CMCC WEBINAR

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Cumulative impacts assessment in marine areas: a multi-disciplinary approach supporting adaptive management of the Adriatic Sea

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To investigate and model our **climate system** and its interactions with **society** to provide reliable, rigorous, and timely **scientific results**, which will in turn stimulate sustainable growth, protect the **environment**, and **develop science driven** adaptation and **mitigation policies** in a **changing climate**

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Cumulative impacts assessment in marine areas: a multi-disciplinary approach supporting adaptive management of the Adriatic Sea

Presenter: Dr. Elisa Furlan

cmcc Centro Euro-Mediterraneo sui Cambiamenti Climatici

Università Ca'Foscari Venezia

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Outline

- **Issues and challenges** for marine planners and managers

- Main **objectives** of the proposed study

- The **multi-risk approach** for cumulative impacts appraisal in marine areas
  - ✓methodological framework and operative steps
  - ✓application in the Adriatic Sea case study

- **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.






Issues and challenges

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).

Issues and challenges

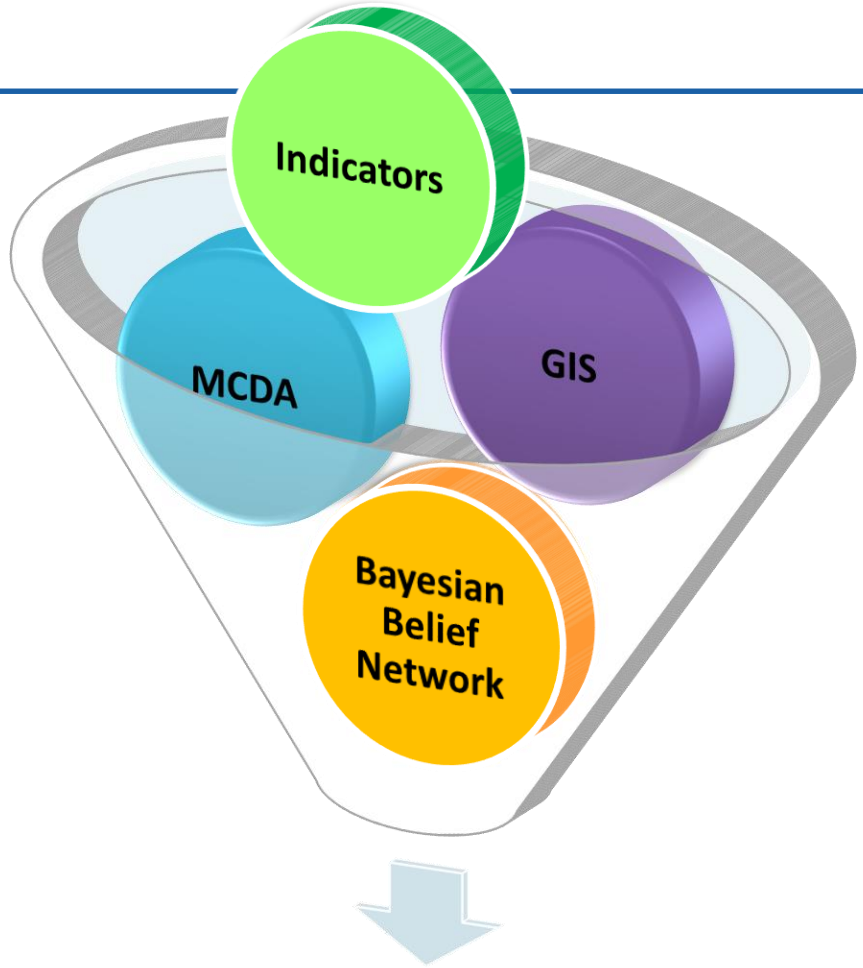
CHALLENGE

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.

Objectives

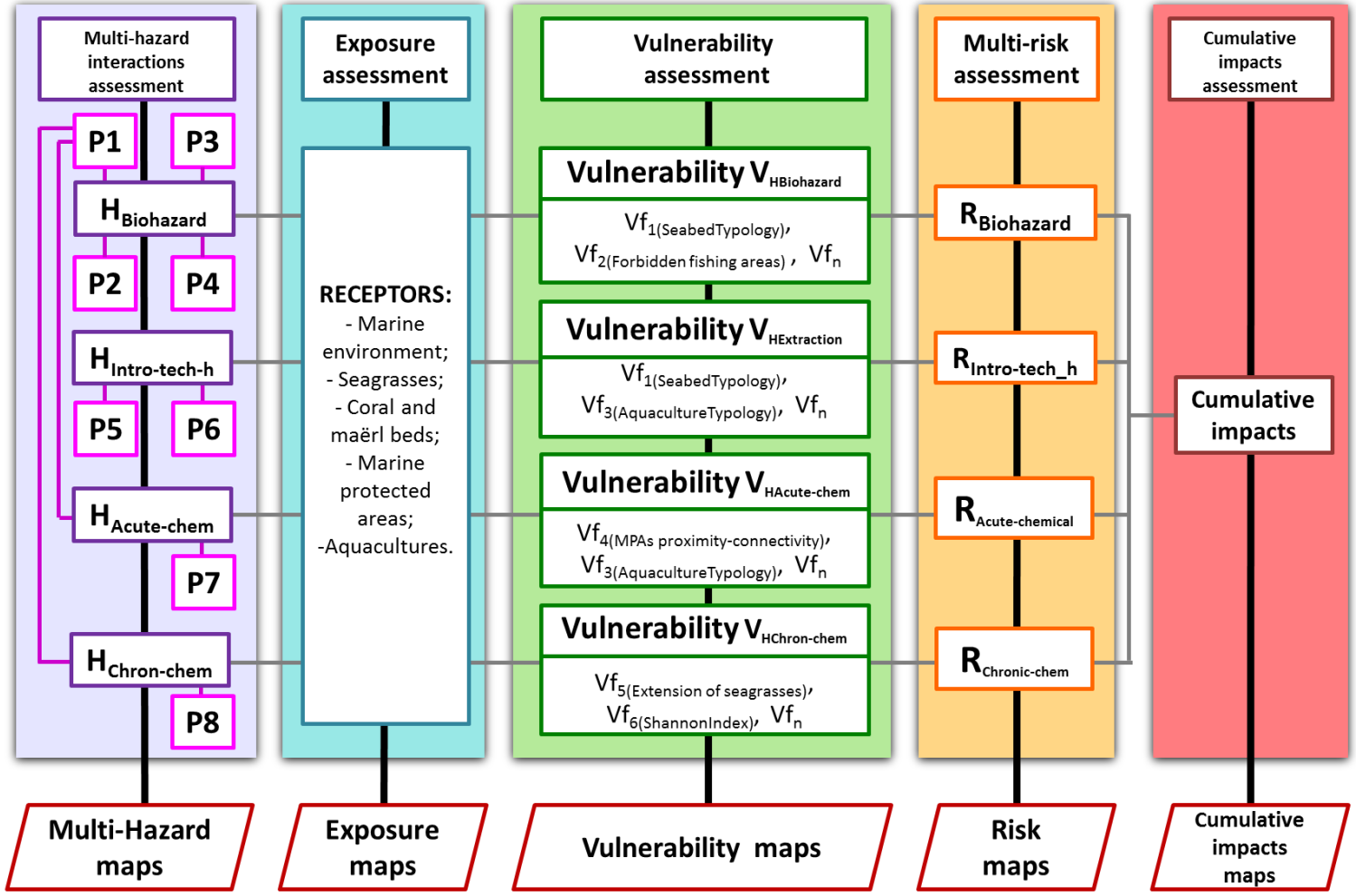
Multi-risk approach integrating different tools
for the evaluation of cumulative impacts in marine areas

- Integrate heterogeneous information by means of **MCDA functions**
- **GIS-based maps** and related statistics representing environmental impacts for marine systems and targets
- Implement a GIS-based **Bayesian Belief Network to assess the impact of alternative scenarios**



Decision support tool
providing useful information and scenarios to set priorities in MSP

The risk-based framework



5-stages process

6 hazards induced by natural and anthropogenic pressures

1 main receptor and 5 hot-spot

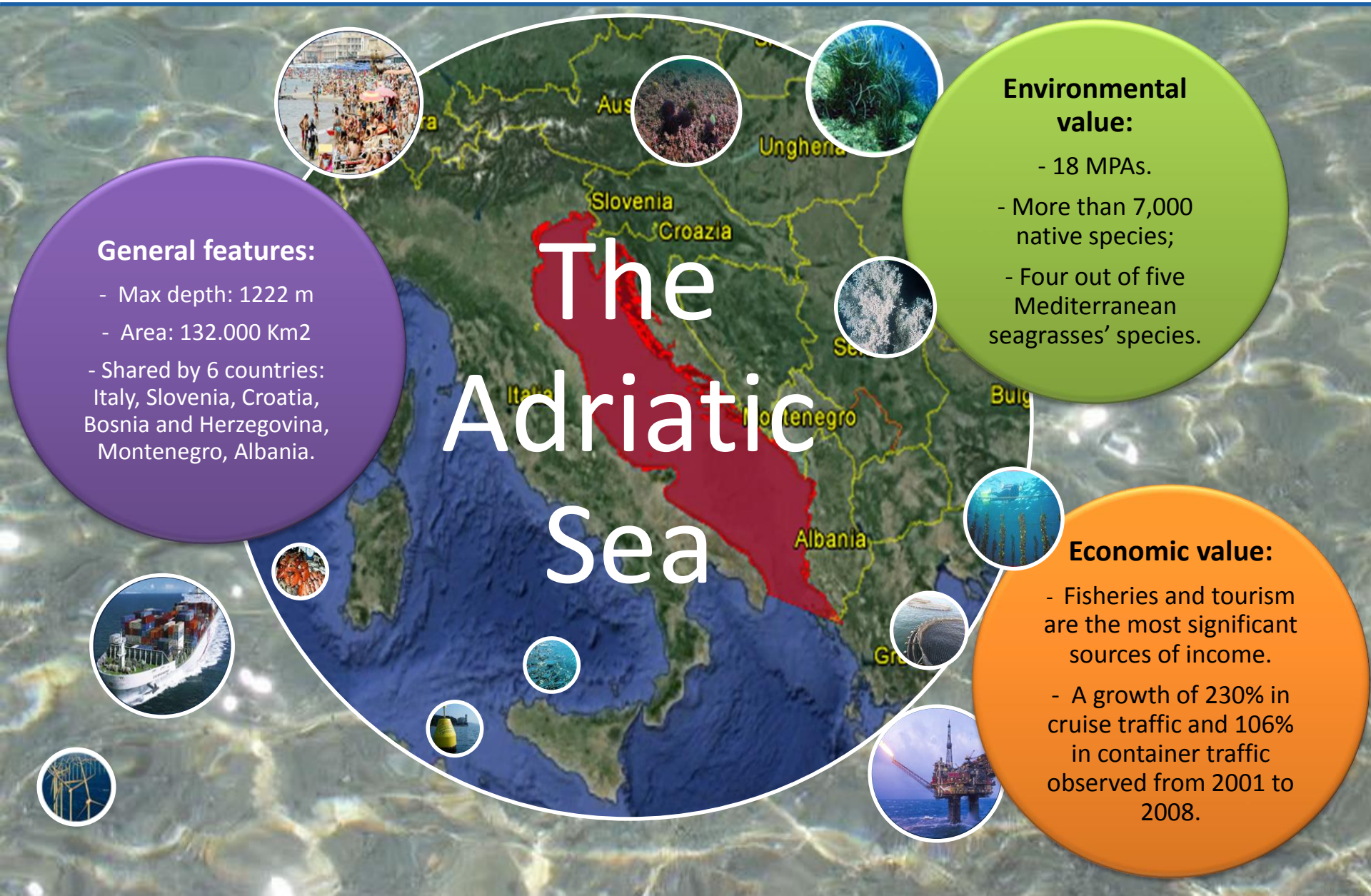
2 climate scenarios

Integration of MCDA and GIS techniques

Expert judgment

Regional coverage

The Adriatic sea case study



General features:

