Catching Congruencies:

Spatially congruent sites of importance for global shark and ray biodiversity

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Background

Species distributions are widely used to explain the patterns seen in global biodiversity, and can help identify places of conservation priority$_1$. Much global prioritization of biodiversity has previously focused on conserving the most species rich areas, however other metrics can also be used to help understand species distributions. Metrics such as endemicity – those species that exist nowhere else, evolutionarily distinct species – those who encompass the greatest share of evolutionary history, and threatened species – species who are at an increased risk of extinction. Each making understanding global biodiversity a high priority for more successful conservation implementation.

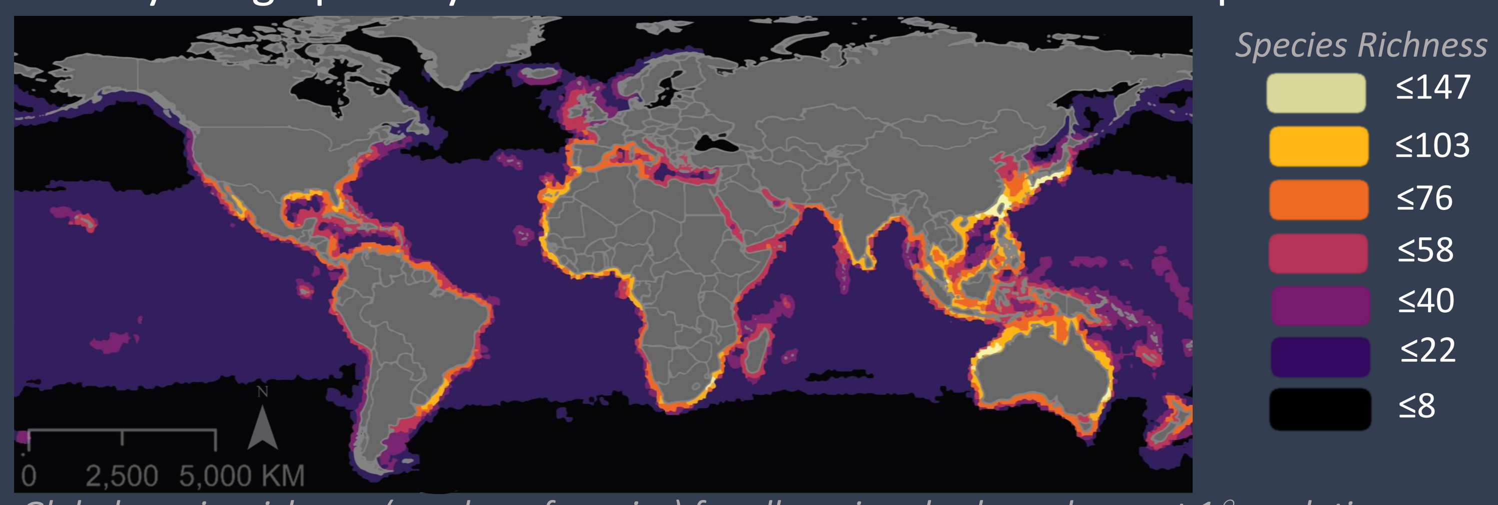


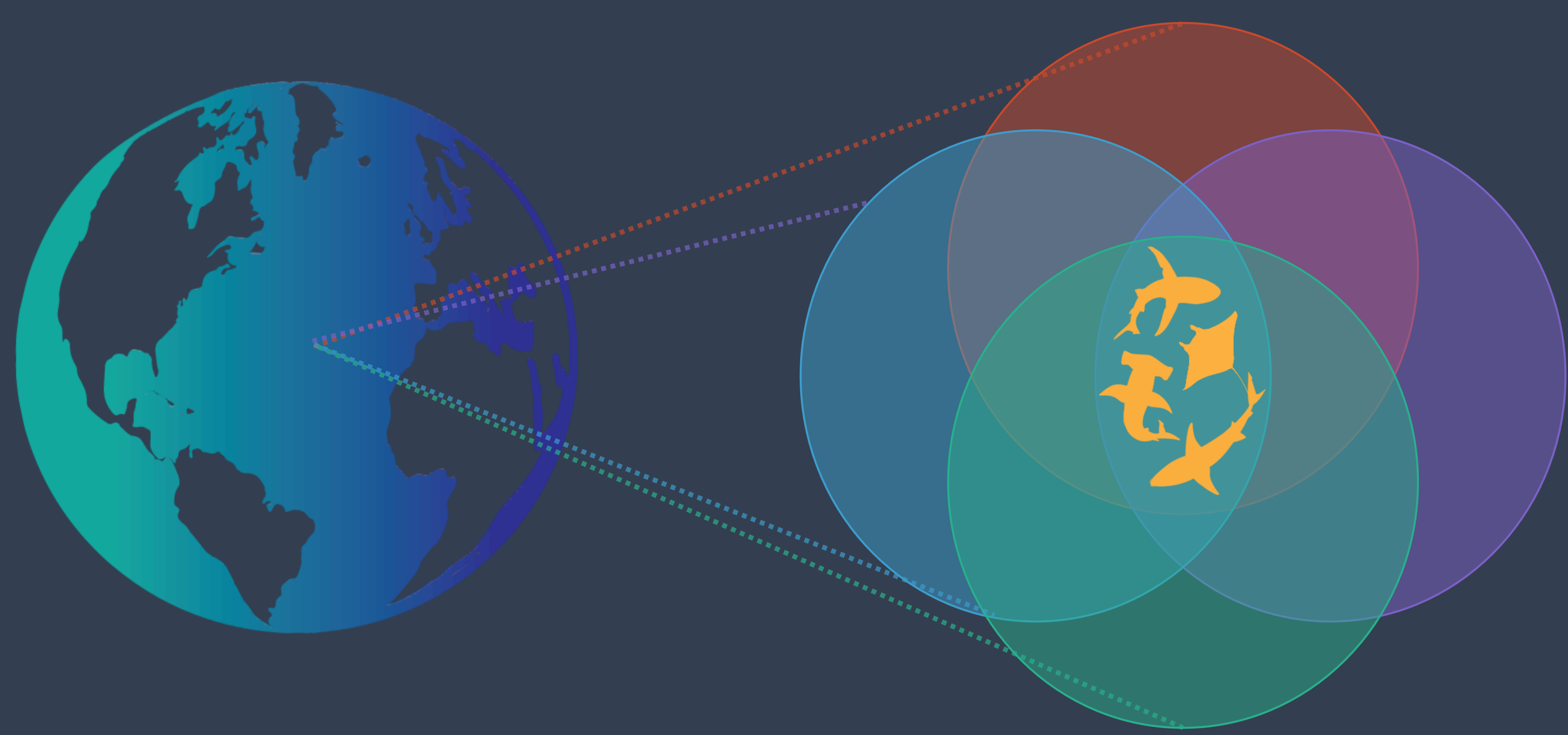
Fig 1. Global species richness (number of species) for all marine sharks and rays at 1° resolution.

One quarter of all sharks and rays are categorized as threatened by the IUCN$_2$ based on their body size and exposure to fisheries$_3$. They are among the most evolutionary distinct vertebrates, one of the most speciose marine predators, and have low population growth rates$_4$. These unique attributes make sharks and rays a good case study to understand how they're spatially distributed in the marine environment.

Objectives

(1) The majority of global prioritization of biodiversity is focused on conserving species rich areas to encapsulate the areas with highest number of species possible. Understanding whether those areas also harbor high numbers of endemics, threatened species or evolutionarily distinct species can help inform conservation efforts, especially in the marine realm where little has been fully understood.

(2) Furthermore, spatial resolution can change the way we interpret species distributions (ie. local vs. global) in the ocean environment.



If we can determine the locations where all four hotspots of biodiversity metrics overlap, then we can be better equipped to help inform conservation priorities for sharks and rays in the ocean.

Methods

Distribution maps for all marine sharks and rays (*n* = 1,083 species) were obtained from the International Union for the Conservation of Nature$_2$. All maps were calculated using a lambert equal area projection. Vector maps are overlain at a cell resolution of 1° by 1° at the equator. Species richness is calculated as the total number of unique species within each grid cell.

