Aligning species range data to better serve science and conservation

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0.1 Abstract

Species distribution data provide the foundation for a wide range of ecological research and conservation science and management, yet most species ranges remain unknown, and existing range maps have little overlap. In the ocean, two global species distribution datasets - AquaMaps and the International Union for Conservation of Nature (IUCN) - dominate our understanding of marine species ranges throughout the world's oceans, representing 24,520 species overall, mostly from AquaMaps, with only 2,166 species overlapping. Here we examine differences in predicted species ranges between the two datasets, propose mechanistic causes and potential solutions for such differences, and explore the implications of these differences for management and conservation decisions. We find that IUCN maps often disregard bathymetry for depth-limited species, leading to predictions of species presence at unsuitable depths, and AquaMaps ranges for data-poor species often extrapolate presence far afield from known occurrences. We illustrate the implications of these differences by repeating two recent applications - the Ocean Health Index biodiversity goal and a global analysis of gaps in coverage of marine protected areas - and find significantly different estimates of the status of species diversity and effectiveness of conservation depending on which dataset was used. Understanding these issues points toward solutions for providers and users of these datasets.

0.2 Significance

subset of the abstract

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1 Introduction

Peer beneath the waves anywhere in the world - a moody kelp forest, a bustling coral reefscape, the frigid depths beneath a polar ice sheet, the endless blue of the open ocean - and you will find a unique ecosystem defined as much by which species are absent as by which species are abundant. Knowing where individuals of a species thrive is fundamental to the sciences of ecology, biogeography, and conservation, among many others. This knowledge provides foundational information for understanding species ranges and diversity, predicting species responses to human impacts and climate change, and managing and protecting species effectively. A rich literature tackles the many dimensions of these questions.

One major outcome of this body of science is the various compiled databases of species distribution maps. Two global-scale repositories predict marine species ranges throughout the world's oceans – AquaMaps modeled species distribution maps (Kaschner et al. 2013) and International Union for Conservation of Nature (IUCN) species range maps (REF). These two spatial datasets are used for a wide range of purposes, including assessing marine species status (Halpern et al. 2012, Selig et al. 2013), evaluating global biodiversity patterns (Coll et al. 2010, Martin et al. 2014), predicting range shifts (Molinos et al. 2015), and setting conservation priorities (Klein et al. 2015).

The two datasets ostensibly describe the same information, but significant differences in methodology and intent could lead to dramatically different understandings of our marine ecosystems, with significant implications for policy and conservation recommendations. Importantly, biases in taxonomic or spatial coverage within a dataset could shift management and conservation actions away from places or species that are most in need. Inaccurate indications of presence or absence could lead to ineffective marine reserve systems and management plans (Rondinini et al. 2006) (Jetz 2008?).

To understand the implications of differences between the AquaMaps and IUCN datasets, we compared how each data source represents the global spatial and taxonomic distribution of species. Most notably, AquaMaps includes range maps for many more species (currently 22,889; 93.3% of total), such that most global analyses related to biodiversity to date have used AquaMaps (IUCN range map data exist for only 4,138 species). For the 2,166 (8.8% of total) species mapped in both datasets, we examined how well the maps align and determined several issues that lead to misalignment between predicted species distributions, and outline possible improvements.

We then subjected two recent marine biodiversity studies - an assessment of the status of global biodiversity within the Ocean Health Index (Halpern et al. 2012, 2015) and a global analysis of gaps in protection afforded by marine protected areas (MPAs) (Klein et al. 2015) - to a sensitivity analysis. … ***substituting*** one dataset over the other, to highlight the possible consequences of different data use decisions on our understanding of *the status of* marine biodiversity. ***BSH suggestion: We used all unique species range data from both sources but substituted one dataset over the other for shared species to highlight the possible consequences of different data use decisions on our understanding of the status of and protection of marine biodiversity.***

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2 Results and Discussion

2.1 How and why the datasets differ

The IUCN publishes species range maps as polygon shapefiles, bundled by taxonomic groups (REF). Using a geographic information system (GIS), experts outline spatial polygons to represent a given species' "limits of distribution" (IUCN 2014) - essentially a refined extent of occurrence, based on observation records and refined by expert understanding of the species' range and habitat preferences. AquaMaps models species distribution maps based environmental preferences (e.g. temperature, depth, salinity) deduced from occurrence records, published species databases such as FishBase, and expert knowledge. The AquaMaps model overlays these environmental preferences atop a map of environmental attributes on a 0.5 degree grid, creating a global raster of probability of occurrence for each species (AquaMaps 2013)

The methodologies behind these datasets imply differences in prediction of species distribution due to errors of commission (falsely indicating species presence) and omission (falsely indicating species absence). Geographic range data such as IUCN range maps generally include large commission errors, while predicted distribution models such as AquaMaps will likely include fewer commission errors but more omission errors. Each type of error bears different implications for conservation goals (Rondinini, 2006).

The two datasets have notably different taxonomic (Fig. 1A) and regional (Fig. 1B,C) coverage. IUCN-mapped species focus on tropical latitudes and away from the Atlantic and Eastern Pacific compared to AquaMaps-mapped species. These differences can be mitigated by using both datasets, but the underlying methodological differences complicate such direct comparisons, and furthermore ***requires resolving differences (or choosing one source over the other) for the 2,166 shared species.***

To explore differences in species distribution and range between the two datasets, we plotted the distribution alignment (where on the map) against the ratio of extent (how much of the map) for each shared species (Fig. 2a).

Dividing the map-paired species into quadrants highlights different categories of relationships. The upper right quadrant includes species (n = 401) whose map pairs agree in both spatial distribution and extent of described ranges. These species tend to be well-studied and predominantly fall within wide-ranging pelagic organisms such as marine mammals, tunas, and billfishes (Fig. 2B). This result is not surprising, as species with very large ranges are likely to be more aligned regardless of methodology simply because they exist nearly everywhere.

The extent-mismatched maps contained in the upper left quadrant (n = 682) provide a richer set of examples to understand the fundamental differences between the datasets. For many of these species, while the spatial distribution is similar, the IUCN range predicts a significant buffer zone beyond the AquaMaps range. Corals dominate this quadrant (294; 43.1% of all species in this quadrant). Most corals and reef-associated organisms prefer shallower waters, and we suspect that many of these disagreements in extent can be explained by bathymetry: seafloor depth is explicitly included in AquaMaps models, while depth is frequently ignored as a factor in IUCN range maps, leading to overprediction of species range into areas too deep to support the species. (For examples and details, see SOM)

The differences in extent of species maps found in the lower right quadrant (n = 682) can in many cases be attributed to "two wrongs make a right." For these species, IUCN ranges frequently overextend into unsuitable depths, as in the case of many upper left quadrant species, while at the same time AquaMaps ranges often aggressively extrapolate presence into locations where IUCN predicts absence. This results in an area ratio close to 100%, but similar extents are meaningless when the distributions are poorly aligned.

Moving from the lower right to lower left quadrant, AquaMaps more frequently extrapolates species presence well beyond known occurrences, resulting in poor matches in both distribution and extent. Of the 401 species in this quadrant, 159 (39.7%) are data-poor (in which the AquaMaps environmental envelope model is based on fewer than 10 known cell occurrences), compared with 21.1% for the full set of map-paired species and only 8.2% of species in the upper left quadrant. A mere 6.2% of AquaMaps maps in this quadrant have undergone expert review, compared with 13.4% of all map-paired species and 24.9% of species in the upper left quadrant.

