MARINE PROTECTED AREAS EUROPE

Regionalisations for Marine Protected Area planning

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Nord University

The MPA Europe project is co-funded by the European Union under the Horizon Europe program (grant agreement no. 101059988)

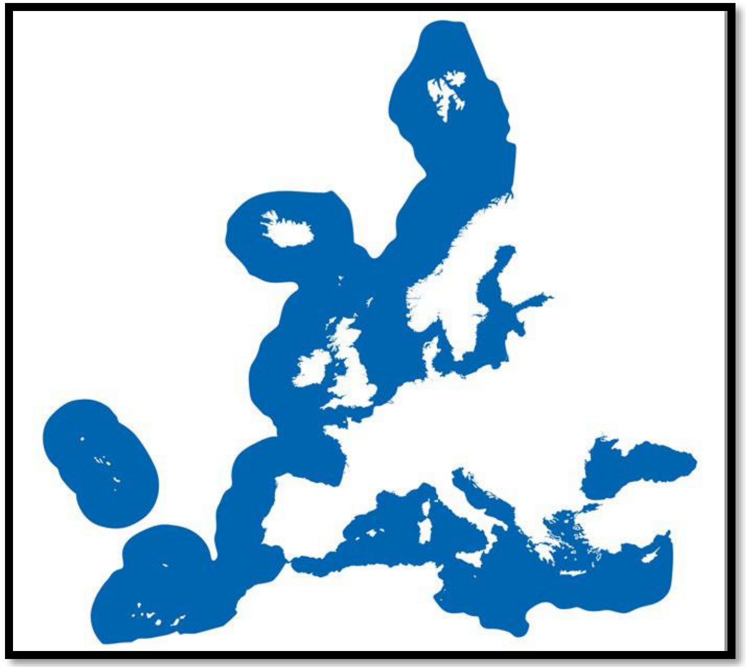
Co-funded by the European Union

UK Research and Innovation

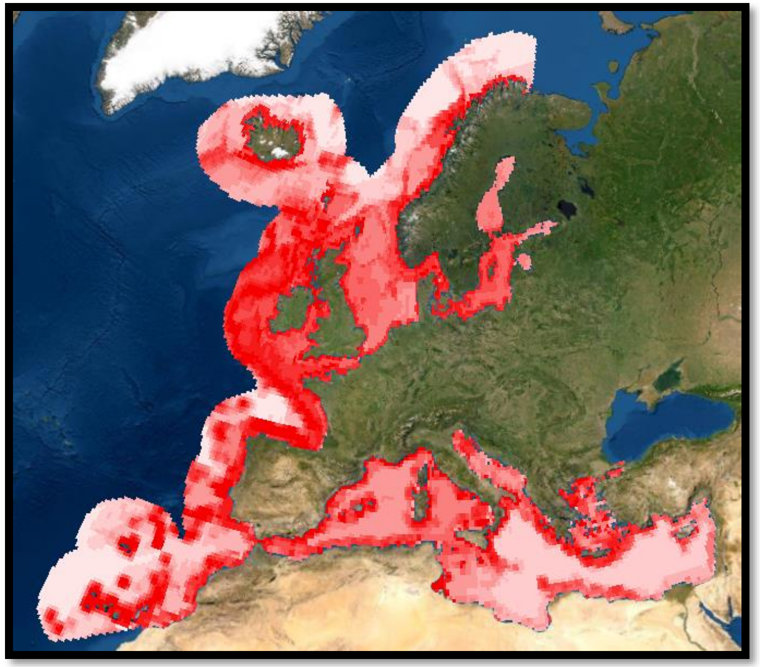
GOAL

MPA Europe is mapping the **optimal locations** for Marine Protected Areas in European seas to support **science-based** Marine Spatial Planning

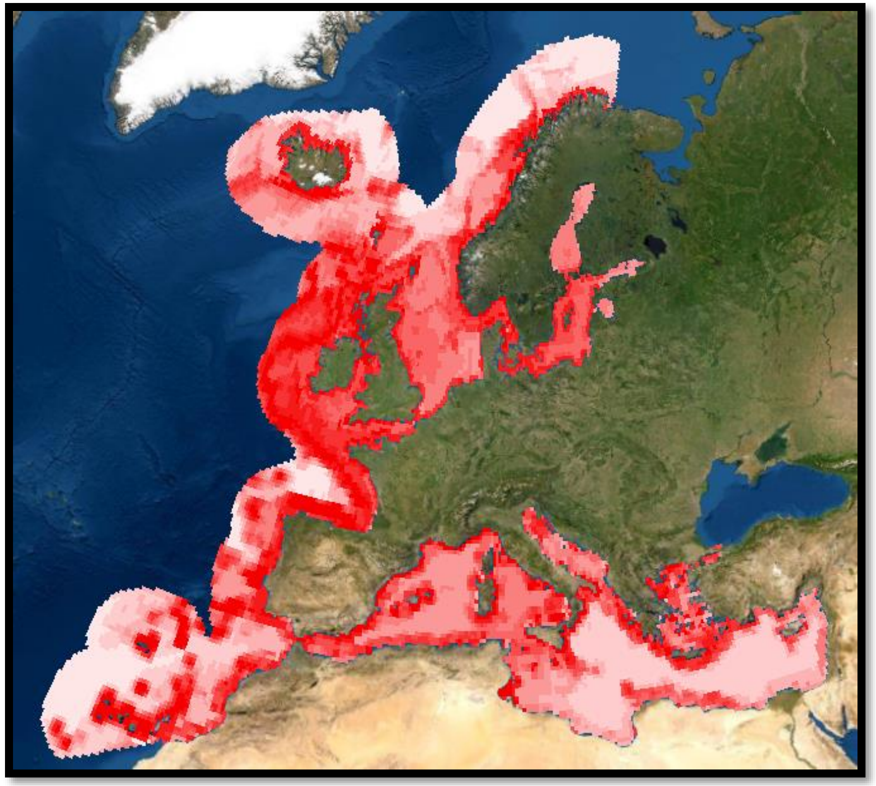
APPROACH

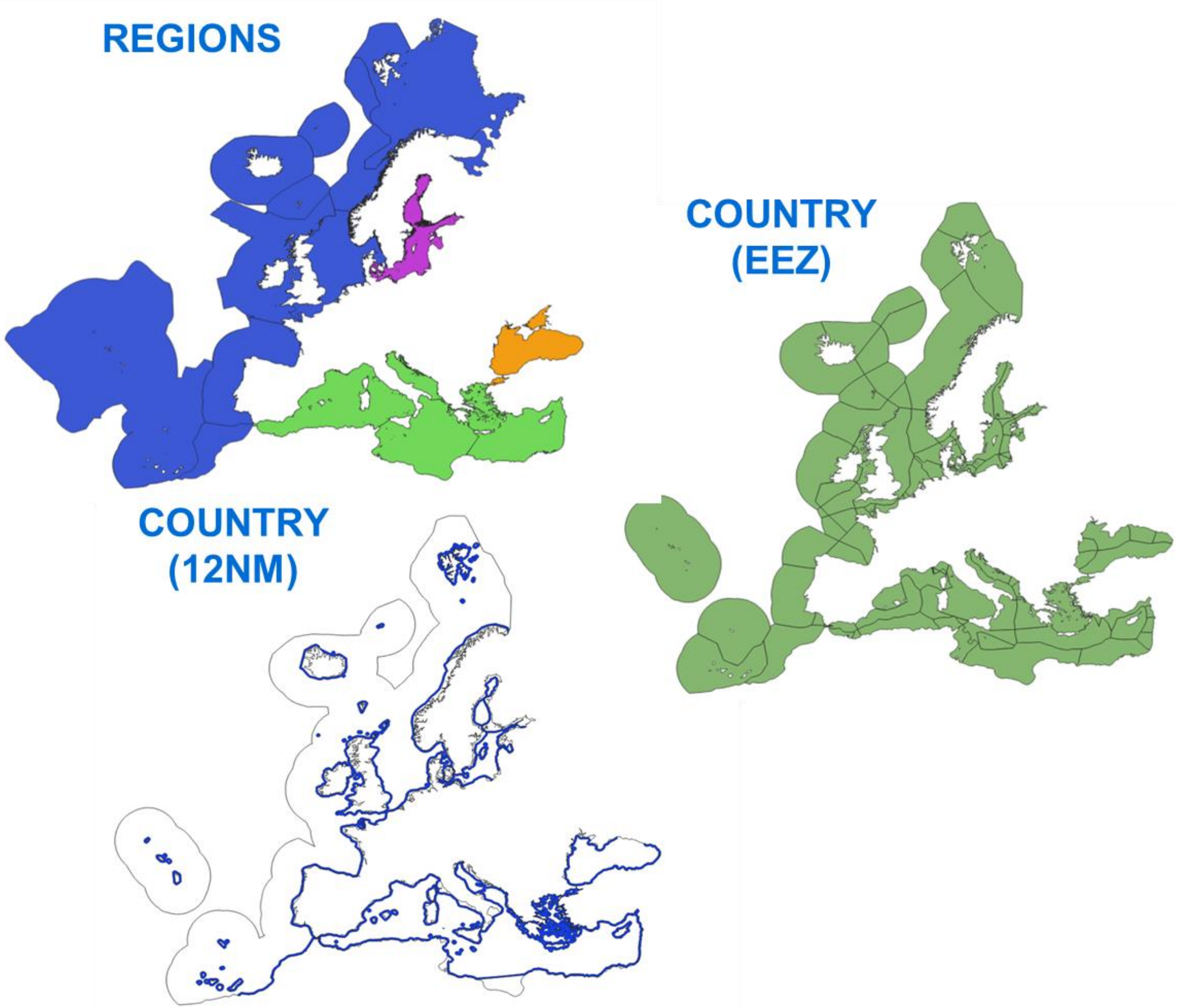


SYSTEMATIC CONSERVATION PLANNING (SCP)



Prioritisation at 3 spatial scales





A global protected area network

should represent biodiversity from species to ecosystems

Need world maps of

- ✓ **Ecosystems**
- ✓ **Biomes**
- ✓ **Habitats**
- ✓ **Species richness**
- ✓ **Species endemicity (realms)**

Photo by Dr Galice Hoarau

Marine species richness

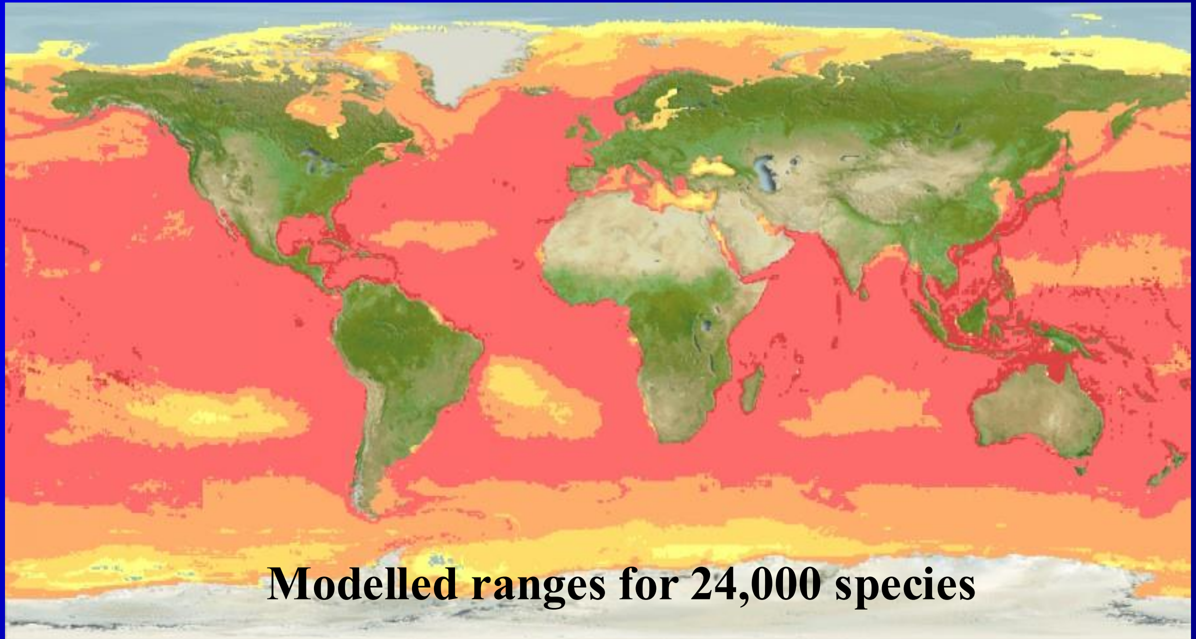
Aquamaps.org

Colours on log-scale.

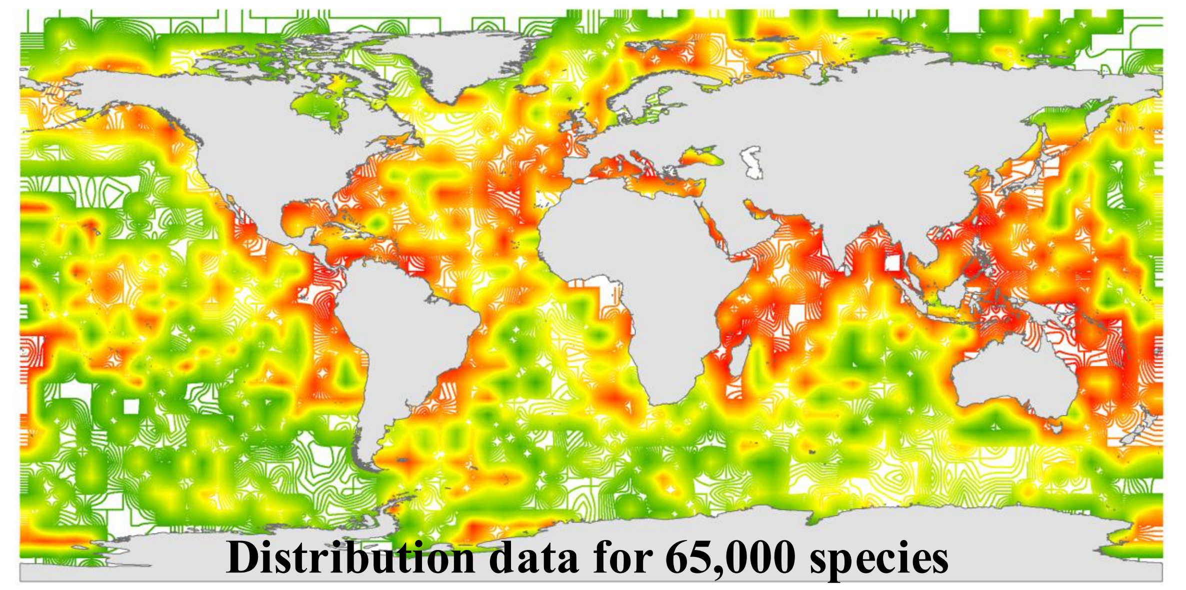
(1) Modelled species ranges (top)
(2) carefully cleaned primary data (bottom) show
most species occur along coasts and tropics

OBIS sample data

ES_{50} index used to standardise for sampling effort.



Modelled ranges for 24,000 species



Distribution data for 65,000 species

Key concepts

- **Biogeographic realms** based on species endemicity (uniqueness)
- As species are unique to each realm, each realm needs protected areas

- **Ecosystems** based on energy flow between adjacent areas
- Relevant to ecosystem function and services, food webs, productivity
- Agnostic to species composition
- Different species may provide similar ecological roles in different areas

Key concepts

- **Biomes**
  - Large areas dominated by habitat forming species
  - May be one or more species
  - Species composition will vary geographically

- **Biogenic habitats**
  - Habitat formed by a particular species at a local scale
  - Is part of a biome

Biogeographic regions

Who wants one?

- IUCN, WWF, CI
- GEO & GEOSS
- FAO and ICES
- IOC and IODE
- Researchers

Why?

- nature conservation reporting
- ecosystem classification
- fishery management
- marine data management
- indicating species distributions

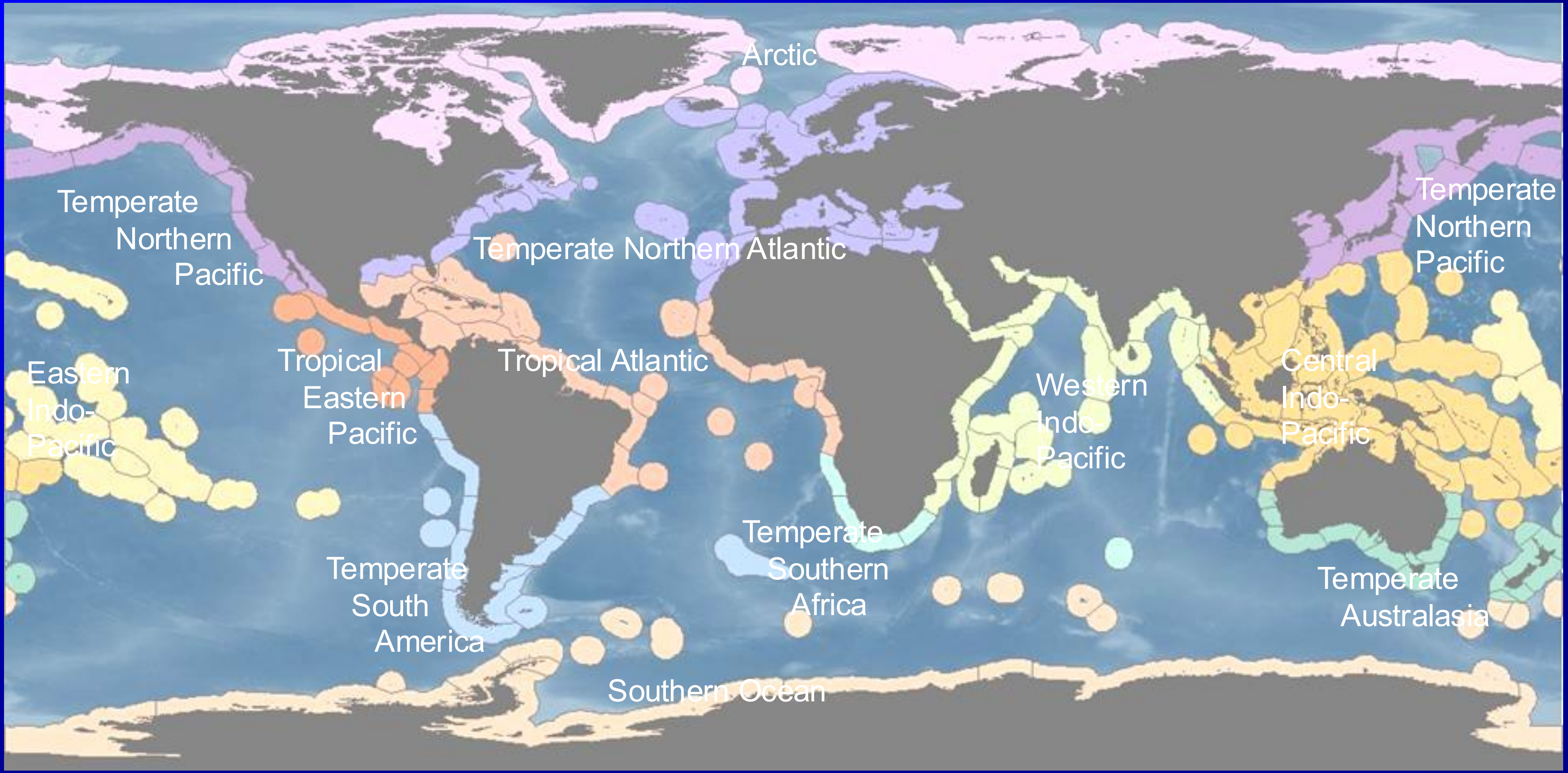
Why not use other geographic regions?

Existing marine ‘regions’

Geographic (Seas and oceans)	→	Global
Political (Exclusive Economic Zones)	→	Global if non-EEZ ‘high-seas’ included
Large Marine Ecosystems	→	Coastal but not all coasts
Marine Ecoregions of the World MEOW	→	Coastal - includes LME & EEZ & other
Global Open Oceans and Deep Seabed GOODS	→	Pelagic and deep sea to complement MEOW
FAO areas	→	Global – fishery boxes
ICES areas	→	Regional - fishery & related management boxes
Longhurst’s pelagic	➢	Global – ocean colour

Marine Ecoregions of the World (MEOW)

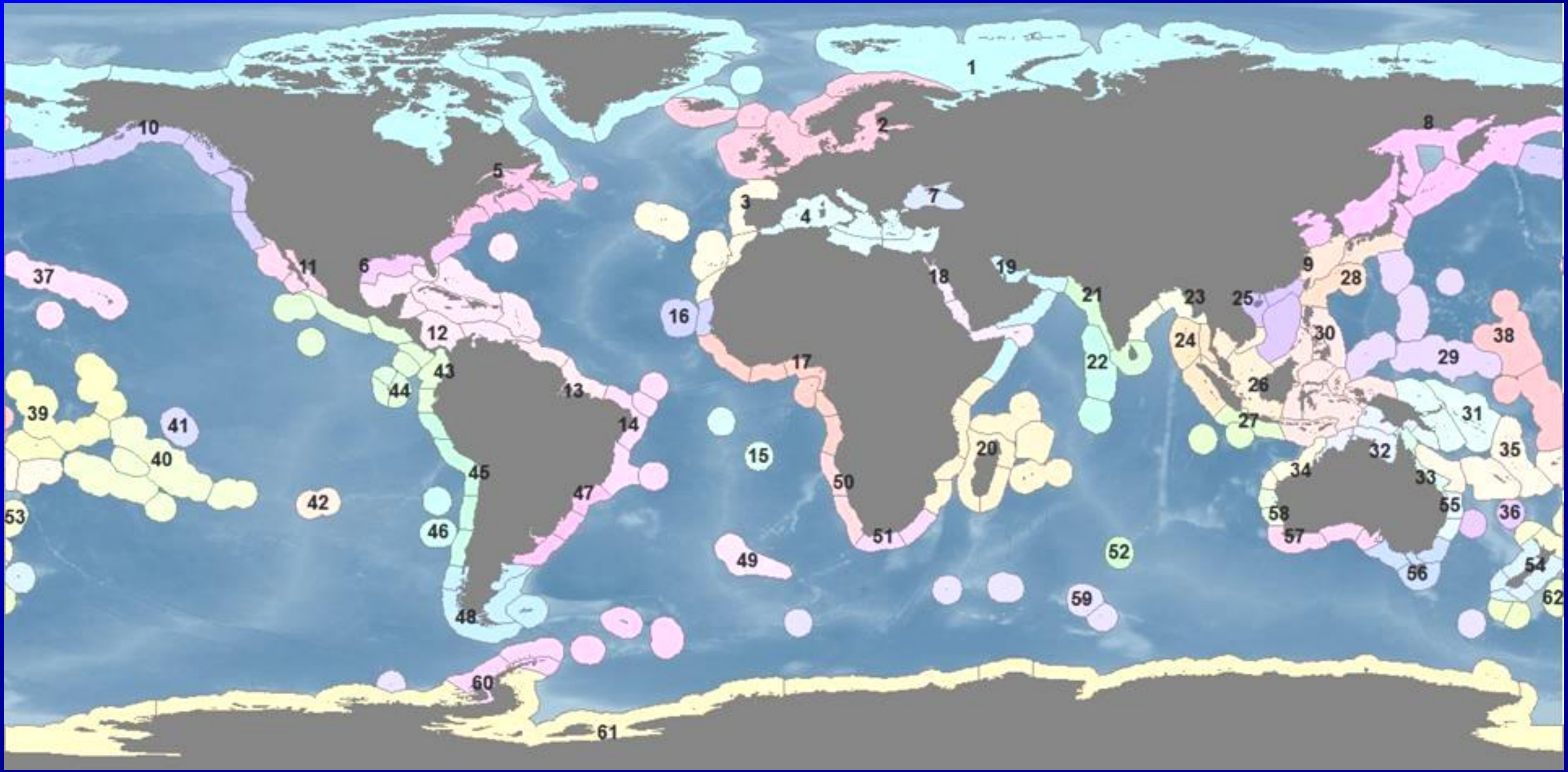
12 Realms



Very large regions of coastal, benthic or pelagic ocean across which biotas are internally coherent at higher taxonomic levels, as a result of a shared and unique evolutionary history. Realms have high levels of endemism, not only at the species level, but also with unique taxa at generic and family levels in some groups.

Marine Ecoregions of the World (MEOW)

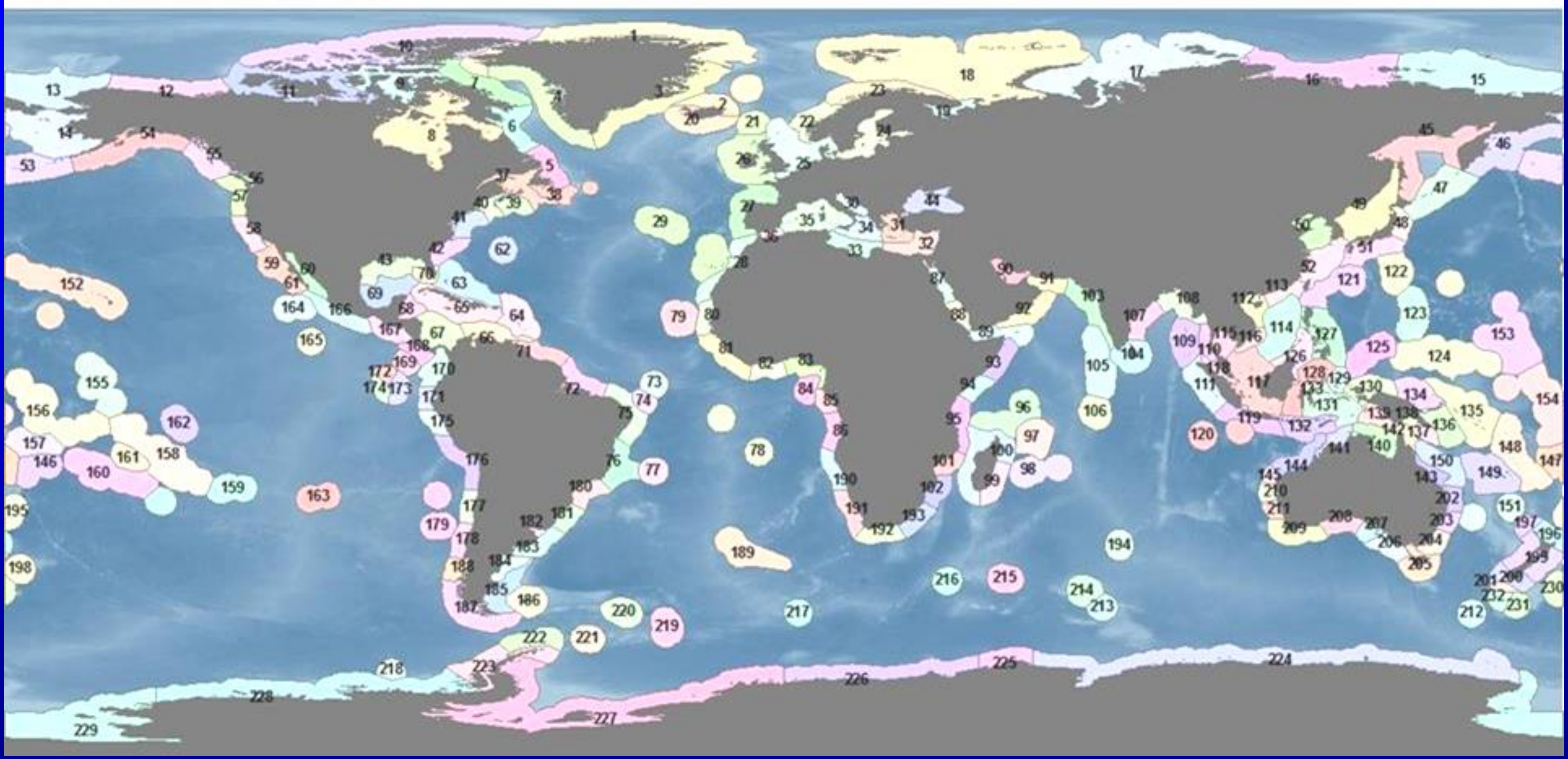
62 Provinces



Large areas defined by the presence of distinct biotas that have at least some cohesion over evolutionary timeframes. Provinces will hold some level of endemism, principally at the level of species

Marine Ecoregions of the World (MEOW)

232 Ecoregions



Areas of relatively homogeneous species composition, clearly distinct from adjacent systems. This species composition is likely to be determined by the predominance of a small number of ecosystems and/or a distinct suite of oceanographic or topographic features.