To classify threatened species richness, we considered the number of species within each grid cell that are listed as Vulnerable, Endangered, or Critically Endangered using the IUCN Red List Categories and Criteria$_1$ (*n* = 178 spp.). Endemic species richness is defined as the total number of species within each grid cell with range sizes below the median of total shark range sizes (419,659 km^2, *n* = 527 spp.) Finally, evolutionarily distinct species richness (ED) is defined as those species with the highest quartile of evolutionary distinctiveness scores (represented as age in millions of years, *n* = 264 spp.) and are recorded as the number of species per cell within that evolutionary distinct upper quartile.

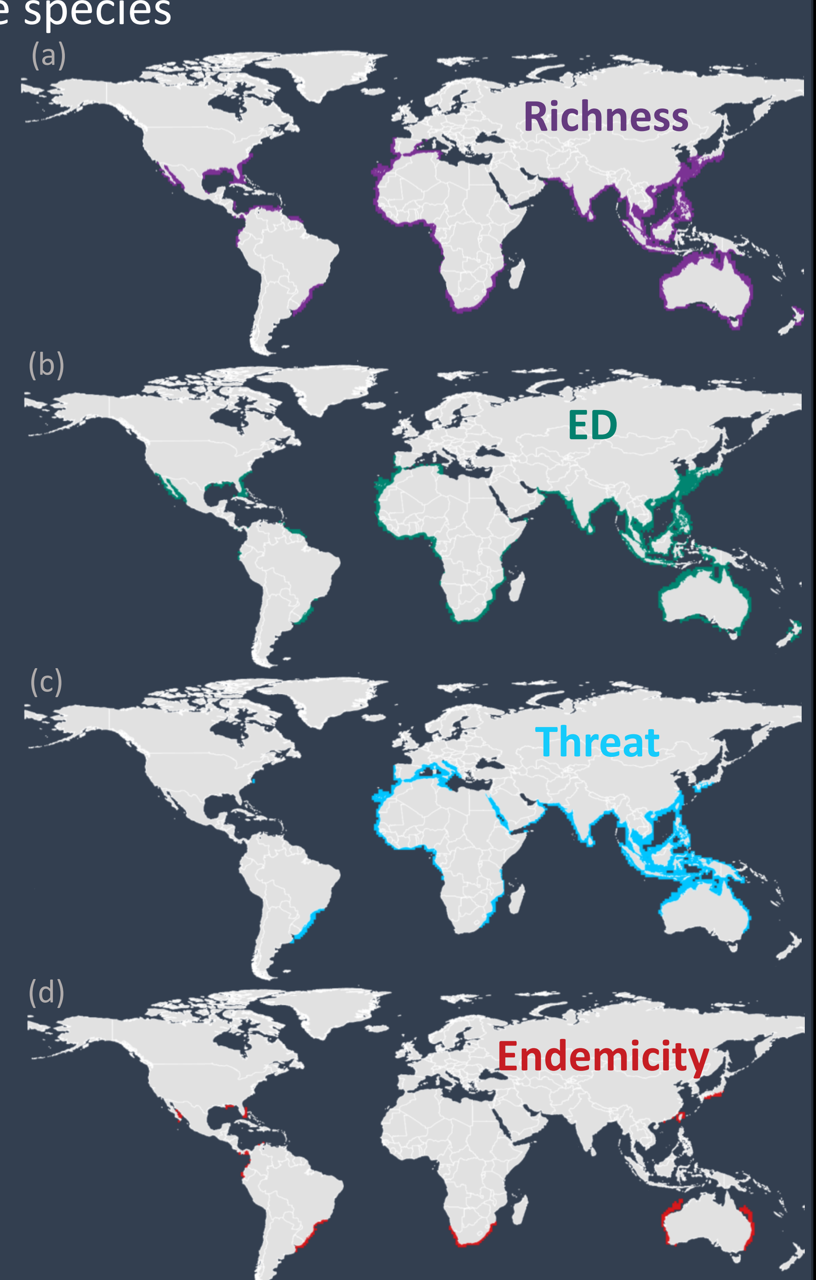


Fig 2. Distributional maps of the top 5% richest areas for the four biodiversity gradients (richness, ED, threat and endemicity) at 1° resolution.

