Relative Abundance and MPA Overlap of *Mobula birostris*

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1. Introduction

The oceanic manta ray (*Mobula birostris*) is the largest living species of ray, reaching up to 7 meters in disc width (DW) (Alava et al., 2002). It inhabits both tropical and temperate oceans and is a large pelagic planktivore (Kashiwagi et al., 2011). Males reach maturity at 3.5–4 m DW and females at 3.8–5 m DW (White et al., 2006; Last et al., 2016; Stevens et al., 2018). Female sexual maturity is estimated at 8.6 years of age, but the first pregnancy may be delayed by up to 4 years, depending on food availability (Rambahiniarison et al., 2018).

Mobulid rays, including *M. birostris*, are vulnerable to both targeted and bycatch fisheries (industrial and artisanal alike) (Couturier et al., 2012; Croll et al., 2016; Stewart et al., 2018). All manta and devil rays are listed in Appendix II of the Convention on International Trade in Endangered Species (CITES), which aims to regulate the international trade of mobulid products, particularly gill plates marketed as health tonics in some Asian countries (O'Malley et al., 2017). Major fisheries have been documented in Indonesia, the Philippines, India, Sri Lanka, Mexico, Taiwan, Mozambique, the Gaza Strip, and Peru (Ward-Paige et al., 2013; Croll et al., 2016).

Due to ongoing population declines worldwide, *M. birostris* has been classified as Endangered on the IUCN Red List as of 2019. Despite increased scientific attention over the past decade (Couturier et al., 2012; Stewart et al., 2018), significant knowledge gaps remain particularly regarding life history, population structure, and habitat use in regions like the Southeastern Pacific. A lack of abundance data continues to hinder accurate assessments of how fisheries and other anthropogenic pressures are impacting this species (Harty et al.,2022).

According to the Global Biodiversity Information Facility (GBIF), the countries with the highest number of *M. birostris* occurrence records are: Mexico, the United States, Ecuador, Peru, Indonesia, and New Zealand. However, the presence of these records alone does not guarantee the species is afforded adequate protection.

This project therefore aims to assess how many of these occurrence records fall within Marine Protected Areas (MPAs) in each of the six countries. By comparing spatial distribution with protection coverage, we seek to better understand the level of conservation currently provided to this endangered species.

2. Objectives

• Retrieve and clean global occurrence data.
• Estimate and visualize relative abundance by country.
• Evaluate spatial overlap with Marine Protected Areas (MPAs).
• Export data layers and figures.

3. Methods

This analysis was conducted using R version 4.4.1 (2024-06-14 ucrt) within the RStudio environm ent, supported by QGIS for spatial verification and map refinement. The workflow involved data acquisition, cleaning, spatial analysis, and visualization using open-access tools and geospatial p ackages.

3.1 Data Sources

- Occurrence records for *Mobula birostris* were downloaded from the Global Biodiversity Information Facility (GBIF) using the rgbif package. This dataset compiles species observation records from global contributors, including museums, universities, and citizen science projects.
- Marine Protected Areas (MPAs) were sourced from the World Database on Protected Areas (WDPA) using the wdpar package. Only marine-designated polygons (MARINE = 1 or 2) were included.

3.2 Data Processing and Cleaning

- Occurrence records were filtered to include only those with geographic coordinates (hasCoordinate = TRUE) and were restricted to the six countries with the highest number of records: Mexico, United States, Ecuador, Peru, Indonesia, and New Zealand.
- The dataset was cleaned by removing missing values and duplicates, and relevant variables were standardized for geospatial processing.

3.3 Spatial Analysis

- Spatial operations were performed in R using the sf and terra packages.
- Occurrence points were converted into sf objects and projected to match the coordinate reference system of the MPA polygons.
- Using the st_intersects() function, each point was spatially assessed to determine whether it fell inside or outside a Marine Protected Area.
- In parallel, QGIS was used to verify spatial alignment, visualize protected areas, and inspect any geometrical inconsistencies in the WDPA data, especially for post-processing and figure production.

3.4 Visualization and Summary

- Aggregations and statistical summaries were generated with dplyr and tidyr.
- Relative abundance by country and protection status were visualized using ggplot2.