Include “Large Marine Ecosystems”

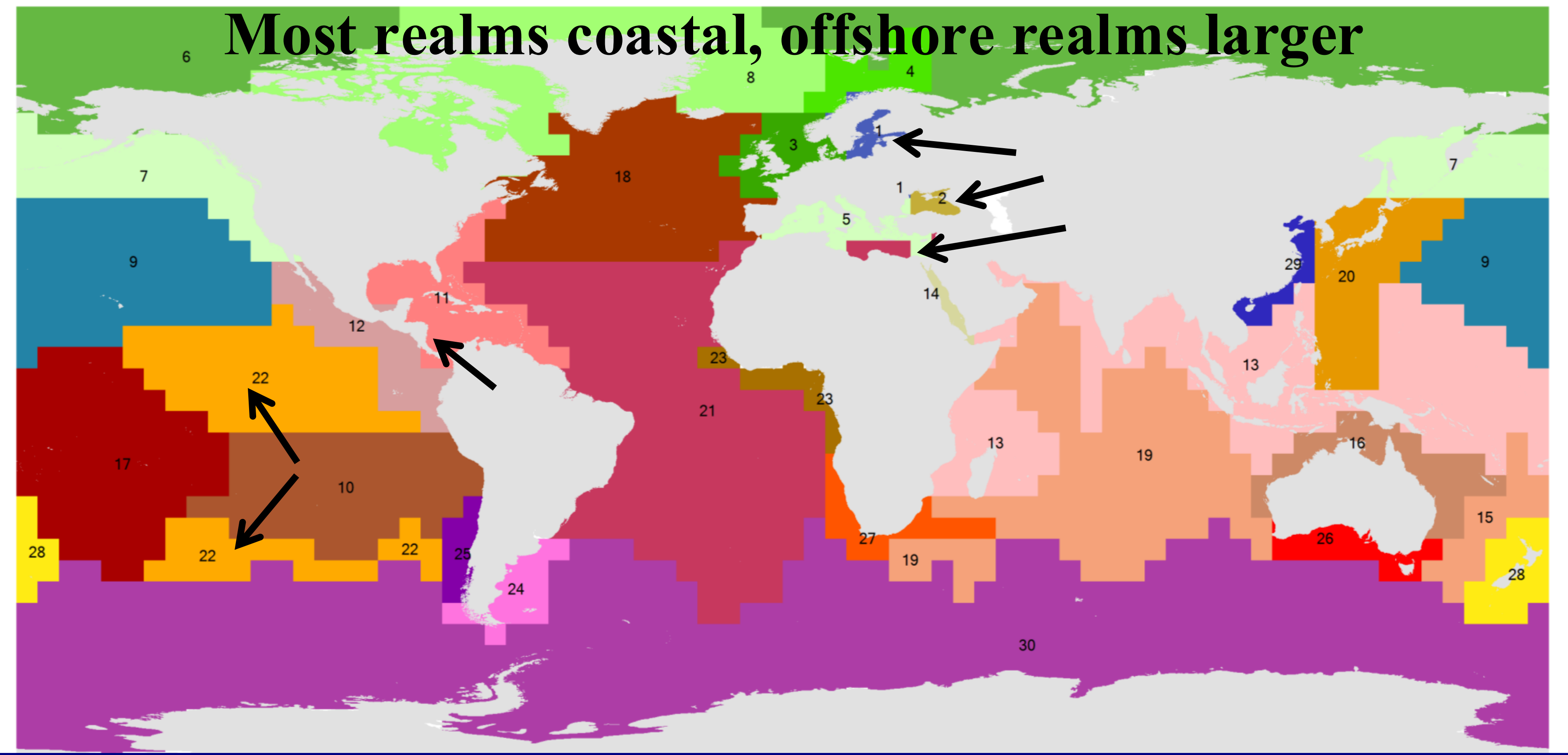
30 biogeographic realms

i.e., areas endemicity based on cluster **analysis 65,000 species from OBIS**

Freshwater influenced Baltic and Black Seas.

Land barriers - Panama isthmus and Suez Canal.

One open ocean realm split in two by another.



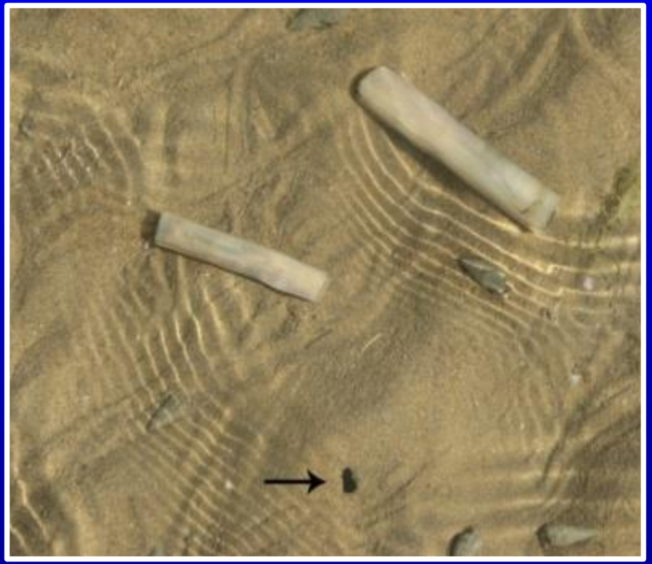
Costello et al. 2017. Marine biogeographic realms and species endemicity. ***Nature Communications***

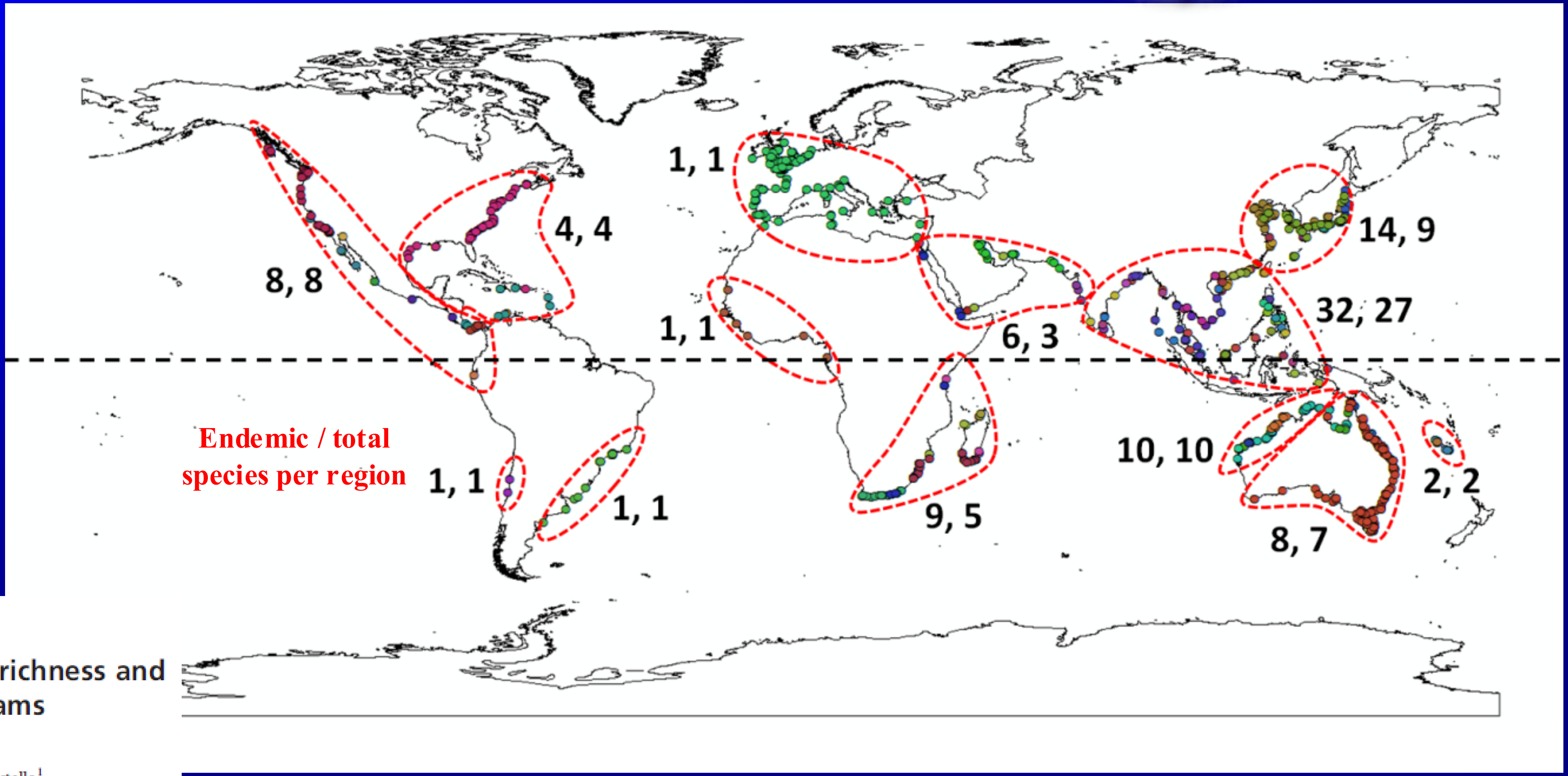
			Seas' group	Realm	% spp unique	# spp
Inner Baltic Sea			Inner Baltic Sea	1	63	458
Black Sea			Black Sea	2	84	192
NE and NW Atlantic and Mediterranean, Arctic and North Pacific	NE Atlantic & Mediterranean (2)	NE Atlantic (3)	NE Atlantic	3	27	7117
		Arctic Europe (5)	Norwegian Sea (in part)	4	43	1345
		Mediterranean (3)	Mediterranean	5	45	3096
	Arctic & N Pacific (2)	Arctic (3)	Arctic seas	6	19	1907
		North Pacific (3)	N Pacific	7	27	5535
	N Atlantic boreal & sub-Arctic from Canada to Greenland Sea (2)		N American Boreal	8	31	1492

Biogeography by species endemicity (unique to an area) is hierarchical

Mid-tropical North Pacific Ocean			--	9	47	2859
South-east Pacific			--	10	59	1618
Mid-Atlantic, Pacific and Indian Oceans including coastal tropics and warm-temperate areas	Tropical W Atlantic & Tropical E Pacific (2)	Tropical W Atlantic (3)	Caribbean & Gulf of Mexico	11	30	13281
		Tropical E Pacific (3)	Gulf of California	12	30	3279
	Coastal Indian Ocean, W Pacific, Arabian Gulf to New Caledonia, S Pacific tropical islands, & N, W & E Australia (2)	Tropical Indo-Pacific (East Indies) & coastal Indian Ocean (3)	Indo-Pacific seas & Indian Ocean	13	31	16508
		Red Sea (4)	Gulfs of Aqaba, Aden, Suez, Red Sea	14	74	997
		Tasman Sea to SW Pacific (3)	Tasman Sea	15	57	1468
		Tropical Australia & Coral Sea (4)	Coral Sea	16	33	10349
	Mid South Tropical Pacific (2)		--	17	44	2818
	Open Atlantic, Indian, & Pacific oceans(2)	Offshore & NW North Atlantic (4)	--	18	26	7591
		Offshore Indian Ocean (5)	--	19	43	3486
		Offshore W Pacific (6)	--	20	40	4678
		Offshore S Atlantic (6)	--	21	33	5512
		Offshore mid-E Pacific (7)	--	22	36	1217
		Tropical E Atlantic (6)	Gulf of Guinea	23	57	992
	S South America (2)	Argentina (3)	Rio de La Plata	24	45	1651
		Chile (3)	--	25	68	584
	S Africa, S Australia, & New Zealand (2)	S Australia (6)	South Australia	26	40	2158
		S Africa (5)	--	27	45	6700
		New Zealand (6)	--	28	33	3126
North West Pacific			N W Pacific	29	47	2551
Southern Ocean			Southern Ocean	30	17	4256

Global biogeography razor clams





Journal of Biogeography (*J. Biogeogr.*) (2016)

ORIGINAL ARTICLE

Bimodal latitudinal species richness and high endemicity of razor clams (Mollusca)

Hanieh Saeedi[1]*, Todd E. Dennis[2] and Mark J. Costello[1]

Other marine biogeography's

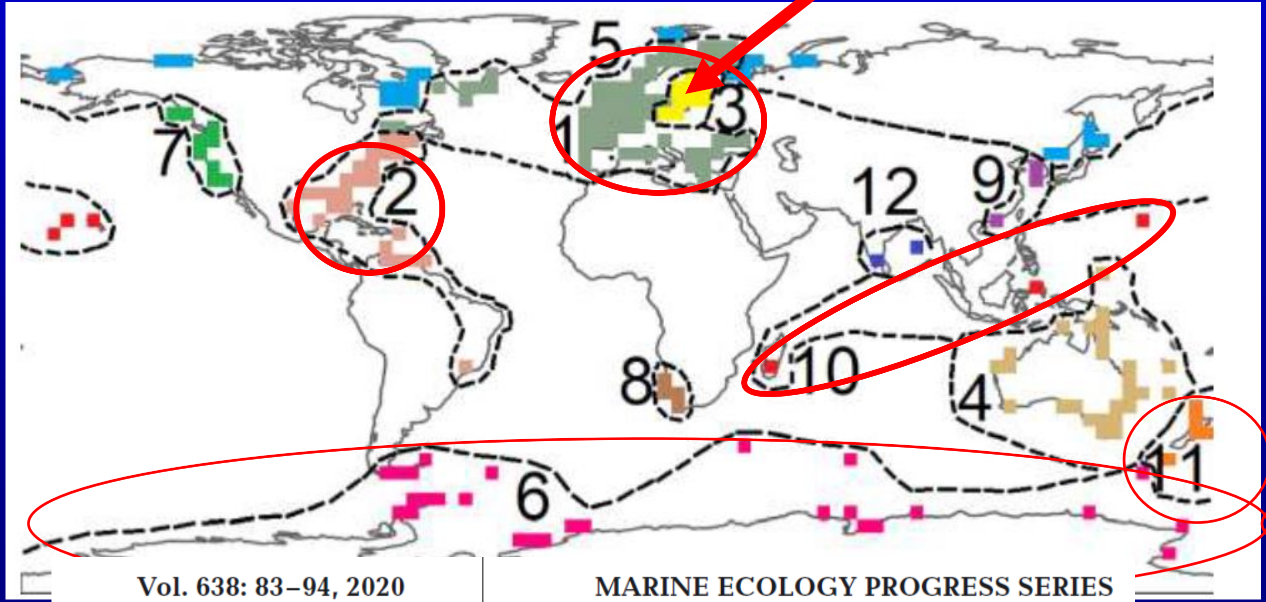
Polychaete worms

Amphipod crustaceans

Baltic Sea contains freshwater species

Global biogeography of marine amphipod crustaceans: latitude, regionalization, and beta diversity

Tri Arfianti[1,2,*], Mark J. Costello[3,4]



Vol. 638: 83–94, 2020
https://doi.org/10.3354/meps13272
MARINE ECOLOGY PROGRESS SERIES
Mar Ecol Prog Ser

Biogeography of polychaete worms (Annelida) of the world

Joko Pamungkas[1,2,*], Christopher J. Glasby[3], Mark J. Costello[4,5]

Vol. 657: 147–159, 2021
https://doi.org/10.3354/meps13531
MARINE ECOLOGY PROGRESS SERIES
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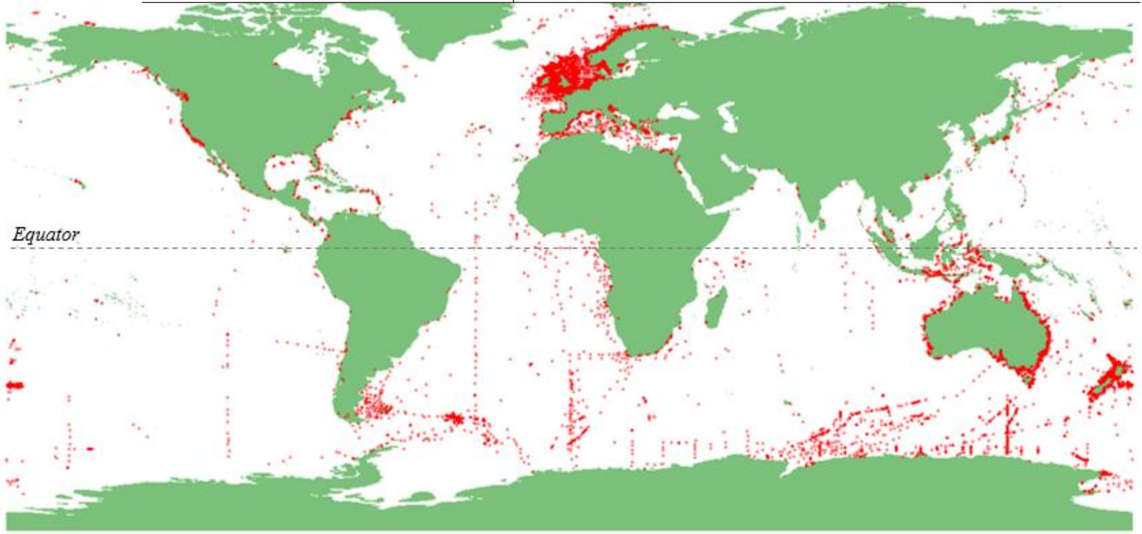
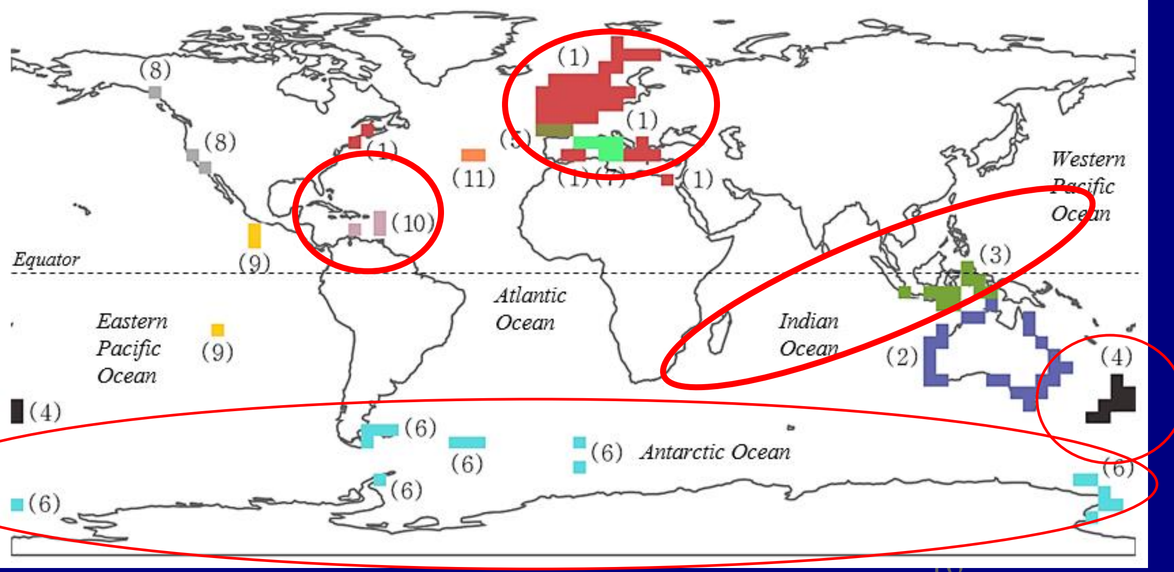
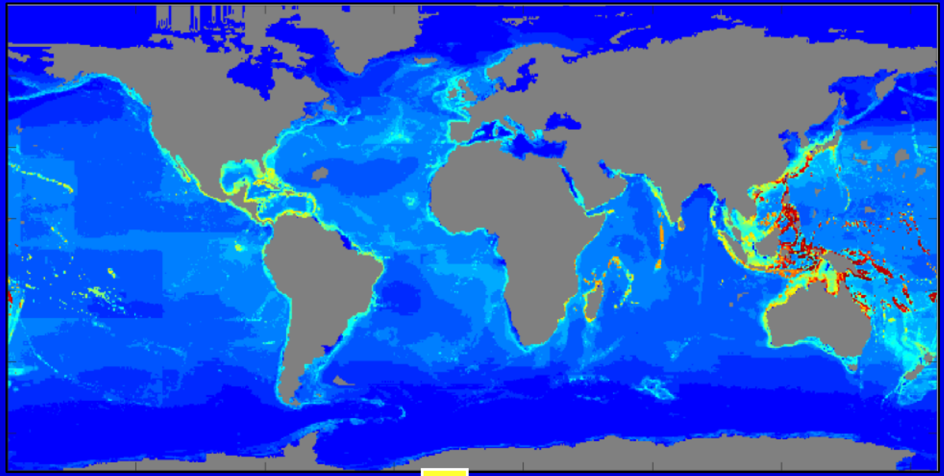
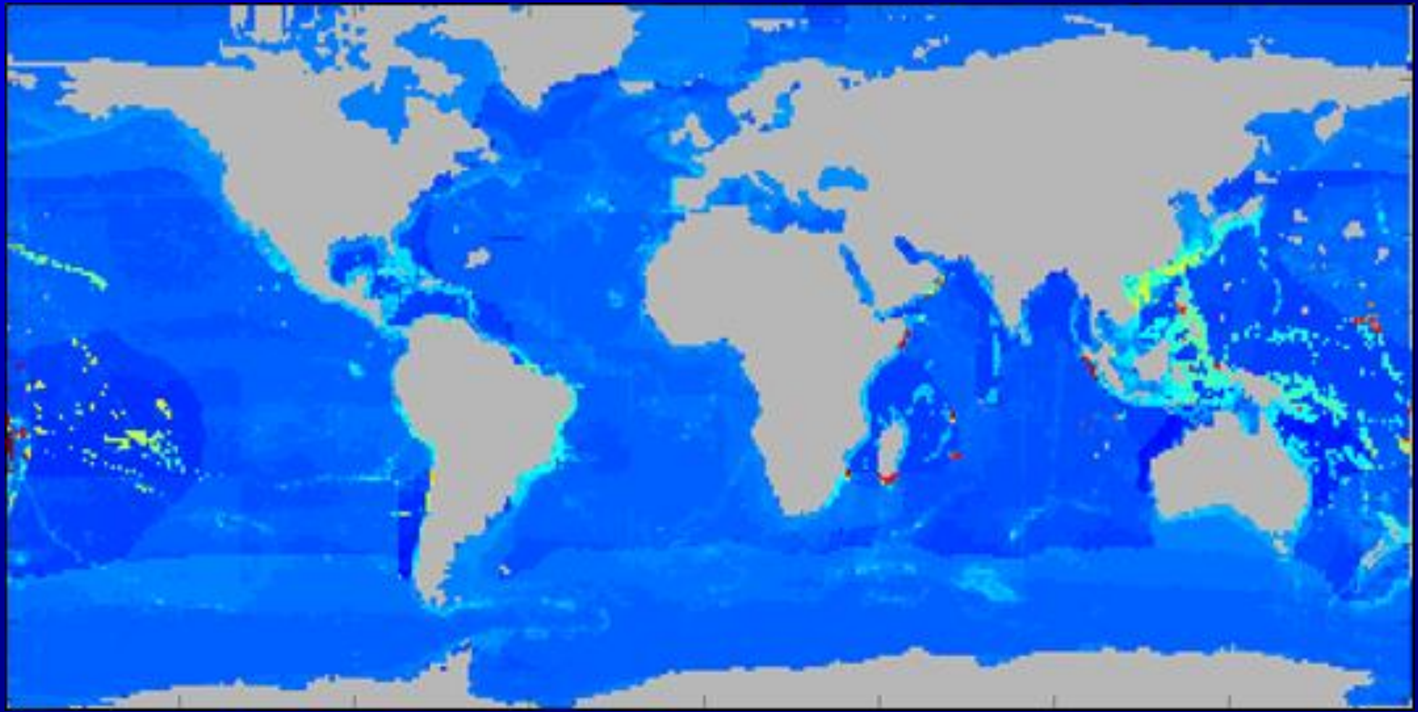


