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Global conservation priorities for wetlands and setting post-2025 targets

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Wetland conservation is becoming increasingly important as wetland areas decline globally. However, no comprehensive global-scale mapping of wetland conservation priorities and targets has been published. This information is needed to extend the current protected area network and improve the conservation efficiency for wetlands. Here, we propose a cost-effective assessment model for wetland conservation by integrating wetland conservation value- and human impact-related indicators to identify global wetland conservation priorities. These priorities cover 28% of the potential global wetland distribution, and of that, only 44% is currently protected by existing protected areas. To protect more wetland conservation priorities, we propose three target-setting scenarios for protected area expansion that offer additional contributions of 9.40%, 42.40%, and 55.97%, respectively. These three global targets can be downscaled to the national level and used to update national wetland biodiversity conservation strategies and action plans under a harmonized legal and regulatory regime at different scales and jurisdictions.

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Wetlands are among the most important ecosystems for biodiversity, yet they have been substantially decreased in extent and degraded by intensifying anthropogenic disturbance and climate change[1,2]. The biodiversity of remaining wetlands faces unprecedented threats[3–6]. Studies show that the area of wetlands has declined by 50% globally since 1900, and perhaps by as much as 87% since 1700[7]. The substantial loss of wetlands has resulted in the listing of 25% of the world's inland wetland-dependent species as threatened, of which 6% are critically endangered[8]. Given these circumstances, the need for wetland conservation is widely recognized and is increasingly prioritized worldwide[9]. Facilitated by international conventions such as the Convention on Wetlands of International Importance Especially as Waterfowl Habitat (Convention on Wetlands) and the Convention on Biological Diversity (CBD)[10,11], research on wetlands has received unprecedented attention in terms of biodiversity conservation and restoration, environmental protection, and carbon sequestration[12,13]. To enhance the efficiency and feasibility of implementing wetland protection and management, research on biodiversity prioritization, PA network optimization, and conservation target setting are particularly urgent.

The 14th Meeting of the Conference of the Contracting Parties to the Ramsar Convention on Wetlands (COP14) was held in Wuhan, China and Geneva, Switzerland in November 2022. At the conference, the final decision was made regarding the post-2025 Strategic Framework for Global Wetland Conservation and Development, requiring a similar format of mapping as the post-2020 Global Biodiversity Framework targets and the Sustainable Development Goals (SDGs)[14]. According to the CBD, a global, outcome-oriented framework should be provided for the development of national sustainable development and biodiversity targets, which is a necessity for global wetland biodiversity conservation. Indicator-based conservation prioritization is another essential need in the establishment of the framework, target setting, and progress tracking[15,16]. The use of fixed targets was proposed as part of the biodiversity framework to avoid delayed compensation for human impacts that reduce ecological resilience and cause prolonged biodiversity losses[17]. However, owing to methodological uncertainty, the difficulty of obtaining wetland data, and the high dependency of stakeholders, no mapping of wetland conservation priorities (WCPs) and targets at the global scale has yet been published.

Indicators exist for wetland extent, overall biodiversity, and human impact, but all three must be considered simultaneously for the prioritization of wetland conservation. The global wetland extent trends (WET) index, a proof of concept for building a global picture of trends in wetland extent over time[18,19], has been applied for key environmental assessments[20,21] and has been included in the Biodiversity Indicators Partnership. Studies that address the conservation needs of global freshwater biodiversity offer a reference for the global conservation policy agenda[22,23]. These achievements provide quantitative indicators and policy implementation priorities for global wetland conservation and management. However, these indicator and policy references lack global conservation priorities that fully account for wetland biodiversity while balancing the impacts of human activities, which are essential for aligning with policy goals[24].

