Current_conservation_effort_supplementary_material

Fabio Favoretto, Joy Kumagai, Octavio Aburto

Last updated 19 enero, 2020

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;

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 the 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 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
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)

Variable	Variable name	Description	Source
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 R code (v.3.6.2) 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")`

Libraries needed:

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

Figure XX

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

```
pressures <- read_csv("data/pressures_gdp_biodiversity.csv")

pA <- pressures %>%
      select(country, eez_area, mpa, pressures_spp, biodiversity_points) %>%
      na.omit() %>%
```

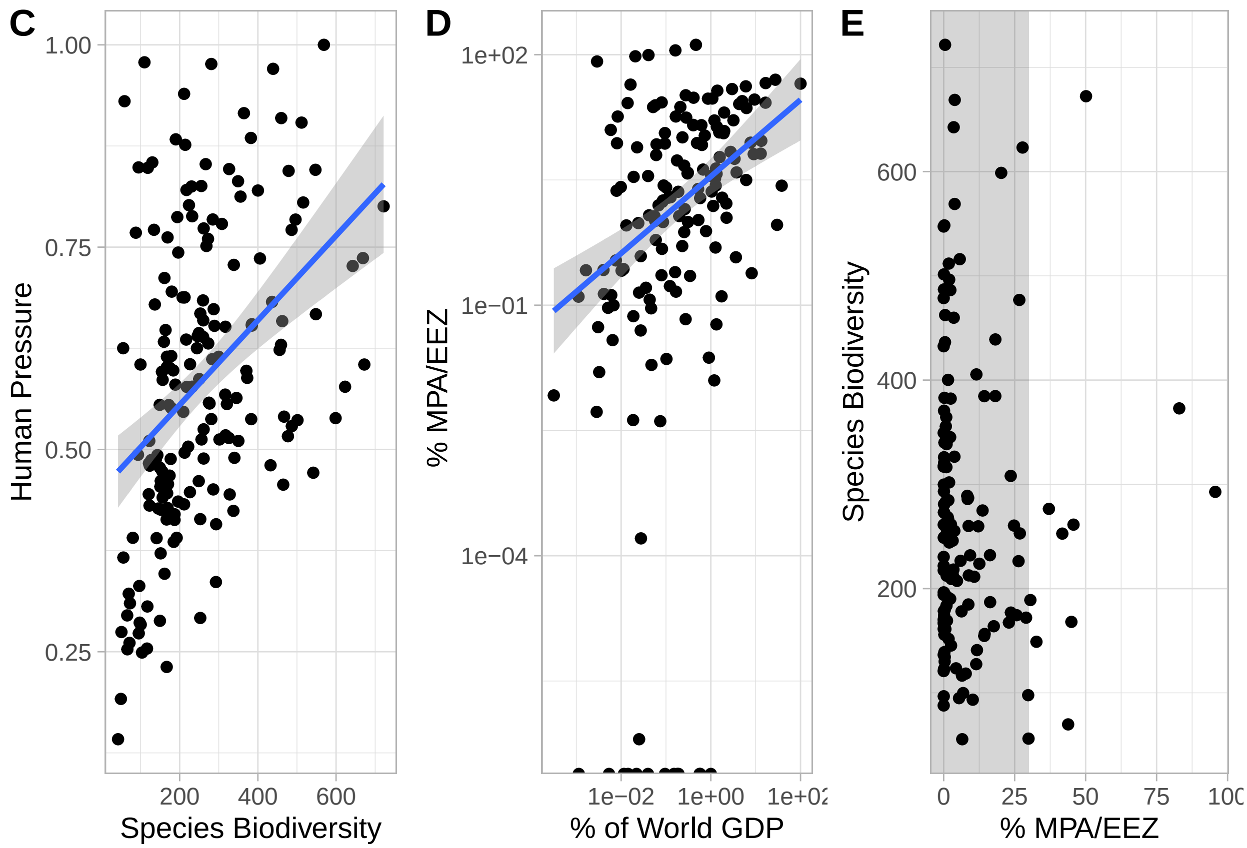
```
      mutate(pressures_spp = pressures_spp/max(pressures_spp)) %>%
      ggplot(aes(x=biodiversity_points, y=pressures_spp)) +
      geom_point() +
      geom_smooth(method='lm',formula=y~x) +
      theme_light() +
      labs(x="Species Biodiversity", y="Human Pressure")

pB <- 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") +
        scale_x_continuous(trans = 'log10') +
        geom_point() +
        geom_smooth(method='lm',formula=y~x) +
        theme_light() +
        labs(x="% of World GDP", y=" % MPA/EEZ")

target <- data.frame(x=c(-Inf,-Inf,30, 30), y=c(-Inf,Inf ,Inf, -Inf), t=c('b', 'b', 'b','b'))

pC <- 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")

plot_grid(pA, pB, pC, 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.

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

% 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

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)))
```

