Response to Reviewers

Favoretto et al.

October 17, 2025

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# Overview

We thank the editor and reviewers for the thoughtful and actionable feedback on our manuscript (ISCIENCE-D-25-10442). In revising the manuscript we:

* Reorganised the manuscript into the STAR★Methods structure requested by *iScience*, refreshed Figures 1–2, and rewrote the narrative so the opening sections frame the disproportionate role of high-capacity jurisdictions and the actionable roadmap that emerges from their decisions.
* Rebuilt the entire analysis as a FAIR, open {targets} pipeline that ingests raw ProtectedSeas Navigator and UNEP-WCMC data, generates all intermediate tables, renders the manuscript, and produces this response letter. Running targets::tar\_make() now regenerates every figure (outputs/figures/), table (outputs/tables/), manuscript export, and appendix directly from source data.
* Added machine-readable outputs, explicit data availability statements, and a repository README that documents dependencies, execution steps, and archiving plans (including a mirrored Zenodo deposit).

These revisions ensure that the study’s structure, storyline, and computational workflow are transparent and reproducible. We respond point-by-point below. Reviewer comments appear in **bold italics**; our replies follow each comment.

# Reviewer 1

***“First, the discussion does not consider the growing role of Other Effective area-based Conservation Measures (OECMs)… Integrating OECMs into the conceptual framework and policy recommendations would provide a more comprehensive understanding.”***

**Response:** We agree that OECMs are an essential complement to MPAs and have substantially revised the manuscript to address this concern. The revised manuscript now:

1. **Introduces OECMs contextually in the Introduction** (lines 55–66) when framing the broader 30×30 strategy, explicitly positioning upgrades as operating in parallel with OECM recognition and new MPA establishment.
2. **Discusses their complementary role throughout** (lines 55–66, 89–96), emphasizing that high-quality OECMs and community-led stewardship models should be encouraged alongside MPA upgrades.
3. **Explains the methodological rationale for exclusion from quantitative analysis** (lines 55–56, 94–96, 164–166): OECMs lack the standardized regulatory frameworks and globally consistent datasets needed for comparable spatial analysis. The ProtectedSeas Navigator provides rule-based, verifiable classifications for MPAs with temporal resolution from 2000–2025, enabling us to quantify upgrade gaps by intersecting high-resolution regulatory rasters (1 km, EPSG:6933) with habitat layers. No equivalent OECM dataset exists with matching spatial coverage, temporal depth, and regulatory detail.
4. **Acknowledges their locally governed conservation value** while explaining why mixing heterogeneous OECM definitions with MPA regulatory data would compromise comparability and potentially overstate protection levels that lack enforceable no-take standards.

The key point is **methodological, not ideological**: our FAIR reproducible pipeline requires spatially explicit, temporally resolved, and globally consistent data to calculate where minimally protected MPAs could be upgraded to full protection. We cannot perform this analysis for OECMs because the necessary standardized global datasets do not yet exist. We explicitly state that future pipelines should incorporate OECMs once validated FAIR products emerge (lines 66, 96), and we highlight Indigenous- and community-led examples as pathways that strengthen enabling conditions even when they cannot yet be included in quantitative totals. This approach acknowledges the importance and growing role of OECMs while remaining transparent about current data limitations and the specific analytical constraints of an upgrade-focused framework.

***“Second, the analysis heavily focuses on coral reefs, seagrasses, mangroves, saltmarshes, and cold-water corals… Expanding the habitat scope or at least discussing this limitation would enhance the generalizability.”***

**Response:** We thank the reviewer for this important observation and have substantially expanded our discussion of habitat scope limitations. The revised manuscript now:

1. **Explicitly addresses this limitation in the Introduction** (lines 57–58), stating that “temperate kelp forests, rocky reefs, and polar habitats remain underrepresented due to the absence of comparable global products” and committing to incorporate them “as standardized datasets emerge.”
2. **Discusses the constraint in the Results** (line 77), noting how the habitat distribution patterns would likely show even stronger concentration in high-latitude, high-enabling jurisdictions if temperate and polar datasets were available—meaning our current estimates are likely *conservative*.
3. **Provides detailed methodological justification in STAR★Methods** (lines 153–163), explaining that we rely on UNEP-WCMC **mapped, observational products** (not statistical models) because they provide globally consistent coverage with comparable spatial effort and quality-controlled metadata.

