Conservation planning in the Eastern Mediterranean Sea accounting for cross-realm threat connectivity

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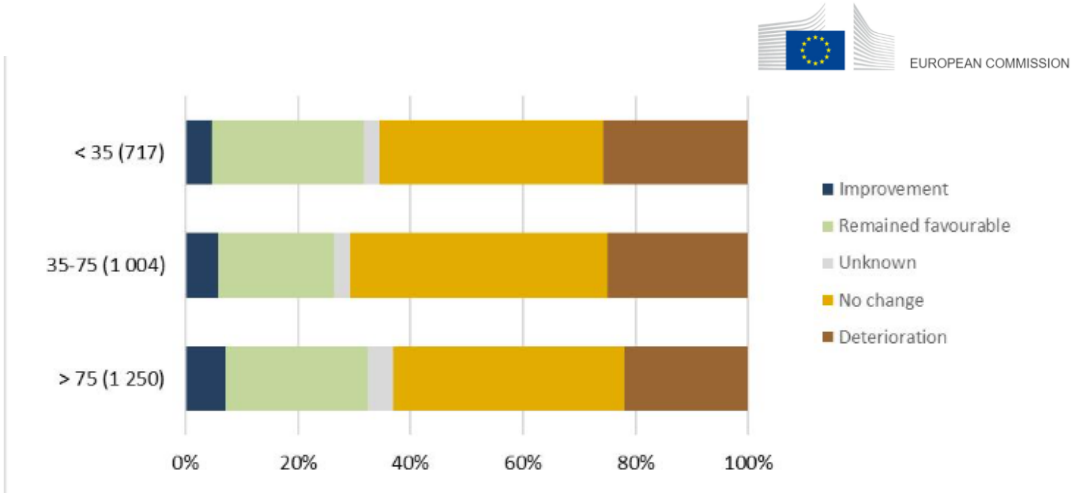
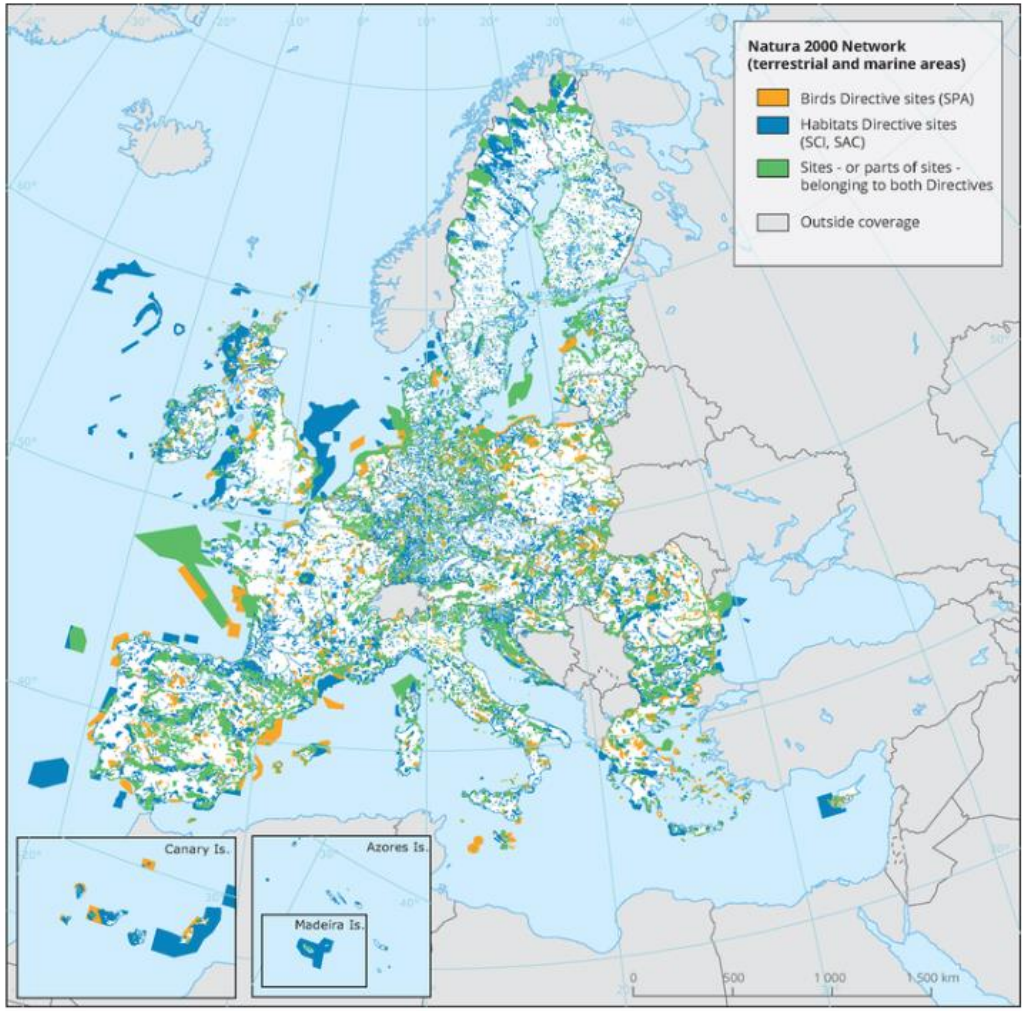
Distribution of Natura 2000 sites (marine and terrestrial)

Changes in conservation status and trends for Annex I habitats within different Natura 2000 coverage classes



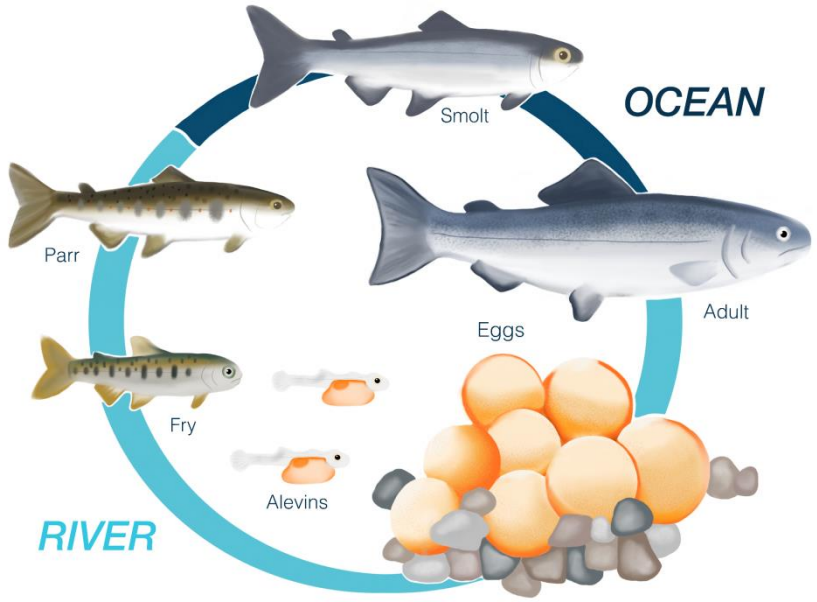
Report done in 2020



- **Still biodiversity loss**
- **Insufficient and ineffective conservation efforts?**

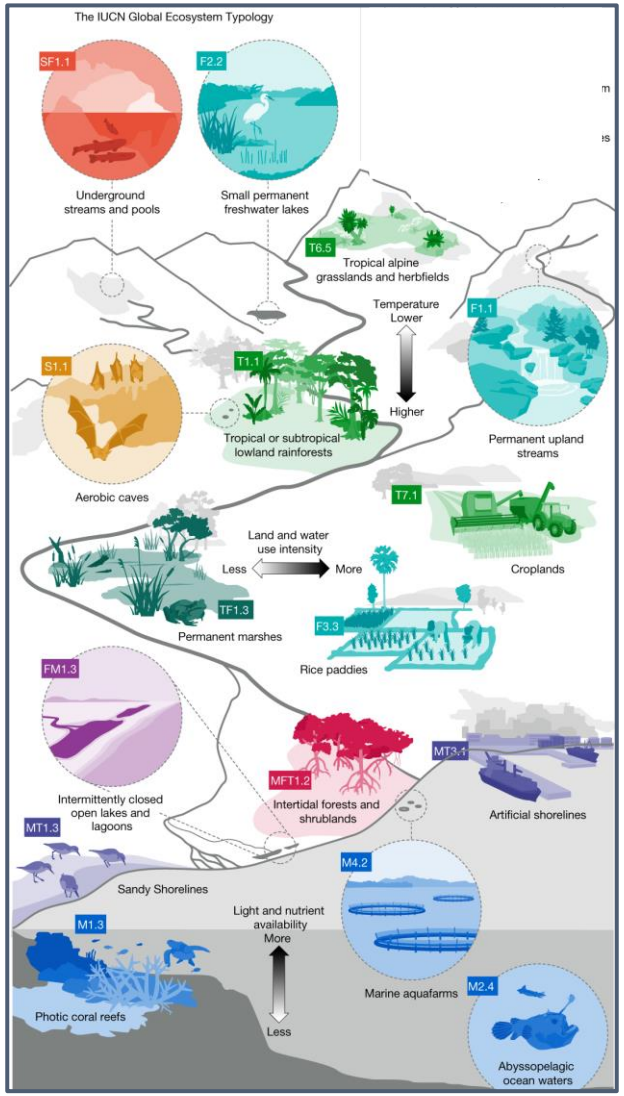
Need of integrated conservation across realms

