Supplementary Material

Table S1. Ecosystem layers used in the Paraguaná Peninsula cumulative impact model.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Data layer** | **Description** | **Native resolution** | **Driver category** | **Source** |
| Thorny bush | Shrub or low tree vegetation with irregular canopy,  product of natural forest degradation. | 1:100,000 | Terrestrial | \*\* |
| Thorny scrub | Shrubs and small trees  (usually <5 m tall), most provided with spines and cacti. | 1:100,000 | Terrestrial | \*\* |
| Riparian vegetation | The Riparian vegetation habitat layer | 1:100,000 | Terrestrial | \*\* |
| Rocky intertidal | Intertidal zone with a predominance of rocky blocks, biologically diverse. | 1:14,000 | Terrestrial/Marine | \* |
| Mud intertidal | Coastal areas with an accumulation of fine sediments and small waves. | 1:14,000 | Terrestrial/Marine | \* |
| Beach | The strip of land between low tide and the line of permanent vegetation | 1:14,000 | Terrestrial/Marine | \* |
| Mangroves | Intertidal forests; predominate in brackish waters near freshwater outlets. | 1:100,000 | Terrestrial/Marine | \* |
| Saltmarsh | Floodplain wetlands. Sometimes swampy. | 1:100,000 | Terrestrial/Marine | \* |
| Coastal lagoon | Transitional, shallow water bodies | 1:100,000 | Terrestrial/Marine | \* |
| Coastal dune | Dune system. Sand mounds parallel to the coast. | 1.100,000 | Terrestrial/Marine | \* |
| Deltas | Form of the mouth of a river in the sea | 1:100,000 | Terrestrial/Marine | \* |
| Coastal plain | Plain that extends along the coast | 1:100,000 | Terrestrial/Marine | \* |
| Coral reef | Coral formation. Interrupted barriers located parallel to the coast. | 1:14,000 | Marine | \* |
| Seagrass | Seagrasses are located in patches in the intertidal zone, with variable coverage. | 1:14,000 | Marine | \* |
| Soft substrate subtidal | Intertidal areas of an unconsolidated substrate (e.g., mud, sand, pebbles, or mix) | 1:14,000 | Marine | \* |
| Hard substrate subtidal | Subtidal area with the consolidated substrate | 1:14,000 | Marine | \* |

\* Mapped from the visual interpretation of the image, Landsat 8 of the year 2017 (LC08\_L1TP\_006052) with an output pixel of 30 m. The result of the interpretation was confirmed in the field \*\* Ecological Systems Map of the central coast of Falcón state, Venezuela. Laboratory of Landscape Ecology, of the Institute of Environmental and Ecological Sciences of the University of Los Andes, Venezuela.