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

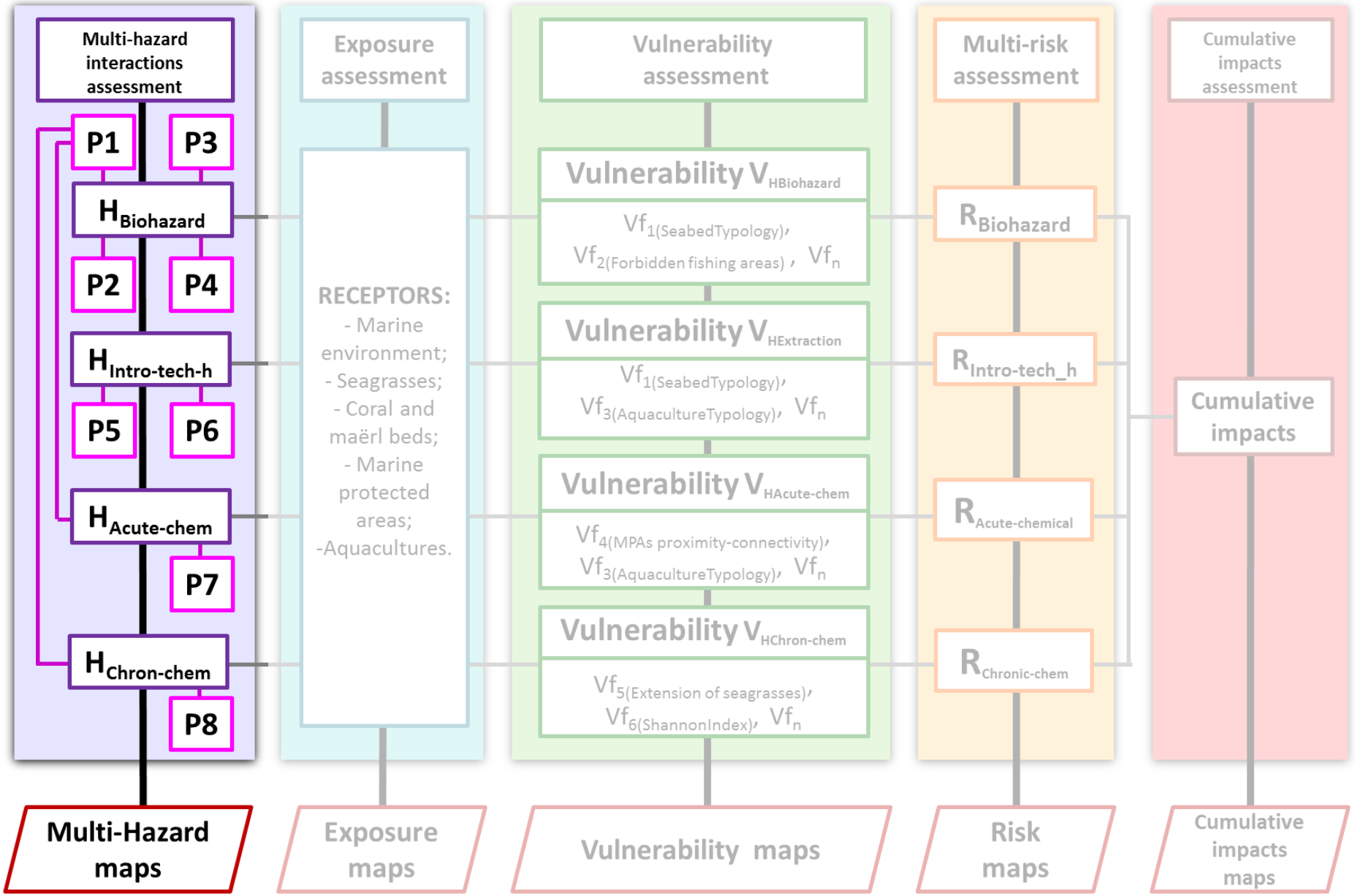
Environmental value:

- 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.

Phase 1 - Multi-hazard interactions assessment



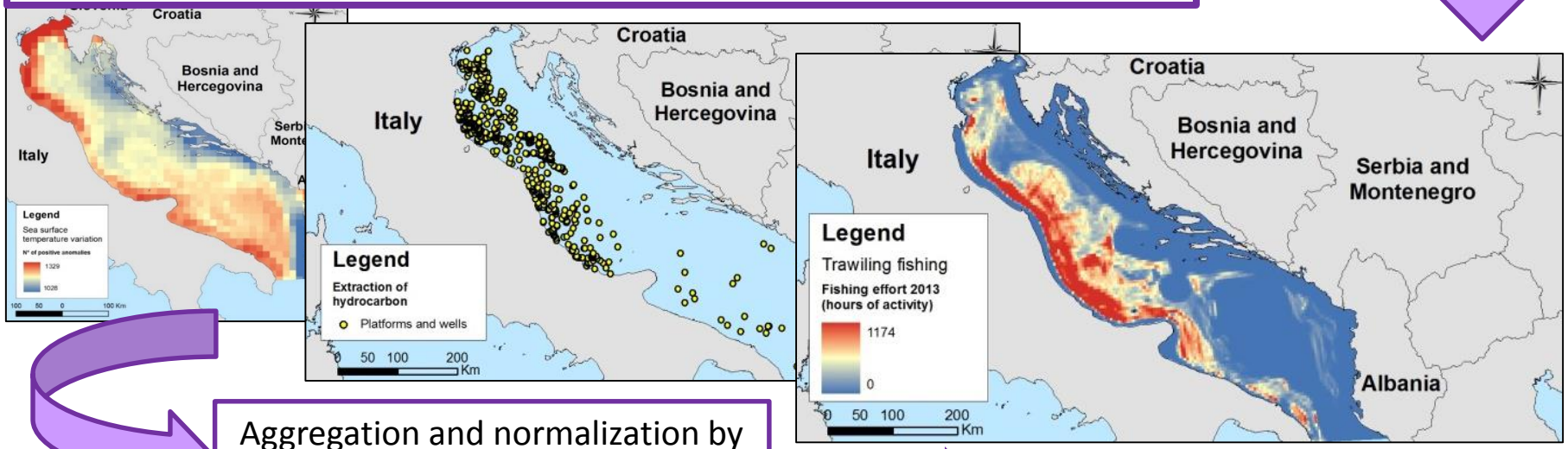
Phase 1 - Multi-hazard interactions assessment

Aggregates metrics and scenarios of climate, ocean, bio-geochemical and anthropogenic pressures for determining potentially affected marine areas

Methodological steps:

1. Select the hazards to be analysed.
2. Define the **temporal window** to be considered.
3. Analyze and **spatially model** single pressures.
4. **Assess** and spatially model **the interactive effects** of multiple pressures occurring in the same area and leading to more complex multi-hazards interactions, **by applying specific MCDA aggregation functions**.
5. **Normalize** the results in a 0-1 range.

According to the MSFD requirements



Aggregation and normalization by means of MCDA

Multi-Hazard maps

Phase 1 - Multi-hazard interactions assessment: available GIS dataset

Which **hazards** can be investigated?

Dataset	Spatial domain ad resolution	Update data	Source
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	2014	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	Adriatic sea, 1:100000	2014	http://atlas.shape-ipaproject.eu/
	Adriatic sea, 1:100000	2015	http://adriplan.eu/
Offshore sand deposit	Adriatic sea, 1:100000	2015	http://adriplan.eu/
Trawling fishing areas	Adriatic sea, 1:100000	2015	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	Mediterranena sea, 1:100000	2014	http://accidents.rempec.org/RempecAccidentsDatabase/
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, 1/8°	2015	http://www.perseus-net.eu
Chlorophyll ‘a’	Mediterranena sea, 1/8°	2015	http://www.perseus-net.eu

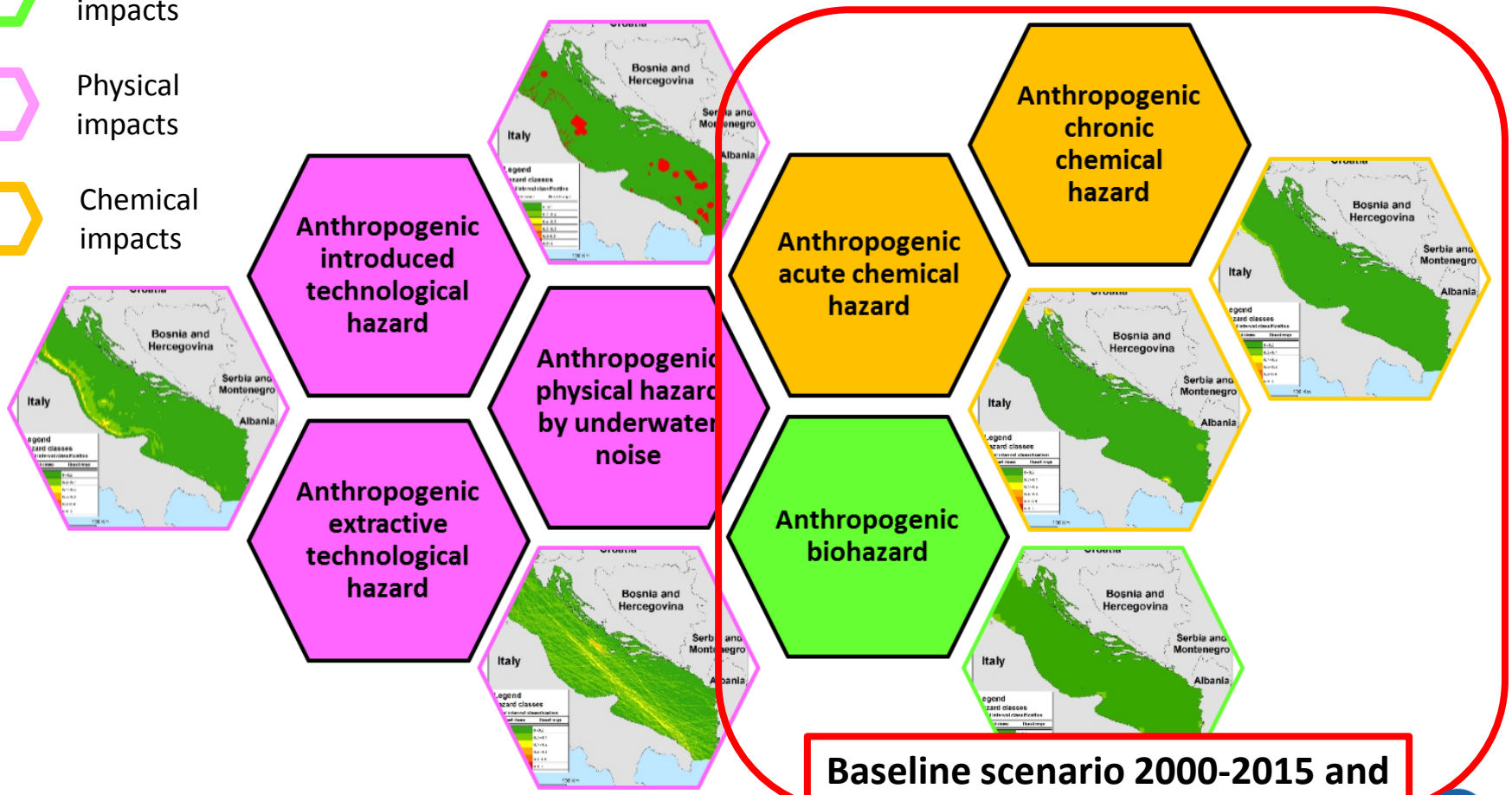
Phase 1 - Multi-hazard interactions assessment: selected hazards