**Why this matters methodologically**: Our analysis intersects regulatory rasters (from ProtectedSeas) with habitat rasters (from UNEP-WCMC) at 1 km resolution in a common equal-area projection (EPSG:6933). This requires: - **Spatially explicit boundaries** (not modeled distributions) - **Global coverage with consistent methods** - **Quality-controlled, peer-reviewed datasets** - **FAIR-compliant metadata** enabling reproducible workflows

For tropical/subtropical habitats, UNEP-WCMC provides exactly this through Global Mangrove Watch v3, Global Seagrasses v7.1, Global Saltmarshes, Global Coral Reefs, and Global Cold-water Corals datasets. For temperate kelp forests, rocky reefs, and polar benthos, comparable global products at matching resolution and quality are not yet available. Mixing in modeled layers or regionally inconsistent datasets would introduce unquantifiable uncertainty and compromise the spatial accuracy of upgrade opportunity calculations.

1. **Frames this as a priority for future work** (lines 57–58, 100, 163), emphasizing that as global kelp, rocky reef, and polar habitat datasets achieve similar observational coverage and FAIR standards, they should be incorporated to expand geographic applicability—likely revealing *additional* upgrade opportunities in high-latitude, high-enabling nations like Canada, Norway, and Iceland.

We thank the reviewer for prompting us to clarify that our habitat scope reflects current data availability rather than an oversight, and that our upgrade opportunity estimates are therefore conservative with respect to temperate and polar ecosystems.

***“In summary… addressing the potential role of OECMs and ensuring broader habitat representativeness would strengthen its policy relevance and global applicability.”***

**Response:** We agree, and the revised storyline now opens by emphasising that a small cohort of high-capacity countries already controls the bulk of fully protected MPAs, while clearly acknowledging the data gaps that currently limit comprehensive OECM and temperate-habitat integration. We believe these revisions make the manuscript’s message—that decisive action by high-capacity jurisdictions is both necessary and measurable—more direct and responsive to the reviewer’s helpful guidance.

## Methods transparency

The request for greater transparency prompted a full rebuild of the workflow. The revised STAR★Methods now walks readers through each stage of the {targets} pipeline—from ingestion of ProtectedSeas and UNEP-WCMC sources, to raster harmonisation, to the generation of maps, tables, and manuscript exports. Every function lives in scripts/01\_data\_preparation.R through scripts/04\_summary\_tables.R, is version-controlled, and is referenced directly in the text. Running targets::tar\_make() reproduces the figures (outputs/figures/), machine-readable tables (outputs/tables/), manuscript (manuscript/manuscript.docx), and this response letter, while the README documents software dependencies, environment management, and archival plans. These additions satisfy the transparency request and ensure the study adheres to FAIR principles.

# Reviewer 2

## Novelty and evidence for stalling

**Reviewer concern:** The manuscript needed clearer evidence that MPA protection is truly “stalling” and stronger articulation of what makes this analysis novel.

**Our response:** We have fundamentally restructured the manuscript to address both concerns:

### Evidence for stalling:

1. **Quantitative documentation of the plateau** (lines 73–74): We now report precise figures showing that fully protected MPAs cover 3.81% of the ocean in 2025, with annual gains dropping below 0.05 percentage points since 2018—a dramatic slowdown from earlier growth rates. Figure 1B directly visualizes this post-2018 plateau by pairing cumulative trajectories with annual increments, making the stalling trend immediately apparent.
2. **Separation of MPAs from other measures** (Figure 1): We explicitly distinguish Marine Protected Areas from other area-based management tools throughout the temporal analysis, demonstrating that the surge in declarations has not translated into stricter regulations within the MPA category specifically.
3. **Habitat-specific stalling** (line 73, Figure 1C): We document that across all five critical coastal habitats analyzed (warm- and cold-water corals, mangroves, seagrasses, saltmarshes), fully protected coverage “remains a small fraction of total extent and has improved only marginally” since our previous 2022 assessment, providing habitat-level corroboration of the global trend.

### Novelty—what this analysis uniquely contributes:

The revised manuscript now opens by emphasizing our **three interconnected contributions** that distinguish this work from prior global MPA assessments:

1. **Temporal regulatory analysis** (lines 61–62): First 25-year time series (2000–2025) distinguishing minimally from fully protected MPAs using rule-based ProtectedSeas classifications rather than IUCN categories, revealing *when* and *how* protection quality stalled.
2. **Critical habitat overlay** (lines 63, 77–79): First analysis showing that 72% of mapped coastal habitat area (corals, mangroves, seagrasses, saltmarshes) already lies within countries scoring ≥50 on enabling conditions, yet remains minimally protected—demonstrating that the problem is not *where* MPAs are located but *how* they are regulated.
3. **Governance-based upgrade roadmap** (lines 64, 85–87): First spatially explicit identification of upgrade opportunities by overlaying habitat exposure with enabling conditions, revealing that a small cohort of high-capacity countries (top 10 sovereign territories stewarding 87% of existing fully protected area) also hold 39% of the global upgrade gap. Critically, we show that many of these opportunities occur in **overseas territories** (France, UK, US), where nations retain jurisdiction over globally significant ecosystems but have not elevated protection levels—a pattern invisible in prior analyses.

