Mapping Marine Ecosystems and Biodiversity Richspots: from Global to the West Pacific

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called for the protection of at least 30% of each marine habitat globally and at least 30% of all the ocean for worldwide effective marine biodiversity conservation by 2030.

1.6% in 2012 (IUCN, 2013) → 7% in 2017 (IUCN, 2018) → 7.7% in 2022 (WDPA2022) → 2030?
1. The Global and general approach

2. The West Pacific and other regions
1. The Global

Ecosystems defined by environmental variables √
Seabed topographic variation (Benthic Rugosity) √
Species richness √
Biomes defined by habitat forming species √
Realms of species endemicity √

Zhao, et al., 2020, Where Marine Protected Areas would best represent 30% of ocean biodiversity. Biological Conservation, 244, 108536.
Zhao et al., 2020, Mapping global marine ecosystems through cluster analysis of environmental data, Ecological Research, 2020; 1–16.
### Physical
- Temperature
- Wind Speed
- Slope
- Land Distance
- Surface Current
- Diffuse Attenuation Coefficient
- Salinity
- Wave Height
- Ice Cover

### Biochemical
- pH
- Photosynthetically Active Radiation
- Chlorophyll-α
- Primary Productivity
- Dissolved Oxygen
- Nitrate
- Calcite

### Nutrients
- Saturated Oxygen
- Utilized Oxygen
- Silicate
- Phosphate
- Nitrate
- Calcite

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**The Raw Data**

1. **Normalization (Z score)**
2. **Principal component analysis**
3. **K-means clustering analysis by cosine similarity**
4. **Validation by Silhouette Values**
Biomes: large geographic areas characterized by the same plant life form, which form large areas of three-dimensional habitats with high primary productivity (Woodward et al., 2004)

Seagrass

(Jayathilake & Costello, 2018)

Mangrove

(Giri et al., 2011)

Kelp

(Jayathilake & Costello, 2019)

Shallow-water Coral Reefs

(UNEP-WCMC et al., 2010)

Host photosynthetic algae (zooxanthellae) and provide complex habitat structure
Rugosity

(Basher et al., 2014)

Depth

Benthic Terrain Modeller 3.0

(Ralbridge et al., 2018)

Covered Canyons, Seamounts, Abyssal hills ……

Rugosity
Within-Realm Species Richness

Species Richness from AquaMaps (Kaschner et al., 2016)

Marine Biogeographic Realms (Costello et al., 2017)

Mean=0 & Std. =1 in each Realm

Within-Realm Species Richness
Prioritization By Iteratively removes cells from lowest significant cells up to the highest following the rule of **Target Based Function (TBF)**.

A cell’s significance:

![Diagram showing prioritization process with cells marked 'High' or 'Low' and target of 30% indicated.](image)
The Prioritization Result

The 30% most highly prioritized areas
Ecosystem 1
Ecosystem 2
Ecosystem 3
Ecosystem 4
Ecosystem 5
Ecosystem 6
Ecosystem 7
Seagrass
Kelp
Mongrove
Shallow-water Coral Reefs
Top 30% Rugosity
Top 30% Within Realm Species Richness

Targeting to cover 30% of each Layer
The EEZs

<table>
<thead>
<tr>
<th>EEZ</th>
<th>Areas ($10^4\times\text{km}^2$)</th>
<th>% EEZ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canada</td>
<td>457</td>
<td>35%</td>
</tr>
<tr>
<td>Australia</td>
<td>392</td>
<td>55%</td>
</tr>
<tr>
<td>United States</td>
<td>380</td>
<td>36%</td>
</tr>
<tr>
<td>Greenland</td>
<td>347</td>
<td>47%</td>
</tr>
<tr>
<td>Indonesia</td>
<td>335</td>
<td>69%</td>
</tr>
<tr>
<td>Russia</td>
<td>331</td>
<td>17%</td>
</tr>
<tr>
<td>New Zealand</td>
<td>192</td>
<td>42%</td>
</tr>
</tbody>
</table>
ADDING THREATENED SPECIES TO REPRESENTATIVE BIODIVERSITY AREAS