Previous studies provide much of the required knowledge to help with this prioritization of wetland conservation. Several studies have identified priority areas for biodiversity conservation, including the Biodiversity Hotspots (BH)[25], Key Biodiversity Areas (KBA)[26,27], Three Global Conditions for Biodiversity Conservation and Sustainable Use (3 C)[28], and Global 200 Ecoregions (G200)[29,30]. These templates on biodiversity could be combined with templates of wetland distribution, such as the Potential Distribution of Global Wetlands (PDGW)[31], as well as of human impacts, such as Low Impact Areas (LIA)[32], to provide a foundation for obtaining key areas and conservation priorities for wetland biodiversity. All these templates of global biodiversity conservation priorities, wetland distribution, and human impacts are widely recognized and represent several important facets of wetland biodiversity conservation prioritization.

To bridge the gap between wetland conservation science and the political theory required for the post-2025 Strategic Framework for Global Wetland Conservation and Development, we propose an assessment model to identify WCPs and set conservation targets for global wetland protected area (PA) optimization, based on the methods and datasets derived from previous studies on wetlands in China[33–37] and globally[38–40]. Three criteria are included: (1) the effectiveness of wetland conservation assessment; (2) the feasibility of implementation for wetland conservation, which requires spatially explicit and quantity-specific conservation targets; (3) the different scenarios for target-setting at global and national scales. By considering the above criteria, our research aims to provide technical and management support for the contracting parties of the Convention on Wetlands and CBD, to achieve the post-2025 goals of global wetland conservation and development.

Results

Distributions of WCPs. The WCPs cover 8.73×10^6 km^2, accounting for 28.3% of the global potential wetland distribution (which covers an area of 30.85×10^6 km^2), with Level 1 covering 0.79%, Level 2 covering 3.78%, Level 3 covering 16.92%, and Level 4 covering 6.82% (Fig. 1, Supplementary Table S1). Asia was home to the largest distribution of WCPs (with an area of 2.36×10^6 km^2), followed by Africa, Europe, and South America (with areas of 1.69×10^6 km^2, 1.65×10^6 km^2, and 1.64×10^6 km^2, respectively) and then by North America (0.93×10^6 km^2) and Oceania (0.46×10^6 km^2).

Level 1 WCPs were mainly distributed in Europe; Levels 2 and 3 in Europe, South America, Africa, and Asia; and Level 4 in Europe, North America, Africa, and Asia (Supplementary Fig. S1). In terms of the coverage ratio of different WCP levels, the countries and regions in North America, South America, and Oceania have relatively high ratios, with Level 1 covering approximately 1% in all countries and regions, Level 2 covering 0–12%, Level 3 covering 5–35%, and Level 4 covering 0%–30% in most countries and regions (Supplementary Fig. S2). Exceptionally high ratios (over 40%) were observed in the Level 2 and 3 WCPs of some countries in Europe, North America, and Oceania.

Conservation efficiency of the current PA network for WCPs. The distribution of WCPs and the existing PA network clarified the spatial location and boundaries of protected and unprotected WCPs (Fig. 2, Supplementary Fig. S3). Globally, many regional WCPs were not included in the global PA network. For example, central Asia and northern Europe are regions of great importance for global wetland biodiversity, yet there are still many unprotected WCPs, despite the relatively high coverage rate of the existing PAs (Fig. 3). On the western European border with Africa and in northeastern Europe, the existing PA coverage is limited, leaving many Level 2 and 3 WCPs unprotected.

Across the globe, 17.0% of terrestrial areas have been designated as PAs (PAs without vector boundaries were not included), but only 44.03% of WCPs were protected, with the remaining 55.97% unprotected. Among all WCPs, the proportion of protected and unprotected WCPs was 1.13% and 1.64% in Level 1, respectively; 5.60% and 7.76% in Level 2, respectively; 26.78% and 33.00% in Level 3, respectively; and 10.52% and 13.57% in Level 4, respectively (Supplementary Fig. S4).

