Exhibit R-084

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Global Conservation Priorities for Marine Turtles

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Abstract

Where conservation resources are limited and conservation targets are diverse, robust yet flexible priority-setting frameworks are vital. Priority-setting is especially important for geographically widespread species with distinct populations subject to multiple threats that operate on different spatial and temporal scales. Marine turtles are widely distributed and exhibit intra-specific variations in population sizes and trends, as well as reproduction and morphology. However, current global extinction risk assessment frameworks do not assess conservation status of spatially and biologically distinct marine turtle Regional Management Units (RMUs), and thus do not capture variations in population trends, impacts of threats, or necessary conservation actions across individual populations. To address this issue, we developed a new assessment framework that allowed us to evaluate, compare and organize marine turtle RMUs according to status and threats criteria. Because conservation priorities can vary widely (i.e. from avoiding imminent extinction to maintaining long-term monitoring efforts) we developed a “conservation priorities portfolio” system using categories of paired risk and threats scores for all RMUs (n = 58). We performed these assessments and rankings globally, by species, by ocean basin, and by recognized geopolitical bodies to identify patterns in risk, threats, and data gaps at different scales. This process resulted in characterization of risk and threats to all marine turtle RMUs, including identification of the world’s 11 most endangered marine turtle RMUs based on highest risk and threats scores. This system also highlighted important gaps in available information that is crucial for accurate conservation assessments. Overall, this priority-setting framework can provide guidance for research and conservation priorities at multiple relevant scales, and should serve as a model for conservation status assessments and priority-setting for widespread, long-lived taxa.
**Introduction**

Major challenges for conservation of widely distributed, long-lived taxa are assessing conservation status at biologically appropriate scales and establishing conservation priorities based on those assessments [1, 3]. However, current global extinction risk frameworks, most notably the IUCN Red List of Threatened Species™ (www.iucnredlist.org), are not designed to capture and assess variation in status and trends of individual populations of wide-ranging species (e.g., sharks [4], marine turtles [5, 6], marine mammals [7]). Thus, assessing the status of and threats to distinct population segments or management units of these species are critical steps toward building sound frameworks for setting conservation priorities [3].

Despite consisting of only seven species, marine turtles are circumbiologically distributed, inhabit nearly all oceans, occupy unique ecological niches, and exhibit intra-specific variations in population sizes, and trends, as well as reproduction and morphology [3]. On a global scale, marine turtle species are currently listed as Vulnerable (olive ridley, *Lepidochelys olivacea*), Endangered (loggerhead, *Caretta caretta*; green turtle, *Chelonia mydas*), Critically Endangered (Kemp's ridley, *Lepidochelys kempii*; hawksbill, *Eretmochelys imbricata*; leatherback, *Dermochelys coriacea*), and Data Deficient (flatback, *Natator depressus*) on the Red List [8]. Threats to marine turtles vary across regions, but general categories include fisheries bycatch (i.e., incidental capture by marine fisheries operating outside of other species), take (e.g., utilization of eggs, meat or other turtle products), coastal development, pollution and pathogens, and climate change [9].

The IUCN Marine Turtle Specialist Group, one of the IUCN/Species Survival Commission’s specialist groups, is responsible for conducting regular Red List assessments of each marine turtle species on a global scale. However, because marine turtle population traits as well as environmental conditions vary geographically [10], the global extinction risk assessment framework represented by the Red List does not adequately assess conservation status of spatially and biologically distinct marine turtle populations (see [5, 6] for review). The MTSG has debated the utility and validity of this global classification system for decades, and has advocated for regional assessments using criteria that are more appropriate for assessing extinction risk of marine turtle populations [3]. In fact, recent MTSG species assessments have attempted to address this problem by evaluating species status in each ocean basin based on data compiled at the subocean basin level [11–14]. Thus, the MTSG has faced a two-fold challenge: 1) to define population units for assessments, and 2) to develop a system for assessing the conservation status of those population units.

To address these challenges, the MTSG leadership convened the Burning Issues Working Group (MTSG BI) of marine turtle experts from around the world who represented government agencies, nongovernmental organizations, and academic institutions (for a brief history of MTSG BI, see [15]). The MTSG BI addressed the first challenge by developing Regional Management Units (RMUs) (i.e., spatially explicit population segments defined by biogeographical data of marine turtle species) as the framework for defining population segments for assessments [3]. Toward addressing the second challenge, the MTSG BI developed criteria and a process for evaluating and prioritizing the conservation status of marine turtle RMUs. This paper describes the assessment criteria and process, as well as the results and their implications for conservation priority setting for marine turtles worldwide.

**Methods**

The framework and process for conservation status assessments of marine turtles was developed during two MTSG BI Working Group meetings held during August 2008 and September 2009, and further refined after both meetings. Briefly, the framework consists of semi-quantitative scoring of criteria related to status of and threats to individual RMUs. Scoring relied upon publicly available data from nearly 1,500 papers, reports, abstracts, and other sources (published through early 2010; full citations available in Dataset S1), exhaustive compilation of data provided by recent MTSG Red List assessments, and expertise of MTSG BI workshop participants, and was later refined during review by the entire MTSG membership. The overall status and threats scores were then used to plot all RMUs on continua from low to high risk (i.e., population viability, based on population characteristics and status; defined below) and low to high threats (i.e., direct and indirect anthropogenic impacts; defined below), which allowed for comparisons of conservation status among all RMUs, and both within and among species.