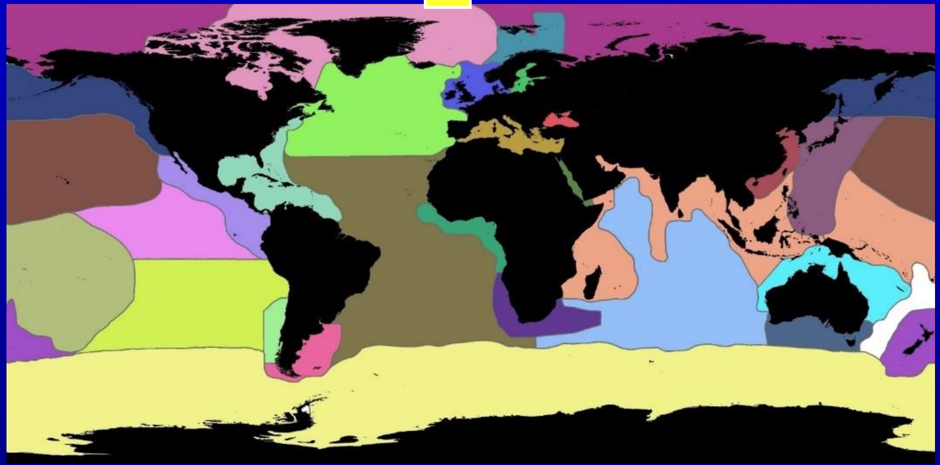


Species richness based on modelled ranges of 24,000 species from AquaMaps



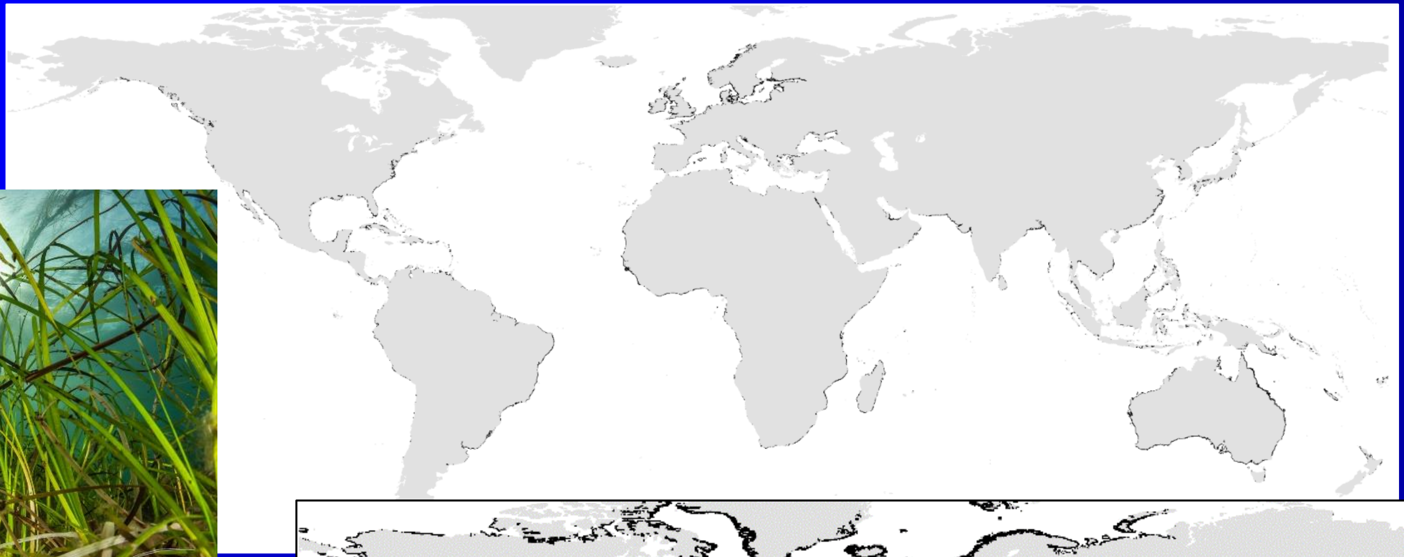
Species richness within realms of endemicity

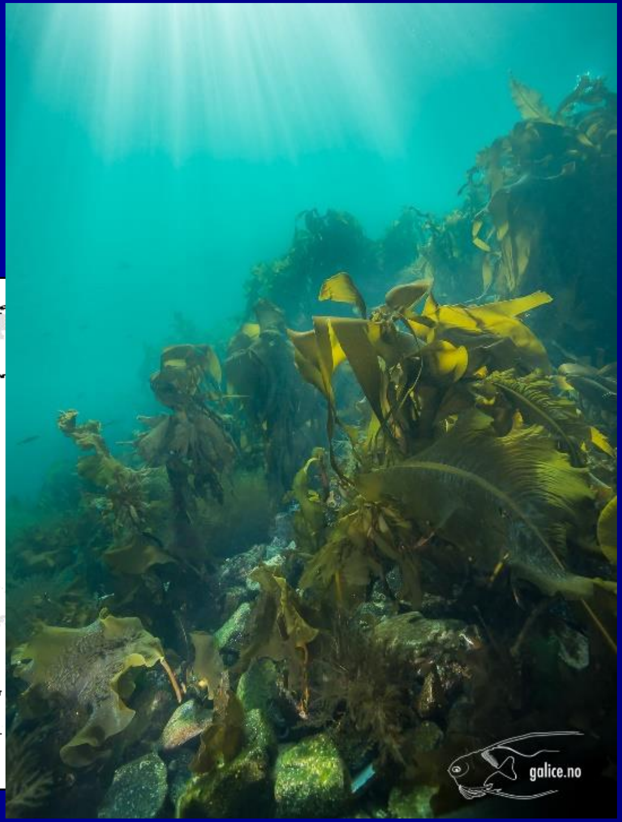




Regions of high endemicity from biogeographic realms

New world maps of seagrass and kelp biomes



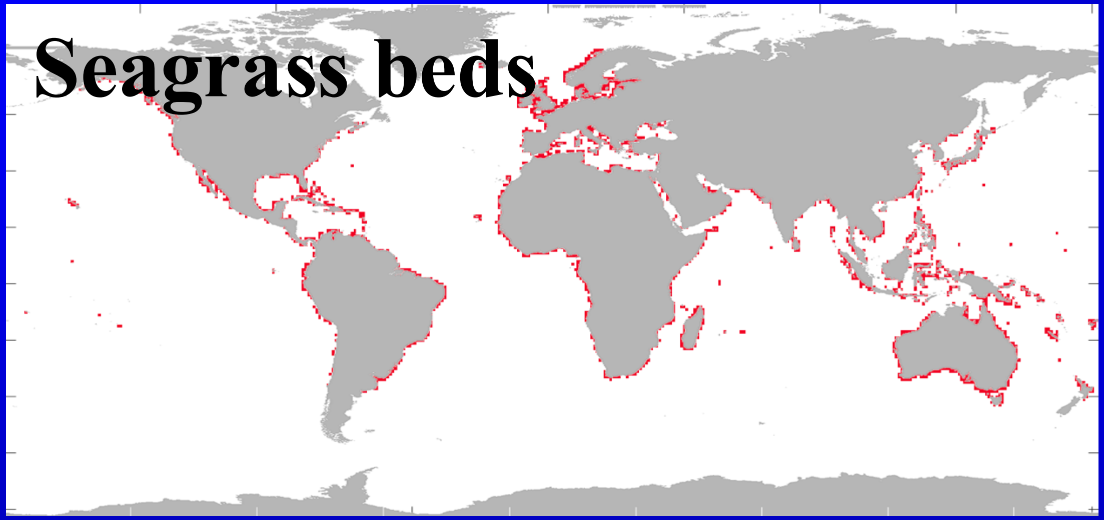


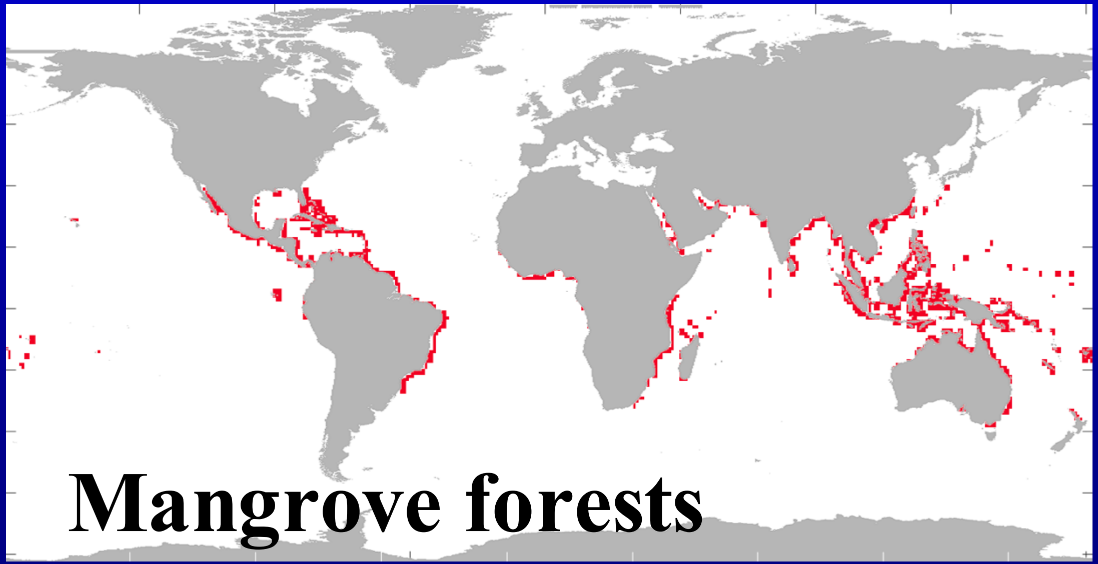
Maps by
Dr Dinusha
Jayathilake

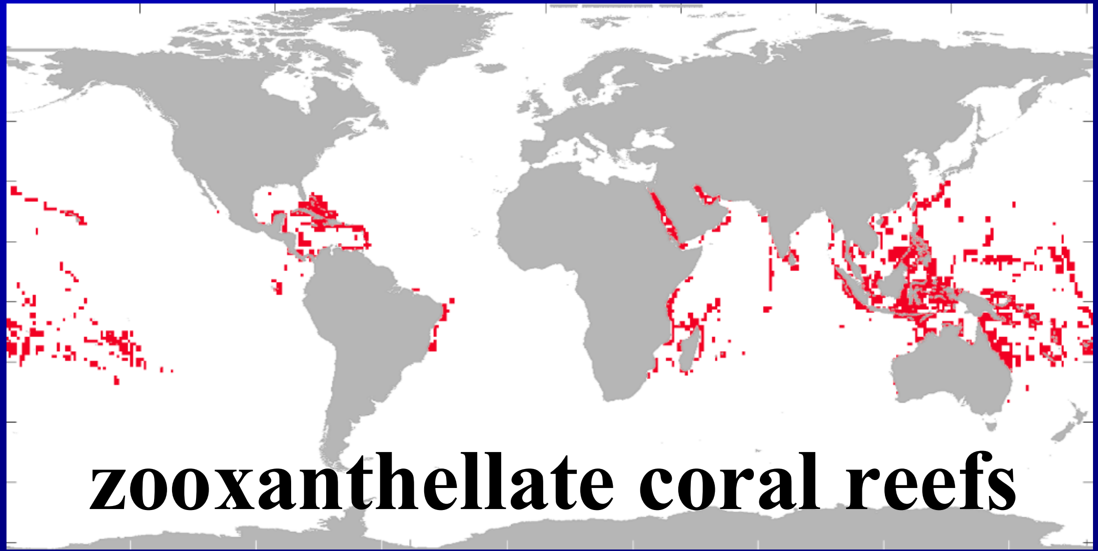
Photos by
Dr Galice Hoarau

GIS maps published at http://data.unep-wcmc.org/datasets
and in the journal *Biological Conservation*

Where do the marine biomes provide productive 3D habitat?



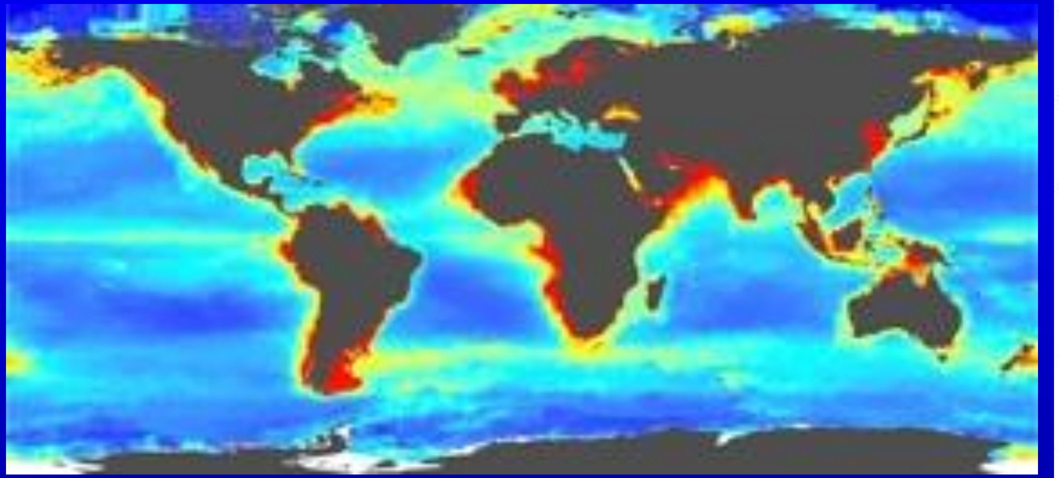


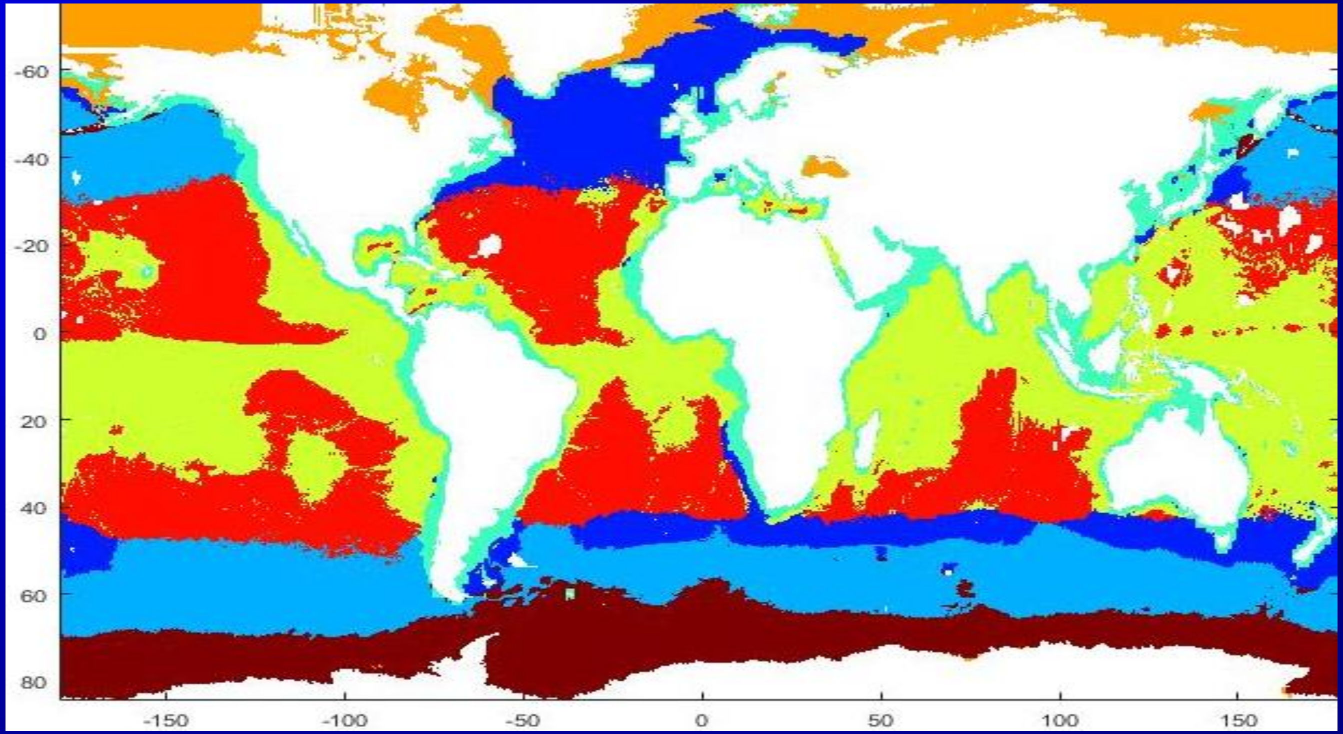


Data from lower maps from UNEP-WCMC Ocean Data Viewer

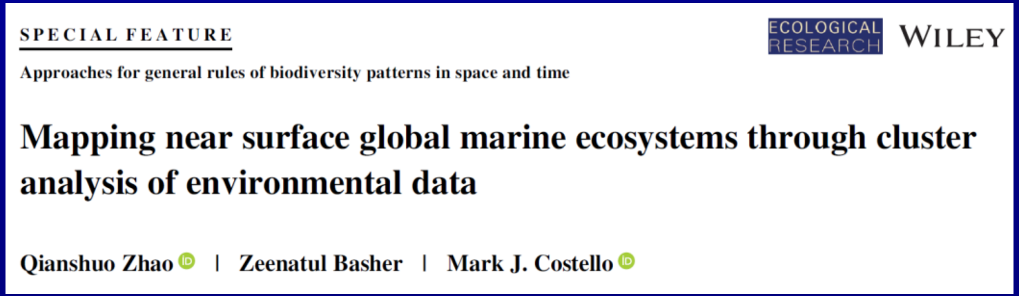
7 marine ecosystems defined by environmental data

Annual phytoplankton productivity is also coastal





7 marine ecosystems distinguished by PCA and k-means clustering of 20 sea surface variables


SPECIAL FEATURE

ECOLOGICAL RESEARCH WILEY

Approaches for general rules of biodiversity patterns in space and time

Mapping near surface global marine ecosystems through cluster analysis of environmental data

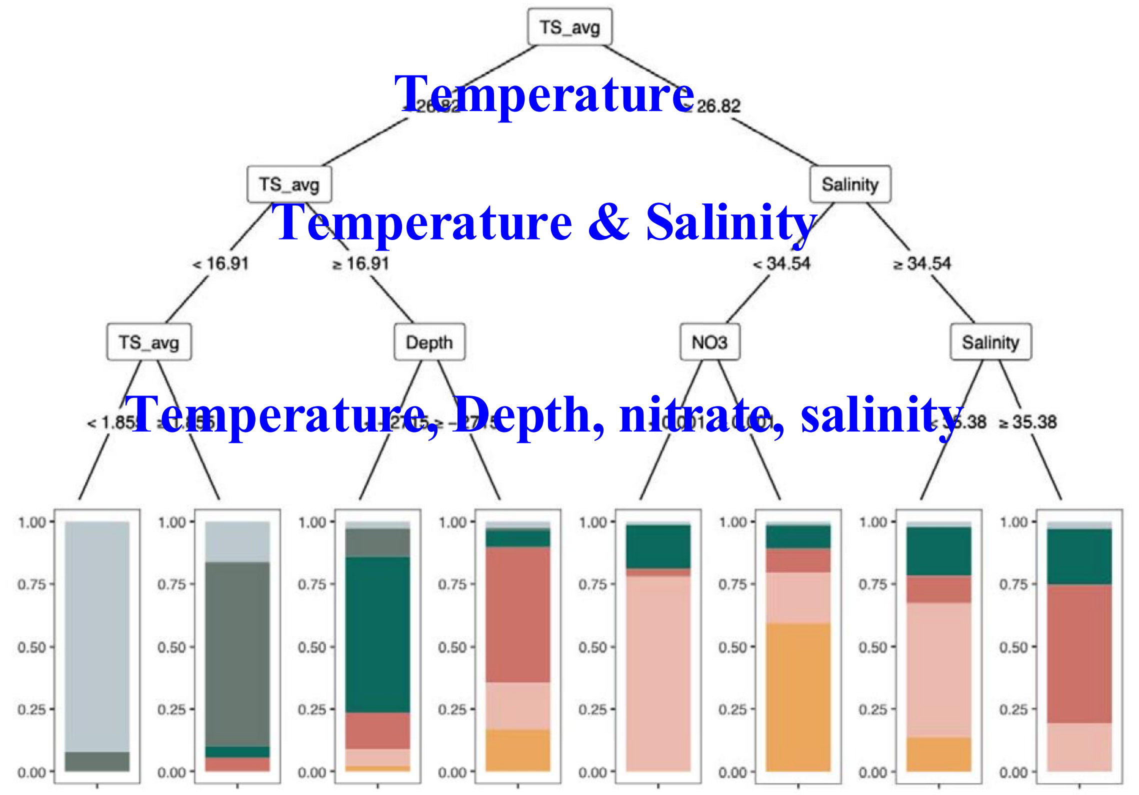
Qianshuo Zhao | Zeenatul Basher | Mark J. Costello

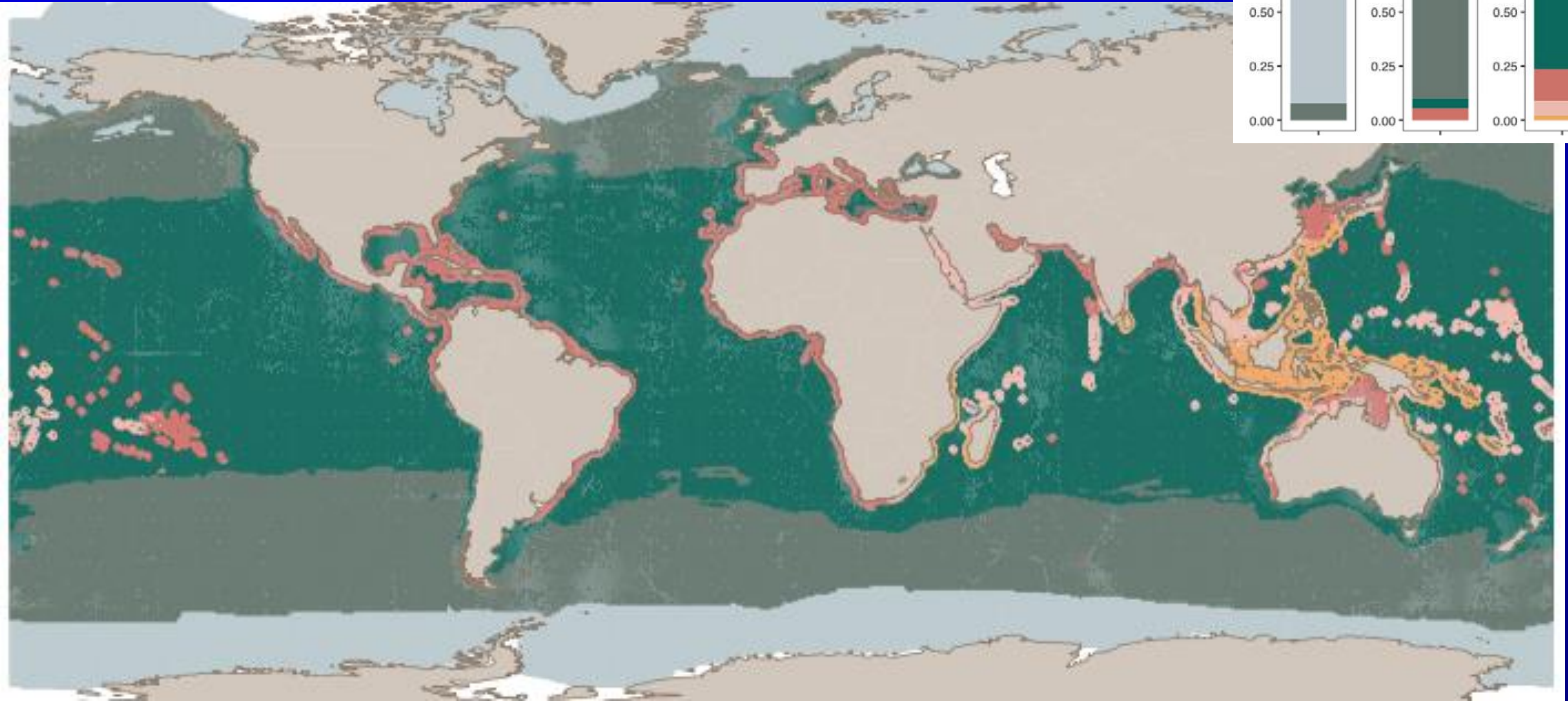
Trophic convergence of marine vertebrate communities worldwide (under review, *PNAS*)

