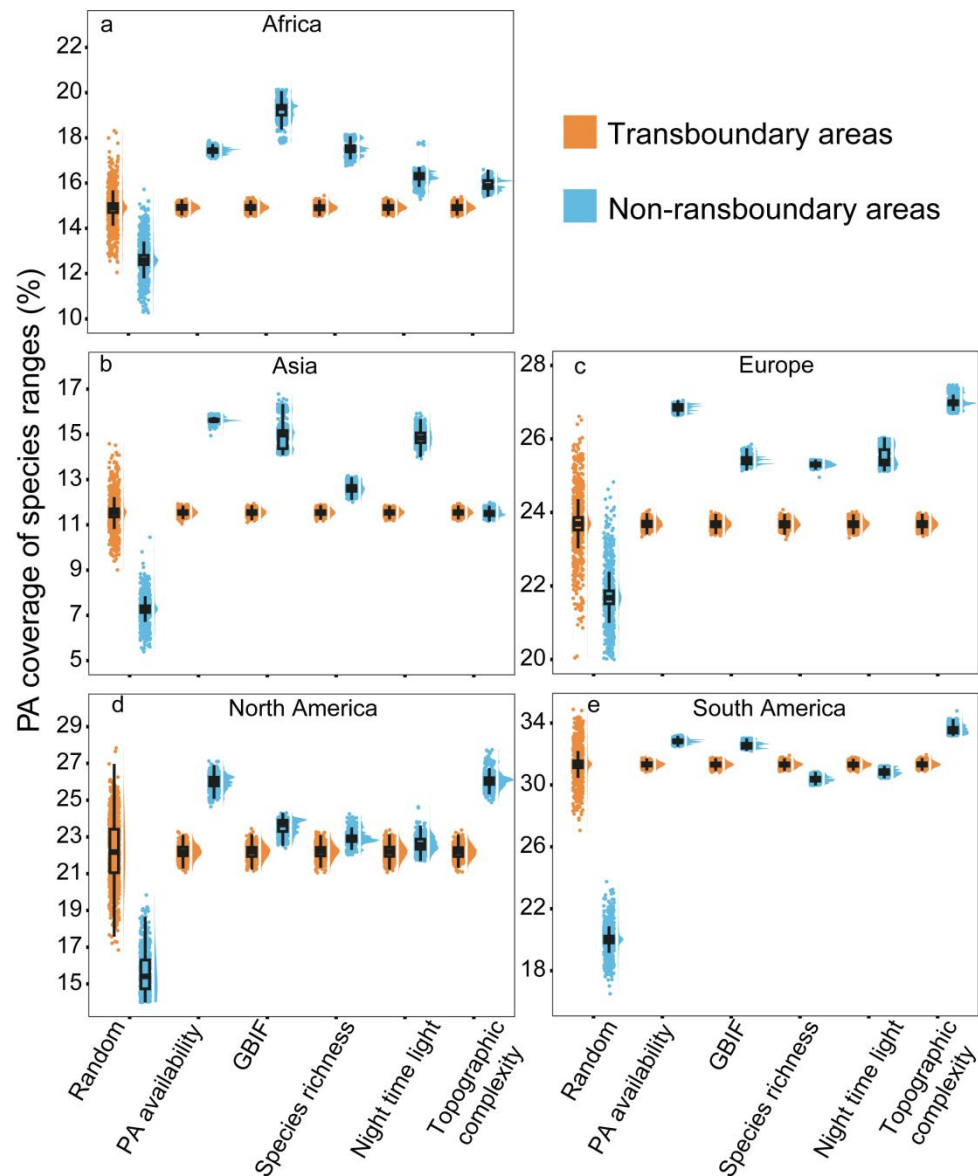


Supplementary Information for

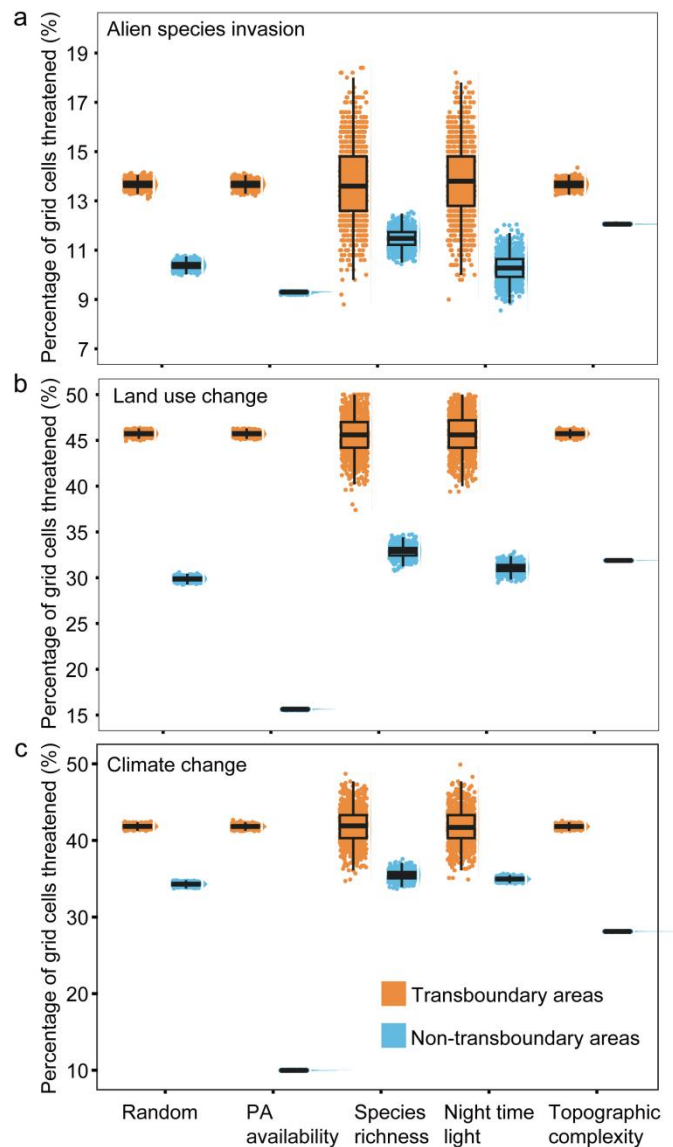
Three-quarters of species' ranges have not been covered by protected areas in global borders

