Supplementary information / Methodology for the manuscript: “Integrating knowledge systems: A prototype methodology connecting natural and social science data to understand ecosystem quality trajectories”

**Data source**

*Fisheries data - present*

Fish stock data for the last decade was collected in each case study country using different assessment methods. In Malaysia, annual fisheries statistics (Department of Fisheries Sabah) were collated for wild caught and aquaculture produced fish and shellfish from three TMP districts (Kudat, Kota Marudu, Pitas) covering the ten-year period of 2009-2018. Only wild catches landed by traditional fishing gears were analyzed to match the socio-economic background of respondents who mainly depended on artisanal fisheries (Teh et al., 2009) (see Table 1)

**Table 1:** Malaysia landing and production data (MT) derived from Annual Fisheries Statistics (Department of Fisheries Sabah). Locations covered are Kudat, Kota Marudu and Pitas, including wild fish, wild shellfish, aquaculture fish, and aquaculture shellfish.

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Sector** | **Site** | **2009** | **2010** | **2011** | **2012** | **2013** | **2014** | **2015** | **2016** | **2017** | **2018** |
| **Wild Fish** | Kudat | 2196.6 | 2291.3 | 2115.4 | 1931.3 | 8475.7 | 4740.08 | 5558.1 | 4815.4 | 4925.8 | 5384.1 |
|  | Kota Marudu | 4.6 | 98.0 | 164.2 | 223.0 | 254.2 | 283.3 | 295.1 | 243.1 | 211.0 | 278.1 |
|  | Pitas | 2374.7 | 3191.04 | 3417.01 | 4345.0 | 2492.09 | 2092.1 | 2294.9 | 3305.4 | 2519.9 | 2375.4 |
|  | All sites | 4575.9 | 5580.7 | 5696.7 | 6499.4 | 11222.7 | 7116.2 | 8148.1 | 8363.8 | 7656.7 | 8037.7 |
| **Wild Shellfish** | Kudat | 365.7 | 286.2 | 219.1 | 319.5 | 1816.5 | 1209.8 | 517.3 | 270.4 | 249.7 | 340.2 |
|  | Kota Marudu | 6.1 | 145.7 | 159.0 | 197.3 | 295.8 | 321.6 | 336.9 | 340.3 | 376.9 | 388.5 |
|  | Pitas | 366.3 | 370.5 | 330.1 | 450.1 | 302.6 | 388.9 | 483.8 | 572.2 | 694.8 | 902.3 |
|  | All sites | 738.1 | 802.4 | 708.2 | 966.9 | 2414.8 | 1920.3 | 1338.1 | 1183.0 | 1321.4 | 1631.0 |
| **Aquaculture Fish** | Kudat | 189.6 | 259.8 | 71.4 | 109.3 | 79.2 | 38.2 | 43.0 | 26.6 | 24.2 | 86.5 |
|  | Kota Marudu | 1.8 | 1.1 | 2.7 | 1.2 | 0.6 | 1.2 | 0.4 | 3.8 | 3.1 | 4.1 |
|  | Pitas | 125.5 | 119.4 | 1.7 | 1.1 | 1.0 | 0.9 | 2.4 | 1.0 | 1.9 | 1.9 |
|  | All sites | 316.8 | 380.2 | 75.7 | 111.6 | 80.8 | 40.3 | 45.7 | 31.4 | 29.2 | 92.4 |
| **Aquaculture Shellfish** | Kudat | 30.1 | 126.7 | 7.1 | 5.3 | 1.4 | 340.8 | 411.1 | 253.0 | 1038.8 | 1319.7 |
|  | Kota Marudu | 298.5 | 17.4 | 0.6 | 0.8 | 0.2 | 4.9 | 9.7 | 5.3 | 1.9 | 1.8 |
|  | Pitas | 0.0 | 0.0 | 0.0 | 0.2 | 1.9 | 7631.1 | 5660.3 | 2733.8 | 1954.8 | 2534.8 |
|  | All sites | 328.6 | 144.2 | 7.7 | 6.3 | 3.5 | 7976.8 | 6081.1 | 2992.1 | 2995.5 | 3856.3 |

For the Indonesian case study landing data for wild fish in Selayar for the period between 2014 to 2018 (Selayar bureau of statistics, 2019) has been included (Table 2).

**Table 2**: Indonesia landing data (MT) derived from. The location covered is Selayar island including wild fish.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Year | 2014 | 2015 | 2016 | 2017 | 2018 |
| Wild fish | 2.9 | 2.42 | 2.41 | 2.02 | 2.16 |

In Palawan, fish stock assessment data of Puerto Princesa has been included indicating the level of density (ind./500 sqm) ). The data was derived from Puerto Princesa City Agriculture Office. The number of local sites surveyed vary from 1 to 17.Table 3 reports the mean density across all sites rather than at a single site.

**Table 3**: Fish survey data (individuals/500 sqm) for the Puerto Princesa area (PPC-CAO, 2019).

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Year** | **2005** | **2006** | **2007** | **2008** | **2009** | **2010** | **2011** | **2012** | **2013** | **2014** | **2015** | **2016** | **2017** |
| **Mean (density)** | 889 | 280 | 227 | 813 | 1,174 | 1644 | 69 | 72 | 75 | 53 | 88 | 92 | 185 |
| **N (Sites)** | 1 | 1 | 5 | 14 | 5 | 17 | 12 | 8 | 11 | 1 | 5 | 5 | 5 |

*Fish data - future*

Data of future fish biomass were extracted from SS-DBEM runs (Cheung et al., 2008; Fernandes et al., 2013) performed within the GCRF Blue Communities project covering the period from 2019 to 2028. This is in line with the present-towards-future time period covered in the community perception surveys. We used projections under two Representative Concentration Pathways (RCP) which is a greenhouse gas concentration trajectory and is used by the IPCC. We used RCP8.5 (sometimes called business as usual) and RCP4.5 (which correspond to a pathway with mitigation measures as planned in the Paris agreement) as climate scenarios provided through a regional model projection (the data is available at https://doi.org/10.5281/zenodo.4775853). The fish model can include different level of fishing using Maximum Sustainable Yield (MSY). The MSY was used in increments of 1 from 0 to 4, to represent a range of possible futures under extremes of fishing. Consequently, the changes in biomass do not reflect the effect of existing fishing level for either study site. Additionally, we found that while the fishing pressure applied in the model has an impact on the abundance of fish, it does not significantly alter the rate of change until past 2050 when the effect of climate change starts being significant. Consequently, we included the projections with the effect of climate change only. Model outputs are available on zenodo.org along with additional information about the model calculations and the set-up of the runs (10.5281/zenodo.4281146)

From the projections, we extracted the relevant time period (2019-2028) for the three relevant case study sites (Sabah, Malaysia; Selayar, Indonesia; and Palawan, Philippines). The model has a resolution of 0.5 degree, with one grid square containing one specific study site and its surroundings. However, the coarse resolution of the model means we might miss some of the spatial variability by using only one grid square, or not include some fishing grounds that are farther. To avoid this bias, we decided to use data from a square “box” around each site. The square is 5 by 5 degree and is centered on the. For Malaysia we used Kota Marudu as the point of reference for the longitudinal center and the bottom latitude of the square on it to include Kudat and Pitas as well as the surrounding waters. The Indonesian box was centered both latitudinally and longitudinally around the island of Selayar and similarly the Philippines box was centered both latitudinally and longitudinally around Puerto Princesa.

Model outputs were averaged over the box to give mean abundance (in grams) of fish in the box per grid square as depicted in Table 4.

**Table 4:** Biomass (in grams) of fish from model projections, per year and spatially averaged for each sites

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **County** | **Site** | **RCP** | **2019** | **2020** | **2021** | **2022** | **2023** | **2024** | **2025** | **2026** | **2027** | **2028** |
| Malaysia | Kota Marudu | 8.5 | 4.19E+10 | 4.18E+10 | 4.27E+10 | 4.18E+10 | 4.47E+10 | 4.12E+10 | 4.12E+10 | 4.17E+10 | 4.46E+10 | 4.16E+10 |
|  |  | 4.5 | 4.29E+10 | 4.21E+10 | 4.33E+10 | 4.19E+10 | 4.16E+10 | 4.05E+10 | 4.26E+10 | 4.20E+10 | 4.29E+10 | 4.03E+10 |
| Philippines | Puerto Princessa | 8.5 | 1.01E+11 | 1.02E+11 | 1.04E+11 | 1.04E+11 | 1.07E+11 | 1.03E+11 | 1.06E+11 | 1.07E+11 | 1.10E+11 | 1.05E+11 |
|  |  | 4.5 | 5.07E+10 | 5.07E+10 | 5.23E+10 | 5.17E+10 | 5.17E+10 | 5.09E+10 | 5.30E+10 | 5.30E+10 | 5.35E+10 | 5.15E+10 |
| Indonesia | Selayar | 8.5 | 3.45E+10 | 3.33E+10 | 3.47E+10 | 3.22E+10 | 3.67E+10 | 3.22E+10 | 3.51E+10 | 3.25E+10 | 3.50E+10 | 2.96E+10 |
|  |  | 4.5 | 1.75E+10 | 1.65E+10 | 1.70E+10 | 1.62E+10 | 1.77E+10 | 1.62E+10 | 1.71E+10 | 1.59E+10 | 1.70E+10 | 1.49E+10 |
| Vietnam | Cu Lao Cham | 8.5 | 3.20E+10 | 2.95E+10 | 3.14E+10 | 2.84E+10 | 3.08E+10 | 2.89E+10 | 3.11E+10 | 2.87E+10 | 3.09E+10 | 2.71E+10 |
|  |  | 4.5 | 3.11E+10 | 2.99E+10 | 3.08E+10 | 2.91E+10 | 3.04E+10 | 2.89E+10 | 3.14E+10 | 2.95E+10 | 3.07E+10 | 2.78E+10 |