**Matrices, assessment criteria, and scoring**

Characteristics of populations (e.g., abundance, trends, vulnerability) and relative impacts of threats to populations are vital components to assessments of extinction risk. With this in mind, we first established two different matrices that would frame the evaluation process: one to evaluate population characteristics and status for each RMU (i.e., risk of decline based on a suite of traits; i.e., “the risk matrix”) and another to evaluate threats to each RMU (i.e., “the threats matrix”). The risk matrix evaluated population characteristics according to relative risk of population decline or loss of genetic diversity, while the threats matrix evaluated the relative impacts of different threats to RMUs. Although ‘hazards’ is the preferred term in risk assessment...
literature [16], we used ‘threats’ as this is the more prevalent term
in the conservation biology community.

To semi quantitatively assess risk and threats for all RMUs, we
established relevant criteria within each matrix. We scored all
criteria on a 1 to 3 scale and calculated overall risk and threats
trends based on the past 10 years of available nesting data reported
in the literature for each RMU through Dataset S2. Significance of numerical values and
scales is explained below.

Risk matrix criteria. In the risk matrix, we wanted not only
to evaluate some direct measures of population viability (e.g.
abundance and trends), but also other factors that are important
considerations for conservation strategies, such as genetic diversity.
Thus, the five criteria established within the risk matrix were: 1)
population size, 2) recent trend, 3) long term trend, 4) rookery
vulnerability, and 5) genetic diversity. We scored risk criteria
defined below) according to relative risk to each RMU conveyed
by each criterion, with risk increasing from 1 (low) to 3 (high).
Thus, average ‘low risk’ criteria scores (closer to 1) would
correspond to large, increasing, genetically diverse RMUs, while
‘high risk’ criteria scores (closer to 3) would correspond to small,
scarcely available rookeries and RMUs, long term trends better
represent marine turtle population dynamics than recent trends
[17,18].

We scored rookery vulnerability defined as the likelihood of
extirpation of functional rookeries that would prevent recovery
based on the number and distribution of rookeries within an
RMU as low (score of 1), medium (score of 2), or high (score of
3). This criterion was intended to assess the relative density of
rookeries within the spatial extent of an RMU as an indicator of
persistence of viable nesting in an RMU given various threats and
potential for range shifts over time.

We scored genetic diversity defined as the number of known
or inferred genetic stocks (from species specific patterns of genetic
distinctiveness among rookeries based on analyses of mitochon
drial DNA) within an RMU as high (≥2 stocks, score of 1),
medium (2 stocks, score of 2), or low (1 stock, score of 3). This
criterion was intended to assess the genetic uniqueness maintained
within RMUs, and to reflect higher risk of loss of isolated genetic
stocks.

Threats matrix criteria. For the threats matrix, we used the
‘Five Hazards to Marine Turtles’ established during BI 3
[9]: 1) fisheries bycatch, 2) take, 3) coastal development, 4)
pollution and pathogens, and 5) climate change. We scored
threats criteria according to relative impact to each RMU from
that criterion, with all threat scores increasing from 1 (low) to 3
(high). Threats were scored separately for each RMU, rather
than among RMUs. If insufficient information was available for
a score to be made for a criterion, it was scored as data deficient
(see below).

We scored fisheries bycatch, or incidental capture of marine
turtles in fishing gear targeting other species, in terms of
population level impacts, taking into account the magnitude and
mortality rates of reported bycatch, as well as life stages affected.
Bycatch was scored low 1, medium 2, high 3, and when
bycatch was scored as ‘high,’ we specified the gear type(s) that
contributed most to this assessment.

We scored take defined to include direct utilization of turtles
or eggs for human use (i.e. consumption, commercial products) relative to population size as low 1, medium 2, or high 3.
When take was scored as ‘high,’ we specified the type(s) of take contributing most to this assessment: a) egg and hatchling loss (feral animals); b) egg utilization (legal and illegal); c) nesting
female take; d) adult/immature take.

We scored coastal development defined to include human
induced alteration of coastal environments due to construction,
dredging, beach modification, etc. as low 1, medium 2, or high 3.
When coastal development was scored as ‘high,’ we
specified the type(s) of development contributing most to this
assessment.

We scored pollution and pathogens defined as marine
pollution and debris that affect marine turtles (i.e. through
ingestion or entanglement, disorientation caused by artificial
lights, making them more susceptible to infections), as well as
impacts of pervasive pathogens (e.g. fibropapilloma virus) on turtle
health as low 1, medium 2, or high 3. When pollution and
pathogens was scored as ‘high,’ we specified the type(s) contributing most to this assessment.

We scored climate change impacts defined as current and
future impacts from climate change on marine turtles and their
habitats (e.g. increasing sand temperatures on nesting beaches
affecting hatching sex ratios, sea level rise, storm frequency and
intensity affecting nesting habitats, etc.) as low 1, medium 2,
or high 3. When climate change was scored as ‘high,’ we
specified the impact(s) contributing most to this assessment.
After initial rounds of scoring threats criteria, we noted an excessive number of data deficient scores for pollution and pathogens (33 of 58 RMUs; 57%) and climate change (36 of 58 RMUs; 66%) (Table 1). With these findings in mind, we determined that in cases where these threats had been given a score, they were disproportionately influential in overall threats scores compared to RMUs for which those threats had not been scored (i.e. scored ‘DD’). Thus, we decided to omit these threats from the calculation of overall threats scores for all RMUs; threats scores and threats data uncertainty indices (defined in next section) were then the average of scores for fisheries bycatch, take, and coastal development. However, we emphasize that enhanced monitoring of impacts to marine turtles from threats of pollution and pathogens as well as climate change are critical data gaps to improve future conservation status assessments [19].

