**Supplementary Information**

**Climate-smart, 3-D protected areas in the high seas**

Isaac Brito-Morales1,2,3, David S. Schoeman4,5, Carissa J. Klein1,6, Daniel C. Dunn1,6, Jason D. Everett3, Jorge García Molinos7,8,9, Michael T. Burrows10, Rosa Mar Dominguez1, Hugh P. Possingham6 and Anthony J. Richardson2,3

1School of Earth and Environmental Sciences, The University of Queensland, St Lucia, QLD, Australia

2Commonwealth Scientific and Industrial Research Organisation (CSIRO) Oceans and Atmosphere, Queensland Biosciences Precinct (QBP), St Lucia, QLD, Australia

3School of Mathematics and Physics, The University of Queensland, St Lucia, QLD, Australia

4Global-Change Ecology Research Group, School of Science, Technology and Engineering, University of the Sunshine Coast, Maroochydore, QLD, Australia

5Centre for African Conservation Ecology, Department of Zoology, Nelson Mandela University, Port Elizabeth, South Africa

6Centre for Biodiversity and Conservation Science (CBCS), The University of Queensland, St Lucia, QLD, Australia

7Arctic Research Center, Hokkaido University, Sapporo, Japan

8Global Station for Arctic Research, Global Institution for Collaborative Research and Education, Hokkaido University, Sapporo, Japan

9Graduate School of Environmental Science, Hokkaido University, Sapporo, Japan

10Scottish Association for Marine Science, Oban, UK

Corresponding author: Brito-Morales, I. ([i.britomorales@uq.edu.au](mailto:i.britomorales@uq.edu.aiu))

Supplementary Table 1. Proportion of the high seas (%) covered by “no regret conservation areas” for each depth layer and between contiguous depth layers in a climate-smart prioritisation approach under different area-based targets of protection.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Area Based Target (%)** | **Proportion of the high seas area (%)** | | | | | **Proportion of additional overlap (%)** | | |
| **Epipelagic** | **Mesopelagic** | **Bathyabyssopelagic** | **Total overlap  among layers** | **Epipelagic -Mesopelagic** | | **Epipelagic - Bathyabyssopelagic** | **Mesopelagic - Bathyabyssopelagic** | |
| 10 – 100 | 33.78 | 44.02 | 36.71 | 10.74 | 9.59 | | 4.07 | 10.92 | |
| 10 – 90 | 26.15 | 34.99 | 29.7 | 6.47 | 7.42 | | 3.31 | 8.29 | |
| 10 – 80 | 20.11 | 27.7 | 24.32 | 4.05 | 5.51 | | 2.63 | 6.07 | |
| 10 – 70 | 15.26 | 21.84 | 19.82 | 2.53 | 4.02 | | 2.00 | 4.34 | |
| 10 – 60 | 11.76 | 17.15 | 15.38 | 1.55 | 3.05 | | 1.39 | 3.00 | |
| 10 – 50 | 8.44 | 12.56 | 11.23 | 0.84 | 2.09 | | 0.86 | 1.92 | |
| 10 – 40 | 6.04 | 9.46 | 7.98 | 0.50 | 1.39 | | 0.52 | 1.27 | |
| 10 – 30 | 3.89 | 6.01 | 5.58 | 0.25 | 0.78 | | 0.26 | 0.76 | |

Supplementary Table 2. Climate models with sea temperature at different depths used in this study.

