Cumulative impact assessment as a key conservation planning tool: an application on *Posidonia oceanica* meadows in Greek waters of the Aegean Sea

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Biological diversity in the world's oceans has a vital role in maintaining the functionality and productivity of ecosystems. **The oceans** cover two-thirds of the planet and **hold a broad phylogenetic diversity of life** but the actual number of species they contain remains unknown.

Some 91% of the species in the ocean and 86% on Earth still await description.

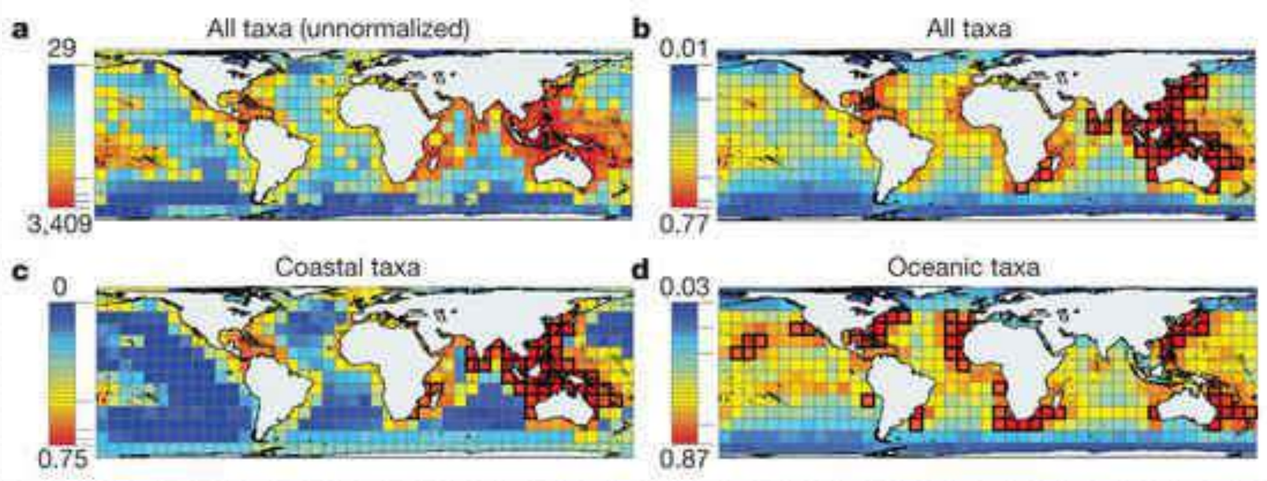
Currently catalogued and predicted total number of species on Earth and in the ocean.

Species	Earth			Ocean		
	Catalogued	Predicted	±SE	Catalogued	Predicted	±SE
Eukaryotes						
Animalia	953,434	7,770,000	958,000	171,082	2,150,000	145,000
Chromista	13,033	27,500	30,500	4,859	7,400	9,640
Fungi	43,271	611,000	297,000	1,097	5,320	11,100
Plantae	215,644	298,000	8,200	8,600	16,600	9,130
Protozoa	8,118	36,400	6,690	8,118	36,400	6,690
Total	1,233,500	8,740,000	1,300,000	193,756	2,210,000	182,000
Prokaryotes						
Archaea	502	455	160	1	1	0
Bacteria	10,358	9,680	3,470	652	1,320	436
Total	10,860	10,100	3,630	653	1,320	436
Grand Total	**1,244,360**	**8,750,000**	**1,300,000**	**194,409**	**2,210,000**	**182,000**

Source: Mora *et al*., 2011

Marine Biodiversity

Global species richness and hotspots across 13 major species groups ranging from zooplankton to marine mammals



Spatial regression analyses revealed **sea surface temperature as the only environmental predictor highly related to diversity** across all 13 taxa. **Habitat availability were also important for coastal species**.

Areas of high species richness were disproportionately concentrated in regions with medium or higher human impacts.

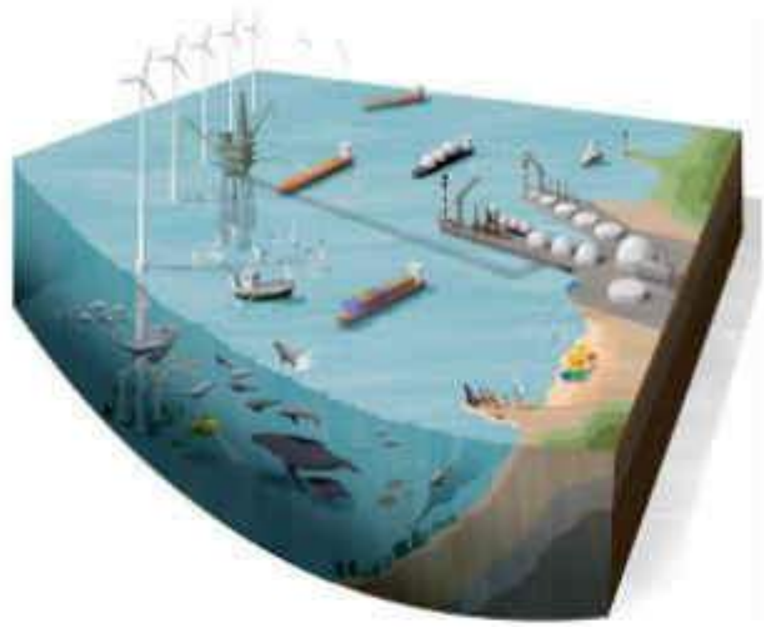
➡ changes in ocean temperature, in conjunction with other human impacts, may ultimately rearrange the global distribution of life in the ocean.

Source: Tittensor *et al.*, 2010

Biodiversity Loss

Since industrialization began in the 19th century marine biodiversity has decreased dramatically.

- **The primary causes for the losses** include the **destruction of habitats** by trawler fishing, **pollution** and **eutrophication** of the seas, as well as **climate change**.
  Threats to biodiversity are complex, persistent, and will likely increase in the future.



✓ Despite some local successes and increasing responses (including extent and biodiversity coverage of protected areas) the rate of biodiversity loss does not appear to be slowing.

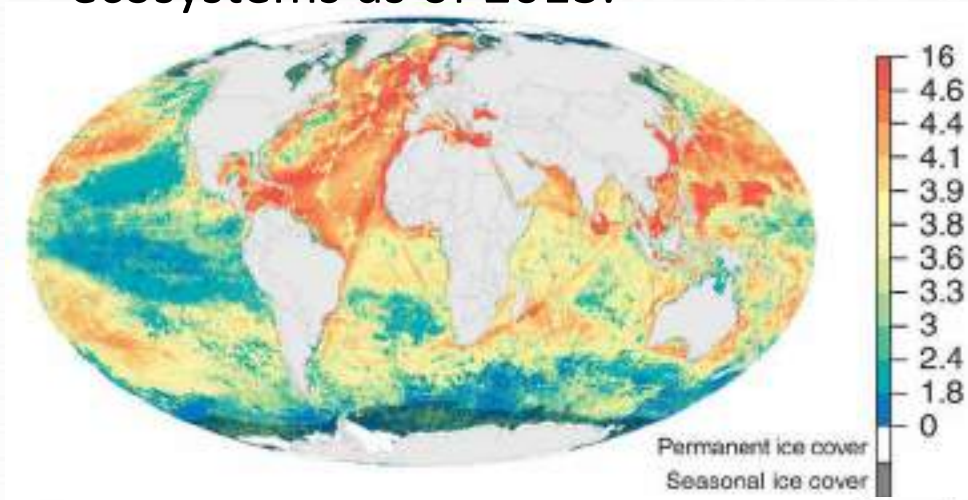
Human pressures on marine ecosystems

Source: UNEP, 2011

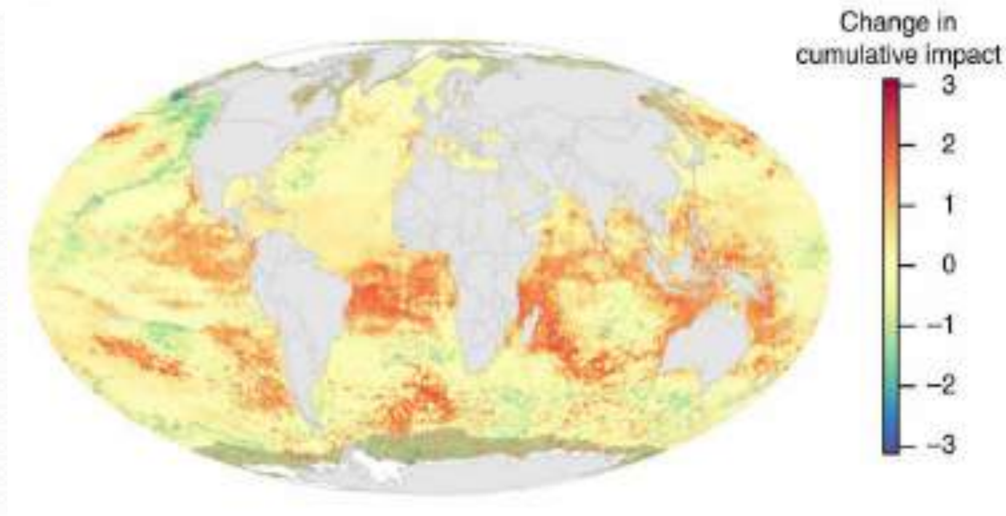
Human impacts to marine ecosystems

Results from the application of a computational tool for quantifying and visualizing the **consequences of a combination of pressures caused by human activities on ecosystem components**.