Data uncertainty index. To account for data deficiencies and quality issues, we included information on data sources of all criteria scores. For a RMU to be ranked in a conservation priority category (see below), it must have received numeric scores for criteria scores. For a RMU to be ranked in a conservation priority and quality issues, we included information on data sources of all numerically scored criteria in each matrix, where low data quality score, which was the average of the data quality scores for threats) for each matrix (range from 0 to 1), and b) the data uncertainty index as the sum of threats scores compared to RMUs for which those threats had not been scored (i.e. scored ‘DD’). Thus, we decided to omit these threats from the calculation of overall threats scores for all RMUs; threats scores and threats data uncertainty indices (defined in next section) were then the average of scores for fisheries bycatch, take, and coastal development. However, we emphasize that enhanced monitoring of impacts to marine turtles from threats of pollution and pathogens as well as climate change are critical data gaps to improve future conservation status assessments [19].

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Results and Discussion

Below we present results of the risk and threats assessments globally, by species, and by ocean basin to identify patterns in risk, threats, and data needs at different scales. In addition, we present results according to recognized MTSG regions (http://iucn mtsg.org/regions/), as well as by UN Food and Agriculture Organization (FAO) recognized Regional Fisheries Bodies (RFBs) with management mandates (http://www.fao.org/fishery/rfb/search/), to determine patterns in risk, threats, and data needs according to relevant geographies and geopolitical bodies with potential to implement conservation strategies to address identified needs.

Global-scale summary

We assessed the risk and threats scores for 58 RMUs (Table 1; Fig. 1, see Table S2 for RMU codes; Dataset S2). Including all RMUs, average scores of risk criteria were moderate, except for that of long term trend, which reflected an overall pattern of population declines across species globally over the past generation. In contrast, average recent trend was near stable, and even slightly increasing (stable 2, overall average recent trend 1.81), perhaps reflecting an encouraging trend of recent conservation.

Table 1. Average scores and number of RMUs scored for all criteria in risk and threats matrices.

<table>
<thead>
<tr>
<th>RISK SCORES</th>
<th>population size</th>
<th>recent trend</th>
<th>long-term trend</th>
<th>rookery vulnerability</th>
<th>genetic diversity</th>
</tr>
</thead>
<tbody>
<tr>
<td>mean</td>
<td>1.95</td>
<td>1.81</td>
<td>2.47</td>
<td>1.72</td>
<td>1.90</td>
</tr>
<tr>
<td>No. RMUs scored</td>
<td>58</td>
<td>43</td>
<td>38</td>
<td>57</td>
<td>58</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>THREATS SCORES</th>
<th>fisheries bycatch</th>
<th>take</th>
<th>coastal development</th>
<th>pollution and pathogens</th>
<th>climate change</th>
</tr>
</thead>
<tbody>
<tr>
<td>mean</td>
<td>2.21</td>
<td>2.08</td>
<td>1.93</td>
<td>1.70</td>
<td>2.20</td>
</tr>
<tr>
<td>No. RMUs scored</td>
<td>56</td>
<td>57</td>
<td>53</td>
<td>25</td>
<td>20</td>
</tr>
</tbody>
</table>

Pollution and pathogens and climate change were omitted from calculations and categorizations (see Methods for descriptions of criteria and calculations).

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successes for some RMUs (e.g. [18]). As for threats criteria, average scores for fisheries bycatch and climate change ranked highest, although climate change was scored in only one third of RMUs. Pollution and pathogens was ranked lowest among threats criteria, although it was scored in less than half of RMUs (Table 1). Our results agreed somewhat with a recent expert based survey ranking anthropogenic threats to marine turtles in which respondents consistently ranked bycatch and coastal development as the most important threats, whereas pathogens (considered separately from pollution) was almost never ranked as a high threat [20].

Overall, 19 of the 58 total RMUs were categorized as High Risk High Threats, nine as High Risk Low Threats, 12 as Low Risk Low Threats, and 17 as Low Risk High Threats (Fig. 1). One RMU (C. mydas, Northeast Indian Ocean) was not scored because of excessive data deficient scores (three risk criteria scored DD). Thus, nearly two thirds of scored RMUs (36 of 57) were categorized as High Threats. Twelve RMUs (including C. mydas, Northeast Indian Ocean) were assessed as critical data needs (Fig. 1; Table S3).

Of those categorized High Risk High Threats, 11 RMUs fell completely within the quadrant boundaries (Fig. 1), and thus can be considered the most endangered marine turtle RMUs in the world (Table 2). The other categories of conservation priorities reflect different risk and threats scores and thus merit different conservation interventions, but these 11 RMUs are, overall, those with population characteristics of highest risk that are simultaneously under the highest degree of threats, and therefore are in the most danger of extinction. Of these 11 RMUs, five occur in the Indian Ocean, and four are E. imbricata.

Assessments by species
Risk scores ranged from 1.00 (C. mydas, northwest Indian Ocean; D. coriacea, Northwest Atlantic Ocean) to 2.70 (L. olivacea, West Indian Ocean), while threats scores ranged from 1.00 (C. mydas, Central North Pacific Ocean [Hawaii]; E. imbricata, Central North Pacific Ocean [Hawaii]) to 3.00 (C. mydas and E. imbricata, East Atlantic Ocean; C. caretta, Northeast Indian Ocean; L. olivacea, West Indian Ocean (Fig. 2; Table S3).

