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## **Spatial Analysis of Fishing Effort within Marine Protected Areas in the Mexican Exclusive Economic Zone**

### **Introduction**

According to the National Commission of Natural Protected Areas (CONANP), Natural Protected Areas (Áreas Naturales Protegidas, ANP) are defined as "territories under national jurisdiction, including those over which the Nation exercises sovereignty and jurisdiction, where original ecosystems have not been significantly altered by human activity or whose ecological functions require preservation or restoration. These areas are subject to the legal regime established in this Law and other applicable provisions."

As of 2024, Mexico has approximately 232 federal protected areas, categorized into the following types:

- Biosphere Reserves
- National Parks
- Flora and Fauna Protection Areas
- Natural Resource Protection Areas
- Natural Monuments
- Sanctuaries
- Voluntarily Conserved Areas

Out of the total, around 40 are marine protected areas (MPAs), which belong to just four of these categories: Biosphere Reserves, National Parks, Flora and Fauna Protection Areas, and Sanctuaries. Among them, National Parks are the most numerous (17), followed by Biosphere Reserves (16) (CONANP, 2024).

CONANP defines these four categories as follows:

- Biosphere Reserves are ecologically significant areas with representative, largely unaltered ecosystems that require preservation and restoration. Core zones allow only preservation, scientific research, and environmental education, while buffer zones permit regulated sustainable use by local communities.

- National Parks are zones characterized by scenic beauty, scientific value, recreational or historic significance, or rich biodiversity. Activities such as conservation, tourism, research, and education are permitted under protective management.
- Flora and Fauna Protection Areas include habitats whose conservation is essential for the survival and development of specific plant and animal species. These areas allow regulated sustainable use, research, propagation, and environmental outreach, in accordance with Mexican official standards.
- Sanctuaries protect specific microhabitats or geographically restricted ecosystems that support unique or vulnerable flora and fauna. Only scientific, educational, and recreational activities compatible with conservation goals are allowed.

All MPAs lie within Mexican waters and the country's Exclusive Economic Zone (EEZ), which is the maritime area extending from the outer edge of the territorial sea up to 200 nautical miles (370.4 km) offshore, measured from the baseline (SIMAR, 2025). Within this zone, Mexico holds sovereign rights for the exploration, exploitation, conservation, and management of natural marine resources, as regulated under Articles 46–56 of the Federal Law of the Sea (CONABIO–SIMAR, 2025).

The Mexican EEZ is the primary region where national fisheries operate, and the marine protected areas within it are legally recognized zones that should be respected and managed to ensure ecological balance. However, compliance with MPA regulations is not always guaranteed, and many of these protected areas experience significant fishing pressure that may undermine their ecological integrity and management effectiveness (CONABIO–SIMAR, 2025).

For this reason, the present study aims to analyze the fishing effort within marine protected areas in the Mexican EEZ, identify which MPAs are most affected, and provide insights that can support evidence-based conservation strategies.

## **Methodology**

### **Data sources and preparation**

Fishing effort data for the year 2024 were obtained from Global Fishing Watch, in raster format, representing the total number of fishing hours per 0.1-degree grid cell within the Mexican Exclusive Economic Zone (EEZ). The raster dataset was pre-clipped to the EEZ boundary to ensure spatial consistency. Marine Protected Areas (MPAs) shapefiles were retrieved from the Comisión Nacional de Áreas Naturales Protegidas (CONANP) and intersected with the EEZ layer.

All spatial layers were projected in WGS 84 (EPSG:4326) and processed using QGIS 3.40. Additional spatial data, including coastlines and EEZ boundaries, were sourced from MarineRegions.org.