Cumulative human impact to marine ecosystems as of 2013.



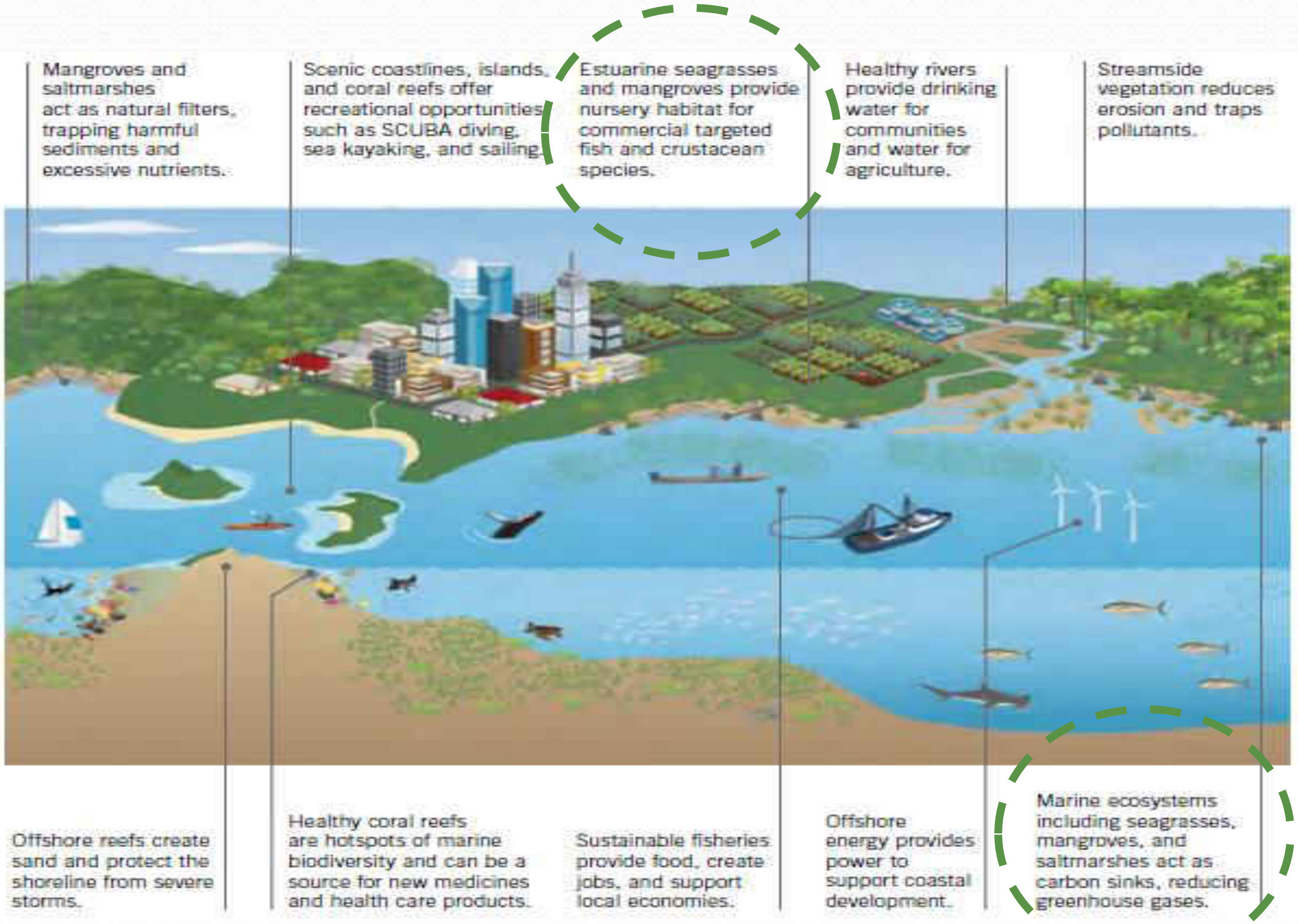
Change in cumulative human impact to marine ecosystems (2013 vs 2008).



Source: Halpern *et al.*, 2015

Ecosystem services are severely threatened

through growth in the scale of human enterprise (population size, per-capita consumption, effects of technologies) and a mismatch between short-term needs and long-term societal well-being



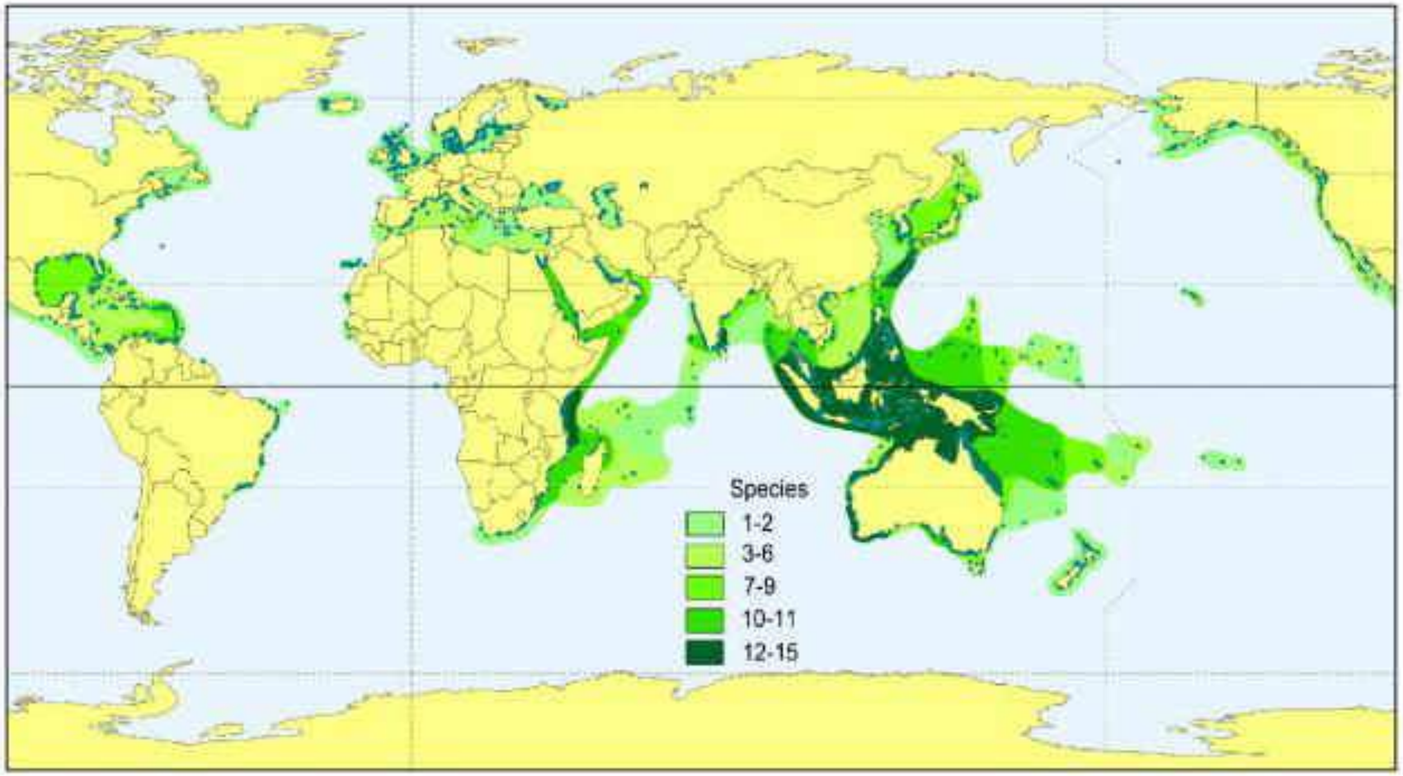
Source: UNEP, 2011

Seagrasses: key ecosystem components

Seagrasses are fundamental parts of the marine ecosystem, considered as important features to help determine the overall health of the ocean.

The global species diversity of seagrasses is low (~ 60 species), but species can have ranges that extend for thousands of kilometers of coastline and can form dense underwater meadows, some of which are large enough to be seen from space.

They are often called foundation plant species or ecosystem engineers because they modify their environments to create unique habitats for other species, provide ecological functions and a variety of services to humans.



Seagrasses are found across the world, from the tropics to the arctic.

Source: Short *et al*., 2007

Seagrasses provide many important services

They support biodiversity and are equally important to commercial fisheries as they create a living habitat providing shelter and food to an incredibly diverse community of animals, from tiny invertebrates to large fish, crabs, turtles, marine mammals and birds.

They are known as the "lungs of the sea", one square meter of seagrass can generate 10 lt of oxygen every day through photosynthesis.