*Mangrove data*

Mangrove forest area for study sites in Malaysia, Indonesia and the Philippines were extracted from Global Mangrove Watch (GMW) (Bunting et al., 2018). This global-scale dataset is generated from the classification of optical and radar satellite data. For further details on the remote sensing methodology and accuracy assessment see Bunting et al., 2018. Data was available for the years 2007-2010 and 2015-2016. As a global-scale dataset generated with a consistent methodology, it is anticipated the accuracy will vary between locations due to local conditions; such as the surrounding vegetation species, mangrove condition and satellite data availability. To correspond to the community perception data which was aggregated at a district level, mangrove extent was extracted for the relevant district or municipality area (Table 5).

**Table 5:** Extent of mangrove in selected case study sites in Malaysia, the Philippines, Indonesia and Vietnam (km2).

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Country** | **Site** | **2003** | **…** | **2007** | **2008** | **2009** | **2010** | **2011** | **2012** | **2013** | **2014** | **2015** | **2016** |
| **Malaysia** | Kudat district |  |  | 126.554 | 126.939 | 127.006 | 127.438 |  |  |  |  | 125.643 | 126.022 |
|  | Kota Marudu  district |  |  | 57.208 | 57.401 | 57.531 | 58.121 |  |  |  |  | 56.835 | 56.795 |
|  | Pitas district |  |  | 152.339 | 152.375 | 152.501 | 153.426 |  |  |  |  | 150.888 | 150.301 |
|  | All TMP |  |  | 340.550 | 341.216 | 341.562 | 343.647 |  |  |  |  | 337.791 | 337.544 |
| **Philippines** | Puerto Princesa Municipality |  |  | 58.398 | 58.357 | 58.163 | 57.733 |  |  |  |  | 57.548 | 57.548 |
|  | Taytay Municipality |  |  | 67.271 | 67.142 | 67.132 | 67.155 |  |  |  |  | 66.010 | 66.010 |
|  | Aborlan Municipality |  |  | 13.407 | 13.413 | 13.413 | 13.413 |  |  |  |  | 13.372 | 13.372 |
|  | All Palawan |  |  | 539.572 | 539.240 | 538.683 | 537.312 |  |  |  |  | 533.973 | 533.927 |
| **Indonesia** | Bontosikuyu |  |  | 1.254 | 1.252 | 1.224 | 1.109 |  |  |  |  | 1.106 | 1.111 |
| **Vietnam** | Cam Thanh | 1.4427 |  |  |  |  |  |  |  |  |  |  | 0.7578 |
|  | Cua Dai | 0.0765 |  |  |  |  |  |  |  |  |  |  | 0.0117 |
|  | All Cu Lao Cham-Hoi An Biosphere Reserve | 3.1604 |  |  |  |  |  |  |  |  |  |  | 1.0531 |

Mangrove extent data was not available from Global Mangrove Watch for the case study area in Vietnam. Mangrove extent data for Cu Lao Cham-Hoi An Biosphere Reserve for the years 2003 and 2016 was obtained from a study by Tin et al., 2019. Tin et al., (2019) used supervised classification of optical (Landsat) imagery to detect mangrove extent change over time (Table 5). For further details on the remote sensing methodology and accuracy assessment see Tin et al., 2019.

*Coral data*

Coral data for Indonesia case study: Two Sentinel-2 satellite images for the years of 2015 and 2019 (24 May 2021) were obtained from an open access European ESA-Copernicus project portal (https://scihub.copernicus.eu/). We used Sentinel-2 product that includes orthorectified top-of-atmosphere (TOA) reflectance (Level 1-C). This version also contains sub-pixel multispectral registration. For the habitat classification related to coral platforms, we restricted the analyses to two sites, Tambolongan and Polassi islands, which were representatives of the region (Bontosikuyu). Subsequent to this, the ‘unsupervised isodata classification’ was conducted using the following criteria: a maximum of 20 classes on Sentinel-2 using bands 2-3-4-8 with 10 m of resolution (Richards 2006). Output images were obtained using unsupervised classification, from which we derived a number of classes into which each pixel area is assigned (Table 6). The assignment was based on interpreting the geomorphologic description of the seabed, with particular reference for coral identifications (Green et al., 2000).

Out of the images generated in each year of the Sentinel-2 satellite data, we classified the coral reef coverage using QGIS by analysing the changes in the raster images from each year of the satellite based coral reefs coverage data.

**Table 6:** Coral extent (ha) data from Tambolongan and Polassi islands, Indonesia.

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Site** | **2015** | **2019** |
| **Indonesia** | Tambolongan and Polassi islands | 1720 | 1432 |

For Vietnam, coral data were obtained from the management board of Cu Lao Cham MPA (2021). In an effort to save the coral reefs, a reef recovery program was implemented in 2011, which aimed to cultivate and restore the coral reef in Cu Lao Cham (Ngoc, 2018). Annually, the reef check method was used to observe water around Cu Lao Cham MPA, which can supply important information for coral reef cover (Table 7).

**Table 7:** Live coral extent (ha) data from Cu Lao Cham MPA (2021).

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | Site | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
| Vietnam | Cu Lao Cham MPA | 30.6944 | 26.2171 | 42.0238 | 49.7368 | 47.9063 | 47.1563 | 61.1563 | 50.9688 | 59.2631 | 59.1667 |

In Palawan, only Puerto Princesa City has time series data on hard coral cover. The data was provided by the City Agriculture Office. The number of surveyed sites vary each year and not all sites are surveyed each year. Nevertheless,the mean cover of hard corals for each year is already indicative of the overall health of the coral reefs (Table 8).

**Table 8:** Hard coral cover (%) in Puerto Princesa City from 1999-2017 (PPC-CAO, 2019).

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Site** | **1999** | **2003** | **2004** | **2005** | **2006** | **2007** | **2008** | **2009** | **2010** | **2011** | **2012** | **2013** | **2014** | **2015** | **2016** | **2017** |
| Philippines | Puerto Princesa City | 35.97 | 39.00 | 18.75 | 13.00 | 35.31 | 44.32 | 33.61 | 19.55 | 34.16 | 34.32 | 30.28 | 35.09 | 30.36 | 41.72 | 30.23 | 13.46 |
|  |  | 1 | 1 | 2 | 1 | 7 | 8 | 14 | 3 | 16 | 13 | 8 | 11 | 2 | 4 | 7 | 5 |

*Seagrass data*

The data on the extent of seagrass beds for the years 2003, 2010 and 2017 was obtained from Tin et al. (2020). Tin et al. used satellite data from ALOS AVNIR-2 and Landsat and field surveys to map seagrass extent for these selected years (Table 9).

**Table 9:** Seagrass bed extent in Cu Lao Cham MPA from Tin et al., 2020.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Site** | 2003 | 2010 | 2017 |
| Vietnam | Cu Lao Cham – Hoi An | 55.89 | 75.23 | 12.78 |

*Community perception data*

Community perceptions data was collected during data collection for the Blue Communities project 6 which explored the links between coastal communities’ marine interactions and their health and wellbeing. The survey was developed in the Philippines using a co-creation method with stakeholders, local communities and researchers and the process was also informed by previous literature. The co-creation process involved focus groups conducted in Aborlan, Taytay and Puerto Princesa in Palawan, Philippines. At the end of this process, the questions which were formulated were found to follow an existing conceptual framework, the ecosystems-enriched Drivers, Pressures, State, Exposure, Effects and Actions (eDPSEEA) model (Reis et al., 2015). Full methodology surrounding the co-creation process can be found in Madarcos et al., (2021). Translation of the survey was done by researchers from each institution, and surveys were piloted to ensure that question wording was understood correctly by respondents from the case study sites.