Wenjie Li, Qing Zhang, Zhining Wang, Xuan Liu*

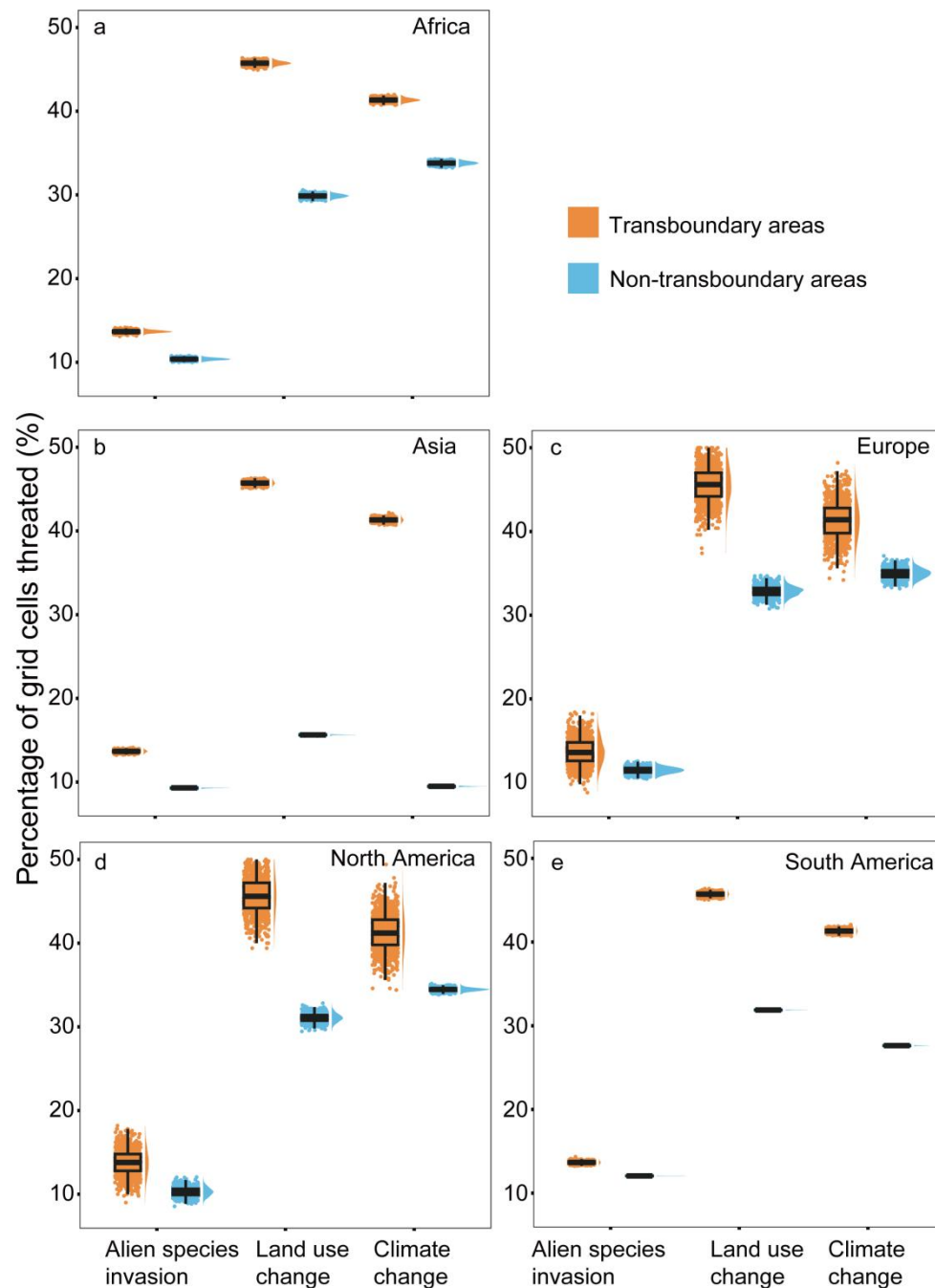
*Corresponding author: liuxuan@ioz.ac.cn



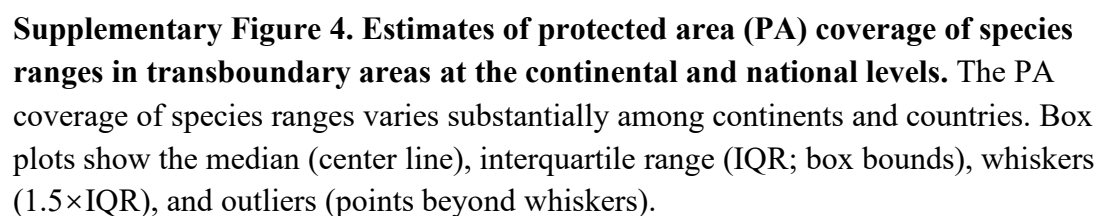
Supplementary Figure 1. Comparison of the protected area (PA) coverage of species ranges in transboundary areas (orange) and non-transboundary areas (blue) across continents. The box plots were generated from 999 mean values ($n = 999$), each calculated from 50,000 randomly selected grid cells of transboundary areas and non-transboundary areas, respectively. These grid cells were selected either randomly completely (Random), or with similar land areas covered by PAs (PA availability), sampling intensities as estimated by the number of GBIF records per grid cell (GBIF), mean species richness (Species richness), socioeconomic conditions (Night time light), and topographic complexity. See Methods for a description of the selection process. In most cases, the PA coverage of species ranges was lower in transboundary areas than in non-transboundary areas after controlling for PA availability and geographical differences in sampling efforts (Kruskal-Wallis test, $P < 0.001$, two-sided; Supplementary Table 3). Box plots show the median (center line), interquartile range (IQR; box bounds), whiskers ($1.5 \times \text{IQR}$), and outliers (points beyond whiskers). Half violin plots show distributions of the values.



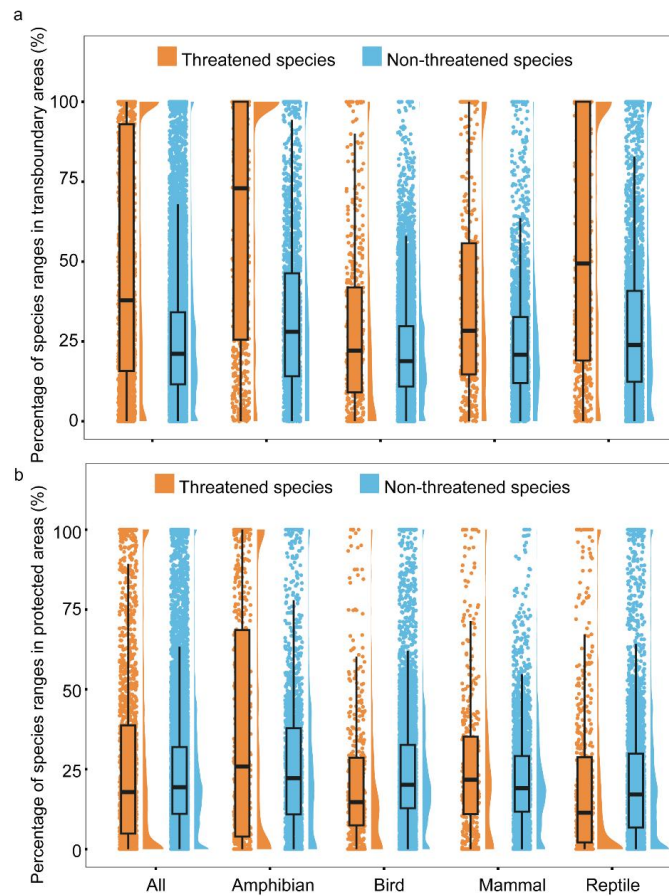
Supplementary Figure 2. Comparison of global change threats in transboundary areas (orange) and non-transboundary areas (blue). The box plots were generated from 999 mean values ($n = 999$), each calculated from 50,000 randomly selected grid cells of transboundary areas and non-transboundary areas, respectively. These grid cells were selected either randomly (Random), or selected with similar land areas covered by PAs (PA availability), mean species richness (Species richness), socio-economic conditions (Night time light), and topographic complexity. In all cases, the global change threats were higher in transboundary areas than in non-transboundary areas (Kruskal-Wallis test, $P < 0.001$, two-sided). Box plots show the median (center line), interquartile range (IQR; box bounds), whiskers ($1.5 \times \text{IQR}$), and outliers (points beyond whiskers). Half violin plots show distributions of the values.



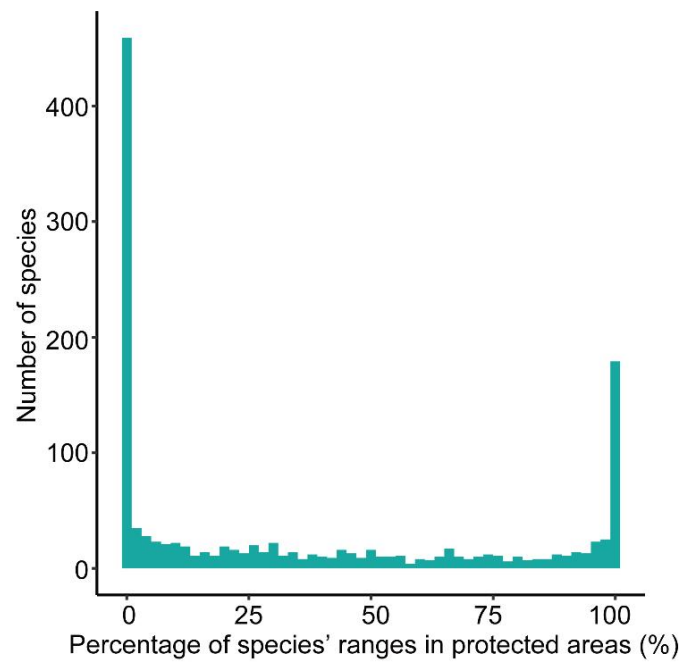
Supplementary Figure 3. Comparison of global change threats in transboundary areas (orange) and non-transboundary areas (blue) across continents. The box plots were generated from 999 mean values ($n = 999$), each calculated from 50,000 randomly selected grid cells of transboundary areas and non-transboundary areas, respectively. These grid cells were selected with similar sampling intensities, as estimated by the number of GBIF records per grid cell. In most cases, global change threats were higher in transboundary areas than in non-transboundary areas (Kruskal-Wallis test, $P < 0.001$, two-sided; Supplementary Table 10). Box plots show the median (center line), interquartile range (IQR; box bounds), whiskers ($1.5 \times \text{IQR}$), and outliers (points beyond whiskers). Half violin plots show distributions of the values.