Table S2. Stressor layers used in the Paraguaná Peninsula cumulative impact model.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Data layer** | **Description** | **Native resolution** | **Standardization** | | | **Driver category** | **Source** | |
| Oil infrastructure | Shapefile | 1.250,000 | No standardization was required as this presence/absence stressor was assumed to occupy most of the grid cell. | | | Terrestrial | Klein, 2008 | | | |
| Coastal engineering | The Coastal Engineering layer included rigid structural elements such as Docks and Ports. | 1:100,000 | This is a presence or absence stressor. Because many coastal engineering structures did not cover a complete 1 ha grid cell, each structure was estimated to impose a coastal engineering stress factor of 10% of the maximum. Consequently, the coastal engineering values were standardized to 10% of the maximum after log.  *Log10(Coastal engineering+1.0) / (Log10(1023+1.0))*  These values are likely to be conservative due to the overestimation of pressure and the extension of the "coastal engineering" works. | | | Terrestrial | \* | |
| Coastal development | The coastal development layer included: populated centres and intervened areas with infrastructure and road networks. | 1:100,000 | No standardization was required as this presence/absence stressor was assumed to occupy most of the grid cell. | | | Terrestrial | \*\* | |
| Nutrient pollution | Contribution of nitrogen and phosphorus from urban discharges. | Five arc minute | Maximum nutrient pollution pressure was 0.33(kg/ha)  *Log10(NutrientPollution+1.0)/ (Log10((1.1\*0.326037)+1.0))* | | | Marine (land-derived) | Halpern 2015 | |
| Organic pollution | Pollutants from sewage, urban runoff, industrial effluents, and agricultural waste. | Five arc minute | The maximum organic pollution pressure was 0.04.  *Log10(OrganicPollution+1.0)/(Log10((1.1\*0.0440226)+1.0))* | | | Marine (land-derived) | Halpern 2015 | |
| Suspended sediments | flocculated Material and a mixture of organic and inorganic particles in suspension in the watercourses | 1:100,000 | No standardization was required as this presence/absence stressor was assumed to occupy most of the grid cell. | | | Marine (land-derived) | \*\* | |
| Aquaculture | Aquaculture included: aquaculture pools and infrastructure. | 1:100,000 | No standardization was required as this presence/absence stressor was assumed to occupy most of the grid cell. | | | Marine | \*\* | |
| Artisanal fishing (demersal) | Artisanal, small-scale and subsistence fishing | 1:16,000,000 | | No standardization was required as this presence/absence stressor was assumed to occupy most of the grid cell. | Marine | | | Klein 2008 | |
| Artisanal fishing (pelagic) | Artisanal, small-scale and subsistence fishing | 1:16,000,000 | No standardization was required as this presence/absence stressor was assumed to occupy most of the grid cell. | | | Marine | Klein 2008 | |
| Shipping | Trajectories and frequency of marine traffic | Five arc minute | The maximum shipping pressure was 0.67.  *Log10(Shipping+1.0)/ (Log10((1.1\*0.6668412)+1.0))* | | | Marine | Halpern, 2015 | |
| Sea level rise | For RCP6  0.25 m | 30 m | No standardization was required as this presence/absence stressor was assumed to occupy most of the grid cell. | | | Climate | A Buffer was created for this study. | |
| Sea surface temperature | The climatological fields ("climatic normals") for which these anomalies were calculated are those from the UK Met Office ATLAS7 GOSTA climatology. In addition, data after 1981 OI from Reynolds and Smith (v.2) SST were used. | 1.0 ° latitude by 1.0 ° longitude | No standardization was required as this presence/absence stressor was assumed to occupy most of the grid cell. | | | Climate | IGOSS nmc Reyn\_SmithOIv2 monthly ssta\_c9120: 1991-2020 Sea surface temperature anomaly data | |
| Terrestrial temperature | Monthly precipitation anomaly. Base period 1991\_2020 | 1.0 ° latitude by 1.0 ° longitude | Maximum terrestrial temperature pressure was 3 (2 m).  *Log10(TerrestrialTemperature+1.0)/ (Log10((1.1\*3.0)+1.0))* | | | Climate | (IRI) Terrestrial temperature model Jan-Mar2016 CFSv2 “data from phase II of the NMME system | |
| Precipitation | Monthly precipitation anomaly for Jan-Mar2017. Base period 1991\_2020 | 1.0 ° latitude by 1.0 ° longitude | Maximum terrestrial temperature pressure was 2 (2 m).  *Log10(Precipitation+1.0)/ (Log10((1.1\*2.0)+1.0))* | | | Climate | (IRI) Precipitation model Jan-Mar2017 CFSv2 “data from phase II of the NMME system | |

\*Mapped from the visual interpretation of the image, Landsat 8 of the year 2017 (LC08\_L1TP\_006052) with an output pixel of 30 m. The result of the interpretation was confirmed in the field. \*\* Ecological Systems Map of the central coast of Falcón state, Venezuela. Laboratory of Landscape Ecology, of the Institute of Environmental and Ecological Sciences of the University of Los Andes, Venezuela.