Data was collected at different times in each case study site. In Palawan, Philippines data was collected in Aborlan, Taytay and Puerto Princesa in June and July 2019. In Sabah, Malaysia data was collected in Kudat, Kota Marudu and Pitas between October 2019 and March 2020. In Hoi An-Cu Lao Cham, Vietnam data was collected at two mainland coastal communities in Hoi An: Cua Dai and Cam Thanh, and in Tan Hiep on the Cu Lao Cham island in May 2020. In Taka Bonerate Kepulauan Selayar, Indonesia data was collected in Bontosikuyu in November 2020. Data was collected through face-to-face interviews at people’s homes. Questions were asked aloud by the enumerator, and respondents answers were recorded using a Computer-Assisted Personal Interviewing (CAPI) program onto a tablet where the survey questions were pre-loaded, with the exception of Malaysia where survey responses were recorded on paper forms (see Dahlui et al., 2020 for the full data collection protocol in Malaysia). The criteria for inclusion in the study were being aged 18 years and over, living in a coastal community and willingness to participate. Recruitment differed slightly between case study sites, but generally once the study locations were selected, and where appropriate the village leader had been consulted, researchers and field assistants were assigned “streets” at random and approached each second house until their target number of interviews had been completed. In total, interviews should take around 25-30 minutes, and were conducted either inside or outside of people’s homes, depending on their preferences. Prior to interviews being conducted, respondents were told about the study using a Participation Sheet which were read aloud to respondents and also given to them to keep. Verbal consent was obtained before the survey commenced, and after the survey was completed respondents were given a Participant Card with their unique respondent ID, and contact details for the researchers in case participants had any questions post-survey and also so that they can request for their data to be removed from the study. Respondents could not use this ID to request access to their survey responses. Details on sample size, demographics as well as item means and standard deviations are found in table 10-12)

Ethical approval for each study was obtained from their respective institutions ethics committee: Universitas Nasional Research Ethics Commission Board (03/DKEP/UNAS/X/2020); Philippines National Ethics Committee (2019-002-Creencia-Blue); Hanoi National University of Education Ethics Committee (Nov19/QĐ-ĐHSPHN/11075); University of Malaya Research Ethics Committee (UM.TNC2/UMREC-522); as well as the University of Exeter Medical School Research Ethics Committee (May19/B/185).

**Table 10**: Number of respondents who chose each response level (-2 to +2 including Missing) for each of the marine habitats and ecosystems services, across each of the study sites

