

SUPPLEMENTARY INFORMATION:

Participatory monitoring drives biodiversity knowledge in global protected areas

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Supplementary Methods

SI TABLE 1.1. Search terms indicative of participatory monitoring used to query dataset descriptions to identify candidate datasets that may be derived from participatory monitoring.

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Supplementary References

Supplementary Methods

SI TABLE 1.1. Search terms indicative of participatory monitoring used to query dataset descriptions to identify candidate datasets that may be derived from participatory monitoring. Search terms were derived from the following publications related to terminology for participatory monitoring: ECSA 2015¹, Kullenberg and Kasperowski 2016², Eitzel et al. 2017³, Cooper et al. 2021⁴.

volunt	crowd	volont
citizen	voluntary	aficionad
community	social	ciudad
public	civic	ciudad
participat	local	borger
amateur	casual	burger
report	collaborative	borgar
submit	app	folk
platform	bioblitz	citoy
casual	ppgis	bénévole
observ	vgi	

SI TABLE 1.2. Dataset fields queried with the search terms indicated in SI Table 1.1 to identify potential participatory monitoring datasets. Datasets containing one or more search terms in one or more of the indicated fields were manually screened for consistency with the definition of participatory monitoring used in this study.

results.description

results.title

results.purpose

results.samplingDescription.studyExtent

results.samplingDescription.sampling

results.samplingDescription.qualityControl

results.samplingDescription.methodSteps

results.project.abstract

results.project.studyAreaDescription

results.project.title

results.project.designDescription

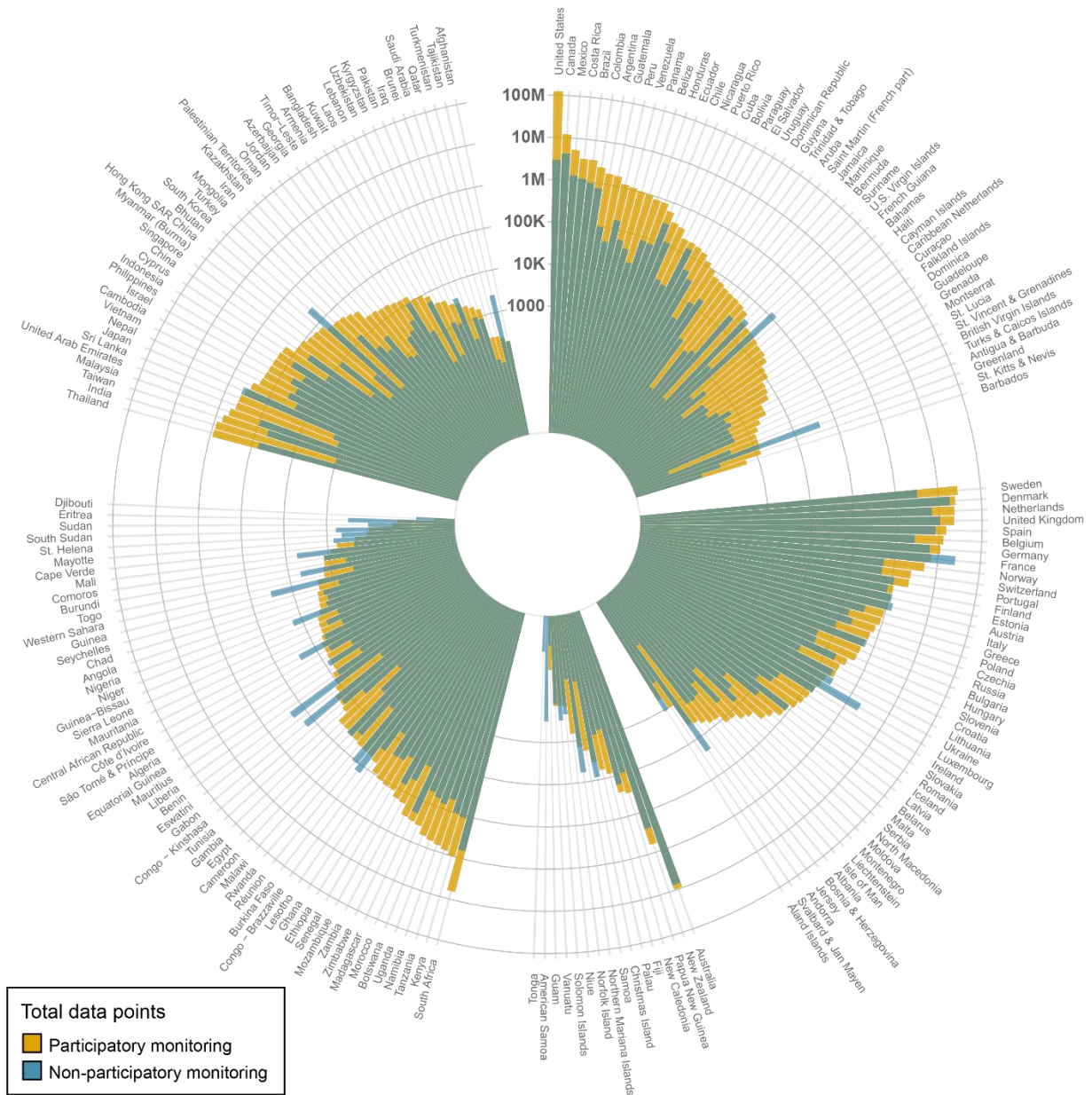
SI TABLE 1.3. Three characteristics of protected areas. We used Kruskal-Wallis non-parametric tests to relate these characteristics to the percentage and amount of participatory monitoring data available for each area. Area size and IUCN protection category were further used as response variables in relation to the participatory monitoring program characteristics defined in SI Table 1.4. Pairwise correlation between the three characteristics was low (Cramer's V ranging from 0.16 to 0.24).