- **Species** with complex life cycles, ecological processes such as genetic flux and migrations



Ilustrated by Kristen Milbury

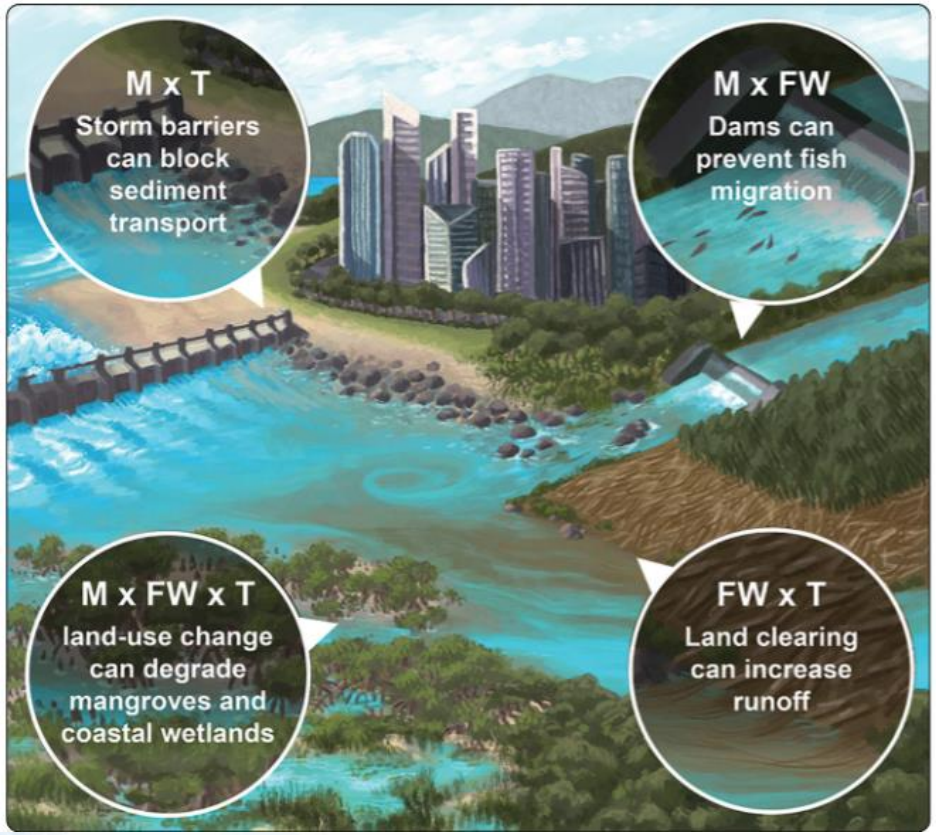
- **Transitional realms** and inter-connectivity



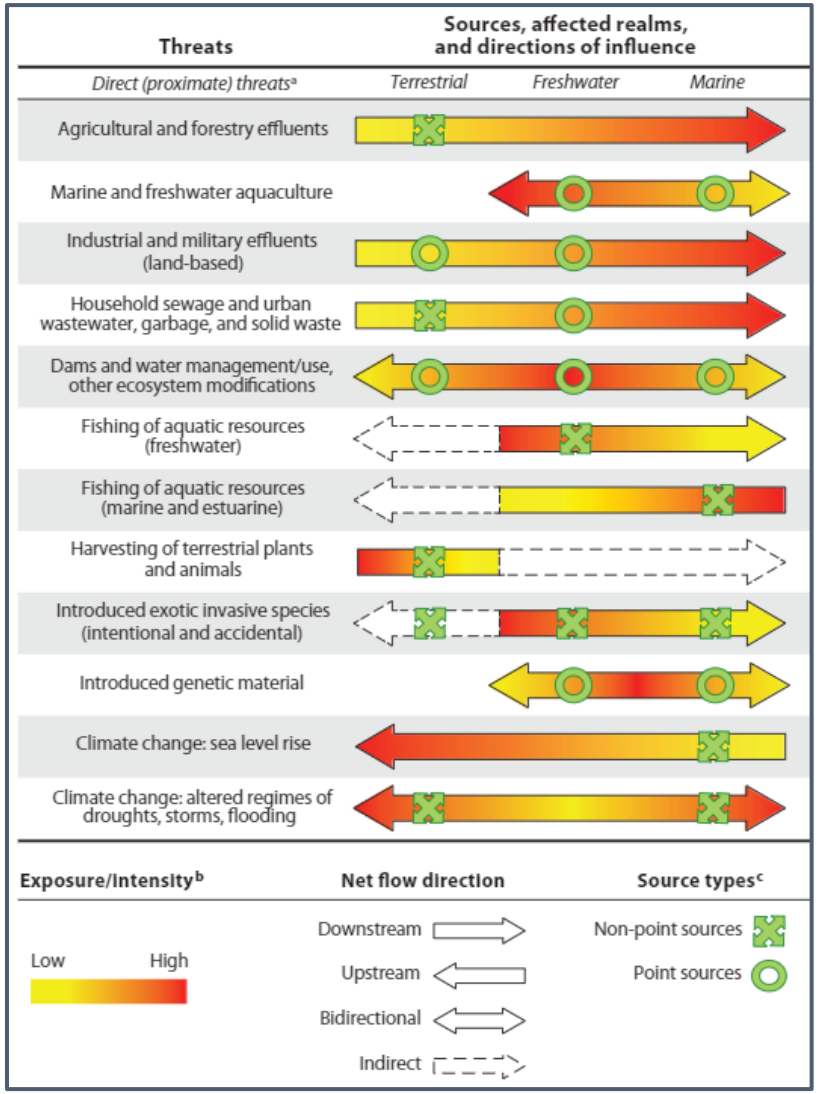
Keith et al., 2022

Need of integrated conservation across realms

- **Threat propagation** and effects of pressures and management actions in one realm



Threlfall et al., 2021. Ilustration by E Pirtle



Álvarez-Romero et al., 2011

biodiversa+ European Biodiversity Partnership

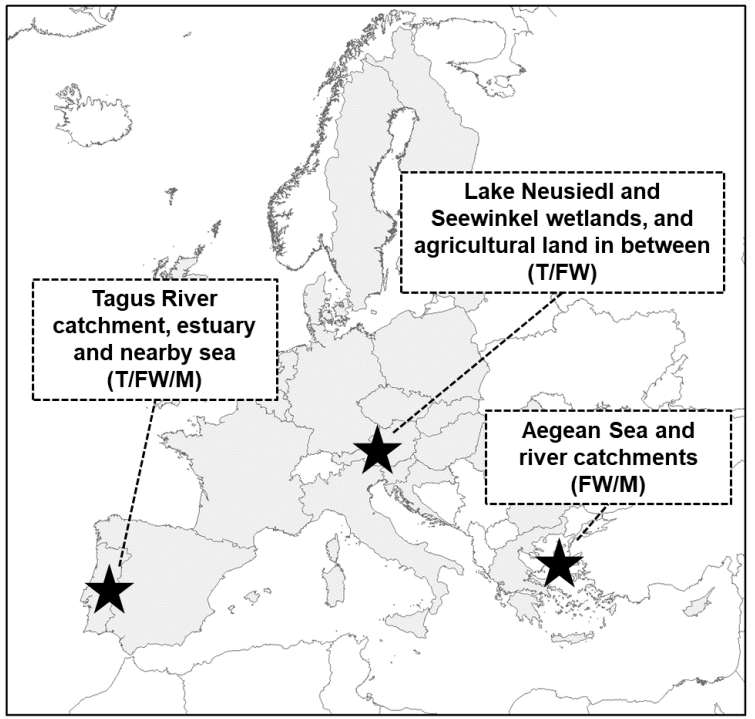
Co-funded by the European Union

INSPIRE INtegrated Spatial PlannIng across REalms

INSPIRE: INtegrated Spatial PlannIng across REalms for biodiversity conservation andhuman development in a context of change

Aims to **enhance conservation** efforts considering dependencies **across realms**: marine, freshwater, and terrestrial

Three case studies



FWF Der Wissenschaftsfonds.