|  | |  | **Tun Mustapha Park, Malaysia** | | | | | | | | | | **Palawan, Philippines** | | | | | | | | | | | | **Hoi An-Cu Lao Cham, Vietnam** | | | | | | | | | | | | **Selayar, Indonesia** | | | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | |  | **Kudat** | | **Kota Marudu** | | | | **Pitas** | | | | **Puerto  Princesa** | | | | **Aborlan** | | | | **Taytay** | | | | **Cam Thanh** | | | | **Cua Dai** | | | | **Tan Hiep** | | | | **Bontosikuyu** | | | |
| **Past** | **Future** | **Past** | | **Future** | | **Past** | | **Future** | | **Past** | | **Future** | | **Past** | | **Future** | | **Past** | | **Future** | | **Past** | | **Future** | | **Past** | | **Future** | | **Past** | | **Future** | | **Past** | | **Future** | |
| **Wild fish** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|  | 2 | | 11 | 20 | 19 | | 35 | | 1 | | 2 | | 28 | | 10 | | 18 | | 16 | | 20 | | 29 | | 0 | | 0 | | 12 | | 4 | | 10 | | 7 | | 164 | | 5 | |
|  | 1 | | 9 | 14 | 0 | | 16 | | 1 | | 2 | | 16 | | 19 | | 1 | | 9 | | 23 | | 17 | | 1 | | 2 | | 0 | | 3 | | 6 | | 13 | | 62 | | 2 | |
|  | 0 | | 37 | 40 | 10 | | 32 | | 64 | | 61 | | 14 | | 23 | | 15 | | 8 | | 27 | | 22 | | 3 | | 15 | | 2 | | 7 | | 3 | | 11 | | 41 | | 37 | |
|  | -1 | | 40 | 48 | 14 | | 49 | | 2 | | 2 | | 40 | | 35 | | 24 | | 14 | | 53 | | 34 | | 3 | | 6 | | 2 | | 8 | | 8 | | 11 | | 6 | | 36 | |
|  | -2 | | 147 | 119 | 155 | | 65 | | 7 | | 3 | | 56 | | 61 | | 24 | | 33 | | 61 | | 75 | | 46 | | 27 | | 59 | | 45 | | 96 | | 64 | | 3 | | 113 | |
|  | Missing | | 55 | 58 | 3 | | 4 | | 35 | | 40 | | 5 | | 11 | | 3 | | 5 | | 3 | | 10 | | 0 | | 3 | | 1 | | 9 | | 0 | | 17 | | 54 | | 137 | |
| Totals | |  | 299 | 299 | 201 | | 201 | | 110 | | 110 | | 159 | | 159 | | 85 | | 85 | | 187 | | 187 | | 53 | | 53 | | 76 | | 76 | | 123 | | 123 | | 330 | | 330 | |
| **Wild shellfish** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|  | | 2 | 8 | 22 | 10 | | 28 | | 1 | | 2 | | 28 | | 7 | | 12 | | 15 | | 31 | | 29 | | 0 | | 0 | | 10 | | 2 | | 11 | | 7 | | 0 | | 0 | |
|  | | 1 | 10 | 15 | 4 | | 20 | | 1 | | 2 | | 13 | | 18 | | 7 | | 11 | | 18 | | 15 | | 2 | | 2 | | 3 | | 1 | | 3 | | 12 | | 0 | | 0 | |
|  | | 0 | 28 | 38 | 10 | | 35 | | 65 | | 62 | | 40 | | 46 | | 18 | | 10 | | 41 | | 36 | | 4 | | 10 | | 4 | | 8 | | 4 | | 9 | | 0 | | 0 | |
|  | | -1 | 47 | 45 | 18 | | 50 | | 2 | | 2 | | 33 | | 29 | | 10 | | 12 | | 45 | | 31 | | 3 | | 7 | | 1 | | 9 | | 5 | | 17 | | 0 | | 0 | |
|  | | -2 | 104 | 74 | 152 | | 60 | | 5 | | 1 | | 26 | | 44 | | 25 | | 27 | | 40 | | 58 | | 42 | | 31 | | 53 | | 43 | | 97 | | 61 | | 0 | | 0 | |
|  | | Missing | 102 | 105 | 7 | | 8 | | 36 | | 41 | | 19 | | 15 | | 13 | | 10 | | 12 | | 18 | | 2 | | 3 | | 5 | | 13 | | 3 | | 17 | | 330 | | 330 | |
| Totals | |  | 299 | 299 | 201 | | 201 | | 110 | | 110 | | 159 | | 159 | | 85 | | 85 | | 187 | | 187 | | 53 | | 53 | | 76 | | 76 | | 123 | | 123 | | 330 | | 330 | |
| **Aquaculture (Fish)** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|  | | 2 | 17 | 26 | 3 | | 24 | | 1 | | 0 | | 9 | | 5 | | 6 | | 10 | | 30 | | 33 | | 13 | | 9 | | 20 | | 15 | | 1 | | 0 | | 0 | | 0 | |
|  | | 1 | 9 | 19 | 3 | | 17 | | 1 | | 2 | | 3 | | 7 | | 7 | | 6 | | 18 | | 18 | | 8 | | 4 | | 9 | | 3 | | 1 | | 2 | | 0 | | 0 | |
|  | | 0 | 38 | 39 | 13 | | 35 | | 64 | | 62 | | 10 | | 12 | | 13 | | 15 | | 30 | | 23 | | 4 | | 8 | | 5 | | 11 | | 0 | | 1 | | 0 | | 0 | |
|  | | -1 | 48 | 37 | 13 | | 36 | | 2 | | 2 | | 8 | | 7 | | 10 | | 9 | | 35 | | 22 | | 6 | | 9 | | 3 | | 10 | | 2 | | 1 | | 0 | | 0 | |
|  | | -2 | 64 | 53 | 124 | | 43 | | 3 | | 0 | | 10 | | 12 | | 8 | | 6 | | 21 | | 36 | | 15 | | 14 | | 23 | | 11 | | 3 | | 2 | | 0 | | 0 | |
|  | | Missing | 123 | 125 | 45 | | 46 | | 39 | | 44 | | 119 | | 116 | | 41 | | 39 | | 53 | | 55 | | 7 | | 9 | | 16 | | 26 | | 116 | | 117 | | 330 | | 330 | |
| Totals | |  | 299 | 299 | 201 | | 201 | | 110 | | 110 | | 159 | | 159 | | 85 | | 85 | | 187 | | 187 | | 53 | | 53 | | 76 | | 76 | | 123 | | 123 | | 330 | | 330 | |
| **Aquaculture (Shellfish)** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|  | | 2 | 9 | 17 | 0 | | 23 | | 1 | | 0 | | 8 | | 3 | | 1 | | 4 | | 26 | | 28 | | 4 | | 4 | | 12 | | 6 | | 0 | | 0 | | 0 | | 0 | |
|  | | 1 | 6 | 10 | 5 | | 16 | | 2 | | 2 | | 5 | | 3 | | 2 | | 4 | | 5 | | 4 | | 7 | | 3 | | 5 | | 5 | | 3 | | 3 | | 0 | | 0 | |
|  | | 0 | 41 | 49 | 12 | | 35 | | 63 | | 62 | | 5 | | 10 | | 5 | | 8 | | 12 | | 22 | | 6 | | 9 | | 6 | | 11 | | 0 | | 1 | | 0 | | 0 | |
|  | | -1 | 49 | 39 | 17 | | 37 | | 2 | | 2 | | 4 | | 6 | | 2 | | 2 | | 16 | | 5 | | 7 | | 11 | | 7 | | 9 | | 0 | | 0 | | 0 | | 0 | |
|  | | -2 | 77 | 64 | 122 | | 44 | | 3 | | 0 | | 5 | | 8 | | 4 | | 1 | | 5 | | 8 | | 22 | | 19 | | 24 | | 15 | | 4 | | 2 | | 0 | | 0 | |
|  | | Missing | 117 | 120 | 45 | | 46 | | 39 | | 44 | | 132 | | 129 | | 71 | | 66 | | 123 | | 120 | | 7 | | 7 | | 22 | | 30 | | 116 | | 117 | | 330 | | 330 | |
| Totals | |  | 299 | 299 | 201 | | 201 | | 110 | | 110 | | 159 | | 159 | | 85 | | 85 | | 187 | | 187 | | 53 | | 53 | | 76 | | 76 | | 123 | | 123 | | 330 | | 330 | |
|  | |  |  |  |  | |  | |  | |  | |  | |  | |  | |  | |  | |  | |  | |  | |  | |  | |  | |  | |  | |  | |
| **Mangroves** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|  | | 2 | 13 | 41 | 8 | | 37 | | 4 | | 3 | | 63 | | 64 | | 34 | | 34 | | 47 | | 63 | | 31 | | 38 | | 18 | | 20 | | 2 | | 0 | | 75 | | 6 | |
|  | | 1 | 19 | 17 | 2 | | 18 | | 3 | | 2 | | 28 | | 35 | | 14 | | 11 | | 21 | | 24 | | 11 | | 7 | | 9 | | 6 | | 1 | | 1 | | 29 | | 13 | |
|  | | 0 | 47 | 42 | 6 | | 32 | | 63 | | 62 | | 38 | | 28 | | 19 | | 12 | | 36 | | 30 | | 5 | | 6 | | 9 | | 12 | | 0 | | 1 | | 73 | | 82 | |
|  | | -1 | 45 | 41 | 10 | | 29 | | 1 | | 1 | | 14 | | 13 | | 5 | | 8 | | 46 | | 18 | | 2 | | 0 | | 7 | | 7 | | 0 | | 1 | | 9 | | 9 | |
|  | | -2 | 71 | 53 | 119 | | 25 | | 2 | | 1 | | 8 | | 10 | | 3 | | 8 | | 30 | | 38 | | 3 | | 1 | | 19 | | 12 | | 0 | | 0 | | 6 | | 52 | |
|  | | Missing | 104 | 105 | 56 | | 60 | | 37 | | 41 | | 8 | | 9 | | 10 | | 12 | | 7 | | 14 | | 1 | | 1 | | 14 | | 19 | | 120 | | 120 | | 138 | | 168 | |
| Totals | |  | 299 | 299 | 201 | | 201 | | 110 | | 110 | | 159 | | 159 | | 85 | | 85 | | 187 | | 187 | | 53 | | 53 | | 76 | | 76 | | 123 | | 123 | | 330 | | 330 | |
| **Coral reef** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|  | | 2 | 14 | 28 | 5 | | 24 | | 3 | | 1 | | 31 | | 20 | | 19 | | 15 | | 37 | | 32 | | 5 | | 7 | | 6 | | 8 | | 66 | | 61 | | 142 | | 10 | |
|  | | 1 | 15 | 11 | 6 | | 22 | | 1 | | 2 | | 21 | | 34 | | 7 | | 19 | | 17 | | 11 | | 4 | | 1 | | 6 | | 3 | | 15 | | 24 | | 51 | | 10 | |
|  | | 0 | 33 | 36 | 9 | | 36 | | 62 | | 61 | | 18 | | 19 | | 15 | | 7 | | 32 | | 31 | | 3 | | 5 | | 5 | | 7 | | 8 | | 10 | | 36 | | 34 | |
|  | | -1 | 36 | 38 | 16 | | 32 | | 2 | | 1 | | 33 | | 26 | | 14 | | 11 | | 41 | | 33 | | 0 | | 0 | | 2 | | 3 | | 9 | | 6 | | 12 | | 33 | |
|  | | -2 | 82 | 66 | 118 | | 39 | | 5 | | 4 | | 37 | | 41 | | 22 | | 23 | | 28 | | 38 | | 1 | | 0 | | 7 | | 3 | | 13 | | 5 | | 4 | | 101 | |
|  | | Missing | 119 | 120 | 47 | | 48 | | 37 | | 41 | | 19 | | 19 | | 8 | | 10 | | 32 | | 42 | | 40 | | 40 | | 50 | | 52 | | 12 | | 17 | | 85 | | 142 | |
| Totals | |  | 299 | 299 | 201 | | 201 | | 110 | | 110 | | 159 | | 159 | | 85 | | 85 | | 187 | | 187 | | 53 | | 53 | | 76 | | 76 | | 123 | | 123 | | 330 | | 330 | |
| **Seagrass** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|  | | 2 | 2 | 23 | 4 | | 27 | | 2 | | 1 | | 50 | | 37 | | 21 | | 17 | | 33 | | 46 | | 1 | | 1 | | 6 | | 5 | | 23 | | 16 | | 83 | | 7 | |
|  | | 1 | 14 | 9 | 2 | | 21 | | 2 | | 2 | | 18 | | 33 | | 9 | | 12 | | 18 | | 12 | | 0 | | 0 | | 1 | | 1 | | 5 | | 9 | | 27 | | 6 | |
|  | | 0 | 46 | 44 | 5 | | 32 | | 64 | | 62 | | 54 | | 35 | | 26 | | 21 | | 69 | | 52 | | 3 | | 3 | | 4 | | 5 | | 20 | | 18 | | 108 | | 106 | |
|  | | -1 | 44 | 50 | 6 | | 24 | | 1 | | 1 | | 16 | | 22 | | 9 | | 10 | | 17 | | 16 | | 0 | | 0 | | 4 | | 2 | | 6 | | 11 | | 3 | | 20 | |
|  | | -2 | 70 | 49 | 113 | | 23 | | 3 | | 2 | | 10 | | 18 | | 6 | | 10 | | 18 | | 22 | | 7 | | 7 | | 14 | | 12 | | 17 | | 11 | | 5 | | 66 | |
|  | | Missing | 123 | 124 | 71 | | 74 | | 38 | | 42 | | 11 | | 14 | | 14 | | 15 | | 32 | | 39 | | 42 | | 42 | | 47 | | 51 | | 52 | | 58 | | 104 | | 125 | |