Conservation portfolio categories of RMUs for each species are displayed in map (Fig. 2) and graphical formats (Fig. S1). The High Risk High Threats category was defined to identify the RMUs with low, declining abundance and low diversity simultaneously under high threats. These RMUs can be
considered as warranting the most urgent conservation intervention because of this combination of high risk and high threats. More than half of *E. imbricata* RMUs (e.g. East Atlantic Ocean, East Pacific Ocean) and roughly 40% of *C. caretta* RMUs (e.g. Northeast Atlantic Ocean, Northeast Indian Ocean, North Pacific Ocean) and *D. coriacea* RMUs (e.g. East Pacific Ocean) were categorized as High Risk High Threats (Figs. 1 and 3; Table S3). Only *L. kempii*, with just one RMU, did not have at least one RMU in this most urgent conservation category (Fig. 2E; Fig. S1F).

High Risk Low Threats RMUs were characterized generally by low, declining abundance and low diversity, i.e. characteristics that make them more susceptible to population decline or loss, particularly if impacts from threats increase in severity. This category included *L. kempii*, Northwest Atlantic Ocean, *C. mydas*, Northwest Pacific, *D. coriacea*, Southwest Indian Ocean, and both RMUs (*C. mydas* and *E. imbricata*) from the Central North Pacific Ocean (Hawaii) (Figs. 1 and 2; Table S3).

RMUs categorized as Low Risk Low Threats were characterized as having high and stable or increasing abundance, high diversity, while being under low to moderate threats. This category is intended to highlight large populations that, in many cases, are well monitored and thus represent continued opportunities to generate valuable information about population abundances and trends, as well as other biological data, for all species that can be applied to situations where such information is unavailable. Low Risk Low Threats included five *C. mydas* RMUs (e.g. South Central and West Central Pacific Ocean), three *E. imbricata* RMUs (e.g. Southwest Pacific Ocean), two *D. coriacea* RMUs (Northwest Atlantic and Southeast Indian Ocean), and one each for *C. caretta* (Northwest Indian Ocean) and *L. olivacea* (East Pacific Ocean arribada RMU) (Figs. 1 and 2; Table S3).

Low Risk High Threats RMUs generally exhibited large, stable or increasing abundance with high diversity while under a relatively high degree of threats. As such, this category highlighted RMUs that are robust at present, but if threats are not abated, could decline in the future, thus warranting intervention before significant population level impacts can manifest. The Low Risk High Threats category included seven *C. mydas* RMUs (e.g. East Atlantic Ocean, West and Southwest Pacific Ocean), four *L. olivacea* RMUs (e.g. East Atlantic Ocean, East Pacific Ocean solitary nesters), three *C. caretta* RMUs (e.g. Mediterranean Sea), two *E. imbricata* (e.g. West Atlantic Ocean), and one *N. depressus* (Southeast Indian Ocean) (Figs. 1 and 2; Table S3).

Six of 13 *E. imbricata* RMUs, two of 10 *C. caretta* RMUs, and three of 17 *C. mydas* RMUs were classified as critical data needs due to excessively high uncertainty in available data (Figs. 1 and 2; Dataset S2).

Assessments by ocean basin

When considering ocean basin scales (i.e. Atlantic Ocean and Mediterranean Sea, Indian Ocean, Pacific Ocean), RMUs in the Pacific Ocean had the highest average risk score (2.05), while RMUs in the Atlantic (including the Mediterranean) had the highest average threat score (2.16). RMUs in the Indian Ocean had the highest average data uncertainty scores for both risk and threats (Table 3).

All basins were represented in relatively similar proportions among categories, except for the Indian Ocean (Table 4). Specifically, among Indian Ocean RMUs, data uncertainty was frequently scored as high for both risk (eight of 17 RMUs scored; Fig. 3A) and threats (seven of 18 RMUs scored; Fig. 3B), while no more than three RMUs in the other ocean basins had high data uncertainty scores.

Although extremely coarse geographically, our analyses by ocean basin suggest some relevant patterns, especially in regard to data uncertainty and data gaps. Specifically, risk and threats scores for RMUs in the Indian Ocean were associated with the lowest availability and quality of data among ocean basins (risk data uncertainty 0.78; threats data uncertainty 0.68). If RMUs from the Southwest Indian Ocean were removed from the calculations, data uncertainty increased further (risk data uncertainty 0.91; threats data uncertainty 0.73). This discrepancy between RMUs in the Southwest Indian Ocean compared to RMUs from the rest of the basin reflects the difference between the relative presence [21-23] and absence [24], respectively, of long term monitoring initiatives in these sub regions.

Assessments by MTSG regions

To put analyses in a context of recommending future strategies to address conservation and data needs within the construct of the MTSG, we assessed risk and threats for RMUs occurring within existing MTSG regions (http://iucn.mtsg.org/regions/). RMUs were counted in each region in which they occurred.

Australasia was the most RMU diverse region, with 20 RMUs occurring within its boundaries, while the Mediterranean was the least diverse region, with four RMUs (Table 5; Fig. 4A). The diversity of RMUs occurring in Australasia (n 20) and the Pacific Islands (n 15) might be attributed to the prevailing geographies of archipelagos and the extensive coastlines present in these regions. The East Atlantic region (n 16 RMUs) also showed high diversity, due not only to the extensive coastline of continental Africa, but also to its variation of foraging areas; several RMUs whose nesting sites are in the West Atlantic demonstrate trans Atlantic connectivity with foraging and developmental areas in the East Atlantic [25-27]. That the two regions at highest latitudes North Atlantic and Mediterranean showed the lowest RMU diversity is not surprising, given that marine turtle distributions are most concentrated in the tropics and decrease with increasing latitudes [3].