They clean the surrounding water by absorbing nutrients in runoff from the land.

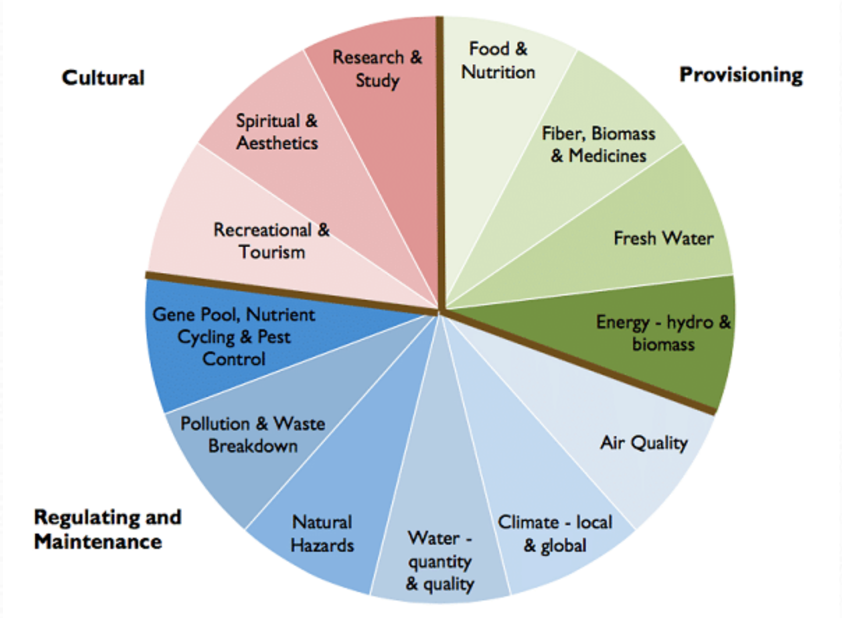
They help taking carbon dioxide out of the atmosphere, while seagrasses occupy only 0.1% of the total ocean floor, they are estimated to be responsible for up to 11% of the organic carbon buried in the ocean (blue carbon).

They prevent coastal erosion by stabilizing sediment in the ocean and decreasing the height of waves softening the blow on the coast.

Source: http://ocean.si.edu/seagrass-and-seagrass-beds

Because of these benefits, **seagrasses are believed to be the third most valuable ecosystem in the world** (only preceded by estuaries and wetlands).

One hectare of seagrass is estimated to be worth over $19,000 per year, making them one of the most valuable ecosystems on the planet!



Source: http://ocean.si.edu/seagrass-and-seagrass-beds

Threats on seagrasses

- **Seagrass coverage is being lost globally at a rate of 1.5% per year**. That amounts to about 2 football fields of seagrass lost each hour. It is estimated that 29% of seagrass meadows have died off in the past century.
- In a 2011 assessment, nearly **one quarter of all seagrasses for which information was adequate to judge were threatened** (endangered or vulnerable) or near threatened using the International Union for the Conservation of Nature (IUCN) Red List criteria.

Source: Smithsonian National Museum of Natural history Ocean Portal

- **Human impacts in the coastal zone are responsible for most threats to seagrass species** (Short *et al*., 2011)

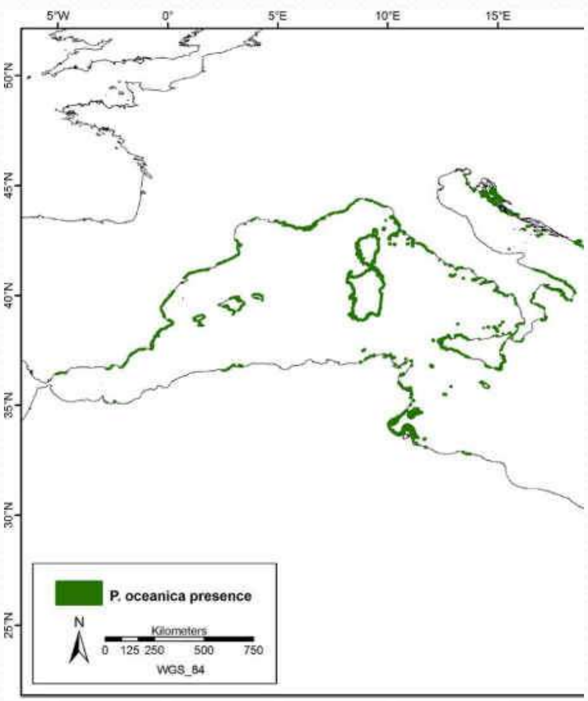
Mediterranean seagrasses

Five species of strictly marine seagrasses (Angiosperms) thrive in the Mediterranean with *Posidonia oceanica*, an endemic species dominating at soft bottom assemblages forming vast meadows, from the sea-surface down to 40 m depth in the clearest waters.

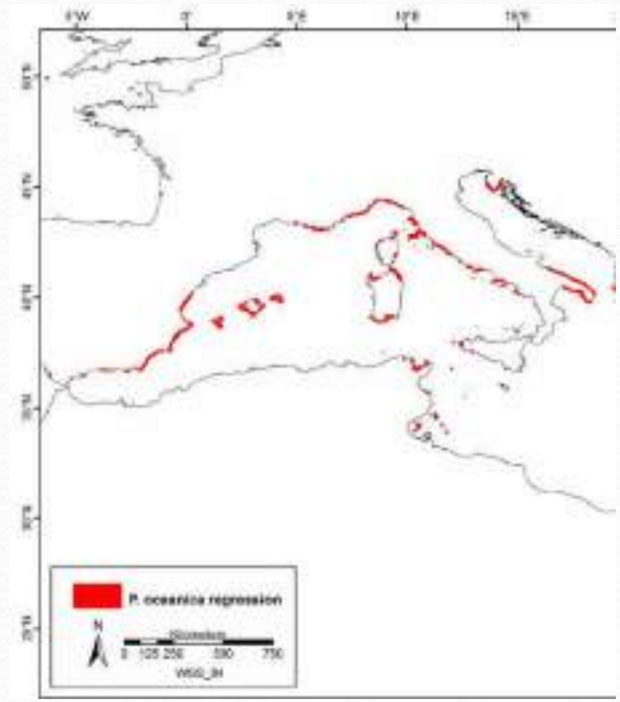
P. oceanica beds cover between 25,000 and 50,000 km^2 of the coastal areas of the Mediterranean, corresponding to 25% of the sea bottom at depths between 0 and 40 m.

Light, temperature and salinity are the abiotic factors controlling *P. oceanica* distribution and production.

Regression of seagrasses in the Med



Current distribution of *Posidonia oceanica meadows*



Coastline with regression of *Posidonia oceanica meadows*

Country	Currently surveyed coastline (%)	Historical surveyed coastline (%)	*P. oceanica* total current area (ha)	*P. oceanica* total historical area (ha)	*P. oceanica* regression (%)	Time range of data
Spain	100%	70%	172,669	222,254	29%[1]	1993–2011
France/Monaco	100%	60%	94,030	96,783	9%[2]	1980–2011
Italy	100%	42%	337,611	395,298	25%[3]	1990–2005

Application of cumulative impact assessment

for quantifying and visualizing the consequences of a combination of pressures caused by human activities on *P. oceanica*

⇩

A fundamental process in Conservation Planning and Marine Spatial Planning efforts based on an Ecosystem-Based Approach.

VULNERABILITY

(Zacharias and Greg, 2005)

Biotic (species, communities)
or
Abiotic (habitats) structures / processes

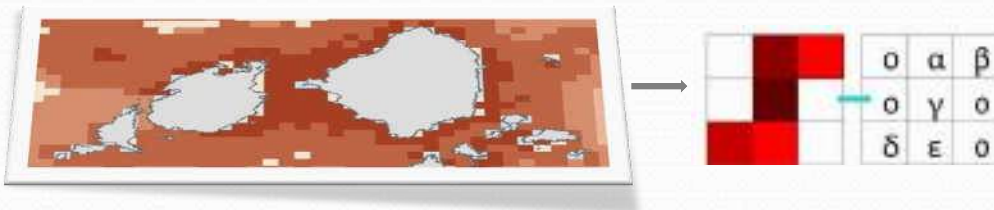
Vulnerability is the probability that a feature will be exposed to a stressor to which it is sensitive

The degree to which marine features respond to a given stress

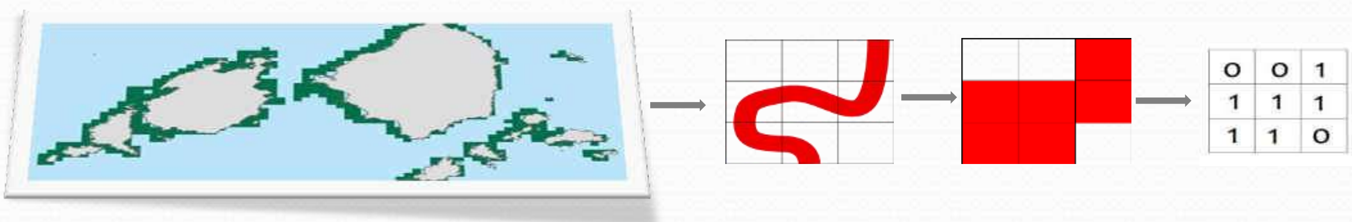
Natural
or
anthropogenic

Methodology

The analysis is based on existing methodology presented in recent studies (Halpern *et al*. 2007, Micheli *et al.* 2013, Korpinen *et al*. 2012).