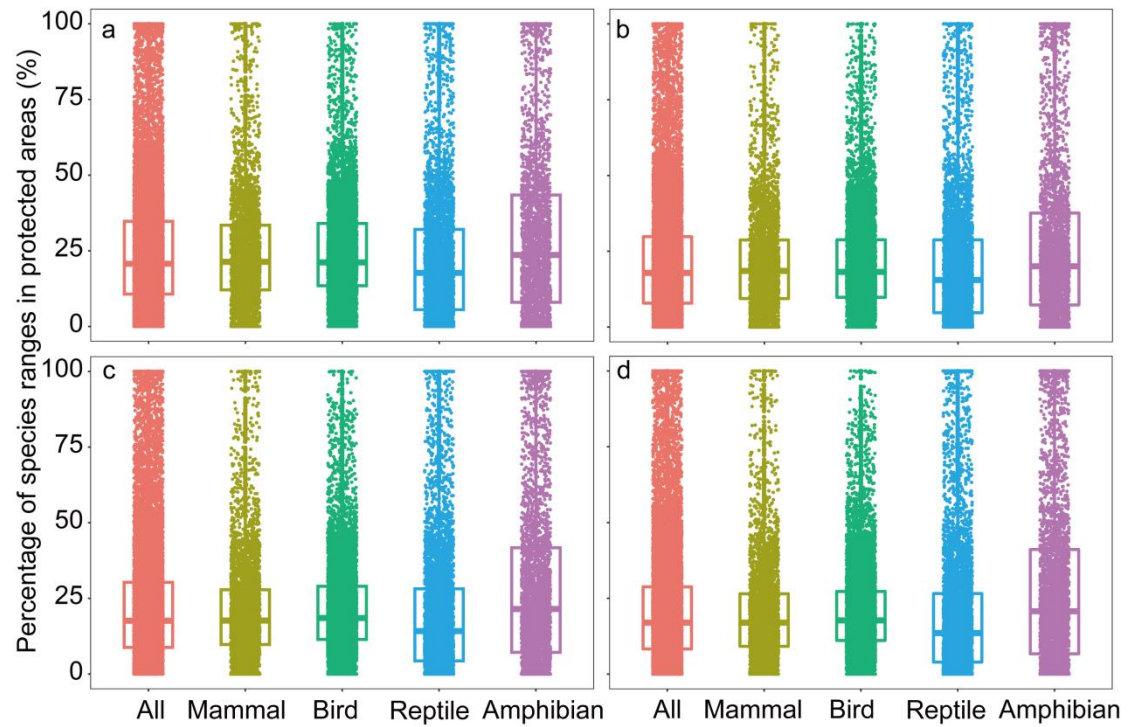
Supplementary Figure 4. Estimates of protected area (PA) coverage of species ranges in transboundary areas at the continental and national levels. The PA coverage of species ranges varies substantially among continents and countries. Box plots show the median (center line), interquartile range (IQR; box bounds), whiskers ($1.5 \times \text{IQR}$), and outliers (points beyond whiskers).



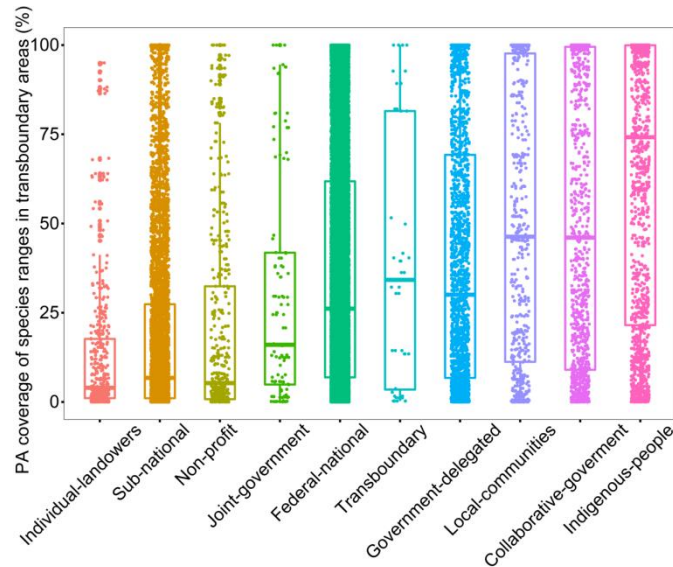
Supplementary Figure 5. Comparison in (a) percentage of species ranges in transboundary areas and (b) percentage of species transboundary ranges in protected areas between species listed as threatened species (Vulnerable, Endangered, or Critically Endangered, in orange) and non-threatened species (Least Concern, Near Threatened, in blue). Box plots show the median (center line), interquartile range (IQR; box bounds), whiskers ($1.5 \times \text{IQR}$), and outliers (points beyond whiskers). Half violin plots show distributions of the values.



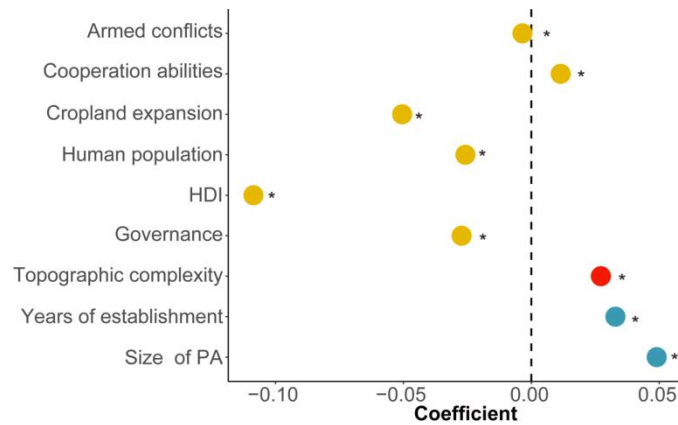
Supplementary Figure 6. Number of species at different percentages of range coverage by protected area (PA) in transboundary areas. We observed that a large proportion of species with all distributional ranges located in transboundary areas have not been covered by PAs in transboundary areas.