As with global averages for species and ocean basins, average risk and threats scores for regions clustered around medium values (i.e. ~2) (Table 5). Average risk scores ranged from 1.68 (North Atlantic) to 2.14 (East Pacific), and Average threat scores ranged from 1.81 (Pacific Islands) to 2.39 (South Asia) (Table 5). The most prevalent category among RMUs within regions was High Risk High Threats (five regions), followed by Low Risk

**Table 2.** The world’s 11 most endangered RMUs (grouped by ocean basin).

<table>
<thead>
<tr>
<th>Regional Management Unit</th>
<th>Ocean Basins</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Lepidochelys olivacea</em>, West Indian Ocean</td>
<td>Caretta caretta, Northeast Indian Ocean</td>
</tr>
<tr>
<td><em>Caretta caretta</em>, Northeast Indian Ocean</td>
<td><em>Lepidochelys olivacea</em>, Northeast Indian Ocean (arribadas)</td>
</tr>
<tr>
<td><em>Eretmochelys imbricata</em>, Northwest Indian Ocean</td>
<td><em>Eretmochelys imbricata</em>, East Atlantic Ocean</td>
</tr>
<tr>
<td><em>Caretta caretta</em>, Northeast Atlantic Ocean (Cape Verde)</td>
<td><em>Eretmochelys imbricata</em>, East Pacific Ocean</td>
</tr>
<tr>
<td><em>Dermochelys coriacea</em>, East Pacific Ocean</td>
<td><em>Caretta caretta</em>, North Pacific Ocean</td>
</tr>
<tr>
<td><em>Eretmochelys imbricata</em>, West Pacific Ocean</td>
<td></td>
</tr>
</tbody>
</table>

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High Threats (four regions); the most prevalent category among Pacific Islands RMUs was Low Risk Low Threats (Table 5; Fig. 4B).

South Asia had the highest proportion of RMUs categorized as critical data needs (~40%), followed by the West Indian Ocean (25%) and Australasia (20%); however, some RMUs occurred in

Figure 2. Conservation priority portfolio categories for RMUs of each marine turtle species. (A) loggerheads (Caretta caretta), (B) green turtles (Chelonia mydas), (C) leatherbacks (Dermochelys coriacea), (D) hawksbills (Eretmochelys imbricata), (E) Kemp’s ridleys (Lepidochelys kempii), (F) olive ridleys (Lepidochelys olivacea), (G) flatbacks (Natator depressus). RMUs were classified as critical data needs if the data uncertainty indices for both risk and threats ≥ 1 (denoting high uncertainty), and are outlined in red. Hatched areas represent spatial overlaps between RMUs. The brown area in Fig. 2B highlights an overlap of four RMUs, while the grey area in Fig. 2B represents the C. mydas Northeast Indian Ocean RMU, which had excessive data deficient scores and was not included in overall calculations and categorization.

doi:10.1371/journal.pone.0024510.g002

Table 3. Average risk and threats scores (and accompanying data uncertainty indices) of RMUs that occur in each ocean basin.

<table>
<thead>
<tr>
<th>Ocean Basin</th>
<th>Average Risk Score</th>
<th>Average Risk Score Data Uncertainty</th>
<th>Average Threats Score</th>
<th>Average Threats Score Data Uncertainty</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atlantic/Med (n = 19)</td>
<td>1.81</td>
<td>0.26</td>
<td>2.16</td>
<td>0.35</td>
</tr>
<tr>
<td>Indian (n = 18)*</td>
<td>1.92</td>
<td>0.78</td>
<td>2.08</td>
<td>0.68</td>
</tr>
<tr>
<td>Pacific (n = 21)</td>
<td>2.03</td>
<td>0.32</td>
<td>1.96</td>
<td>0.48</td>
</tr>
</tbody>
</table>

*One RMU (C. mydas northeast Indian Ocean) not scored.
doi:10.1371/journal.pone.0024510.t003
more than one of these regions, probably contributing to the similarities (Table 5). The only regions with no critical data needs RMUs were the North Atlantic and the Mediterranean. South Asia RMUs also had the highest average data uncertainty for both risk and threats corroborating results at the ocean basin scale (Table 3) whereas the lowest uncertainty scores were associated with RMUs from the Mediterranean and North Atlantic (Table 5). The low data uncertainty in these latter regions is probably due to the fact that the regions are comprised predominantly of developed countries, and are characterized by several long term monitoring projects [22,26 30].

Assessments by international management frameworks

Due to their highly migratory, geographically widespread nature, marine turtles warrant transboundary conservation strategies that often include multiple institutions and governing bodies, spanning several geopolitical borders, agreements, and instruments at local, national, and international scales [31,32]. Navigating this complex management framework requires knowledge about the distributions, status, and trends of marine turtle populations that occur within various relevant borders [3].

The RMU conservation portfolio framework can be applied by various geographical entities at different scales to inform management strategies toward marine turtle conservation. To demonstrate this potential, we assessed risk and threats (specifically fisheries bycatch) to RMUs occurring in Regional Fisheries Bodies (RFBs) that have mandates for management of marine resources within their Areas of Competence (Fig. S2; for complete lists Areas of Competence of RFBs by ocean basin, see FAO fishery governance fact sheets: http://www.fao.org/fishery/rfb/search/en). RMUs were counted in each RFB in which they occurred.

As RFBs represent international entities with distinct mandates to effectively manage marine resources, the overlaps of RMUs with multiple RFBs demonstrate the extremely complex system of management responsibility for protected species like marine turtles in high seas areas (e.g. [31,32]). Nonetheless, this straightforward exercise provided information that can refine management approaches to reducing marine turtle bycatch in fisheries activities and help to prioritize broad scale funding and conservation efforts, especially in situations where RMUs are high risk and under high bycatch threats (Table 6). Additional international management frameworks that would be good candidates for conservation status assessments of marine turtle RMUs would be the Inter American Convention for the Protection and Conservation of Sea Turtles (IAC: http://www.iacscaturtle.org/), signatories to the Convention on the Conservation of Migratory Species of Wild Animals (CMS or the Bonn Convention: http://www.cms.int/), or FAO fishing areas (http://www.fao.org/fishery/area/search/en).

