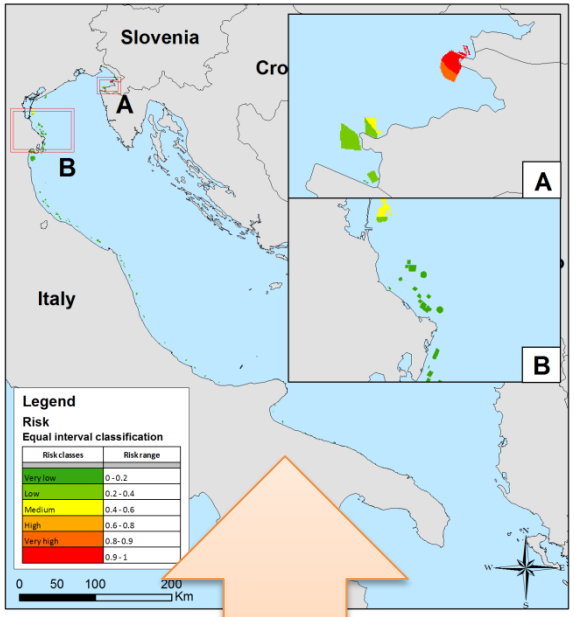
Higher risk scores (0.8-1) for both the receptors due to high hazard scores in the whole marine environment and high sensitivity of these targets to unusually warm temperatures.

Moderate risk scores (0.2-0.6) for the MPAs, focused in the central part of the Adriatic sea due high maritime traffic in the area



Risk of underwater noise for marine protected areas

Risk of contamination for acquacultures



Higher risk scores (0.8-1) for fisheries located in the North Adriatic sea due to localized high hazard scores and high sensitivity of fisheries to chemical contamination.

RISK MAPS: support future Maritime Spatial Planning and the development of integrated and adaptive policies aimed at managing the conflicting uses and threats to the marine areas and achieve and maintain their GES.

Lessons learnt - Challenges

- **Risk analysis** as a decision support tool for setting the scene for the development of **science-based policies and management measures** of marine areas that **consider spatially relevant issues** and that are **consistent with the objectives of MSFD.**

- **Screening risk scenarios** to identify key threats, vulnerabilities and sensitive targets in wide marine regions, in order to both evaluate the **progress toward the implementation of the MSFD** and provide useful information to local public authorities to **set priorities in planning and management** of marine areas.

- Evaluate **potential future climate scenarios** compared with a reference (i.e. baseline) scenario to assess the **evolution of key factors** and how these factors will affect the **achievement of GES and policy goals**.

- Need to identify appropriate methods and algorithms for **analyzing the complex interactions among multiple hazards** (e.g. cascading events) potentially leading to more **severe cumulative and interactive impacts**.

Thanks for your attention!

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For more information:

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Euro-Mediterranean Center on Climate Change (CMCC), RAAS - Risk assessment and adaptation strategies, Venice: www.cmcc.it/it/divisions/raas

Regional Risk Assessment approach (Landis, 2005)

Regional Risk Assessment (RRA):
prioritization of impacts, targets and affected areas at the regional scale

RRA is a methodology that enables to evaluate **all the components contributing to** the computation of **risk** in different **sub-areas** of the same region, to **prioritize** the importance of these zones and finally combine the information for estimating the **relative risk** in the individual sub-areas of the region and rank the individual risk factors.

- Useful in situations where **multiple stressors** are of concern and for assessments covering **broad geographic areas**;
- Allow the **identification** and **ranking** of the **sources**, **habitats** and **impacts** in the region;
- Based on a **Relative Risk Model**: a system of numerical **ranks** and **weights** factors developed in order to combine and assess different kinds of risks.

Maps of the prioritized **risk regions** and of the spatial distribution of the analyzed **stressors** and **targets**.