This breakdown by quadrant helps explain the negative linear relationship seen in the plot, in which increasing similarity in extent correlates with decreasing distribution alignment. Expanding species range beyond known occurrences, the marginal range predicted by the AquaMaps model will fall in different locations than the marginal range predicted using IUCN methodology. For species with dissimilar extents, predicted distribution for the smaller range can more easily fall within the generous bounds of the larger range. As we examine species with increasingly similar extents, the differences in methodology become more difficult to "hide," and the distribution alignment generally becomes poorer.

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3 Implications of the differences

From JSL: *I think you need a broader discussion of implications. How many times has IUCN/Aquamaps been cited? How long have they been around? What scales are the studies? Then you can muse about how results/interpretations would be different depending on which dataset they used, and reference Fig 3's.*

Then, say for example, the OHI uses these datasets together (don't need to get too much into OHI background I think, maybe they don't even need to know about the biodiversity goal?), but say that to try to combine them they use a threshold at 40% since others use this threshold (but check out the SOM for analyses about thresholds)

3.1 Application to OHI

The global Ocean Health Index (OHI) (Halpern et al. 2012, 2015), a composite index made up of 10 sustainable benefits provided by a healthy ocean, uses species spatial distribution data and IUCN Red List conservation status to calculate biodiversity status (scored from zero to 100) for each of the world's 221 exclusive economic zones. To maximize the number of represented species, OHI gleans spatial distributions from both IUCN and AquaMaps datasets, prioritizing IUCN data for the subset of species in both sources. OHI uses a probability threshold of 40% to determine species presence for AquaMaps data.

We recalculated the OHI species status score under several scenarios to observe the impact of toggling the prioritized data set from IUCN to AquaMaps, and toggling the AquaMaps presence threshold from 40% to 0% (Figure 3). Most country scores varied by fewer than five points across the three scenarios; a few country scores decreased by as many as 12 points, indicating a more dire assessment of species conservation status.

Since the Ocean Health Index Species subgoal relies on spatial data from both datasets, the impacts of these threshold and preference changes will be somewhat muted. When IUCN range maps are the preferred data source, only the subset of AquaMaps-only species will be affected by threshold changes; and when AquaMaps is the preferred source, the IUCN-only species will dampen the effect of a threshold change.

3.2 Application to MPA Gap Analysis

Klein et al. (2015) compared the global distribution of species to the global distribution of marine protected areas to assess how well the MPAs protect key species, and to identify which species fall through the gaps in protection. The MPA gap analysis relied on the AquaMaps database available in early 2015, comprising distribution maps for XXX species. Species presence was defined using a probability threshold of 50% or greater. The study defined four subsets of protected areas using the World Database of Protected Areas, based upon combinations of IUCN protected area classification, marine designation, and spatial marine coverage. The study determined that currently defined marine protected areas (IUCN categories I through IV overlapping with marine areas) are woefully inadequate in protecting marine biodiversity; 90.5% of species have less than 5% of their overall range represented within marine protected areas.

working on the analysis...

Predictions: What happens when using a 0% threshold instead of a 50%? What happens when using IUCN rather than AM? IUCN tends to overestimate extent esp for coastal species? More species will be included in MPAs so fewer apparent gap species. Included range area inside MPAs will increase. Policy implications?

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4 Conclusions: What can be done to address the differences

Understanding the causes and implications of the differences between these two important datasets can help us better align the predictions of species distributions, increasing their utility for conservation goals.

Suggestions for data providers:

- The training manual for experts creating IUCN Red List maps for marine species suggests that "bathymetry can be used to delineate species' ranges limited by depth in the same way as elevation is used for terrestrial species" (REF https://www.conservationtraining.org/mod/scorm/player.php?a=1412&currentorg=M5L1_ORG&scoid=6492). Unfortunately, this recommendation appears to be applied haphazardly. Especially for demersal communities dependent on photosynthesis, bathymetry should be a primary consideration; even a simple cutoff at the photosynthetic limit of 200 meters would improve the utility of species range maps.

- The AquaMaps model is a powerful tool for quickly estimating species distribution based on limited information; however, the model's output is only as good as the input data, which for marine species is often sorely limited. AquaMaps encourages experts to review and comment on the predicted species distribution maps; lessons from the small sample of reviewed maps can be generalized, for example to other species in the same taxonomic group, to further refine the predictions, especially for data-poor species.
- In addition to environmental preferences and conditions, AquaMaps mapping parameters include area restrictions to help limit over-extrapolation of AquaMaps models. Currently the area restrictions are denoted by FAO Major Fishing Areas (REF find a reference in AquaMaps somewhere); however, allowing area restrictions based on biogeographical criteria, a la Marine Ecoregions of the World (), would likely have better resolution and predictive power, especially for data-poor species.

Suggestions for data users:

- understand that range maps a la IUCN tend to overestimate presence; AquaMaps are less likely to overestimate presence, but trade off for overestimating absence. Both better than simple point locality data. (Rondinini etc)
- Using both datasets together can increase the taxonomic and spatial breadth of coverage, as long as the differences between the datasets can be reasonably minimized. Consider:
  - An AquaMaps presence threshold of 0% more closely approximates the "limits of distribution" outlined by IUCN range maps.
  - Additional filters and criteria on AquaMaps distribution maps can help avoid overextrapolation for data poor species. The AquaMaps native range dataset includes information on expert review and the number of occurrence cells used to generate the environmental envelope.
  - For depth-limited species or taxa, clipping IUCN range polygons to a reasonable bathymetry contour can limit overprediction of species presence into unsuitable habitats.

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5 Methods

5.0.1 comparison of taxonomic and regional distribution

To examine the overall taxonomic distribution across the spatial datasets (Fig. 1a), we grouped species by taxonomic class and data source (IUCN, AquaMaps, or both), and examined the proportion of each class represented in each data source category.

To compare the spatial representation of the two datasets directly, we rasterized the IUCN species polygons to the same 0.5° grid as the AquaMaps species maps; species presence within a grid cell was determined by any non-zero overlap of a species polygon with the cell, and species richness per cell was simply the count of the species present. For the AquaMaps dataset, we determined per-cell species richness by counting all species with non-zero probability of occurrence, to best approximate the "extent of occurrence" generally indicated by IUCN maps. We represented relative distribution of species richness for each dataset by plotting average species count against latitude and longitude (Fig. 1b, 1c).

5.0.2 comparison of paired maps

Using genus and species binomials as a matching key, we selected the subset of marine species that have range maps in both IUCN and AquaMaps current native distribution. To avoid double-counting, we removed subpopulations and species aliases. We determined species presence within each spatial cell using the same criteria as outlined above.

Overlaying paired distribution maps for a given species, we defined and calculated *distribution alignment* and *extent alignment* and plotted these in Fig. 2:

$$\alpha_{dist} = \frac{A_{small \cap large}}{A_{large}} * 100\%$$

$$\alpha_{area} = \frac{A_{small}}{A_{large}} * 100\%$$

We visually inspected a random selection of paired distribution maps from each quadrant to identify possible mechanistic causes of misalignment. To verify that IUCN predicted unsuitable habitat for depth limited species, we used QGIS (REF) to overlay a selection of IUCN and AquaMaps maps with a 200 meter bathymetry contour.