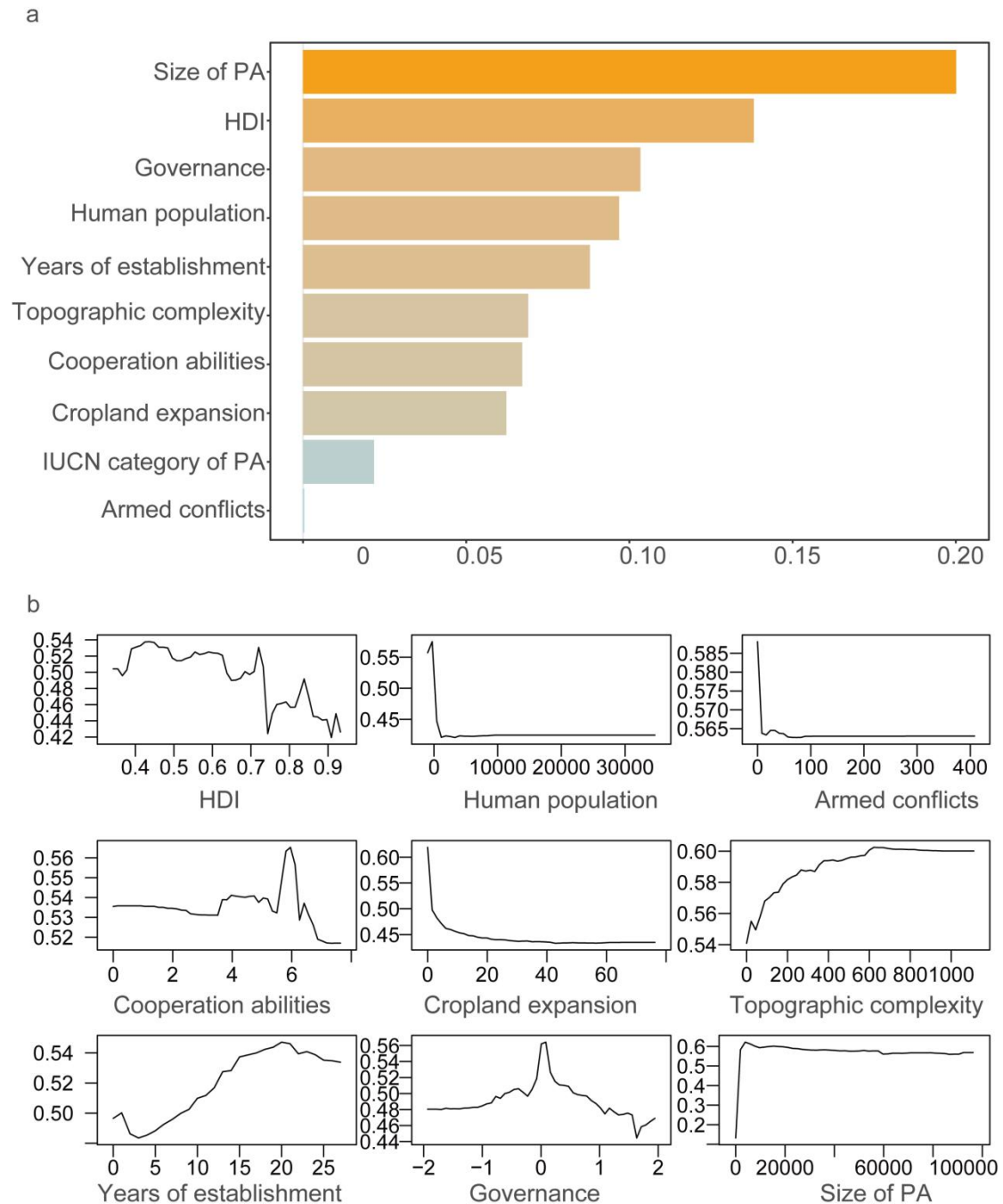
Supplementary Figure 7. Sensitivity analysis using different grid cell sizes and distances to borders defining transboundary areas. Our results were robust to data uncertainties as sensitivity analyses revealed similar findings on the average coverage of species ranges by PAs in transboundary areas using $5 \text{ km} \times 5 \text{ km}$ grid cells with a buffer distance of (a) 25 km or (b) 100 km to the borderlines, and using (c) $10 \text{ km} \times 10 \text{ km}$ grid cells or (d) $25 \text{ km} \times 25 \text{ km}$ grid cells with a buffer distance of 50 km to the borderlines. Box plots show the median (center line), interquartile range (IQR; box bounds), whiskers ($1.5 \times \text{IQR}$), and outliers (points beyond whiskers).



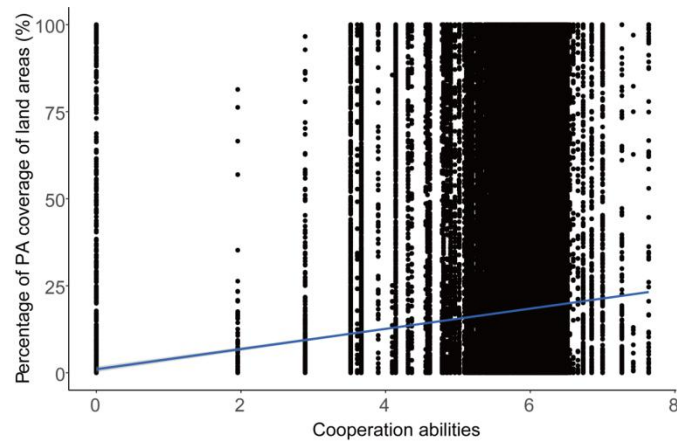
Supplementary Figure 8. The relationship between protected area (PA) coverage of species range and different government types in the transboundary areas. PAs that are governed by indigenous people, local communities, and collaborative governments are among the top three PAs with the highest coverage of species ranges. The government types of each protected area were coded from WDPA as stated in the ‘GOV-TYPE’ field. Box plots show the median (center line), interquartile range (IQR; box bounds), whiskers ($1.5 \times \text{IQR}$), and outliers (points beyond whiskers).



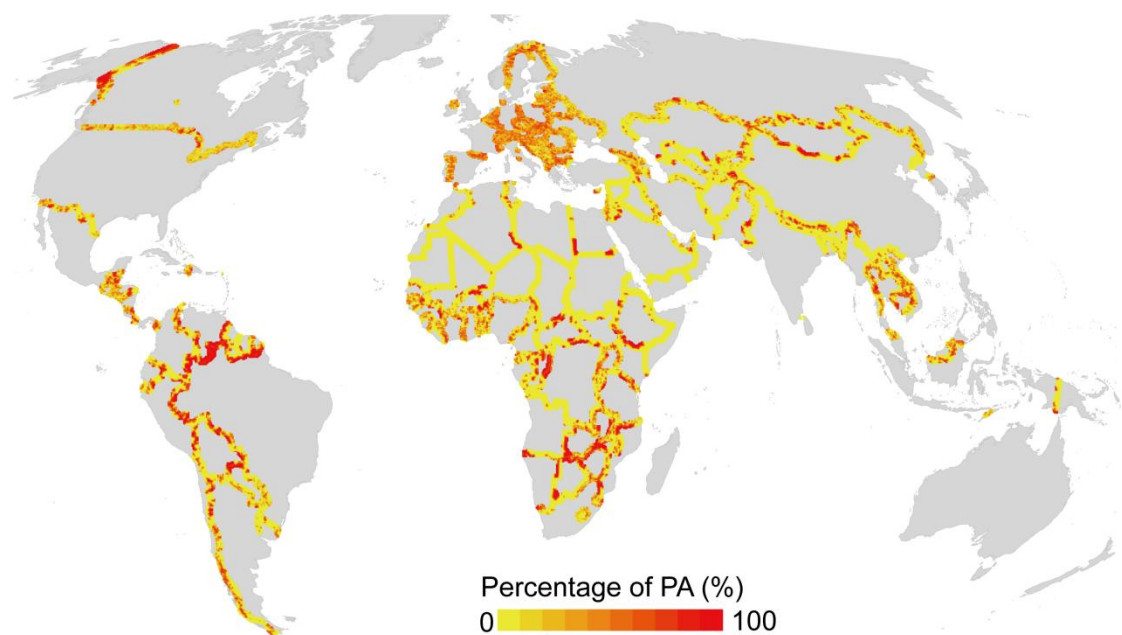
Supplementary Figure 9. Coefficients of the generalized additive model (GAM) to test for the correlations between different predictor variables and protected area (PA) coverage of species ranges after accounting for spatial autocorrelation. This test was performed by applying a GAM to the same combination of factors as in the LMM approach, plus a tensor product of longitude and latitude to explicitly simulate spatial autocorrelation. The points represent the mean estimates from the GAM, and error bars indicate 95% confidence interval estimates of the means. Positive values indicate that the PA coverage increases with the variable, while negative values indicate that the PA coverage decreases with the variable. The yellow, red, and blue dots indicate socioeconomic, ecological, and PA characteristic factors, respectively. Asterisks indicate statistical support for the effects. The standard errors of the estimates are very small and not visible at this scale. HDI is for human development index.