## **Analytical workflow**

The analysis followed these steps:

1. Effort characterization in the EEZ: Basic statistics were calculated for all non-NaN cells in the effort raster, including sum, mean, standard deviation, maximum, and coefficient of variation (CV).
2. MPA overlay: The raster was clipped using the polygon layer of MPAs to isolate fishing effort within protected areas.
3. Statistical comparison: The same set of summary statistics was computed for the raster values within MPAs.
4. Percentage calculations: The proportion of valid effort cells and total fishing effort occurring within MPAs was computed relative to the entire EEZ.
5. Distribution analysis: A histogram of fishing effort per cell was generated, using a log scale on the y-axis to better visualize skewness and outliers.
6. Map creation: A thematic map displaying fishing effort intensity and MPA overlap was produced in QGIS. Five effort categories were visualized using a diverging color scale:
  - Low (0–50 hours)
  - Moderate (50–150)
  - High (150–300)
  - Very High (300–400)
  - Extreme (>400)

## **Results**

A spatial analysis of fishing effort within the Mexican Exclusive Economic Zone (EEZ) during 2024 revealed a total of 21,564.7 fishing hours distributed across 3,663 valid grid cells. The average effort per cell was 5.89 hours, with values ranging from 0 to 441.4 hours. The standard deviation was 14.99 hours, yielding a coefficient of variation of 254.6%, indicating a highly uneven distribution of fishing activity, with intense concentrations in specific coastal and offshore regions (Table 1).

Table 1. Summary statistics of fishing effort in the Mexican EEZ and Marine Protected Areas (MPAs)

Summary statistics of fishing effort		
Mexican EEZ and Marine Protected Areas (2024)		
	Fishing Effort	
	EEZ	MPAs
Valid cells (n)	3663	847
Total effort (hours)	21564.7	3915.1
Mean effort per cell	5.89	4.62
Standard deviation	14.99	8.77
Coefficient of variation	254.6%	189.8%
Max effort (hours)	441.4	120.4

Table 2. Summary statistics of fishing effort in the Mexican EEZ and Marine Protected Areas (MPAs)

Within the network of Marine Protected Areas (MPAs) in the EEZ, 847 grid cells recorded valid effort values. These accounted for a total of 3,915.1 hours, which is 18.1% of the total effort detected in the EEZ. Meanwhile, MPAs comprised 23.1% of the spatial extent with active fishing effort. The average fishing effort within MPAs was 4.62 hours per cell, with a standard deviation of 8.77 hours and a coefficient of variation of 189.8%.

These results suggest that while MPAs encompass nearly a quarter of the spatial footprint of fishing activity, they account for a proportionally smaller share of the total effort. This may indicate a partial reduction in pressure due to protective measures. However, the presence of moderate to high effort values within certain MPAs raises concerns regarding compliance, enforcement, or potential weaknesses in MPA design.

The log-scaled histogram (Figure 1) of effort distribution highlights a strong positive skew, with most grid cells registering <10 fishing hours, and a small number exceeding 100 hours. This reflects the presence of distinct fishing hotspots. The final map visualization (Figure 2) confirms this spatial heterogeneity, clearly displaying areas of overlap between high fishing effort and MPA boundaries, particularly in the Pacific region.