- Additional visualization tools like mapview, ggspatial, and leaflet were used for map rendering and interactive exploration.
- All geospatial outputs were saved in .gpkg format for use in GIS platforms like QGIS.

4. Results

According to the Global Biodiversity Information Facility (GBIF), and as shown in both Table 1 and Figure 1, the highest number of occurrence records and the greatest relative abundance of *Mobula birostris* were found in Ecuador**,** with a total of 1,186 records and a relative abundance of 0.729**.**
In contrast, the lowest values for both metrics were observed in New Zealand**,** with only 46 records and a relative abundance of 0.028**.**

Table 1. Number of GBIF occurrence records and calculated relative abundance of *Mobula birostris* in the six countries analyzed.

Country	No. of Records	Relative abundance
Ecuador	1,186	0.72939729
Peru	187	0.11500615
Mexico	160	0.09840098
Indonesia	47	0.02890529
New Zealand	46	0.02829028

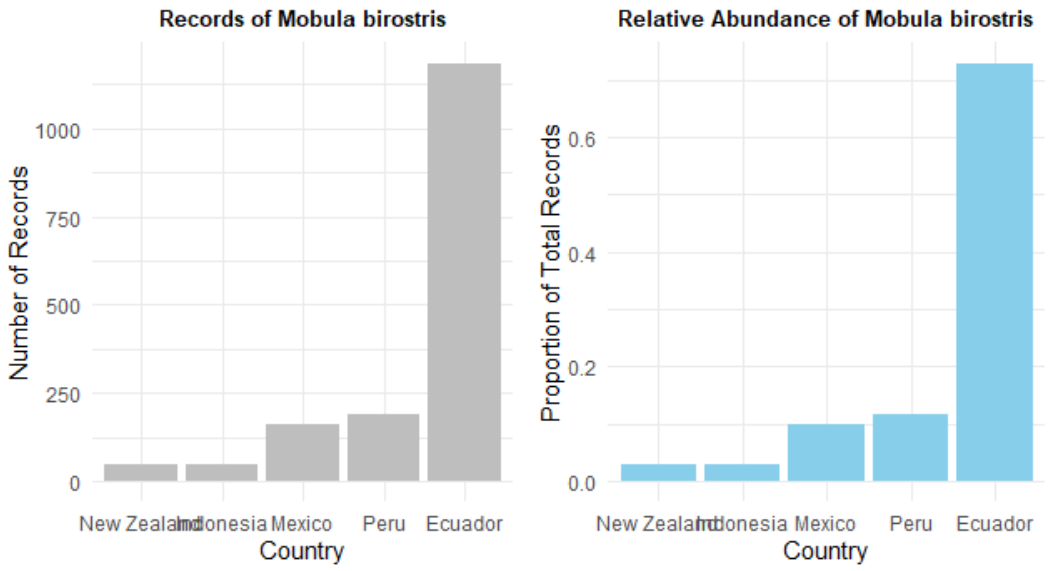

Figure 1. Number and Relative abundance of *Mobula birostris* by country, calculated as the proportion of total occurrence records.

The analysis of Marine Protected Areas (MPAs) reveals that approximately 84% of the recorded individuals in Ecuador were found outside of MPAs, corresponding to 1,005 occurrences, while only 16% were located within protected areas.

In contrast, Mexico had the highest proportion of individuals found within MPAs, with 81% of the records (131 occurrences) located in protected areas.
These results are summarized in Tables 2 and 3 and visualized in Figure 2.

Table 2. Number of *Mobula birostris* occurrence records located inside and outside Marine Protected Areas (MPAs) by country.

Country	location	No. of individuals
Ecuador	Inside MPA	181
Ecuador	Outside MPA	1,005
Indonesia	Inside MPA	30
Indonesia	Outside MPA	17

Mexico	Inside MPA	131
Mexico	Outside MPA	29
New Zealand	Inside MPA	0
New Zealand	Outside MPA	46
Peru	Inside MPA	29
Peru	Outside MPA	158

Table 3. Proportion of *Mobula birostris* records inside versus outside MPAs across the six countries studied.