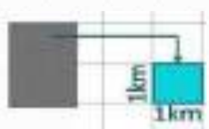


D_i : human activities



E_j : ecosystem components

	E1	E2
D1	μ_1	μ_2
D2	μ_3	μ_4



$\mu i,j$: the rate of vulnerability of each ecosystem component to the main drivers of change (human uses) obtained by experts

$$I = \sum_{i=1}^{n} \frac{1}{m} \sum_{j=1}^{m} D_i \times E_j \times \mu_{i,j}$$

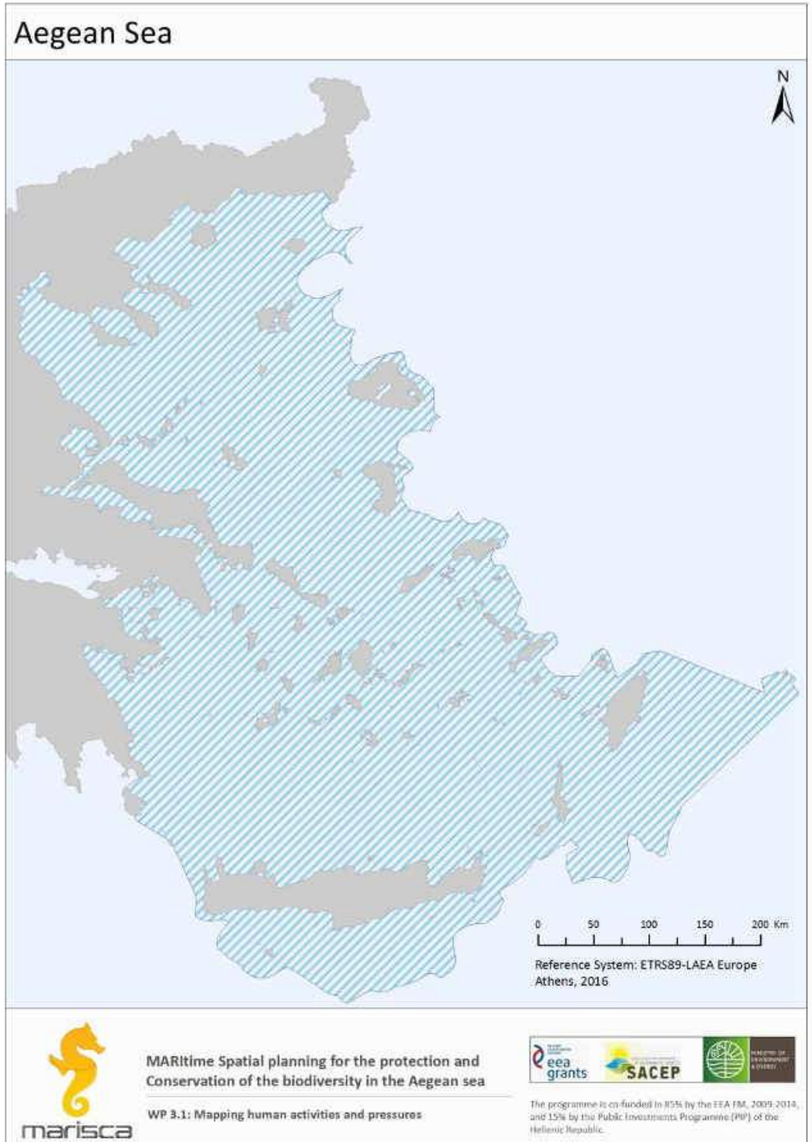
I: impact score (Ic) representing the per-pixel average of each ecosystem component vulnerability-weighted stressor intensities

Ecosystem vulnerability weights

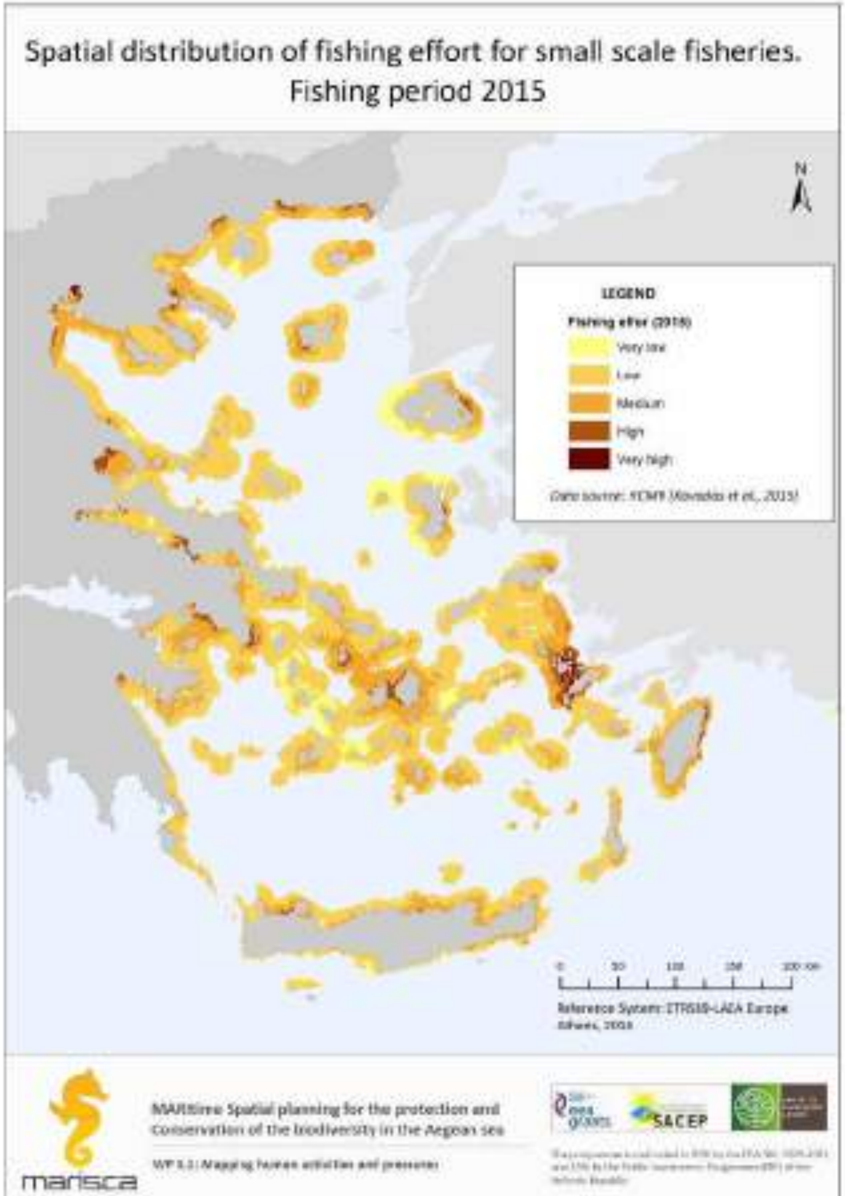
- Based on experts judgement (use the average of all experts scores)
- Criteria by Halpern *et al.*, 2007

