Response to Reviewers – ISCIENCE-D-25-10442

Favoretto et al.

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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 and created a dedicated, supporting repository for the manuscript that allow to fully replicate the results.
* Added machine-readable outputs, explicit data availability statements, and a repository README that documents dependencies, execution steps.

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 potentially capable to complement MPAs and have substantially revised the manuscript to address this concern. The revised manuscript now:

1. **Introduces OECMs contextually in the Introduction** (lines 44–48) 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 85–87, 155–157), 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 48, 94, 153–157): 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 (even if we acknowledge the WDPA OECMs spatial shapefiles, they are not explicit in their regulations). We explicitly state that future pipelines should incorporate OECMs once comparable regulatory products emerge (lines 50, 153) and highlight Indigenous- and community-led examples as pathways that strengthen enabling conditions even when they cannot yet be included in quantitative totals (line 85). 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** (line 50), 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. **Reiterates the constraint in the Limitations** (line 94), noting how the absence of comparable temperate and polar datasets currently constrains upgrade estimates and likely renders them conservative.
3. **Provides detailed methodological justification in STAR★Methods** (lines 140–148), 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**:

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** (line 153), 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 and Data & code availability sections (lines 112–132, 138–157) now walk 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. The manuscript directs readers to the version-controlled scripts in scripts/ (R) and scripts\_py/ (Python) and documents where the pipeline writes figures and machine-readable tables (outputs/figures/, outputs/tables/), ensuring the entire analysis can be rerun from raw inputs.

# 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. 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. 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**: 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**: 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**: 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 85, ref 29)

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 46, 85; refs 8, 11)

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 8) 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**

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**

The Discussion 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**

We explicitly address *why* governments initially chose minimal protection (lower short-term costs, broader stakeholder acceptance) and *what has changed* (Figure 1D): 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 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 8). 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** (line 85): “Upgrades complement rather than replace the establishment of new MPAs and recognition of high-quality OECMs; they unlock immediate conservation gains while broader spatial planning, new designations, and BBNJ implementation advance in parallel18,28.”
2. **Acknowledges the BBNJ Agreement** (lines 48, 87) 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 44–48, 85–87, 155–157, 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** (line 89): “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 (line 89): “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 their production documented in the Methods (lines 140–153) and Data & code availability (lines 128–132).
* The manuscript now contains a dedicated Data and code 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 124–132).

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

* The STAR★Methods (lines 138–157) detail the modular pipeline that ingests, harmonises, and summarises the datasets, aligning the narrative with the version-controlled scripts referenced in the Data & code availability section.
* The manuscript points readers to the {targets}-based workflow and repository locations that regenerate figures and tables (outputs/figures/, outputs/tables/) from raw inputs (lines 128–132), ensuring reproducibility for editors and reviewers.

# 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;
* 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.