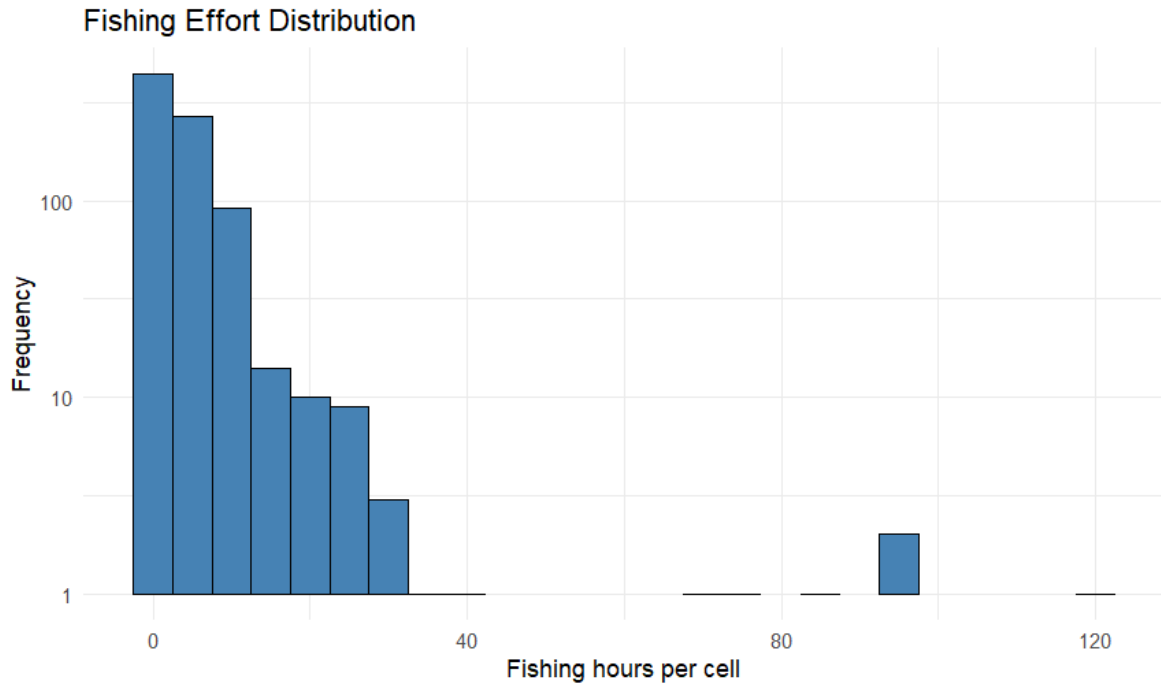


Figure 1 Distribution of fishing effort per cell in the Mexican EEZ (log scale)

A closer inspection of the fishing effort distribution across individual Marine Protected Areas (MPAs) in the Mexican EEZ revealed that certain protected areas concentrate a disproportionate amount of fishing pressure.

The MPA with the highest total fishing effort in 2024 was *Pacífico Mexicano Profundo*, registering over 2,300 cumulative fishing hours. It was followed by *Islas del Pacífico de la Península de Baja California* and *Arrecifes del Golfo de México-Sur*, all of which exhibited substantial accumulated pressure (Figure 3). These MPAs are generally large in size, which explains the high total effort, but may also reflect their accessibility and biological productivity.