University of Salford MANCHESTER

AGENCIA ESTATAL DE INVESTIGACIÓN

MUR Ministero dell'Università e della Ricerca

GSRI GENERAL SECRETARIAT FOR RESEARCH AND INNOVATION

Swiss National Science Foundation

FCT Fundação para a Ciência e a Tecnologia

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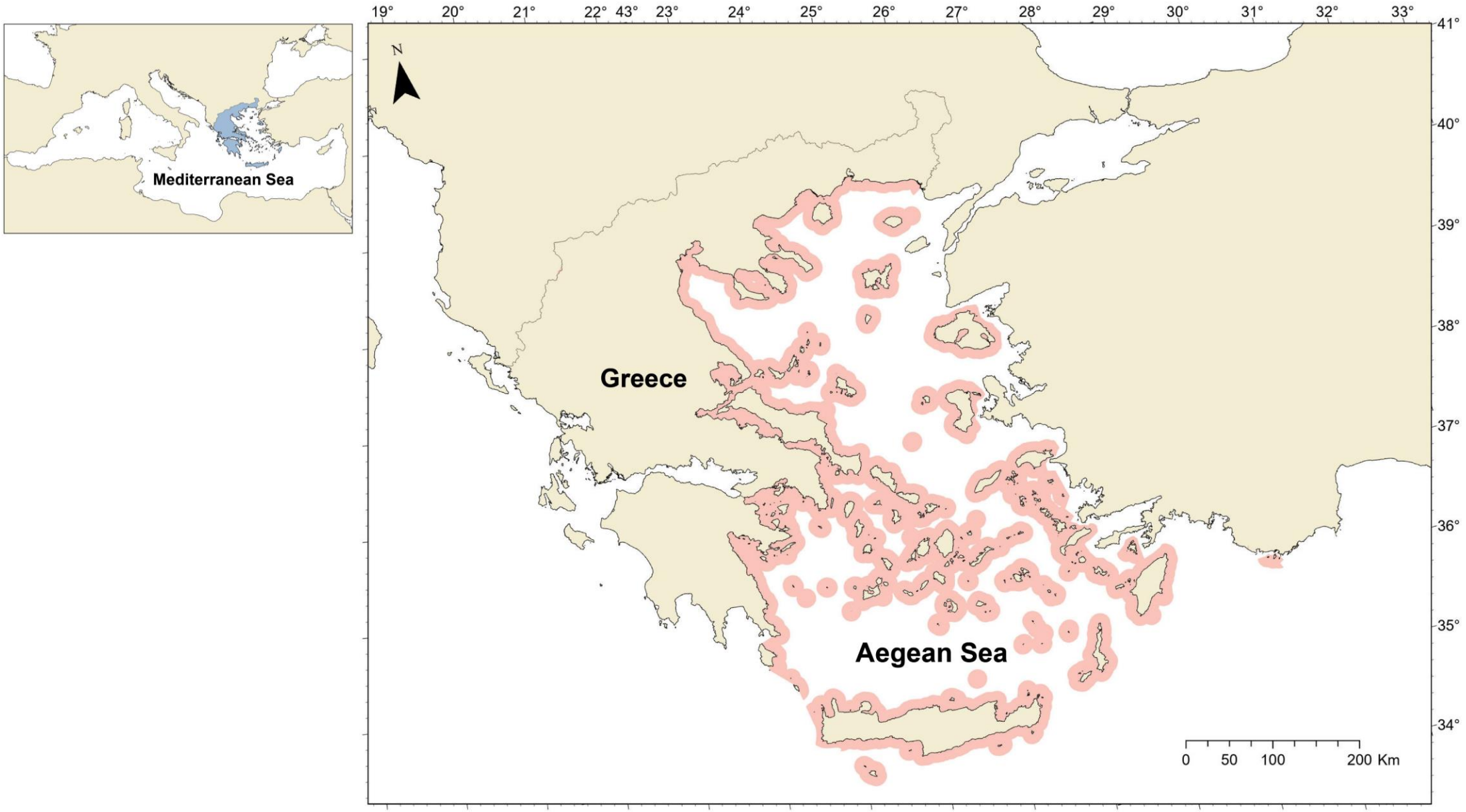
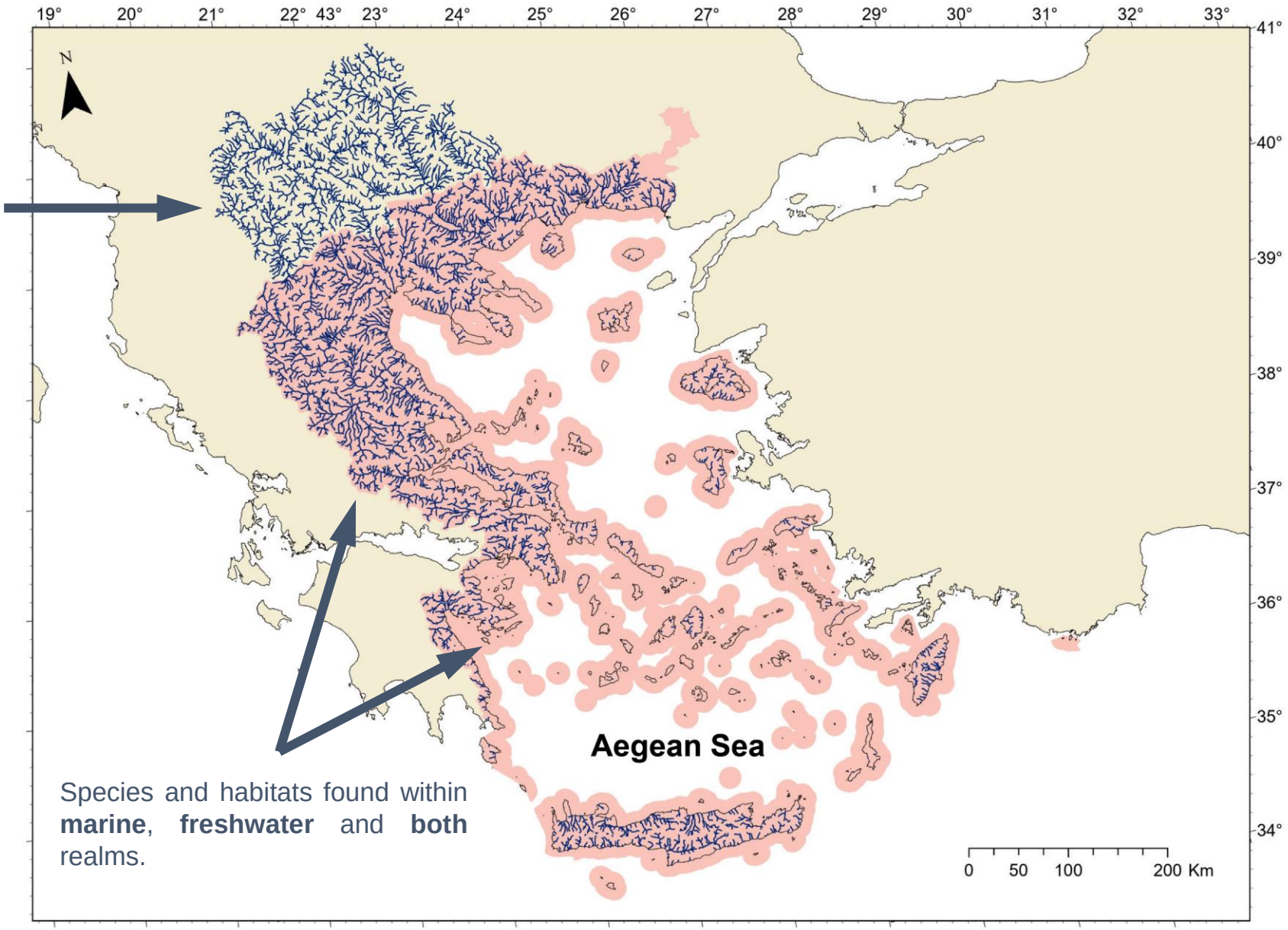

Mediterranean Sea
N
Greece
Aegean Sea
0 50 100 200 Km
19° 20° 21° 22° 43° 23° 24° 25° 26° 27° 28° 29° 30° 31° 32° 33°
41° 40° 39° 38° 37° 36° 35° 34°

Propagation of **threats**



Species and habitats found within **marine**, **freshwater** and **both** realms.