Aggregates metrics and scenarios of climate, ocean, bio-geochemical and anthropogenic pressures for determining potentially affected marine areas

Biological impacts

Physical impacts

Chemical impacts



Baseline scenario 2000-2015 and future scenario 2035-2050

Phase 1 - Multi-hazard interactions assessment: interactive pressures

HAZARD TO BE INVESTIGATED	TYPE	EXAMPLE	MAIN INTERACTIVE PRESSURES
Anthropogenic biohazard	Anthropogenic but exacerbated by natural pressures (climate)	Non-indigenous, introduced and invasive species	• Sea surface temperature variation. • Shipping traffic • Port activity • Aquaculture
Acute chemical hazard	Anthropogenic but exacerbated by natural pressures (climate)	Pollution from one-off spillages, oil spills by shipping accidents	• Sea surface temperature variation • Oil-spill
Chronic chemical hazard	Anthropogenic but exacerbated by natural pressures (climate)	Diffuse pollution by nutrients input from land-based run-off and discharges	• Sea surface temperature variation • Nutrient input

Phase 1 - Multi-hazard interactions assessment: the expert questionnaire

A multi-risk model for the assessment of cumulative environmental impacts in marine areas:

Expert questionnaire supporting the aggregation of hazard interactions based on the Choquet integral.

Name	
Surname	
Title	
Affiliation	
Contact	
Competence within marine science or risk assessment	1. General competence: 2. Specific Competence: 3. Years of experience: 4. Familiarity with the case study area (Adriatic s

1. Rationale

Marine areas represent complex and dynamic systems facing increasing threats and degradation due to multiple human activities and interactive pressures (e.g. fishing, sands and hydrocarbon extraction, tourism, energy infrastructures). A further complication is determined by climate change which is expected to pose additional pressures on marine ecosystems through rising sea levels, increased sea temperatures and ocean acidification (IPCC, 2014). The cumulative and synergic impact of these pressures is triggering severe alteration on biological, chemical and physical processes, with negative consequences for the environment and the socio-economic system. In this setting, multi-risk assessment represents an effective approach to address different risks posed by multiple and interactive pressures affecting marine ecosystems and activities (Gallina et al., 2016). Moreover, MCDA has been widely used to aggregate information about environmental risks and vulnerabilities and aid decision-making process (Rizzi et al., 2015; Torresan, et al., 2012; Linkov et al., 2006; Giove et al., 2009).

Here we propose a spatially explicit multi-risk approach to evaluate the cumulative impacts induced by climate drivers in combination with local to regional anthropogenic pressures in marine areas. The case study area selected for the implementation of the developed methodology is represented by the marine sub-region of the Adriatic sea located in the wider Mediterranean sea (Figure 1).

Figure 1: The Adriatic sea case study area

The methodology, as represented in the framework included in Annex A, is based on the consecutive analysis of a wide array of pressures (e.g. temperature variation, bottom stress by abrasion and sealing), hazards (e.g. bio-hazard, anthropogenic acute chemical hazard), exposed targets and vulnerability factors (e.g. sensitive habitat extent and typology, biodiversity indexes). Multi Criteria Decision Analysis (MCDA) is used at each step of the assessment to consecutively aggregate information about multi-hazards, multi-vulnerability and risks. Results of the assessment can be displayed on GIS-based maps useful to define

aquacultures for which classes (and related 0 and 1 scores) are reported in the suitable tables in Annex B.
Therefore, there are 16 combinations to be compiled for the considered hazard as showed in the following table.

ID	SST variation	Shipping traffic	Port activity	Aquaculture	Score
1	0	0	0	0	
2	1	0	0	0	
3	0	1	0	0	
4	0	0	1	0	
5	0	0	0	1	
6	1	1	0	0	
7	1	0	1	0	
8	1	0	0	1	
9	0	1	1	0	
10	0	1	0	1	
11	0	0	1	1	
12	1	1	1	0	
13	1	1	0	1	
14	1	0	1	1	
15	0	1	1	1	
16	1	1	1	1	

As pointed out in the row co
means that the parameter S
value (i.e. score equal to 1)
the area, with a related score
"How would I score a scena
of unusually warm events (
and port activity, but no aqua
The same exercise can be
questionnaire (Table 1).

In order to better fill in the
the basics of the Choquet int
- 0: an empty set has n
- 1: the maximum set h
- A new added criteri
decrease. For instanc
than the combination

BIOLOGICAL HAZARD ASSESSMENT

Please fill in the Score column, valuing the combination where the selected parameters may be in the highest class (1= maximum value) or in the lowest class (0= minimum value).
The assigned score can varying between 0 and 100.

SST variation	Shipping traffic	Port activity	Aquaculture	Score
0	0	0	0	0
1	0	0	0	
0	1	0	0	
0	0	1	0	
0	0	0	1	
1	1	0	0	
1	0	1	0	
1	0	0	1	
0	1	1	0	
0	1	0	1	
0	0	1	1	
1	1	1	0	
1	1	0	1	
1	0	1	1	
0	1	1	1	
1	1	1	1	100

The 0 and 1 classes for the considered parameters are reported in Annex B.

Phase 1 - Multi-hazard interactions assessment: the expert questionnaire

Anthropogenic biohazard				
SST variation	Shipping traffic	Port activity	Aquaculture	**Interaction weight**
0	0	0	0	**0**
1	0	0	0	**42**
0	1	0	0	**17**
0	0	1	0	**19**
0	0	0	1	**8**
1	1	0	0	**58**
1	0	1	0	**61**
1	0	0	1	**48**
0	1	1	0	**36**
0	1	0	1	**25**
0	0	1	1	**28**
1	1	1	0	**82**
1	1	0	1	**72**
1	0	1	1	**69**
0	1	1	1	**43**
1	1	1	1	**100**

Coalition scenario

Presence of the pressure in its minimum value (**minimum intensity**)

Presence of the pressure in its maximum value (**maximum intensity**)

Interaction weight for each coalition scenarios, based on expert judgment

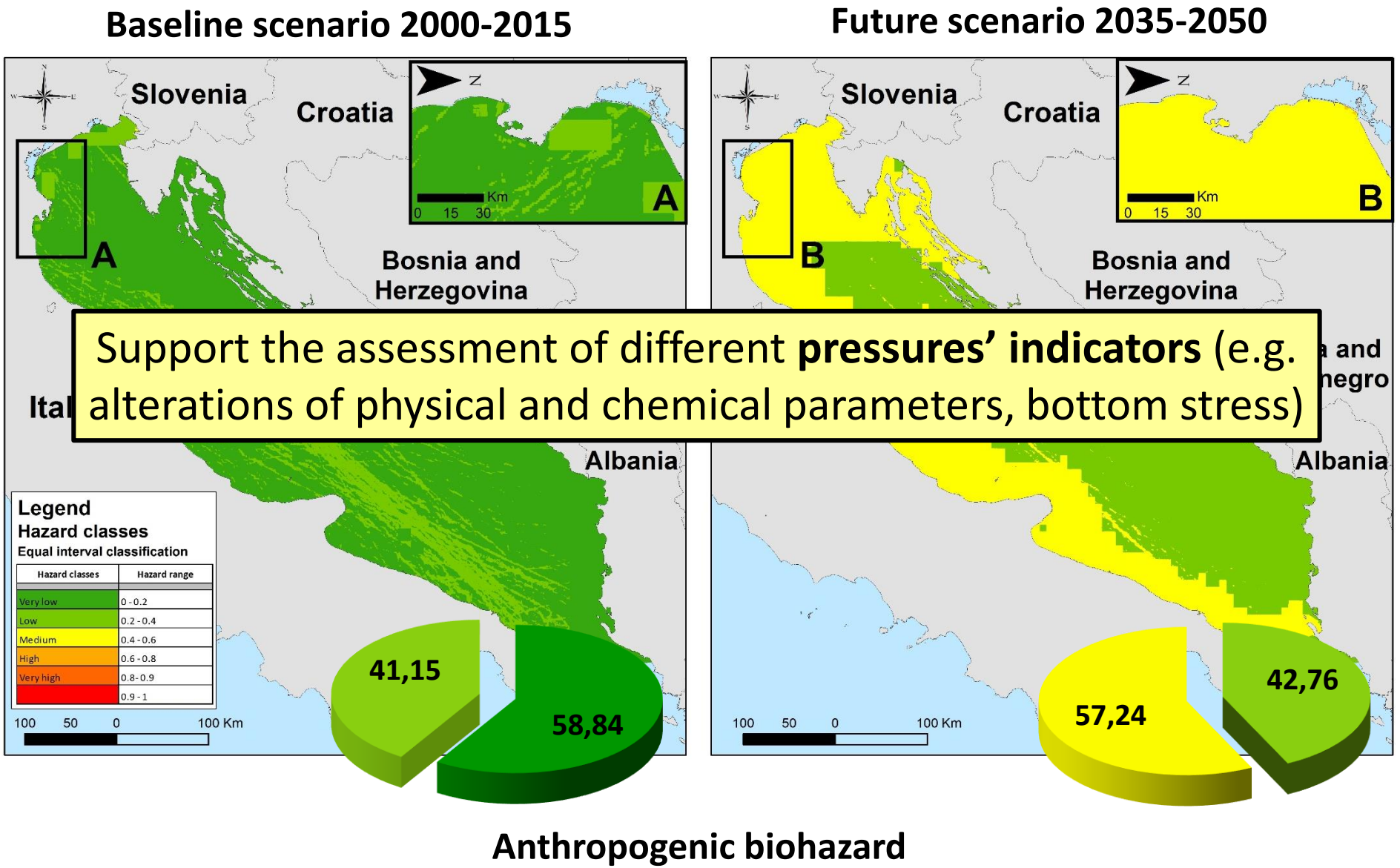
Phase 1 - Multi-hazard interactions assessment: the expert questionnaire

Anthropogenic biohazard				
SST variation	Shipping traffic	Port activity	Aquaculture	**Interaction weight**
0	0	0	0	**0**
1	0	0	0	**42**
0	1	0	0	**17**
0	0	1	0	**19**
0	0	0	1	**8**
1	1	0	0	**58**
1	0	1	0	**61**
1	0	0	1	**48**
0	1	1	0	**36**
0	1	0	1	**25**
0	0	1	1	**28**
1	1	1	0	**82**
1	1	0	1	**72**
1	0	1	1	**69**
0	1	1	1	**43**
1	1	1	1	**100**