Caveats and future improvements

An inherent challenge to assessments that use expert opinion is dealing with incongruities among evaluators in terms of how...
Figure 3. Risk (i.e. population viability) scores (A) and threats (i.e. direct and indirect anthropogenic impacts) scores (B) with data uncertainty indices by ocean basin.

Symbols bordered in red are scores with accompanying data uncertainty indices that exceed 1 (see Methods for details). Refer to Table S3 for full list of RMU IDs. NOTE: C. mydas Northeast Indian Ocean RMU was not plotted due to excessive data deficient scores.

doi:10.1371/journal.pone.0024510.g003

Global Conservation Priorities for Marine Turtles
criteria are scored. For example, species specific or regional scoring patterns might reflect the non uniform influence of certain experts or expertise [20]. Also, universal agreement about qualitative scoring scales is very difficult to achieve, especially for impacts of threats that are poorly known or studied. We tried to overcome these potential biases by including a diverse representation of MTSG Regional Vice Chairs for broad geographic expertise, assessors of recent Red List assessments for species specific expertise, as well as other MTSG members with ample overall expertise in marine turtle biology and conservation. Moreover, during the scoring process, we relied on information available in published literature not only expert opinion to substantiate criteria scores and achieve consensus. Also, an extended comment period for the entire MTSG membership (ca. 230 people) allowed members to evaluate the system and results and to suggest improvements and changes.

Although the paired risk and threats scores provided overall assessments of conservation status for RMUs, an important discrepancy existed in terms of which life stages were assessed by the two different sets of criteria. Whereas the risk criteria were based on information from nesting colonies (i.e. nesting females only), threats criteria were evaluations of degree of impact posed by each threat to the entire population (i.e. multiple life stages, including adult males and immature individuals). Although risk criteria like population size and trends are estimates based on nesting females only, these metrics are proxies for underlying population processes that include mortality patterns and other vital rates related to other life stages [17], which were considered in the threats criteria scores. Because this discrepancy is a common impediment to effective monitoring and conservation of marine turtle populations, abundance estimates and trends based on nesting females need to be accompanied by long term mark recapture studies to enable interpretation of observed trends and identification of drivers of population dynamics [17].

The preponderance of data deficient scores for pollution and pathogens and climate change presented a challenge in terms of calculating threats scores. While scores and data citations for both of these threats appear in the threats matrix (Dataset S2), these values were not included in overall threats scores for RMUs due to a lack of reliable information. This was a disadvantage to those RMUs where impacts of either or both of these threats are reasonably well known (e.g. pollution and pathogens for C. mydas, North Central Pacific Ocean [Hawaii]: [35,36]; climate change for C. caretta, Northwest Atlantic Ocean: [37]; C. mydas, Southwest Pacific Ocean; [38]). However, these findings provide clear support for enhancing efforts to quantify impacts to marine turtles of pollution and pathogens as well as climate change to improve our overall evaluation of threats (see [19] for review of global research priorities for marine turtles).

To partially counteract the above issues, this system, under the auspices of the MTSG, will rely on and allow for periodic updates to adjust scores and improve data reliability as new information becomes available. By listing all citations that were considered in scoring risk and threats criteria (see Datasets S1 and S2), we made the assessments themselves transparent, which will allow users to evaluate not only the scores but also the justifications for the scores, and to suggest changes or improvements. This user driven evaluation system will facilitate collaboration within the MTSG and broader marine turtle conservation community, will make marine turtle status evaluations straightforward, and could provide a model for conservation assessments of other taxa that are also widely distributed and require regional conservation strategies (e.g. sharks: [4]; marine mammals: [7]).

Although this system evaluates risk and threats to marine turtles, conservation priority setting frameworks should also include ecological, legal, and social information to balance technical, governance, and societal factors in decision making [39]. In this light, future iterations of the marine turtle priority setting framework and process presented here could incorporate "conservation capacity," or the suite of factors that exists in each RMU that influence the feasibility and efficacy of efforts to protect and recover marine turtle populations. A conservation capacity matrix might include the factors (e.g. degree of research conducted, socioeconomic issues), institutions (e.g. NGOs, government agencies), and legal frameworks (e.g. laws to protect marine turtles, protected areas, enforcement and implementation capacity) in place that can be evaluated in relation to the risk and threats criteria for each RMU to provide further information for setting conservation priorities.