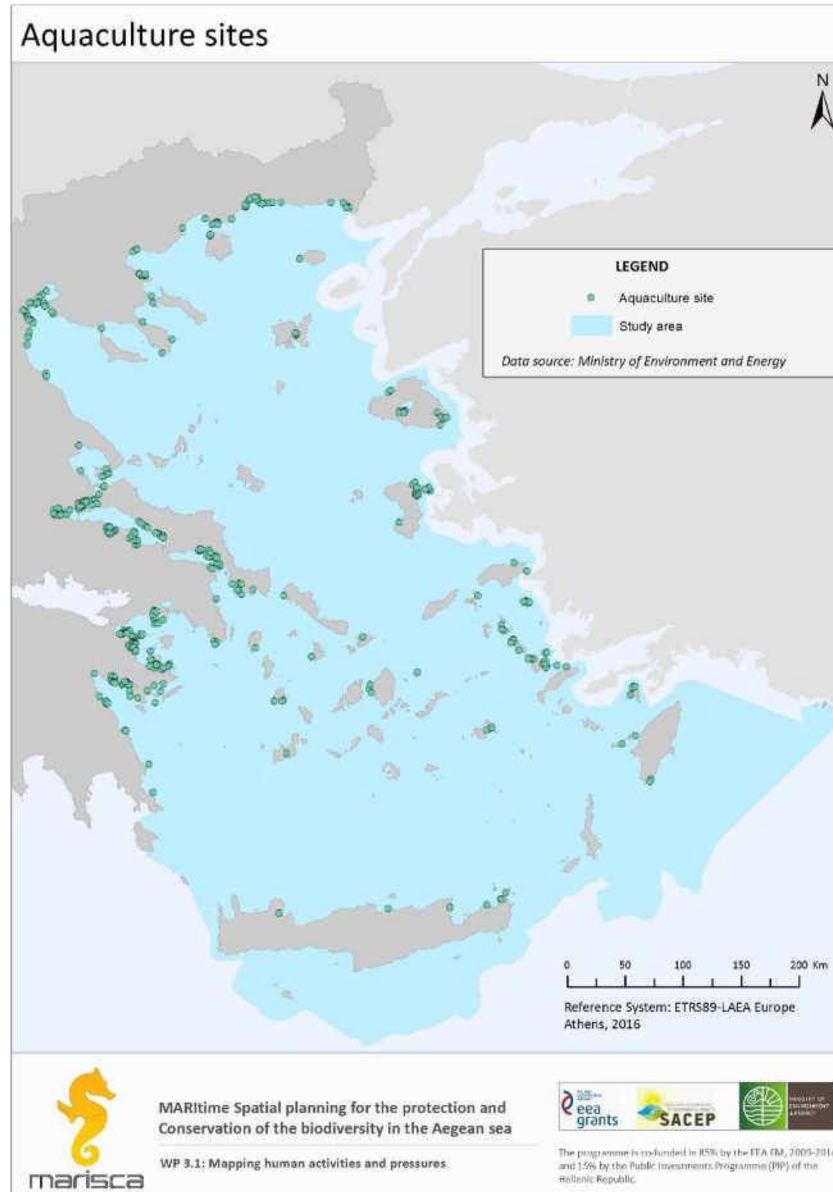
Measure	Categories	Rank
Scale Average scale at which a threat event affects ecosystem	no threat	0
	<1	1
	1-10	2
	10-100	3
	100-1,100	4
	1,100-10,000	5
	>10,000	6
Frequency How often discrete threat events occur in a given ecosystem	never occurs	0
	rare	1
	occasional	2
	annual or regular	3
	persistent	4
Functional impact Threats affect only a few species or the entire ecosystems	no impact	0
	species (single or multiple)	1
	single trophic level	2
	>1 trophic level	3
	entire community	4
Resistance Average tendency of an ecosystem to react to a threat	no impact	0
	high	1
	medium	2
	low	3
Recovery time (years) Average time to return to pre-threat state	no impact	0
	<1	1
	1-10	2
	10-100	3
	>100	4
Certainty Level of confidence of the respondents	none	0
	low	1
	medium	2
	high	3
	very high	4

Example - Case study area: Aegean Sea

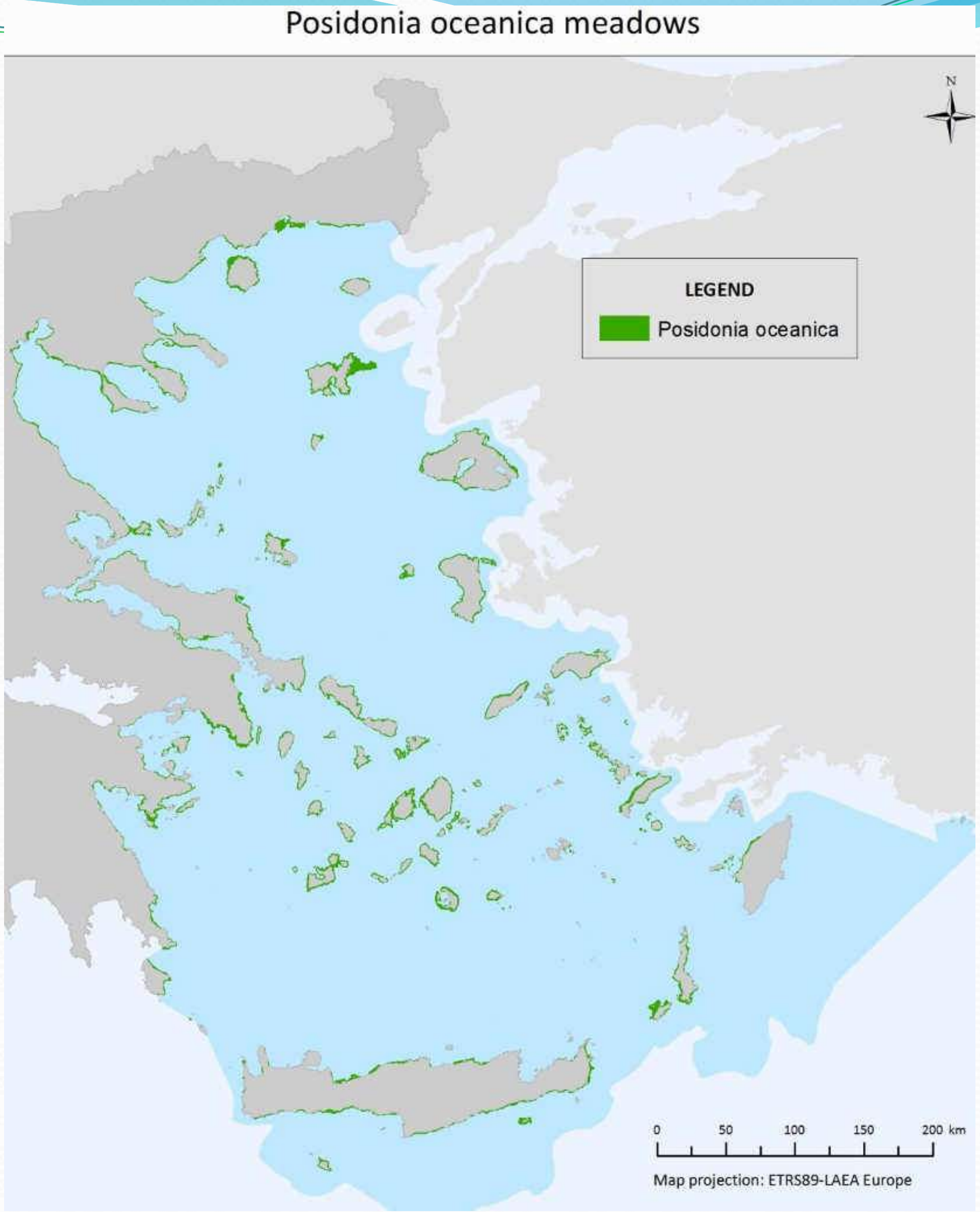


Human activities in Aegean Sea





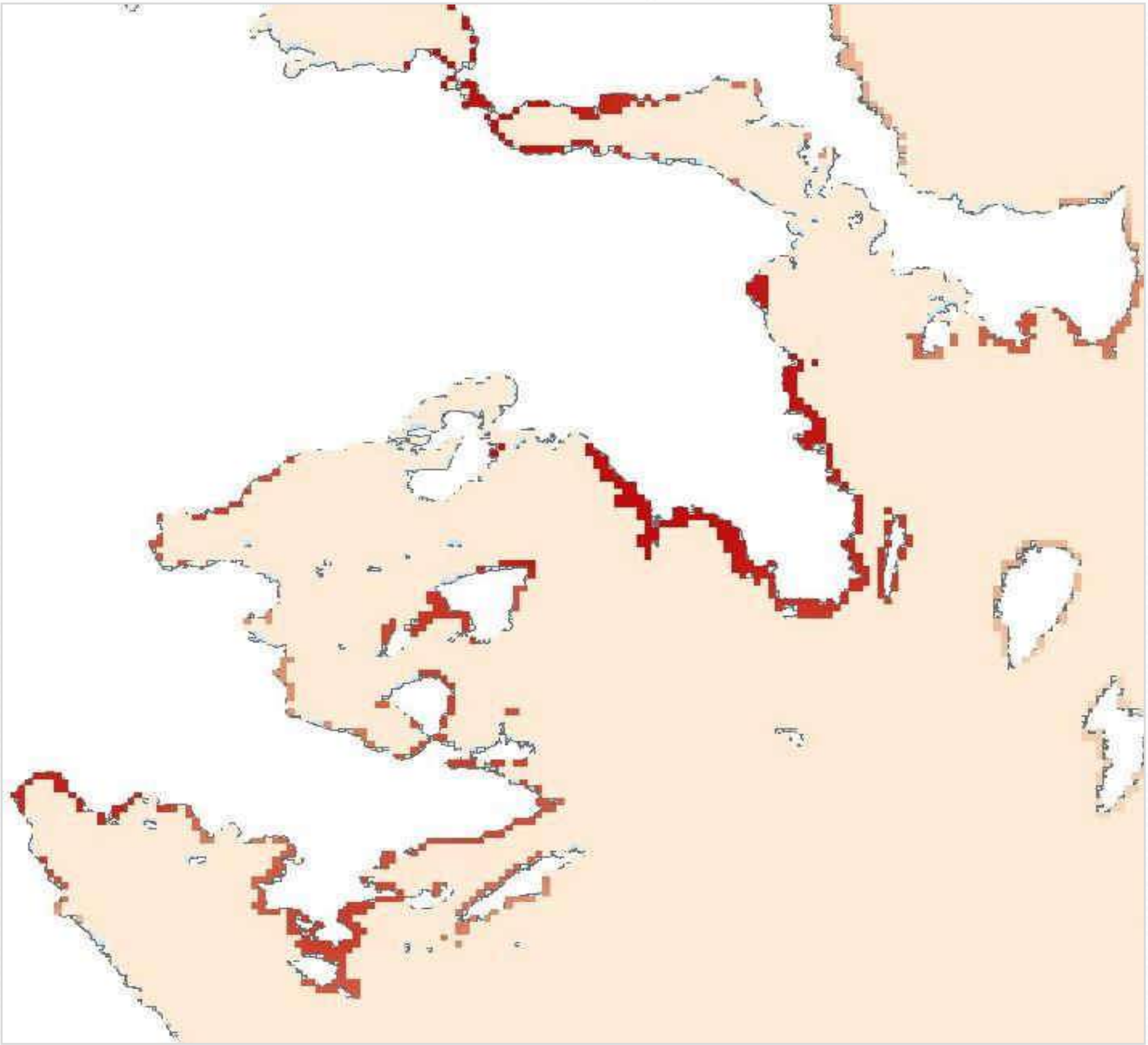
Posidonia oceanica meadows in Aegean Sea