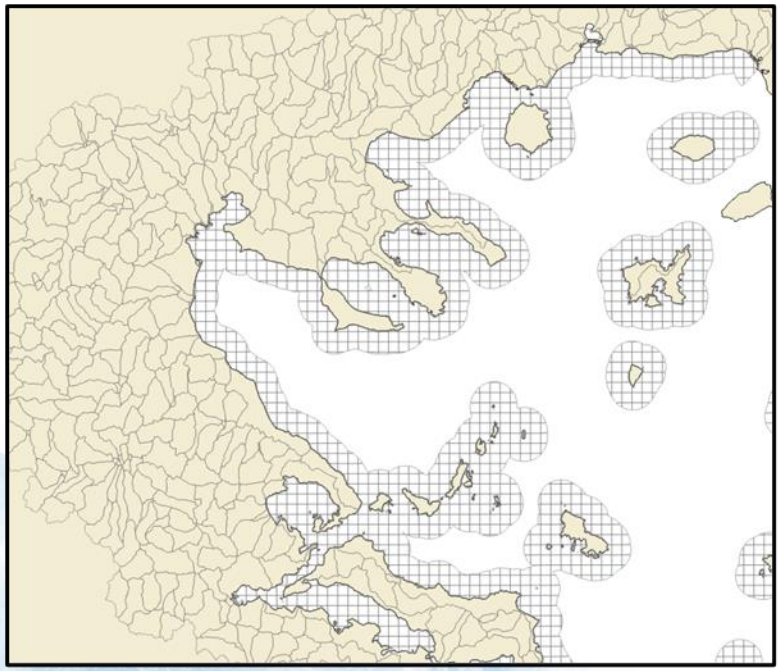
Outputs within different scenarios and approaches

MARXAN conservation solutions

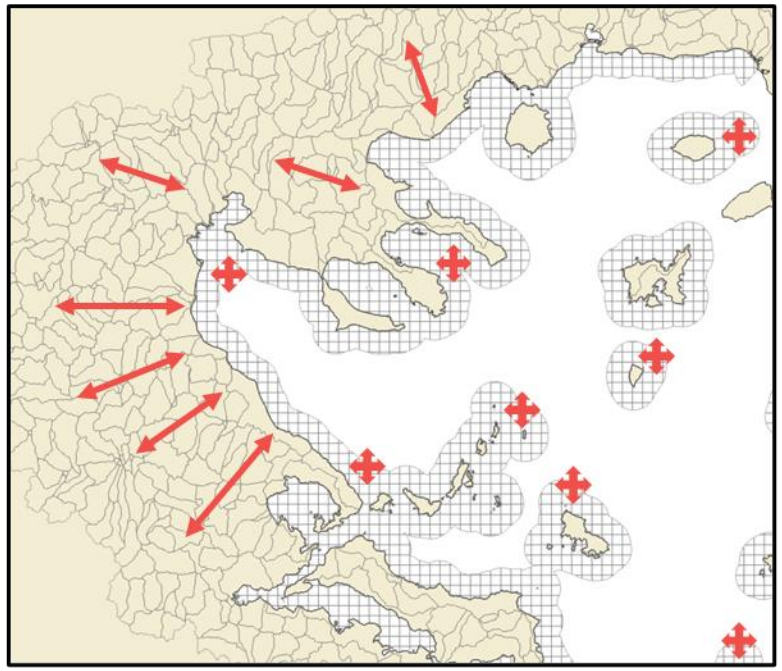
Ball et al., 2009. Marxan and relatives: Software for spatial conservation prioritization

- **Spatial selection** and **overlap** between scenarios
- **Total area** identified for protection
- **Total threat accumulated** in the selected network of protected areas

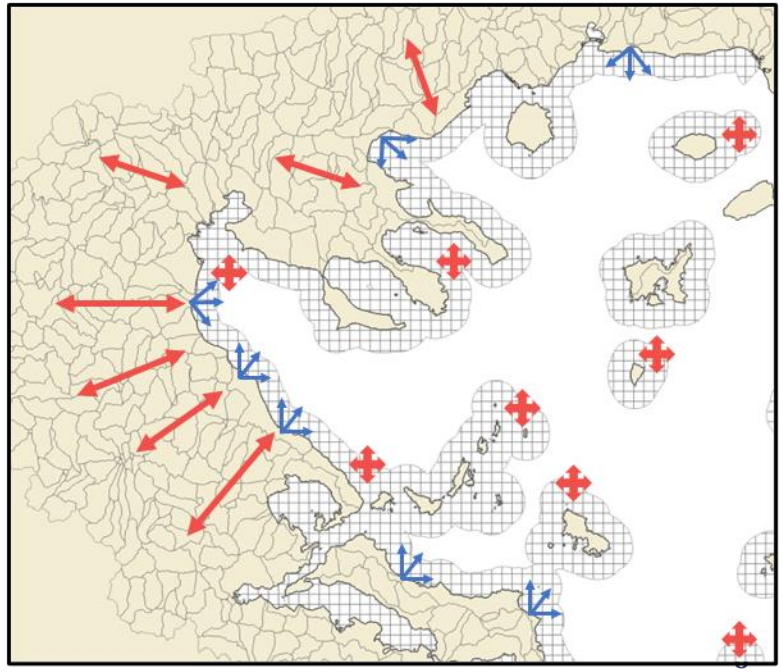
Scenario 1 – No Connectivity



Scenario 2 – Connectivity **within** realms



Scenario 3 – Connectivity **across** realms



Decision support tool

MARXAN conservation solutions

Ball et al., 2009. Marxan and relatives: Software for spatial conservation prioritization

Input data

- **Conservation Features:** species, habitats and their conservation targets
- **Cost**
- **Connectivity values**

Marxan Analysis

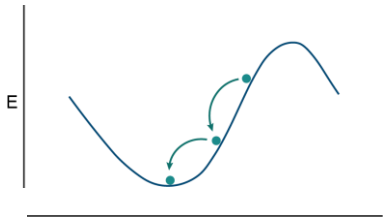
100 runs for each Scenario

Objective Function

$$minimize \sum_i^{N_s} x_i\, c_i + b \sum_i^{N_s} \sum_{ii}^{N_s} x_i(1 - x_h) cv_{ih}$$

Cost | **Connectivity cost**

"Minimum set problem"



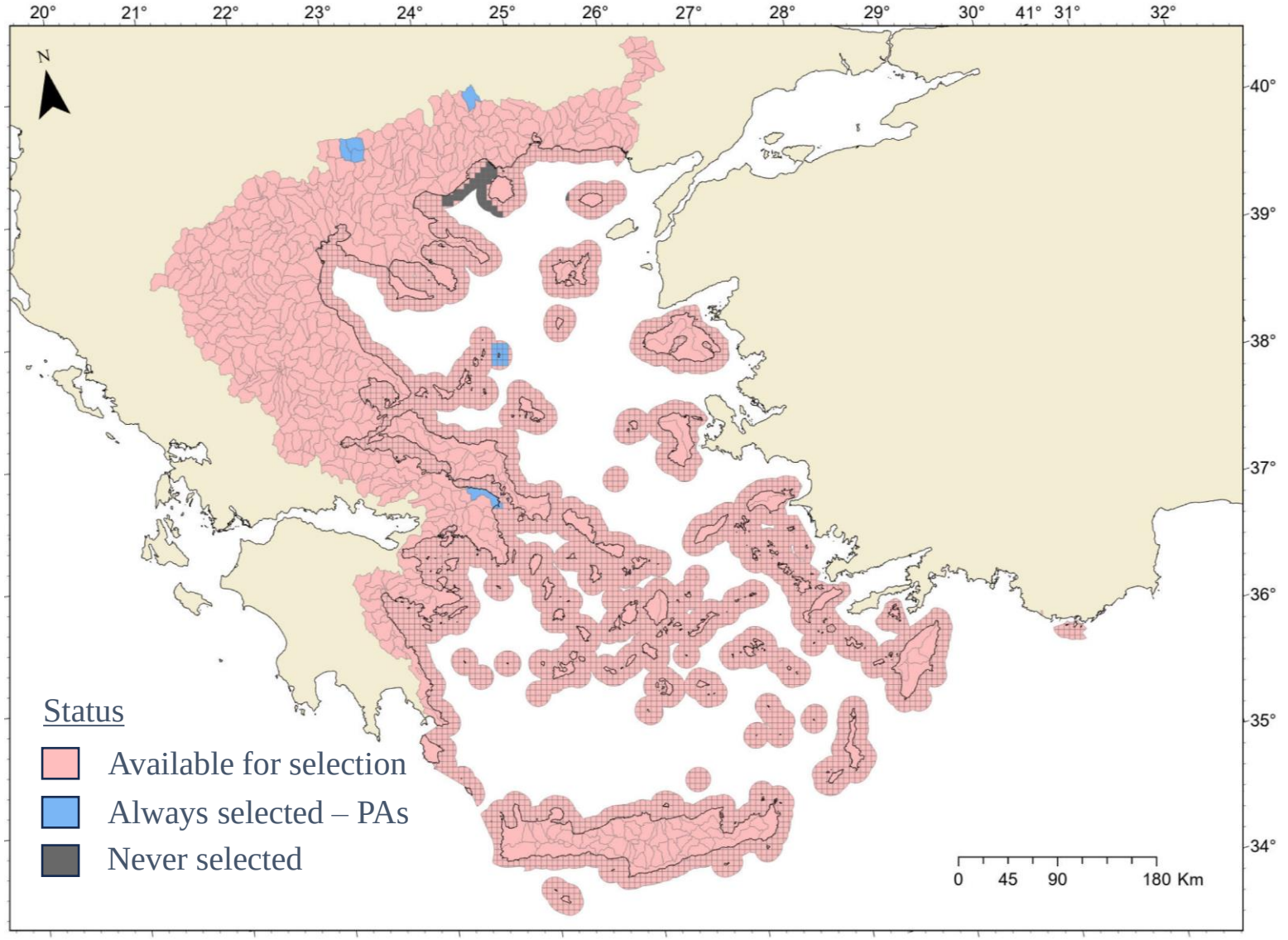
subject to meeting all conservation targets:

$$\sum_i^{N_f} x_i\, r_{ij} \geq T_j \forall\, j$$

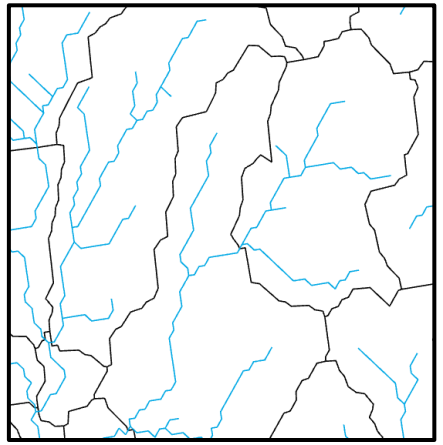
Outputs

- **Best Solution**

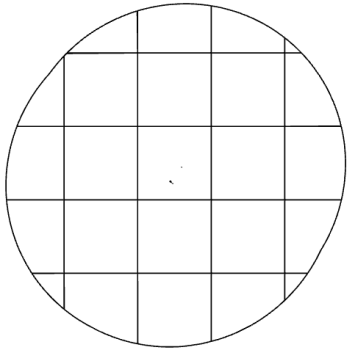
Planning Region and Planning Units (PUs)



Terrestrial and Freshwater realms as **660** river sub-catchements (Lehner et al., 2008)



Marine realm as **5310** 5x5 km square-size cells as PUs



Conservation Features

- Freshwater species

Amphibians	8	
Birds	45 →	28
Actinopterygii	47 →	4
Reptiles	13	

- Marine species and priority habitats

Cnidaria	19
Chondrichthyes	16
Echinodermata	2
Actinopterygii	3
Marine mammals	8
Mollusca	6
Porifera	8
Habitats	6

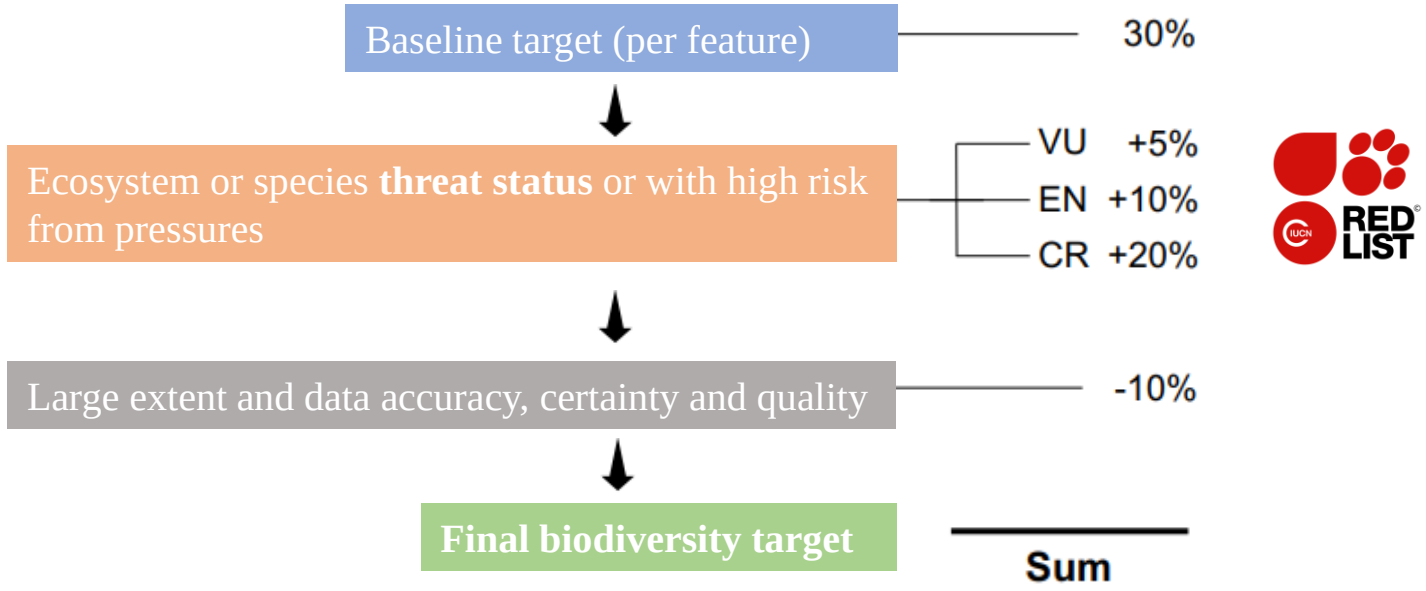
209 Conservation Features

- Species included in the **92/43 - EN - Habitats Directive**, **Birds Directive (Directive 79/409/EEC)**, **BCN Convention** and the **endemic** species.

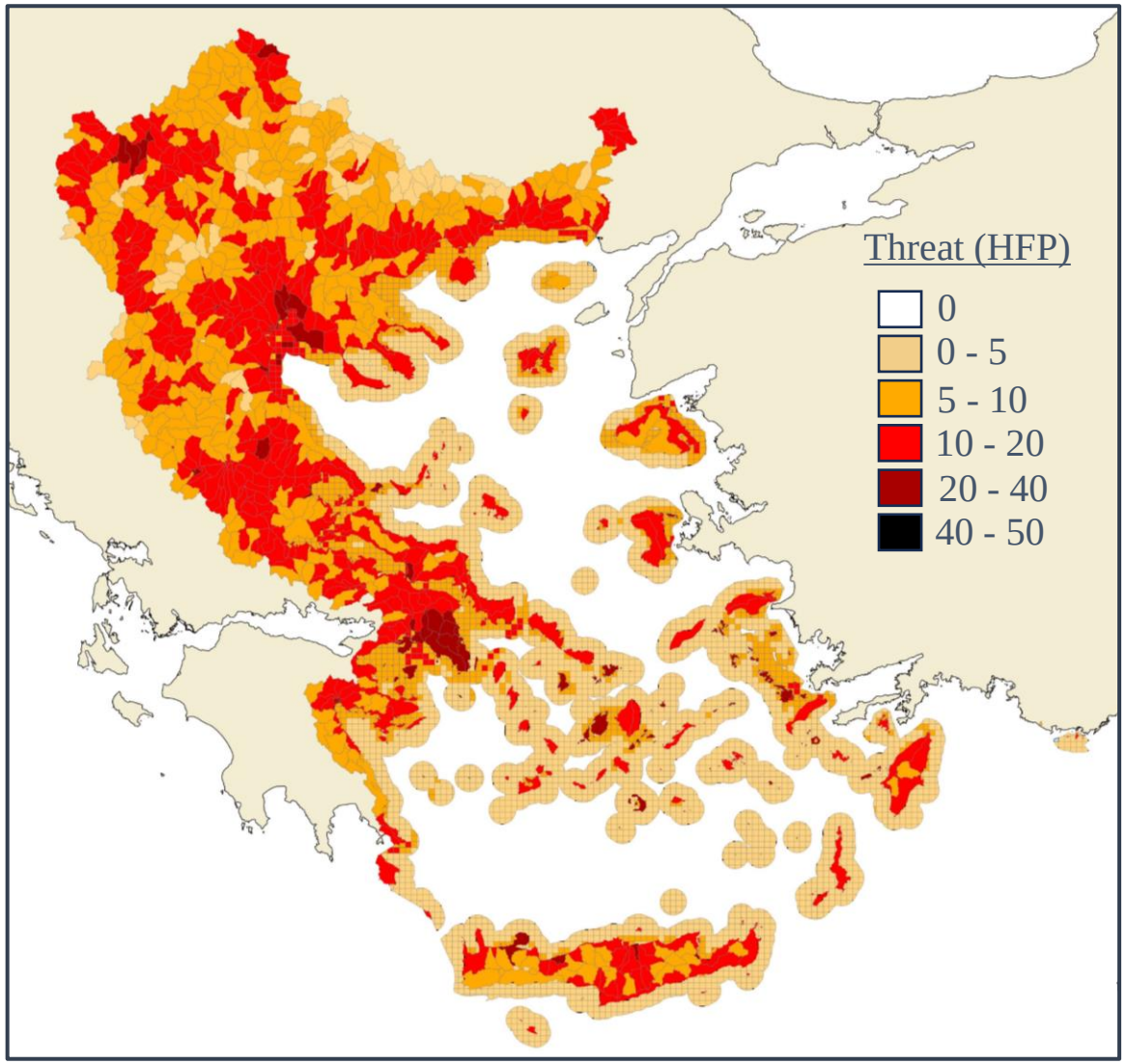
European Commission | UN environment programme | Mediterranean Action Plan Barcelona Convention