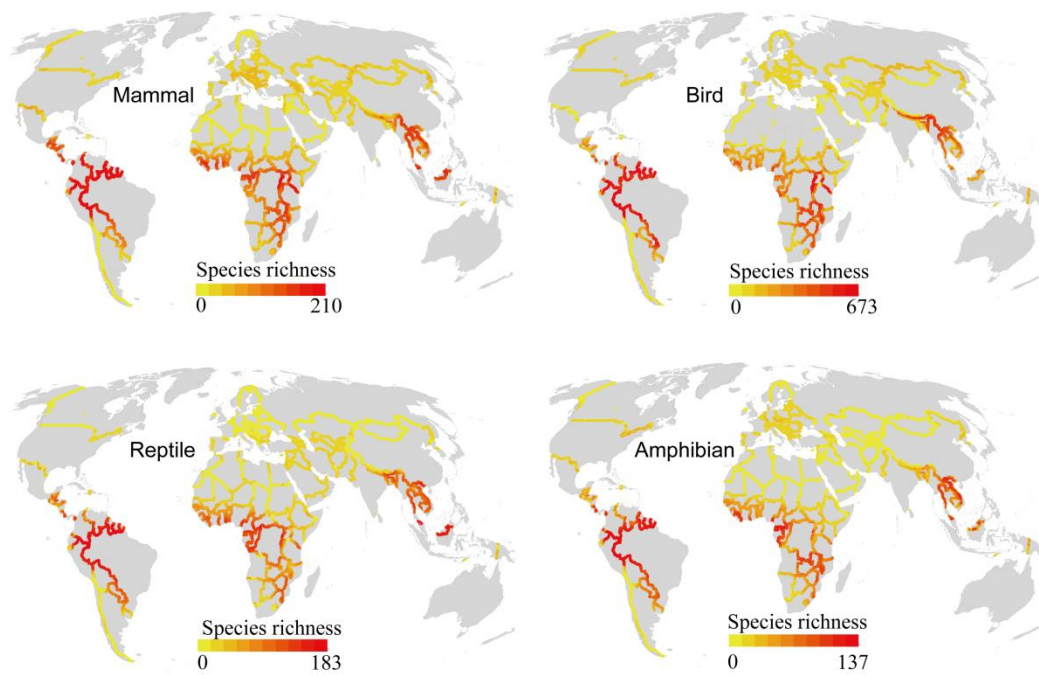
Supplementary Figure 10. Random forest analyses showing correlations of different predictor variables with the protected area (PA) coverage of species ranges in transboundary areas. (a) Random forest variable importance indices (mean decrease accuracy) for the geographic patterns of the PA coverage of species ranges. Colors indicate different predictors. **(b)** Partial dependence plot for each factor in the random forest model, ranked by the mean decrease accuracy. The plot depicts the correlation between a factor and the PA coverage of species ranges. HDI is for human development index.



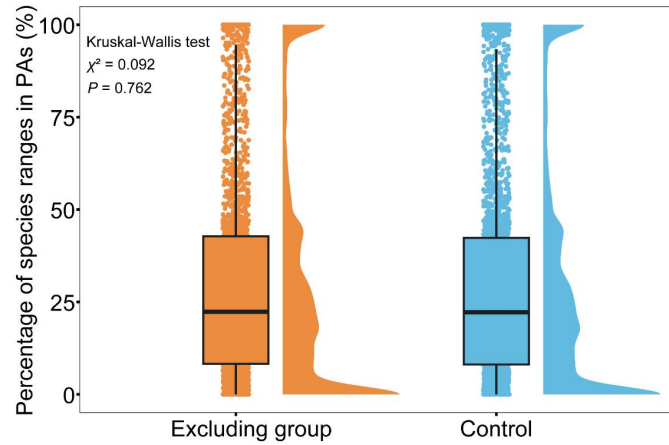
Supplementary Figure 11. The relationship between cooperation abilities and the percentage of protected area (PA) in transboundary areas. We find a positive correlation between bilateral cooperation abilities and the percentage of PAs in transboundary areas (LMM, estimate $\pm$ SEM, 0.061 ± 0.008 , $t = 7.705$, $P < 0.001$; $n = 824,518$). The blue line indicates the linear regression with 95% CI.



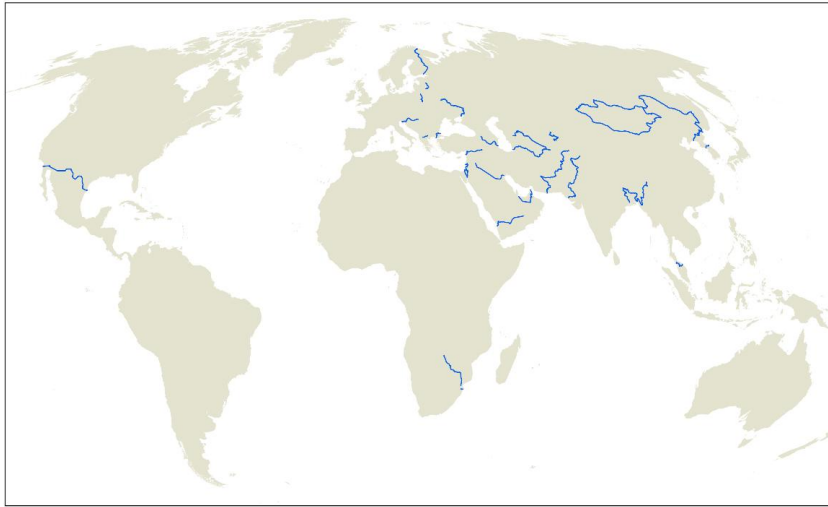
Supplementary Figure 12. Global pattern of protected area (PA) coverage of land areas in transboundary areas. Deeper colors correspond to a greater percentage of PA coverage. The colour scale is based on 10 quantile classes.



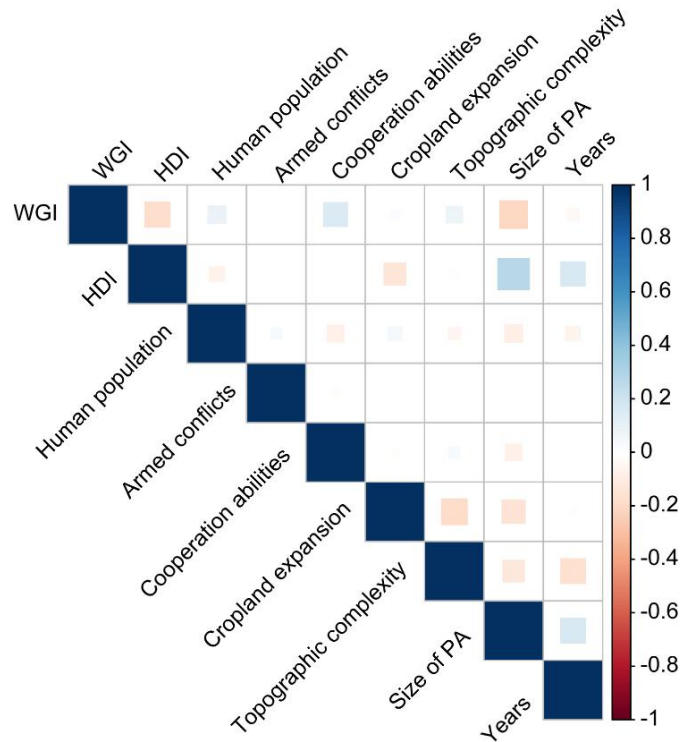
Supplementary Figure 13. Global distribution of species richness in transboundary areas. Deeper colors correspond to a greater species richness. The distribution of species' transboundary ranges was concentrated primarily in Southeast Asia, South America, Central Africa and West Africa.



Supplementary Figure 14. Effects of species with range maps stopping at the country boundaries. The orange color indicates analysis excluding species with range maps stopping at the country boundaries (Excluding group, $n = 18,231$) and blue indicates all species (Control, $n = 19,039$), respectively. Box plots show the median (center line), interquartile range (IQR; box bounds), whiskers ($1.5 \times \text{IQR}$), and outliers (points beyond whiskers). Half violin plots show distributions of the values.



Supplementary Figure 15. Mapping of physical fencing distributions across the globe. The blue lines show the global fencings, which are mainly located in Eurasia. Physical barrier data are based on Titley et al. (2021)¹.



Supplementary Figure 16. Correlation analysis for predictor variables used in regression analysis. HDI is for human development index. WGI is for national governance level. Years is for years of establishment of protected areas. No correlation coefficient was larger than 0.7.

Supplementary Table 1. Number and proportion of the assessed species that have distribution ranges at least partly in transboundary areas.

Class	Total species assessed	Number of species in transboundary areas	%
Amphibian	7,231	2,943	40.7
Reptile	10,899	4,906	45.1
Bird	10,987	7,710	70.2
Mammal	5,577	3,480	62.4
Total	34,694	19,039	54.9

Supplementary Table 2. Protected area (PA) coverage of land and species ranges in transboundary areas.

Group	PA coverage of land (%)	PA coverage of species ranges (%)
Global	17.85	23.0
Africa	15.69	20.43
Asia	11.39	17.0
Europe	23.50	25.25
North America	21.90	18.67
South America	31.40	31.98

Supplementary Table 3. Comparison of the PA coverage of species ranges in transboundary areas and non-transboundary areas after controlling for protected area (PA) availability and sampling bias using the Kruskal-Wallis test.