Activities that have impacts on *Posidonia oceanica*

Small scale fishing

Activities that have impacts on *Posidonia oceanica*

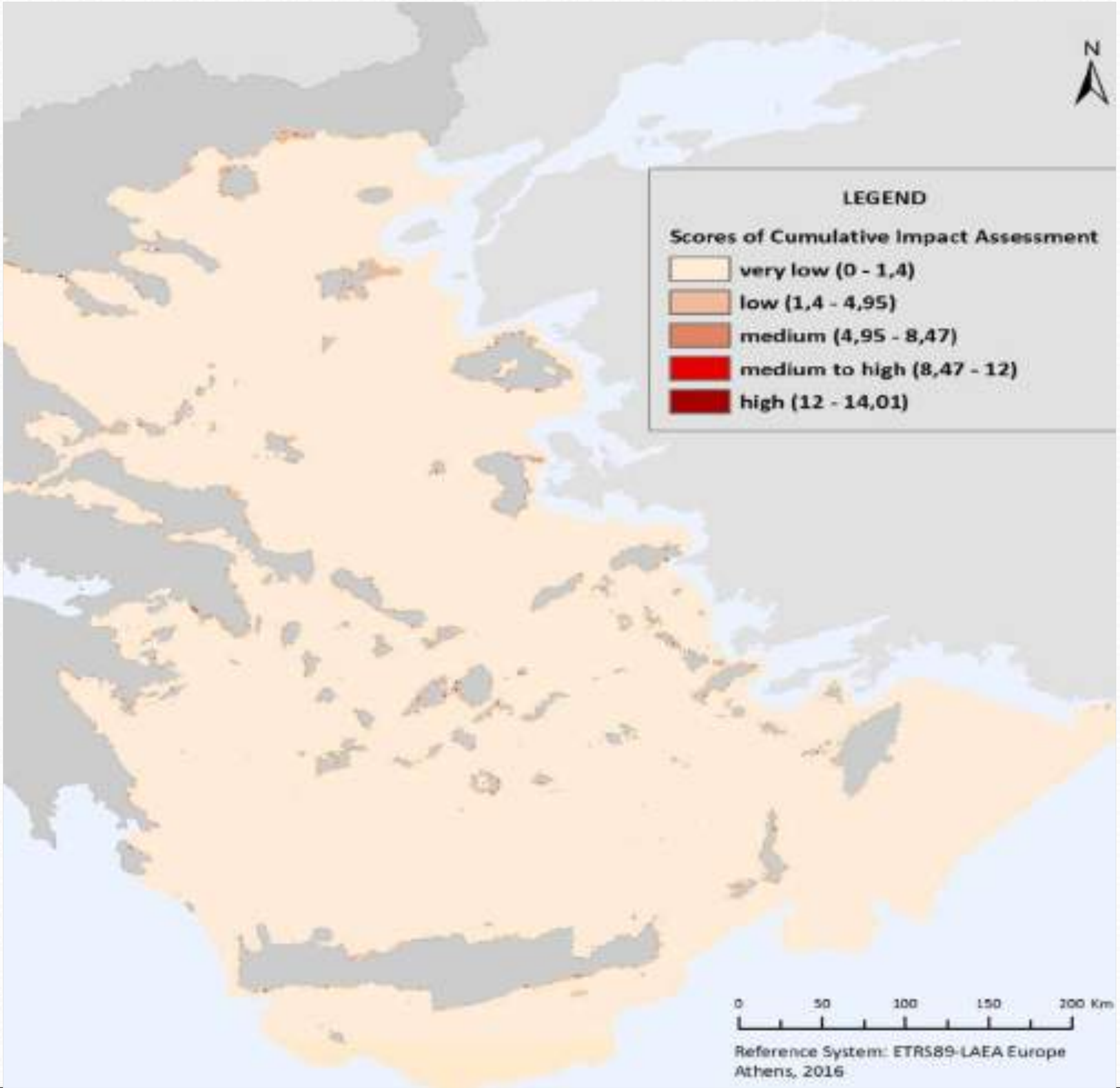


Population density

Impact scores for each acivity and total cumulative impact score (I)

ACTIVITY		Posidonia oceanica
FISHERIES	Fishing ports	3,5
	Fishing effort (bottom trawlers)	0
	Fishing effort (purse seiners)	2,55
	Small scale fishing	3
AQUACULTURE	Aquaculture	2,8
SEA TRANSPORTATION	Ports	3,5
	Marinas	2,2
	Anchorage	2,2
	Shipping routes	0
ENERGY	Areas for hydrocarbons extraction	0
	Gas pipelines	0
CABLES/PIPELINES	Telecommunication cables	0
TOURISM	Touristic areas	0,4
	Diving	0
LAND USES	Population density	1
	Waste water	1
	Industry	2
	Agricultural run offs	1,41
	Final score	14,01

Map of cumulative impact analysis for *Posidonia oceanica*



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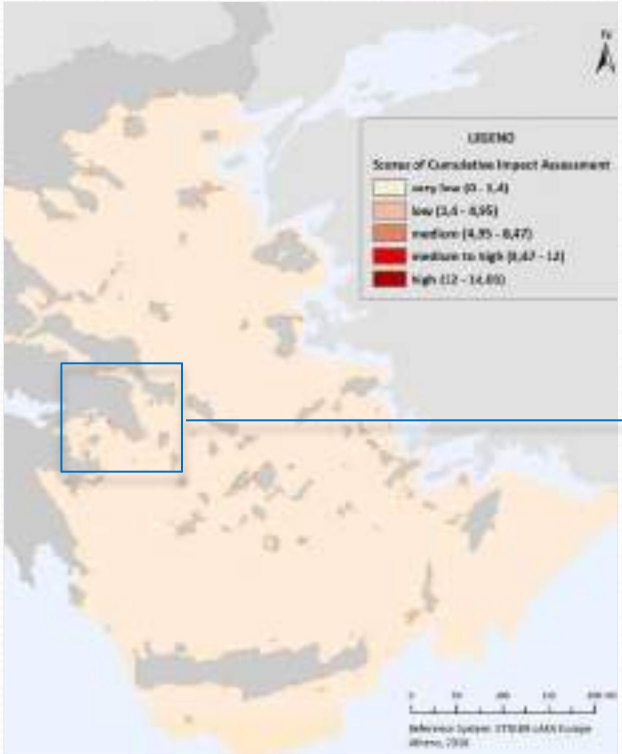
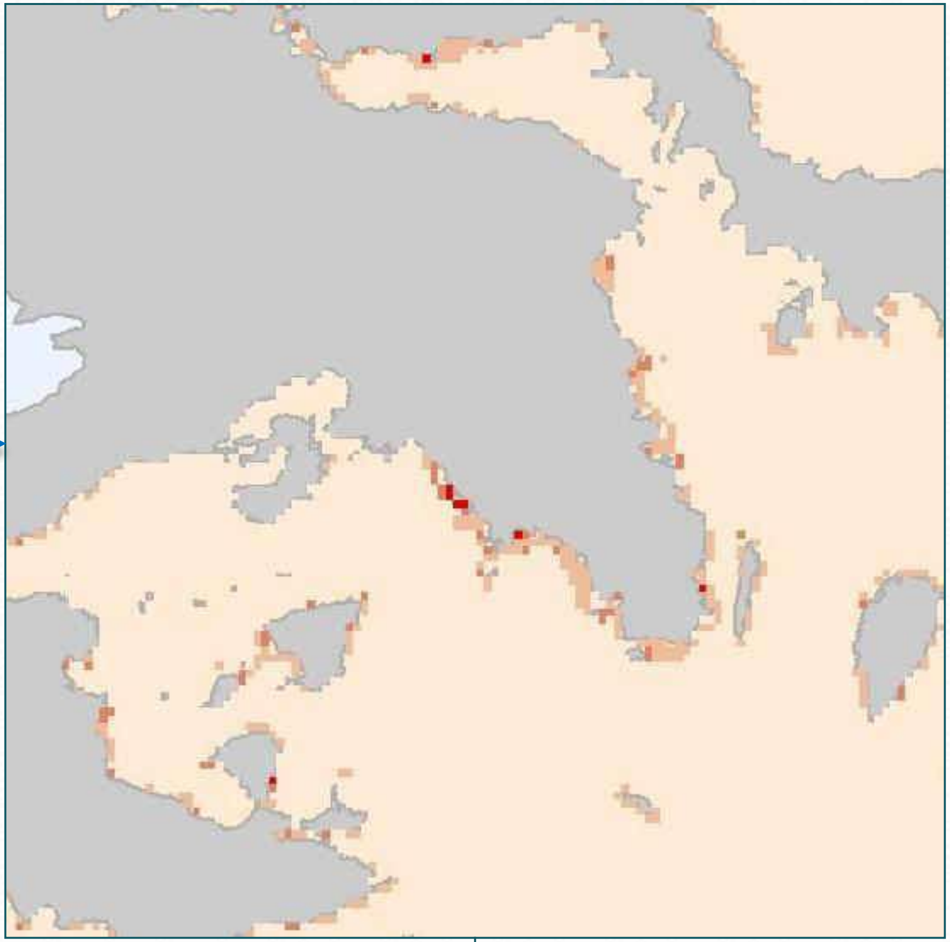
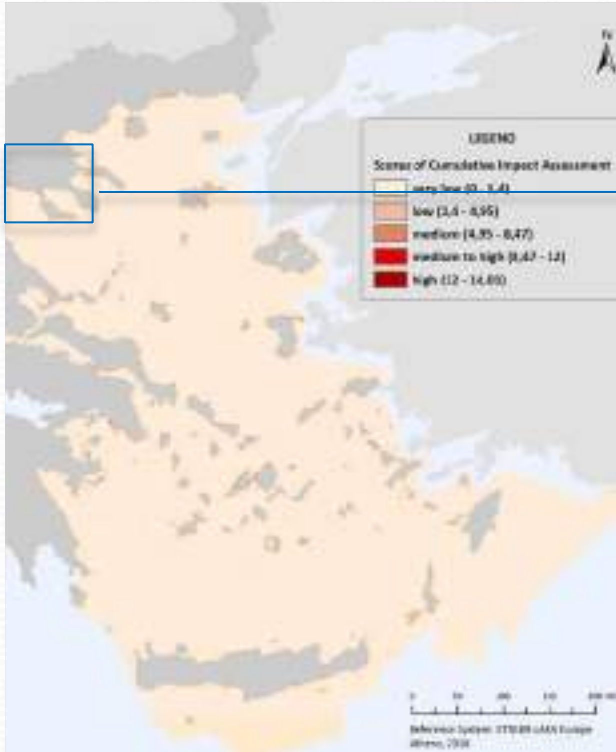