Country	**Location**	**Proportion**
Ecuador	Inside MPA	0.1526138
Ecuador	Outside MPA	0.8473862
Indonesia	Inside MPA	0.6382979
Indonesia	Outside MPA	0.3617021
Mexico	Inside MPA	0.8187500
Mexico	Outside MPA	0.1812500
New Zealand	Inside MPA	0.0000000

New Zealand	Outside MPA	1.0000000
Peru	Inside MPA	0.1550802
Peru	Outside MPA	0.8449198

The map (Figure 3) shows the distribution of *Mobula birostris* within the countries of Mexico, the United States, Ecuador, Peru, Indonesia, and New Zealand, as well as the position of these occurrences in relation to each country's Marine Protected Areas (MPAs).

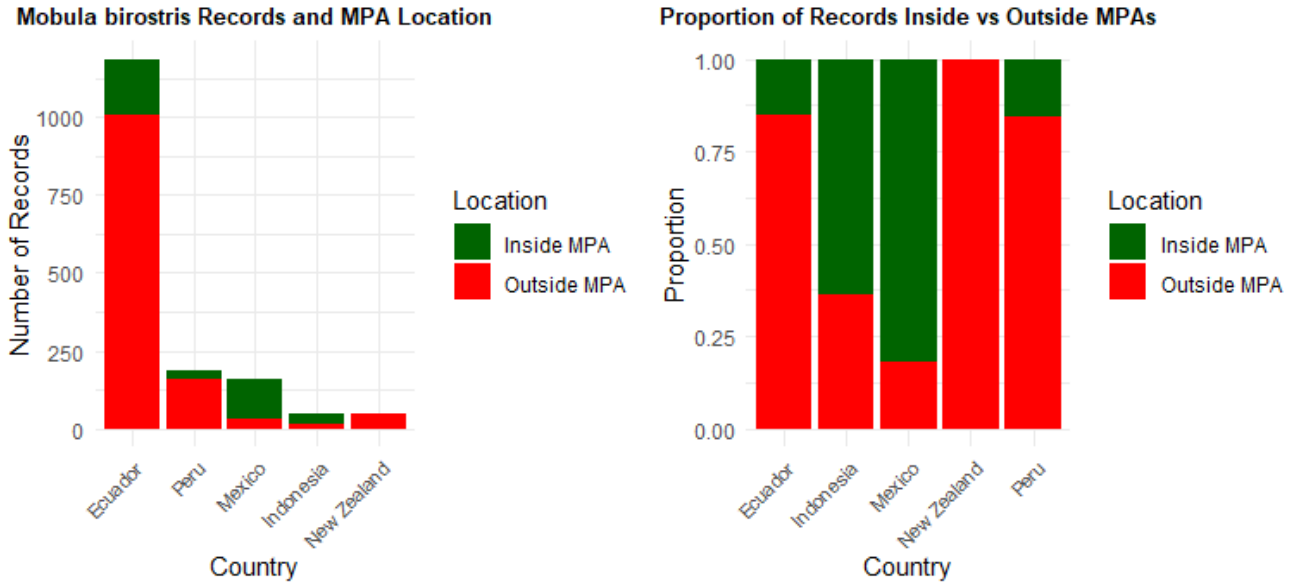

Figure 2. Number and Proportional distribution of *Mobula birostris* records within and outside MPAs for each country

