Current conservation effort: supplementary material

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Contents

Premise

This supplementary material is associated with figure XX, XXX of main text. By following this supplementary it is possible to replicate in full both figures and the analysis.

In this supplementary, we assume some basic knowledge of the R programming language. If instructions are followed, this should be fully reproducible using R studio. For further comments on the results of this analysis please refer to the main paper, or please find **the contacts informations** to get in touch with the authors to report bugs or problems.

Data and R code scripts to replicate figures and analysis can be downloaded from **here**.

Wrangled datasets of all the data mentioned in Table SI and SII are available in the `data` folder.

Datasets are three `.csv` text files:

- `habitat_data`: which contains all the habitat extensions in squared kilometers for each country, as well as the area of each country Economic Exclusion Zone (EEZ) and total MPA area both in squared kilometers;
- `habitat_protected`: which contains how much of each habitat within each country is protected (protected);
- `pressures_gdp_biodiversity`: which contains the environmental pressures, the total GDP (Gross Domestic Product in USD) and the estimated biodiversity for each of the country;

Download an .Rmd version of this file from **here**.

Data Sources

Beware that while all data used are open source (except for kelp which source has been removed until the dataset is published), specific permission to reuse and publish them are needed from data providers. Credit for the use of those data should also go to the proper source listed in Table SI and SII.

Habitat area

We obtained the polygons of 6 habitats closely associated with the coast, and 6 more closely associated with open ocean, for a total of 12 majour habitats (Table SI). We then calculated the area for each habitat by dissolving the resulting layer by Country and projecting it into the World Cylindrical Equal Area projection, and then using the "Calculate Geometry" tool in ArcGIS v.10.5 Desktop software. Losses and gains in habitat extension that occurred the data aquisition dates were not accounted for. These data are available in the `habitat_data` file.

Table SI: habitat data type, date of creation, and detailed references

Habitat	Date of Data	Data Type	Source
Estuaries	2003	Polygon	Alder (2003)
Mangroves	1997 - 2000	Polygon	Giri, et al. (2011)
Saltmarsh	1973 - 2015	Points	McOwen, et al. (2017)
Seagrasses	1934 - 2015	Polygon	UNEP-WCMC, Short FT (2017)
Coral Reefs	1954 - 2018	Polygon	UNEP-WCMC, WorldFish Centre, WRI, TNC (2018)
Kelp	NA	Point	Jorge Assis (submitted for publication)
Cold Corals	1915 - 2014	Point	Freiwald A (2017)
Sills	1950-2009	Polygon	Harris et al. (2014)
Seamounts/Guyots	1950-2009	Polygon	Harris et al. (2014)
Bridges	1950-2009	Polygon	Harris et al. (2014)
Rift Valleys	1950-2009	Polygon	Harris et al. (2014)
Hydrothermal Vents	1994-2019	Point	Beaulieu, S.E., Szafranski, K. (2019)

The other variables used in this study and featured in the `pressures_gdp_biodiversity` file of the dataset are described in Table SII.

Table SII: other variables used in this study

Variable	Variable name	Description	Source
Exclusive Economic Zone	eez_area	Area of the EEZ for each country in squared kilometers	Sala *et al.,* 2018

Variable	Variable name	Description	Source
Marine Protected Area	mpa	MPA extension in squared kilometers in each country. The dataset was filtered by MPAs whose status was either designated, inscribed, adopted or established, thus removing not reported and proposed categories	We obtained MPA extension from the World Database of Protected Areas (UNEP-WCMC accessed in February 2019)
Species Biodiversity	biodiversity_points	Extracted value of estimated species diversity	Reygondeau and Dunn (2018)
Pressures on the Marine Environment	pressures	The ecological and social factors that decrease health status	Ocean Health Index: http://www.oceanhealthindex.org/
Gross Domestic Product per capita	gdp_total	total GDP per country (current USD)	World Bank Open data: https://data.worldbank.org/
Protected habitat area	protected	Overlap between protected area and the target habitat in squared kilometers	This paper

We calculated the protected habitat area by intersecting the dissolved MPA layer per each country EEZ for each of the habitat listed in Table SI. The resulting data are reported in the dataset `habitat_protected`. It needs to be clarified that being inside a MPA does not mean the habitat is protected, since the MPA objective and regulamentation might not involve the habitat at all. However, we consider that being inside an environmentally managed area should provide at least some indirect benefits to the habitat conservation.

R-code for the figures

Below we reproduce the R code used to produce figure X and XX step by step.