5.0.3 Methods for OHI comparison

Using methods and supplemental materials from OHI (Halpern et al. 2012, 2015), we modified the original code for OHI 2015 Species status (SPP) (REF), allowing for flexibility in prioritized data source and AquaMaps presence threshold. We ran the SPP code three times, prioritizing IUCN over AquaMaps for a 0% threshold, and prioritizing AquaMaps over IUCN for both a 40% and 0% threshold. We compared each of these to the output of the published OHI 2015 SPP model (prioritizing IUCN over AquaMaps at a 40% threshold).

5.0.4 Methods for MPA Gap Analysis comparison

Based upon the methods described in Klein et al. 2015, we reconstructed the analysis using the subset of protected areas spatially covering a marine area and classified as IUCN I-IV ***(Klein paper, table 1, subset 4 - seems to be the one they focus on the most)***, converting the World Database of Protected Areas (WDPA, REF) dataset to a raster of 0.5° cells indicating proportion of protected area within the cell ***(consider also: filter on STATUS == 'Designated', and filter out those pesky fishery management areas and manatee speed zones. . .)***. To verify our reconstruction we ran the analysis using the AquaMaps dataset available in April 2015 (REF) at a presence threshold of 50%. We then updated the analysis using the most recent AquaMaps dataset (REF?) at 50% threshold

- Possible analyses:
  - run AquaMaps (new data) with threshold at 0%
    - already done in original paper, but redo it to compare to AM + IUCN scenario below
  - run with AquaMaps only, but filtering out data-poor species?
  - run with IUCN maps only in place of AquaMaps?
  - run with AquaMaps and IUCN both, using 0% threshold; which preferred?
    - Should we clip corals (and coral-associated taxa) to 200 meter bathymetry, just for fun?
- Which aspects of the analysis should we focus on?:
  - overall vs broken down by taxonomic groups? (see paper, figure 1)
  - spatial distribution of gap species (see paper, figure 2)

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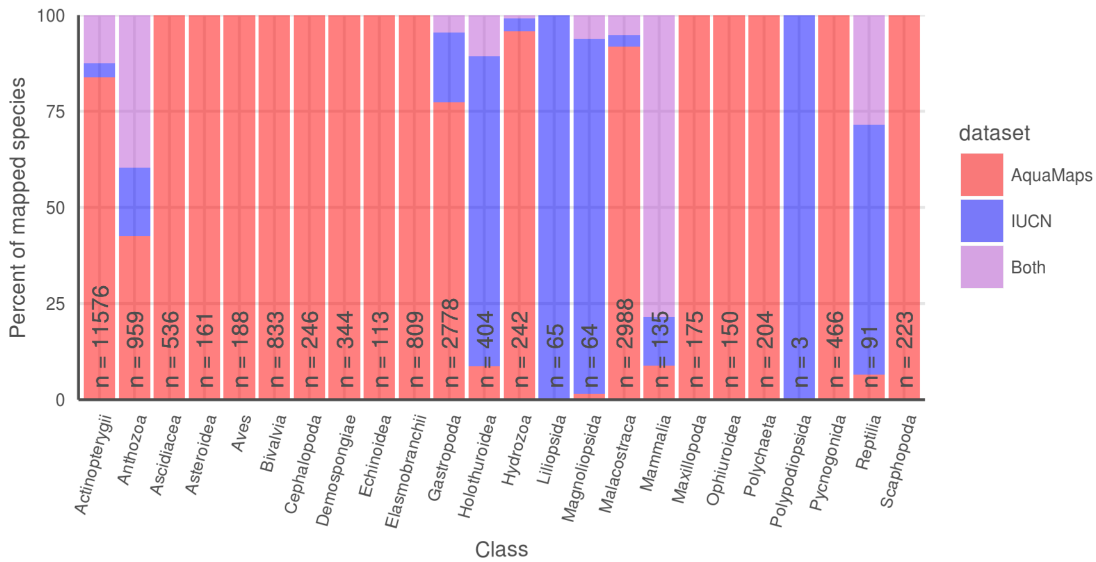
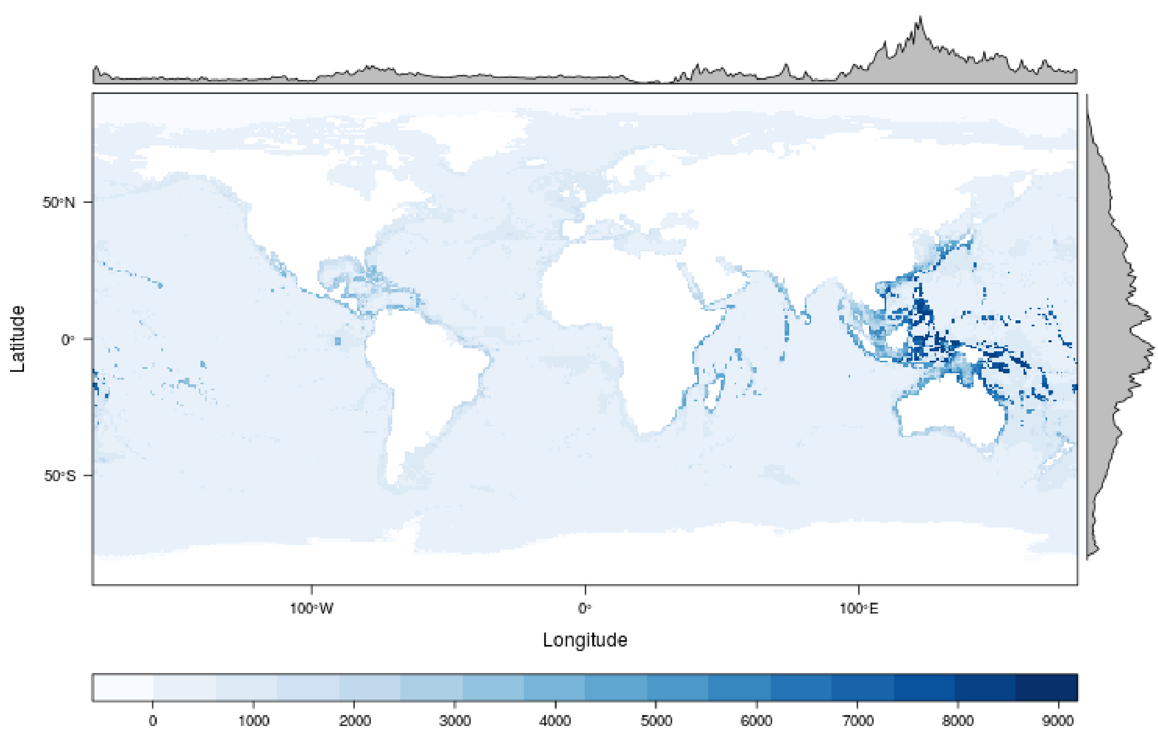
6 Figures

6.0.5 Figure 1



Percent of mapped species
100
75
50
25
0
n = 11576
n = 959
n = 536
n = 161
n = 188
n = 833
n = 246
n = 344
n = 113
n = 809
n = 2778
n = 404
n = 242
n = 65
n = 64
n = 2988
n = 135
n = 175
n = 150
n = 204
n = 3
n = 466
n = 91
n = 223
Actinopterygii
Anthozoa
Ascidiacea
Asteroidea
Aves
Bivalvia
Cephalopoda
Demospongiae
Echinoidea
Elasmobranchii
Gastropoda
Holothuroidea
Hydrozoa
Liliopsida
Magnoliopsida
Malacostraca
Mammalia
Maxillopoda
Ophiuroidea
Polychaeta
Polypodiopsida
Pycnogonida
Reptilia
Scaphopoda
Class
dataset
AquaMaps
IUCN
Both