| Totals | |  | 299 | 299 | 201 | | 201 | | 110 | | 110 | | 159 | | 159 | | 85 | | 85 | | 187 | | 187 | | 53 | | 53 | | 76 | | 76 | | 123 | | 123 | | 330 | | 330 | |
|  | |  | **Tun Mustapha Park, Malaysia** | | | | | | | | | **Palawan, Philippines** | | | | | | | | | | | | **Hoi An-Cu Lao Cham, Vietnam** | | | | | | | | | | | | **Selayar, Indonesia** | | | |
|  | |  | **Kudat** | | **Kota Marudu** | | | **Pitas** | | | | **Puerto  Princesa** | | | | **Aborlan** | | | | **Taytay** | | | | **Cam Thanh** | | | | **Cua Dai** | | | | **Tan Hiep** | | | | **Bontosikuyu** | | | |
| **Past** | **Future** | **Past** | **Future** | | **Past** | | **Future** | | **Past** | | **Future** | | **Past** | | **Future** | | **Past** | | **Future** | | **Past** | | **Future** | | **Past** | | **Future** | | **Past** | | **Future** | | **Past** | | **Future** | |
| **Wild fish** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|  | | 2 | 11 | 20 | 19 | 35 | | 1 | | 2 | | 28 | | 10 | | 18 | | 16 | | 20 | | 29 | | 0 | | 0 | | 12 | | 4 | | 10 | | 7 | | 164 | | 5 | |
|  | | 1 | 9 | 14 | 0 | 16 | | 1 | | 2 | | 16 | | 19 | | 1 | | 9 | | 23 | | 17 | | 1 | | 2 | | 0 | | 3 | | 6 | | 13 | | 62 | | 2 | |
|  | | 0 | 37 | 40 | 10 | 32 | | 64 | | 61 | | 14 | | 23 | | 15 | | 8 | | 27 | | 22 | | 3 | | 15 | | 2 | | 7 | | 3 | | 11 | | 41 | | 37 | |
|  | | -1 | 40 | 48 | 14 | 49 | | 2 | | 2 | | 40 | | 35 | | 24 | | 14 | | 53 | | 34 | | 3 | | 6 | | 2 | | 8 | | 8 | | 11 | | 6 | | 36 | |
|  | | -2 | 147 | 119 | 155 | 65 | | 7 | | 3 | | 56 | | 61 | | 24 | | 33 | | 61 | | 75 | | 46 | | 27 | | 59 | | 45 | | 96 | | 64 | | 3 | | 113 | |
|  | | Missing | 55 | 58 | 3 | 4 | | 35 | | 40 | | 5 | | 11 | | 3 | | 5 | | 3 | | 10 | | 0 | | 3 | | 1 | | 9 | | 0 | | 17 | | 54 | | 137 | |
| Totals | |  | 299 | 299 | 201 | 201 | | 110 | | 110 | | 159 | | 159 | | 85 | | 85 | | 187 | | 187 | | 53 | | 53 | | 76 | | 76 | | 123 | | 123 | | 330 | | 330 | |
| **Wild shellfish** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|  | | 2 | 8 | 22 | 10 | 28 | | 1 | | 2 | | 28 | | 7 | | 12 | | 15 | | 31 | | 29 | | 0 | | 0 | | 10 | | 2 | | 11 | | 7 | | 0 | | 0 | |
|  | | 1 | 10 | 15 | 4 | 20 | | 1 | | 2 | | 13 | | 18 | | 7 | | 11 | | 18 | | 15 | | 2 | | 2 | | 3 | | 1 | | 3 | | 12 | | 0 | | 0 | |
|  | | 0 | 28 | 38 | 10 | 35 | | 65 | | 62 | | 40 | | 46 | | 18 | | 10 | | 41 | | 36 | | 4 | | 10 | | 4 | | 8 | | 4 | | 9 | | 0 | | 0 | |
|  | | -1 | 47 | 45 | 18 | 50 | | 2 | | 2 | | 33 | | 29 | | 10 | | 12 | | 45 | | 31 | | 3 | | 7 | | 1 | | 9 | | 5 | | 17 | | 0 | | 0 | |
|  | | -2 | 104 | 74 | 152 | 60 | | 5 | | 1 | | 26 | | 44 | | 25 | | 27 | | 40 | | 58 | | 42 | | 31 | | 53 | | 43 | | 97 | | 61 | | 0 | | 0 | |
|  | | Missing | 102 | 105 | 7 | 8 | | 36 | | 41 | | 19 | | 15 | | 13 | | 10 | | 12 | | 18 | | 2 | | 3 | | 5 | | 13 | | 3 | | 17 | | 330 | | 330 | |
| Totals | |  | 299 | 299 | 201 | 201 | | 110 | | 110 | | 159 | | 159 | | 85 | | 85 | | 187 | | 187 | | 53 | | 53 | | 76 | | 76 | | 123 | | 123 | | 330 | | 330 | |
| **Aquaculture (Fish)** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|  | | 2 | 17 | 26 | 3 | 24 | | 1 | | 0 | | 9 | | 5 | | 6 | | 10 | | 30 | | 33 | | 13 | | 9 | | 20 | | 15 | | 1 | | 0 | | 0 | | 0 | |
|  | | 1 | 9 | 19 | 3 | 17 | | 1 | | 2 | | 3 | | 7 | | 7 | | 6 | | 18 | | 18 | | 8 | | 4 | | 9 | | 3 | | 1 | | 2 | | 0 | | 0 | |
|  | | 0 | 38 | 39 | 13 | 35 | | 64 | | 62 | | 10 | | 12 | | 13 | | 15 | | 30 | | 23 | | 4 | | 8 | | 5 | | 11 | | 0 | | 1 | | 0 | | 0 | |
|  | | -1 | 48 | 37 | 13 | 36 | | 2 | | 2 | | 8 | | 7 | | 10 | | 9 | | 35 | | 22 | | 6 | | 9 | | 3 | | 10 | | 2 | | 1 | | 0 | | 0 | |
|  | | -2 | 64 | 53 | 124 | 43 | | 3 | | 0 | | 10 | | 12 | | 8 | | 6 | | 21 | | 36 | | 15 | | 14 | | 23 | | 11 | | 3 | | 2 | | 0 | | 0 | |
|  | | Missing | 123 | 125 | 45 | 46 | | 39 | | 44 | | 119 | | 116 | | 41 | | 39 | | 53 | | 55 | | 7 | | 9 | | 16 | | 26 | | 116 | | 117 | | 330 | | 330 | |
| Totals | |  | 299 | 299 | 201 | 201 | | 110 | | 110 | | 159 | | 159 | | 85 | | 85 | | 187 | | 187 | | 53 | | 53 | | 76 | | 76 | | 123 | | 123 | | 330 | | 330 | |
| **Aquaculture (Shellfish)** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|  | | 2 | 9 | 17 | 0 | 23 | | 1 | | 0 | | 8 | | 3 | | 1 | | 4 | | 26 | | 28 | | 4 | | 4 | | 12 | | 6 | | 0 | | 0 | | 0 | | 0 | |
|  | | 1 | 6 | 10 | 5 | 16 | | 2 | | 2 | | 5 | | 3 | | 2 | | 4 | | 5 | | 4 | | 7 | | 3 | | 5 | | 5 | | 3 | | 3 | | 0 | | 0 | |
|  | | 0 | 41 | 49 | 12 | 35 | | 63 | | 62 | | 5 | | 10 | | 5 | | 8 | | 12 | | 22 | | 6 | | 9 | | 6 | | 11 | | 0 | | 1 | | 0 | | 0 | |
|  | | -1 | 49 | 39 | 17 | 37 | | 2 | | 2 | | 4 | | 6 | | 2 | | 2 | | 16 | | 5 | | 7 | | 11 | | 7 | | 9 | | 0 | | 0 | | 0 | | 0 | |
|  | | -2 | 77 | 64 | 122 | 44 | | 3 | | 0 | | 5 | | 8 | | 4 | | 1 | | 5 | | 8 | | 22 | | 19 | | 24 | | 15 | | 4 | | 2 | | 0 | | 0 | |
|  | | Missing | 117 | 120 | 45 | 46 | | 39 | | 44 | | 132 | | 129 | | 71 | | 66 | | 123 | | 120 | | 7 | | 7 | | 22 | | 30 | | 116 | | 117 | | 330 | | 330 | |
| Totals | |  | 299 | 299 | 201 | 201 | | 110 | | 110 | | 159 | | 159 | | 85 | | 85 | | 187 | | 187 | | 53 | | 53 | | 76 | | 76 | | 123 | | 123 | | 330 | | 330 | |
| **Mangroves** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|  | | 2 | 13 | 41 | 8 | 37 | | 4 | | 3 | | 63 | | 64 | | 34 | | 34 | | 47 | | 63 | | 31 | | 38 | | 18 | | 20 | | 2 | | 0 | | 75 | | 6 | |
|  | | 1 | 19 | 17 | 2 | 18 | | 3 | | 2 | | 28 | | 35 | | 14 | | 11 | | 21 | | 24 | | 11 | | 7 | | 9 | | 6 | | 1 | | 1 | | 29 | | 13 | |
|  | | 0 | 47 | 42 | 6 | 32 | | 63 | | 62 | | 38 | | 28 | | 19 | | 12 | | 36 | | 30 | | 5 | | 6 | | 9 | | 12 | | 0 | | 1 | | 73 | | 82 | |
|  | | -1 | 45 | 41 | 10 | 29 | | 1 | | 1 | | 14 | | 13 | | 5 | | 8 | | 46 | | 18 | | 2 | | 0 | | 7 | | 7 | | 0 | | 1 | | 9 | | 9 | |
|  | | -2 | 71 | 53 | 119 | 25 | | 2 | | 1 | | 8 | | 10 | | 3 | | 8 | | 30 | | 38 | | 3 | | 1 | | 19 | | 12 | | 0 | | 0 | | 6 | | 52 | |
|  | | Missing | 104 | 105 | 56 | 60 | | 37 | | 41 | | 8 | | 9 | | 10 | | 12 | | 7 | | 14 | | 1 | | 1 | | 14 | | 19 | | 120 | | 120 | | 138 | | 168 | |
| Totals | |  | 299 | 299 | 201 | 201 | | 110 | | 110 | | 159 | | 159 | | 85 | | 85 | | 187 | | 187 | | 53 | | 53 | | 76 | | 76 | | 123 | | 123 | | 330 | | 330 | |
| **Coral reef** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|  | | 2 | 14 | 28 | 5 | 24 | | 3 | | 1 | | 31 | | 20 | | 19 | | 15 | | 37 | | 32 | | 5 | | 7 | | 6 | | 8 | | 66 | | 61 | | 142 | | 10 | |
|  | | 1 | 15 | 11 | 6 | 22 | | 1 | | 2 | | 21 | | 34 | | 7 | | 19 | | 17 | | 11 | | 4 | | 1 | | 6 | | 3 | | 15 | | 24 | | 51 | | 10 | |
|  | | 0 | 33 | 36 | 9 | 36 | | 62 | | 61 | | 18 | | 19 | | 15 | | 7 | | 32 | | 31 | | 3 | | 5 | | 5 | | 7 | | 8 | | 10 | | 36 | | 34 | |
|  | | -1 | 36 | 38 | 16 | 32 | | 2 | | 1 | | 33 | | 26 | | 14 | | 11 | | 41 | | 33 | | 0 | | 0 | | 2 | | 3 | | 9 | | 6 | | 12 | | 33 | |
|  | | -2 | 82 | 66 | 118 | 39 | | 5 | | 4 | | 37 | | 41 | | 22 | | 23 | | 28 | | 38 | | 1 | | 0 | | 7 | | 3 | | 13 | | 5 | | 4 | | 101 | |
|  | | Missing | 119 | 120 | 47 | 48 | | 37 | | 41 | | 19 | | 19 | | 8 | | 10 | | 32 | | 42 | | 40 | | 40 | | 50 | | 52 | | 12 | | 17 | | 85 | | 142 | |
| Totals | |  | 299 | 299 | 201 | 201 | | 110 | | 110 | | 159 | | 159 | | 85 | | 85 | | 187 | | 187 | | 53 | | 53 | | 76 | | 76 | | 123 | | 123 | | 330 | | 330 | |
| **Seagrass** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|  | | 2 | 2 | 23 | 4 | 27 | | 2 | | 1 | | 50 | | 37 | | 21 | | 17 | | 33 | | 46 | | 1 | | 1 | | 6 | | 5 | | 23 | | 16 | | 83 | | 7 | |
|  | | 1 | 14 | 9 | 2 | 21 | | 2 | | 2 | | 18 | | 33 | | 9 | | 12 | | 18 | | 12 | | 0 | | 0 | | 1 | | 1 | | 5 | | 9 | | 27 | | 6 | |
|  | | 0 | 46 | 44 | 5 | 32 | | 64 | | 62 | | 54 | | 35 | | 26 | | 21 | | 69 | | 52 | | 3 | | 3 | | 4 | | 5 | | 20 | | 18 | | 108 | | 106 | |
|  | | -1 | 44 | 50 | 6 | 24 | | 1 | | 1 | | 16 | | 22 | | 9 | | 10 | | 17 | | 16 | | 0 | | 0 | | 4 | | 2 | | 6 | | 11 | | 3 | | 20 | |
|  | | -2 | 70 | 49 | 113 | 23 | | 3 | | 2 | | 10 | | 18 | | 6 | | 10 | | 18 | | 22 | | 7 | | 7 | | 14 | | 12 | | 17 | | 11 | | 5 | | 66 | |
|  | | Missing | 123 | 124 | 71 | 74 | | 38 | | 42 | | 11 | | 14 | | 14 | | 15 | | 32 | | 39 | | 42 | | 42 | | 47 | | 51 | | 52 | | 58 | | 104 | | 125 | |
| Totals | |  | 299 | 299 | 201 | 201 | | 110 | | 110 | | 159 | | 159 | | 85 | | 85 | | 187 | | 187 | | 53 | | 53 | | 76 | | 76 | | 123 | | 123 | | 330 | | 330 | |