Characteristic	Summary
Area size	Area size is derived from the geographic area (km ²) of protected areas. It is binned into four categories: areas with a size of ≤ 0.50 km ² ; $> 0.51 - 5.00$ km ² ; $5.01 - 50.00$ km ² ; > 50 km ² . Area size is binned because we have no reason to expect a linear relationship but rather expect that several additional protected area characteristics (e.g., accessibility to the public, habitat connectivity, and allocated management resources) might relate broadly to area size categories and might indirectly impact the contribution of participatory monitoring.
IUCN protection category	Protected areas are classified by the IUCN ⁵ into the following categories: Ia (Strict Nature Reserve); Ib (Wilderness Area); II (National Park); III (National Monument or Feature); IV (Habitat/Species Management Area); V (Protected Landscape/Seascape); VI (Protected Area with Sustainable Use of Natural Resources). Because the meaning of these areas is expected to vary somewhat across global contexts, we have followed the approach of Jones et al. 2018 ⁶ , binning the categories into the following two groups for analysis: Strictly Managed Areas (consisting of categories Ia, Ib, and II) and Less Strictly Managed Areas (consisting of categories III, IV, V, and VI). We excluded all areas classified as Not Reported, Not Available, or Not Assigned from analyses relating to IUCN protection category.
Governance structure	Governance structure describes the authority with decision-making power over a protected area and is classified according to IUCN guidelines ^{7,8} . We grouped protected areas into the eleven governance types recognized by the IUCN: Federal or national ministry or agency; subnational ministry or agency; government-delegated management; transboundary governance; collaborative governance; joint governance; individual landowners; non-profit organizations; for-profit organizations; Indigenous peoples; local communities ⁷ . We excluded all areas classified as Not Reported from analyses relating to governance structure. We further excluded areas classified with transboundary governance and for-profit organization governance structure due to low sample size ($n = 2$ and $n = 34$, respectively).