Group	Random		PA availability		Species richness		GBIF		Night time light		Topographic complexity	
	χ^2	<i>P</i>	χ^2	<i>P</i>	χ^2	<i>P</i>	χ^2	<i>P</i>	χ^2	<i>P</i>	χ^2	<i>P</i>
Global	1497.6	<2.2×10⁻¹⁶	1497.8	<2.2×10⁻¹⁶	1497.8	<2.2×10⁻¹⁶	1497.8	<2.2×10⁻¹⁶	1497.8	<2.2×10⁻¹⁶	1497.8	<2.2×10⁻¹⁶
Africa	1379.7	<2.2×10⁻¹⁶	1497.8	<2.2×10⁻¹⁶	1497.8	<2.2×10⁻¹⁶	1497.8	<2.2×10⁻¹⁶	1497.7	<2.2×10⁻¹⁶	1497.8	<2.2×10⁻¹⁶
Asia	1497.3	<2.2×10⁻¹⁶	1497.8	<2.2×10⁻¹⁶	1497.8	<2.2×10⁻¹⁶	1497.8	<2.2×10⁻¹⁶	1497.8	<2.2×10⁻¹⁶	44.235	<2.91×10⁻¹¹
Europe	1257.5	<2.2×10⁻¹⁶	1497.8	<2.2×10⁻¹⁶	1497.8	<2.2×10⁻¹⁶	1498.6	<2.2×10⁻¹⁶	1497.8	<2.2×10⁻¹⁶	1497.8	<2.2×10⁻¹⁶
North America	1493.0	<2.2×10⁻¹⁶	1497.8	<2.2×10⁻¹⁶	1145.2	<2.2×10⁻¹⁶	1477.4	<2.2×10⁻¹⁶	472.63	<2.2×10⁻¹⁶	1497.8	<2.2×10⁻¹⁶
South America	1497.8	<2.2×10⁻¹⁶	1497.8	<2.2×10⁻¹⁶	1497.8	<2.2×10⁻¹⁶	1497.8	<2.2×10⁻¹⁶	1329.7	<2.2×10⁻¹⁶	1497.8	<2.2×10⁻¹⁶

Supplementary Table 4. Results from model averaging analyses on the relationship of different ecological and socioeconomic factors with the protected area (PA) coverage of species ranges in transboundary areas at the global level.

The best model selects within 2 AIC units (i.e., $\Delta AIC < 2$) includes 9 predictor variables shown in the table.

Parameter	estimate	s.e.	t value	Pr(> t)
Intercept	-0.081	0.028	-2.86	0.0047
Cropland expansion	-0.048	0.0006	-80.04	<0.001
Human development index	-0.012	0.0009	-13.81	<0.001
Bilateral cooperation abilities	0.054	0.0052	10.37	<0.001
Human population density	-0.02	0.0005	-36.1	<0.001
Governance index	0.014	0.0014	10.21	<0.001
Topographic complexity	0.064	0.0008	76.88	<0.001
Years of establishment of PA	0.042	0.0007	61.1	<0.001
Size of PAs	0.056	0.001	53.65	<0.001
IUCN categories of PA	0.02	0.0014	14.31	<0.001

Supplementary Table 5. The top models investigating the relationship between different ecological and socioeconomic factors and the protected area (PA) coverage of species ranges in transboundary areas according to the information theory (Akaike's Information Criterion, AIC). The best model selects within 2 AIC units (i.e., $\Delta AIC < 2$) includes 9 significant predictor variables as shown in the table.

Variables	Model1	Model2	Model3	Model4	Model5
Frequency of armed conflicts			-0.001	-0.001	
Cropland expansion	-0.048	-0.048	-0.048	-0.048	-0.048
Human development index	-0.012	-0.012	-0.012	-0.012	-0.011
Bilateral cooperation abilities	0.054	0.054	0.054	0.054	0.053
Human population density	-0.02	-0.02	-0.02	-0.02	-0.02
Governance index	0.014	0.014	0.014	0.014	
Topographic complexity	0.064	0.064	0.064	0.064	0.064
Size of PAs	0.0564	0.0564	0.0564	0.0564	0.0564
IUCN categories of PA	0.02	0.02	0.020	0.020	0.020
Years of establishment	0.042	0.042	0.042	0.042	0.041
AIC	168,607.56	168,615.58	168,618.68	168,626.7	168,698.38
R ²	0.325	0.325	0.325	0.325	0.325
ΔAIC	0	8.02	11.12	19.13	90.82

Supplementary Table 6. Results from model averaging analyses on the relationship between different ecological and socioeconomic factors and the protected area (PA) coverage of species ranges in transboundary areas in Africa. Standardized and centered model-averaged estimates, standard errors (s.e.), adjusted standard errors (Adj. s.e.), z values, and significance values. Only those variables that are included in the best model ($\Delta\text{AIC} < 2$) are shown in the table.

Parameter	estimate	s.e.	Adj. s.e.	z value	Pr(> z)
Frequency of armed conflicts	-0.0036	0.001	0.001	3.62	<0.001
Cropland expansion	-0.036	0.001	0.001	31.94	<0.001
Bilateral cooperation abilities	0.069	0.008	0.008	9.08	<0.001
Human population density	-0.027	0.001	0.001	21.42	<0.001
Governance index	0.006	0.002	0.002	3.60	<0.001
Topographic complexity	0.006	0.001	0.001	4.77	<0.001
Size of PA	0.053	0.002	0.002	9.08	<0.001
Years of establishment	0.019	0.002	0.002	9.90	<0.001

Supplementary Table 7. Results from model averaging analyses on the relationship between different ecological and socioeconomic factors and the protected area (PA) coverage of species ranges in transboundary areas in Asia. Standardized and centered model-averaged estimates, standard errors (s.e.), adjusted standard errors (Adj. s.e.), z values, and significance values. Only those variables that are included in the best model ($\Delta AIC < 2$) are shown in the table.

Parameter	estimate	s.e.	Adj. s.e.	z value	Pr(> z)
Cropland expansion	-0.051	0.002	0.002	27.37	<0.001
Human population density	-0.027	0.001	0.001	21.42	<0.001
HDI	-0.008	0.002	0.002	4.18	<0.001
Topographic complexity	0.1	0.003	0.003	24.5	<0.001
IUCN categories of PA	0.055	0.005	0.005	11.00	<0.001
Size of PA	0.069	0.003	0.003	24.50	<0.001
Years of establishment of PA	-0.011	0.003	0.003	3.58	<0.001

Supplementary Table 8. Results from model averaging analyses on the relationship between different ecological and socioeconomic factors and the protected area (PA) coverage of species ranges in transboundary areas in Europe. Standardized and centered model-averaged estimates, standard errors (s.e.), adjusted standard errors (Adj. s.e.), z values, and significance values. Only those variables that are included in the best model ($\Delta\text{AIC} < 2$) are shown in the table.

Parameter	estimate	s.e.	Adj. s.e.	z value	Pr(> z)
Cropland expansion	-0.061	0.001	0.001	61.96	<0.001
Human population density	-0.070	0.001	0.001	64.12	<0.001
Governance	0.012	0.002	0.002	7.87	<0.001
Topographic complexity	0.090	0.001	0.001	60.68	<0.001
IUCN categories of PA	0.028	0.002	0.002	14.05	<0.001
Size of PA	0.044	0.001	0.001	51.88	<0.001
Years of establishment of PA	0.051	0.001	0.001	54.04	<0.001

Supplementary Table 9. Results from the model averaging analyses on the relationship between different ecological and socioeconomic factors and the protected area (PA) coverage of species ranges in transboundary areas in North America. Standardized and centered model-averaged estimates, standard errors (s.e.), adjusted standard errors (Adj. s.e.), z values, and significance values. Only those variables that are included in the best model ($\Delta AIC < 2$) are shown in the table.

Parameter	estimate	s.e.	Adj. s.e.	z value	Pr(> z)
Cropland expansion	-0.032	0.003	0.003	11.47	<0.001
Human population density	-0.036	0.003	0.003	12.56	<0.001
HDI	0.410	0.059	0.059	6.99	<0.001
Topographic complexity	0.060	0.003	0.003	20.12	<0.001
IUCN categories of PA	0.029	0.009	0.009	3.35	<0.001
Size of PA	0.094	0.003	0.003	29.44	<0.001

Supplementary Table 10. Results from model averaging analyses on the relationship between different ecological and socioeconomic factors and the protected area (PA) coverage of species ranges in transboundary areas in South America. Standardized and centered model-averaged estimates, standard errors (s.e.), t values, and significance values. Only those variables that are included in the best model ($\Delta AIC < 2$) are shown in the table.