Note: Sample size for each study site – Kudat (N = 299), Kota Marudu (N = 201), Pitas (N = 110), Puerto Princesa (N = 145), Aborlan (N = 81), Taytay (N = 175), Cam Thanh (N = 53), Cua Dai (N = 76), Tan Hiep (N = 123), Taka Bonerate Kepuluaun Selayar (N = 330)

**Table 11:** Median community perception scores ± standard deviations.

|  | **Tun Mustapha Park,  Sabah, Malaysia** | | | **Palawan, Philippines** | | | **Hoi An-Cu Lao Cham, Vietnam** | | | **Taka Bonerate  Kepuluaun  Selayar, Indonesia** |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Kudat** | **Kota  marudu** | **Pitas** | **Puerto Princesa City** | **Aborlan** | **Taytay** | **Cam Thanh** | **Cua Dai** | **Tan Hiep** | **Bontosikuyu** |
| Wild fish | | | | | | | | | | |
| Past | -2 ± 1 | -2 ± 1 | 0 ± 1 | -1 ± 2 | -1 ± 1 | -1 ± 1 | -2 ± 1 | -2 ± 1 | -2 ± 1 | 2 ± 1 |
| Future | -1 ± 1 | -1 ± 1 | 0 ± 1 | -1 ± 1 | -1 ± 2 | -1 ± 2 | -2 ± 1 | -2 ± 1 | -2 ± 1 | -2 ± 1 |
| Wild shellfish | | | | | | | | | | |
| Past | -2 ± 1 | -2 ± 1 | 0 ± 1 | 0 ± 1 | 0 ± 1 | 0 ± 1 | -2 ± 1 | -2 ± 1 | -2 ± 1 | NA |
| Future | -1 ± 1 | -1 ± 1 | 0 ± 0 | -1 ± 1 | -1 ± 2 | -1 ± 1 | -2 ± 1 | -2 ± 1 | -2 ± 1 | NA |
| Aquaculture (Fish) | | | | | | | | | | |
| Past | -1 ± 1 | -2 ± 1 | 0 ± 1 | 0 ± 1 | 0 ± 1 | 0 ± 1 | 0 ± 2 | 0 ± 2 | -1 ± 2 | NA |
| Future | -1 ± 1 | -1 ± 1 | 0 ± 0 | 0 ± 1 | 0 ± 1 | 0 ± 2 | -1 ± 2 | 0 ± 2 | 0 ± 1 | NA |
| Aquaculture (Shellfish) | | | | | | | | | | |
| Past | -1 ± 1 | -2 ± 1 | 0 ± 1 | 0 ± 2 | 0 ± 1 | 0 ± 1 | -1 ± 1 | -1 ± 2 | -2 ± 2 | NA |
| Future | -1 ± 1 | -1 ± 1 | 0 ± 0 | 0 ± 1 | 0 ± 1 | 0 ± 1 | -1 ± 1 | -1 ± 1 | 0 ± 1 | NA |
| Mangroves | | | | | | | | | | |
| Past | -1 ± 1 | -2 ± 1 | 0 ± 1 | 1 ± 1 | 1 ± 1 | 0 ± 1 | 2 ± 1 | 0 ± 2 | 2 ± 1 | 1 ± 1 |
| Future | 0 ± 1 | 0 ± 1 | 0 ± 1 | 1 ± 1 | 1 ± 1 | 1 ± 2 | 2 ± 1 | 0 ± 2 | 0 ± 1 | 0 ± 1 |
| Coral reef | | | | | | | | | | |
| Past | -1 ± 1 | -2 ± 1 | 0 ± 1 | 0 ± 2 | 0 ± 2 | 0 ± 1 | 1 ± 1 | 0 ± 2 | 2 ± 1 | 2 ± 1 |
| Future | -1 ± 1 | 0 ± 1 | 0 ± 1 | 0 ± 1 | 0 ± 2 | 0 ± 1 | 2 ± 1 | 0 ± 1 | 2 ± 1 | -2 ± 1 |
| Seagrass | | | | | | | | | | |
| Past | -1 ± 1 | -2 ± 1 | 0 ± 1 | 0 ± 1 | 0 ± 1 | 0 ± 1 | -2 ± 1 | -1 ± 2 | 0 ± 2 | 0 ± 1 |
| Future | -1 ± 1 | 0 ± 1 | 0 ± 0 | 0 ± 1 | 0 ± 1 | 0 ± 1 | -2 ± 1 | -1 ± 2 | 0 ± 1 | 0 ± 1 |