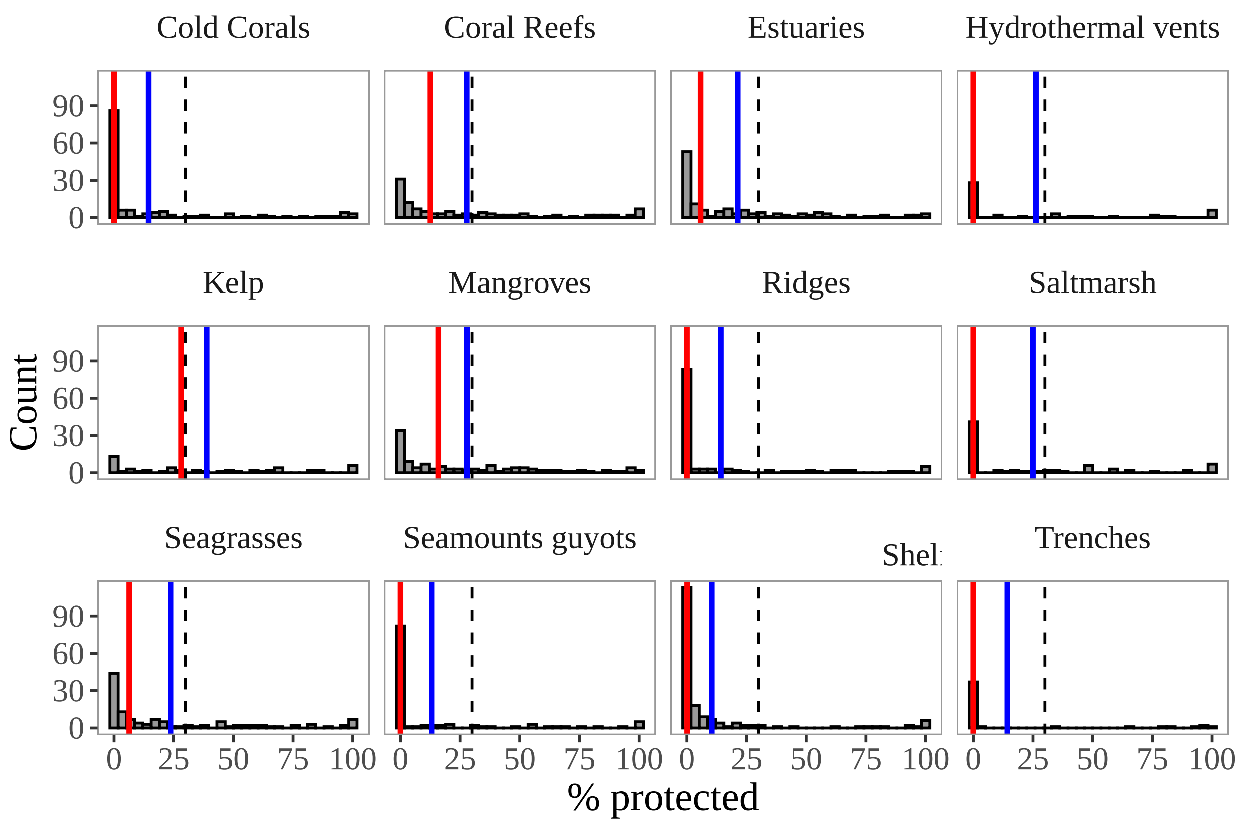
term	estimate	std.error	statistic	p.value
(Intercept)	272.2317201	13.4290483	20.2718550	0.0000000
percent_MPA	0.0068833	0.7806563	0.0088173	0.9929772

Figure XXX

```
protected_areas <- read_csv("data/habitat_protected.csv")

protected_areas %>%
        filter(habitat_area > 0) %>%
        mutate(pp = (protected/habitat_area)*100) %>%
        mutate(pp_to_EEZ = (protected/eez_area)*100) %>%
        mutate(relative_to_EEZ = (habitat_area/eez_area)*100) %>%
        group_by(habitat) %>%
        mutate(world_hab_habitat_area = sum(habitat_area)) %>%
        ungroup() %>%
        mutate(relative_habitat_area_to_world = ((habitat_area/world_hab_habitat_area)*100)) %>%
        mutate_if(is.numeric, round, digits = 2) %>%
        select(habitat, country, pp) %>%
        group_by(habitat) %>%
        mutate(mean_pp = mean(pp),
               median_pp = median(pp)) %>%
        ungroup() %>%
        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"))
```



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.

Contacts

- Fabio Favoretto: favoretto.fabio@gmail.com
- Joy Kumagai: jkumagai96@gmail.com
- Octavio Aburto: maburto@ucsd.edu