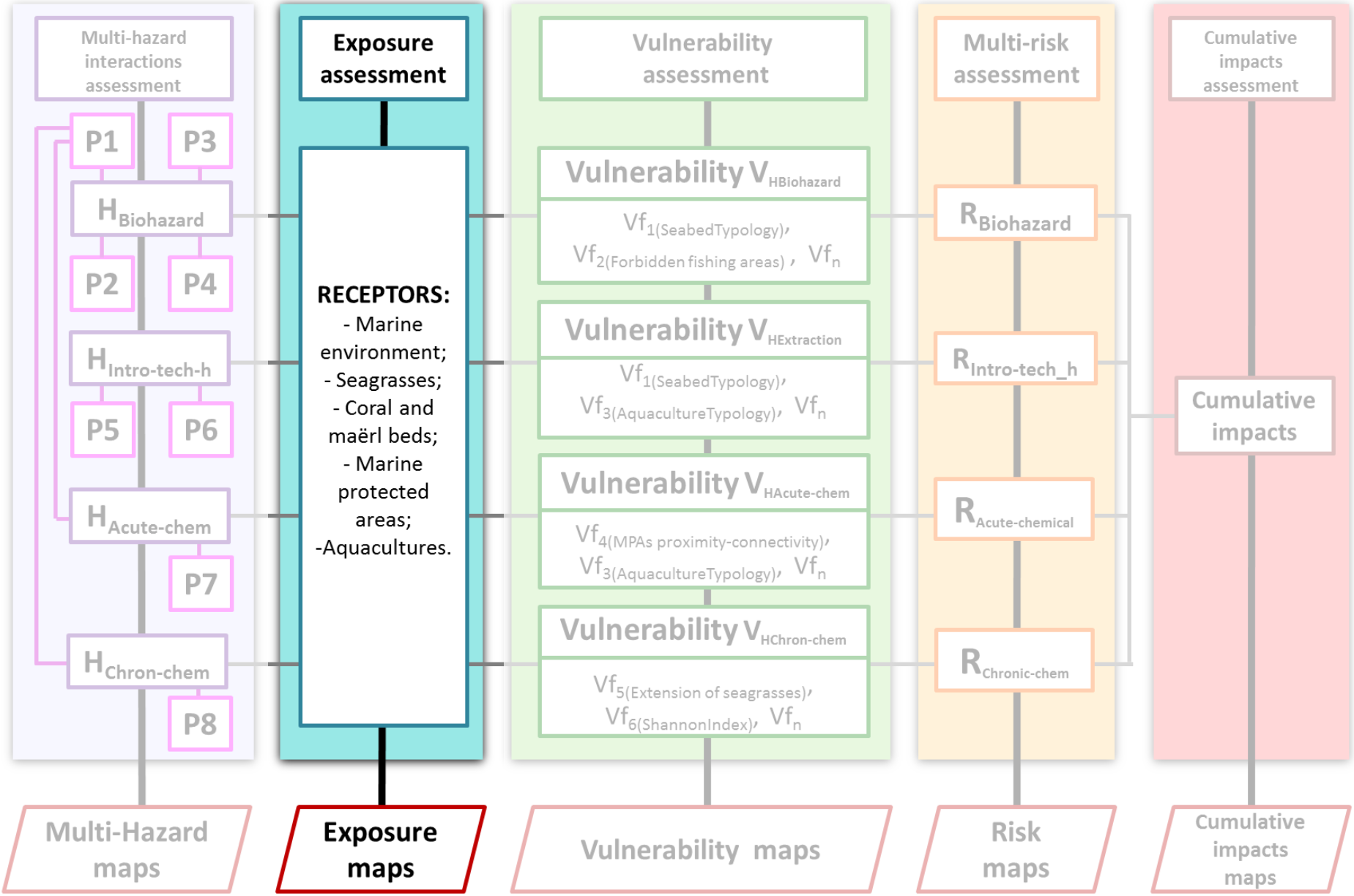
Choquet integral

Aggregate and normalize in a 0-1 range the considered interactive pressures and related scenarios of coalitions, for all the considered hazards.

Phase 1 - Multi-hazard interactions assessment: main output

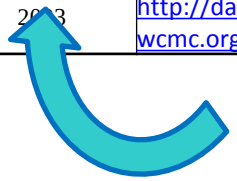


Phase 2 – Exposure assessment



Phase 2 – Exposure assessment: available GIS dataset

Dataset	Spatial domain ad resolution	Update data	Source
Adriatic marine region	Adriatic sea, 1:50000	2014	http://atlas.shape-ipaproject.eu/
Marine administrative zones	Adriatic sea, 1:50000	2014	http://atlas.shape-ipaproject.eu/
Marine Protected areas (MPAs)	Global ocean 1:1.000.000	2014	www.protectedplanet.net
	Adriatic sea, 1:25000	2014	http://atlas.shape-ipaproject.eu/
Sites of Community Importance (SCI), Zone of Special Protection (ZSP)	Adriatic sea, 1:25000	2014	http://atlas.shape-ipaproject.eu/
Nationally designated areas	Adriatic sea, 1:100000	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/
Aquacultures	Adriatic sea, 1:10000	2013	http://atlas.shape-ipaproject.eu/
EUNIS seabed habitat	Adriatic sea, 1: 1.000.000	2014	http://www.emodnet.eu/seabed-habitats
Seagrasses	Adriatic sea, 1: 1.000.000	2013	http://www.emodnet.eu/seabed-habitats
Coralligenous and maërl beds habitats	Adriatic sea, 1: 1.000.000	2014	http://www.emodnet.eu/seabed-habitats
Biodiversity Shannon's Index	Global scale, hex grid	2014	http://www
Seagrass species richness	Global ocean 1:1.000.000	2013	http://data.unep-wcmc.org/



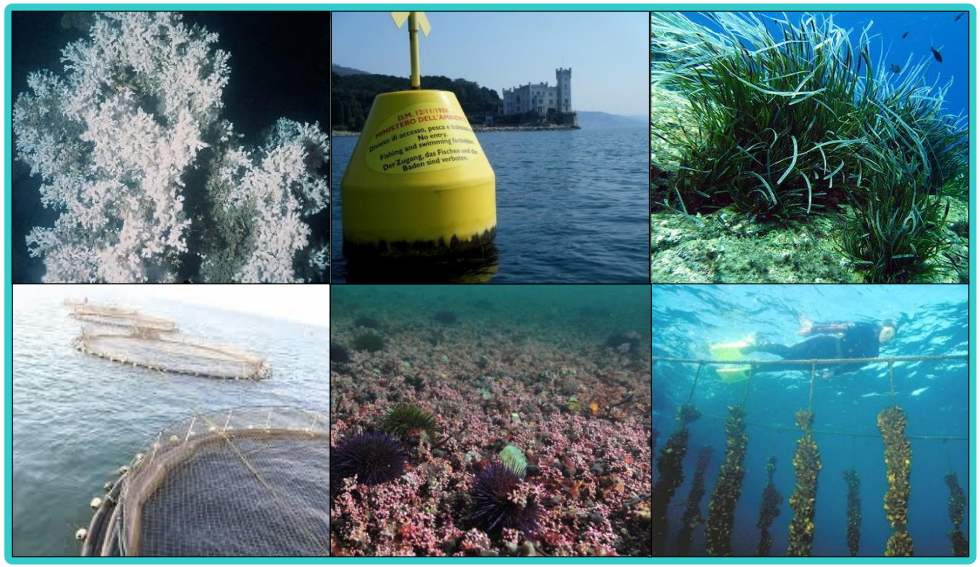
Which **elements potentially at risk and vulnerability factors** can be identified?

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.



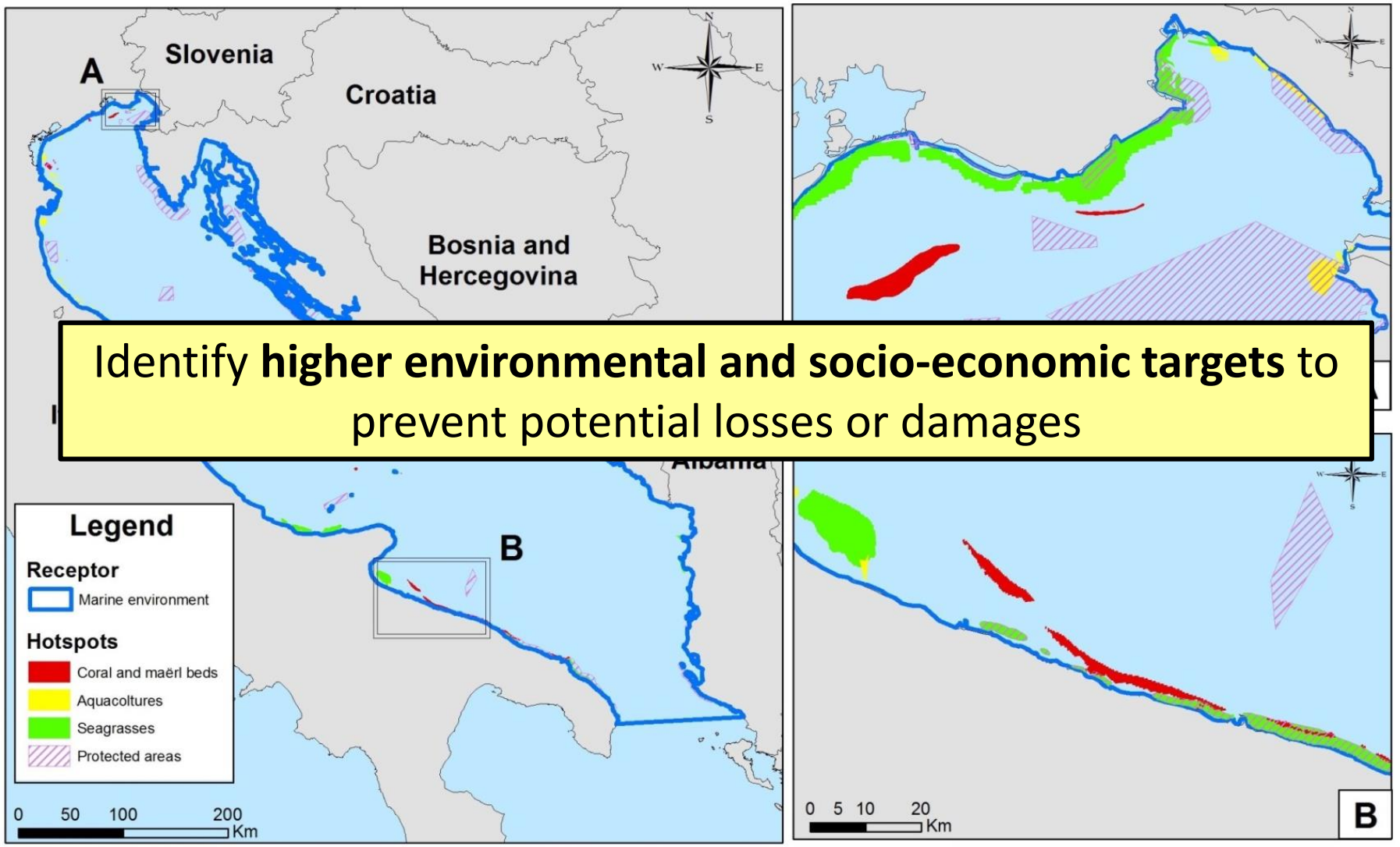
Selected receptor:

- Marine environment

Hot-spot with high environmental and economic value:

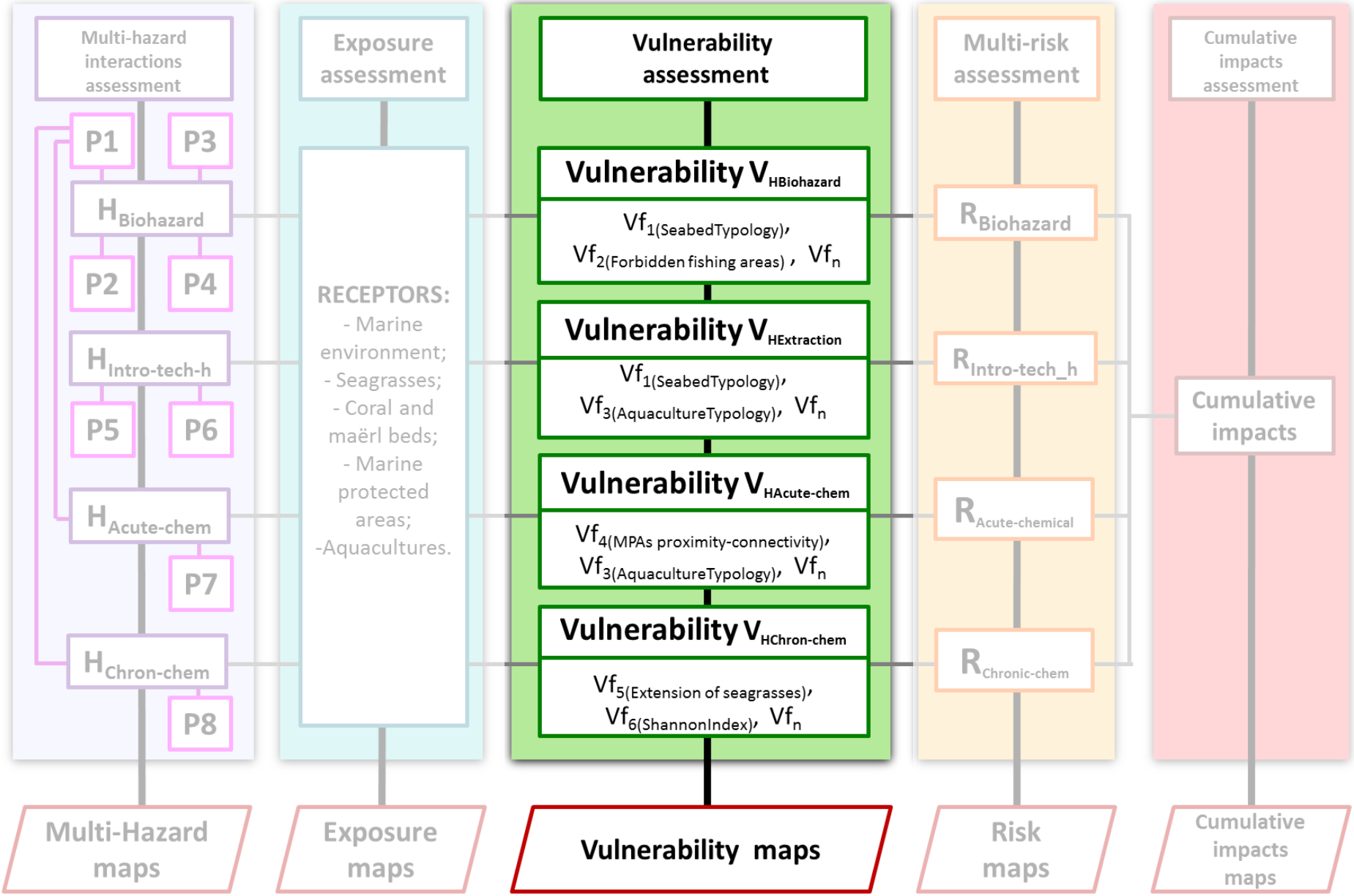
- Seagrasses
- Coral and maërl beds
- Marine protected areas
- Aquacultures

Phase 2 – Exposure assessment: main output



Identify **higher environmental and socio-economic targets** to prevent potential losses or damages

Phase 3 – Vulnerability assessment



Phase 3 – 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.

Hazard	Vulnerability factors							
	Seabed typology	MPAs proximity-connectivity	Extension of coral and maërl beds	Extension of seagrasses	Seagrasses species richness	Shannon index	Aquacolture typology	Forbidden fishing areas
Anthropogenic introduced technological hazard								
Anthropogenic extractive technological hazard								
Anthropogenic physical hazard by underwater noise								
Anthropogenic chronic chemical hazard								
Anthropogenic acute chemical hazard								
Anthropogenic biohazard								

Phase 3 – 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.

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
	95.55 - 137.55	1
Extension of seagrasses (Km²)	0.02 - 6.01	1
	6.02 - 27.37	0,6
	27.38 - 103.75	0,2
Shannon Index	1.39 - 2.62	1
	2.63 - 3.65	0,8
	3.66 - 4.34	0,6
	4.35 - 4.80	0,4
	4.81 - 5.55	0,2
Extension of coral and maërl beds habitats (Km²)	0.07 - 17.79	1
	17.80 - 53.45	0,6
	53.46 - 2014.49	0,2
Aquaculture typology	Fish farms	0,6
	Mussel farms	1
Forbidden fishing areas	Forbidden areas	0,2
	Not forbidden areas	0,5
Seagrasses Species Richness	Very low richness (n° 1 of species)	1
	Low richness (n° 2 of species)	0,8
	Medium richness (n° 3 of species)	0,6
	High richness (n° 4 of species)	0,4
	Very high richness (n° 5 of species)	0,2
Seabed typology		

Phase 3 – 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.

Vulnerability factor	Vulnerability class	Anthropogenic extractive technological hazard	Anthropogenic biohazard	Anthropogenic chronic chemical hazard	Anthropogenic acute chemical hazard
Seabed typology	Mediterranean coralligenous communities moderately exposed to or sheltered from hydrodynamic action	1	1	1	1
	Shallow sublittoral rock and biogenic reef	1	1	1	1
	Shallow sublittoral coarse sediment	0,2	0,5	0,5	0,5
	Shallow sublittoral sand	0,2	0,5	0,7	0,7
	Shallow sublittoral mud	0,2	0,5	0,8	0,8
	Shallow sublittoral mixed sediment	0,2	0,5	0,7	0,7
	Maerl beds	1	1	1	1
	Sublittoral seagrass beds including Cymodocea and Posidonia beds	0,6	1	1	1
	Bathyal sediment	0,4	0,2	0,2	0,2
	Abyssal sediment	0,4	0,2	0,2	0,2

Phase 3 – 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.

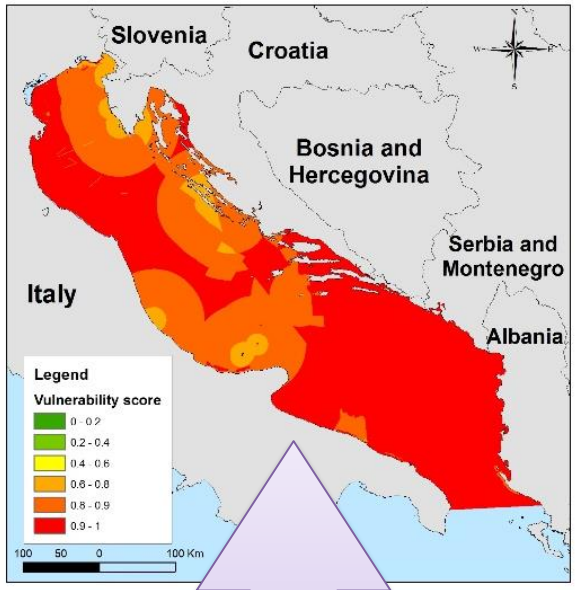
$$V = f(vf_i)$$

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.

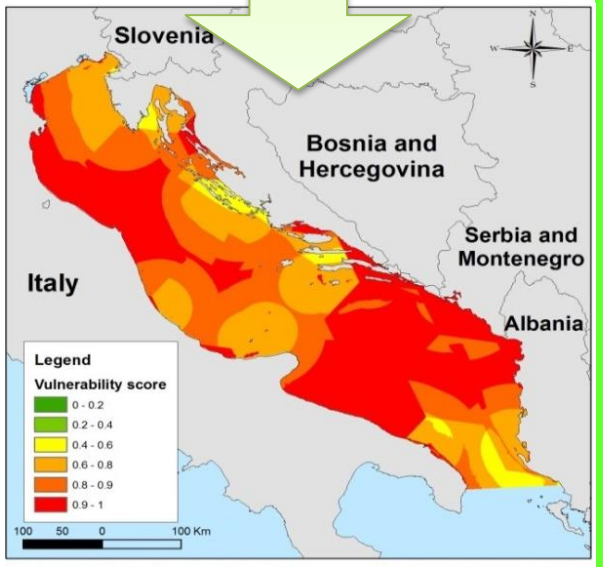
Phase 3 – Vulnerability assessment: main output

Vulnerability at the Anthropogenic acute chemical hazard



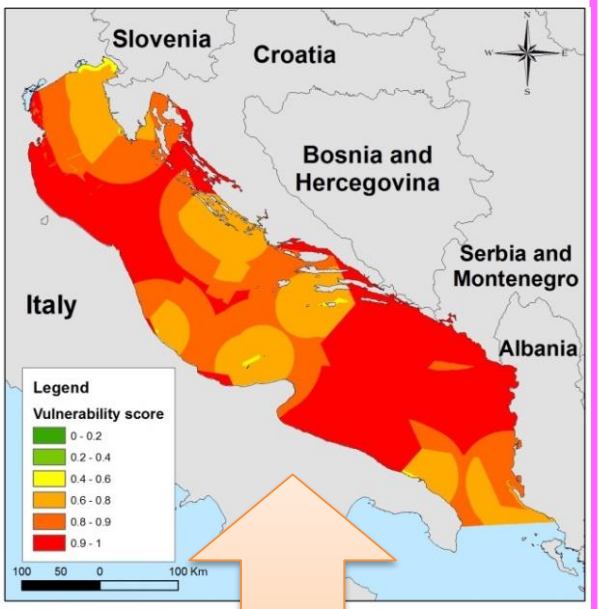
Homogenous high vulnerability scores in the whole case study (0.8-1). Slightly lower values (0.6-0.8) in the Croatian coast due to many MPAs close to each other in the area and high bio-l diversity.

Higher vulnerability scores (0.8-1) in the N/W and S-central Adriatic Sea due to valuable habitats located in the area. Lower values (0.4-0.8) in the N/E part and in the lower limit of the sea due to the high level of biodiversity and high presence of MPAs.