Need to protect 40% of the ocean to protect 30% of range of each threatened species

Tamlin Jefferson et al., 2021 Biological Conservation
SO FAR, 5 DATA-DRIVEN MARINE PRIORITISATIONS

This “consensus map” shows where they overlap

Selig et al. 2014  *PLoS One*
Zhao et al. 2020  *Biological Conservation*
Jones et al. 2020  *One Earth*
Visalli et al. 2020  *Marine Policy*
Sala et al. 2021  *Nature*
2. The West Pacific

Surface Ecosystems  Benthic Ecosystems

Data source: Bio-oracle 2.2
Species Richness

Data source: AquaMaps

Seagrass

Laminarian kelp

Species Richness

Data source: AquaMaps

Mangrove

Shallow water coral reefs

Benthic Rugosity

Data source: UNEP-WCMC Ocean Data Viewer
Prioritization for Biodiversity

| Ecosystems defined by environmental variables | ✓ | Species richness | ✓ |
| Seabed topographic variation (Benthic Rugosity) | ✓ | Biomes defined by habitat forming species | ✓ |
The proportion covered by the West Pacific richspots

Surface Ecosystem 1
Surface Ecosystem 2
Surface Ecosystem 3
Surface Ecosystem 4
Surface Ecosystem 5
Surface Ecosystem 6
Surface Ecosystem 7
Surface Ecosystem 8
Surface Ecosystem 9
Surface Ecosystem 10
Surface Ecosystem 11
Benthic Ecosystem 1
Benthic Ecosystem 2
Benthic Ecosystem 3
Benthic Ecosystem 4
Benthic Ecosystem 5
Benthic Ecosystem 6
Benthic Ecosystem 7
Benthic Ecosystem 8
Benthic Ecosystem 9
Benthic Ecosystem 10
Benthic Ecosystem 11
Benthic Ecosystem 12
Seagrass
Kelp
Mangrove
Shallow-water Coral Reef
Top 30% Species Richness
Top 30% Rugosity
The overlap (green) between the biodiversity richspots (red) with the areas (blue) of:
(a) all the MPAs;
(b) marine reserves (no-take MPAs).
Method verification

Ecosystems distribution

Data source: CMEMS

Density of marine species distribution data from OBIS Europe

Other regions

Led by Mark Costello
Thank you!
<table>
<thead>
<tr>
<th>Physical</th>
<th>Biochemical</th>
<th>Nutrient</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sea Surface Temperature mean (°C)</td>
<td>Wind Speed (m·s(^{-1}))</td>
<td>Slope (degree)</td>
</tr>
<tr>
<td>Land Distance (km × 100)</td>
<td>Surface Current (m·s(^{-1}))</td>
<td>Diffuse Attenuation Coefficient (m(^{-1}))</td>
</tr>
<tr>
<td>Salinity (PSS)</td>
<td>Wave Height (m)</td>
<td>Ice Cover (%)</td>
</tr>
<tr>
<td>pH</td>
<td>Primary Productivity (mgC·m(^{-2})·day(^{-1})·cell(^{-1}))</td>
<td>Chlorophyll-a mean (mg·m(^{-3}))</td>
</tr>
<tr>
<td>Photosynthetically Active Radiation (Einstein·m(^{-2})·day(^{-1}))</td>
<td>Saturate Oxygen (ml·l(^{-1}))</td>
<td>Utilized Oxygen (ml·l(^{-1}))</td>
</tr>
<tr>
<td>Silicate (μmol·l(^{-1}))</td>
<td>Phosphate (μmol·l(^{-1}))</td>
<td>Dissolved Oxygen (ml·l(^{-1}))</td>
</tr>
<tr>
<td>Nitrate (μmol·l(^{-1}))</td>
<td>Calcite (mol·m(^{-3}))</td>
<td>Normalization: Mean = 0; Std. = 1</td>
</tr>
</tbody>
</table>

Principal Components Analysis: Choose the most principal components explain ≥ 85%