Juan David González-Trujillo, Jorge Assis, Ester Serrão, Mark John Costello,

Eliza Fragkopoulou, Manuel Mendoza, Miguel B. Araújo

The trophic guilds spatially align with Zhao's Ecosystems





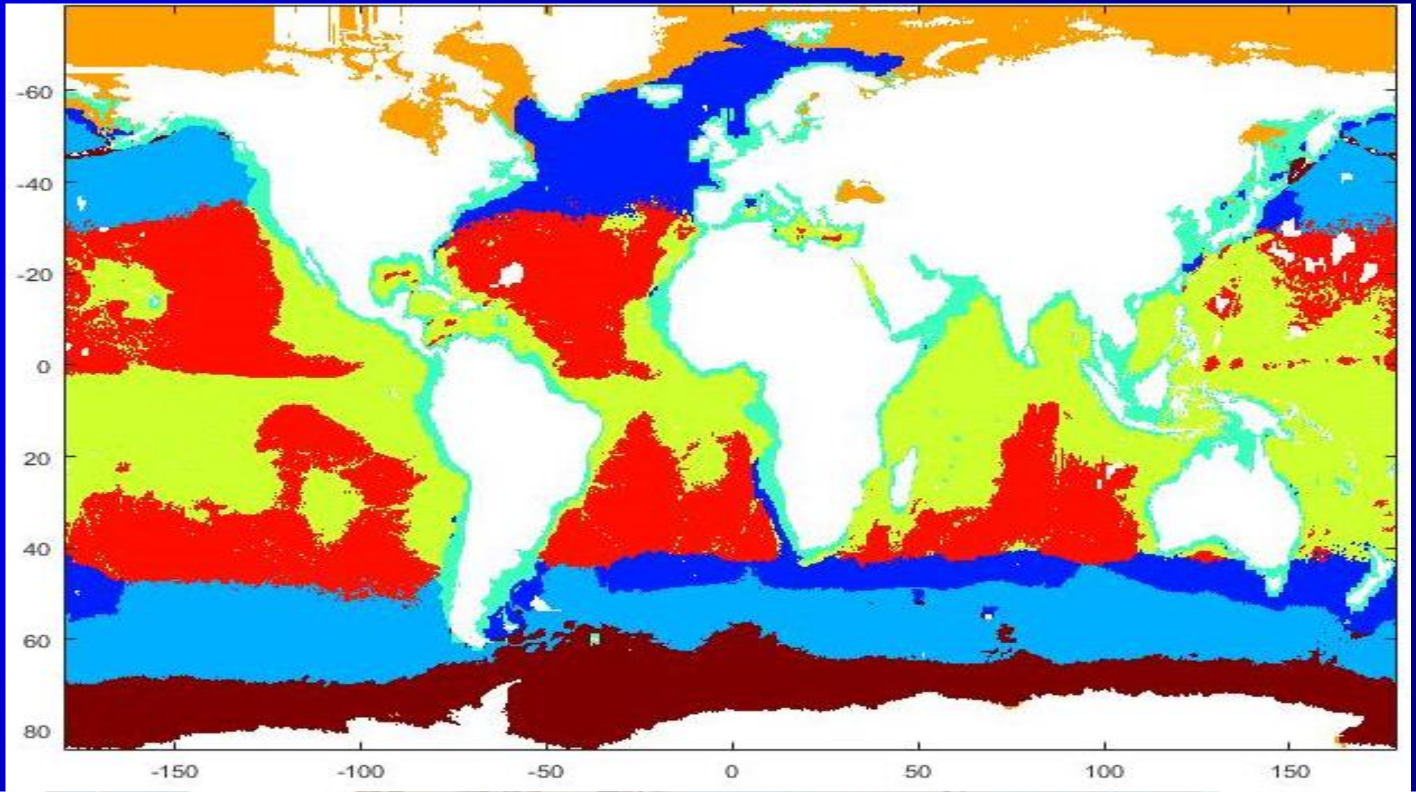
The guilds are distinguished by

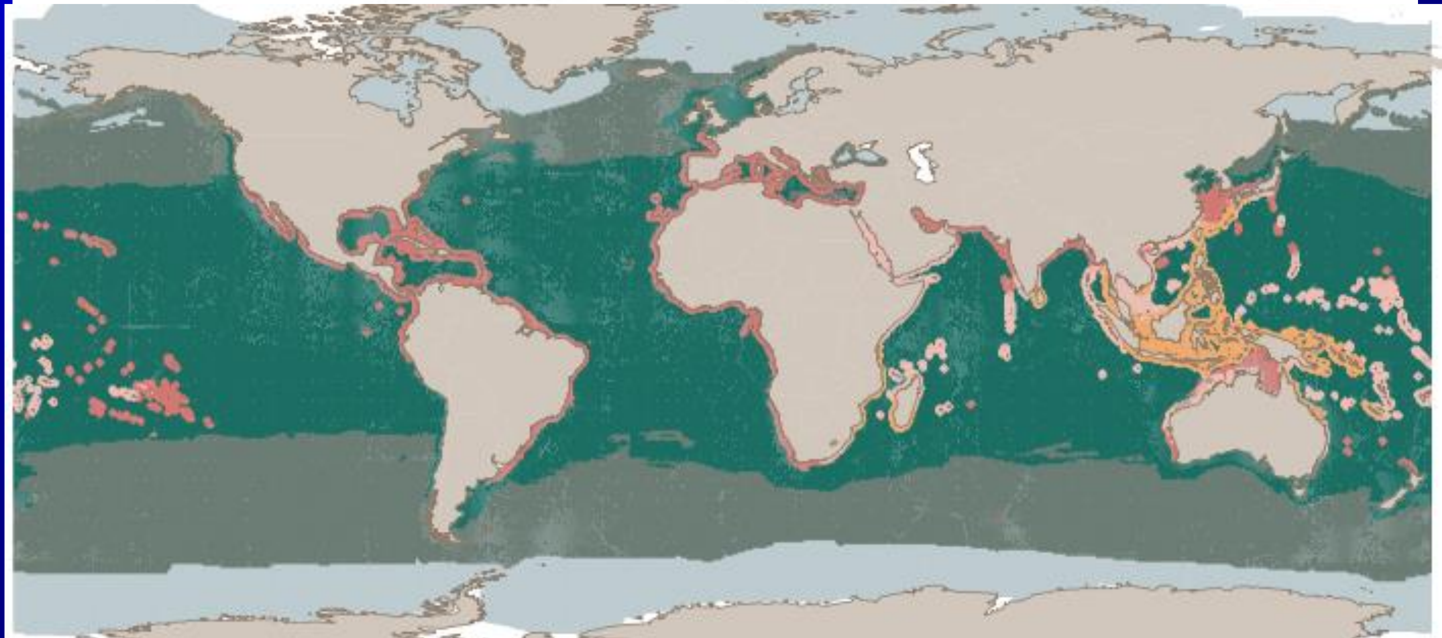
environmental variables,

not biogeography

Ecosystems

Distinct polar, boreal, tropical and
coastal
ecosystems and trophic guilds





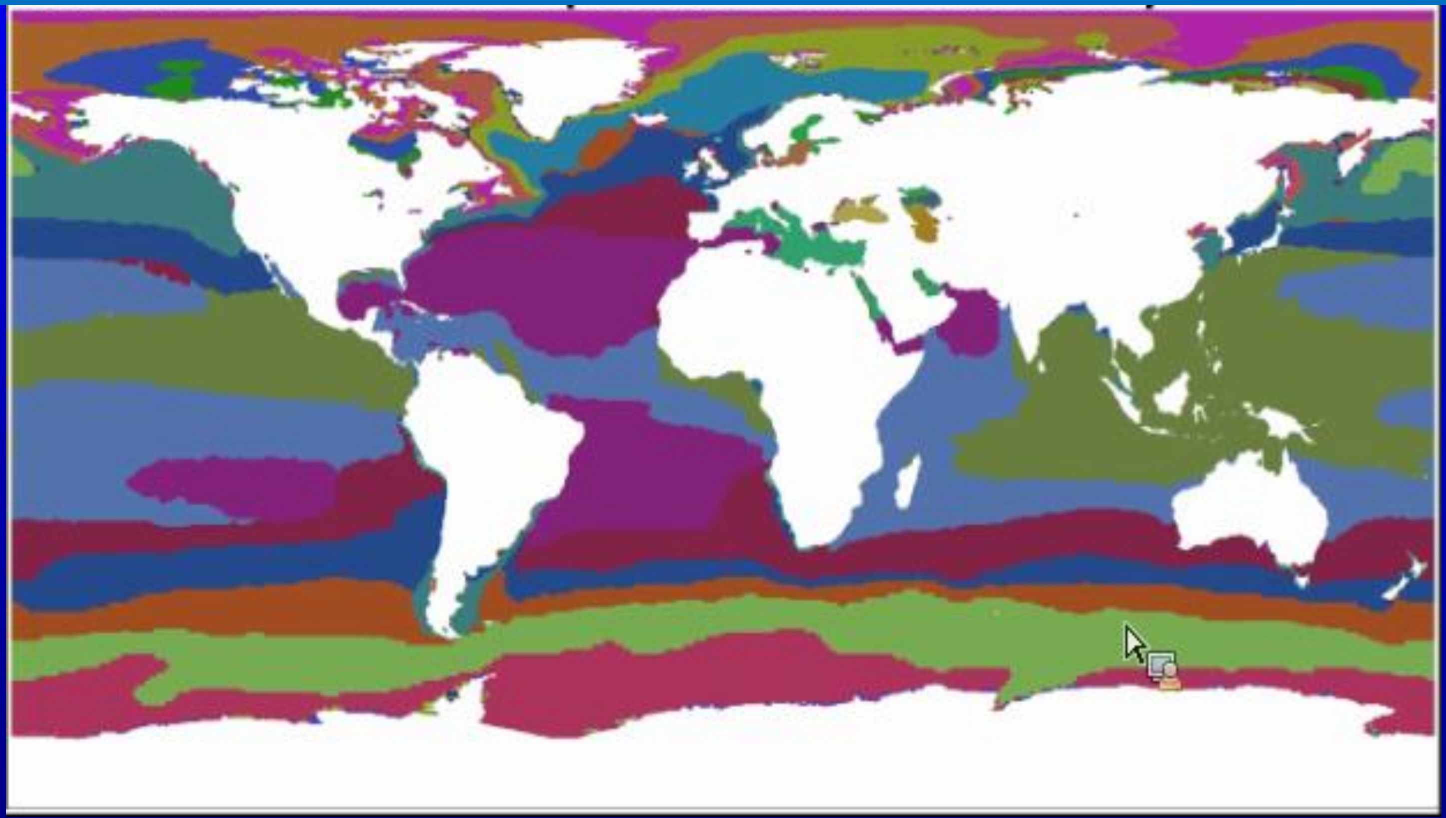
Trophic guilds

3D environmental mapping by Esri

53 million data points in ArcGIS Pro

0.25^{o} latitude-longitude * 5 m to 500 m deep cells

6 variables: **temperature, salinity, oxygen, nitrate, phosphate, silicate**



Called
"Ecological Marine Units"
but conceptually
the same as
Zhao "ecosystems"

Sayre et al. 2017. A three-dimensional mapping of the ocean based on environmental data. *Oceanography*

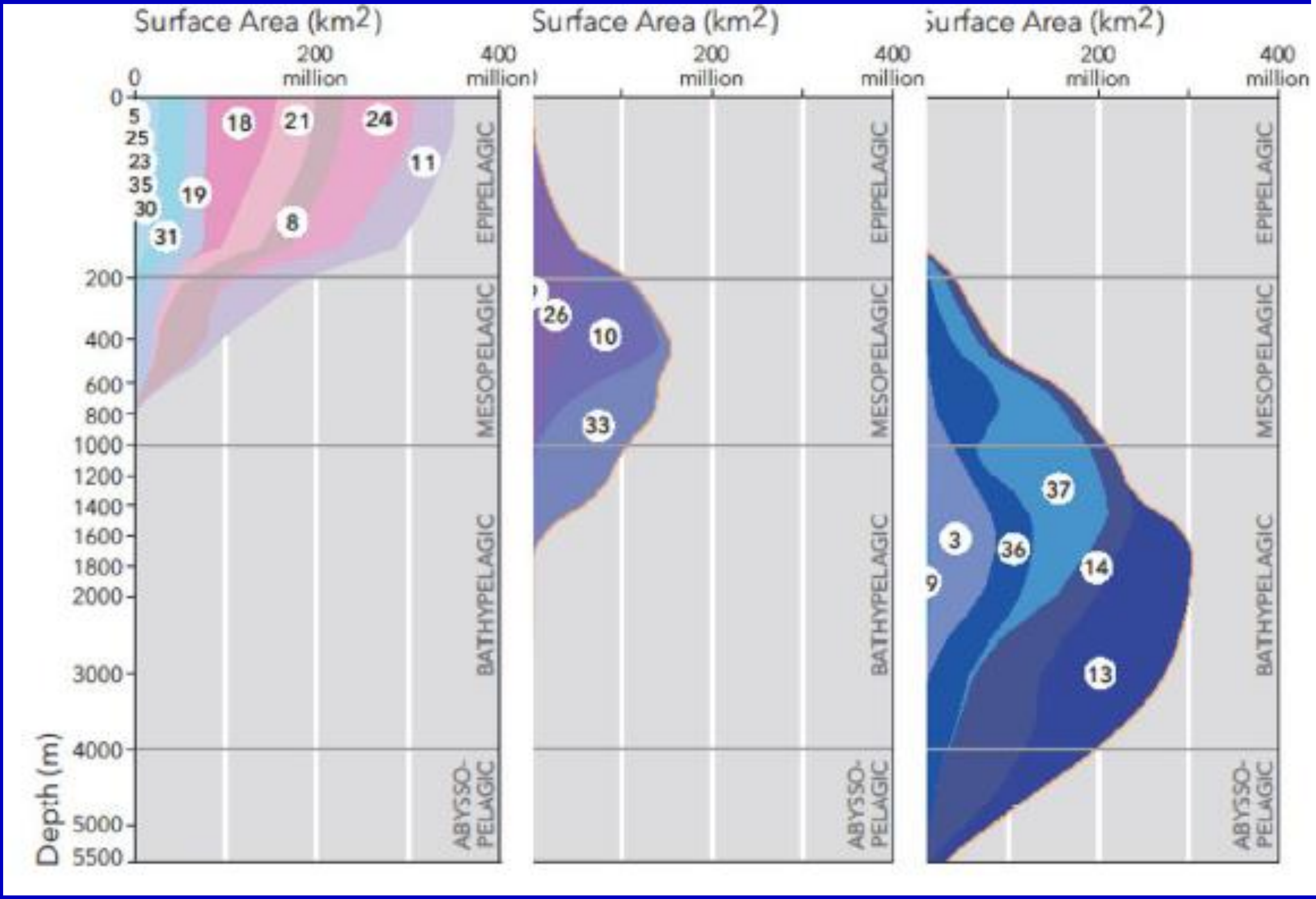
SCIENTIFIC REPORTS

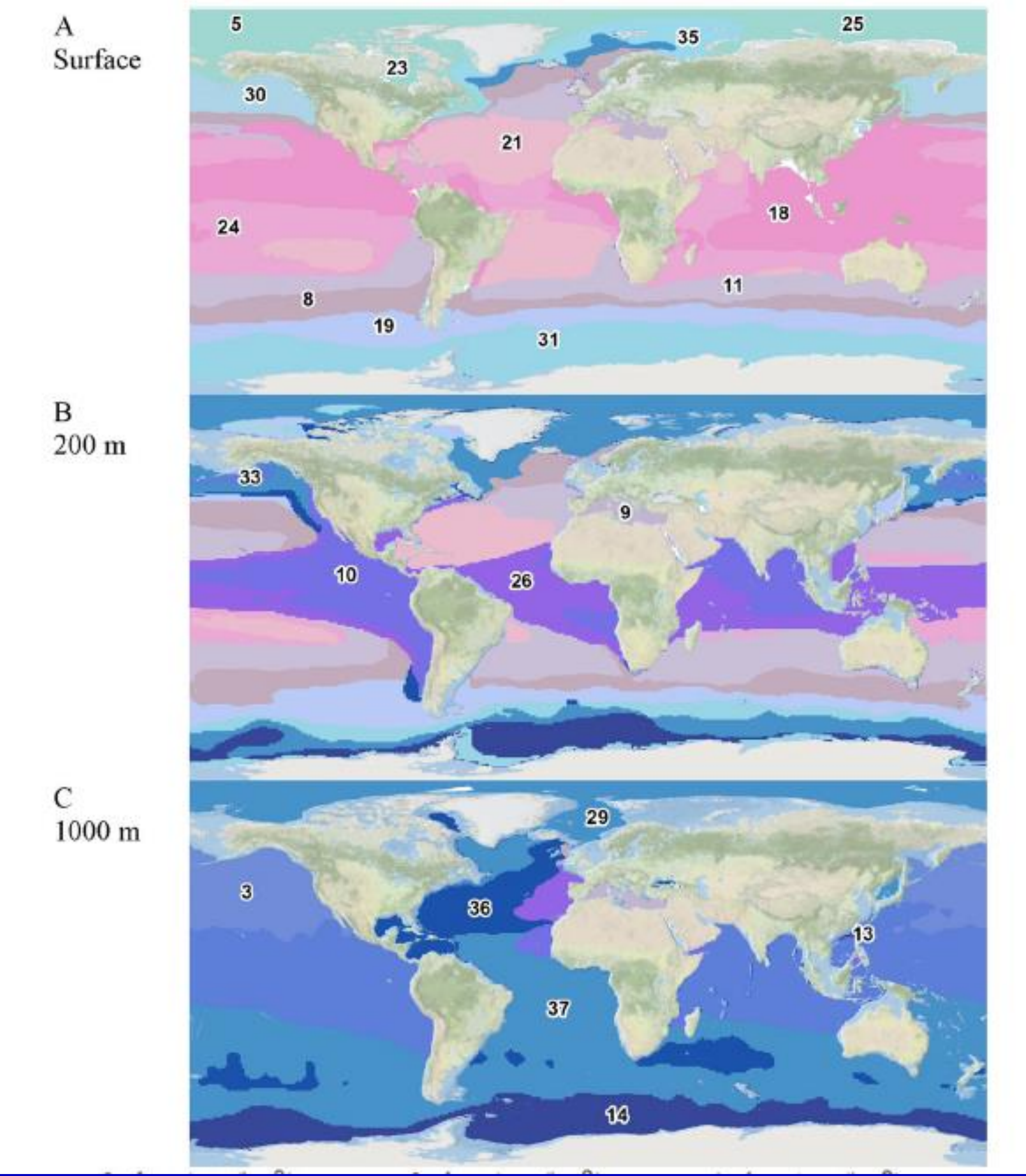
OPEN

Stratifying ocean sampling globally and with depth to account for environmental variability

ed: 5 September 2017

Mark John Costello[1], Zeenatul Basher[2], Roger Sayre[2], Sean Breyer[3] & Dawn J. Wright[3]





SCIENTIFIC REPORTS

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Stratifying ocean sampling globally and with depth to account for environmental variability

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Table 4 Depth zones and associated nomenclature in the ocean.

Depth (m)	Environment	Pelagos	Benthos	Ecosystem function
0	Tidal air exposure	Epipelagic (phytoplankton)	Littoral	Photosynthesis and respiration. Variable nutrients and oxygen.
200	Photic zone		Infralittoral (seaweeds)	
1000	Twilight zone < 1% light	Mesopelagic	Circalittoral	
2000	Aphotic zone < 4 °C	Bathypelagic	Deep-sea	Respiration low. Higher nutrients. Low oxygen.
4000		Abyssopelagic Hadopelagic	Abyss	

No.	Characteristics	Sea areas
7	Cool Brackish	Caspian
32	Warm Brackish	Caspian
15	Cold Brackish Anoxic High Si *deep*	Black
4	Cold Brackish Anoxic High Si	Black
34	Very Cold Brackish Anoxic High Si	Black
10	Cold Anoxic *deep*	Tropical Indian, Atlantic, Pacific
26	Cool Hypoxic *deep*	Tropical
3	Very Cold Anoxic High Si *deep*	N. Pacific, Arabian
33	Very Cold Anoxic med Si *deep*	Tropical Pacific, Indian
9	Cool	Mediterranean, Red
29	Very Cold *deep*	Arctic, N. Atlantic
36	Very Cold *deep*	
37	Very Cold med Si *deep*	Sub-Antarctic, S. Atlantic, N. Pacific
13	Very Cold Hypoxic High Si *deep*	Pacific, Indian
14	Very Cold High Si *deep*	Antarctic, Sub-Antarctic
19	Cold	Sub-Antarctic, N. Pacific
8	Cool	Sub-Antarctic, N. Atlantic, N. Pacific
11	Cool	Subtropical N. S.
31	Frozen med Si	Antarctic, Bering
2	Cold Brackish Hypoxic	Black, Caspian
20	Very Cold Brackish	Baltic
1	Cold Brackish Anoxic High Si	Black, Caspian
12	Very Cold Brackish Anoxic	Baltic
16	Very Cold Brackish Anoxic	Baltic
17	Cold Brackish Anoxic	Baltic
28	Cool Brackish	Caspian
18	Warm	Subtropical N. Pacific, Indian
21	Warm	Subtropical Atlantic, S. Pacific
24	Warm	Tropical Pacific, Indian, Atlantic
23	Frozen	Arctic, Labrador
25	Frozen	Arctic, Labrador
6	Cold Brackish	Black, Caspian
27	Very Cold Brackish	Caspian
30	Very Cold	N. Pacific, Beaufort
35	Frozen	Arctic, Labrador
5	Frozen Brackish	Arctic
22	Cold Brackish Hypoxic	Baltic, Black

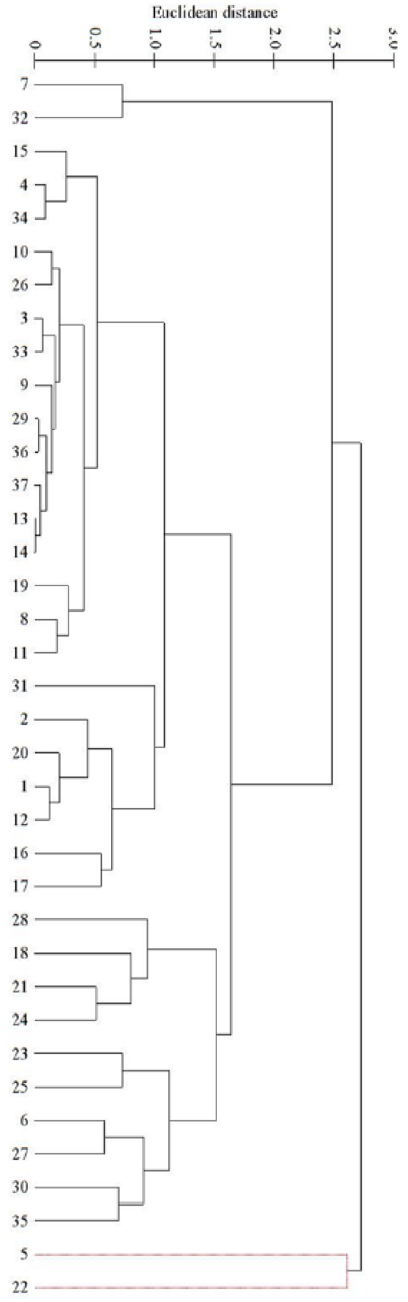
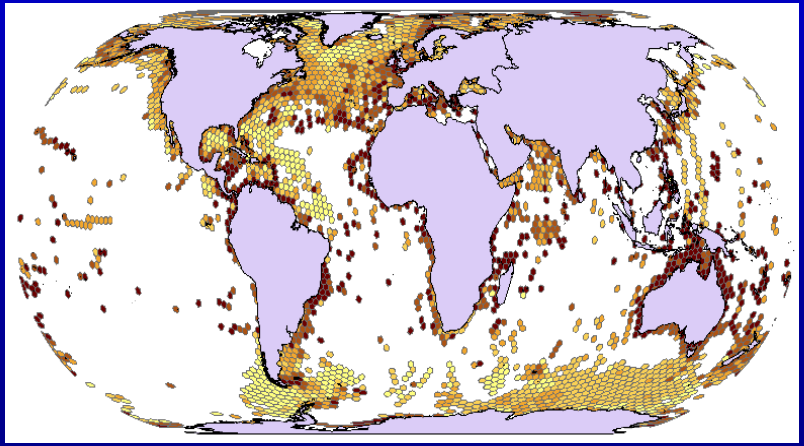
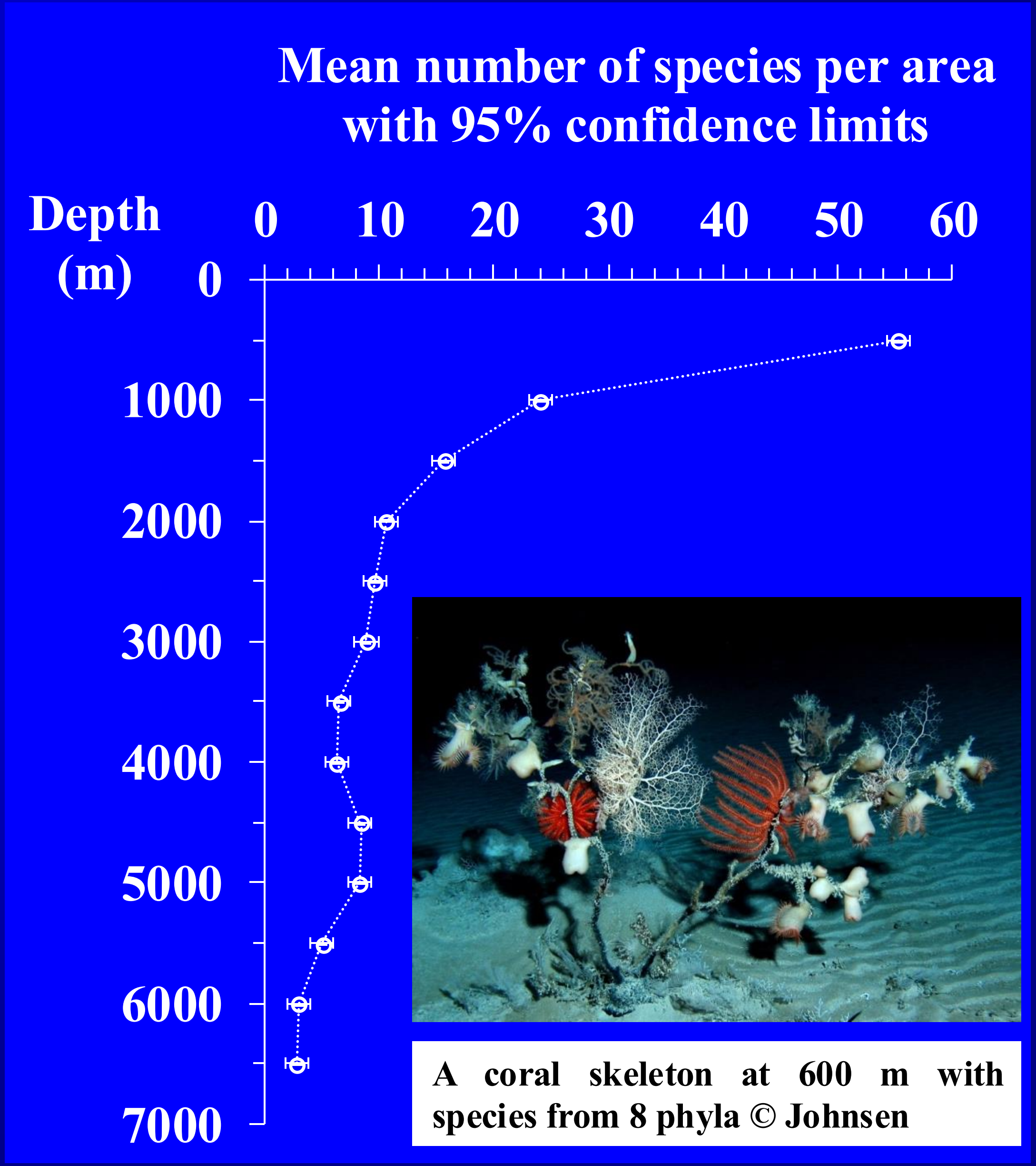


Figure 6. Hierachical classification of Ecological Marine Units according to the similarity of their environments based on salinity, temperature, oxygen, nitrate, phosphate, and silicate. N = north, S = south.