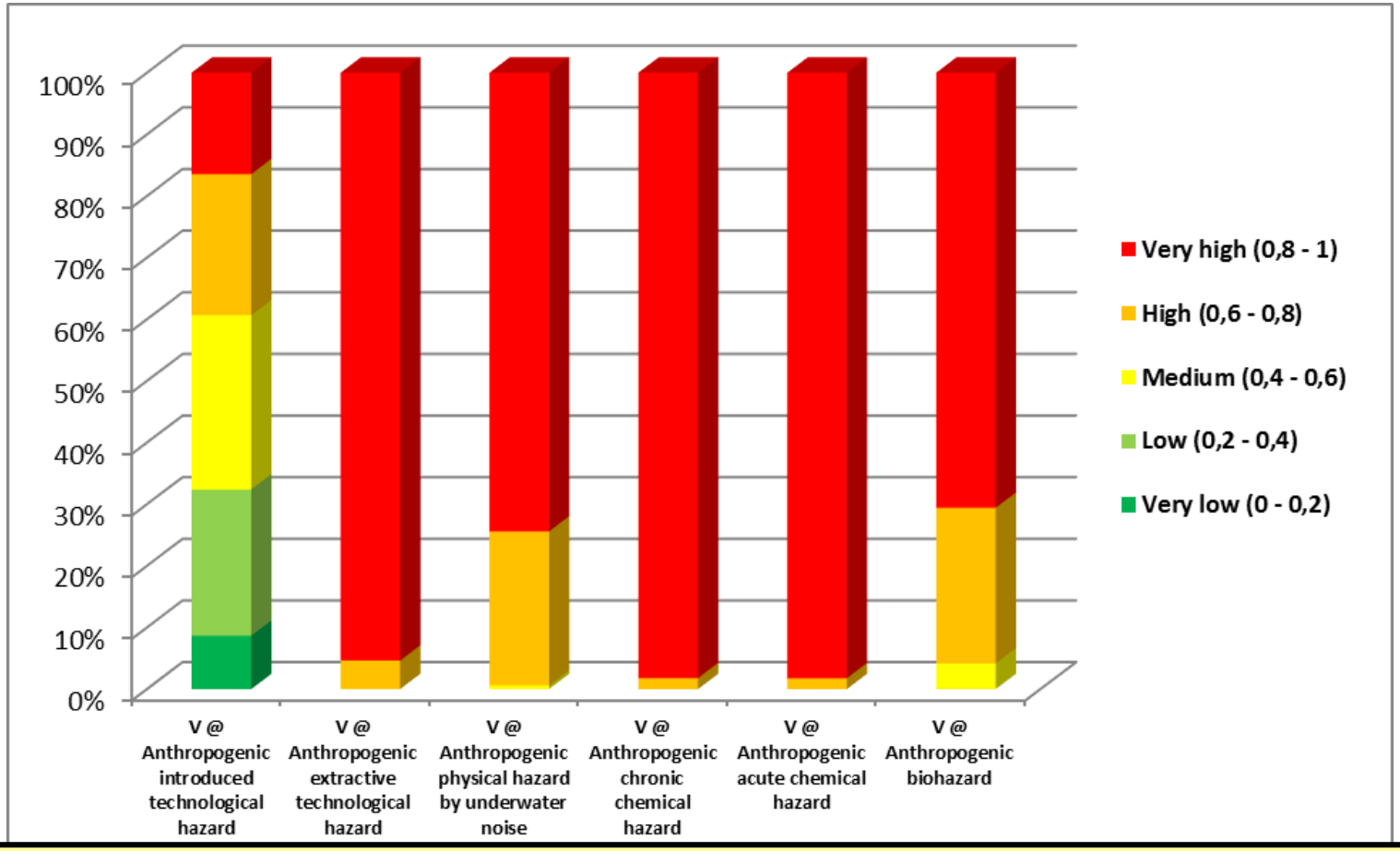
Vulnerability at the Biohazard

Vulnerability at the physical hazard by underwater noise



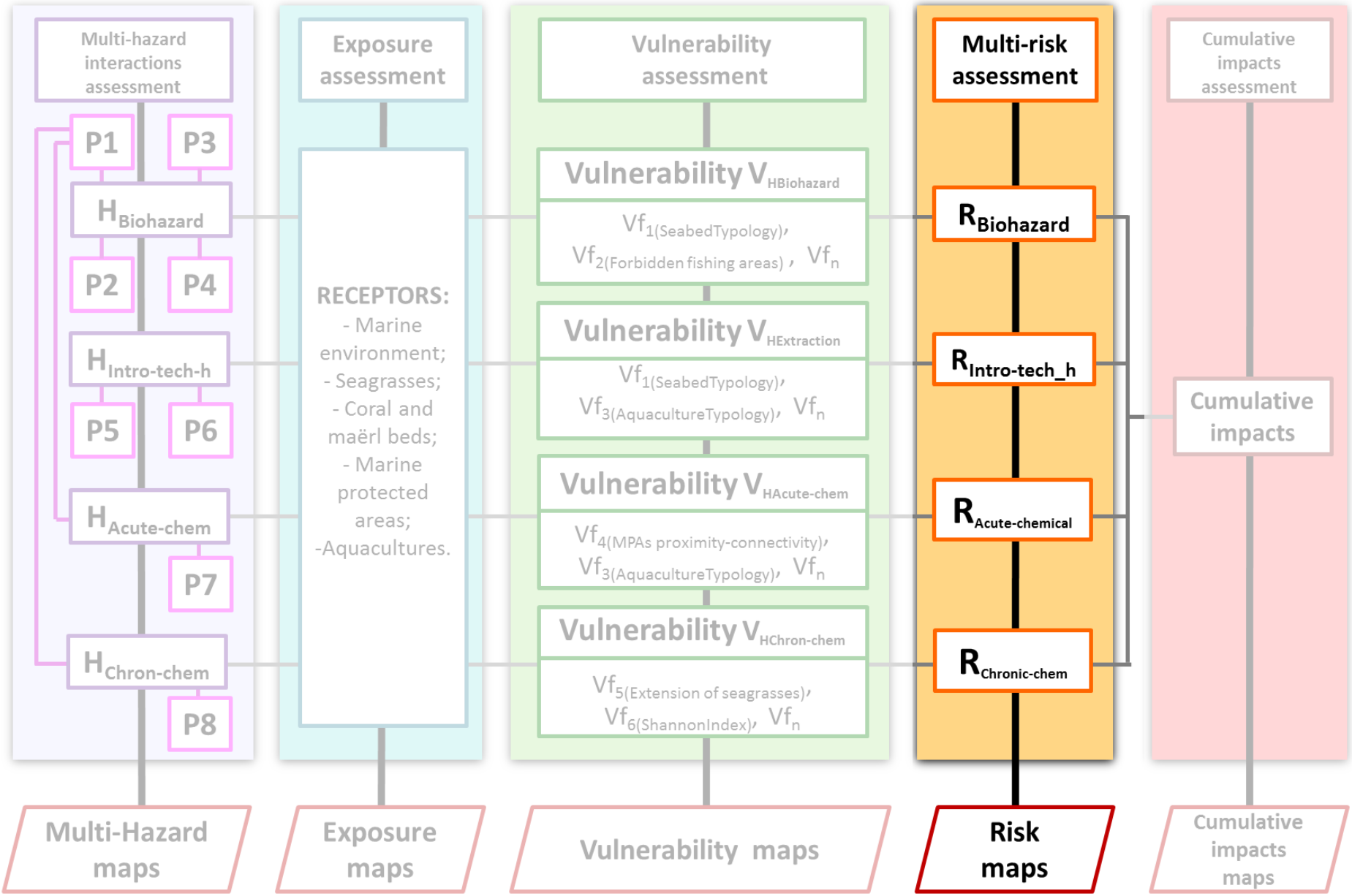
Homogenous high vulnerability scores in the whole case study (0.8-1). Spots with moderate scores (0.4- 0.6) due to fishing restriction and shipping traffic in protected areas.

Phase 3 – Vulnerability assessment: main output



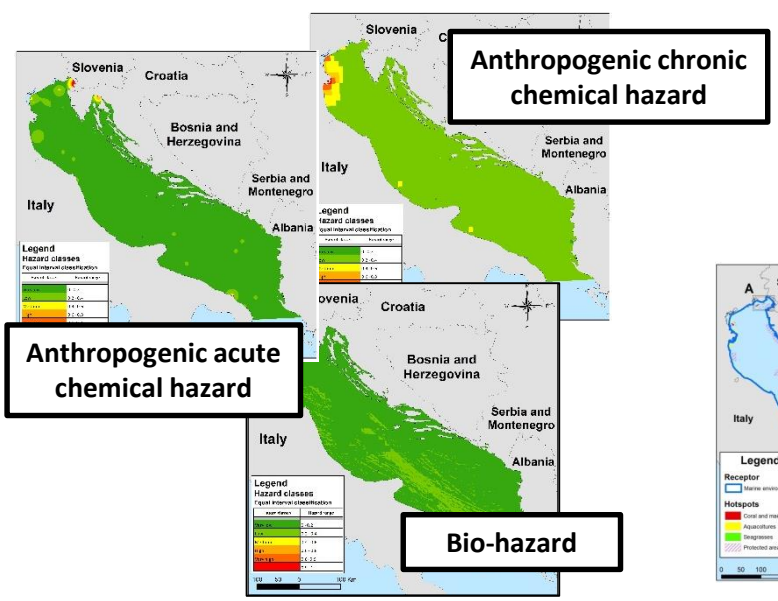
Support the design and implementation of **nature-based solutions for increasing resilience** of vulnerable targets

Phase 4 – Multi-risk assessment



Phase 4 – Multi-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 in the baseline (2000-2015) and future scenario (2035-2050)



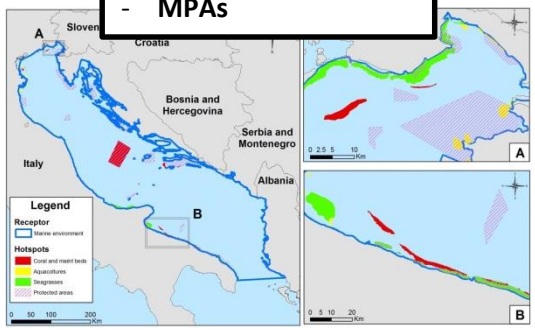
Anthropogenic chronic chemical hazard

Anthropogenic acute chemical hazard

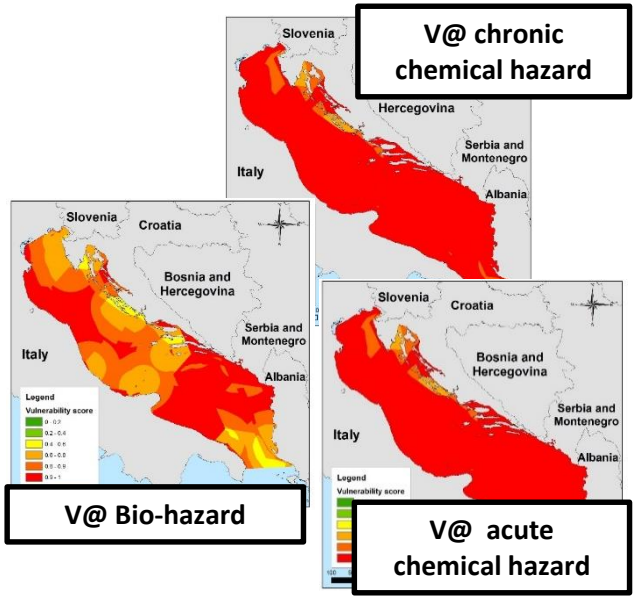
Bio-hazard

Multi-hazard maps

Marine environment including:
- Seagrasses
- Coral and maërl beds
- Acquacultures
- MPAs