The following code was built with 3.6.2 and was written using R-studio IDE (v.1.2.5033), as well as this document, using the following packages that can be installed in R or through R-studio using the following commands:

- `install.packages("dplyr")`
- `install.packages("ggplot2")`
- `install.packages("readr")`
- `install.packages("cowplot")`
- `install.packages("ggthemes")`
- `install.packages("broom")`
- `install.packages("knitr")`
- `install.packages("RCurl")`

Libraries needed:

```r
library(dplyr)
library(ggplot2)
library(readr)
library(cowplot)
library(ggthemes)
library(broom)
library(knitr)
library(RCurl)
```

Figure XX c,d,e

To reproduce the scatterplots relating biodiversity, pressures, protection and GDP one can use the following code:

```r
# Loading pressure data
pressures <- read.csv(text = getURL("https://raw.githubusercontent.com/Fabbiologia/BluePaper-10_Suppleme

# Figure XXC

pC <- pressures %>%
      select(country, eez_area, mpa, pressures_spp, biodiversity_points) %>%
      na.omit() %>%
      mutate(pressures_spp = pressures_spp/max(pressures_spp)) %>%
      ggplot(aes(x=biodiversity_points, y=pressures_spp)) +
      geom_point() +
      geom_smooth(method='lm',formula=y~x) +
      theme_light() +
      labs(x="Species Biodiversity", y="Human Pressure")

# Figure XXD

pD <- pressures %>%
        select(country, eez_area, mpa, gdp_tot) %>%
        na.omit() %>%
        mutate(percent_GDP = (gdp_tot/max(gdp_tot))*100) %>%
        mutate(percent_MPA = (mpa/eez_area)*100) %>%
        ggplot(aes(x=percent_GDP, y=percent_MPA)) +
```

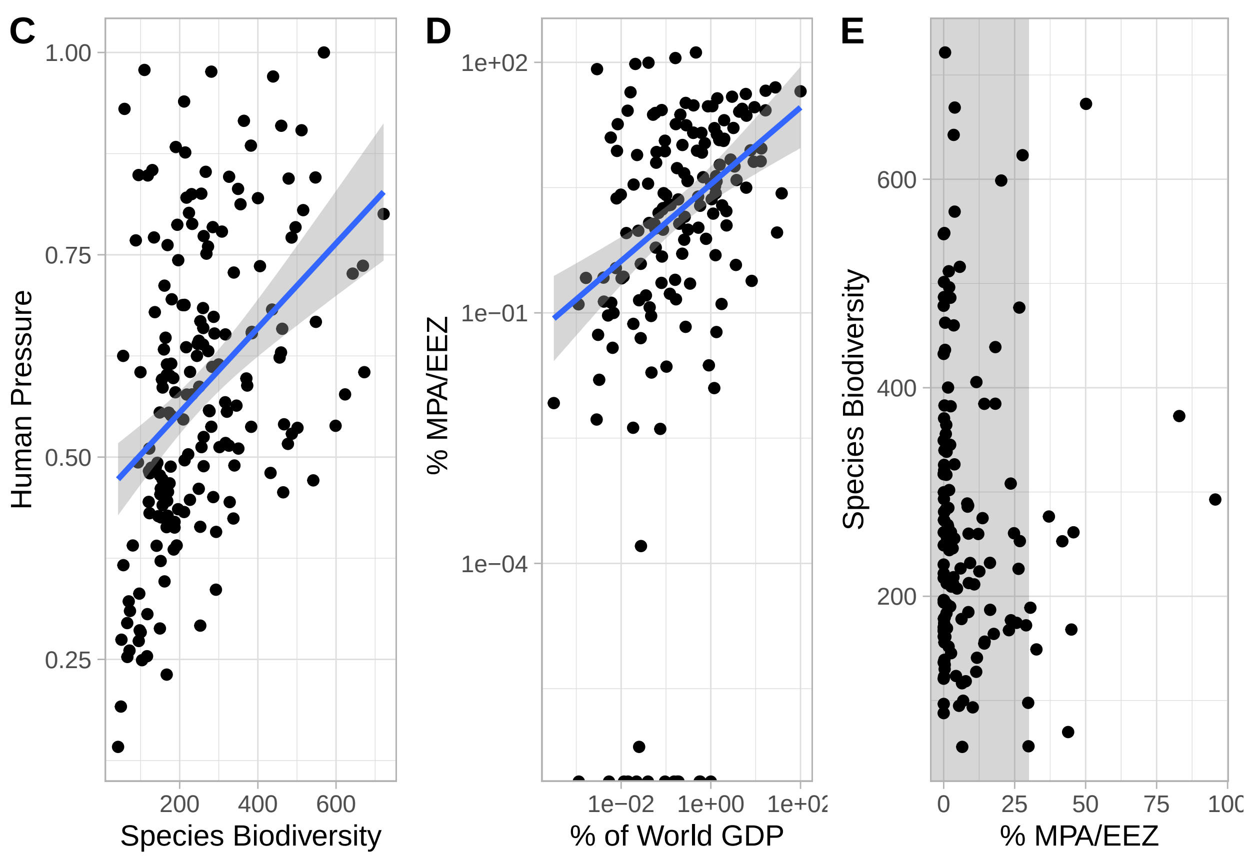
```
        scale_y_continuous(trans = "log10") +  # data transformation in base 10 logarithm
        scale_x_continuous(trans = 'log10') +  # data transformation in base 10 logarithm
        geom_point() +
        geom_smooth(method='lm',formula=y~x) +
        theme_light() +
        labs(x="% of World GDP", y=" % MPA/EEZ")

# Figure XXE

# here we create a target polygon to be used as a reference in the graph
target <- data.frame(x=c(-Inf,-Inf,30, 30), y=c(-Inf,Inf ,Inf, -Inf), t=c('b', 'b', 'b','b'))

pE <- pressures %>%
   select(country, eez_area, mpa, gdp_tot, biodiversity_points) %>%
   na.omit() %>%
   mutate(percent_MPA = (mpa/eez_area)*100) %>%
   ggplot(aes(x=percent_MPA, y=biodiversity_points)) +
   geom_polygon(data=target, mapping=aes(x=x, y=y, group=t), alpha=0.2) +
   geom_point() +
   theme_light() +
   labs(x="% MPA/EEZ", y="Species Biodiversity")


# this function creates a panel with all the plots created above
plot_grid(pC, pD, pE, labels=c("C", "D", "E"), nrow = 1)
```