- **Number of species declines with depth in the ocean**
- **Most species are shallow water**

51,000 species analysed in 50,000 km^2 hexagons by Dr Chhaya Chaudhary





A coral skeleton at 600 m with species from 8 phyla © Johnsen

Costello & Chaudhary 2017. Marine biodiversity, biogeography, deep-sea gradients, and conservation. *Current Biology* 27

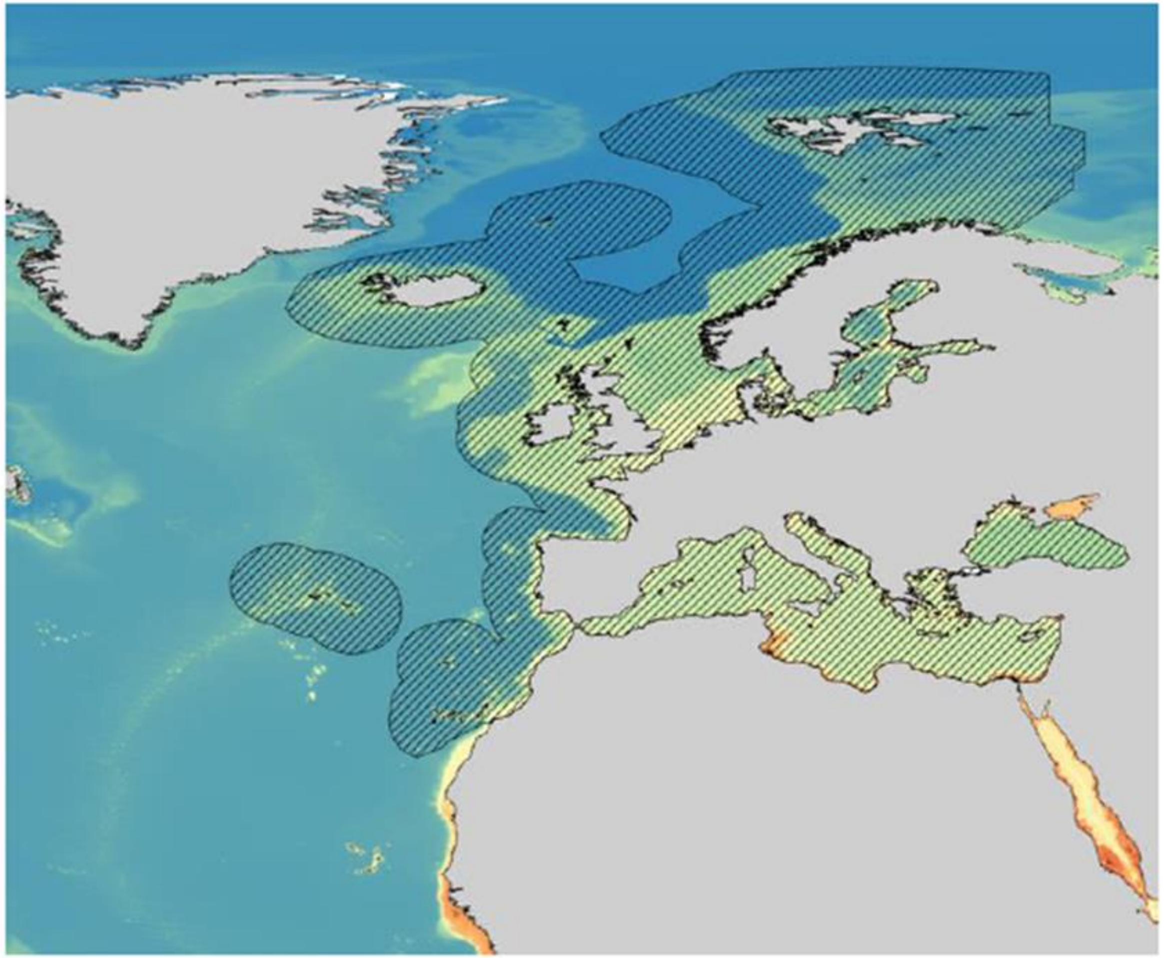
For Europe

1. Now we have more environmental and biological data
2. Newly available variable “wave exposure”
3. Models of oceanographic connectivity
4. At finer scale spatial resolutions
5. For recent and climate change scenarios

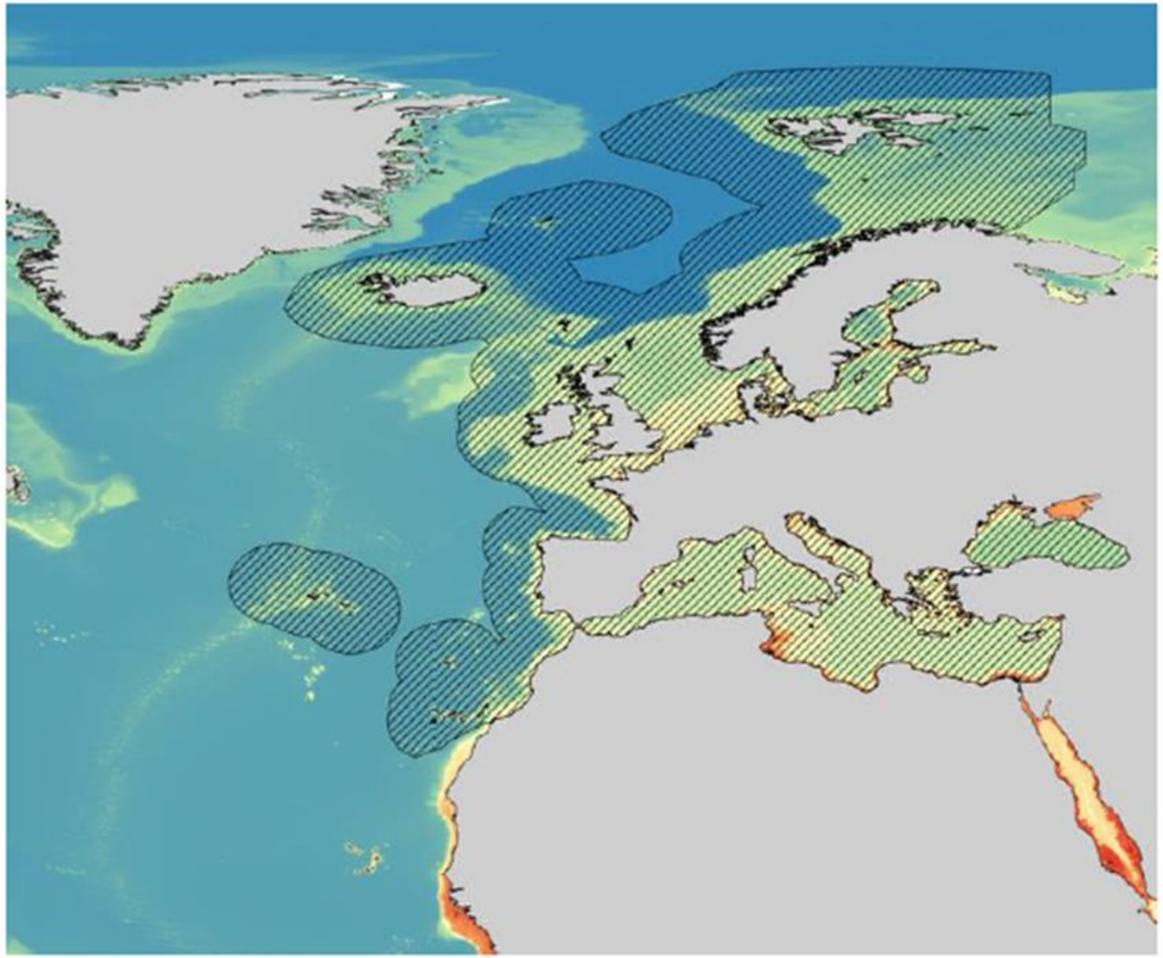
WP2 - ecosystem and connectivity modelling

24 Environmental variables

Modelled in updated version of BioOracle (open access)



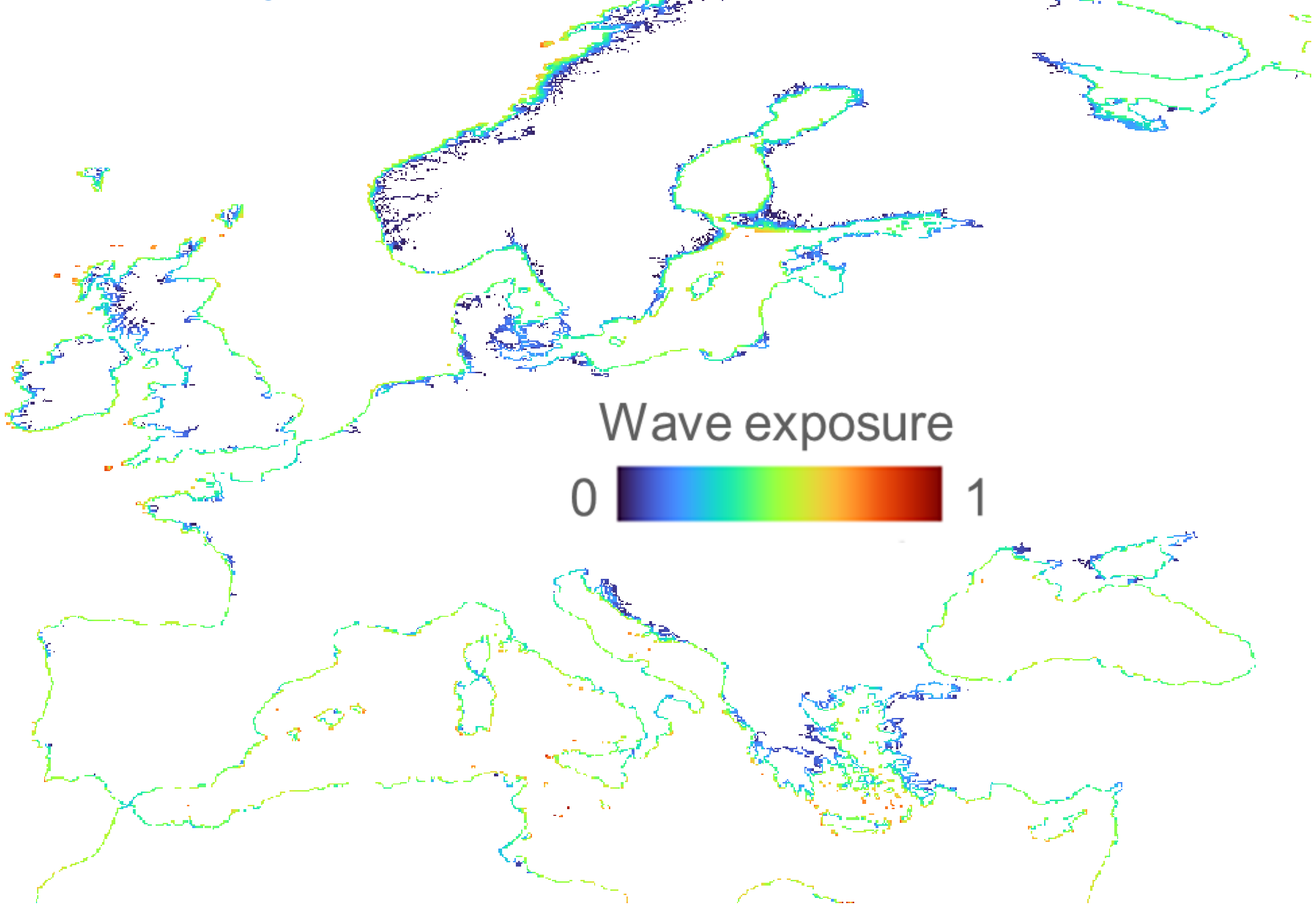
Present-day seafloor temperature



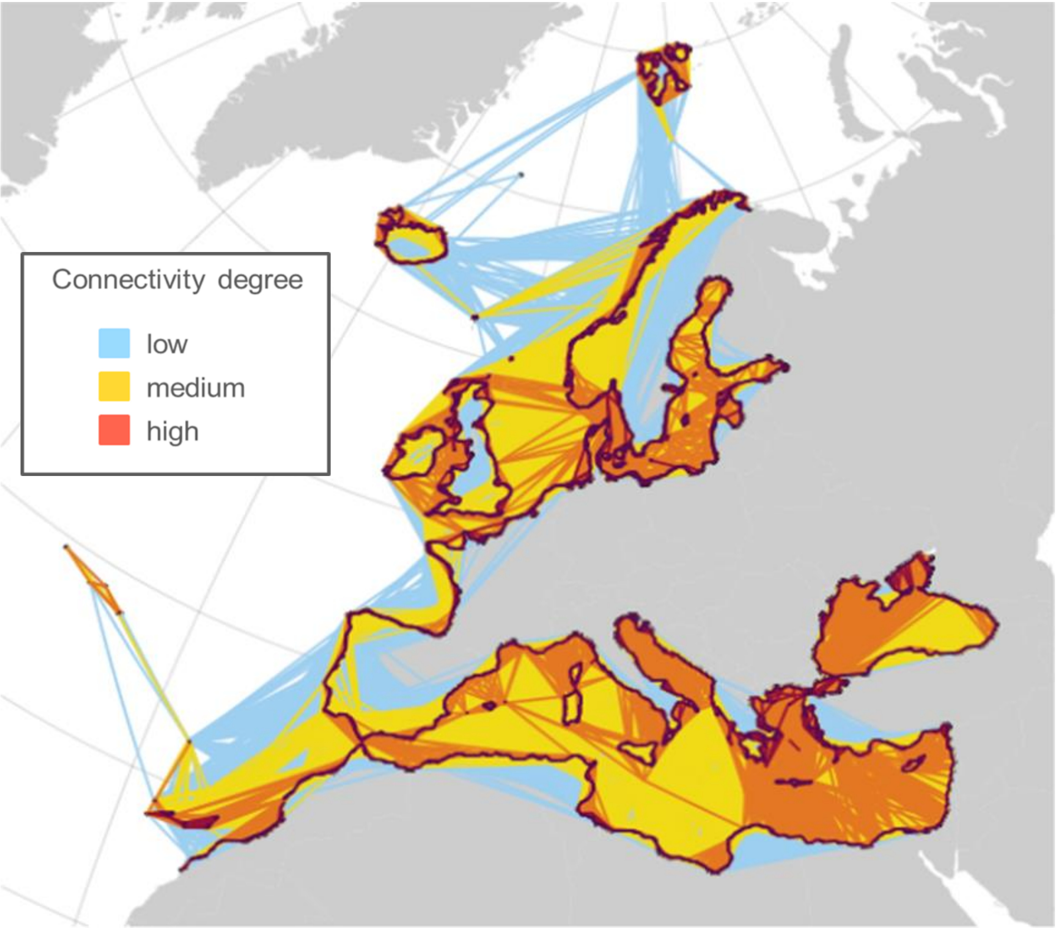
Future (decade 2090) seafloor temperature

WP2 - ecosystem and connectivity modelling

WAVE EXPOSURE – significantly influences distribution of marine species (and organic carbon) but no European scale data on it previously available

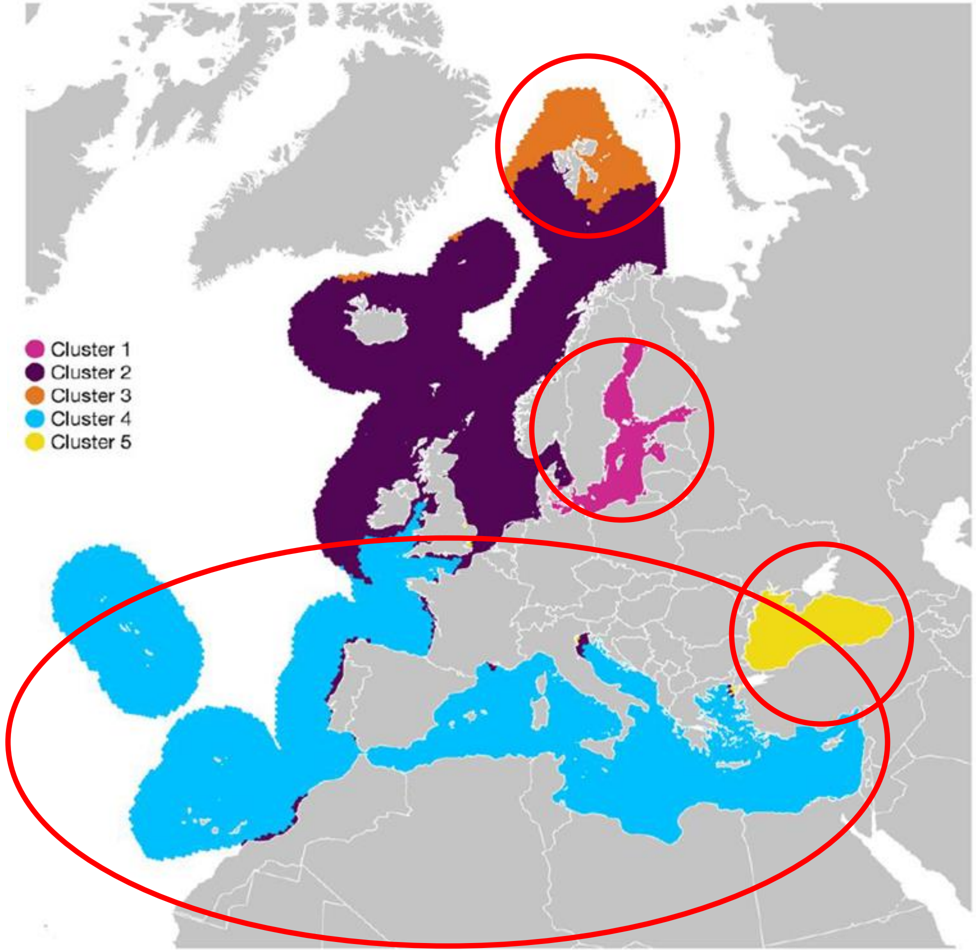


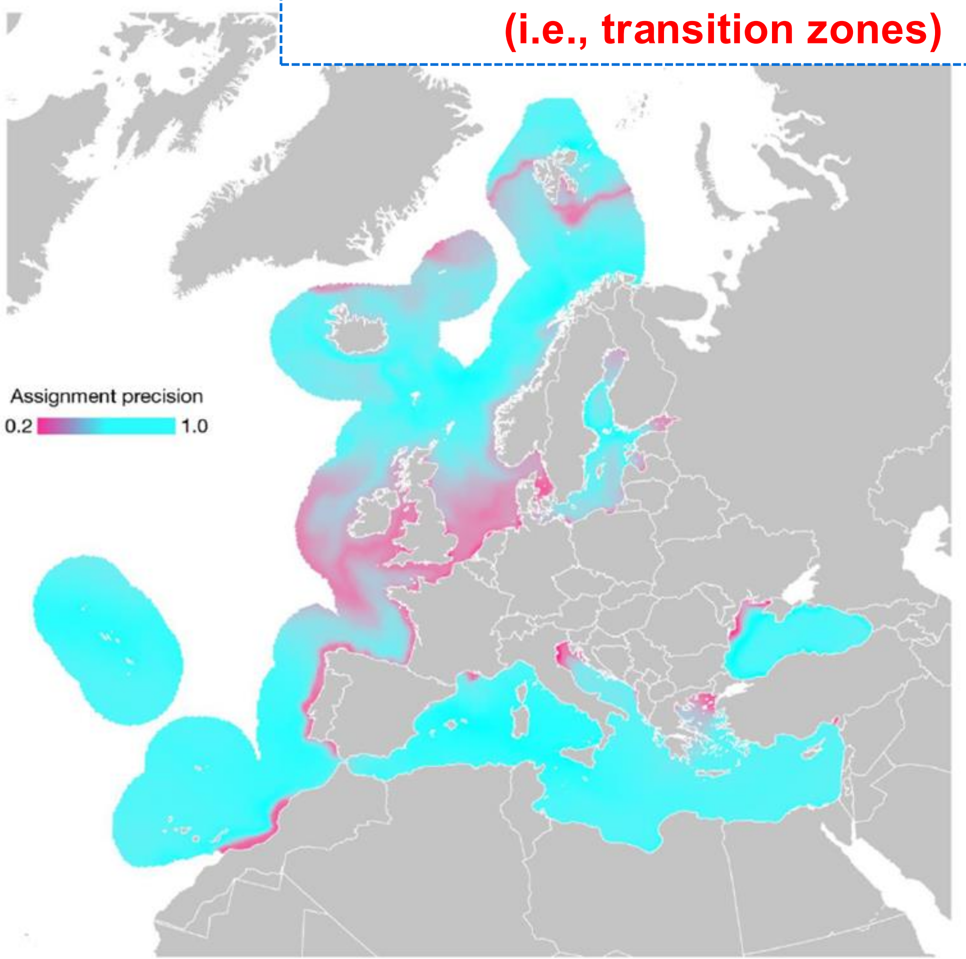
OCEANOGRAPHIC CONNECTIVITY



Ecosystem classification – sea surface

Lower precision = greater environmental variability (i.e., transition zones)

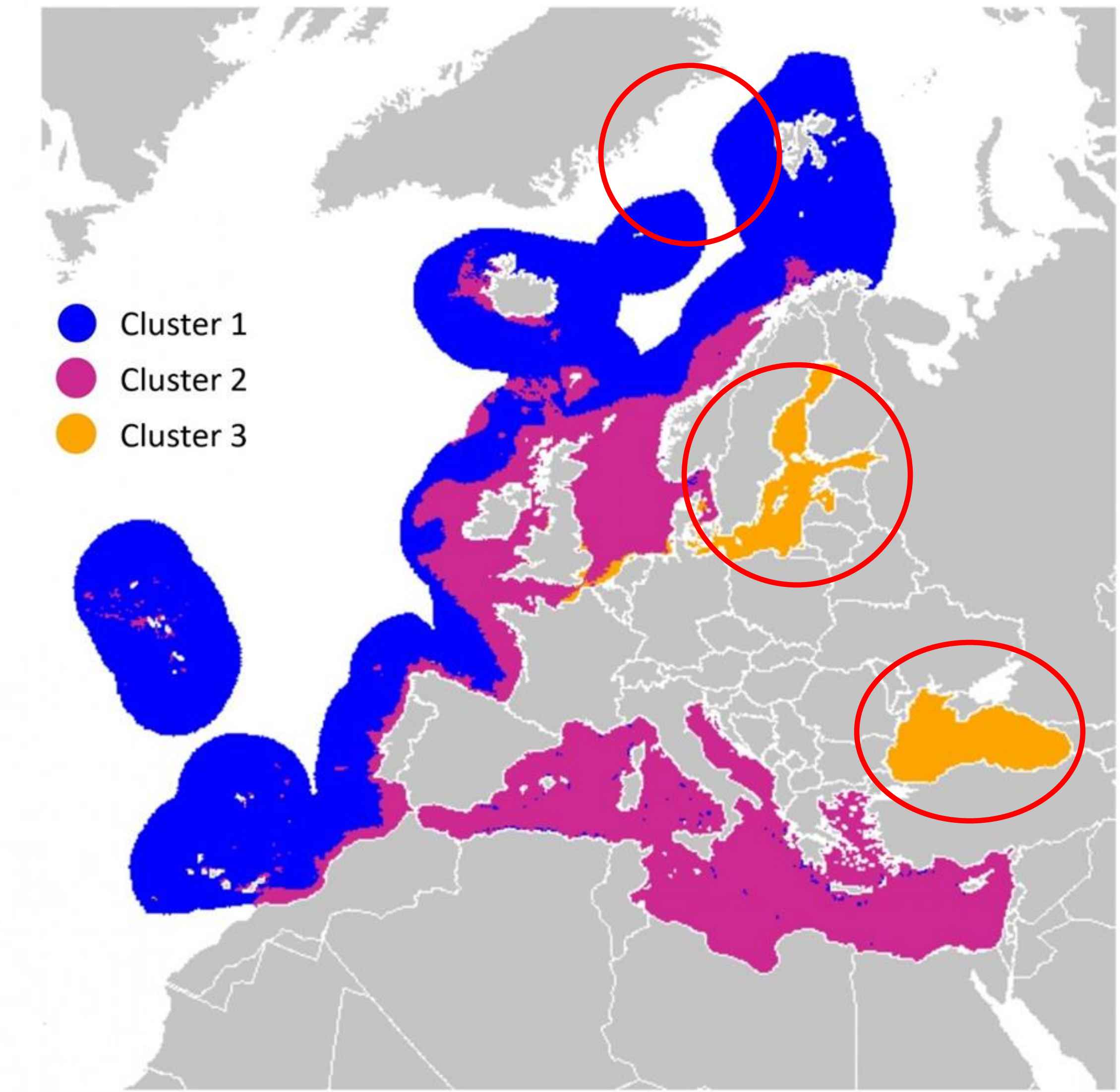


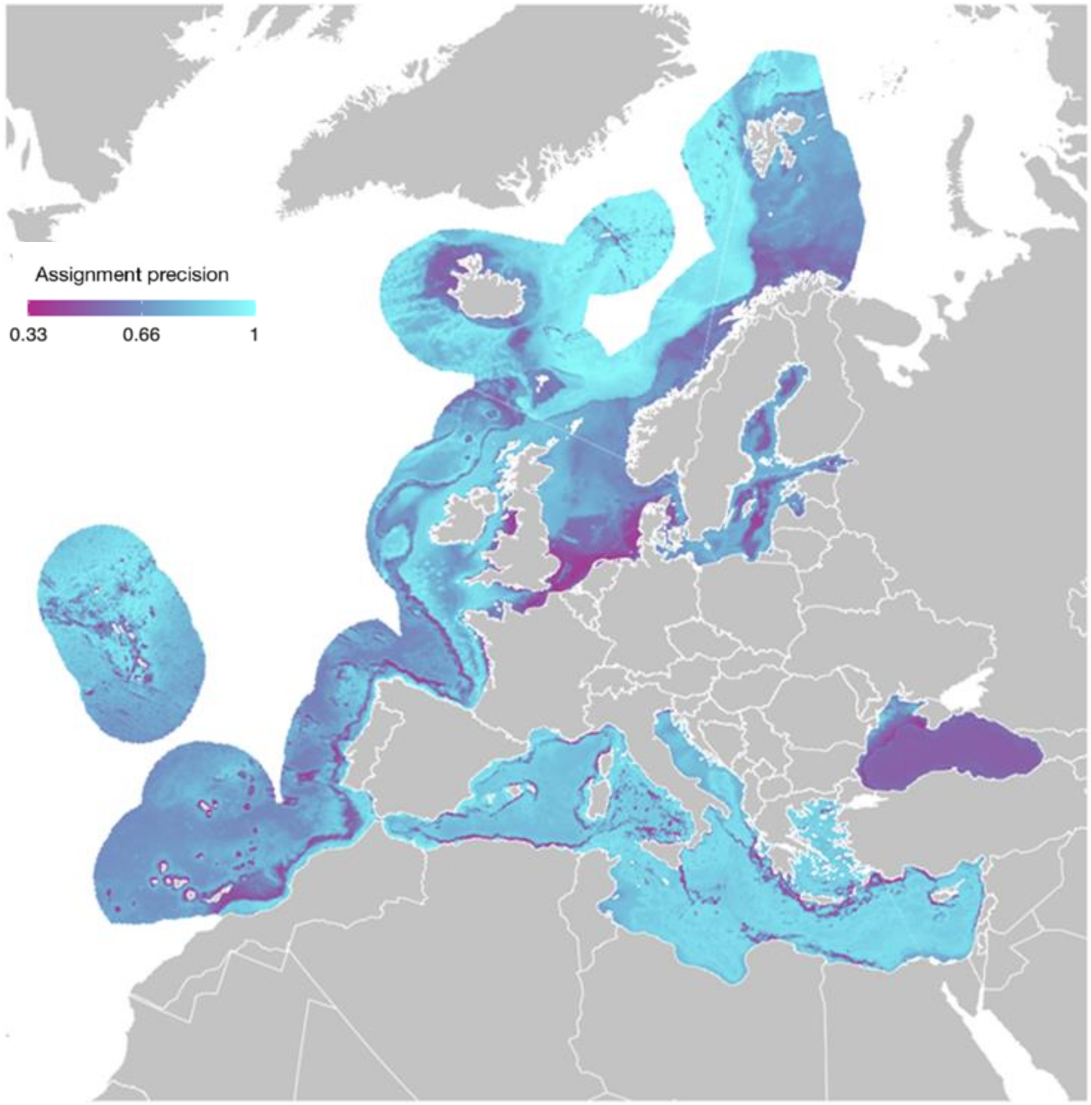


European marine ecosystems of **surface waters** estimated by k-means clustering analysis of environmental data (left) and clustering assignment precision based on fuzzy logic (right)

WP2 - ecosystem and connectivity modelling

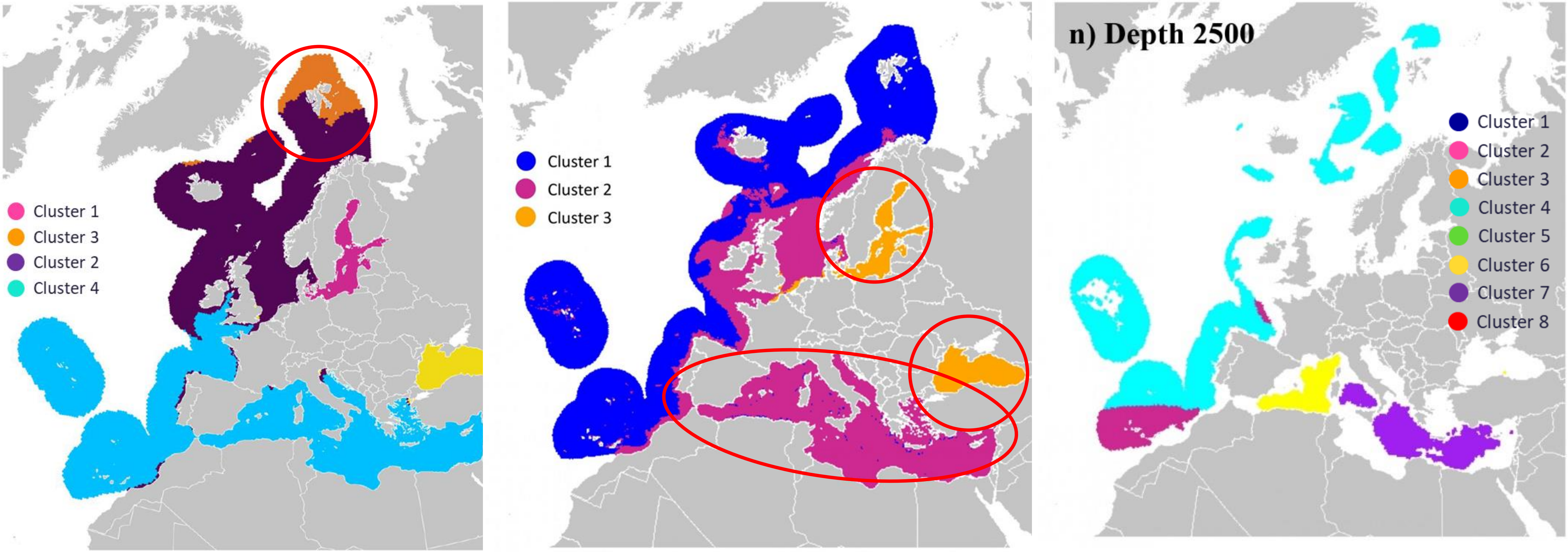
Ecosystem classification – near seabed





WP2 - ecosystem and connectivity modelling

Classifying marine ecosystems – but what is their biological significance?