### Table 5. Conservation Priorities Portfolio results by MTSG regions.

<table>
<thead>
<tr>
<th>MTSG Region</th>
<th>No. RMUs</th>
<th>critical data needs RMUs</th>
<th>average risk score</th>
<th>average risk score data uncertainty</th>
<th>average threats score</th>
<th>average threats score data uncertainty</th>
<th>*most prevalent category</th>
</tr>
</thead>
<tbody>
<tr>
<td>North Atlantic</td>
<td>7</td>
<td>0</td>
<td>1.68</td>
<td>0.17</td>
<td>2.19</td>
<td>0.17</td>
<td>LR HT</td>
</tr>
<tr>
<td>East Atlantic</td>
<td>16</td>
<td>1</td>
<td>1.94</td>
<td>0.33</td>
<td>2.09</td>
<td>0.44</td>
<td>HR HT</td>
</tr>
<tr>
<td>Mediterranean</td>
<td>4</td>
<td>0</td>
<td>1.65</td>
<td>0.10</td>
<td>2.25</td>
<td>0.17</td>
<td>LR HT</td>
</tr>
<tr>
<td>Wider Caribbean</td>
<td>12</td>
<td>1</td>
<td>1.81</td>
<td>0.26</td>
<td>2.06</td>
<td>0.28</td>
<td>LR HT</td>
</tr>
<tr>
<td>Southwest Atlantic</td>
<td>12</td>
<td>1</td>
<td>1.81</td>
<td>0.26</td>
<td>2.00</td>
<td>0.35</td>
<td>LR HT</td>
</tr>
<tr>
<td>South Asia**</td>
<td>12</td>
<td>5</td>
<td>1.94</td>
<td>0.74</td>
<td>2.39</td>
<td>0.74</td>
<td>HR HT</td>
</tr>
<tr>
<td>Australasia</td>
<td>20</td>
<td>5</td>
<td>1.96</td>
<td>0.57</td>
<td>2.11</td>
<td>0.66</td>
<td>HR HT</td>
</tr>
<tr>
<td>West Indian</td>
<td>12</td>
<td>3</td>
<td>1.93</td>
<td>0.53</td>
<td>2.03</td>
<td>0.51</td>
<td>HR HT</td>
</tr>
<tr>
<td>East Pacific</td>
<td>11</td>
<td>2</td>
<td>2.14</td>
<td>0.27</td>
<td>2.01</td>
<td>0.47</td>
<td>HR HT</td>
</tr>
<tr>
<td>Pacific Islands</td>
<td>15</td>
<td>2</td>
<td>1.96</td>
<td>0.27</td>
<td>1.81</td>
<td>0.47</td>
<td>LR LT</td>
</tr>
</tbody>
</table>

*CATEGORIES: HR HT = High Risk High Threats; HR LT = High Risk Low Threats; LR LT = Low Risk Low Threats; LR HT = Low Risk High Threats.
**One RMU (C. mydas, northeast Indian Ocean) was scored critical data needs only.

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Conclusions

The conservation priorities portfolio framework allowed evaluation of risk and threats to marine turtles at various scales, and can provide guidance for research and conservation priorities of biogeographically defined RMUs. Because the complete matrices, including scores for risk, threats, and data uncertainty are available to users and fully cited, the specific criteria that drive risk or threat scores for RMUs can be identified and targeted for future research or conservation efforts at multiple relevant scales.

Another important feature of the portfolio system is that it reflects the reality that conservation priorities vary widely with objectives and values of different management entities, NGOs, researchers, funding bodies, and other stakeholders. By recognizing that conservation priorities can range from prevention of imminent extinctions to maintaining long term monitoring projects, from preserving genetic diversity to managing fisheries more sustainably, this approach provides sufficient information to allow for numerous applications.

Nonetheless, assessing relative extinction risk is of particular importance to species focused conservation at many geographic scales, and is a primary objective of many NGOs, government agencies, and international agreements and conventions. Our assessment priority setting exercise produced a global list of the 11 marine turtle RMUs most threatened with extinction, which includes RMUs from four different species, all three major ocean basins, and from four different MTSG regions (Fig. 1; Table 2). The ‘Top 11 most endangered RMUs’ include well documented cases of populations that have collapsed and are under high threat (e.g. *D. coriacea*, East Pacific Ocean; [40 42]), as well as other RMUs about which little is known (e.g. *C. caretta* and *E. imbricata*, Northeast Indian Ocean; [24]; *E. imbricata*, East Pacific Ocean; [43]). The RMUs on this list merit immediate attention, whether through reduction of threats, increased monitoring to more confidently assess risk and threats, or both.

The portfolio approach also permitted detection of RMUs that are priorities for continued or enhanced monitoring (i.e. Low Risk...
Low Threats, critical data needs; Fig. 1). Specifically, large, stable or increasing, highly diverse populations under low to moderate threats were categorized as Low Risk Low Threats, which places value on the ongoing census and conservation efforts directed toward these RMUs because these initiatives tend to generate valuable information about marine turtle biology, ecology, and population demography [17,18,44]. In addition to recognizing the importance of Low Risk Low Threats, we also classified RMUs with high data uncertainty as critical data needs. Because we have relatively less confidence in the paired risk and threats scores for these RMUs, they are clear priorities for enhancing population monitoring and quantification of threats impacts to improve confidence in risk and threats assessments.

In terms of regional patterns, five of the 11 most endangered RMUs occurred within the Indian Ocean (Table 2), indicating generally high basin wide risk and threats scores, and a high number of critical data needs RMUs (Tables 3, 5 and 6), making it the region of most conservation concern. Both bycatch and take are pervasive threats to marine turtles in the Indian Ocean, particularly in the northern areas [24], and long term monitoring projects with effective conservation efforts are largely limited to the Southwest Indian Ocean [21,23]. Ongoing collaborative efforts through the Indian Ocean Southeast Asia Marine Turtle Memorandum of Understanding (IOSEA) an inter governmental agreement made under the auspices of the CMS hold promise to address these issues in the region by integrating monitoring and recovery initiatives at national and regional scales, but much work remains to address the conservation issues facing marine turtles in this region.

Finally, the current criteria and evaluation framework we present here might offer an effective resource for the MTSG’s need to balance its mandate to conduct timely assessment of marine turtle species using IUCN Red List criteria with widespread recognition of the inability of Red List criteria and process to adequately assess marine turtle extinction risk [5,6]. While much work remains to align the portfolio framework criteria and process with the Red List criteria and assessment process, this approach holds great potential to address a fundamental challenge for the MTSG and to establish a system for future conservation status assessments of marine turtle RMUs and species.