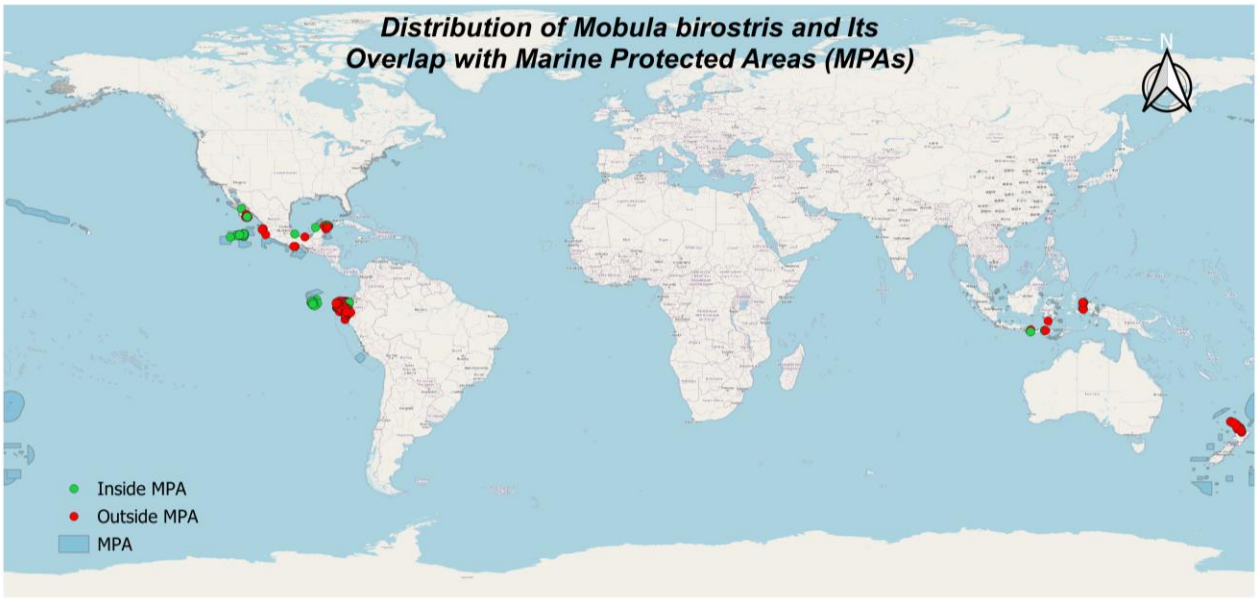

Figure 3. Spatial distribution of *Mobula birostris* occurrences and the location of Marine Protected Areas in the six focus countries.

5. Discussion

The results of this analysis provide important insights into the spatial distribution and conservation coverage of *Mobula birostris*. The highest number of records and relative abundance were found in Ecuador, representing over 72% of all analyzed occurrences. However, a significant proportion (84%)of those records fall outside Marine Protected Areas (MPAs). This highlights a potential conservation gap, as high-density areas for the species may lack formal protection.

In contrast, Mexico stands out for having the highest proportion of records within MPAs (81%), suggesting that existing protected areas in Mexican waters may be better aligned with the known distribution of *M. birostris*. This alignment could serve as a model for other countries aiming to improve spatial coverage of conservation areas for pelagic species.

The presence of *M. birostris* across such ecologically diverse countries as Indonesia, Peru, the United States, and New Zealand confirms its broad habitat range, but also implies that conservation strategies must be regionally adapted. For instance, while New Zealand had the lowest number of records and relative abundance, it may still play a key role as a migratory corridor or edge habitat for the species.

Despite providing a broad overview, this analysis is subject to several limitations. GBIF data are subject to sampling bias and uneven reporting efforts across countries and time periods. For example, some countries may have more complete datasets due to stronger research infrastructure or data sharing policies. Additionally, GBIF records reflect presence-only data and

do not provide population density or abundance estimates, which limits our ability to assess population health or trends.

Another notable gap is the lack of data for large areas of the Southeastern Pacific, where sightings are rare or unreported. This may reflect a real ecological pattern or simply a lack of monitoring effort.

Finally, the analysis assumes that the presence of records within MPAs corresponds to effective protection. However, the mere overlap with MPAs does not guarantee conservation success, as many protected areas suffer from weak enforcement or limited management capacity.

6. Conclusion

This study provides a spatial overview of *Mobula birostris* occurrences across six countries with the highest number of records, using open-access biodiversity and conservation datasets. The findings highlight clear disparities between species distribution and conservation coverage.

While Ecuador hosts the largest share of records, most of its occurrences fall outside Marine Protected Areas, revealing a potential vulnerability for local populations. On the other hand, Mexico demonstrates a more favorable alignment between *M. birostris* distribution and MPA coverage, with most records falling within protected zones.

These results underscore the importance of spatial planning in marine conservation, particularly for wide-ranging and vulnerable species like *M. birostris*. By identifying regions where records are concentrated but poorly protected, this type of analysis can help inform national conservation strategies, the designation or expansion of MPAs, and future research priorities.

Despite data limitations, the use of occurrence records from GBIF and protected area boundaries from WDPA provides a valuable starting point for integrating species presence with management frameworks.

7. References

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