Hotspots are defined as those containing the top 5% of richest cells for each of the biodiversity metrics. Using ArcGIS Pro 2.4.3 and R v.3.6.1, we tested for congruence between shark hotspots by measuring the extent of spatial overlap of four biodiversity metrics. Furthermore, we recalculated overlap under two more classifications of spatial resolution (4° and 8°) to explore how the spatial distribution of biodiversity and the level of congruency changes.

Results

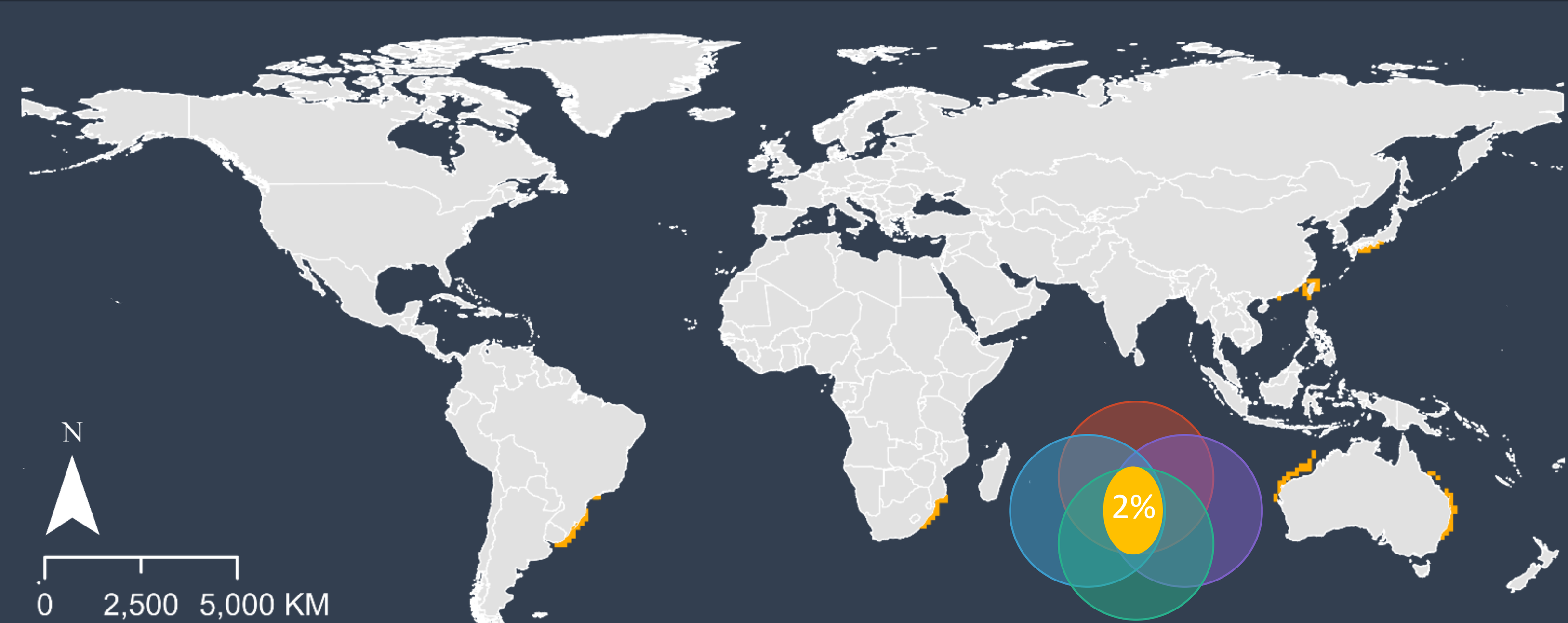


Fig 3. Areas of congruence between the four biodiversity metrics at 1° spatial resolution. Congruency is 2% of total area (46,344,248 km^2) covered by the biodiversity metrics.

In general, there was very low spatial congruence between the four shark biodiversity hotspots (richness, endemicity, threat and ED). Cumulatively, all four biodiversity hotspots at 1° resolution occupied an area of 46,344,248 km^2, of which only 2% (935,469 km^2) were congruent between all four metrics (Fig 3).