Parameter	estimate	s.e.	t value	Pr(> t)
Cropland expansion	-0.018	0.001	-17.78	<0.001
Human population density	-0.012	0.001	-11.96	<0.001
HDI	-0.08	0.004	-21.04	<0.001
Governance	0.069	0.004	18.40	<0.001
Topographic complexity	0.011	0.001	8.29	<0.001
IUCN categories of PA	0.023	0.003	8.62	<0.001
Size of PA	0.039	0.002	24.99	<0.001

Supplementary Table 11. Kruskal-Wallis test on the comparison of global change threats in transboundary areas and non-transboundary areas after controlling for sampling bias.

Group	Alien species invasion		Land use change		Climate change	
	χ^2	P	χ^2	P	χ^2	P
Global	748.59	$<2.2 \times 10^{-16}$	749.25	$<2.2 \times 10^{-16}$	749.25	$<2.2 \times 10^{-16}$
Africa	189.09	$<2.2 \times 10^{-16}$	494.58	$<2.2 \times 10^{-16}$	443.1	$<2.2 \times 10^{-16}$
Asia	1498.3	$<2.2 \times 10^{-16}$	1497.9	$<2.2 \times 10^{-16}$	1497.9	$<2.2 \times 10^{-16}$
Europe	1490.9	$<2.2 \times 10^{-16}$	563.63	$<2.2 \times 10^{-16}$	1270.5	$<2.2 \times 10^{-16}$
North America	1494.5	$<2.2 \times 10^{-16}$	1299.8	$<2.2 \times 10^{-16}$	0.622	0.4304
South America	1291.2	$<2.2 \times 10^{-16}$	822.91	$<2.2 \times 10^{-16}$	275.54	$<2.2 \times 10^{-16}$

Supplementary Table 12. Summary for the existing cross-boundary conservation initiatives across the globe².

Transboundary initiative	The definitions and explanation	Examples
Transboundary Protected Area	A Transboundary Protected Area is a clearly defined geographical space that includes protected areas that are ecologically connected across one or more international boundaries and involves some form of cooperation.	Lake Neusiedl National Park in Austria and Seewinkel Fertő-Hanság National Park in Hungary are a transboundary wetland area in the western part of the Carpathian Basin, at the last foothills of the Alps, Austria and Hungary. The bilateral national park was formally opened in 1994. The setting up of this Transboundary Protected Area marked the end of years of division along the so-called Iron Curtain. http://www.nationalpark-neusiedlersee-seewinkel.at/ ; http://www.ferto-hansag.hu .
Transboundary Conservation Landscape	A Transboundary Conservation Landscape is an ecologically connected area that includes both protected areas and multiple resource use areas across one or more international boundaries and involves some form of cooperation.	The Greater Virunga Landscape encompasses a network of protected areas located in the Democratic Republic of Congo, Rwanda and Uganda. The Virunga National Park in the Democratic Republic of Congo is contiguous with Semliki, Rwenzori, Queen Elizabeth and Mgahinga Gorilla National Parks in Uganda. Mgahinga Gorilla National Park also adjoins the Volcanoes National Park in Rwanda. Bwindi Impenetrable National Park and a chain of wildlife and forest reserves in Uganda are located in between. This southern area of the landscape supports the entire world population of mountain gorillas. Queen Elizabeth National Park connects with Virunga National Park in the Ishasha sector. Ecologically, Kalinzu and Kasyoha-Kitomi Forest Reserves are part of this landscape. Kyambura and Kigezi Wildlife Reserves also buffer Queen Elizabeth National Park and lie within the landscape area.

Transboundary Migration Conservation Area	Transboundary Migration Conservation Areas are wildlife habitats in two or more countries that are necessary to sustain populations of migratory species and involve some form of cooperation.	The Convention on the Conservation of Migratory Species of Wild Animals (CMS) is the key instrument for creating Transboundary Migration Conservation Area.
A Park for Peace	A Park for Peace is a special designation that may be applied to any of the three types of Transboundary Conservation Areas, and is dedicated to the promotion, celebration and/or commemoration of peace and cooperation.	(1) The Waterton-Glacier International Peace Park is a good example of a Park for Peace established to celebrate longstanding peaceful relations between Canada and the USA. They may also help to reinforce peace and cooperation: the Cordillera del Condor shows how transboundary conservation efforts can help foster peace and improve relationships between partners through working together. (2) A Park for Peace could be used to promote peace at some point in future: for example, the on-going but as-yet unrealized project to create an EcoPeace Park along the Demilitarized Zone (DMZ) on the Korean peninsula.
International and regional approaches to transboundary conservation practice	There are important related designations for transboundary conservation at both the international and regional levels.	The UNESCO Man and the Biosphere Programme promotes interdisciplinary approaches to biodiversity conservation and the sustainable use of natural resources, and maintains the World Network of Biosphere Reserves.

Supplementary Table 13. Variables used to control for potential differences in sampling efforts quantified by various anthropogenic factors in comparison analyses of protected area (PA) coverage of species ranges and facing global change factors between transboundary and non-transboundary areas.

Variables	Proxy variable	Description	Data source
PA availability	PA availability is defined as the percentage of land areas covered by PAs in transboundary areas and non-transboundary areas	The locations of PAs are non-random and often biased toward remote areas, and farther from population centers ³ .	World Database on Protected Areas. Available at: https://www.protectedplanet.net/en .
Species richness	Total number of species per grid cell	The number of species varied distinctly among regions, which reflect differences in need for biodiversity conservation investment ⁴ .	Mammals and amphibians: IUCN Red List of Threatened Species, (https://www.iucnredlist.org). Birds: Handbook of the Birds of the World and BirdLife International digital checklist of the birds of the world (http://datazone.birdlife.org/userfiles/file/Species/Taxonomy/IBW-BirdLife_Checklist_v7_Dec22.zip). Reptiles: GARD 1.7 (https://doi.org/10.5061/dryad.9cnp5hqmb).
Sampling efforts	GBIF records	We considered the number of records provided by GBIF as a proxy to account for spatial variation in sampling efforts.	Available at: www.gbif.org ; https://doi.org/10.15468/dl.qn6kww .
Human population density and wealth	Nighttime light index	Nightlights have been widely used as an indicator of economic status. Nightlights are a robust proxy for GDP, poverty, inequality in human development, and	Li <i>et al.</i> 2020 ⁶ .

Topographic complexity	The difference between the maximum and minimum altitudes	informal economic activities, especially in developing countries ⁵ . High topographic complex can create a wide variety of habitats and environmental niches, which may attract more conservation attentions ⁷ .	EarthEnv. Available at http://www.earthenv.org/topography .
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Table 14. Proposed relationships between the ecological and socioeconomic factors and the protected area (PA) coverage of species ranges.

Parameter	Predicted effect	Rationale	Database	Description of database
Governance effectiveness	Positive	The government effectiveness indicator reflects perceptions of the quality of public services, the quality of the civil service and the degree of its independence from political pressures, the quality of policy formulation and implementation, and the credibility of the government's commitment to such policies. High governance is considered the primary driver of PA designation ⁸ .	World Bank Governance Indicators ⁹	This dataset contains six governance metrics that combined create a governance score. This score is available for the majority of countries and is measured annually, ranging from 1996-2022. Available at: https://info.worldbank.org/governance/wgi/ .
Bilateral cooperation abilities	Positive	Neighboring countries with higher bilateral collaborations might be easier to establish cross-border conservation alliance and design systematic or strategic PAs ¹⁰ , therefore have higher PA coverage.	Worldwide Integrated Crisis Early Warning System ¹¹	This is a daily dataset of coded interactions between socio-political actors from 1995 to 2017. This was the longest available time frame to assess collaboration between neighboring countries and is used to determine the extent to which neighbors have been cooperative in the past as an indicator for potential collaboration.