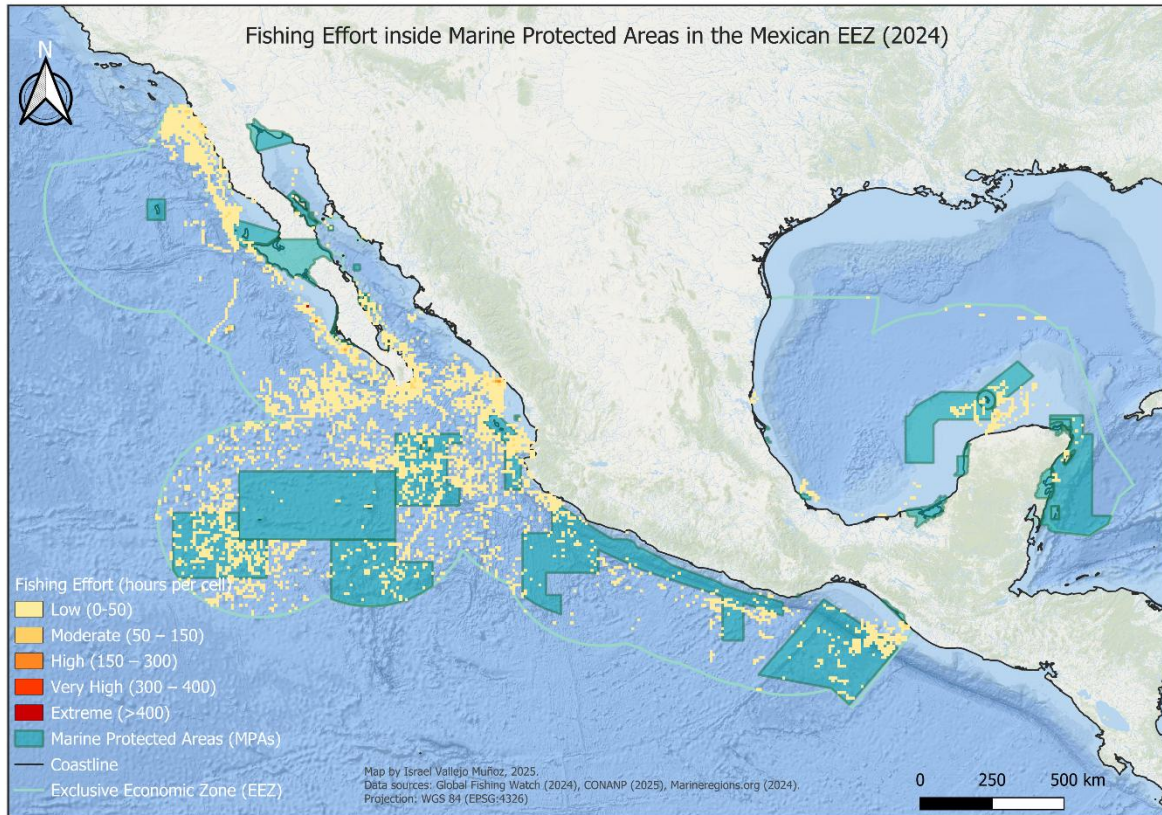
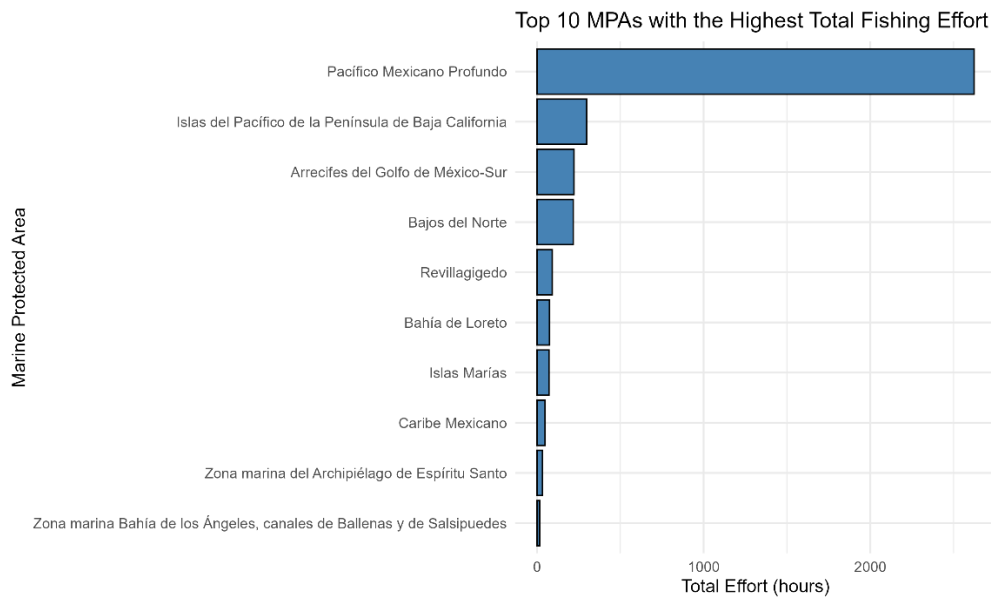