**Why this matters:** Previous studies documented that *most* MPAs are ineffective (Pike et al. 2024, Grorud-Colvert et al. 2021), and that MPA expansion into low-governance jurisdictions is unlikely (Mouillot et al. 2024). We advance the conversation by showing *exactly where* existing MPAs could be upgraded *now* to deliver measurable gains, and which countries control those decisions. By identifying the specific jurisdictions where governance capacity, habitat concentration, and minimal current protection intersect, we provide actionable targets rather than general policy recommendations.

## Plausibility of upgrades versus new MPAs

**Reviewer concern:** “*Why would governments that implemented minimally protected MPAs suddenly adopt full protection?*”

**Our response:** This is the central political-economy question our analysis addresses. We argue that upgrades are plausible in high-enabling jurisdictions for five interconnected reasons, now detailed throughout the revised manuscript:

### 1. **Empirical precedent exists** (line 91, ref 27)

We cite Favoretto et al. (2023), which documented that Mexico upgraded the Revillagigedo Archipelago to full protection without harming industrial fishing fleets—demonstrating that regulatory strengthening is feasible where governance structures support transparent consultation and adaptive management. Other examples include expansions in Cabo Pulmo (Mexico), Ascension Island (UK), and Chile’s marine parks, where upgrades proceeded despite initial opposition once enabling conditions (enforcement capacity, stakeholder engagement, benefit-sharing) were established.

### 2. **Enabling conditions predict success** (lines 53, 87, ref 9)

We specifically target jurisdictions scoring ≥50 on enabling conditions—a composite index of governance quality, rule of law, and blue economy readiness (Cisneros-Montemayor et al. 2021). These are not countries “suddenly” changing policy; they are jurisdictions that already possess: - **Institutional capacity** for enforcement (coast guard, surveillance technology) - **Legal frameworks** enabling regulatory adjustments within existing MPAs - **Economic diversification** reducing dependence on extractive sectors - **Civil society engagement** that can mobilize support for conservation

Recent socioeconomic modeling (Mouillot et al. 2024, ref 9) shows that MPA expansion into *low*-enabling jurisdictions is unlikely to succeed, precisely because these prerequisites are absent. Our roadmap inverts the problem: instead of pushing new MPAs where they will fail, we identify where *existing* MPAs can be strengthened where conditions favor success.

### 3. **Political momentum and international commitments** (lines 93, ref 48)

The 2025 UN Ocean Conference “Pact for the Ocean” and the 30×30 targets under the Kunming-Montreal Framework create political windows for action. High-capacity countries—particularly those with overseas territories—face growing scrutiny over whether their domestic and territorial waters match their international leadership rhetoric. Upgrades provide a credible way to demonstrate substantive action rather than just declaring more minimally protected areas.

### 4. **Financial mechanisms now exist** (lines 93, refs 41–42)

The Discussion (lines 93) references blue bonds, debt-for-nature swaps, and benefit-sharing arrangements that align costs and benefits of stricter protection. These instruments did not exist at scale when many minimally protected MPAs were first designated; they now provide viable pathways for financing enforcement, compensating affected sectors, and ensuring equitable transitions.

### 5. **Social contract dynamics** (lines 81–82, refs 24, 36–38)

We explicitly address *why* governments initially chose minimal protection (lower short-term costs, broader stakeholder acceptance) and *what has changed* (Figure 1D, lines 81–82): accumulating evidence that minimally protected MPAs deliver uncertain benefits while demanding continuous management effort. When communities co-govern and share economic returns (ecotourism, fisheries spillover), compliance improves and the political calculus shifts. The manuscript cites participatory planning frameworks (refs 24, 37, 38) showing that successful upgrades require transparent processes where affected communities assess trade-offs and share gains—not top-down imposition.

**The key insight:** We are not proposing that governments will *suddenly* upgrade. We are identifying where they *can* upgrade because the enabling conditions, financial tools, international pressure, and empirical precedents now align. The alternative—continued expansion into low-governance jurisdictions—has been shown to fail (ref 9). Our roadmap provides a politically and economically tractable pathway for high-capacity countries to demonstrate leadership while building the track record that could eventually shift norms globally.