Table S3. Impact weights for the ecosystem and stressor combinations used in the Paraguaná Peninsula cumulative impact model.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | Bush | Scrub | Riparian forest | Rocky int. | Mud int. | Beach | Mangroves | Saltmarsh | Coastal lagoon | Dunes | Deltas | Coastal plain | Coral | Seagrass | Soft sub. | Hard sub. |
| Oil infrastructure | 1.5 d | 1.6 d | 1.1 d | 1.0 a | 0.9 a | 0.8 a | 1.3 a | 0.9 a | 2.0 d | 1.5 d | 1.2 d | 1.8 d | 0.5 a | 1.6 a | 0.9 a | 1.0 a |
| Coastal engineering | 1.6 d | 1.6 d | 1.2 d | 2.7 b | 2.1 b | 2.8 b | 3.1 b | 2.3 b | 2.0 d | 1.5 d | 1.2 d | 1.3 d | 2.3 b | 2.4 b | 2.3 b | 1.5 b |
| Coastal development | 1.8d | 1.6 d | 2.6 d | 2.7 b | 2.9 b | 3.2 b | 3.4 b | 2.8 b | 2.0c | 1.6d | 1.5 d | 2.4 d | 2.9 b | 3.3 b | 2.4 b | 3.8 b |
| Nutrient pollution | 2.0d | 0.7c | 0.8 c | 1.8a | 1.6 a | 0.4 a | 1.4 a | 1.7 a | 1.7 c | 1.5 c | 1.1 c | 1.1 c | 1.2 a | 2.1 a | 2.6 b | 1.4 b |
| Organic pollution | 1.6 c | 2.2 c | 2.4 c | 2.1a | 2.8 a | 0.1 a | 1.4 a | 1.7 a | 1.4 c | 1.5 d | 2.4 c | 2.4 c | 1.2 a | 1.0 a | 2.6 b | 1.6 b |
| Suspended sediments | 2.0 d | 2.0 d | 2.0 d | 2.4 b | 2.0 b | 0.1 b | 2.2 b | 2.2 b | 2.0 d | 1.3 d | 1.2 d | 1.8 d | 2.8 b | 2.9 b | 1.5 b | 1.7 b |
| Aquaculture | 1.9 d | 1.8 d | 2.0 d | 2.0 b | 2.0 b | 0.1 b | 3.1 b | 1.7 b | 1.1 d | 1.6 d | 2.6 d | 2.2 d | 1.8 b | 2.1 b | 1.8 b | 3.0 b |
| Artisanal fishing (demersal) | 0.9 d | 0.9 d | 0.9 d | 1.2 b | 1.4 b | 0.2 b | 0.0 b | 1.0 b | 1.6 d | 1.1 d | 0.9 d | 0.9 d | 1.2 b | 0.2 b | 2.1 b | 3.1 b |
| Artisanal fishing (pelagic) | 0.9 d | 0.9 d | 0.9 d | 1.1 b | 0.5 b | 0.8 b | 1.2 b | 0.5 b | 0.9 d | 0.9 d | 0.9 d | 0.9 d | 0.2 b | 0.0 b | 0.0 b | 2.8 b |
| Shipping | 0.9 d | 0.9 d | 0.9 d | 0.3 a | 1.9 a | 1.9 a | 2.0 a | 1.4 a | 0.9 d | 0.9 d | 0.9 d | 0.9 d | 1.5 a | 1.9 a | 0.3 b | 0.3 b |
| Sea level rise | 1.2 d | 1.6 c | 2.4 d | 2.5 a | 1.9 a | 2.1 a | 3.0 a | 3.1 a | 2.1 c | 2.5 c | 2.0 d | 2.0 c | 2.4 a | 2.6 a | 2.2 b | 2.2 b |
| Sea surface temperature | 1.2 d | 0.9 d | 0.9 d | 2.8 c | 1.4 c | 0.6 c | 2.4 c | 1.4 c | 2.1 d | 2.1d | 1.5 d | 2.6 d | 2.8 c | 2.1 c | 0.5 b | 3.0 b |
| Terrestrial temperature | 2.3 d | 1.3 d | 2.3 d | 2.0 d | 2.6 d | 1.8 d | 2.4 d | 2.3 d | 2.6 d | 2.4 d | 2.0 d | 2.6 d | 2.0 d | 2.3 d | 2.0 d | 2.0 d |
| Precipitation | 2.0 d | 2.0 d | 2.0 d | 2.2 d | 2.4 d | 1.6 d | 2.4 d | 2.3 d | 2.2 d | 2.4 d | 2.0 d | 2.4 d | 2.5 d | 2.2 d | 2.0 d | 2.0 d |

a Halpern et al., 2015

b Halpern et al. 2007

c Meeken 2020

d Expert judgement (this study)

e Klein, 2008

Table S4. Average, sum, standard deviation (SD), and maximum values of the stressors that contributed the most to the cumulative impact score, measured for all marine and coastal ecosystems within the central coast of Falcón state, Venezuela.

|  |  |  |  |
| --- | --- | --- | --- |
| **Threats** | **Max** | **Mean** | **Std. dev** |
| Nutrients\_stand\_gapFilled | 0.92074639 | 0.4926527 | 0.27100554 |
| Chempoll\_stand\_gapfill | 0.9110195 | 0.1494944 | 0.19656399 |
| Shipping\_stand\_gapfilled | 0.9304114 | 0.52733354 | 0.28411658 |

Regarding the contribution of the rest of the threats, detailed results per pixel were not obtained since most of the layers were rasters with a single value (1) that denoted a polygonal extension (e.g., urban areas, oil spill); they yielded average values, min, max, std dev = 1.

**Supplementary Material References**

a Halpern, B. S., Frazier, M., Potapenko, J., Casey, K. S., Koenig, K., Longo, C., et al. (2015). Spatial and temporal changes in cumulative human impacts on the world's ocean. Nat. Commun. 6, 7615. doi: 10.1038/ncomms8615

b Halpern BS, Selkoe KA, Micheli F, Kappel CV (2007) Evaluating and ranking the vulnerability of global marine ecosystems to anthropogenic threats. Conserv Biol 21: 1301–1315.

c Meeken, E. W. (2020). Threats to coastal biodiversity: Cumulative human impacts on Earth's coastal habitats (Master's thesis). Enschede, Netherlands. University of Twente

d Expert judgement (this study)

e Klein, 2008 Klein E. (editor). 2008. Prioridades de PDVSA en la conservación de la biodiversidad en el caribe venezolano. Petróleos de Venezuela, S.A. - Universidad Simón Bolívar - The Nature Conservancy. Caracas, Venezuela. 72 p. base de datos: (http://bdb2.intecmar.usb.ve)