SURFACE WATERS

NEAR SEABED WATERS

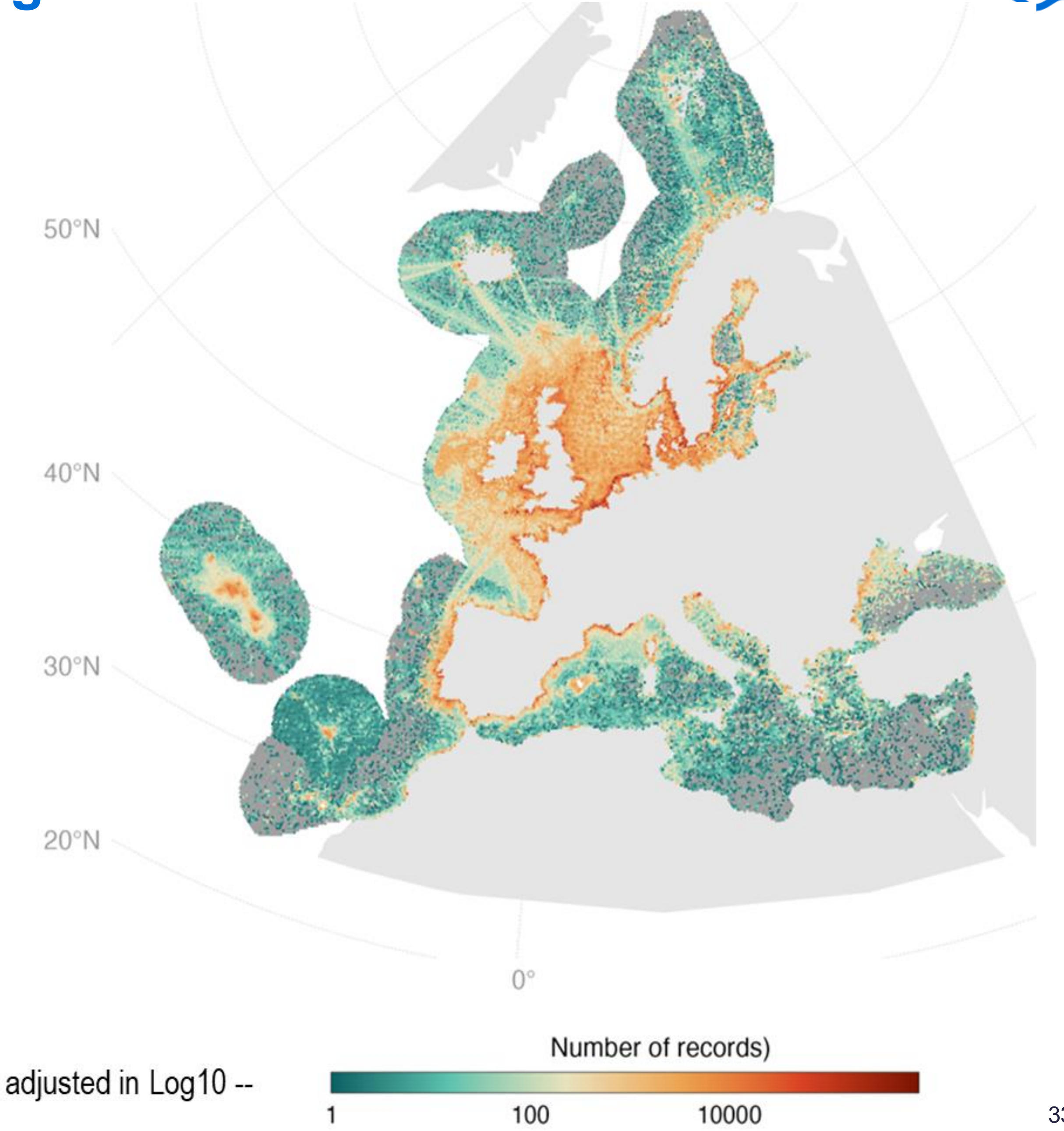
DEPTH-INTEGRATED
(ALL DEPTHS FROM 0 TO 2,500 m)

WP3 – species and biogenic habitat distributions

~ 35,000 species

➢ 67,000,000 records

> 12,000 species ranges modelled



Marine species biogeography

Not in original proposal

Aim

How do "ecosystems" classified based on environment variables align with biogeography (i.e., species composition)?

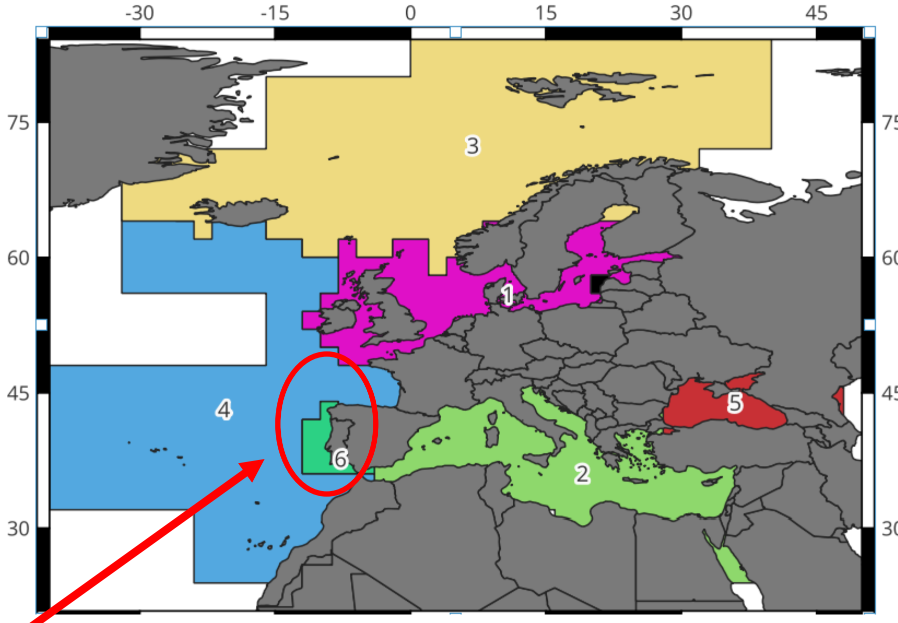
Use neural network analysis (InfoMap Bioregions) to define biogeographic regions for European seas using 5,000 species'

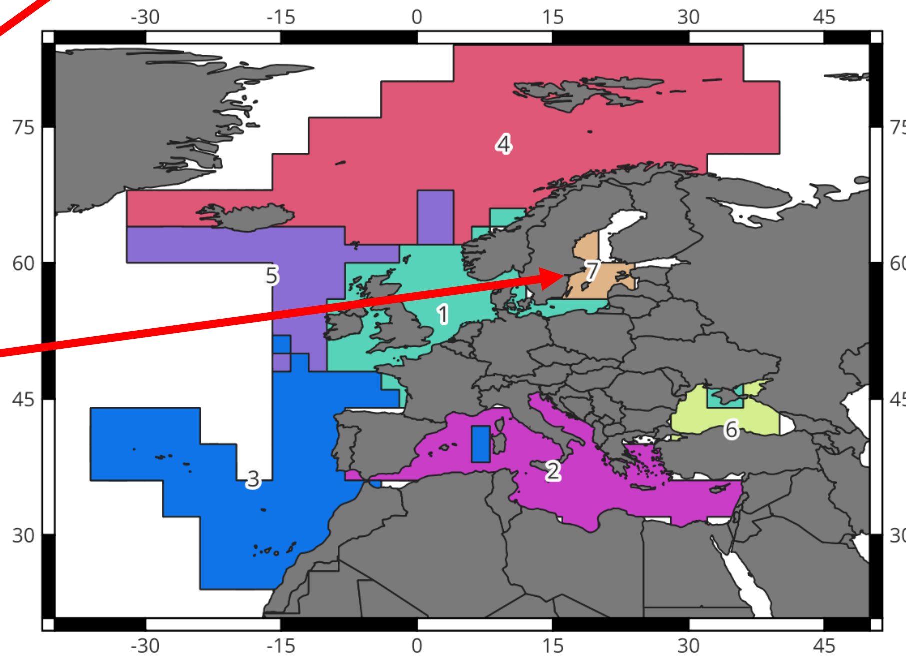
- distribution records in OBIS (subject to sampling bias, underestimate species distribution): n = **6 realms**
- range maps from AquaMaps (overestimate species occurrence): **7 realms**

West Iberian realm artefact of data in OBIS

Note brackish realm 7 in AquaMaps

Comparison with ecosystem classification in progress





key messages

1. Present regions “Basins” are a good approximation of species’ biogeography
2. The MPA network may need to include the 6 regions*
3. but the prioritisation analysis may account for this if species used are representative of all the study area.

*Baltic, Black and Mediterranean Seas

*Arctic-Boreal, Mid-European Atlantic

*Offshore mid-southern European Atlantic

Marine biogeographic realms and species endemicity

nature COMMUNICATIONS

Mark J. Costello[1,2], Peter Tsai[2], Pui Shan Wong[2], Alan Kwok Lun Cheung[3], Zeenatul Basher[1,4] & Chhaya Chaudhary[1]

Marine Biodiversity, Biogeography, Deep-Sea Gradients, and Conservation

Current Biology

Mark J. Costello* and Chhaya Chaudhary

Contents lists available at ScienceDirect

Biological Conservation

A modelled global distribution of the kelp biome

Dinusha R.M. Jayathilake *, Mark John Costello

A modelled global distribution of the seagrass biome

Dinusha R.M. Jayathilake*, Mark J. Costello

World Maps of Ocean Environment Variables

Zeenatul Basher, Institute of Marine Science, The University of Auckland, A
Mark J Costello, School of Environment, The University of Auckland, Auck

Environ. Sci. Techn

Surface Area and the Seabed Area, Volume, Depth, Slope, and Topographic Variation for the World's Seas, Oceans, and Countries

MARK JOHN COSTELLO,*,† ALAN CHEUNG,† AND NATHALIE DE HAUWERE§

PERSPECTIVE

Frontiers of Biogeography
the scientific journal of
the International Biogeography Society

The universal evolutionary and ecological significance of 20 °C

Mark John Costello[1,2,*], Ross Corkrey[3], Amanda E. Bates[4], Michael T. Burrows[5], Chhaya Chaudhary[6], Graham J. Edgar[7], Rick D. Stuart-Smith[7], Moriaki Yasuhara[8,9], and Chih-Lin Wei[10]

Marine Biogeography and Bioregionalization's

Mark J Costello, Faculty of Biosciences and Aquaculture, Nord University, B
Ocean University of China, Qingdao, China
Qianshuo Zhao, College of Marine Life Science, Ocean University of China, (

RESEARCH ARTICLE

OPEN ACCESS Check for updates

Exceptional endemicity of Aotearoa New Zealand biota shows how taxa dispersal traits, but not phylogeny, correlate with global species richness

Mark John Costello

Faculty of Biosciences and Aquaculture, Nord University, Bodo, Norway

ABSTRACT
Species' with more limited dispersal and consequently less gene flow are more likely to form new spatially segregated species and thus contribute disproportionally to endemic biota and global species richness. Aotearoa New Zealand has exceptional endemicity, with 52% of its 54,000 named species endemic, including 32%, 39% and 68% for freshwater, marine and terrestrial environments respectively. The lower endemicity of freshwater biota (excluding insects) is attributed to their need to disperse between habitats that are temporary on evolutionary

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HANDLING EDITOR
Graham Wallis

KEYWORDS
Biogeography; biodiversity; marine; freshwater; terrestrial; body size

Defining Marine Spatial Units: Realms, Biomes, Ecosystems, Seascapes, Habitats, Biotopes, Communities and Guilds

Mark John Costello, Faculty of Biosciences and Aquaculture, Nord University, Bodo, Norway; and School of Environment, University of Auckland, Auckland, New Zealand
Qianshuo Zhao and Dinusha RM Jayathilake, Institute of Marine Science, University of Auckland, Auckland, New Zealand

Marine Ecosystems of the World

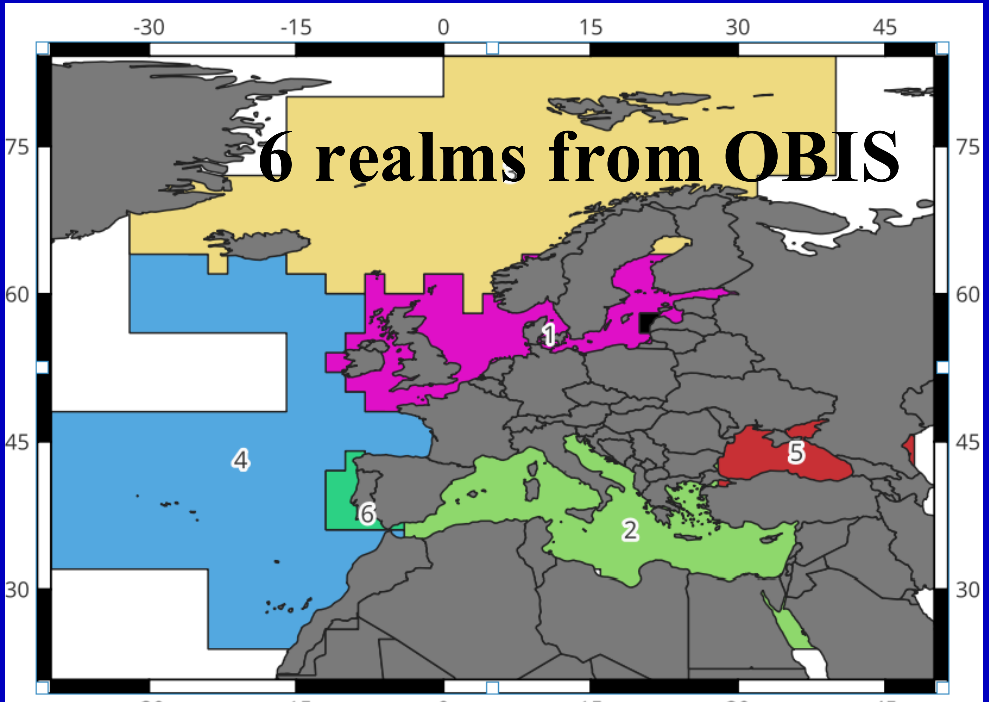
Qianshuo Zhao and Mark J Costello, University of Auckland, Auckland, New Zealand

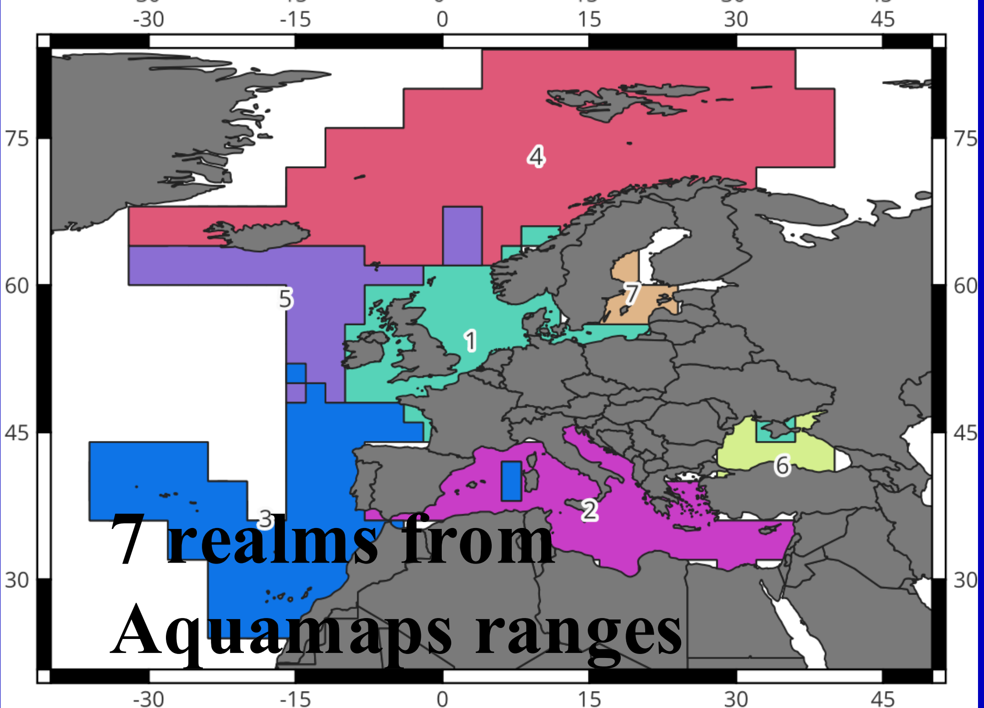
Table 1 Key concepts in marine biogeographic and regional classifications. To help reduce confusion that sometimes occurs the concepts are explained, an example given, and a statement of what they are not, included. For more details and a glossary see (Costello *et al.*, 2020a,b)

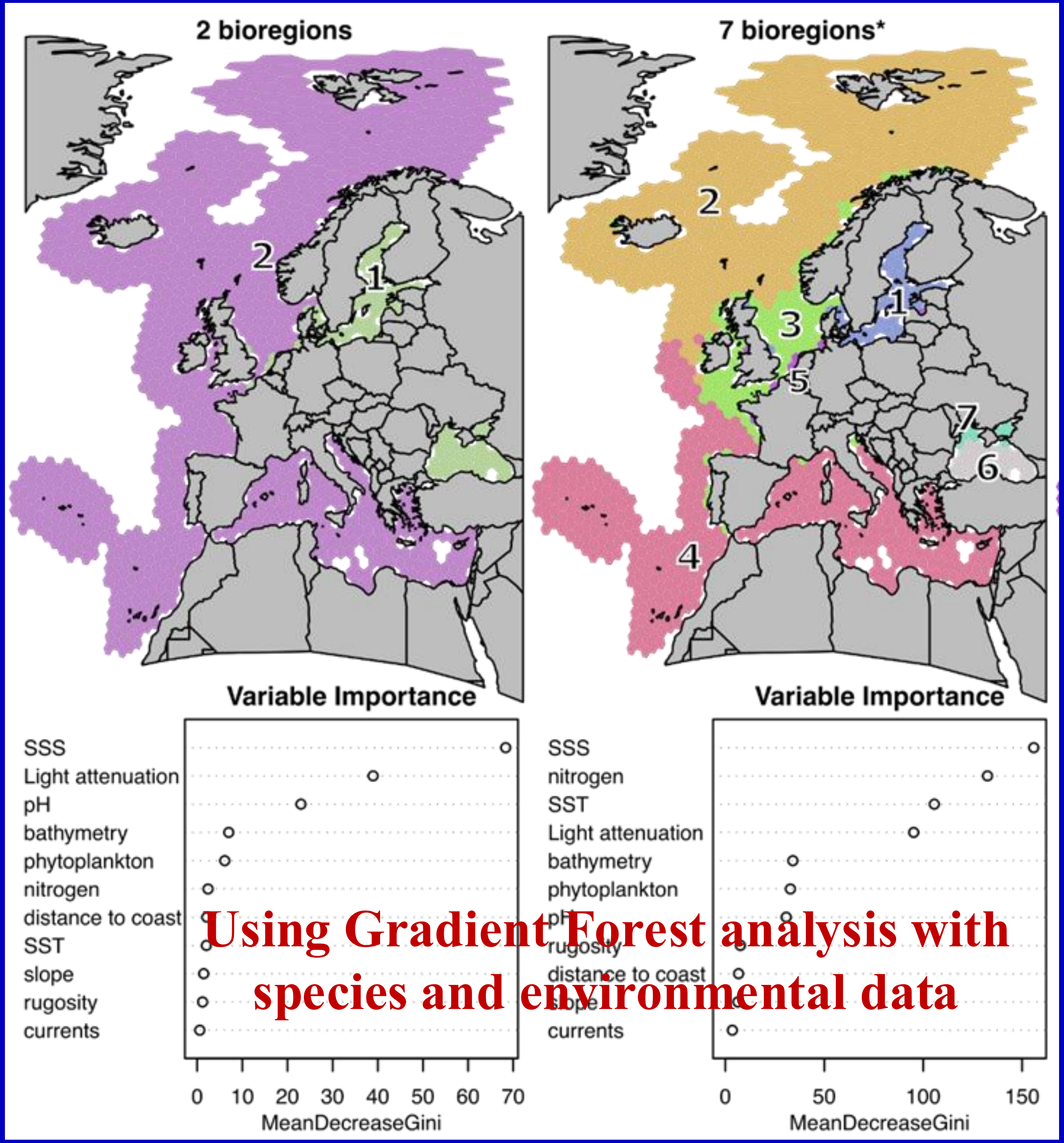
Concept	*What it is*	*Examples*	*What it is not*
Realm	Area of high species endemicity indicating species have evolved there in isolation from other areas.	Half of the marine species of the Antarctica and Southern Ocean realm occur nowhere else (Costello *et al.*, 2017)	An environmentally defined area.
Province	Are defined based on distinct fauna and flora, such as within a realm.	Sub-units with realms defined as part of the Marine Ecoregions of the World (Spalding *et al.*, 2007).	A political region.
Biome	Large area with a distinctive plant growth form. The species may vary geographically, and there may be from one to several species in the biome at any particular location.	Seagrass meadows, kelp forests, mangrove forests, zooxanthellate coral reefs (Jayathilake and Costello, 2018, 2020a,b,c, 2021)	An environmentally defined area.
Ecosystem	Geographic area of any size where biological and energy interactions are greater within the area than with adjacent areas (ecosystems)	The marine coastal shelf ecosystem is distinct from offshore ecosystems (Zhao *et al.*, 2020a,b).	A habitat or community.
Seascape	As in landscape, an area with a distinct geomorphology and topography.	Estuary, canyon, seamount, plain (Costello, 2009)	A habitat, ecosystem or area.
Habitat	The physical and chemical environmental niche to which one or more species is limited.	Strandline on the seashore, hydrothermal vent, kelp forest (Costello, 2009).	An area.
Community	A group of species living together and ecologically interacting.	Benthic community at a particular location (Costello, 2009)	An assemblage.
Biotope	The combination of a distinct community and habitat.	Mussels and fucoid algae on moderately wave exposed rocky seashores (Costello and Emblow, 2005)	An area.
Assemblage	A group of species occurring in the same place but which may or may not interact with each other.	List of fish species living at a location.	–

Beyond MPA Europe

- Assumptions
  - Our data are representative of biodiversity in the region
- Limitations
  - Species are only present in locally suitable habitats within their range
- Next steps
  - Use the MPA Europe data layers to provide a geographic context for planning MPA in cooperation with local stakeholders, e.g., using the SeaSketch platform as used in the Azores.


6 realms from OBIS
-30 -15 0 15 30 45
75
60
45
30
1
2
4
5
6


7 realms from
Aquamaps ranges
-30 -15 0 15 30 45
75
60
45
30
1
2
3
4
5
6
7


2 bioregions
7 bioregions*
Variable Importance
SSS
Light attenuation
pH
bathymetry
phytoplankton
nitrogen
distance to coast
SST
slope
rugosity
currents
0 10 20 30 40 50 60 70
MeanDecreaseGini
Variable Importance
SSS
nitrogen
SST
Light attenuation
bathymetry
phytoplankton
pH
rugosity
distance to coast
slope
currents
0 50 100 150
MeanDecreaseGini
Using Gradient Forest analysis with
species and environmental data

2^{nd} key message

Even in worst case scenarios,

- Most species will remain in their current geographic range
- With increased species richness in northernmost (Arctic)
- Possible extirpations of some species in the Mediterranean

3rd message

Map of organic carbon concentrations available for European seabed.

Management could ban disturbance of sediments with high organic carbon to minimise release of greenhouse gases from sediments (CO_2, CH_4).

4^{th} key message(s)

1. MPA do not only benefit biodiversity, there are ~50 examples of benefits to fisheries through spillover effects.

2. There is no published evidence of any MPA reducing fishery catch anywhere.

3. There is no evidence of fishery displacements effects, but there is of improved fishery CPUE around MPA locally and globally.

Implications of key message(s)

- Because biodiversity includes all species and ecosystems, it cannot be protected piecemeal.

- Nature conservation should prioritise strictly protected areas where people are prohibited from killing any marine wildlife and damaging their habitats.