Latitude
50°N
0°
50°S
100°W
0°
100°E
Longitude
0
1000
2000
3000
4000
5000
6000
7000
8000
9000

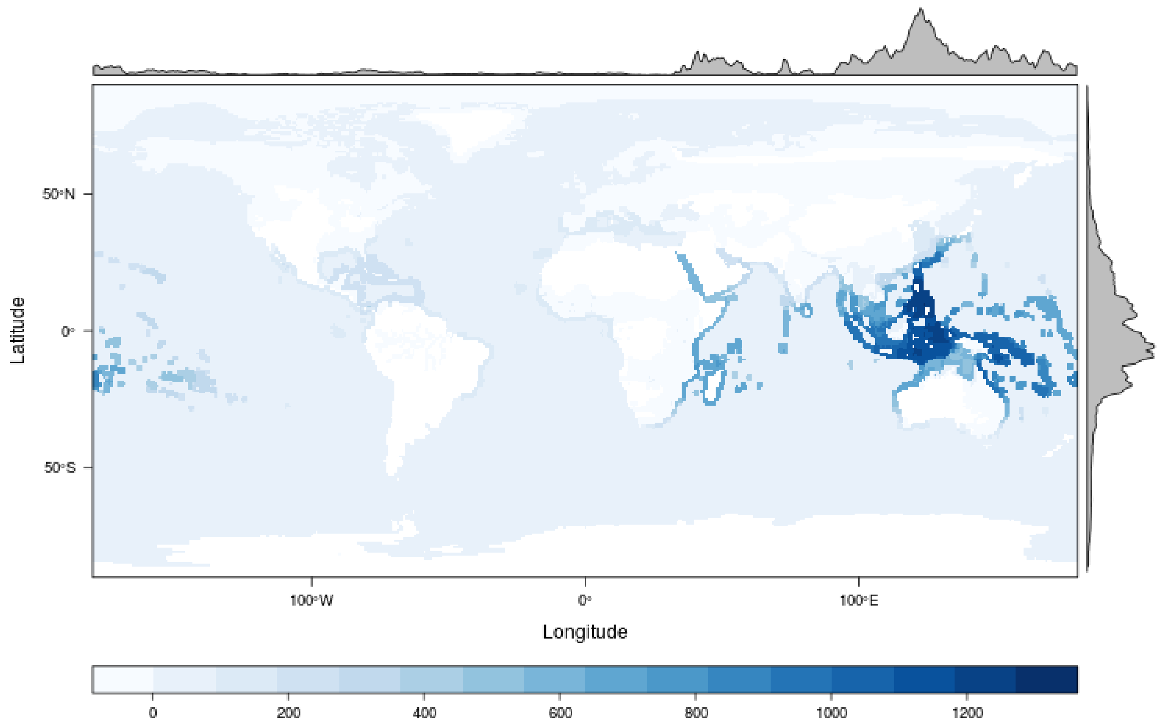


Figure 1(a): Number and proportion of species, listed by taxa, included in each dataset: IUCN, AquaMaps, or both. AquaMaps encompasses a broader range of taxa than IUCN, while IUCN focuses on comprehensively assessing select taxonomic groups, typically at the level of order or family. Overlapping species are dominated by bony fishes (1304 species, primarily tropical taxa) and corals (505 species).

Figure 1 (b, c): Global marine species richness according to (b) AquaMaps dataset and (c) IUCN dataset. The frequency plot to the right of each map shows relative species count per cell at each latitude; while both datasets peak in tropical latitudes near the equator, the frequency for IUCN maps drops quickly beyond 30°N and 30°S, while the frequency for AquaMaps remains robust well into temperate latitudes. The frequency plot above each map shows relative species count at each longitude, showing a slight bias in the IUCN dataset away from the Atlantic and eastern Pacific compared to AquaMaps.

6.0.6 Figure 2

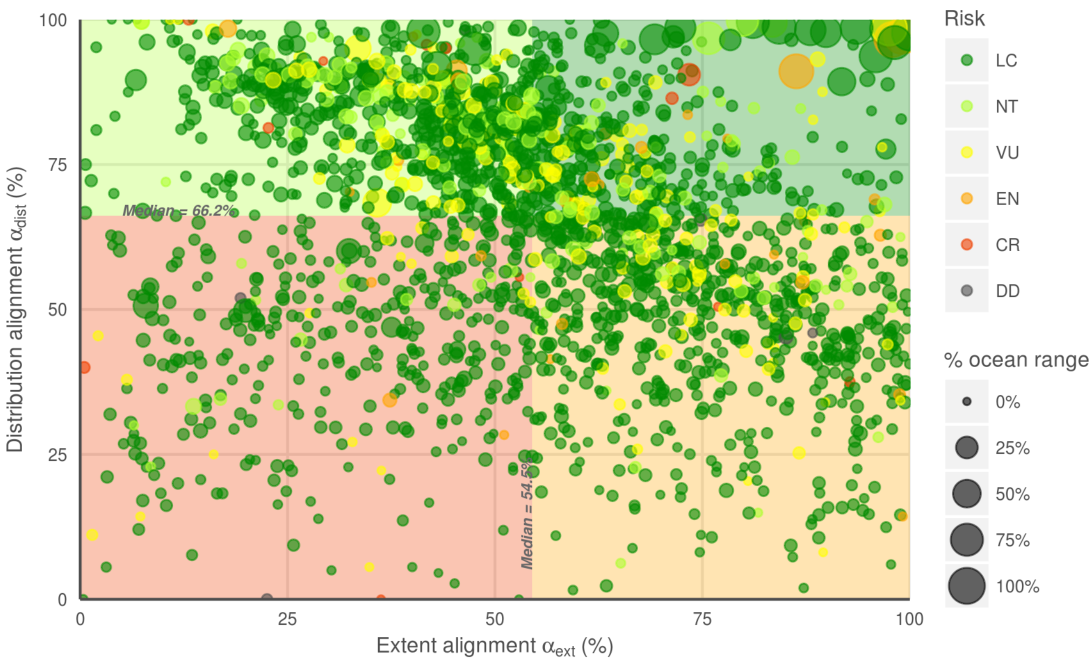


Figure 2 (a):

The upper right quadrant (quadrant 1) comprises species whose maps largely agree (better than median value) in both spatial distribution and the extent of described ranges (n = 400; 18.5 %). The upper left quadrant (quadrant 2) comprises species whose maps agree well in distribution, but disagree in extent (n = 684; 31.6 %). The lower right quadrant (quadrant 3) includes species for which the paired maps generally agree in range extent, but disagree on where those ranges occur (n = 681; 31.4 %). The lower left quadrant (quadrant 4) indicates species for which the map pairs agree poorly in both area and distribution (n = 401; 18.5 %).