| **Modelling Centre** | **Institute ID** | **Model Name** | **depths (m)** |
| --- | --- | --- | --- |
| Commonwealth Scientific and Industrial Research Organization/Queensland Climate Change Centre of Excellence | CSIRO-QCCCE | ACCESS-CM2 ACCESS-ESM1-5 | **epipelagic**: 5, 15, 25, 35, 45, 55, 65, 75, 85, 95, 105, 115, 125, 135, 145, 155, 165, 175, 185, 195  **mesopelagic**: 205, 217, 241, 343, 427, 537, 665, 813, 969  **bathyabyssopelagic**: 1131, 1290, 1456, 1623, 1802, 1985, 2183, 2388, 2611, 2843, 3092, 3351, 3628, 3913, 4214, 4522, 4843, 5166, 5499, 5831 |
| Beijing Climate Center, China Meteorological Administration | BCC | BCC-CSM2-MR | **epipelagic**: 5, 15, 25, 35, 45, 55, 65, 75, 85, 95, 105, 115, 125, 135, 145, 155, 165, 175, 185, 195  **mesopelagic**: 205, 217, 239, 276, 336, 421, 538, 689, 879  **bathyabyssopelagic**: 1101, 1378, 1688, 2039, 2427, 2851, 3305, 3786, 4288, 4807, 5334 |
| National Center for Atmospheric Research | NCAR | CESM2-WACCM CESM2 | **epipelagic**: 5, 15, 25, 35, 45, 55, 65, 75, 85, 95, 105, 115, 125, 135, 145, 155, 165, 175, 186, 197  **mesopelagic**: 209, 222, 236, 251, 267, 285, 305, 326, 351, 378, 408, 443, 482, 527, 579, 638, 707, 787, 878, 984  **bathyabyssopelagic**: 1106, 1244, 1400, 1573, 1764, 1968, 2186, 2413, 2649, 2889, 3133, 3379, 3627, 3876, 4125, 4375, 4625, 4875, 5125, 5375 |
| Tsinghua University, Department of Earth System Science | THU | CIESM | **epipelagic**: 5, 15, 25, 35, 45, 55, 65, 75, 85, 95, 105, 115, 125, 135, 145, 155, 165, 175, 186, 197  **mesopelagic**: 209, 222, 236, 251, 267, 285, 305, 326, 351, 378, 408, 443, 482, 527, 579, 638, 707, 787, 878, 984,  **bathyabyssopelagic**: 1106, 1244, 1400, 1573, 1764, 1968, 2186, 2413, 2649, 2889, 3133, 3379, 3627, 3876, 4125, 4375, 4625, 4875, 5125, 5375 |
| Canadian Centre for Climate Modelling and Analysis | CCCMA | CanESM5 | **epipelagic**: 3, 9, 16, 23, 32, 41, 51, 63, 77, 93, 112, 134, 160, 191  **mesopelagic**: 227, 270, 322, 382, 452, 534, 627, 734, 855, 989  **bathyabyssopelagic**: 1136, 1297, 1470, 1655, 1850, 2054, 2266, 2485, 2710, 2939, 3173, 3410, 3650, 3892, 4137, 4382, 4629, 4877, 5125, 5375, 5624 |
| EC-Earth-Consortium | EC-EARTH | EC-Earth3-Veg | **epipelagic**: 0.50, 1.5, 2.6, 3.8, 5., 6, 8, 9, 11, 13, 16, 19, 22, 26, 30, 35, 41, 47, 53, 61, 69, 77, 86, 97, 108, 120, 133, 147, 163, 180, 199  **mesopelagic**: 221, 244, 271, 300, 333, 370, 411, 457, 508, 565, 628, 697, 773, 856, 947  **bathyabyssopelagic**: 1045, 1151, 1265, 1387, 1516, 1652, 1795, 1945, 2101, 2262, 2429, 2600, 2776, 2955, 3138, 3324, 3513, 3704, 3897, 4093, 4289, 4488, 4687, 4888, 5089, 5291, 5494, 5698, 5902 |
| Sate Key Laboratory of Numerical Modeling for Atmospheric Sciences and Geophysical Fluid Dynamics, Institute of Atmospheric Physics, Chinese Academy of Sciences | LASG/IAP, CAS | FGOALS-g3 | **epipelagic**: 5, 15, 25, 35, 45, 55, 65, 75, 85, 95, 105, 115, 125, 135, 145, 156, 178  **mesopelagic**: 222, 303, 432, 621, 876  **bathyabyssopelagic**: 1203, 1603, 2074, 2612, 3209, 3855, 4538, 5243 |
| Institute for Numerical Mathematics | INM | INM-CM4-8 INM-CM5-0 | **epipelagic**: 0, 10, 20, 30, 50, 75, 100, 125, 150  **mesopelagic**: 200, 250, 300, 400, 500, 600, 700, 800, 900  **bathyabyssopelagic**: 1000, 1100, 1200, 1300, 1400, 1500, 1750, 2000, 2500, 3000, 3500, 4000, 4500, 5000, 5500 |
| Atmosphere and Ocean Research Institute (The University of Tokyo), National Institute for Environmental Studies, and Japan Agency for Marine-Earth Science and Technology | MIROC | MIROC6 | **epipelagic**: 1, 3, 7, 11, 15, 20, 26, 32, 38, 46, 54, 62, 70, 78, 87, 97, 108, 120, 133, 147, 162, 179, 198  **mesopelagic**: 220, 246, 275, 307, 345, 387, 435, 485, 535, 585, 635, 685, 740, 805, 875, 950  **bathyabyssopelagic**: 1030, 1120, 1230, 1350, 1480, 1630, 1800, 1990, 2190, 2390, 2590, 2815, 3065, 3315, 3565, 3815, 4065, 4365, 4740, 5190, 5690, 6240, 6870, 7250 |

Supplementary Table 3. List of phyla included in the climate-smart prioritisation analysis in the high seas with their corresponding number of species (i.e., conservation features). Computed using a threshold of 0.5 probability of occurrence.

|  |  |  |  |
| --- | --- | --- | --- |
| **Phylum** | **Number of species** | | |
| **Epipelagic** | **Mesopelagic** | **Bathyabyssopelagic** |
| Acanthocephala |  | 1 |  |
| Annelida | 389 | 116 | 42 |
| Arthropoda | 1545 | 998 | 314 |
| Bacillariophyta | 1 |  |  |
| Brachiopoda | 8 | 16 | 8 |
| Bryozoa | 59 | 32 | 6 |
| Chaetognatha | 16 | 17 | 3 |
| Chlorophyta | 51 |  |  |
| Chordata | 3393 | 1829 | 659 |
| Cnidaria | 767 | 337 | 64 |
| Ctenophora | 4 | 5 |  |
| Cyanobacteria | 5 |  |  |
| Dinophyta | 1 |  |  |
| Echinodermata | 335 | 195 | 84 |
| Echiura | 3 |  |  |
| Foraminifera | 12 | 25 | 13 |
| Gastrotricha | 3 |  |  |
| Hemichordata | 3 | 2 |  |
| Kamptozoa | 2 |  |  |
| Magnoliophyta | 1 |  |  |
| Mollusca | 1674 | 685 | 244 |
| Nematoda | 1 |  |  |
| Nemertea | 2 |  |  |
| Ochrophyta | 31 | 1 |  |
| Phoronida | 3 |  |  |
| Platyhelminthes | 1 |  |  |
| Porifera | 131 | 47 | 11 |
| Priapulida |  | 2 | 1 |
| Rhodophyta | 70 |  |  |
| Sagenista | 2 |  |  |
| Sipuncula | 21 | 21 | 23 |
| Tracheophyta | 4 |  |  |
| **TOTAL** | **8538** | **4329** | **1472** |