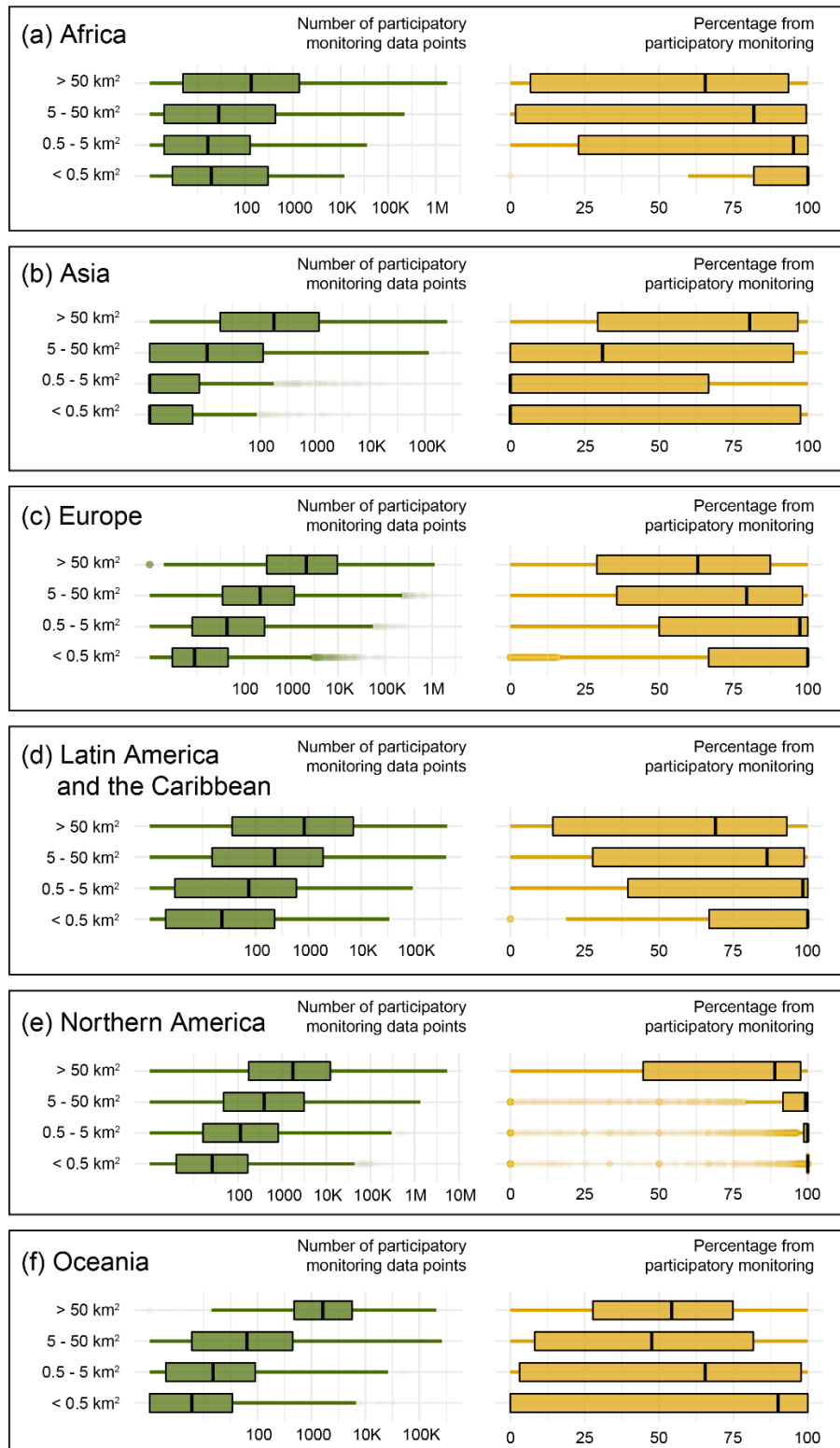
SI TABLE 1.4. Four characteristics of participatory monitoring programs. Monitoring programs are defined as distinct datasets accessed from GBIF ($n = 970$). We used chi-squared tests to relate these characteristics to the size and IUCN protection category (as defined in SI Table 1.3) of areas in which each program is active and to the IUCN Red List status of the species recorded by each program. Pairwise correlation between the four characteristics was low (Cramer's V ranging from 0.04 to 0.30).

Characteristic	Summary
Monitoring program size	Monitoring program size was defined here as the number of species observations collected by the program within global protected areas during the years covered by this study (2000 through 2021). Program sizes were binned because we had no reason to expect a linear relationship but rather expected that broad characteristics potentially associated with program size (e.g., level of funding support, resources and staffing, and number of participants) might affect the areas where such programs were most active. Bins were classified as follows: ≤ 800 observations; 801 - 8000 observations; 8001 - 80,000 observations; $> 80,000$ observations.
Taxonomic focus	Monitoring programs were classified into one of three categories relating to taxonomic focus: those that collected data on five or fewer species; those that collected data on more than five species but only one broad taxonomic group (as defined in Figure 1); and those that collected data on multiple taxonomic groups.
Geographic focus among protected areas	Monitoring programs were classified into one of three categories relating to geographic focus among protected areas: those that collected data in only one protected area; those that collected data in 20 or fewer areas; and those that collected data in more than 20 areas.
Geographic focus among nations	Monitoring programs were classified into one of three categories relating to geographic focus among nations: those that collected data in only one nation; those that collected data in five or fewer nations; and those that collected data in more than five nations.