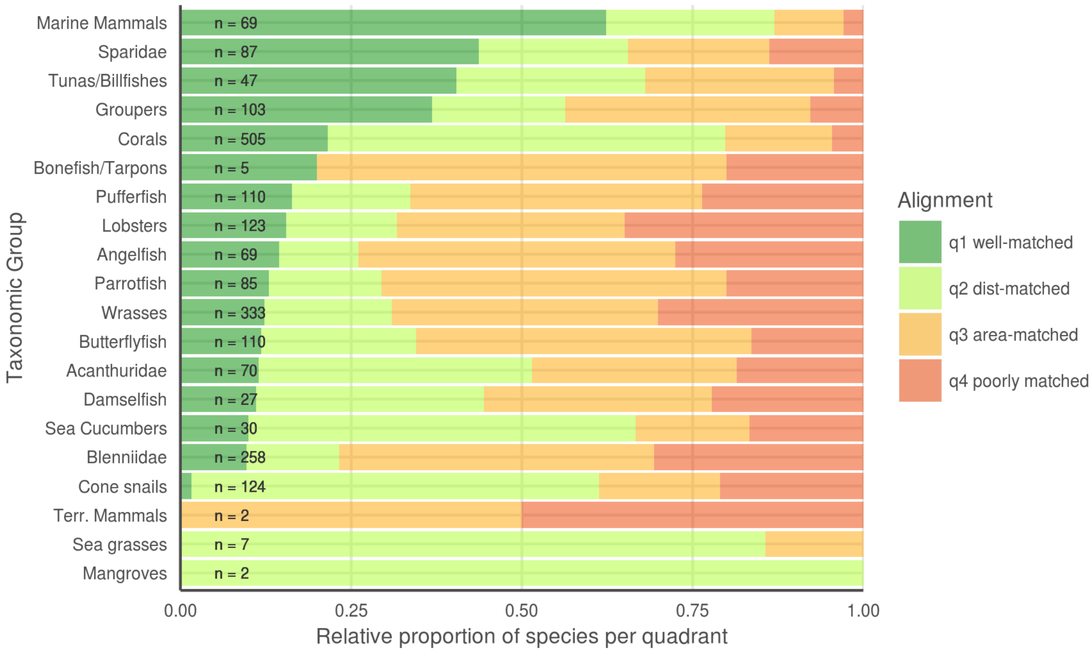
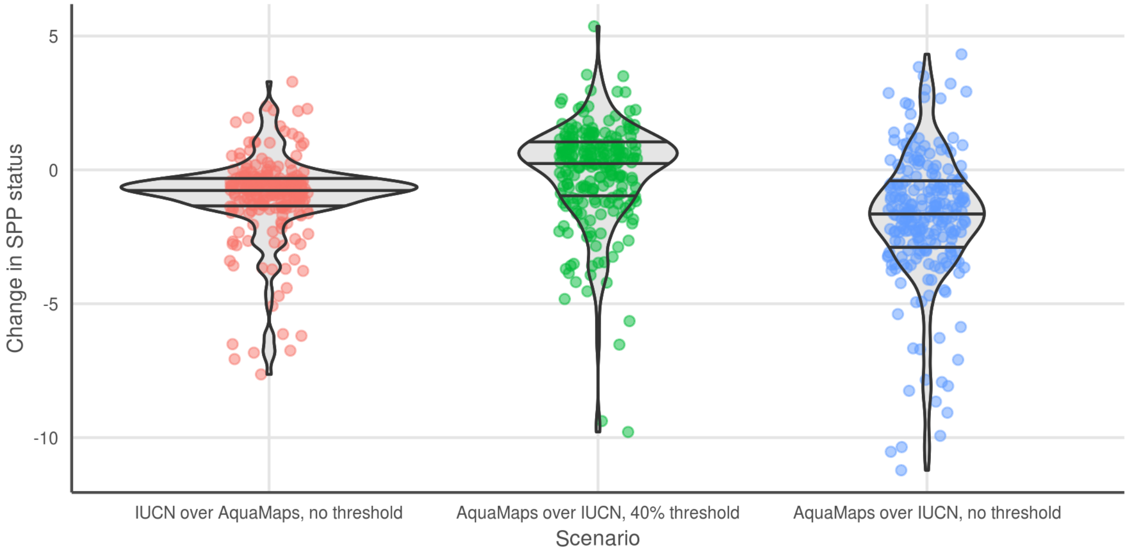


Figure 2 (b): Spatial alignment of paired-map species by taxonomic group. ***REDO with all corals grouped together!*** *Also - is it distracting to use order names for some groups and not others? Some of the groups had pretty long names ("acanthuridae" is way shorter than "surgeonfish, tangs, and unicornfish")*

6.0.7 Figure 3



NOTE: These figures still need to be recreated using the latest and greatest data! *currently they use data generated in November or so, in ohiprep.*

Figure 3: Change in status score for the Species Subgoal within the global Ocean Health Index under three different scenarios.

Scenario	Priority data source	AquaMaps presence threshold
Scenario 0 (current)	IUCN	>= 40%
Scenario 1	IUCN	> 0%
Scenario 2	AquaMaps	>= 40%
Scenario 3	AquaMaps	> 0%

- Scenario 1 shows the effect of reducing the presence threshold for AquaMaps presence. Reducing the threshold increases the apparent range of a species; the slight decrease in average score suggests increased spatial representation of threatened species.
- Scenario 2 shows the effect of prioritizing AquaMaps data over IUCN, while maintaining the same presence threshold. This will have different effects depending on the species; in general, AquaMaps ranges are smaller than IUCN ranges, so most overlapping species will see a decrease in represented range. The slight bump in mean score may indicate a small increase in spatial representation of low-risk species, a small decrease in spatial representation of high-risk species, or more likely a combination of both.
- Scenario 3 shows the effect of prioritizing AquaMaps data over IUCN, while eliminating the presence threshold. Just as a presence threshold of zero in scenario 1 drives a decrease in average score relative to the baseline, the zero threshold in scenario 3 drives a decrease in scores relative to scenario 2. The large decrease indicates that within the set of paired-map species, a zero threshold greatly increases the spatial representation of high-risk species relative to low-risk species.

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7 References

Key AquaMaps publications:

Kaschner, K., R. Watson, A. W. Trites, D. Pauly (2006). Mapping world-wide distributions of marine mammal species using a relative environmental suitability (RES) model. Marine Ecology Progress Series 316: 285–310. *check this citation journal name... This outlines the basic RES methodology - AM development*

Kaschner, K., D.P. Tittensor, J. Ready, T Gerrodette and B. Worm (2011). Current and Future Patterns of Global Marine Mammal Biodiversity. PLoS ONE 6(5): e19653. PDF *just what the title says - AM development, presence threshold 60%, also analyzes richness as a function of threshold*

Ready, J., K. Kaschner, A.B. South, P.D Eastwood, T. Rees, J. Rius, E. Agbayani, S. Kullander and R. Froese (2010). Predicting the distributions of marine organisms at the global scale. Ecological Modelling 221(3): 467-478. PDF *Presents AM; assessing AquaMaps against other presence-only species models*

Papers based on AquaMaps:

Jones, M.C., S.R. Dyeb, J.K. Pinnegar and W.W.L. Cheung (2012). Modelling commercial fish distributions: Prediction and assessment using different approaches. Ecological Modelling 225(2012): 133-145. PDF *comparison of species distribution models including AquaMaps, Maxent and the Sea Around Us Project*

Coll, M., C. Piroddi, J. Steenbeek, K. Kaschner, F. Ben Rais Lasram et al. (2010). The biodiversity of the Mediterranean Sea: estimates, patterns, and threats. PLoS ONE 5(8): e11842. PDF *used AquaMaps to predict Med biodiversity. Also: Threshold = 0.*