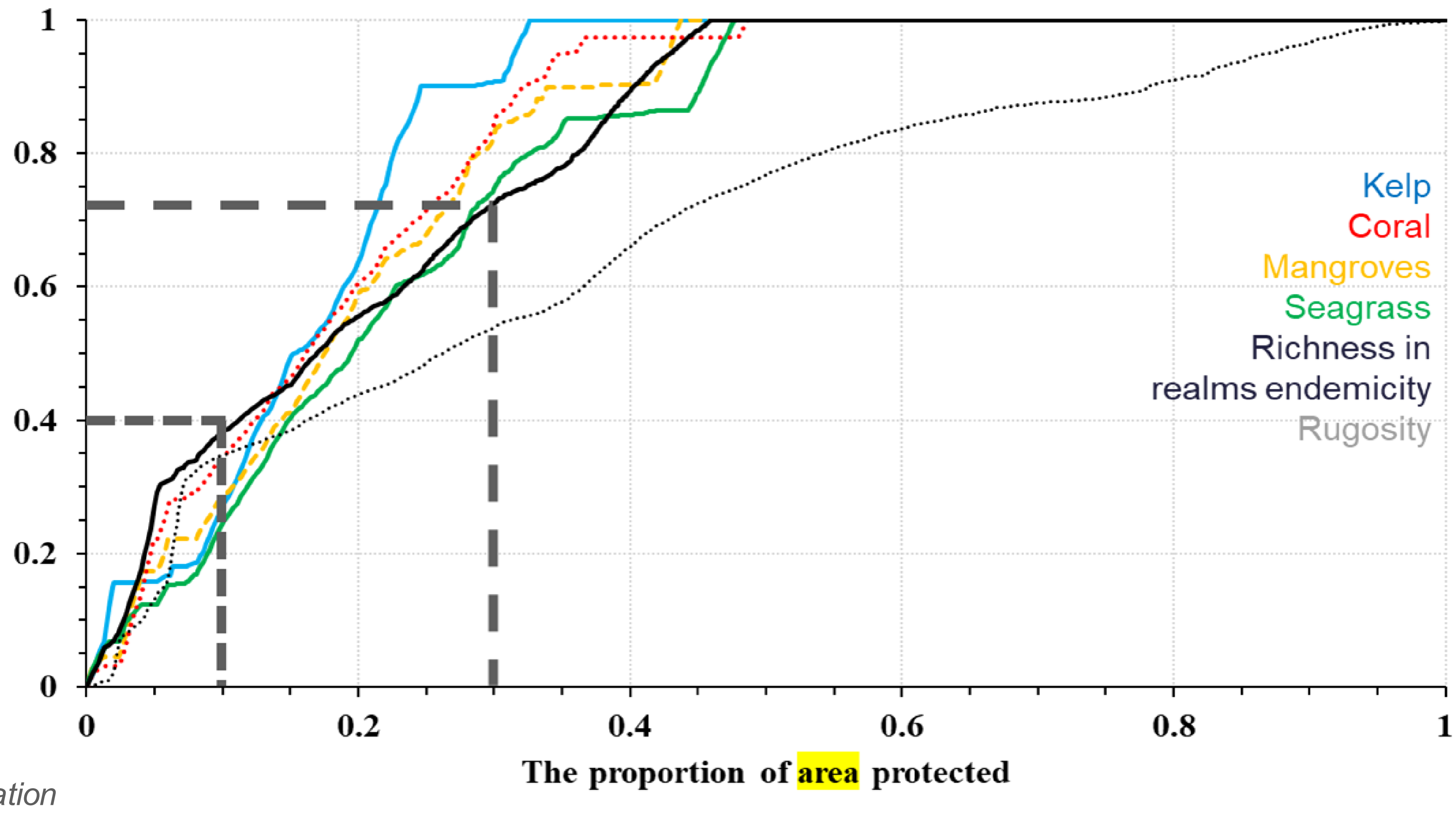
- An ecologically representative (coherent) network of MPA is appropriate now and under future climate change.

Systematic Conservation Planning designs a network of areas that best represent (include) measures of biodiversity

Aim for at least 80% representation of biodiversity within 30% of the sea area

Example is from a global prioritisation in 2020

The proportion of a measure of biodiversity per area

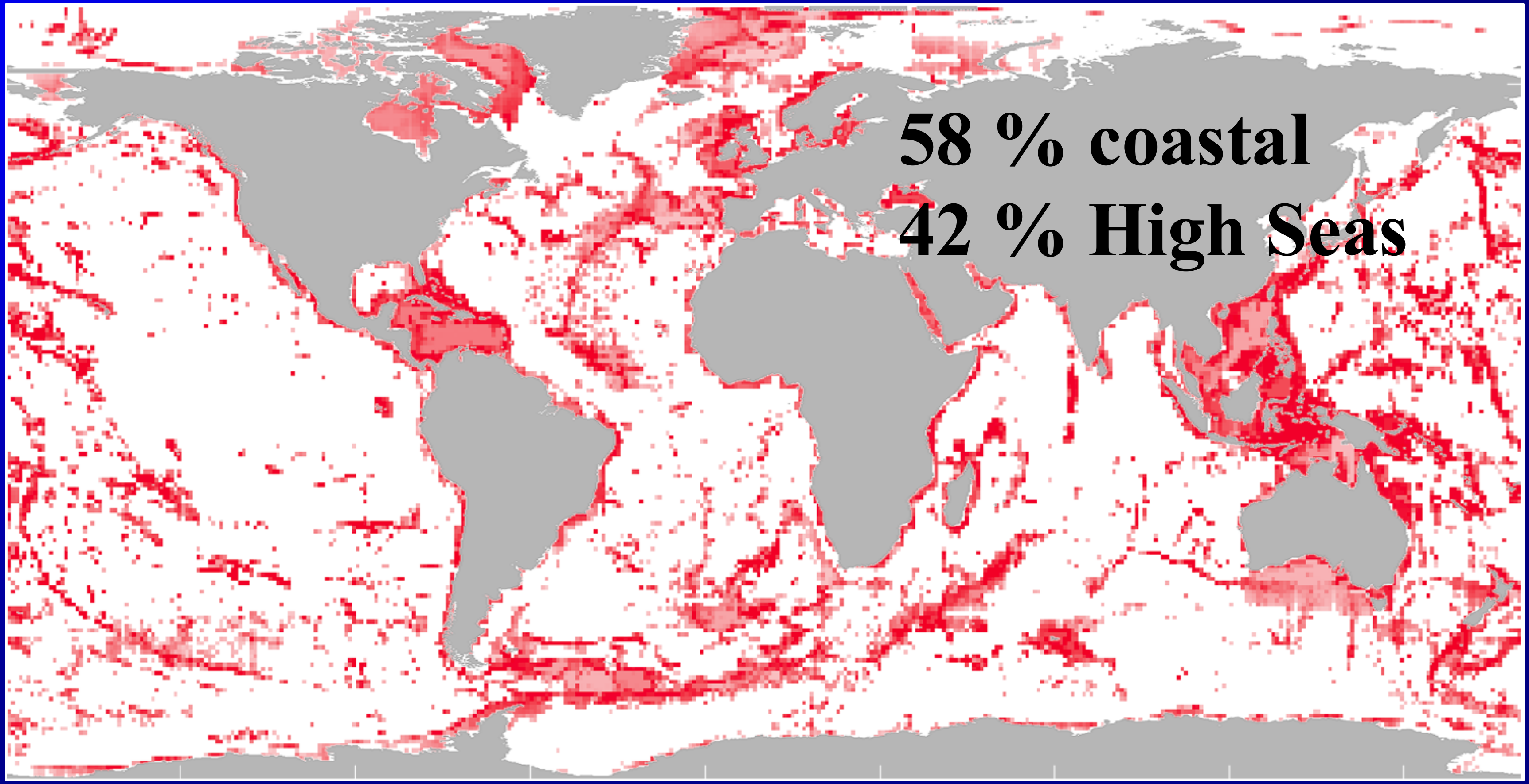


From Zhao et al. 2020, *Biological Conservation*

Most *Representative Biodiversity Areas* for a global MPA network, covers 30% of ocean, 70% species, 90% biomes & habitats

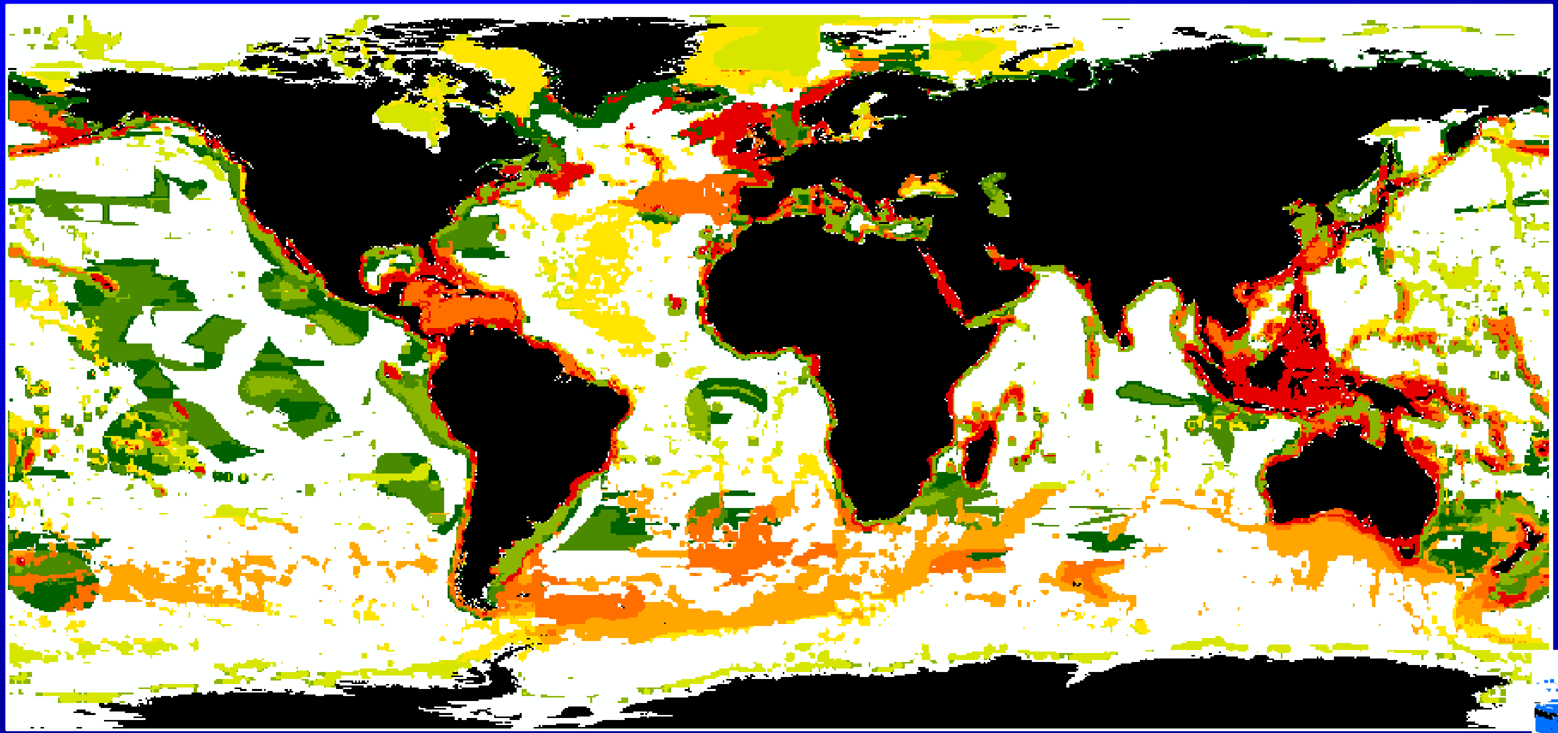
Data layers

1. Ecosystems = 20 environmental variables
2. Biogeographic realms = endemicity
3. Species richness = ranges
4. Biomes = mangrove, coral, seagrass, kelp
5. Habitat = seabed rugosity



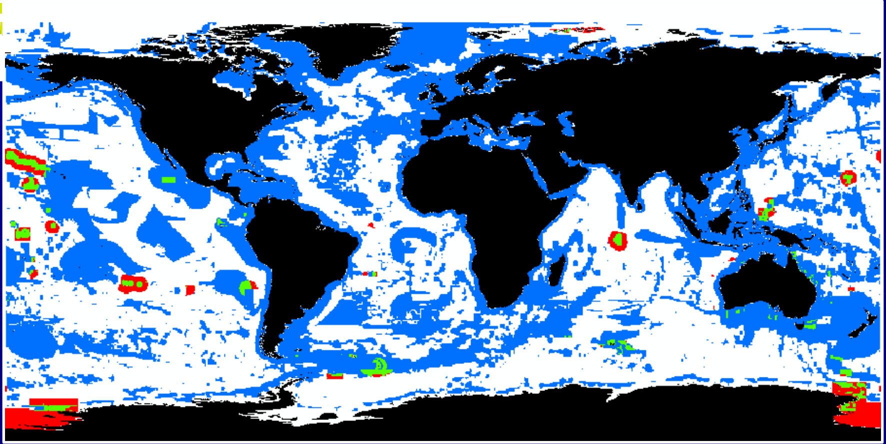
Zhao et al. 2020. Where Marine Protected Areas would best represent 30% of ocean biodiversity. *Biological Conservation*

Adding threatened species to Representative Biodiversity Areas



Below
Priority Areas in Blue.
Verified (fully protected) MPA in red (not in priority areas) & green cover only 2.7% of the ocean.

Only 34% these MPA in the Prioritised Areas.



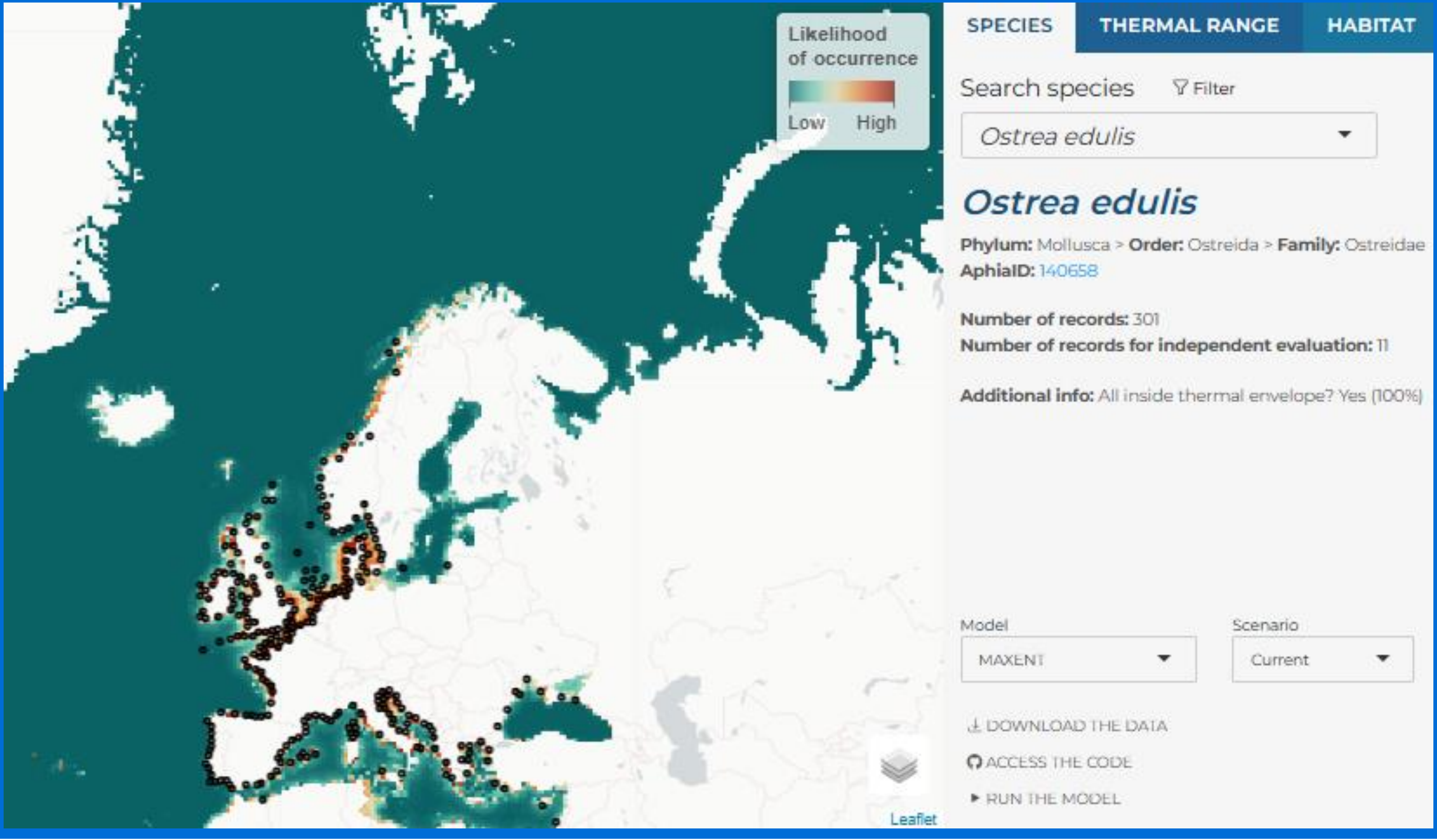
Need to protect 40% of the ocean to protect 70% of biodiversity plus 30% of range of each ~1,000 threatened species

Jefferson, Costello, Zhao. 2021. Conserving threatened marine species and biodiversity requires 40% ocean protection.

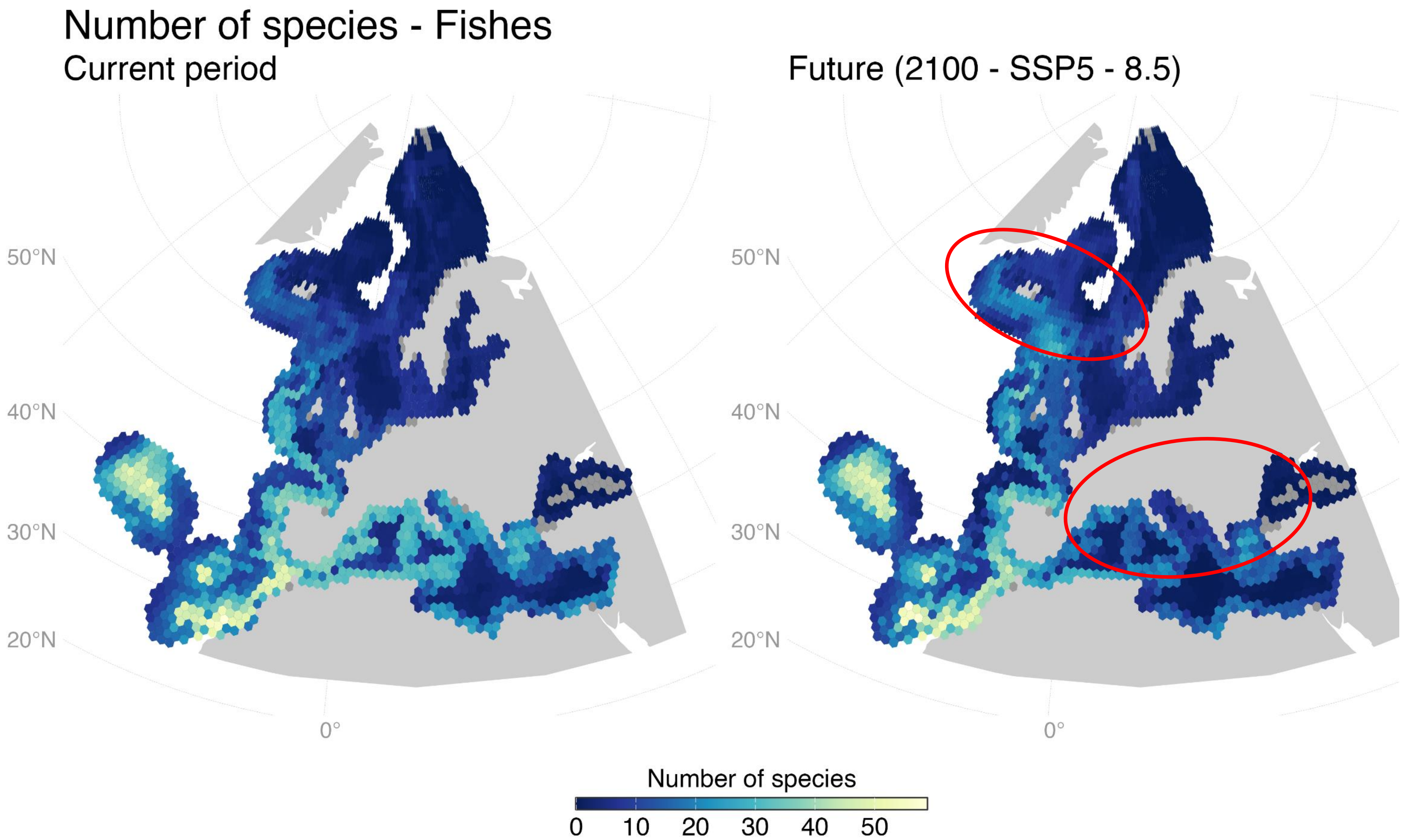
https://shiny.obis.org/distmaps/

Example of species range map for the native oyster

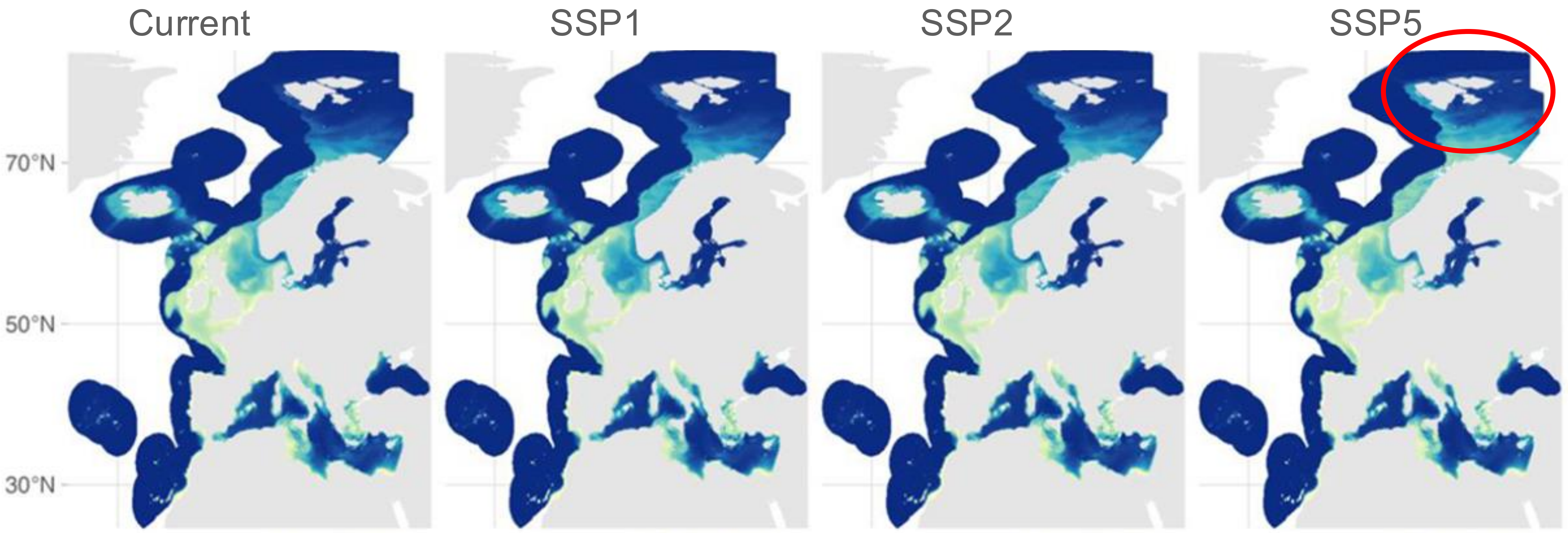
Showing likelihood of occurrence and data points used in the model



WP3 – species and biogenic habitat distributions

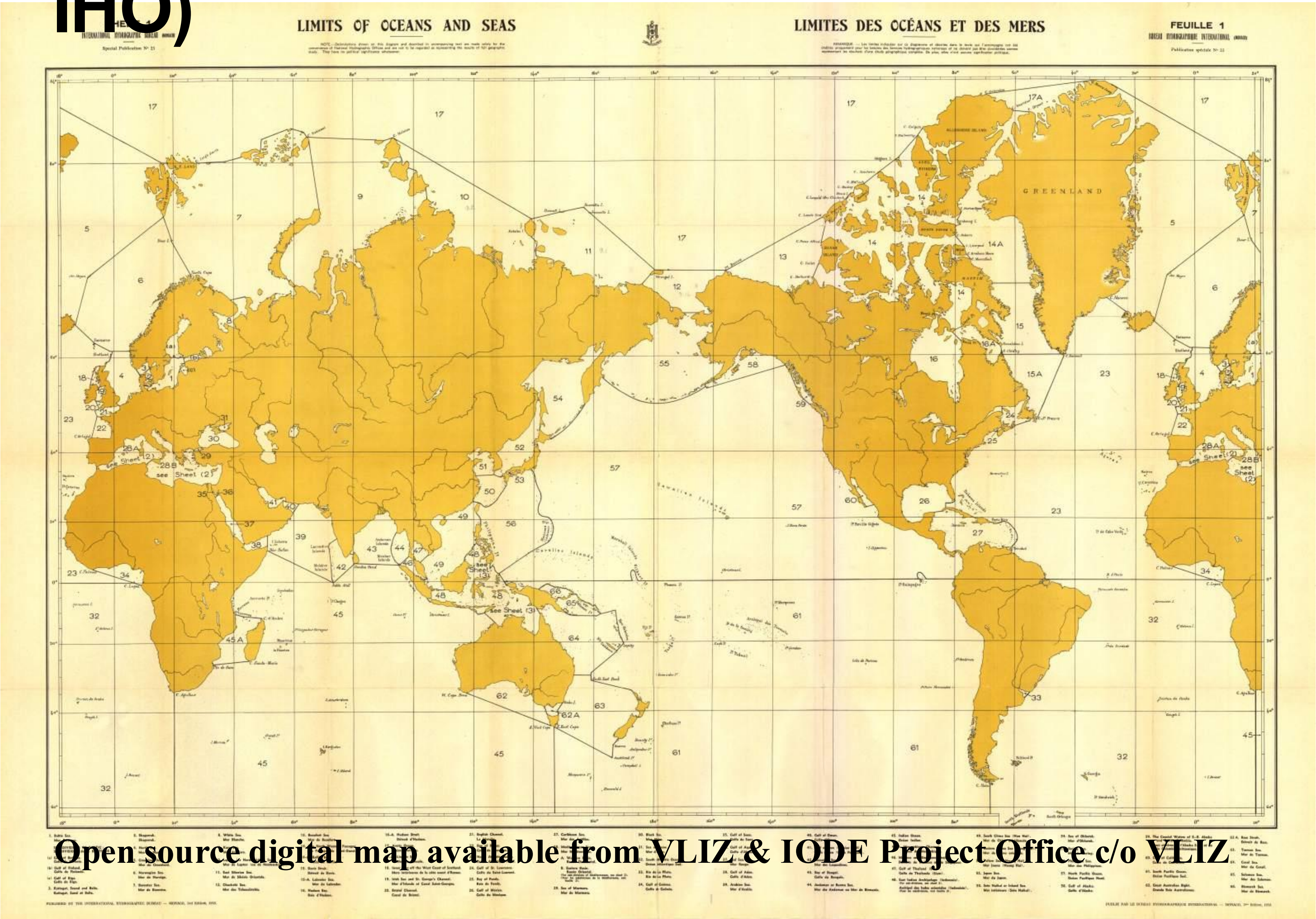


Species range maps, present and under 3 climate change scenarios



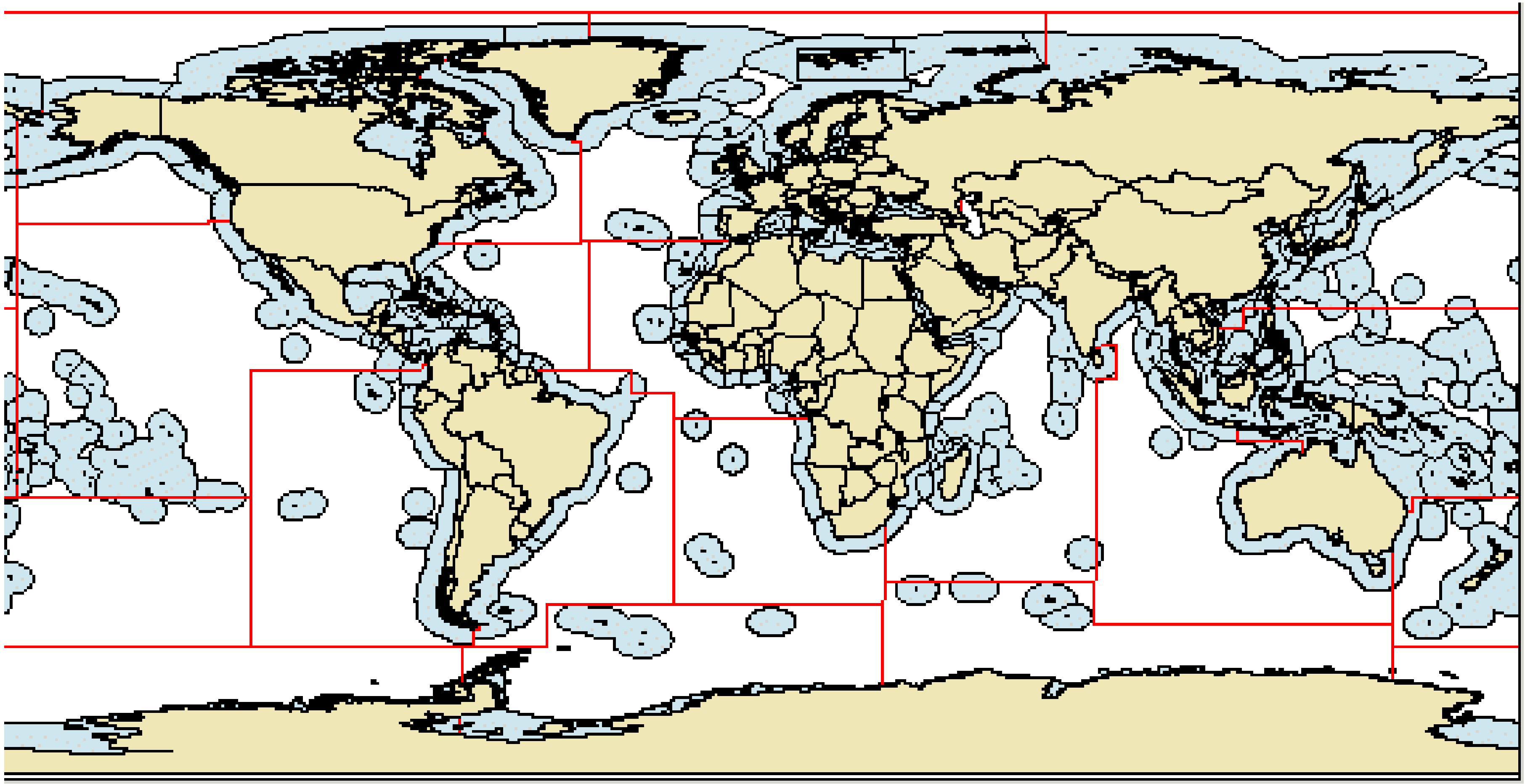
for the ray species *Raja brachyura*

Seas and oceans of the world (from IHO)