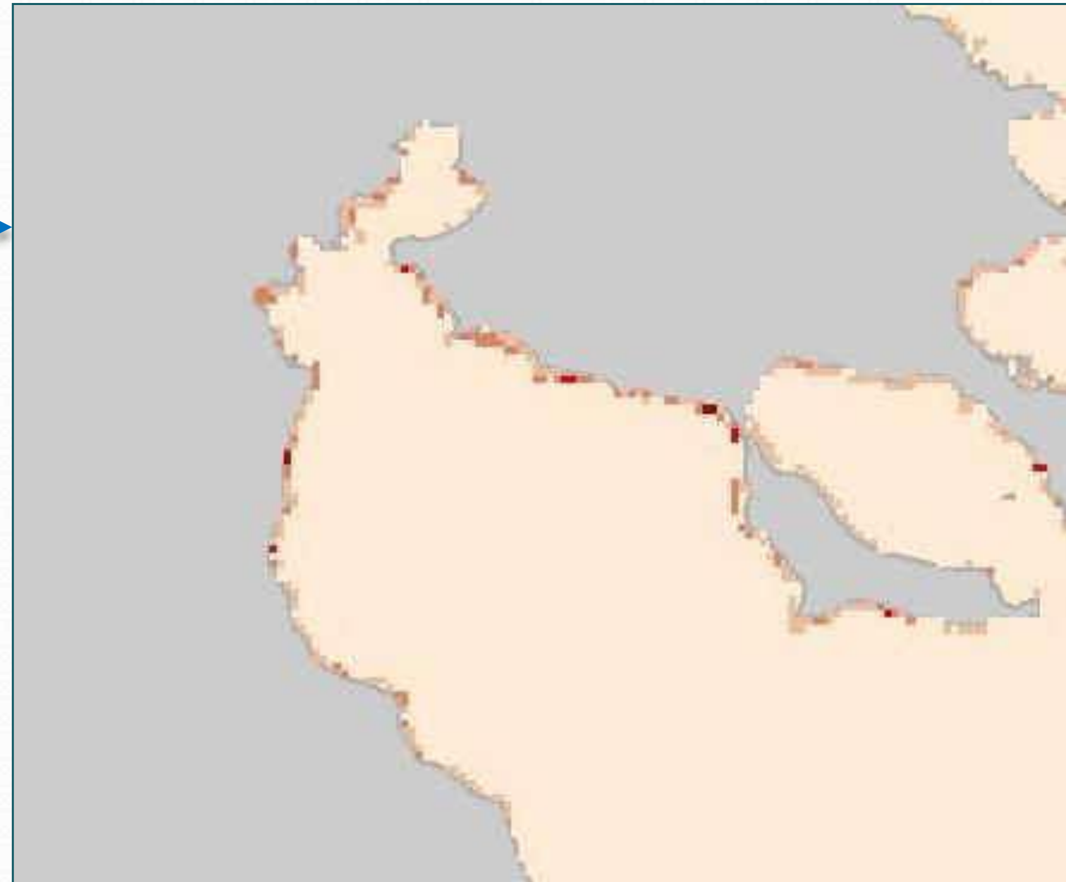


Activities that impact Attiki region

Small scale fishing, urbanization

Map of cumulative impact analysis for *Posidonia oceanica*

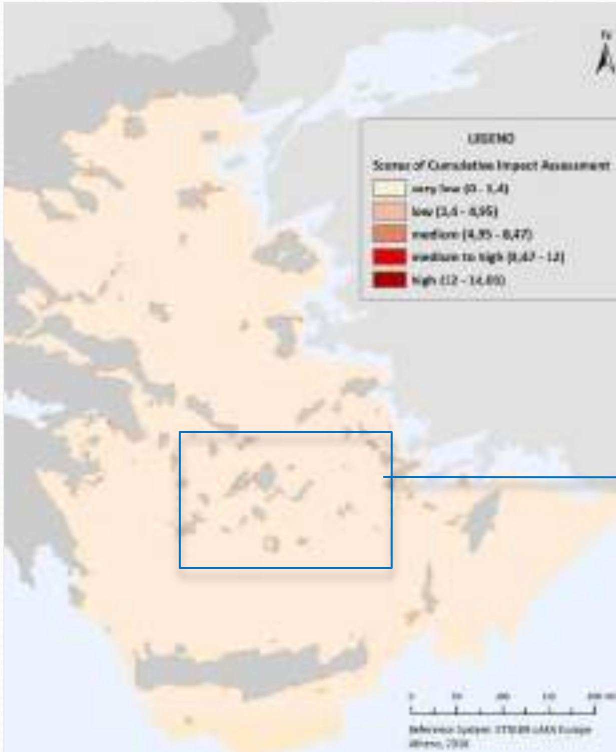




Activities that impact Thessaloniki golf

Small scale fishing, urbanization, fishing ports, agricultural run offs

Map of cumulative impact analysis for *Posidonia oceanica*



Activities that impact Cyclades island complex

Small scale fishing, fishing ports, tourism

Impact scores on *Posidonia oceanica*

Total impact	Score	Cells	(%) of the total area
Very low	0-1,4	465	9,3%
Low	1,4-4,95	3977	79,8%
Medium	4,95-8,47	471	9,4%
Medium to high	8,47-12	69	1,4%
High	12-14,01	5	0,1%
Total		4987	100%