Martin C.S., Fletcher R., Jones M.C., Kaschner K., Sullivan E., Tittensor D.P., Mcowen C., Geffert J.L., van Bochove J.W., Thomas H., Blyth S., Ravillious C., Tolley M., Stanwell-Smith D. (2014). Manual of marine and coastal datasets of biodiversity importance. May 2014 release. Cambridge (UK): UNEP World Conservation Monitoring Centre. 28 pp. (+ 4 annexes totalling 174 pp. and one e-supplement). PDF *report on marine data sets and data gaps etc, incl both IUCN and AM*

Hurlbert 2007 Species richness, hotspots, and the scale dependence of range maps in ecology and conservation. _mostly rasters of range maps? "The scale dependence of range-map accuracy poses clear limitations on braod-scale ecological analyses and conservation assessments. … we provide guidance about the approriate scale of their use_

Jetz 2008 Ecological Correlates and Conservation Implications of Overestimating Species Geographic Ranges *EOO maps are usually highly interpolated and overestimate small-scale occurrence, which may bias research outcomes*

Pimm 2014 The biodiversity of species and their rates of extinction, distribtuion, and protection. *uses range maps to show biodiversity areas; may use IUCN range maps. Also discusses gaps and possible things that can be done about them.*

Rondinini 2006 Tradeoffs of different types of species occurrence data for use in systematic conservation planning *compares point locality, range maps, and distribution models in terms of omission and commission errors; also outlines Extent of Occurrence and Area of Occupancy distinctions.*

García Molinos, Jorge, Benjamin S. Halpern, David S. Schoeman, Christopher J. Brown, Wolfgang Kiessling, Pippa J. Moore, John M. Pandolfi, Elvira S. Poloczanska, Anthony J. Richardson, and Michael T. Burrows. "Climate Velocity and the Future Global Redistribution of Marine Biodiversity." Nature Climate Change advance online publication (August 31, 2015). doi:10.1038/nclimate2769.

Halpern, Benjamin S., Catherine Longo, Darren Hardy, Karen L. McLeod, Jameal F. Samhouri, Steven K. Katona, Kristin Kleisner, et al. "An Index to Assess the Health and Benefits of the Global Ocean." Nature 488, no. 7413 (August 30, 2012): 615–20. doi:10.1038/nature11397.

Klein, Carissa J., Christopher J. Brown, Benjamin S. Halpern, Daniel B. Segan, Jennifer McGowan, Maria Beger, and James E.M. Watson. "Shortfalls in the Global Protected Area Network at Representing Marine Biodiversity." Scientific Reports 5 (December 3, 2015): 17539. doi:10.1038/srep17539.

Selig, Elizabeth R., Catherine Longo, Benjamin S. Halpern, Benjamin D. Best, Darren Hardy, Cristiane T. Elfes, Courtney Scarborough, Kristin M. Kleisner, and Steven K. Katona. "Assessing Global Marine Biodiversity Status within a Coupled Socio-Ecological Perspective." PLoS ONE 8, no. 4 (April 11, 2013): e60284. doi:10.1371/journal.pone.0060284.

- IUCN reference:
  - https://www.conservationtraining.org/course/view.php?id=217&lang=en
  - http://www.iucnredlist.org/technical-documents/red-list-training/iucnspatialresources
  - IUCN Red List - accessed 12/21/2015
- AquaMaps reference, and accessed date?

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8 Supplemental Information

8.1 Info on data prep

8.1.1 processing AquaMaps

- start with .sql files - three of 'em - how to get 'em?
- turn into .csvs, which columns are critical for this analysis? simplify

8.1.2 downloading and processing IUCN maps

- which data sets are included?
- raster::extract() to convert polys to csvs
- which columns are included?

8.1.3 creating master species list for co-listed species

- using AquaMaps and IUCN, and IUCN master list, create the big list
- which columns are included?
- adjust this master list to use IUCN SID only for parent - eliminate the whole question of parent/subpop? for the purpose of this analysis

8.2 descriptions of IUCN and AM data sets

IUCN: While the polygons roughly define regions of presence/absence, additional attributes provide information on extant/extinct ranges, native/introduced ranges, and seasonality.

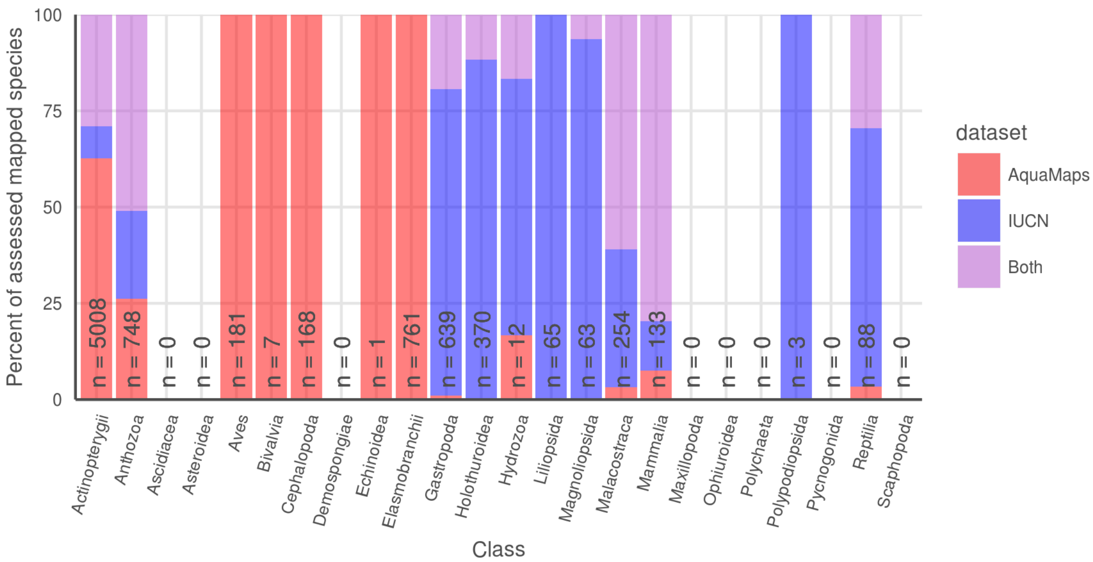
As of December 2015, IUCN had published species distribution maps for 4138 marine species across 24 taxonomic groups. For this analysis, we did not consider IUCN range maps for bird species, as those data are hosted separately by BirdLife International.

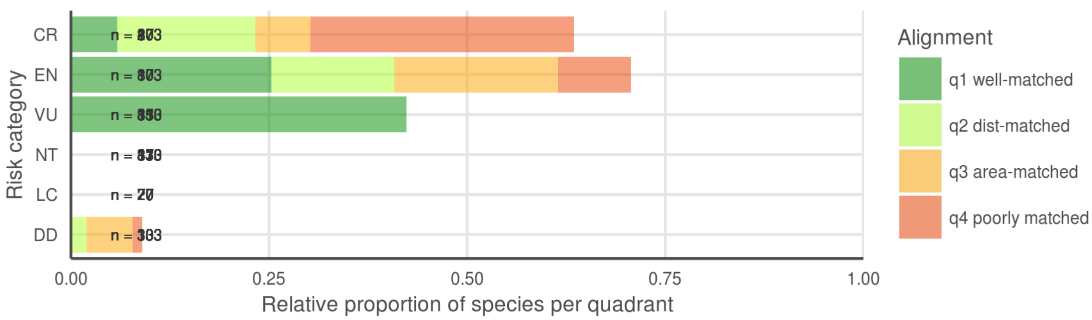
As of December 2015, AquaMaps current native distribution maps have been produced for 22889 species.