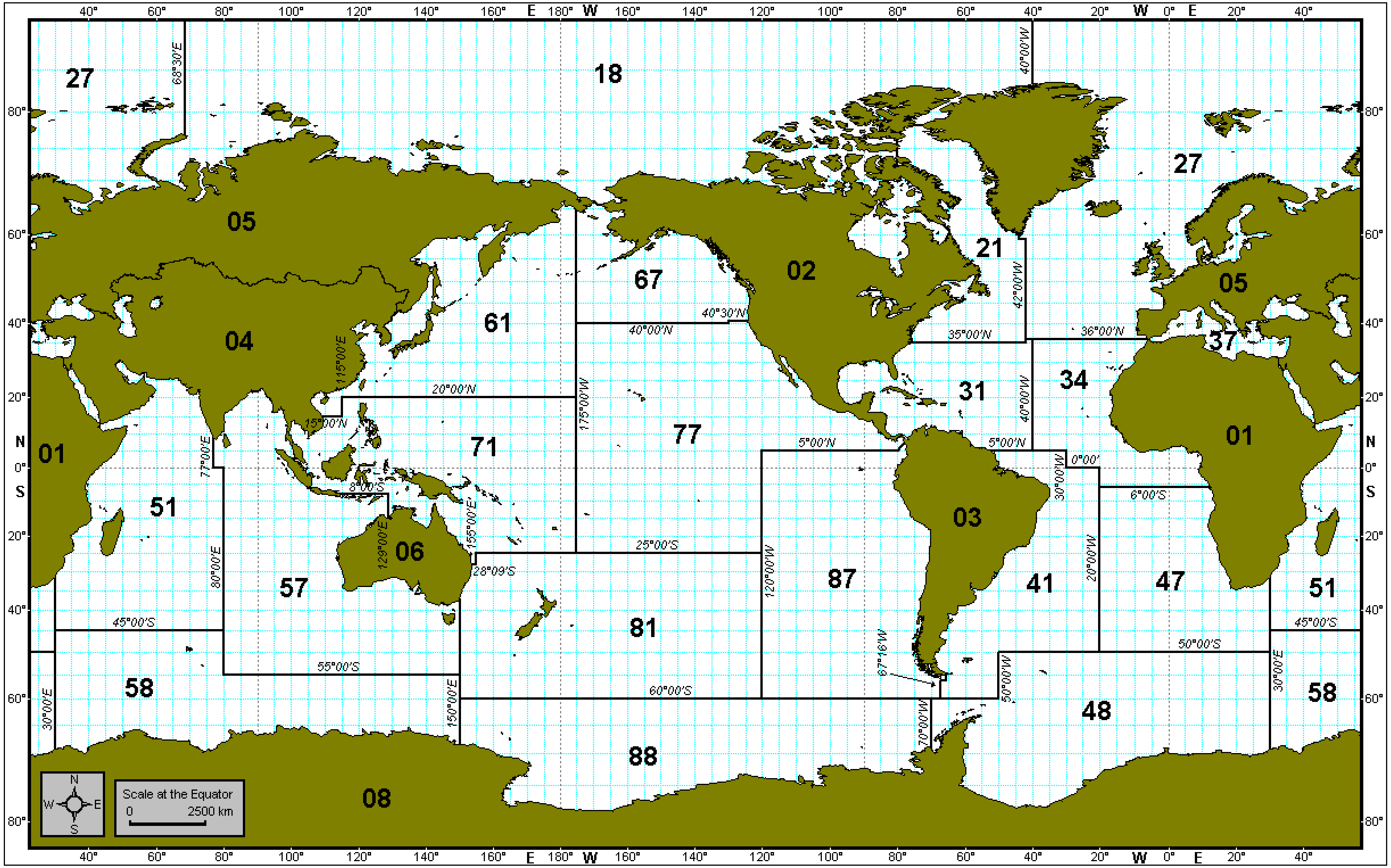


Open source digital map available from VLIZ & IODE Project Office c/o VLIZ

Countries Exclusive Economic Zones

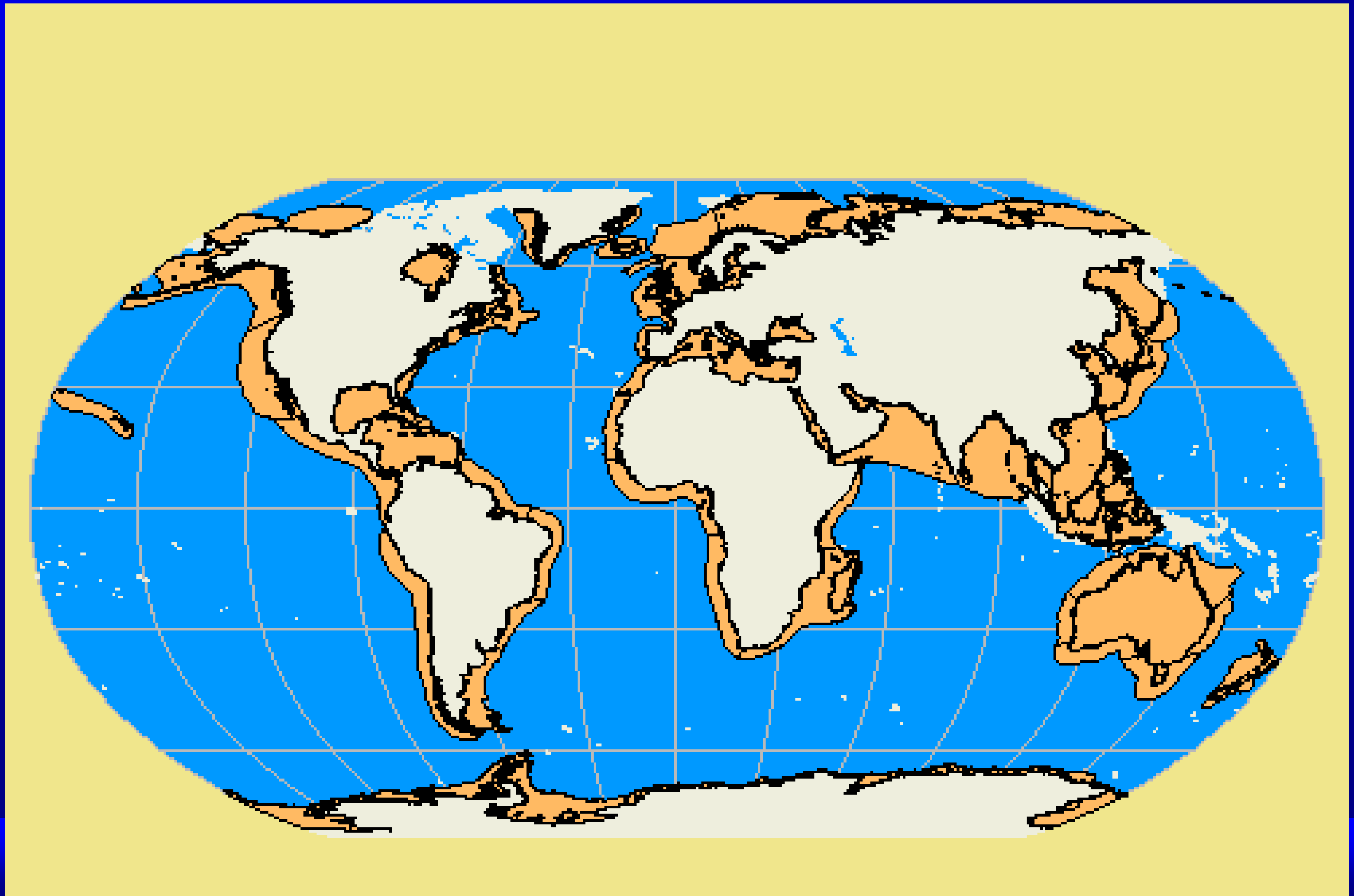


FAO fishery areas or boxes

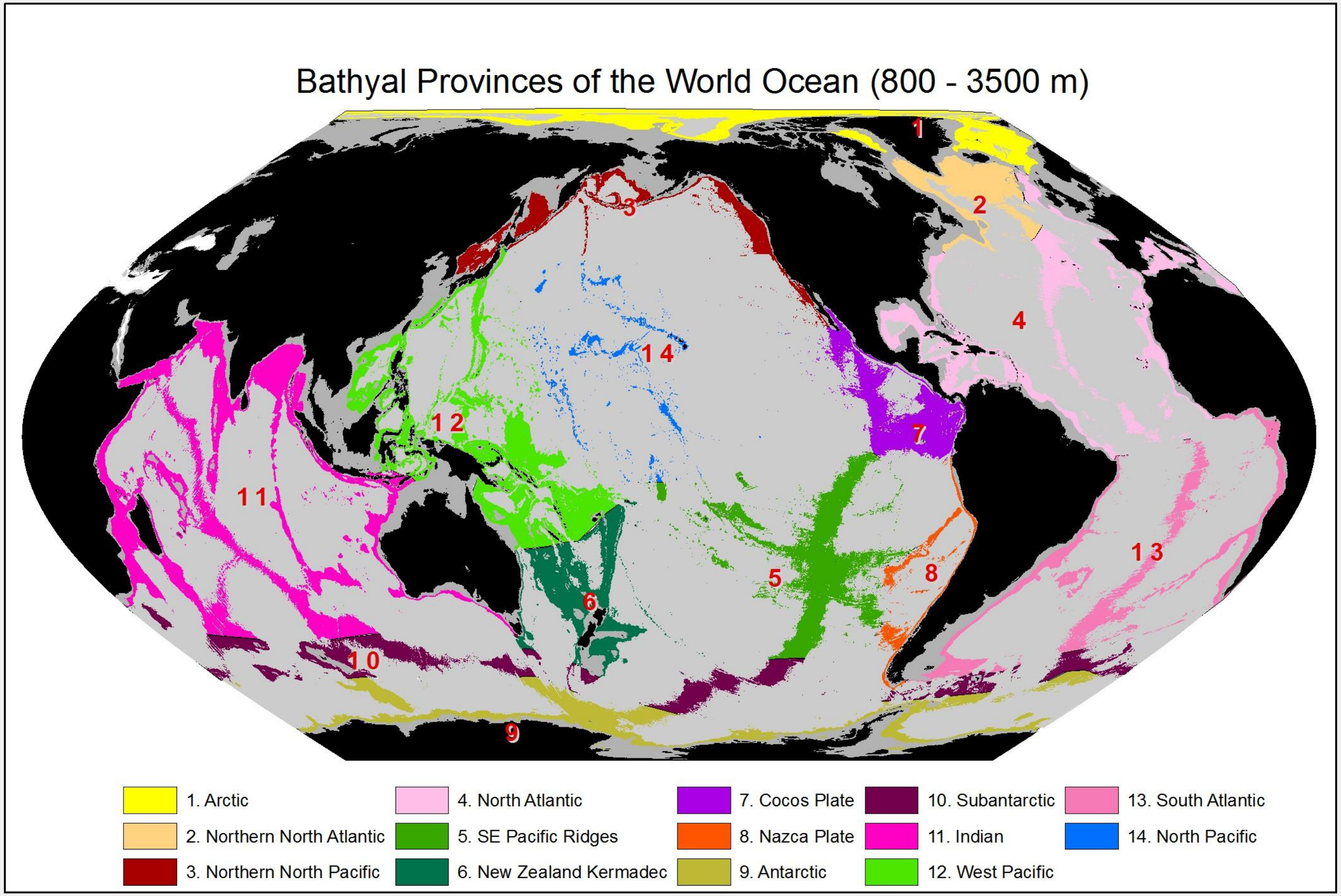


“Large Marine Ecosystems” LME

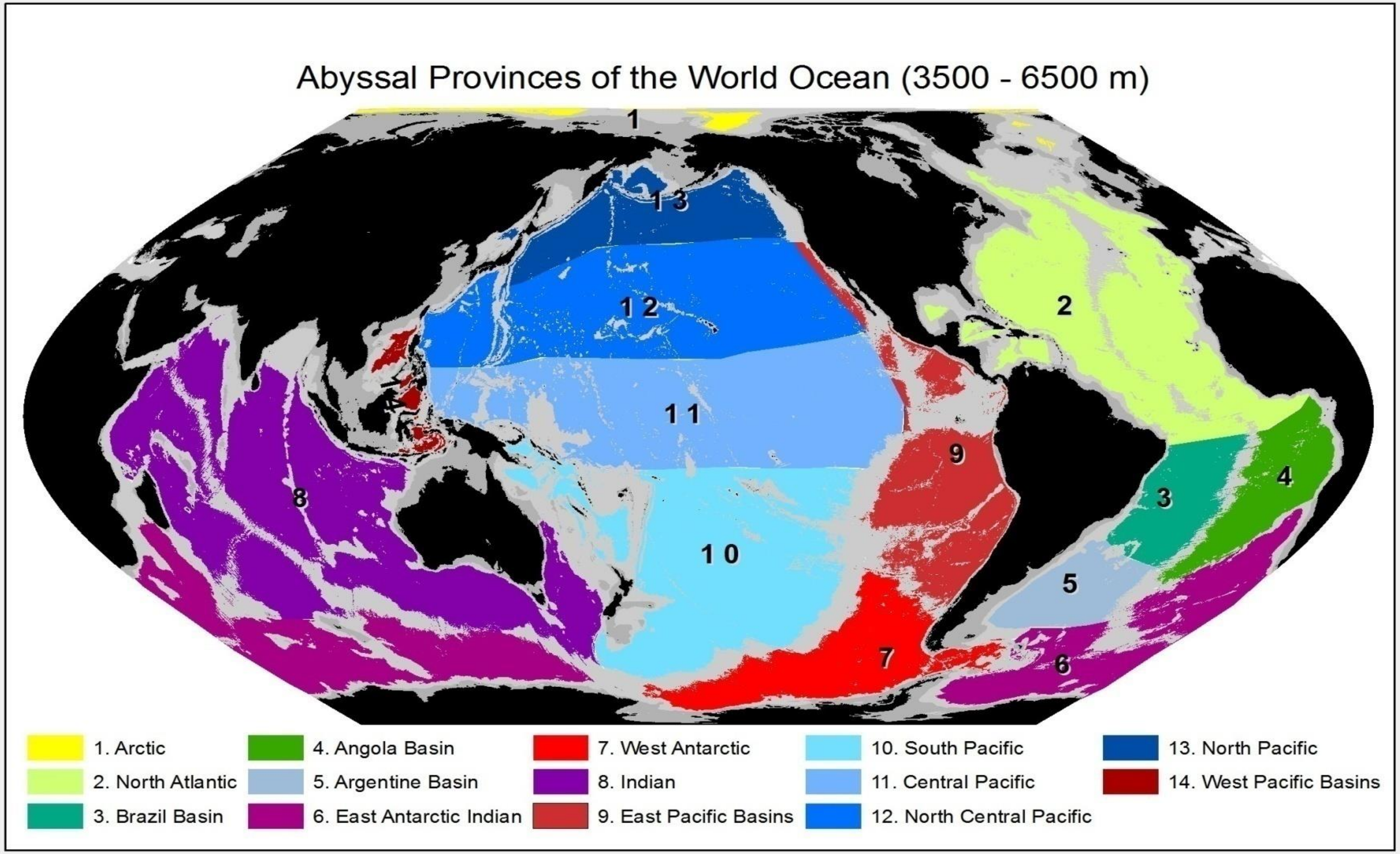
Based on areas of political and economic interest where a case could be made to study the ‘ecosystem’ because of its importance for fisheries or due to pollution threats



Global Open Oceans and Deep Sea-habitats bioregional classification (GOODS) (UNESCO 2008)



GOODS: abyssal



GOODS: Hadal

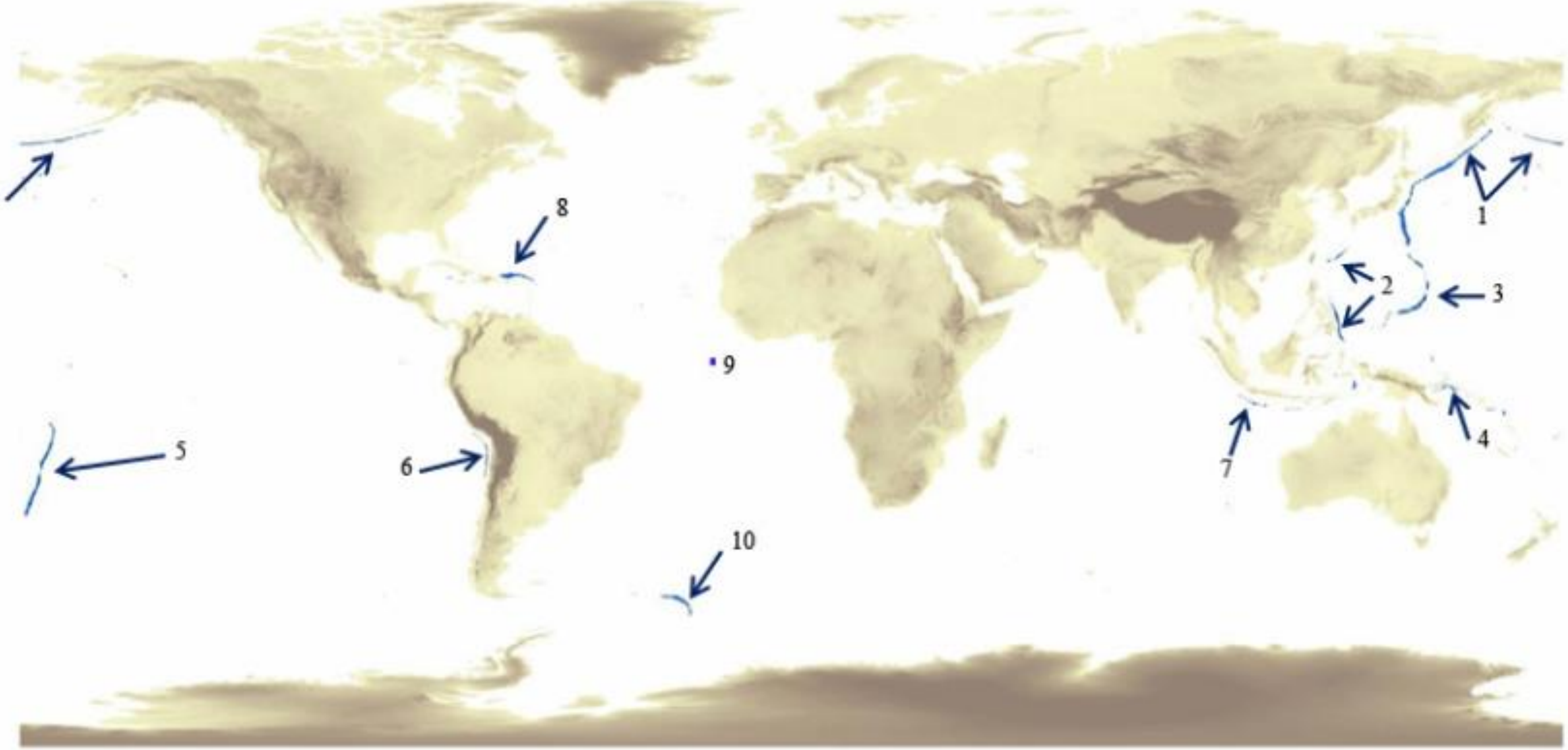
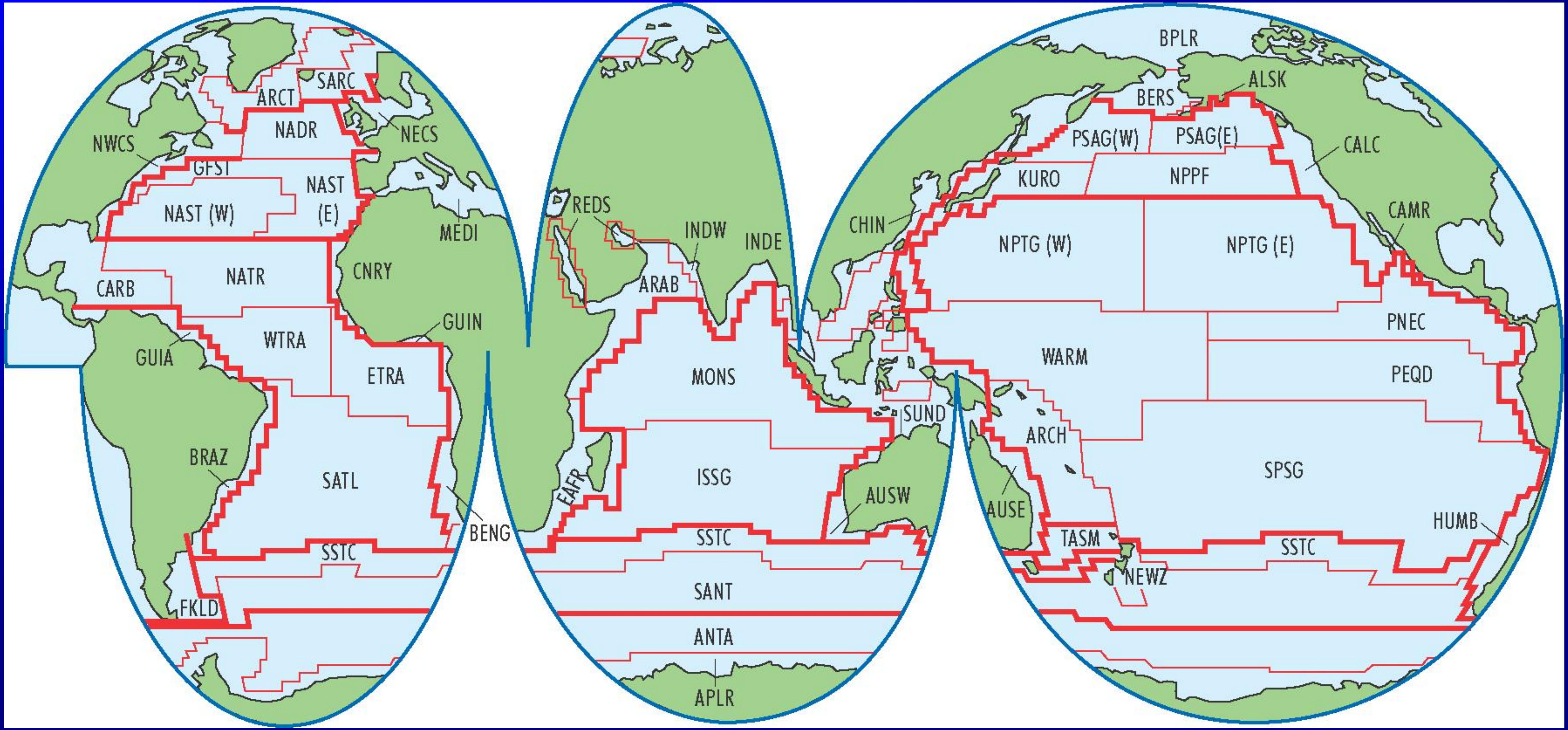


Figure 15: Hadal provinces. 1 - Aleutian-Japan Province (Aleutian, Kuril-Kamchatka, Japan, Izu-Bonin Trenches); 2 - Philippine Province (Philippine and Ryuku Trenches); 3 - Mariana Province (Volcano, Mariana, Yap and Palau Trenches); 4 - Bougainville-New Hebrides Province (New Britain, Bougainville, Santa Cruz, and New Hebrides Trenches); 5 - Tonga-Kermadec Province; 6 - Peru-Chile Province; 7 - Yavan Province; 8 - Puerto Rico Province; 9 - Romanche Province; and 10 - Southern Antilles Province

Longhurst's pelagic regions

Based on ocean colour and his opinion (no data analysis)



	1%	2%	3% - 6%	Seas' group	Eckman	MEOW regions
1	1 Inner Baltic Sea					Baltic Sea Ecoregion
2	2 Black Sea			Black Sea	Black Sea	Black Sea Province and ecoregion
3	3 NE and NW Atlantic and Mediterranean, Arctic and North Pacific	3.1 NE Atlantic and Mediterranean	3.1.1 NE Atlantic	NE Atlantic[b]	European Boreal. Part of a North Atlantic Boreal	North European Seas Province with 7 ecoregions
4			3.1.2 Arctic Europe	Norwegian Sea (in part)		
5			3.1.3 Mediterranean	Mediterranean[c]	Mediterranean	Mediterranean Province[2]
6		3.2 Arctic + North Pacific	3.2.1 Arctic	Arctic seas	Arctic	1. Arctic Realm.
7			3.2.2 North Pacific[3]	North Pacific	North West American	3. Temperate North Pacific realm
8		3.3 North Atlantic boreal and sub-Arctic from Canada to Greenland Sea		North American Boreal	North American Boreal.	Arctic real