In this figure we report three comparisons among the variables in the `pressures_gdp_biodiversity` dataset. In Figure XXC a scatterplot represents the biodiversity values averaged for each EEZ compared with the pressure data for each EEZ. A linear model is fitted to the data, which resulted significant (Table SIII). In Figure XXD, we calculated the percentage of EEZ covered by an MPA (%MPA/EEZ) and plot it against the % of world GDP of each country. Data were transformed using the base 10 logarithm. The relationship resulted significant (Table SIV). Finally, in Figure XXE, we plotted biodiversity *vs* the percentage of EEZ covered by an MPA (%MPA/EEZ). This comparison resulted not significant. The grey box represent an ideal 30% of EEZ area protected target.¨

Table SIII: Human Pressure vs Species Biodiversity regression

```
kable(tidy(lm(pressures_spp~biodiversity_points, data=pressures)))
```

term	estimate	std.error	statistic	p.value
(Intercept)	27.9450920	1.6003084	17.46232	0
biodiversity_points	0.0324365	0.0054683	5.93176	0

Table SIV: % MPA/EEZ vs % of World GDP regression

```
pressures2 <- pressures %>%
        select(country, eez_area, mpa, gdp_tot) %>%
        na.omit() %>%
        mutate(percent_GDP = (gdp_tot/max(gdp_tot))*100) %>%
        mutate(percent_MPA = (mpa/eez_area)*100)

kable(tidy(lm(percent_MPA ~ percent_GDP, data=pressures2)))
```

term	estimate	std.error	statistic	p.value
(Intercept)	9.5595649	1.6668579	5.735081	0.0000000
percent_GDP	0.3746134	0.1741082	2.151613	0.0329567

Table SV: Species Biodiversity vs % MPA/EEZ regression

```
pressures3 <- pressures %>%
        select(country, eez_area, mpa, gdp_tot, biodiversity_points) %>%
        na.omit() %>%
        mutate(percent_MPA = (mpa/eez_area)*100)

kable(tidy(lm(biodiversity_points ~ percent_MPA, data=pressures3)))
```

term	estimate	std.error	statistic	p.value
(Intercept)	272.2317201	13.4290483	20.2718550	0.0000000
percent_MPA	0.0068833	0.7806563	0.0088173	0.9929772