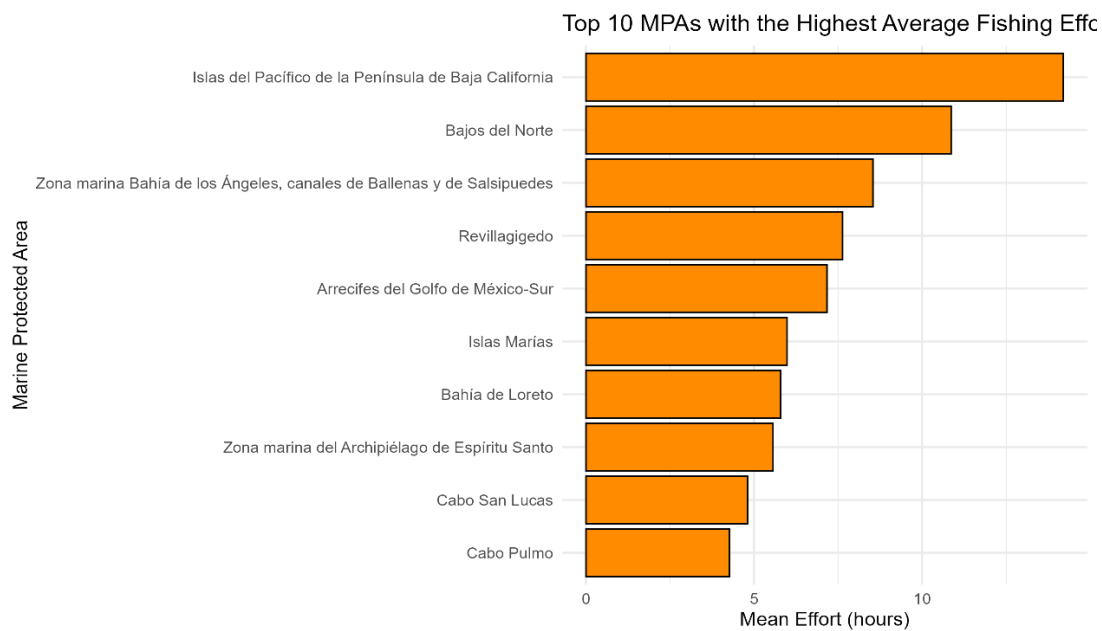
Figure 2 Spatial distribution of fishing effort within Marine Protected Areas in the Mexican EEZ (2024)

However, when analyzing the average effort per cell, which reflects local fishing intensity, a different pattern emerged. *Islas del Pacífico de la Península de Baja California* again topped the list, but smaller MPAs such as *Bajos del Norte*, *Bahía de los Ángeles*, and *Revillagigedo* also ranked highly (Figure 4). These results indicate that while some MPAs may experience widespread pressure due to their size, others face localized but intense fishing activity that could threaten key ecological functions.



*Figure 3 Top 10 Marine Protected Areas with the Highest Total Fishing Effort in the Mexican EEZ (2024)*

These findings highlight the need for differentiated management strategies: while large MPAs may benefit from improved surveillance coverage, smaller yet heavily fished MPAs could require targeted enforcement and monitoring.



*Figure 4 Top 10 Marine Protected Areas with the Highest Average Fishing Effort per Cell in the Mexican EEZ (2024)*

## Discussion

The analysis of fishing effort within Mexico's Marine Protected Areas (MPAs) in the Exclusive Economic Zone (EEZ) revealed clear patterns of spatial concentration, regulatory gaps, and varying vulnerability levels among protected areas. While MPAs are designed to conserve biodiversity and maintain ecosystem functions, this study confirms that fishing activity remains a persistent pressure within many of them.

In 2024, approximately 18.1% of total fishing effort in the EEZ occurred within MPAs, despite these areas comprising 23.1% of the spatial footprint of fishing activity. This indicates a lower-than-expected concentration of effort inside MPAs, suggesting some protective effect—but not full exclusion—of fishing activities. The coefficient of variation was high both inside MPAs (189.8%) and across the EEZ (254.6%), confirming that fishing effort is highly clustered, with certain zones experiencing disproportionately high use.

The histogram and spatial map showed that while most grid cells have low fishing intensity, a small number exhibit effort values above 100 hours per cell, forming critical hotspots of fishing pressure. Alarming, several of these high-effort zones overlap directly with the boundaries of federally protected MPAs.