Move to supplementary materials. - BH: For example, as of this writing, IUCN has released no spatial data for class Elasmobranchii (cartilaginous fishes including sharks and rays); and while IUCN offers a large number of maps within class Actinopterygii (ray-finned bony fishes), the available maps include only a few primarily tropical taxonomic sub-groups, such as wrasses, damselfish, butterflyfish, tunas, and billfishes, but are missing economically important subgroups including salmon, rockfish, and clupeids. However, IUCN's criterion of comprehensive assessment greatly reduces the risk of sample bias within the bounds of the assessed taxonomic groups.

Probably just cut, but maybe include in Suppl Materials. - BH: The release of AquaMaps distribution maps is not limited to comprehensively-assessed taxa, and maps are available across a much larger range of taxonomic classes; however, there is no guarantee that the list of species included within each class is a representative cross section of the entire class.

Red List inclusion:



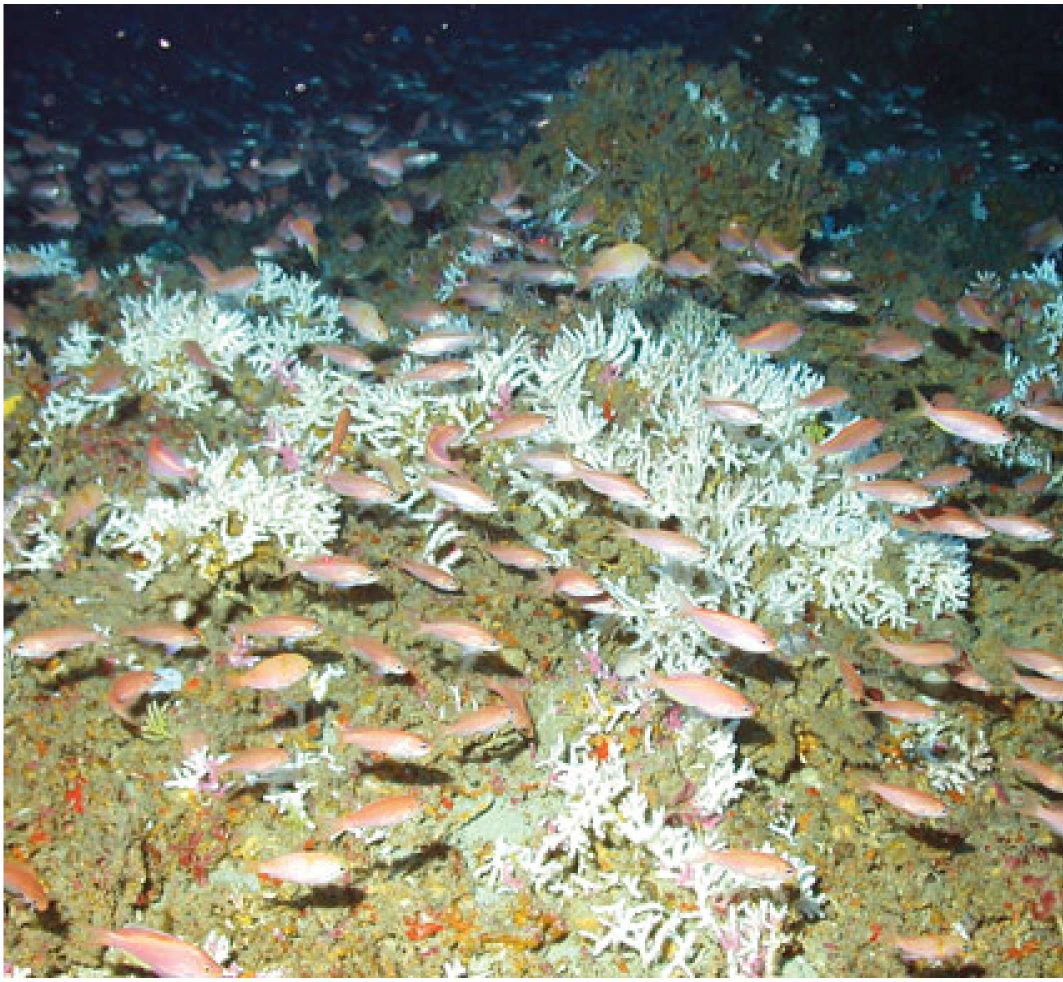


- Breaking down the quadrants by IUCN extinction risk categories (FIG 3c), we found that species with higher extinction risk tend to be better aligned between the two datasets, perhaps correlated to increased expert scrutiny. Does higher perceived risk lead to increased attention, and thus better understanding of species distribution? Or conversely, does increased attention to species distribution reveal more species at risk? Likely both mechanisms are at play on a case-by-case basis, depending on the species' taxon and region. *does this argument bear up to closer scrutiny? CR isn't dominated by Q1 any more*

table to show data poor status and reviewed status for AquaMaps maps represented in the quadrant plot *- perhaps update the quadrant plot to reveal data-poor species (and reviewed species? little overlap of reviewed & data-poor) instead of, say, red-list category which doesn't get discussed in the body of the paper? then this table can go in SOM if we like it*

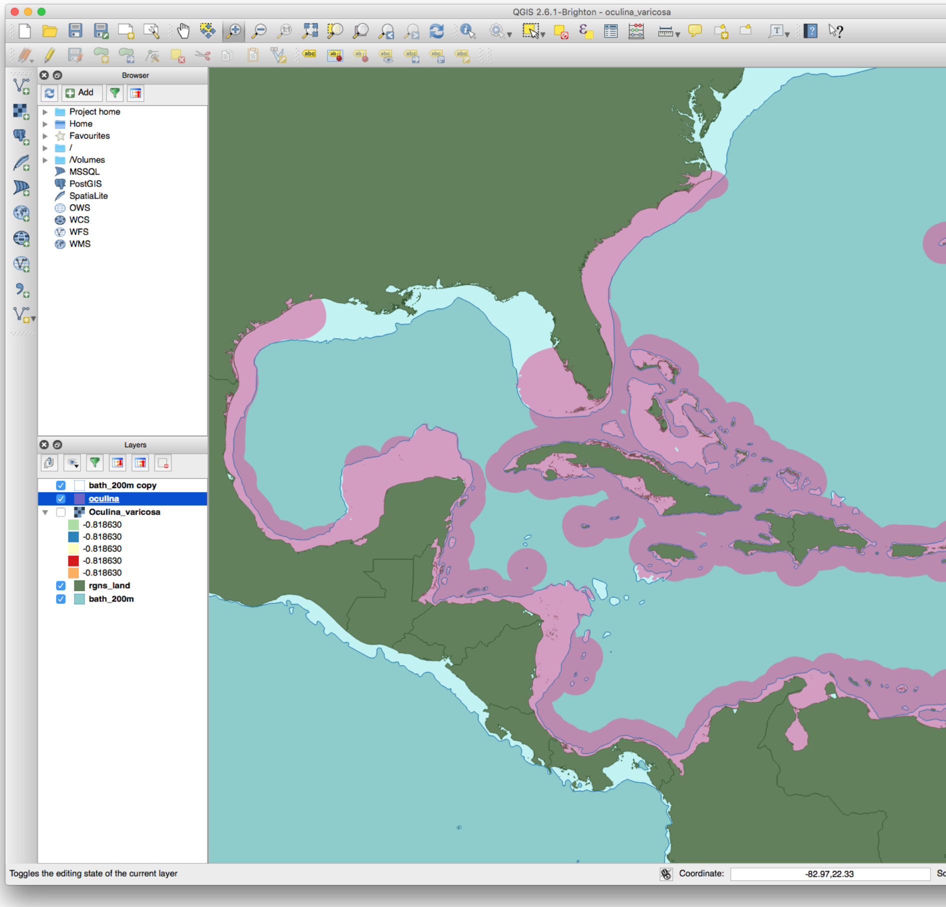
quadrant	n species	n data poor species	mean (median) data points	n reviewed species
all AM	22889	8749 (38.2%)	57.1 (16)	1296 (5.7%)
AM&IUCN	2166	457 (21.1%)	89.9 (33)	290 (13.4%)
q1	401	33 (8.2%)	233.0 (78)	100 (24.9%)
q2	682	151 (22.1%)	77.4 (39)	100 (14.7%)
q3	682	114 (16.5%)	52.4 (29)	65 (9.5%)
q4	410	159 (39.7%)	32.1 (13)	25 (6.2%)