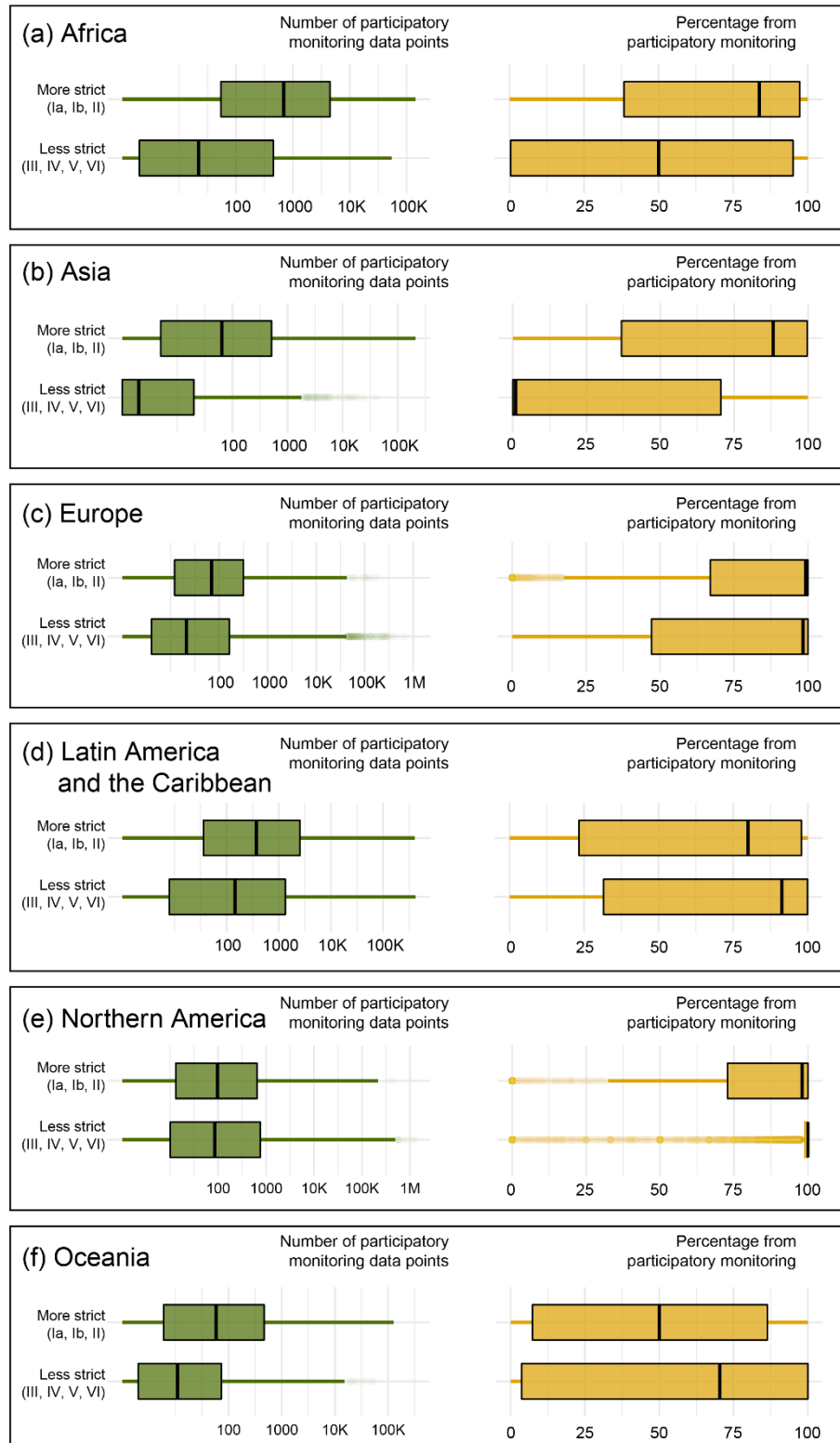
SI FIGURE 2.1. The biodiversity data on GBIF derived from participatory monitoring (yellow) and other monitoring approaches (blue) for all protected areas within nations.