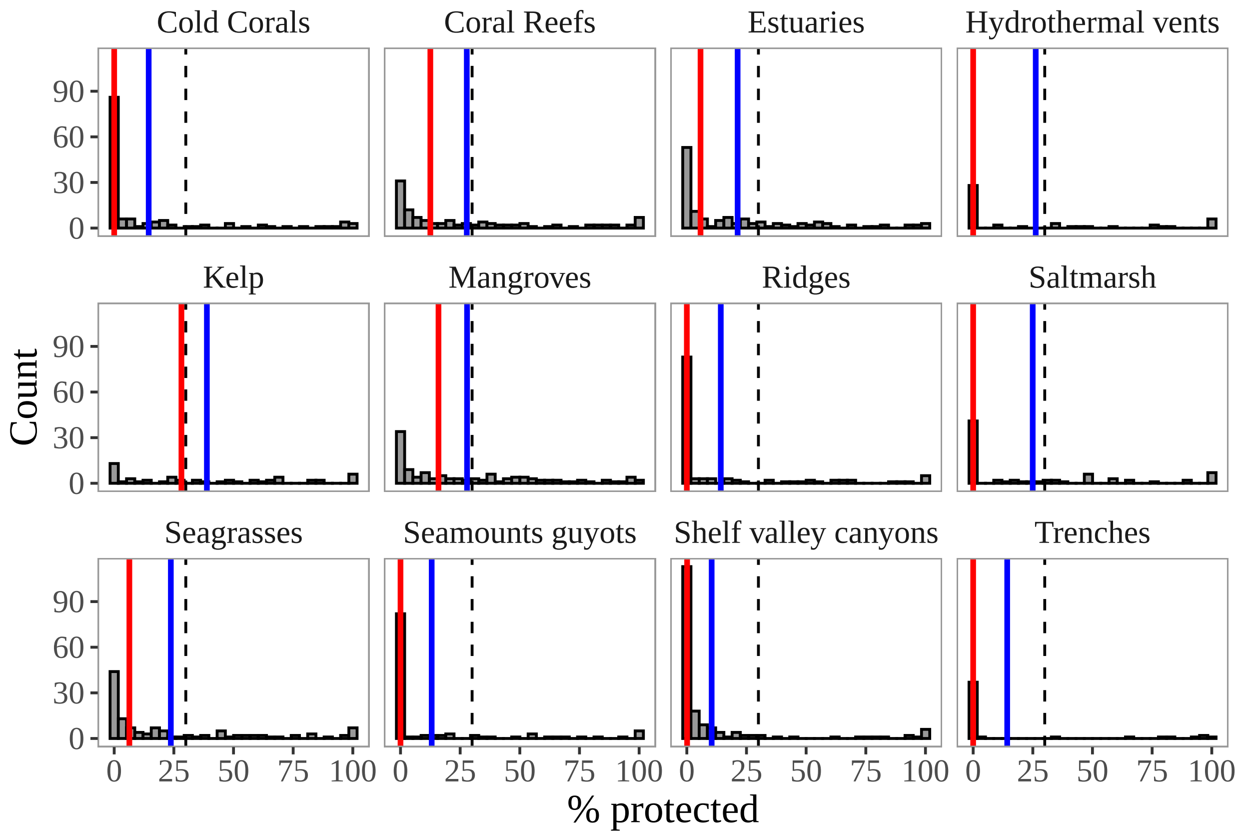
Figure XXX

To reproduce the histograms of the conservation effort one can use the code below:

```
protected_areas <- read.csv(text = getURL("https://raw.githubusercontent.com/Fabbiologia/BluePaper-10_Su

protected_areas %>%
        filter(habitat_area > 0) %>% # first we filter absent habitat for each country
```

```
    mutate(pp = (protected/habitat_area)*100) %>% # Then we calculate the % protected of each habit
    group_by(habitat) %>% # we group the data for each habitat
    mutate(mean_pp = mean(pp),
           median_pp = median(pp)) %>% # here we calculate the mean percent protected and the media
    ungroup() %>% # the code section below is for graphic purposes
    mutate(habitat = factor(.$habitat, labels=c("Cold Corals",
                                                "Coral Reefs",
                                                "Estuaries",
                                                "Hydrothermal vents",
                                                "Kelp",
                                                "Mangroves",
                                                "Ridges",
                                                "Saltmarsh",
                                                "Seagrasses",
                                                "Seamounts guyots",
                                                "Shelf valley canyons",
                                                "Trenches"))) %>%
    ggplot(aes(x=pp))+
    geom_histogram(fill="grey60", col="black")+
    geom_vline(aes(xintercept=mean_pp), col="blue", size=1)+
    geom_vline(aes(xintercept=median_pp), col="red", size=1)+
    geom_vline(aes(xintercept=30), col="black", linetype="dashed")+
    labs(x= "% protected", y="Count")+
    facet_wrap(~habitat)+
    theme_tufte()+
    theme(text = element_text(size = 15),
          panel.border = element_rect(fill = NA, colour = "grey60"))
```