Human development index (HDI)	Positive	Countries with high development index are related to higher development level, and can also have higher capacity to protect biodiversity ¹² .	UN human development index	HDI is a synthetic measure capturing elements of life expectancy, education, and wealth. This dataset describes the human development index scores for the majority of countries, which is measured annually, and ranges from 1990 to 2022. Available at: https://hdr.undp.org/ .
Frequency of armed conflicts	Negative	The high incidence of armed conflicts poses significant challenges in achieving conservation targets ¹³⁻¹⁴ . Regions with higher intensity of conflicts are likely to have less PA coverage.	UCDP-PRIO ¹⁵	The UCDP/PRIO Armed conflict dataset lists conflicts between 1946-2022. This dataset is global in extent. Available at: https://ucdp.uu.se/downloads/ .
Human population density	Negative	High human density is likely associated with increased anthropogenic land uses and represents competition for space. Areas with higher human population density are thus expected to have less PA coverage ¹⁶ .	GPWv4 database ¹⁷	The Gridded Population of the World, Version 4 (GPWv4): Administrative Unit Center Points with Population Estimates consists of UN-adjusted estimates of human population counts and densities for the years 2000, 2005, 2010, 2015 and 2020 by administrative unit center point (centroid) location. Available at: https://doi.org/10.7927/H4F47M2C .

Cropland expansion	Negative	Areas suitable for agriculture are less prone to protection. Protected area designations tend to be biased towards places that have low value to human activities like fisheries and agriculture ^{18,19} . Thus, countries with lower dependency upon terrestrial resources are expected to have greater PA coverage.	Potapov et al.'s cropland data ²⁰	This dataset contains global time series cropland maps from 2000 to 2019 at a spatial resolution of 30 m. Available at https://glad.umd.edu/dataset/croplands .
Topographic complexity	Positive	High topographic complex can create a wide variety of habitats and environmental niches where higher terrestrial biodiversity is found, which may attract more conservation attentions ⁷ .	EarthEnv	Available at http://www.earthenv.org/topography .
UCN category of PA	Positive	A correlation exists between the biophysical properties of an area and its management, with stricter protection typically designated in areas of higher altitude, lower accessibility and steeper slopes when compared to other categories ²¹⁻²³ .		
Size of PA	Positive	Larger protected areas may allow a greater fraction of speices with wide home ranges to remain protected ^{24,25} .	World Database on Protected Areas	This dataset describes the spatial distribution of PAs from 1960-2023, representing by a series of polygons. Available at: https://www.protectedplanet.net/en .
Years of establishment of PA	Positive	The years of establishment measures the age of a PA. New PAs may be established in locations that minimize conflict with local community, but are not targeting high diversity of threatened species ³ .		

References

1. Titley, M. A., Butchart, S. H. M., Jones, V. R., Whittingham, M. J. & Willis, S. G. Global inequities and political borders challenge nature conservation under climate change. *Proc. Natl. Acad. Sci. U. S. A.* **118**, e2011204118 (2021). doi: 10.1073/pnas.2011204118.
2. IUCN (World Conservation Union) World Commission on Protected Areas, Global Transboundary Conservation Network. 2011. "Types of transboundary conservation practice." Accessed November 22, 2011. <http://tbpa.net/page.php?ndx=83>."
3. Venter, O. *et al.* Bias in protected-area location and its effects on long-term aspirations of biodiversity conventions. *Conserv. Biol.* **32**, 127–134 (2018). doi: 10.1111/cobi.12970.
4. Jenkins, C. N., Pimm, S. L. & Joppa, L.N. Global patterns of terrestrial vertebrate diversity and conservation, *Proc. Natl. Acad. Sci. U. S. A.* **110**, E2602–E2610 (2013). doi: 10.1073/pnas.1302251110.
5. Ellis, E. C., Klein Goldewijk, K., Siebert, S., Lightman, D. & Ramankutty, N. Anthropogenic transformation of the biomes, 1700 to 2000. *Glob. Ecol. Biogeogr.* **19**, 589–606 (2010). doi: 10.1111/j.1466-8238.2010.00540.x.
6. Li, X., Zhou, Y., Zhao, M. & Zhao, X. A harmonized global nighttime light dataset 1992–2018. *Sci. Data* **7**, 168 (2020). doi: 10.1038/s41597-020-0510-y.
7. Stein, A. & Kreft, H. Terminology and quantification of environmental heterogeneity in species-richness research. *Biol. Rev.* **90**, 815–836 (2015). doi: 10.1111/brv.12135.
8. Amano, T. *et al.* Successful conservation of global waterbird populations depends on effective governance. *Nature* **553**, 199–202 (2017). doi: 10.1038/nature25139.
9. Johnson, T. F., Isaac, N. J. B., Paviolo, A. & González-Suárez, M. Socioeconomic factors predict population changes of large carnivores better than climate change or habitat loss. *Nat. Commun.* **14**, 74 (2023). doi: 10.1038/s41467-022-35665-9.
10. Pouzols, F. M. *et al.* Global protected area expansion is compromised by projected land-use and parochialism. *Nature* **516**, 383–386 (2014). doi: 10.1038/nature14032.

11. Boschee, E. *et al.* ICEWS Coded Event Data (Harvard Dataverse, 2015); <https://doi.org/10.7910/DVN/28075>.
12. Fox, H. E. *et al.* Explaining global patterns and trends in marine protected area (MPA) development. *Mar. Policy* **36**, 1131–1138 (2012). doi: 10.1016/j.marpol.2012.02.007.
13. Hammill, E., Tulloch, A. I. T., Possingham, H. P., Strange, N. & Wilson, K. A. Factoring attitudes towards armed conflict risk into selection of protected areas for conservation. *Nat. Commun.* **7**, 11042 (2016). doi: 10.1038/ncomms11042.
14. Hanson, T. *et al.* Warfare in Biodiversity Hotspots. *Conserv. Biol.* **23**: 578–587 (2009). doi: 10.1111/j.1523-1739.2009.01166.x.
15. Davies, S., Pettersson, T. & Öberg, M. Organized violence 1989–2022, and the return of conflict between states. *J. Peace Res.* **60**, 691–708 (2023). doi: 10.1177/00223433231185169.
16. Venter, O. *et al.* Sixteen years of change in the global terrestrial human footprint and implications for biodiversity conservation. *Nat. Commun.* **7**, 12558 (2016). doi: 10.1038/ncomms12558.
17. Center for International Earth Science Information Network - CIESIN - Columbia University. Gridded Population of the World, Version 4 (GPWv4): Population Density Adjusted to Match 2015 Revision UN WPP Country Totals, Revision 11, Palisades, New York: NASA Socioeconomic Data and Applications Center (SEDAC, 2018); <https://doi.org/10.7927/H4F47M65>.
18. Loucks, C., Ricketts, T. H., Naidoo, R., Lamoreux, J. & Hoekstra, J. Explaining the global pattern of protected area coverage: relative importance of vertebrate biodiversity, human activities and agricultural suitability. *J. Biogeogr.* **35**, 1337–1348 (2008). doi: 10.1111/j.1365-2699.2008.01899.x.
19. Vijay, V. & Armsworth, P. R. Pervasive cropland in protected areas highlight trade-offs between conservation and food security. *Proc. Natl. Acad. Sci. U. S. A.* **118**, e2010121118 (2021). doi: 10.1073/PNAS.2010121118.
20. Potapov, P. *et al.* Global maps of cropland extent and change show accelerated cropland expansion in the twenty-first century. *Nat. Food* **3**, 19–28 (2022). doi: 10.1038/s43016-021-00429-z.

21. Joppa, L. N. & Pfaff, A. High and Far: Biases in the Location of Protected Areas. *PLoS One* **4**, e8273 (2009). [doi: 10.1371/journal.pone.0008273](https://doi.org/10.1371/journal.pone.0008273)
22. Vimal, R. *et al.* The global distribution of protected areas management strategies and their complementarity for biodiversity conservation. *Biol. Conserv.* **256**, 109014 (2021). doi: 10.1016/j.biocon.2021.109014.
23. Mouillot, D. *et al.* The socioeconomic and environmental niche of protected areas reveals global conservation gaps and opportunities. *Nat. Commun.* **15**, 9007 (2024). doi: 10.1038/s41467-024-53241-1.
24. Struhsaker, T. T., Struhsaker, P. J. & Siex, K. S. Conserving Africa's rain forests: problems in protected areas and possible solutions. *Biol. Conserv.* **123**, 45–54 (2005). doi: 10.1016/j.biocon.2004.10.007.
25. Caughley, G. Directions in conservation biology. *J. Anim. Ecol.* **63**, 215–244 (1994). doi: 10.2307/5542.