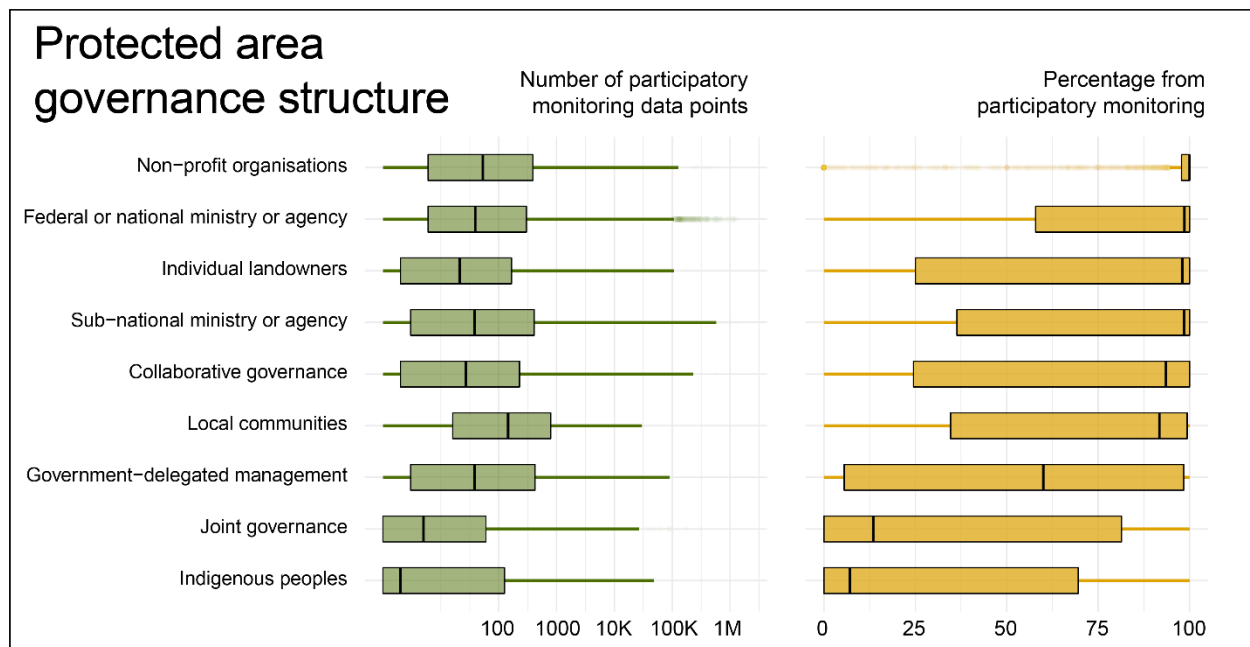
SI FIGURE 2.2. The amount of participatory monitoring data (on the left, in green) and the percentage of overall data that it comprises (on the right, in yellow) associated with protected areas of varying size, as shown in Figure 5, shown here by global region. Bars indicate median values, box indicates interquartile range, whiskers indicate data within 1.5 times the interquartile range, and points indicate outliers.