Exposure map



V@ chronic chemical hazard

V@ Bio-hazard

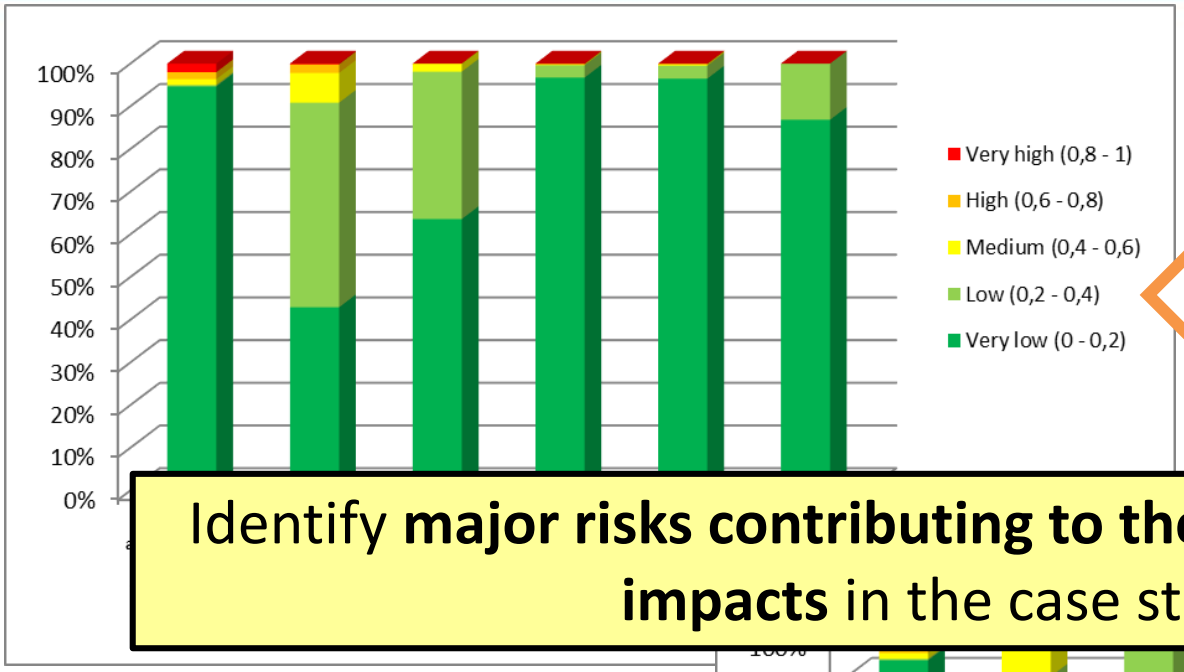
V@ acute chemical hazard

Vulnerability maps

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

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

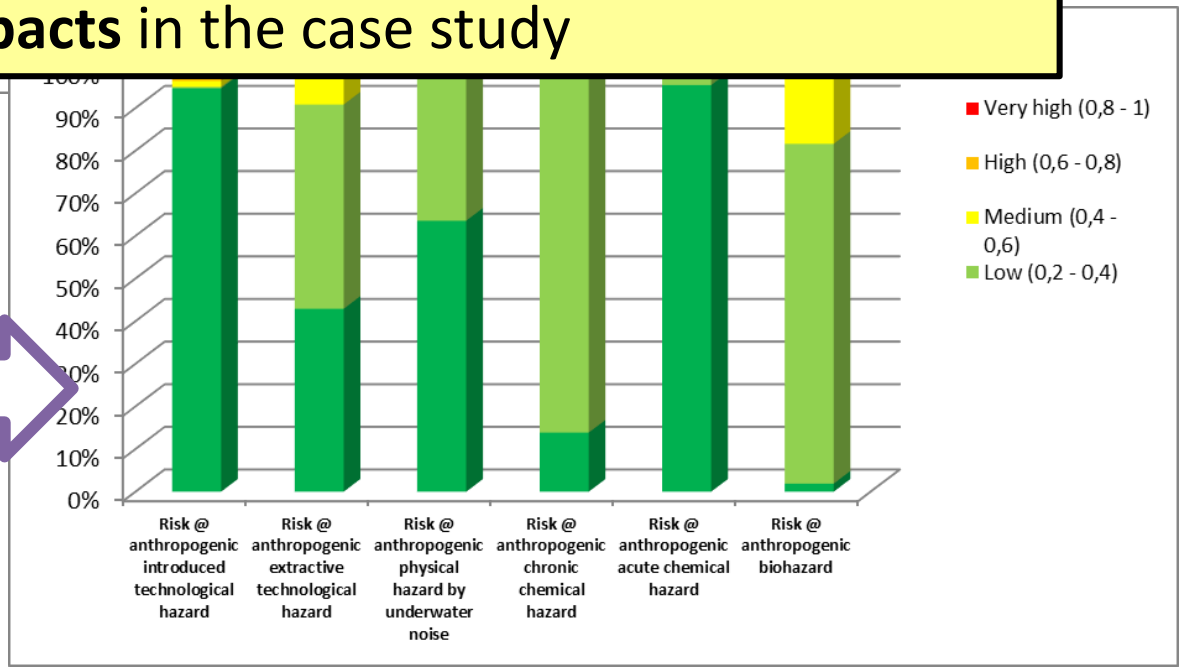
Phase 4 – Multi-risk assessment: main output



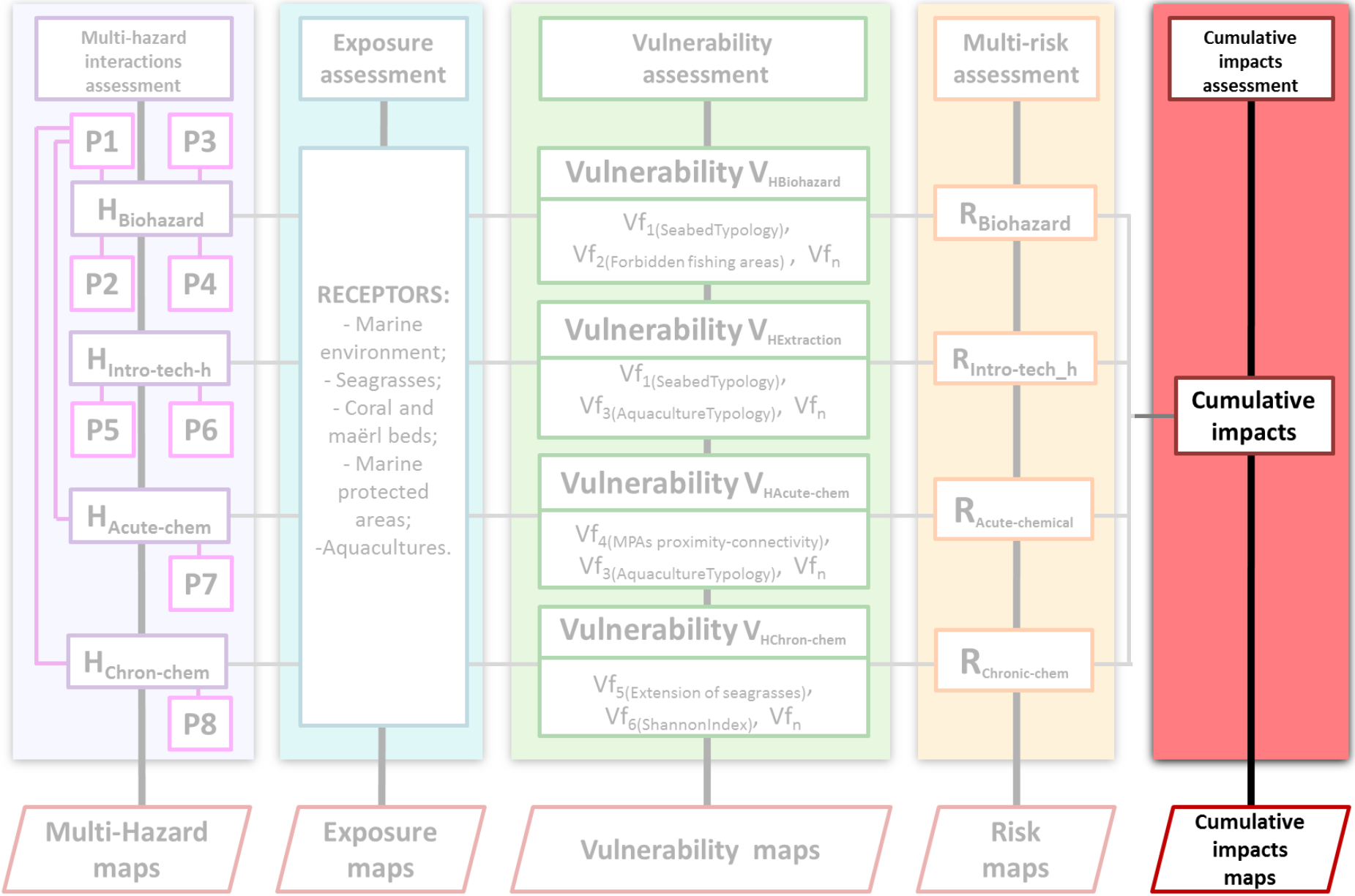
Baseline scenario 2000-2015

Identify **major risks contributing to the overall cumulative impacts** in the case study