- **Conservation Targets**: proportion of species to retain

Harris & Holness, 2023



Cost defined as threat for each Planning Unit

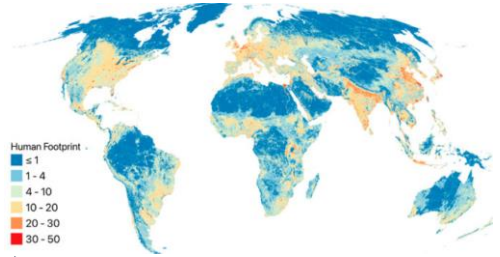


All HFP values ranged from 0 to 50

Freshwater and terrestrial Realm

Terrestrial Human Footprint (HFP-100) obtained from *Mazzariello and Gassert, 2023* and *Gassert et al., 2023*. Data from 2020

1. Population density
2. Electric infraestructura
3. Roadways
4. Railways
5. Navigable waterways
6. Land cover change (built environments, crop lands, pasture lands)



Marine Realm

Marine Human Footprint estimated from public data on:

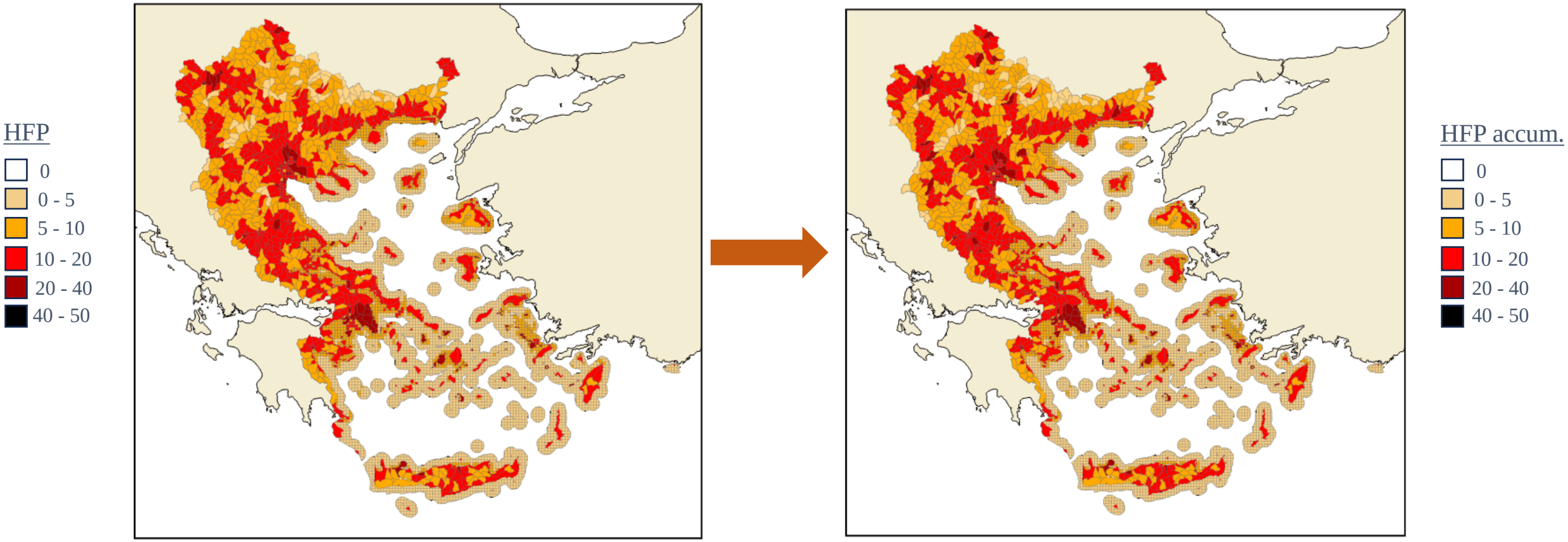
1. Aquaculture presence
2. Small scale fishing impact (CFPI – impact index)
3. Passenger density (route density)
4. Cargo density (route density)
5. Fishing by purse seines (hrs / year)
6. Fishing by Otter Bottom Trawlers (hrs / year)

Pressures weighted according to *Halpern et al., 2007*

Threat propagation through connectivity

Local threats

Threats Accumulated



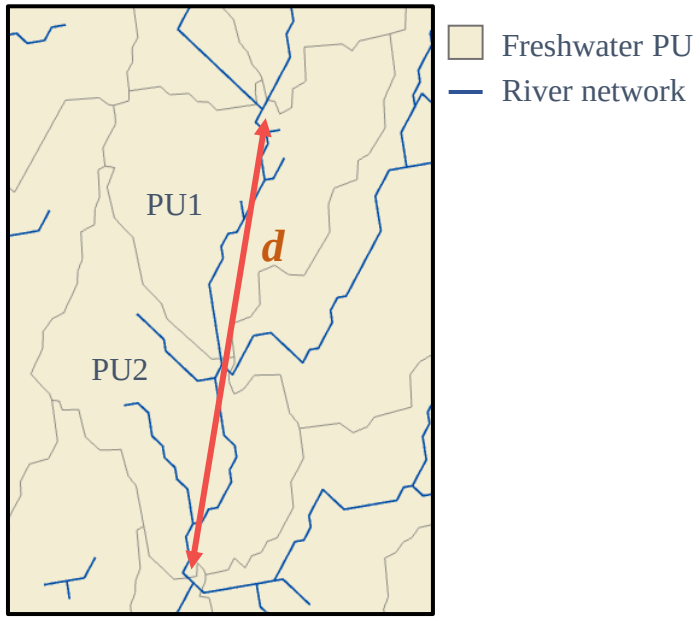
b: connectivity value between PUs
***d*:** distance between PUs
2: decay value

$$\text{Local Threat} \times b/d^2 = \text{Threat propagated} + \text{Local Threat}$$

Following Salgado-Rojas et al., (2024)

Connectivities between Planning Units

Within freshwater realm

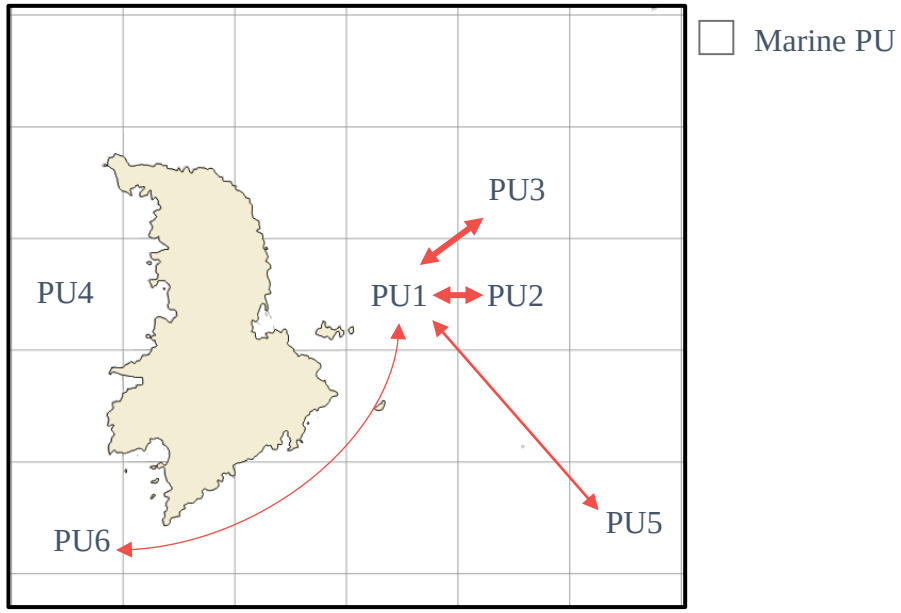


Local sub-catchment with their upstream watersheds and the next downstream catchment. Longitude of the main river and a decay function:

$$1/\sqrt{d}$$

d: *Longitude of the river between PUs*

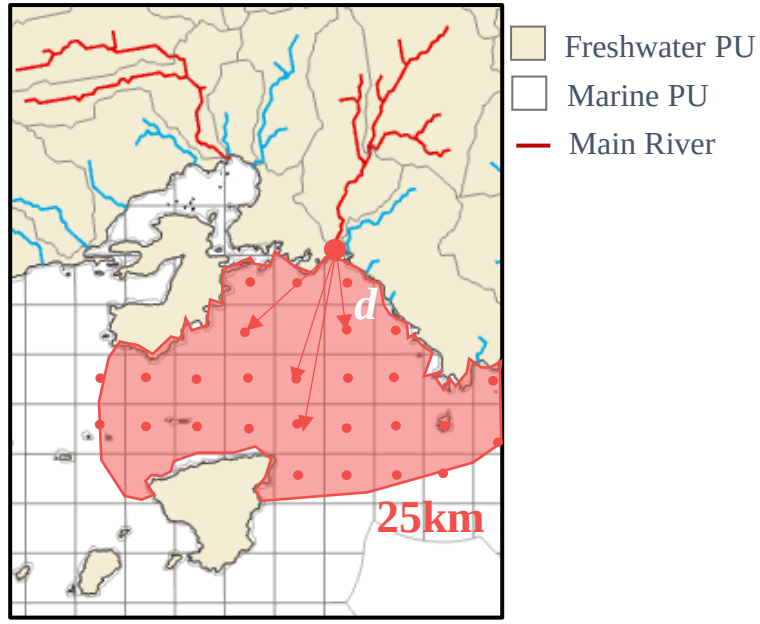
Within marine realm



Oceanographic model

*Probability of a drifter transferred to a PU to another based on **current velocities** of the past 10 years, on daily basis*

Across realms



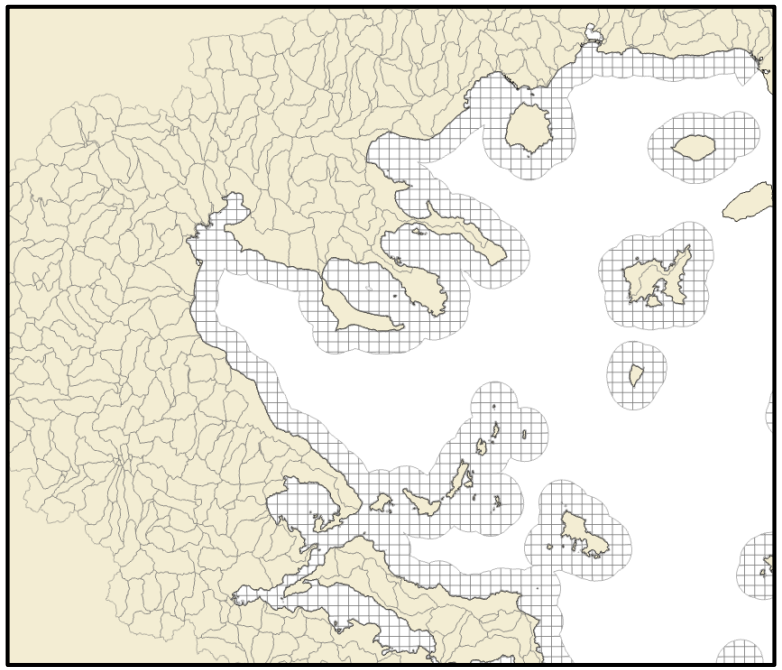
Only large rivers - 10 km river outflow

Buffer area of 25 km in the marine real

$$1/\sqrt{d}$$

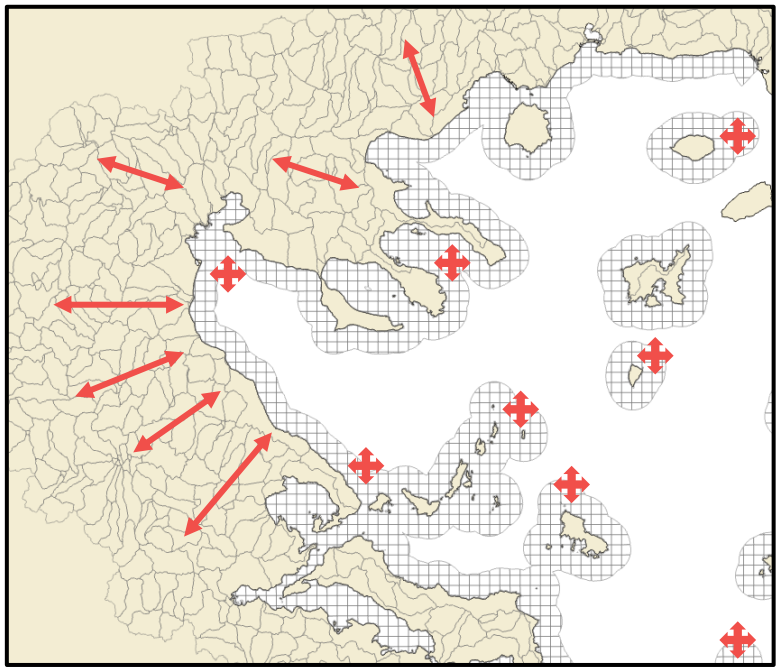
***d*:** Euclidean distance between main river centroid and marine Pus centroid