**Table 12**: Demographics for the community perception data across case study sites

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Cu Lao Cham** | **Palawan** | **Selayar** | **Tun Mustapha Park** |
| **Sample Size** | *NCLC*= 252 | *NPAL=* 431 | *NSEL=* 330 | *N*TMP= 610 |
| **Gender** | Female:  119 (47.2%)  Male:  133 (52.8%) | Female:  259 (60%)  Male:  172 (40%) | Female:  126 (38.2%)  Male:  204 (61.8%) | Female:  339 (55.6%)  Male:  271 (44.4%) |
| **Age** | Mean age: 50.8 (SD=14.7)  20-35=48 (19%)  36-45=41 (16.3%)  46-55=48 (19%)  56-65=74 (19.4%)  66-99=41 (16.3%) | Mean age: 44.9 (SD=13.6)  18-29:61 (14.2%)  30-39: 102 (23.7%)  40-49: 114 (26.5%  50-59: 84 (19.5%)  60-90: 66 (15.3%)  Missing data: (4.9%) | Mean age: 42.3 (SD=12.2)  18-28: 43 (13.0%)  29-39: 99 (30.0%)  40-50: 113 (34.2%)  51-61: 52 (15.8%)  62-72: 22 (6.7%) | Mean age: 42.6 (SD=14.9)  18-29: 140 (23.0%)  30-39: 143 (23.4%)  40-49: 110 (18.0%)  50-59: 108 (17.7%)  60-90: 101 (16.6%) |
| **Employment** | Fishing: 82 (32.5%)  Tourism: 66 (26.2%)  Others: 104 (41.3%) | Aquaculture (caged fish / fin-fish):17(3.9%)  Crabbing / Shrimping: 20 (4.6%)  Fishing: 300 (69.6%)  Post-harvest activities:7 (1.6%)  Seaweed farming:44 (10.2%)  Taking tourists on boats etc.:3 ( 0.7%)  Missing data=40 (9.3%) | Receive income from fisheries sector: 168 (50.9%)  Receive income from other sectors: 139 (42.1%) | Land Agriculture:  39 (6.4%)  Mining & Quarrying:  1 (0.2%)  Construction:  24 (3.9%)  Services:  80 (13.1%)  Fishing & Aquaculture:  101 (16.6%)  Unemployed:  365 (59.8%) |
| **Education** | No schooling: 20 (7.9%)  Primary and secondary: 171 (67.9%)  High school and college/university: 61 (24.2%) | Primary (finished and not finished): 168 (39.0 %)  Secondary (finished and not finished): 201 (46.6 %)  Tertiary (finished and not finished): 56 (13.0 %)  Missing Data: 6 (1.4%) | Primary level: 50 (15.2%)  Primary graduate: 117 (35.5%)  Secondary level: 4 (1.2%)  Secondary graduate: 49 (14.8%)  Senior high school level: 7 (2.1%)  Senior high school graduate: 78 (23.6%)  College level: 2 (0.6%)  College graduate: 23 (7.0%) | No education:  147 (24.1%)  Primary:  189 (31.0%)  Secondary:  226 (37.0%)  Certificate/Skill (Post-Secondary):  25 (4.1%)  College/University:  23 (3.8%) |
| **Income** | Poverty: 0 (0%)  Moderate and above: 252 (100%) | *Note:* Income range in USD  Poor (<164.02):232 (53.8%)  Low Income (164.02 to 328.04):146 (33.9 %)  Lower Middle income (328.04 to 656.09):27 (6.3 %)  Middle  Income (656.09 to 1,640.26):4 (0.9%)  Upper Middle income (1,640.26 to 2,460.40): 2 (0.5%)  Upper income (2,460.40 to 3,280.53):0.0%  Rich (>3,280.53): 0.0 %  Missing data: 20 (4.6%) | Average monthly income in IDR:  < 1 million: 119 (36.1%)  1-2 million: 103 (31.2%)  2-3 million: 61 (18.5%)  3-4 million: 26 (7.9%)  4-5 million: 6 (1.8%)  > 5 million: 14 (4.2%)  Missing data: 1 (0.3%) | Average monthly income by category:  Paid-employment:  RM 1117.40 (n=73, 12 %)  Self-employment:  RM 864.10 (n=159, 26.1 %)  Pension received:  RM 984.60 (n=13, 2.1 %)  Other income:  RM 581.4 (n=175, 28.7 %)  Household income:  RM 1028.70 (n=330, 54.1 %)  No income:  (n=280, 45.9 %) |
| **Number and name of sites** | Cam Thanh; 2 villages : 53 (21.0%)  Cua Dai; 2 villages: 76 (30.2%)  Tan Hiep; 3 villages: 123 (48.8%) | Aborlan: 2  Puerto Princesa City: 4  Taytay: 4 | Bontosikuyu District, consisting of 12 villages | Kudat: 6  Kota Marudu: 4  Pitas: 3 |
| **Religion** | None: 185 (41.3%)  Buddhism: 64 (25.2%)  Christianity: 3 (1.2%) | Roman Catholic: 348 (80.8%)  Baptist Church: 17 (3.9%)  Born Again Christian:22 (5.1%)  Iglesia Ni Cristo: 9 (2.1 %)  Islam:2 (0.5%)  Others:32 ( 7.4%)  Missing data:3 (0.7%) | Islam: 291 (88.2%)  Christian: 2 (0.6%)  Catholic: 1 (0.3%) | Islam: 531 (87.0%)  Christian: 77 (12.6%)  Others: 2 (0.3%) |
| **Period of data collection** | May 2020 | June and July 2019 | 11 March – 10 Nov 2020 | November 2019 – February 2020 |

**Mapping Methodology**

*Community perception data harmonizing*

Across the case study sites, there were differences in the survey wording and response scales. In Indonesia and Malaysia the survey question asked people to compare the past to now, for example the question wording for Indonesia was: “Compared to now, would you say the quality of coral reefs and diversity of coral types 10 years ago (2010) in Kabupaten Selayar is better, worse the same?”. Whereas in the Philippines and Vietnam, respondents were asked to compare now to the past, for example in the Philippines the question wording was: “Compared to 10 years ago (2009) would you say the quality of coral reefs and diversity of coral types in Palawan is better, worse the same?”. The response scales also differed between countries. In the Philippines and Vietnam responses were recorded on a 7-point scale ranging from (1) “Much worse” to (7) “Much better”. In Malaysia, the responses were reversed with 1 equating to “Good/More” and 7 equating to “Worse/Less”. In Indonesia, response scales were on a 5-point Likert scale ranging from (1) “Much worse” to (5) “Much better”. In each case study respondents could also choose not to answer, or answer as don’t know and for these questions their answers were recorded as missing responses.

Due to these differences data went through a harmonisation process to ensure consistency across study sites. Firstly, the Indonesia data was reversed, so that for example an original score of 1 (“Much worse”) became a score of 5 (“Much better”). Although the Malaysia question was also worded in the same way as Indonesia, we did not reverse the scores themselves but changed what the scores meant for example where previously a score of 1 meant “Good/More” it now meant “Worse/Less”. This was due to the responses in Malaysia already being in the opposite direction compared to the other countries. Finally, we needed to have all of the responses on the same 5-point scale, for this we did two steps. Firstly, we re-coded the scores for the Philippines, Malaysia and Vietnam so that a score of 1 and 2 became 1, a score of 6 and 7 became 7 so that we had a 5-point scale of 1,3,4,5,7. This method most closely aligned the countries with a 7-point scale to the data collected in Indonesia. We then re-coded all scores so that the scales ranged from -2 for the lowest scores in all case studies and +2 for the highest scores in all case studies, with the middle scores (4 for the Philippines, Malaysia and Vietnam and 3 for Indonesia) becoming 0. Re-coding responses in this way, from a negative to positive value makes interpretation of results more intuitive as negative values represent decline and positive values represent improvement.

*Natural science data harmonizing*

Where possible, natural science data was collected or identified matching the ten year periods covered by the community perception data. Due to the diverse nature of the data we included, each natural science dataset had to be treated slightly differently when converting to the 5-point scale used for the community perception data. Standardization in this way made it possible to compare trends across different data types. Note that if an appropriate reference point existed in the litterature to indicate the intensity of the change we used this value, otherwise we used the median and standard deviation to evaluate the amplitude of the natural variability and determine what could be considered a significant change.

1) Fisheries – present and future

Fisheries data were either landings data (Malaysia, Indonesia) or survey of stocks (Philippines). A few risk factors have to be considered, such as the potential for high variability within fisheries data due to either natural variability in the fish populations (e.g. small pelagic stocks like sardines and anchovies) or changes in the fishing effort itself. Considering that the beginning or end point of the time series could be “outliers”, and relying on these values exclusively could bias the outcome, an average year-on-year change was calculated and expressed as percentage of change. The median of the year-on-year change was then used as the value to compare with the community perception data.

Using this method, we found that the measured year-on-year change varied from +25% to -50% with a median value of +2% and a standard deviation of 18. We used this to create categories to scale the natural science data to the 5-point scale (see Table 20 below for the categories).

This method levels out extreme values caused by sudden increases or decreases in catch. In relation to the overall value of change across the ten year period, this method produces a similar value and overall direction of change, however less affected by extremes.

The same method was applied to the model outputs for the future data. The two RCP scores were treated separately in case the speed of climate change caused significant differences in the final scoring, which ultimately was not the case. We found that the measured change from year to year varied between +/- 15%, which is within the natural variability found in present day data that we collected for this study. The median change per site and scenario varied from -5% to +1% which represents a slight change. Score for all sites and both present and future data are in Table 13 below.

**Table 13:** Scoring of the natural science data for four fisheries sectors at sites in Vietnam, Palawan, Indonesia and Malaysia

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Country** | **Malaysia** | | | | | | | | **Indonesia** | | **Philippines** | | **Vietnam** | | | |
| **Site** | Kudat |  | Kota Marudu |  | Pitas |  | All TMP |  | Kepulauan Selayar |  | Palawan |  | Tan Hiep |  | All CLC |  |
|  | Past | Future | Past | Future | Past | Future | Past | Future | Past | Future | Past | Future | Past | Future | Past | Future |
| **Wild Fish** | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 -1 | 0 NA | 0 | 0 | 0 | NA | 0 | 0 |
| **Wild Shellfish** | -1 | NA | 0 | NA | 1 | NA | 0 | NA |  |  |  |  | 0 | NA | 0 | NA |
| **Aquaculture Fish** | 0 | NA | -1 | NA | 0 | NA | 0 | NA |  |  |  |  |  |  |  |  |
| **Aquaculture Shellfish** | 1 | NA | -2 | NA | 0 | NA | -1 | NA |  |  |  |  |  |  |  |  |

2) Mangroves

For each site, the mean annual rate of change in mangrove cover was calculated for the time period available. Where sites were missing mangrove cover estimates for a number of intermediate years, a constant change rate has been assumed over this period and the annual percent change has been calculated. The mean of the year-on-year change was then used as the value to compare with the community perception data.