## Integration with 30×30 and OECMs

**Reviewer concern:** “*30×30 was negotiated only recently; OECMs and broader strategies should be included.*”

**Our response:** We agree and have revised the manuscript to position MPA upgrades explicitly within the broader 30×30 portfolio, clarifying that this is not an either/or proposition:

### How upgrades fit within 30×30:

The revised manuscript now:

1. **Frames upgrades as complementary, not exclusive** (lines 55–56, 66, 91): “This upgrade-focused strategy operates in parallel with the establishment of new MPAs and the recognition of high-quality OECMs. By demonstrating where governments can immediately strengthen existing statutory protections, we provide a practical pathway to accelerate progress toward 30×30 while longer-term efforts to expand coverage and improve BBNJ implementation continue.”
2. **Acknowledges the BBNJ Agreement** (lines 55–56, 94–95) while explaining that operational mechanisms for high-seas protections are still emerging, so countries can act *now* within their EEZs to build credibility and track records while BBNJ institutions mature.
3. **Discusses OECMs throughout** (lines 55–56, 93–96, Reviewer 1 response above), emphasizing their value for locally governed conservation while explaining why their current heterogeneity prevents inclusion in quantitative upgrade calculations. We explicitly state that high-quality OECMs should be encouraged and counted toward 30×30 once standardized monitoring frameworks exist.
4. **Quantifies the magnitude of the 30×30 challenge** (lines 95–96): “Achieving 30% protection of territorial seas alone will require protecting an additional 1.68 million km² (approximately 188,000 coastal MPAs at an average size of 10 km²) by 2030.” This context shows why *quality* matters as much as quantity—adding 188,000 new minimally protected MPAs would meet the numerical target while delivering limited ecological outcomes.

### The strategic logic:

The 30×30 target creates urgency but also risk: countries could rush to declare minimally protected areas to meet the 30% number without ensuring effectiveness. Our analysis argues for a **quality-first pathway** that: - Upgrades existing MPAs in high-capacity jurisdictions (immediate, measurable gains) - Establishes targeted new MPAs where needed (closing geographic gaps) - Recognizes high-performing OECMs (supporting community-led conservation) - Builds enabling conditions in lower-capacity jurisdictions (long-term sustainability)

This is not a rejection of new MPAs or OECMs—it is a prioritization framework showing where governments can act *immediately* to demonstrate substantive progress while the full 30×30 portfolio develops. As the Discussion now states (lines 96): “A strategy prioritizing regulatory quality, supported by targeted new designations and high-performing OECMs, offers a more effective approach than continued expansion of minimally protected areas.”

## Data availability and transparency

***“The information analysed is not presented.”***

* Four machine-readable tables are now generated automatically (annual protection, growth rates, upgrade opportunities, global habitat coverage) and saved under outputs/tables/, with generation documented in the targets workflow (lines 163-199, 265-345).
* The manuscript now contains a dedicated Data Availability section describing how to access the ProtectedSeas Navigator records, UNEP-WCMC habitat datasets, and the Cisneros-Montemayor enabling-condition scores, while distributing all processed rasters and tables with this repo (lines 265-270).

***“The manuscript is well structured but methods should be reproducible.”***

* All data ingestion, cleaning, and summarising functions are modularised in scripts/01\_data\_preparation.R through scripts/04\_summary\_tables.R, with the corresponding methods narrative at lines 265-345.
* targets::tar\_make() rebuilds figures (outputs/figures/), tables (outputs/tables/), the manuscript (manuscript/manuscript.html), and this response letter (manuscript/response\_to\_reviewers.docx), ensuring reproducibility from raw data (lines 265-345).

# Additional changes

* Reframed the manuscript (new title, updated Summary/Discussion, revised Figures 1–2) so the narrative clearly highlights how a small cohort of high-capacity countries both delivers most fully protected MPAs and holds the largest upgrade gaps—an emphasis directly inspired by the reviewers’ comments—and stresses that visible upgrades, including across overseas territories, would demonstrate global leadership.
* Added detailed methodological context describing the UNEP-WCMC habitat rasters, the decision to focus on sovereign EEZ jurisdictions, the rationale for leaving OECMs outside the quantitative workflow while discussing them qualitatively, and the links to the 2025 UN Ocean Conference outcomes.
* Documented the FAIR workflow in a repository README, including dependencies, pipeline execution, and replication guidance; archived the prior project in archive/original\_project/ to preserve provenance.
* Added a manuscript Data Availability statement and committed to depositing the complete {targets}-based analysis pipeline—with all scripts, configuration files, and processed datasets—as supplementary material and in a mirrored public archive so editors and readers can rerun every result.

We appreciate the reviewers’ insights, which significantly improved the clarity and robustness of the study.