We created this figure by filtering all the habitats with a higher than 0 cover in each country and we calculated how much habitat is protected in % in each country. Then, we calculated the mean percent protected of each habitat in all the countries, and the median percent protected of each habitat in all the countries. In the plot, the histogram bars represent how many countries (`Count`) fall within a % protection interval (i.e. histogram bins). Now, mean and median % protection for each habitat are represented by a blue and red vertical line respectively, and the dashed vertical line represent the ideal 30% protected threshold to maintain habitat functionality.

References

- **EEZ data reference**: Sala, E., Mayorga, J., Costello, C., Kroodsma, D., Palomares, M. L. D., Pauly, D., […] Zeller, D. (2018). The economics of fishing the high seas. Science Advances, 4(6), eaat2504. https://doi.org/10.1126/sciadv.aat2504
- **Biodiversity data reference**: Reygondeau, Gabriel, and Daniel Dunn. "Pelagic Biogeography ." (2018).

Habitat data references

- **Estuaries**: Alder J (2003). Putting the coast in the "Sea Around Us". The Sea Around Us Newsletter 15: 1-2. URL: http://seaaroundus.org/newsletter/Issue15.pdf; http://data.unep-wcmc.org/datasets/23 (version 2.0)
- **Mangroves**: Giri, C., E. Ochieng, L. L. Tieszen, Z. Zhu, A. Singh, T. Loveland, J. Masek, and N. Duke. (2011). "Status and Distribution of Mangrove Forests of the World Using Earth Observation Satellite Data: Status and Distributions of Global Mangroves." Global Ecology and Biogeography 20 (1): 154–59. https://doi.org/10.1111/j.1466-8238.2010.00584.x.
- **Saltmarsh**: Mcowen C, Weatherdon LV, Bochove J, Sullivan E, Blyth S, Zockler C, Stanwell-Smith D, Kingston N, Martin CS, Spalding M, Fletcher S (2017). A global map of saltmarshes. Biodiversity Data Journal 5: e11764. Paper DOI: https://doi.org/10.3897/BDJ.5.e11764; Data URL: http://data.unep-wcmc.org/datasets/43 (v.6)
- **Seagrasses**: UNEP-WCMC, Short FT (2018). Global distribution of seagrasses (version 6.0). Sixth update to the data layer used in Green and Short (2003). Cambridge (UK): UN Environment World Conservation Monitoring Centre. URL: http://data.unep-wcmc.org/datasets/7
- **Coral Reefs**: UNEP-WCMC, WorldFish Centre, WRI, TNC (2018). Global distribution of warm-water coral reefs, compiled from multiple sources including the Millennium Coral Reef Mapping Project. Version 4.0. Includes contributions from IMaRS-USF and IRD (2005), IMaRS-USF (2005) and Spalding et al. (2001). Cambridge (UK): UN Environment World Conservation Monitoring Centre. URL: http://data.unep-wcmc.org/datasets/1
- **Kelp**: Jorge Assis (submitted for publication)
- **Cold corals**: Freiwald A, Rogers A, Hall-Spencer J, Guinotte JM, Davies AJ, Yesson C, Martin CS, Weatherdon LV (2017). Global distribution of cold-water corals (version 5.0). Fifth update to the dataset in Freiwald et al. (2004) by UNEP-WCMC, in collaboration with Andre Freiwald and John Guinotte. Cambridge (UK): UN Environment World Conservation Monitoring Centre. URL: http://data.unep-wcmc.org/datasets/3
- **Sills-Rift Valleys**: Harris, P. T., Macmillan-Lawler, M., Rupp, J., & Baker, E. K. (2014). Geomorphology of the oceans. Marine Geology, 352, 4–24. https://doi.org/10.1016/j.margeo.2014.01.011 Hydrothermal vents: Beaulieu, S.E., Szafranski, K. (2018) InterRidge Global Database of Active Submarine Hydrothermal Vent Fields, Version 3.4. World Wide Web electronic publication available from http://vents-data.interridge.org Accessed 2019-02-20.

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