8.3 illustrative maps for different quadrants and different mechanistic problems



Oculina varicosa - Ivory tree coral

- from IUCN: Colonies are found to depths of 152 m depth on limestone rubble, low-relief limestone outcrops, high-relief, steeply sloping prominences, and soft-bottom sloping habitats. Colonies are semi-isolated, patchy and low-growing in shallow water, or they form larger, massive coalescing aggregates (thickets or coppices) with substantial topographic relief in 50-100 m depth. In shallow waters (2-30m) the form is zooxanthellate, inhabiting limestone ledges. In deeper waters, an azooxanthellate form is known from the shelf edge off eastern Florida, USA from Ft. Pierce to Daytona (Reed 1980, 1983, 2002; Brooke and Young 2003).



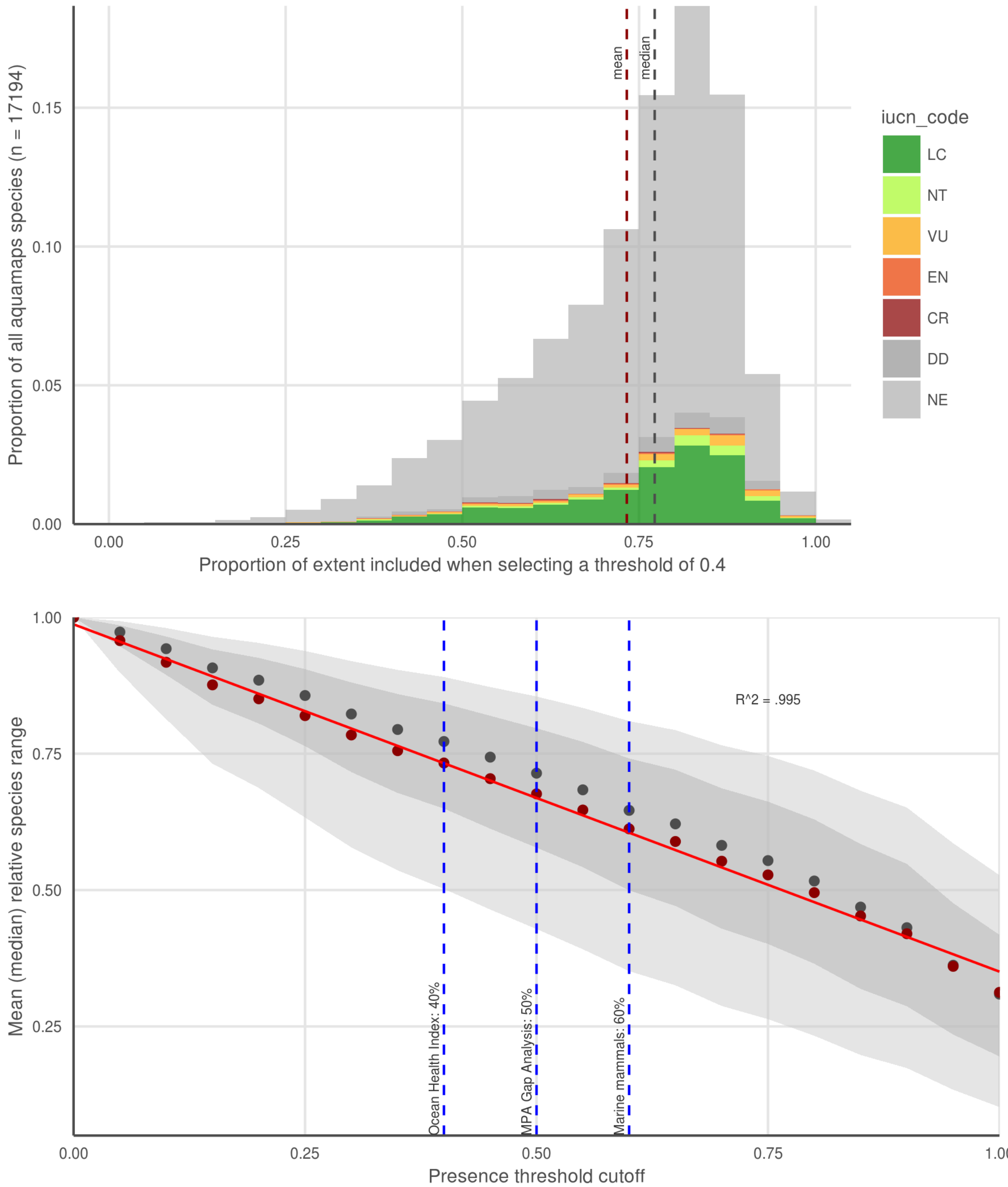
plotted against a 200 m bathymetry line:

8.4 AquaMaps: Effect of changing "presence" threshold on apparent distribution

8.4.1 AquaMaps presence threshold analysis - move to SOM

For our comparisons of global distribution of represented biodiversity and spatial alignment between datasets, we considered "present" to be any cell with a non-zero probability of occurrence, to best approximate the "extent of occurrence" as generally indicated by IUCN maps. To examine the effect of different presence threshold selections on the represented range of a species, we varied the threshold from 0.05 to 1.00 and calculated the average species range relative to a zero threshold.

8.4.2 Figure 5 (a, b):



AquaMaps distribution map extent remaining after applying a presence threshold. (a) A 40% threshold applied to all species in the AquaMaps dataset shows a mean loss of XXX, with a wide distribution in which some species lose nearly all of their apparent range. (b) Mean (median) remaining extent at increments of presence threshold. Dark grey ribbon includes 25% to 75% quantiles, while light grey ribbon includes 9% to 91% quantiles.

AquaMaps distribution maps indicate "probability of occurrence" within each 0.5° cell, with values ranging from zero to one, rather than a simple present/absent value as indicated by IUCN maps. Many studies convert this AquaMaps probability to a simple presence value by assigning a threshold value (REF references here). A higher threshold constrains an analysis to cells with near certainty of occurrence, while a low threshold captures larger areas of increasingly marginal suitability.

At a presence threshold of 40%, as used in the Ocean Health Index Species subgoal, the bulk of AquaMaps species suffer a significant decrease in represented range, and some species lose nearly their entire range. Incrementing the presence threshold from 0.00 to 1.00 for the entire AquaMaps dataset, the shallow downward trend indicates a low but consistent sensitivity to threshold choice, with no surprising tradeoffs that could suggest an "optimal" threshold. This pattern may not hold true for all subsets of AquaMaps species, however, whether subsetting by taxa or by georegion.