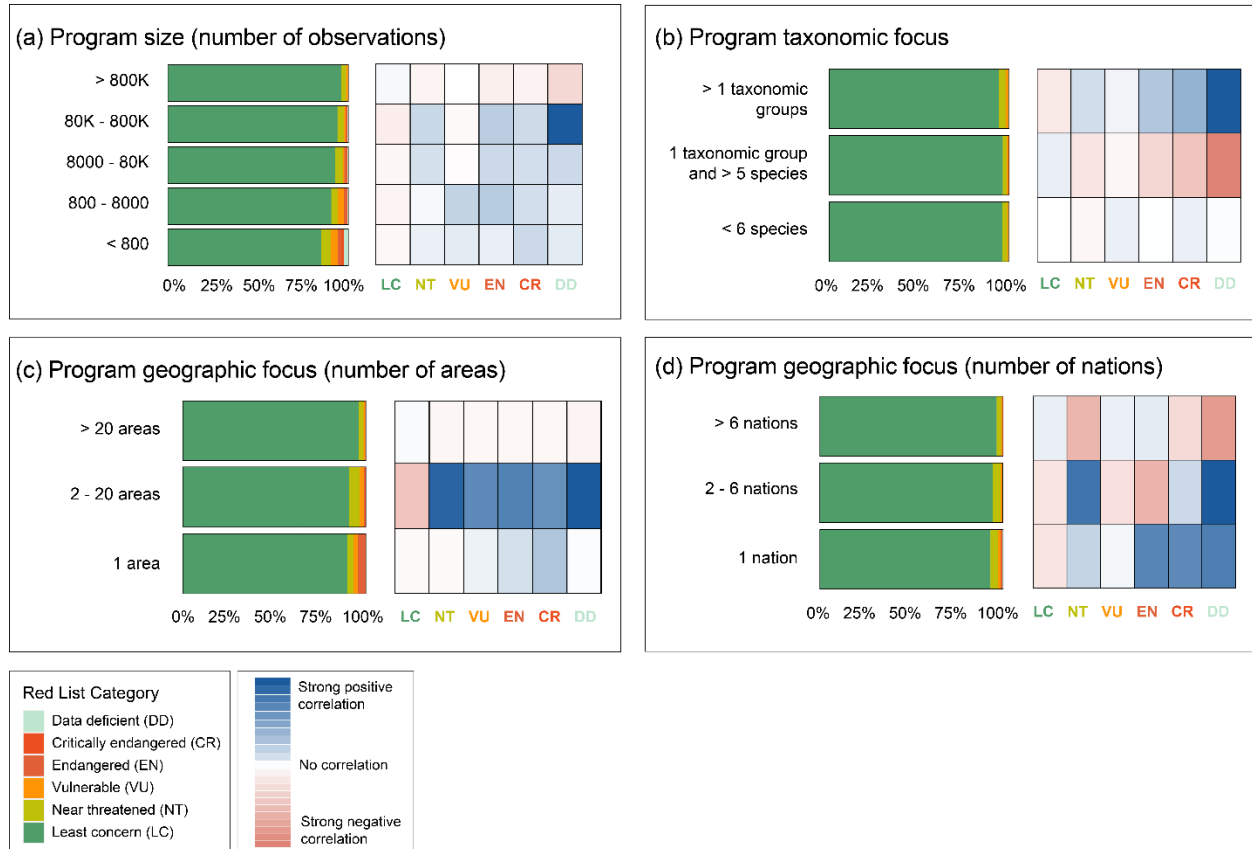
SI FIGURE 2.3. The amount of participatory monitoring data (on the left, in green) and the percentage of overall data that it comprises (on the right, in yellow) associated with protected areas of varying IUCN protection category strictness, as shown in Figure 5, shown here by global region. Bars indicate median values, box indicates interquartile range, whiskers indicate data within 1.5 times the interquartile range, and points indicate outliers.