Congruency remained low even when spatial resolution decreased from 1° (2%, Fig 3), to 4° (4%; Fig 4A), and 8° (4%; Fig 4B). However, changing spatial resolution resulted in the areas of congruency shifting in location. For example, as spatial resolution decreased from a resolution of 1° towards 8°, the majority of overlap disappeared altogether from the coasts of Brazil/Uruguay, as well as the west coast of Australia, and became predominant surrounding Asia and South Africa (Fig 4).

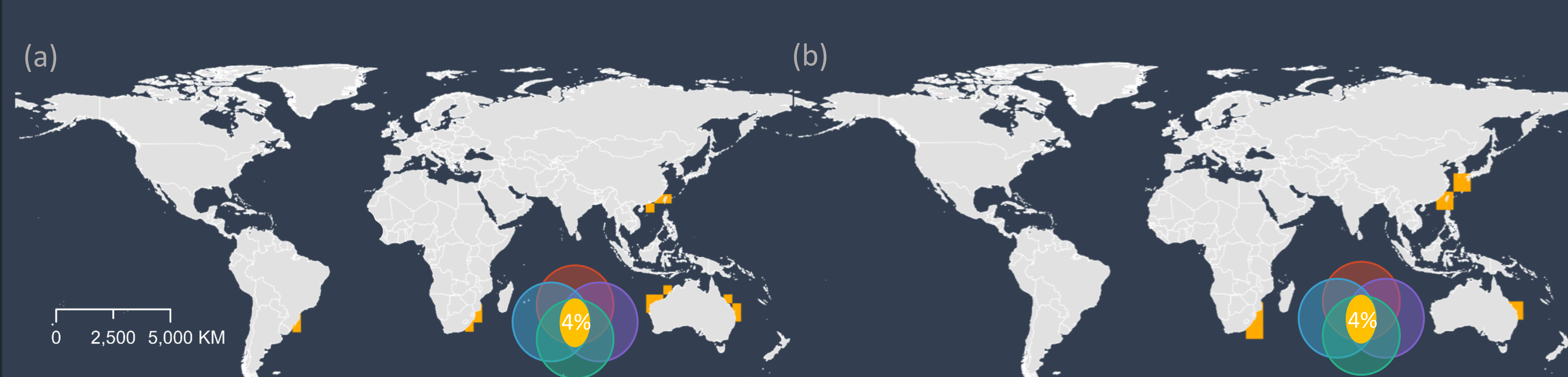


Fig 4. Areas of congruence between the four biodiversity metrics at (a) 4° resolution representing 2% overlap, and (b) 8° resolution having 3% overlap. Data are in Lambert equal area projection.

Conclusions

The novelty of this research underscores that while increasing spatial resolution inevitably captures greater congruency of biodiversity metrics, the extent at which this occurs remains relatively low and shifts geographic locations as resolution changes. Hence, focusing conservation efforts on species-rich areas are inadvertently overlooking other desirable dimensions of biodiversity, such as endemicity, threat and evolutionary distinctiveness. Therefore, these identified areas of congruency could provide a starting point for which management efforts could implement in their efforts for the conservation of shark and ray biodiversity.

(1) Lucifora LO, García VB, Menni RC, Worm B. Spatial patterns in the diversity of sharks, rays, and chimaeras (Chondrichthyes) in the Southwest Atlantic. Biodivers Conserv. 2012;21: 407–419. doi:10.1007/s10531-011-0189-7

(2) International Union for Conservation of Nature (IUCN). 2018. The IUCN Red List of Threatened Species. 2011.1. Available: http://www.iucnredlist.org

(3) Dulvy NK, Fowler SL, Musick JA, Cavanagh RD, Kyne PM, Harrison LR, et al. Extinction risk and conservation of the world's sharks and rays. Elife. 2014;2014: 1–34. doi:10.7554/eLife.00590.001

(4) Pardo SA, Kindsvater HK, Reynolds JD, Dulvy NK. Maximum intrinsic rate of population increase in sharks, rays, and chimaeras: The importance of survival to maturity. Can J Fish Aquat Sci. 2016;73: 1159–1163. doi:10.1139/cjfas-2016-0069