Linking cumulative impact assessment to Ecosystem Services

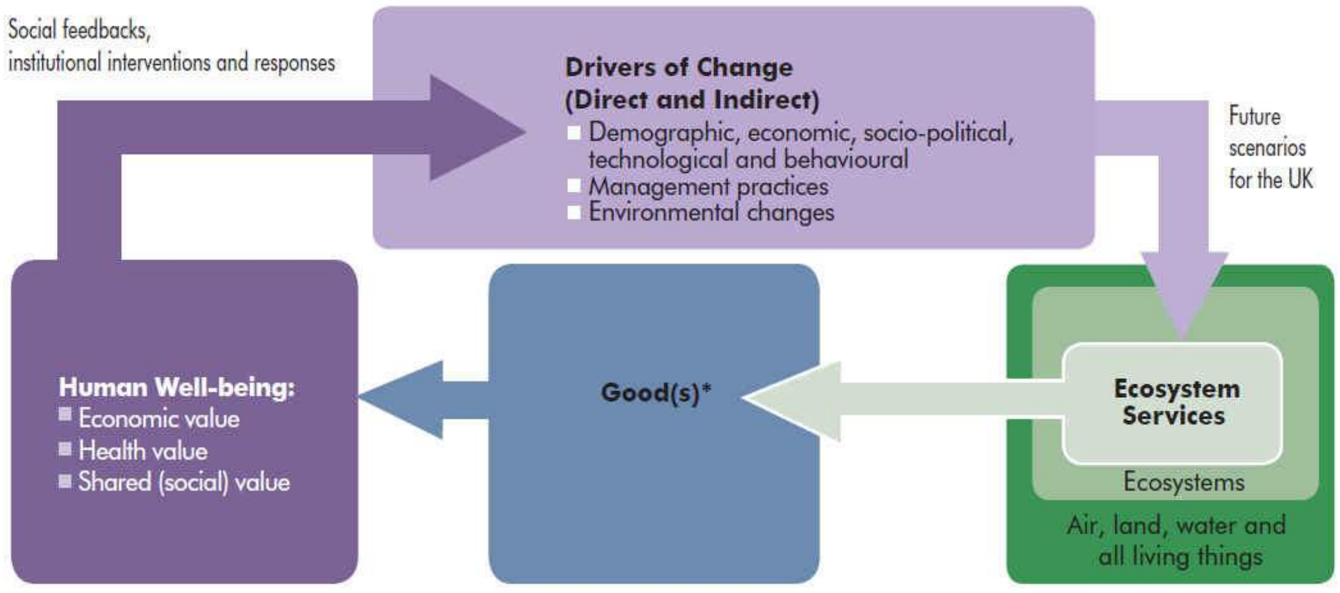


Figure 2.1 Overall Conceptual Framework for the UK NEA showing the links between ecosystems, ecosystem services, good(s), valuation, human well-being, change processes and scenarios. *Note that the term good(s) includes all use and non-use, material and non-material outputs from ecosystems that have value for people.

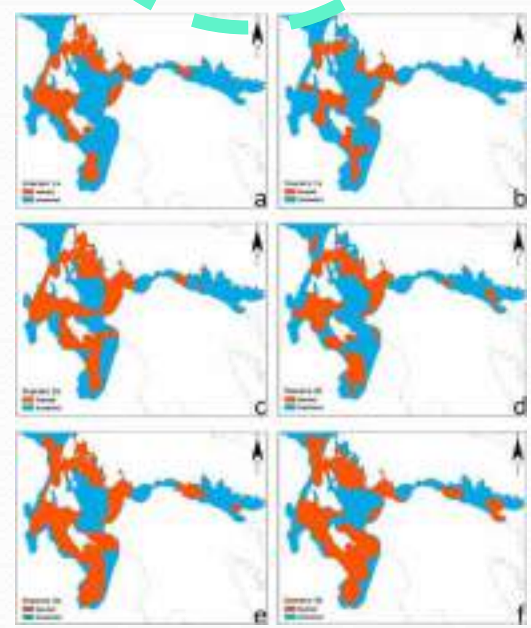
Source: Mace et al. (2011)

account for the cost from the degradation of ecosystem services

Conservation Planning/Marine Spatial Planning

Cumulative impact assessment → Socio-ecological assessment → Configuration of targets for biodiversity features for which protection is desired → Scenarios for protected areas

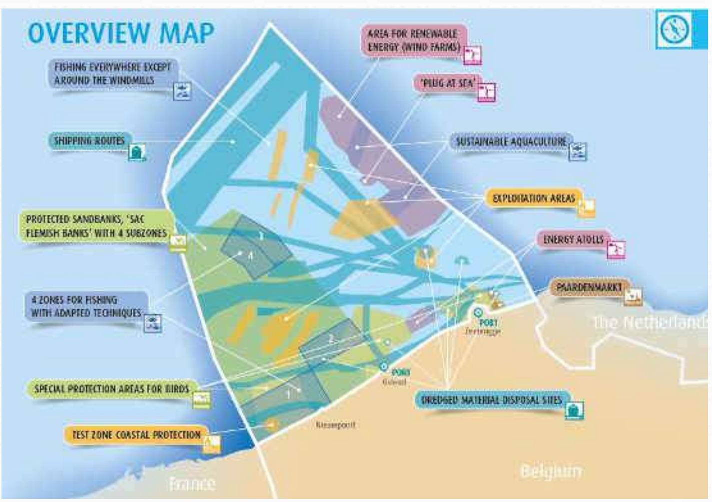
Stakeholder engagement is a crucial step



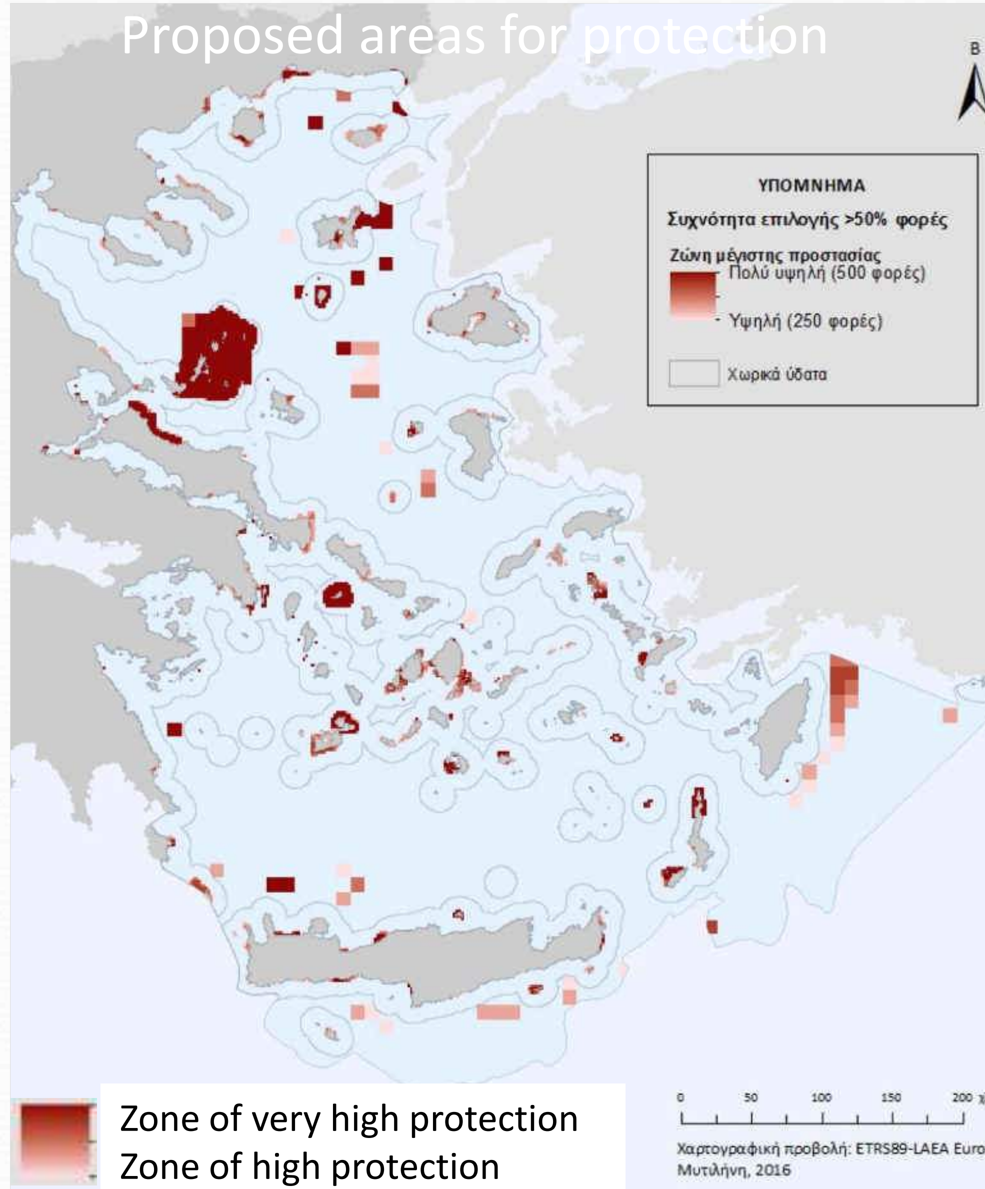
Designing a network of Marine Protected Areas

A key element for Marine Spatial Planning

Integration of conservation priorities and socio-economic goals through balancing trade-offs of all MSP actors



http://www.health.belgium.be/eportal/Environment/Environmentalrigh/Environmentalrights/PublicConsultations/seaspatialplan/index.htm



Conclusions

The **cumulative impact analysis** quantifies the spatial conflicts and pressures between human uses and the selected ecosystem components and **can be used for identifying areas where the environmental/ecological components are more exposed to anthropogenic pressures** and evaluate indicative impacts scores.

- ✓ **Combined with other decision making tools, it can be a key component in Marine Spatial Planning efforts under an Ecosystem-Based Approach**.


Thank you for listening!
Photo: Y. Issaris