The ranking of MPAs by total and average effort revealed two distinct, yet complementary patterns:

- MPAs like *Pacífico Mexicano Profundo*, with over 43 million hectares of protected seafloor, experience the highest total fishing effort. This enormous offshore biosphere reserve safeguards deep-sea ecosystems starting at 800 meters below sea level, including hydrothermal vents, abyssal plains, submarine ridges, seamounts, and ocean trenches (CONANP, 2024). While its vastness partly explains the accumulated effort, the ecological sensitivity and limited knowledge of its biodiversity call for urgent monitoring and regulation.
- In contrast, MPAs such as *Islas del Pacífico de la Península de Baja California*, which includes ecologically rich archipelagos like *Bahía Magdalena*, *Isla Cedros*, and *Archipiélago San Benito*, showed both high total and average fishing effort per cell. These islands host a remarkable diversity of marine mammals, seabirds, and endemic species found nowhere else (CONANP, 2024). Their accessibility and productive coastal environments make them particularly vulnerable to sustained fishing pressure.
- The recently designated *Bajos del Norte Flora and Fauna Protection Area*, located in the Campeche Bank of the Gulf of Mexico, also ranked among the most intensely fished. Although it was only established in 2024, its core zone (344,467 ha) and buffer zone (959,647 ha) already show significant fishing activity (CONANP, 2024). This highlights the need to implement immediate management measures and monitor compliance from the early stages of protection.

These findings emphasize that size alone does not guarantee protection. Large MPAs may accumulate more effort due to their extent, while smaller MPAs can suffer from high



localized pressure that threatens their ecological integrity. A one-size-fits-all approach is therefore insufficient.

## Conclusions and Recommendations

This study provides a spatially explicit assessment of fishing pressure within Marine Protected Areas (MPAs) in the Mexican Exclusive Economic Zone (EEZ), revealing critical mismatches between legal protection and actual fishing activity. While MPAs show slightly lower average fishing effort compared to the broader EEZ, significant levels of fishing persist within their boundaries. Several MPAs—particularly *Pacífico Mexicano Profundo*, *Islas del Pacífico de la Península de Baja California*, and *Bajos del Norte*—exhibit disproportionately high total or average fishing effort, highlighting areas of concern that warrant urgent attention.

The effectiveness of marine conservation depends not only on the legal designation of MPAs, but also on consistent enforcement, ongoing monitoring, and adaptive governance. To strengthen the ecological integrity of MPAs and improve compliance, the following management strategies are recommended:

- Enhance surveillance and regional coordination in MPAs with high total effort (e.g., *Pacífico Mexicano Profundo*), especially in offshore or hard-to-monitor areas.
- Implement targeted enforcement measures—including seasonal closures and participatory monitoring—in MPAs with high average effort per cell (e.g., *Bajos del Norte*, *Islas del Pacífico*), where localized fishing intensity poses significant ecological risks.
- Develop early enforcement protocols, community outreach, and ecological baseline studies in newly designated MPAs to ensure that protection begins effectively from the outset.
- Integrate satellite-derived fishing effort data with in situ patrol reports and biodiversity monitoring to support adaptive, evidence-based conservation and to better prioritize management actions.

By aligning spatial data, enforcement tools, and ecological priorities, marine spatial planning in Mexico can more effectively meet its conservation goals and ensure the long-term sustainability of its protected marine ecosystems.

## References

- CONABIO–SIMAR. (2025). Zona Económica Exclusiva (ZEE). Sistema de Información sobre la Biodiversidad Marina de México. <https://simar.conabio.gob.mx>
- CONANP. (2024). Áreas Naturales Protegidas. Comisión Nacional de Áreas Naturales Protegidas. <https://www.gob.mx/conanp/documentos/areas-naturales-protegidas-278226>
- CONANP. (2024). Fichas descriptivas de Áreas Naturales Protegidas. Comisión Nacional de Áreas Naturales Protegidas. <https://descubreanp.conanp.gob.mx>

- Global Fishing Watch. (2024). Global Fishing Effort by Gear Type – 2024 Dataset. <https://globalfishingwatch.org/data-download/datasets/>
- MarineRegions.org. (2024). Exclusive Economic Zones (EEZ). Flanders Marine Institute (VLIZ). <https://www.marineregions.org>