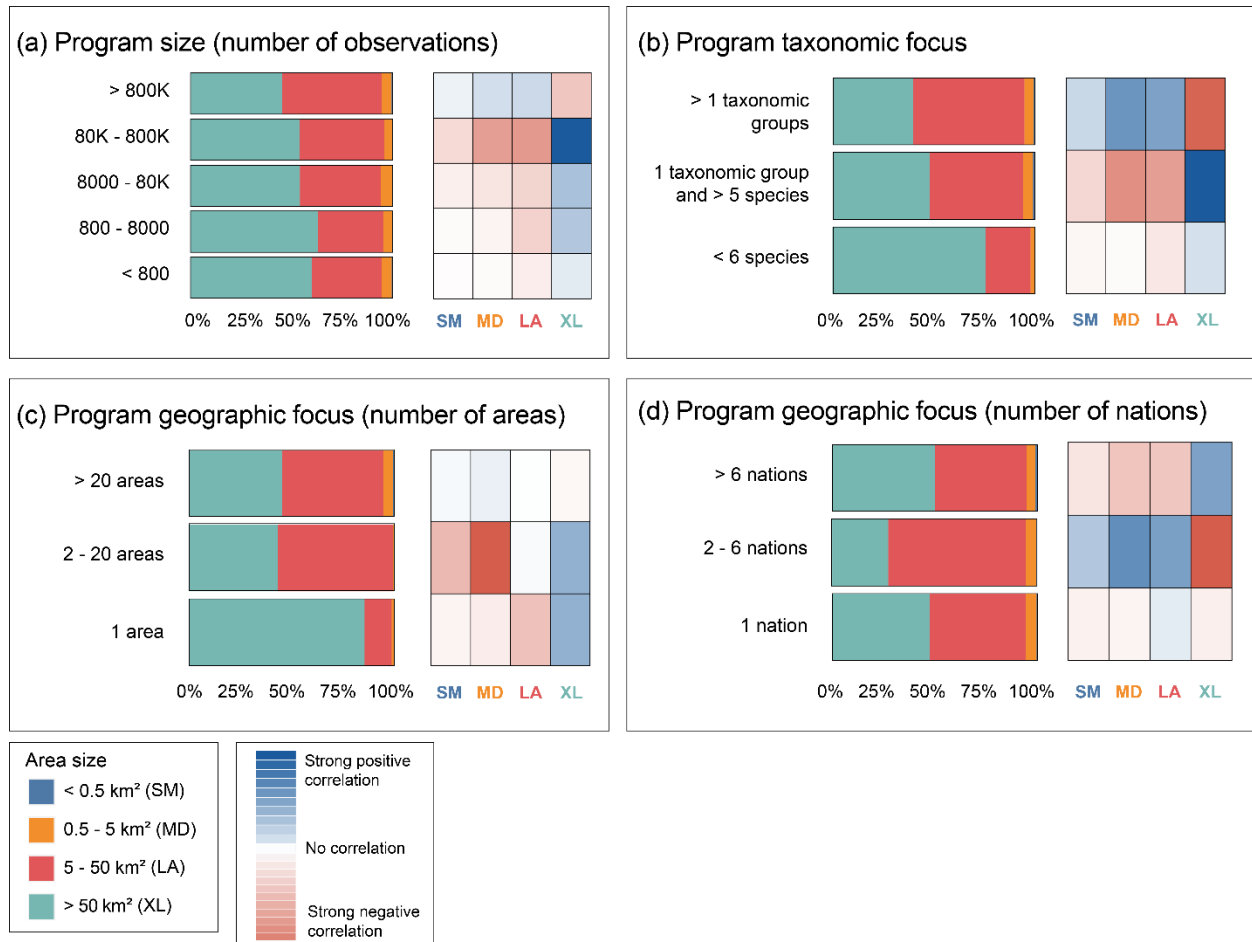
SI FIGURE 2.4. The amount of participatory monitoring data (on the left, in green) and the percentage of overall data that it comprises (on the right, in yellow) associated with protected areas of varying governance structure. For the amount of data from participatory monitoring, ‘Non-profit’, ‘Local communities’, and ‘Individual landowners’ each differ slightly from all other categories, while the rest of the categories overlap with at least one other category (Kruskal-Wallis $H = 874$; $p < 0.0001$). For the percentage of data from participatory monitoring, all categories differ from each other with the exceptions of ‘Individual landowners’, ‘Sub-national ministry or agency’, and ‘Local communities’ (Kruskal-Wallis $H = 3442$; $p < 0.0001$). Bars indicate median values, box indicates interquartile range, whiskers indicate data within 1.5 times the interquartile range, and points indicate outliers.