Scenario 1 – No Connectivity



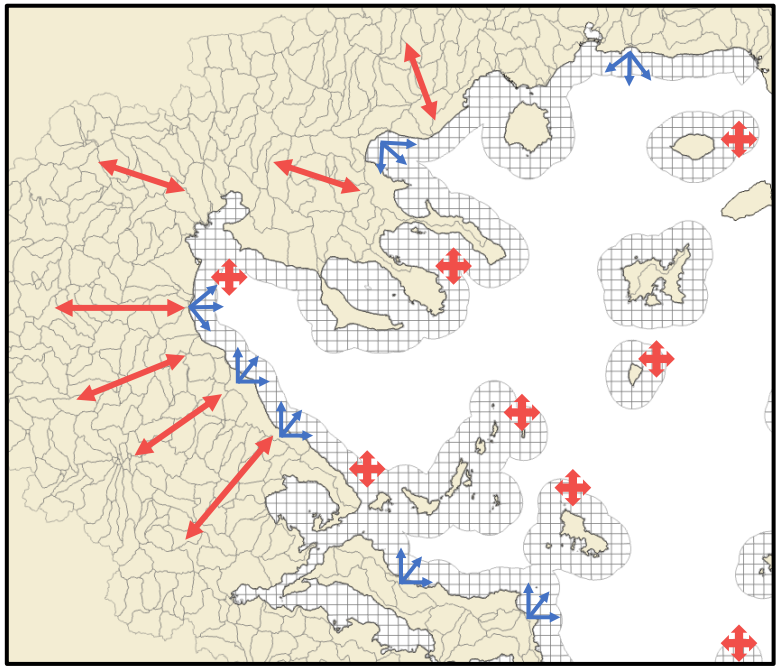
- ***No** connectivity values*

Scenario 2 – Connectivity **within** realms



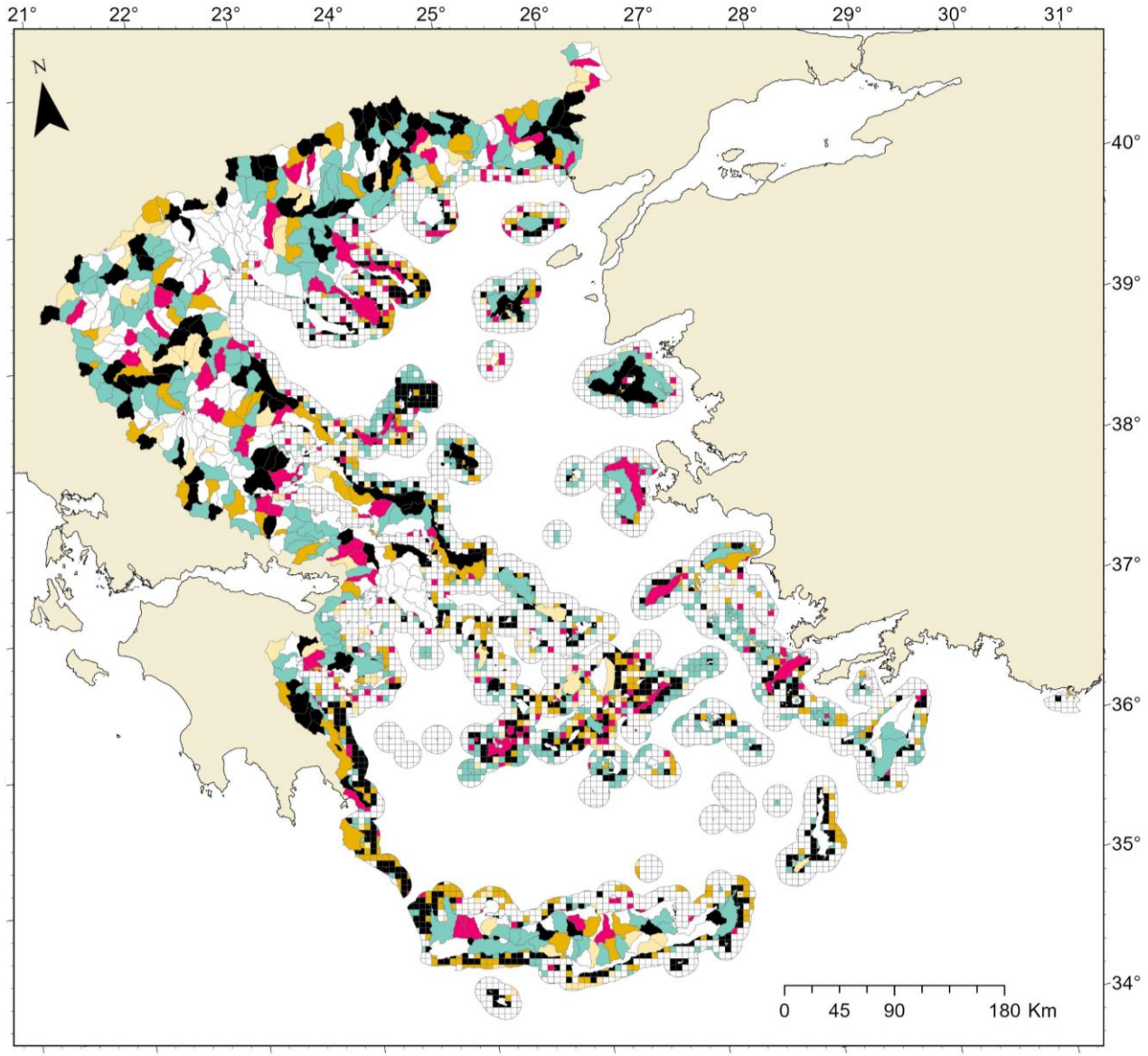
- *Connectivity **within** freshwater realm*
- *Connectivity **within** marine realm*
- ***Threats propagation just in the freshwater realm***

Scenario 3 – Connectivity **across** realms



- *Connectivity **within freshwater realm***
- *Connectivity **within** marine realm*
- *Connectivity **across** freshwater and marine realm*
- ***Threats propagation to the marine realm***

Spatial overlap of the Best Solutions between scenarios according to the connectivity approach



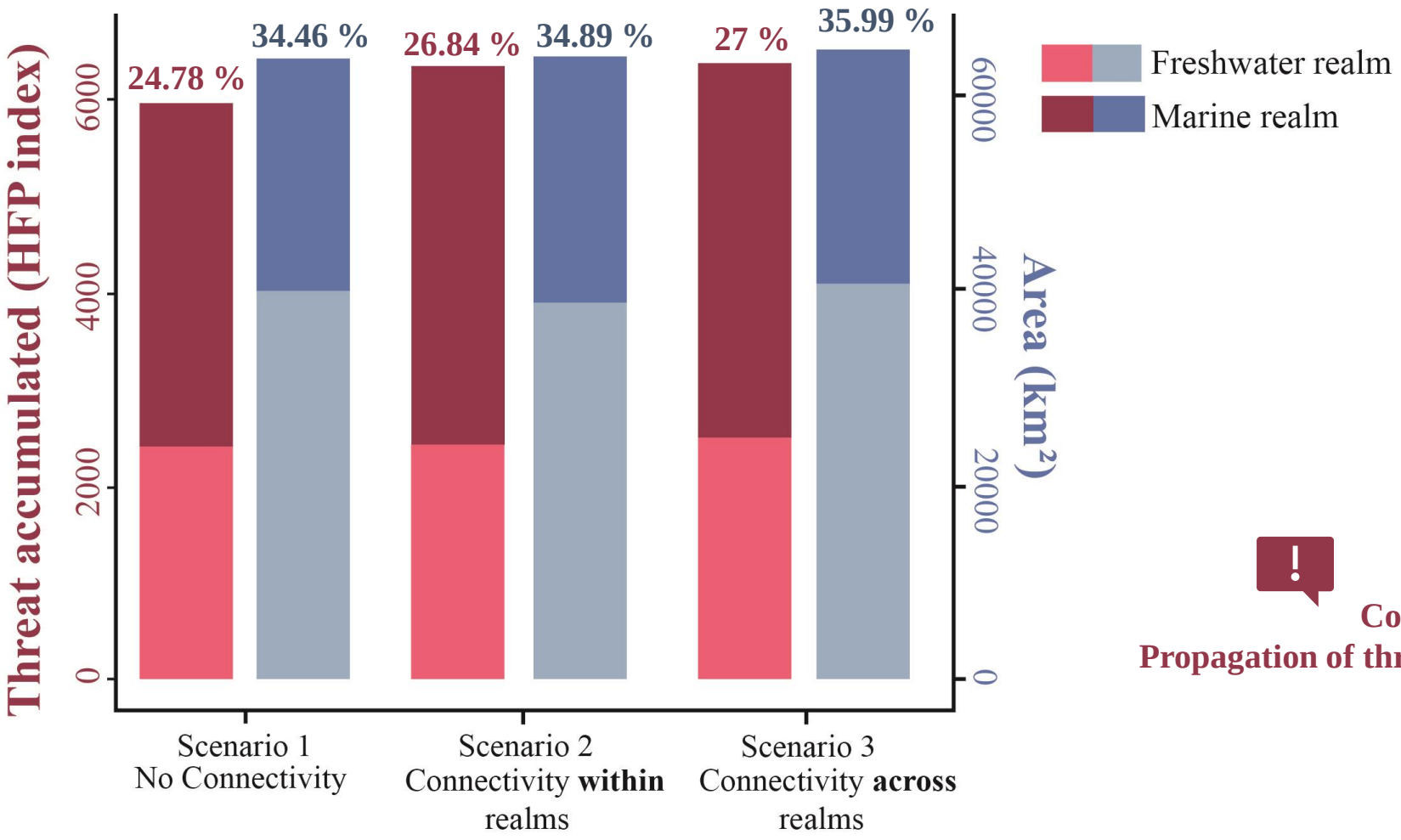
- Never selected
- Other combinations (e.g., scenario 1, scenario1-2)
- Scenario 2 – just connectivity within
- Scenario 2 and 3 – connectivity
- Scenario 3 – connectivity within and across
- Selected in all scenarios

Cohen's Kappa Statistic (0 – 1):

- Scenario 1 – 2: **0.47** Moderate agreement
- Scenario 1 – 3: **0.47** Moderate agreement
- Scenario 2 – 3: **0.62** Substantional agreement

Cohen's Kappa	Interpretation
0	No agreement
0.10 - 0.20	Slight agreement
0.21 - 0.40	Fair agreement
0.41 - 0.60	Moderate agreement
0.61 - 0.80	Substantial agreement
0.81 - 0.99	Near perfect agreement
1	Perfect agreement

Outputs of threats accumulated and area selected at each scenario



Consideration:
Propagation of threats accumulated at each PU

- At comparing scenarios, all three selected the **same amount of area** with **similar threat accumulation**. The difference was found in the **spatial configuration**, being Scenario 3 more adequate at including the connectivity within and across realms.

- This approach better represent species and habitats found in more than one realm and can account for **ecological processes**.

- Accounting for the **propagation of threats** through connectivity enhances the resilience of conservation efforts and maximises conservation outcomes.

- Integrated and systematic planning across different realms (terrestrial-freshwater-marine) can identify **priority areas** for conservation more **cost-effectively** than single-realm planning.

Future perspectives

- Within this study, incorporate **all the Aegean Sea** and all the across-realm connections no just within Greece.
- Incorporating **propagation of threats** within the **marine realm** (e.g., aquaculture)

INSPIRE
INtegrated Spatial Planning across REalms

- Identifying and map **social-ecological linkages** and **cross-sectoral** objectives.
- Developing **alternative management strategies** (e.g., potential OECMs) and estimating their consequences.
- Incorporating **dynamic conditions** into planning generating scenarios based on potential pathways.

Thank you for you attention

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