Conservation status assessments and subsequent priority setting require the best available information for the species or populations being evaluated. The system we have developed is robust and flexible, and can be improved and refined with continuous user input. Taken together, the RMU framework [3] and conservation portfolio system described here provide a significant advance for status evaluations and conservation priority setting for widely distributed, long lived taxa.

**Supporting Information**

Figure S1 Paired risk and threats scores for RMUs of each marine turtle species. (A) loggerheads (Caretta caretta), (B) green turtles (Chelonia mydas), (C) leatherbacks (Dermochelys coriacea, *Categories: HR HT = High risk High threats; HR LT = High risk Low threats; LR LT = Low risk Low threats; LR HT = Low risk High threats. RFB acronyms: CCAMLR: Commission on the Conservation of Antarctic Marine Living Resources; CCBS: Convention on the Conservation and Management of Pollock Resources in the Central Bering Sea; CCBT: Commission for the Conservation of Southern Bluefin Tuna; GFCM: General Fisheries Commission for the Mediterranean; IATTC: Inter American Tropical Tuna Commission; ICCT: International Commission for the Conservation of Atlantic Tunas; IOTC: Indian Ocean Tuna Commission; IPHC: International Pacific Halibut Commission; NAFO: Northwest Atlantic Fisheries Organization; NASCO: North Atlantic Salmon Conservation Organization; NEAF: Northeast Atlantic Fisheries Commission; NPFAC: North Pacific Anadromous Fish Commission; PSC: Pacific Salmon Commission; REOFI: Regional Commission for Fisheries; SEAF: Southeast Atlantic Fisheries Organization; SIOFA: South Indian Ocean Fisheries Agreement; SPRFMO: South Pacific Regional Fisheries Management Organization; WCPC: Western and Central Pacific Fisheries Commission.**

**One RMU (C. mydas, northeast Indian Ocean) was scored critical data needs only.**

<table>
<thead>
<tr>
<th>RFB</th>
<th>No. RMUs</th>
<th>No. critical data needs RMUs**</th>
<th>average risk scores</th>
<th>average bycatch scores</th>
<th>*most prevalent category</th>
</tr>
</thead>
<tbody>
<tr>
<td>CCAMLR</td>
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</tr>
<tr>
<td>CCBS</td>
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<td>0</td>
<td>2.20</td>
<td>2.00</td>
<td>HR HT</td>
</tr>
<tr>
<td>CCBT</td>
<td>22</td>
<td>3</td>
<td>1.89</td>
<td>2.07</td>
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<tr>
<td>GFCM</td>
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<td>0</td>
<td>1.65</td>
<td>3.00</td>
<td>LR HT</td>
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<tr>
<td>IATTC</td>
<td>13</td>
<td>2</td>
<td>2.13</td>
<td>2.08</td>
<td>HR HT</td>
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<tr>
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<td>2.52</td>
<td>LR HT</td>
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<tr>
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<td>2.19</td>
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<tr>
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<td>0</td>
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<td>2.50</td>
<td>HR HT</td>
</tr>
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<td>NAFO</td>
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<td>2.20</td>
<td>HR HT</td>
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<tr>
<td>NASCO</td>
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<td>1.68</td>
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<td>HR HT and LR HT</td>
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<tr>
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<td>0</td>
<td>1.69</td>
<td>3.00</td>
<td>HR HT</td>
</tr>
<tr>
<td>NPFAC</td>
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<td>0</td>
<td>2.20</td>
<td>2.50</td>
<td>LR LT</td>
</tr>
<tr>
<td>PSC</td>
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<td>0</td>
<td>2.20</td>
<td>2.50</td>
<td>LR LT</td>
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<tr>
<td>REOFI</td>
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<td>3</td>
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<td>2.50</td>
<td>HR HT</td>
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<tr>
<td>SEAF</td>
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<tr>
<td>SIOFA</td>
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<td>1.88</td>
<td>2.09</td>
<td>LR HT</td>
</tr>
<tr>
<td>SPRFMO</td>
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<td>2</td>
<td>1.93</td>
<td>2.20</td>
<td>HR HT</td>
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<tr>
<td>WCPC</td>
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<td>6</td>
<td>2.00</td>
<td>1.84</td>
<td>HR HT and HR LT</td>
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</tbody>
</table>

* doi:10.1371/journal.pone.0024510.t006
(D) hawksbills (*Eretmochelys imbricata*), (E) olive ridleys (*Lepidochelys olivacea*), (F) Kemp’s ridleys (*Lepidochelys kempi*) and flatbacks (*Natator depressus*). Vertical and horizontal bars associated with each paired score represent the data uncertainty index; see text for details. RMUs in red denote critical data needs, i.e. data uncertainty indices for both risk and threats ≥1.

(TIF)


(DOCX)

### Table S1 Scoring system for population size criterion in risk matrix.

<table>
<thead>
<tr>
<th>Species</th>
<th>Category</th>
<th>Threats</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Chelonia mydas</strong></td>
<td>LR</td>
<td>Low</td>
</tr>
<tr>
<td><strong>Lepidochelys olivacea</strong></td>
<td>LR</td>
<td>Low</td>
</tr>
<tr>
<td><strong>Natator depressus</strong></td>
<td>LR</td>
<td>Low</td>
</tr>
</tbody>
</table>

(TIF)

### Table S2 List of Regional Management Unit (RMU) codes used in Fig. 1. Species: *Caretta caretta*, loggerhead; *Chelonia mydas*, green turtle; *Dermochelys coriacea*, leatherback; *Eretmochelys imbricata*, hawksbill; *Lepidochelys kempi*, Kemp’s ridley; *Lepidochelys olivacea*, olive ridley; *Natator depressus*, flatback.

### References