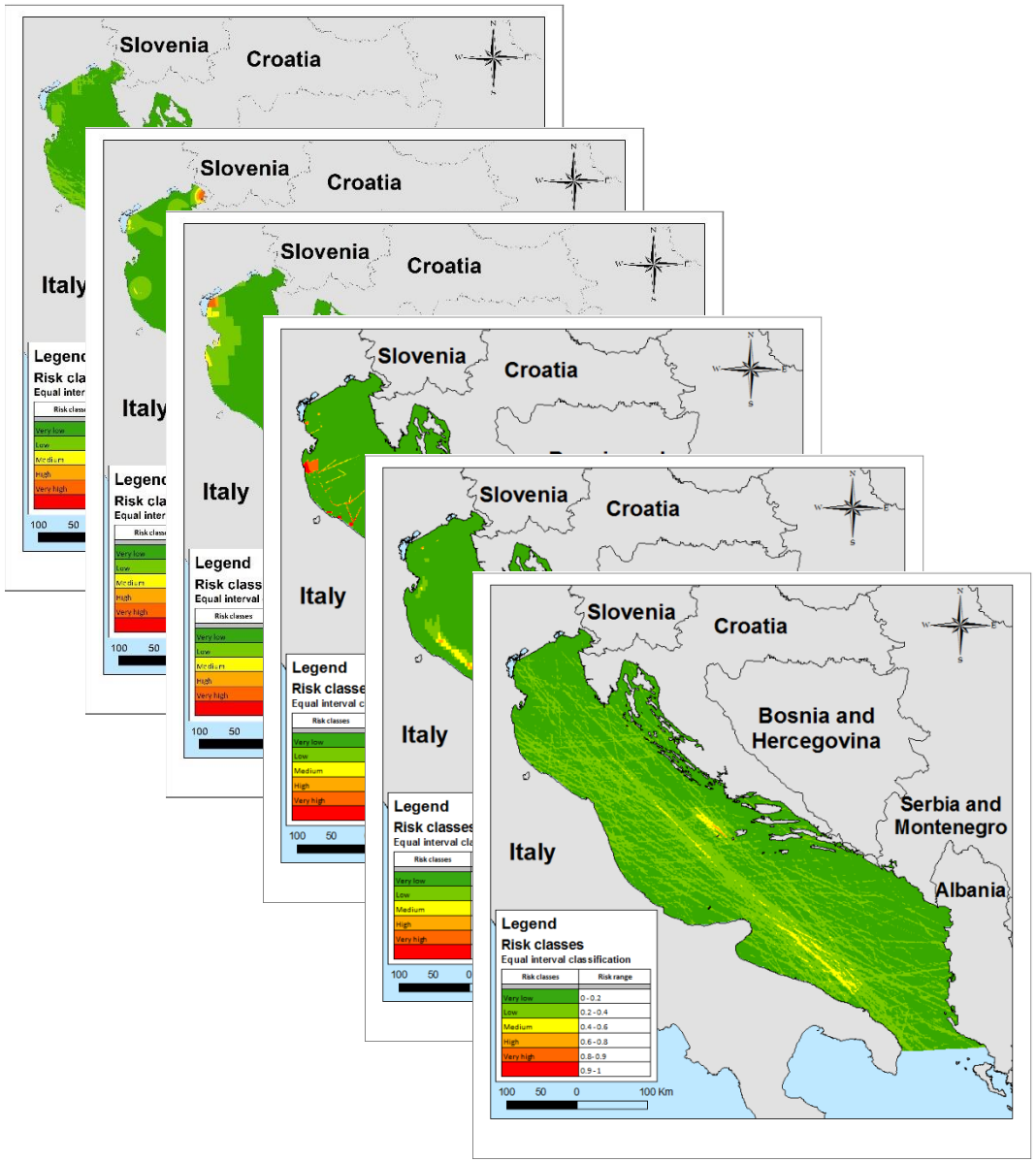
Future climate scenario 2035-2050



Phase 5 – Cumulative impact assessment



Phase 5 – Cumulative impact assessment



$$\mathrm{CI}_c = \sum_{i=1}^{m} R_{i,c}$$

Where:

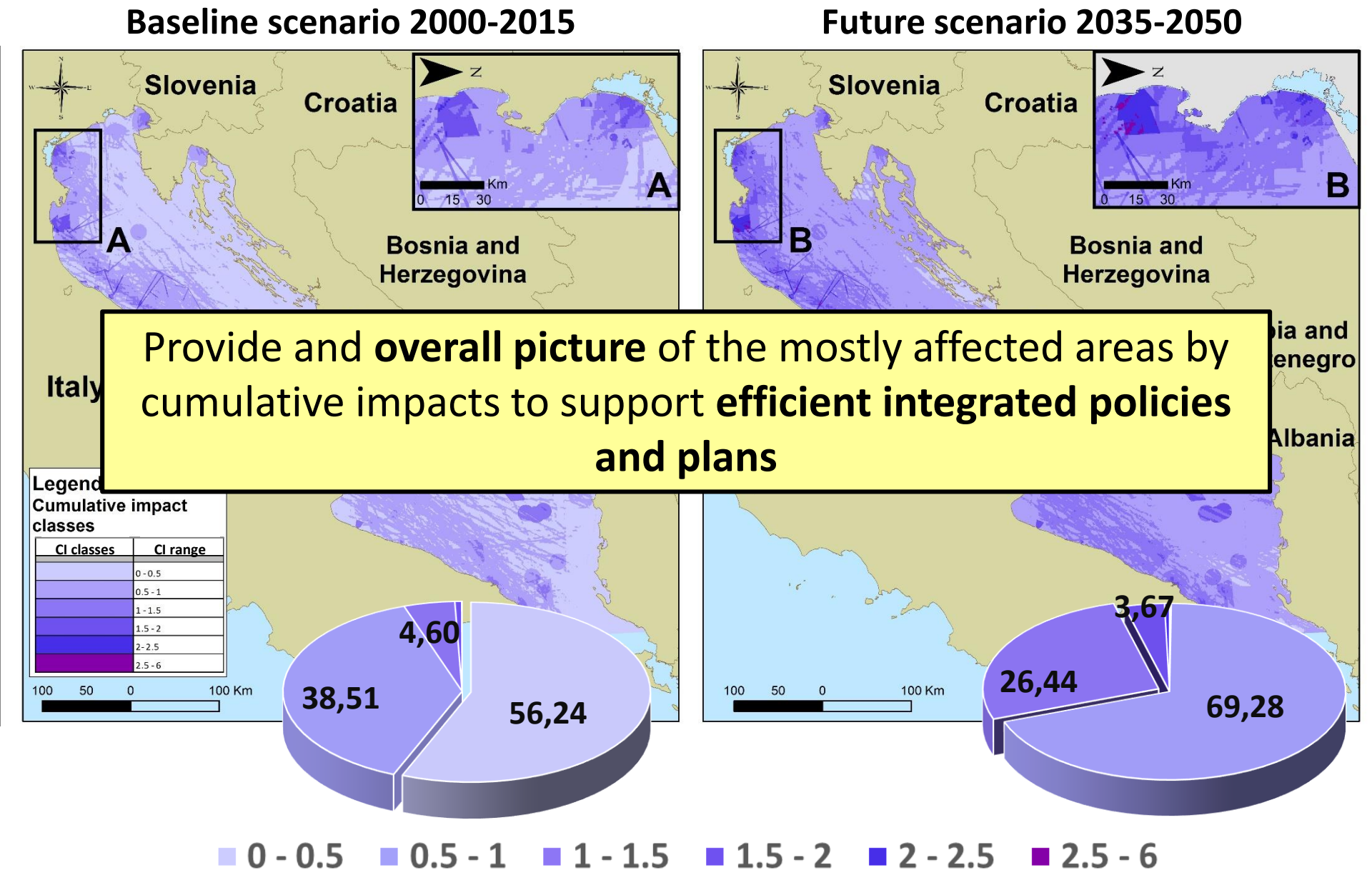
CI_c = **cumulative impact** (calculated in the cell *c* for the case study area and considered timeframe scenarios, ranging from 0 to 6);

c = the cell of concern;

m = **6 anthropogenic and natural risks**;

$R_{i,c}$= **the normalized value of anthropogenic and natural risk** *i* in the cell c (scaled between 0 and 1) .

Phase 5 – Cumulative impact assessment: main output



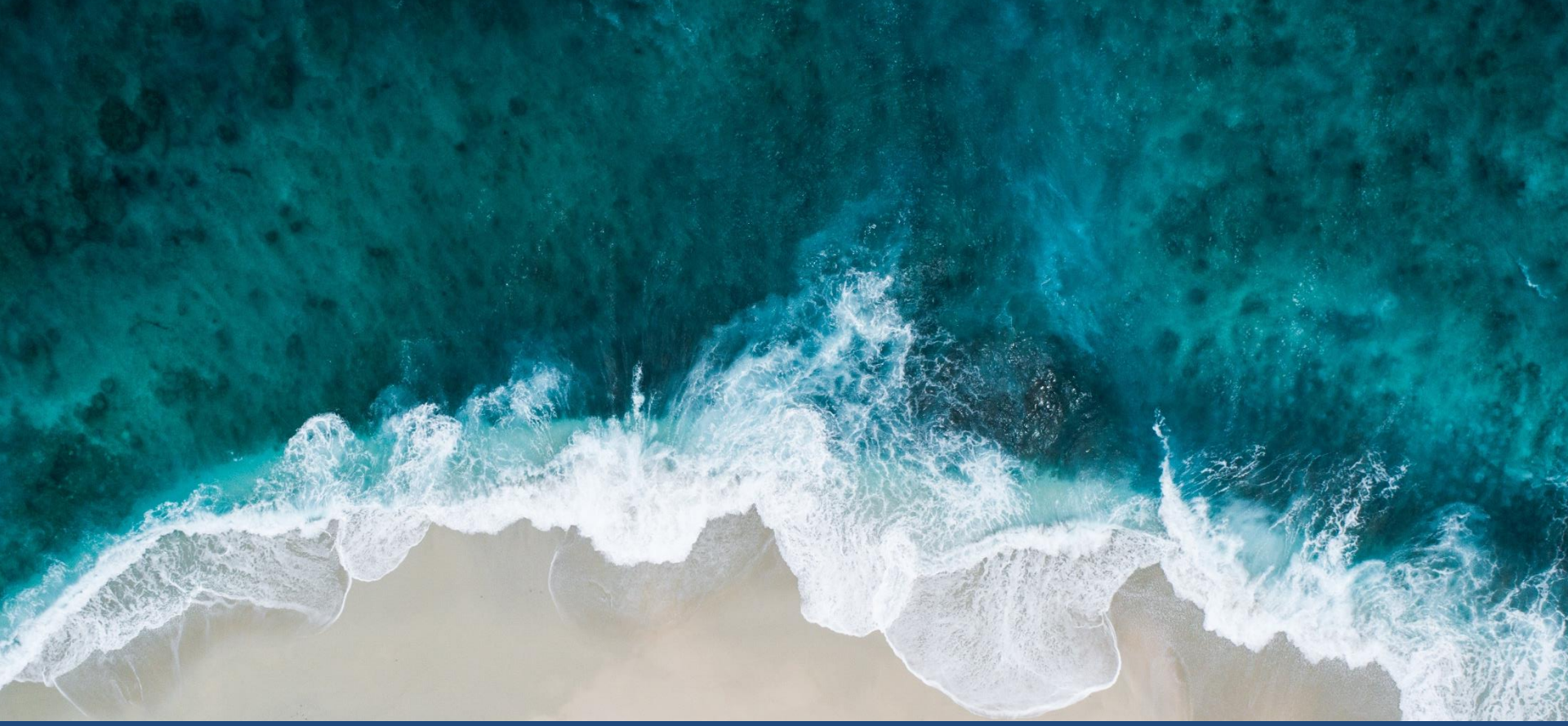
Take home messages

- **Multi-risk approach integrating different** tools, acting together as a **Decision Support System** for the development of science-based policies and management measures of marine areas that consider **spatially relevant issues** and are **consistent with the EU integrated maritime policy.**

- Scenarios' analysis through BBN considering a wide spectrum of options in order to develop **integrated management schemes** able to balance use/exploitation and conservation of the marine environment.

- **Dynamic behaviors** of pressures, hazard and vulnerabilities in temporal and spatial dimensions (e.g. pressure persistence, cascading effects, changing in ecosystem resilience and coping capacity, 3D pattern and marine circulation)**.**

- **Exploit machine learning algorithms potential** to automatize time-consuming data pre-processing processes and simplify cumulative impact appraisal and multi-scenarios analysis under different input data and constraints



Thanks for your attention!
Questions?

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http://www.cmcc.it/it/divisions/raas

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FAO and the Koronivia Joint Work on Agriculture

February 19, 2019 – h. 12:00 pm CET

Centro Euro-Mediterraneo sui Cambiamenti Climatici

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