The mean annual rate of mangrove extent change at the study sites over this period ranged from -0.03% to -13.45%, with a median rate of -0.16%. Richards and Friess (2016) and Goldberg et al., (2020) found an annual rate of mangrove deforestation of ~0.2% per year in Southeast Asia for the periods 2000-2012 and 2000-2016 respectively. Estimates of annual change rates for individual countries in southeast Asia vary more widely and range from 0.0% to - 0.5% per year. The median and maximum national rates of mangrove loss for southeast Asian countries from Tin, Ni, Tuan, Saizen, and Catherman (2019); Tin et al. (2020) were used to create categories to scale annual rates of mangrove cover change. (Table 20). The scale below assumes that a net increase in mangrove cover reflects an improvement in mangrove status, and a decrease in extent reflects a decline. This data does not directly reflect ecosystem health and the condition of mangrove stands, but the geographical area covered by the mangrove canopy only. Scores for all sites are in the table 14 below.

**Table 14:** Scoring of the natural science data for mangrove coverage at sites in Malaysia, Indonesia, Philippines and Vietnam.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Country** | **Malaysia** | | | | | | | | **Indonesia** | | **Philippines** | | | | | | | | **Vietnam** | | | | | | |
| **Site** | Kudat | | Kota Marudu | | Pitas | | All TMP | | Bontosikuyu, Kepulauan Selayar | | Puerto Princesa City | | Taytay Municipality | | Aborlan Municipality | | All Palawan | | Cam Thanh | | Cua Dai | | All Cu Lao Cham-Hoi An Biosphere Reserve | |
|  | Past | Future | Past | Future | Past | Future | Past | Future | Past | Future | Past | Future | Past | Future | Past | Future | Past | Future | Past | Future | Past | Future | Past | Future |
| **Mean annual change rate (%)** | -0.05 | NA | -0.08 | NA | -0.15 | NA | -0.10 | NA | -1.29 | NA | -0.16 | NA | -0.21 | NA | -0.03 | NA | -0.12 | NA | -4.83 | NA | -13.45 | NA | -8.11 | NA |
| **Score** | 0 | NA | 0 | NA | -1 | NA | 0 | NA | -2 | NA | -1 | NA | -1 | NA | 0 | NA | -1 | NA | -2 | NA | -2 | NA | -2 | NA |

3) Coral

For Indonesia case study, the coral area are expressed in Hectares (Table 15). Observation made for the years of 2015 and 2019 indicated a decrease of 16.74% in coral coverage area over the period 4 years, from 1,720 Ha in 2015 to 1,432 Ha in 2019. Assuming that the yearly change of coral coverage is constant, the estimated yearly decrease of coral area is 4.2%. To enable comparison of this number to community perception data, we used data from Bruno & Selig (2007) as a guide to create categories as presented in Table 17 below.

**Table 15:** Scoring of the natural science data for coral cover at sites in Indonesia, Philippines and Vietnam.

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Country** | **Indonesia** | | **Philippines** | | | | **Vietnam** | | | |
| **Site** | Bontosikuyu, Kepulauan Selayar | | Puerto Princesa City | | All Palawan | | Tan Hiep | | All Cu Lao Cham-Hoi An Biosphere Reserve | |
|  | Past | Future | Past | Future | Past | Future | Past | Future | Past | Future |
| **Coral** | -2 | NA | -1 | NA | -1 | NA | 2 | NA | 2 | NA |

4) Seagrass

The annual rate of change in seagrass cover was calculated for the years available (Table 16). The mean of the year-on-year change was then used as the value to compare with the community perception data. In a global analysis on temporal changes in seagrass beds, Waycott et al. (2009) estimated that seagrass beds were disappearing at a rate of 7% year globally. In a literature review from 2000 to 2020, an overall average decline of seagrass beds of 4.7% per year was identified (Sudo et al., 2021). These rates from the literature have been used to guide to create the categories to compare the change in seagrass beds extent to the community perception data (Table 17).

**Table 16:** Scoring of the natural science data for seagrass coverage at sites in Vietnam.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Country | Vietnam | | | |
| Site | Tan Hiep | | All Cu Lao Cham-Hoi An Biosphere Reserve | |
|  | Past | Future | Past | Future |
| Seagrass | -1 | NA | -1 | NA |

**Comparison of Community perception and Natural science data**

By harmonizing the natural and social science data to a 5-point scale ranging from -2 to 2, and then subtracting these scores from each other, we have been able to calculate a new set of scores (ranging from -4 to +4) that indicates how closely the two types of data overlap (see Table 2 in the main paper). We used different color scales to represent individual scores, with lighter colors indicating a higher level of agreements between community perceptions and natural sciences.

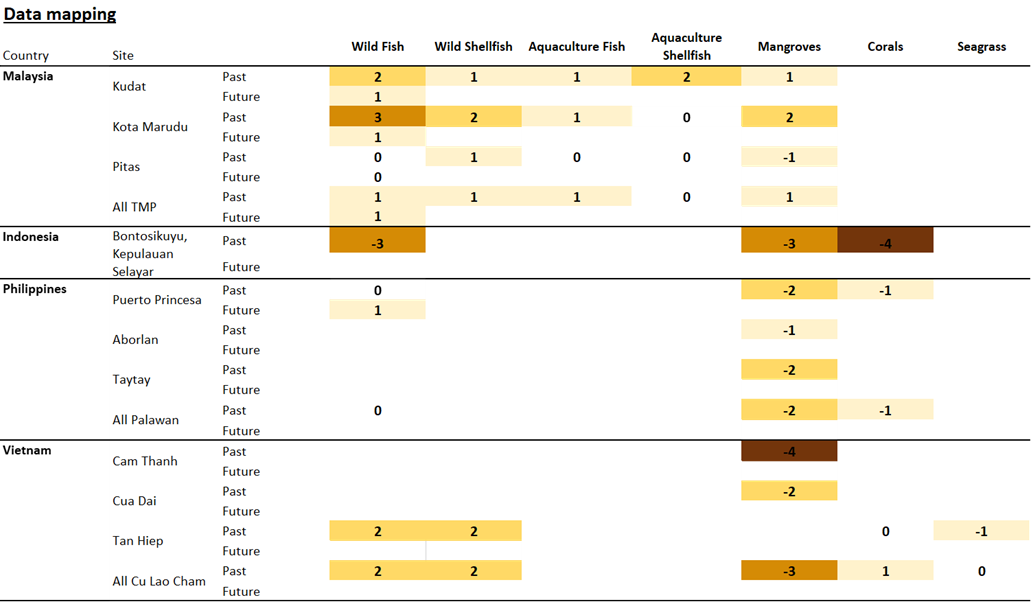
Our results were then visualized using two differently colored arrows (blue for community perception data, red for natural sciences), with different arrow directions representing the 5-point scales of community perceptions and natural sciences (see Table 20 for key). The arrows were further presented in normal font or bold, depending on the data confidence. The marine habitats and ecosystem services have been visualized using icons. We selected this way of visualization as it allows easy interpretation of our results by a broad audience, independent of literacy and language skills. This is particularly relevant as we collated data from four different case study sites, across four countries, and covering remote areas with relatively low rates of general literacy.

**Table 17:** Summary of in values for each sector of the natural science data and the community perception data, the meaning of the perceived or calculated change harmonized to a 5- point scale with both numerical value and arrows for visualization.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Fisheries  Year-on-year median change (%) | Mangrove  Annual rate of mangrove extent change (%) | Coral  Annual rate of coral extent change (%) | Seagrass  Annual rate of seagrass beds extent change (%) | Community perception  Original 5-point / 7-point Likert scale values | Meaning | 5 point scale | Arrows for NS (red) and CP (blue) |
| > 20 | > 0.5 | > 2 | > 5 | 2/3 | Greatly improved | +2 | ↑↑ |
| 10 to 20 | 0.1 to 0.5 | 1 to 2 | 1 to 5 | 1 / 1, 2 | Improved | +1 | ↗↗ |
| -10 to 10 | -0.1 to 0.1 | \_1 to 1 | -1 to 1 | 0 | No or slight change | 0 | →→ |
| -10 to -20 | -0.1 to -0.5 | -1 to 2 | -1 to -5 | -1 / -1, -2 | Degraded | -1 | ↘↘ |
| < -20 | < -0.5 | < 2 | < 5 | -2 / -3 | Greatly degraded | -2 | ↓↓ |

*Levels of divergence and convergence*

The heat map (Figure 2) represents scores of convergence and divergence ranging from 0 (full convergence) to -4/+4 (full divergence).



**Figure 1:** Heat map illustrating scores of convergence and divergence across sites, habitats and time periods [-4;4]. For scores and colour codes, see Table 2. Empty cells represent cases in which only one data source or no data could be obtained.

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