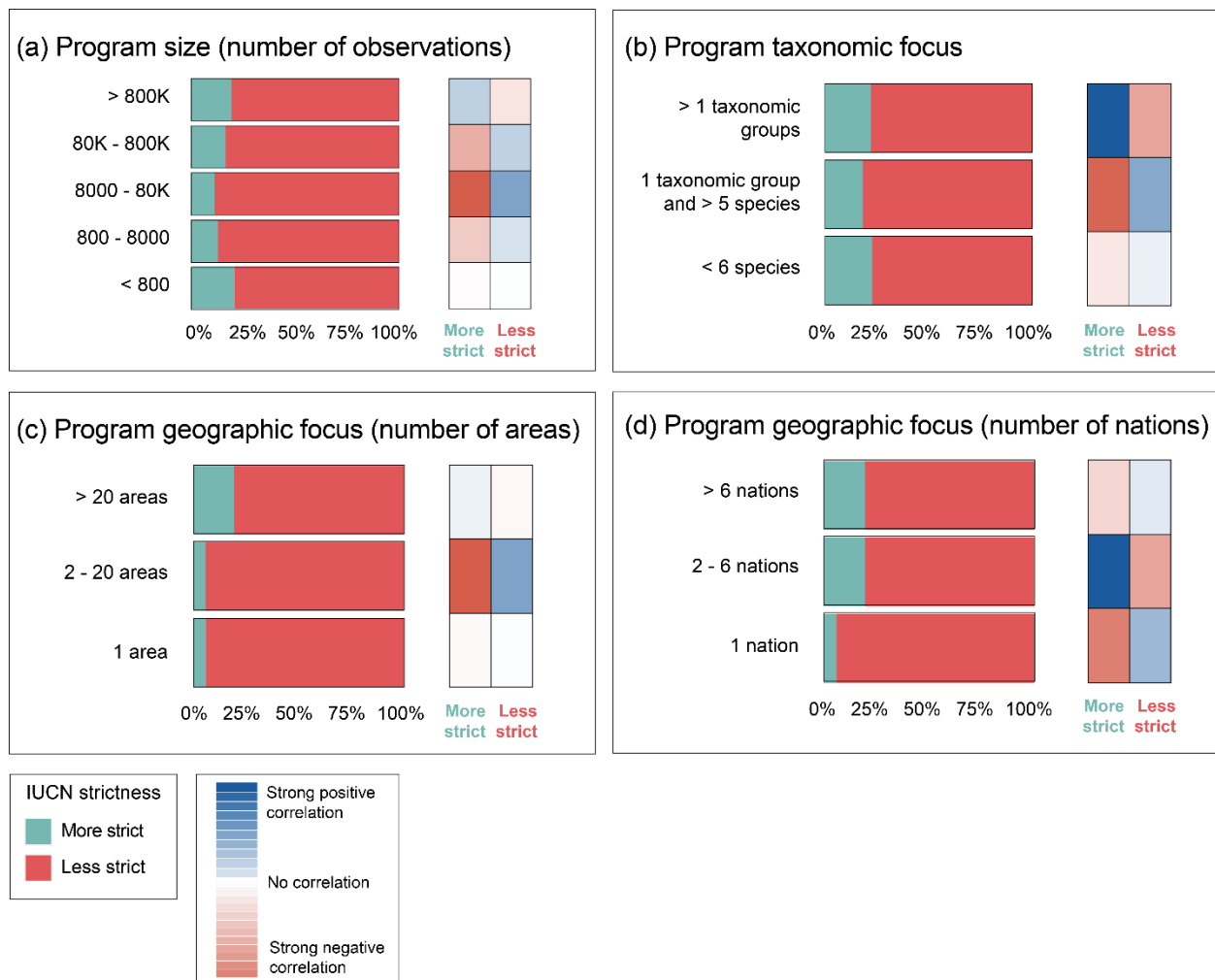
SI FIGURE 2.5. The number of observations of species in each Red List category, recorded by participatory monitoring programs divided by the following characteristics: (a) size of the monitoring program; (b) taxonomic focus of the monitoring program; (c) geographic focus of the monitoring program among protected areas; (d) geographic focus of the monitoring program among nations. The left figures in each panel indicate the distribution of data and the right figures indicate the correlation between the two variables. Chi-squared tests support a relationship between all four monitoring program characteristics and the Red List status of monitored species (a: $\chi^2 = 96400$; b: $\chi^2 = 102822$; c: $\chi^2 = 5535$; d: $\chi^2 = 53376$; all: $p < 0.0001$).



SI FIGURE 2.6. The number of observations recorded by participatory monitoring programs within protected areas of varying size, divided by the following characteristics: (a) size of the monitoring program; (b) taxonomic focus of the monitoring program; (c) geographic focus of the monitoring program among protected areas; (d) geographic focus of the monitoring program among nations. The left figures in each panel indicate the distribution of data and the right figures indicate the correlation between the two variables. Chi-squared tests support a relationship between all four monitoring program characteristics and the size of areas where programs are active (a: $\chi^2 = 431435$; b: $\chi^2 = 149639$; c: $\chi^2 = 110340$; d: $\chi^2 = 2879468$; all: $p < 0.0001$).



SI FIGURE 2.7. The number of observations recorded by participatory monitoring programs within protected areas of varying IUCN protection category strictness, divided by the following characteristics: (a) size of the monitoring program; (b) taxonomic focus of the monitoring program; (c) geographic focus of the monitoring program among protected areas; (d) geographic focus of the monitoring program among nations. The left figures in each panel indicate the distribution of data and the right figures indicate the correlation between the two variables. Chi-squared tests support a relationship between all four monitoring program characteristics and the IUCN protection category of areas where programs are active (a: $\chi^2 = 125846$; b: $\chi^2 = 230117$; c: $\chi^2 = 67268$; d: $\chi^2 = 993737$; all: $p < 0.0001$).



Supplementary References

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