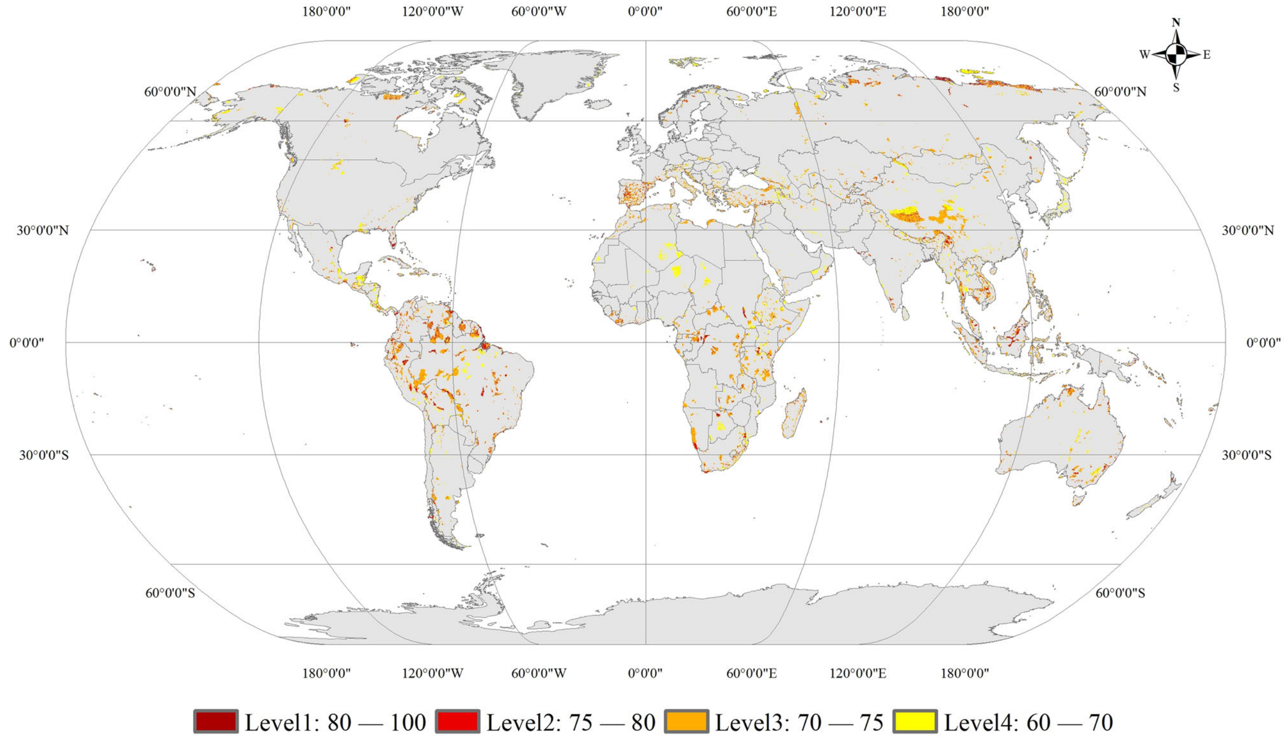


Fig. 1 Spatial distribution of wetland conservation priority areas (WCPs) at different priority levels. The darkest red color represents the WCPs with the highest priority, while the lightest yellow color indicates the WCPs with the lowest priority.

The contribution of countries to the conservation of global WCPs varied widely, with nine countries, namely the Russian Federation, China, Brazil, Canada, Australia, the United States, Indonesia, Spain, and Peru, contributing more than 50% of the total global WCPs. At the same time, the proportion of unprotected WCPs in the Russian Federation, China, Brazil, the United States, Australia, Spain, and Turkey exceeded 50% of the total area of WCPs (Fig. 4). Bridging these wetland protection gaps and improving the global network of PAs can improve the effectiveness of wetland protection and thus enhance the quality of the PA network.

Global and national conservation target setting. Under the three scenarios of Conservative, Moderate, and Ambitious targets, the global coverage rate of PAs reached 17.68%, 19.29%, and 20.00%, respectively, providing an additional 9.40%, 42.40%, and 55.97% coverage for WCPs. For each continent, an additional 1.5%–4.5% of the continent's area must be protected to achieve its Ambitious targets (Supplementary Fig. S5). Under any of the targets, countries or regions with a PA coverage rate of more than 17% were mainly located in South America and Africa (Fig. 5).

The number of countries or regions in Classes 4 and 5 (high PA coverage rate more than 17%) distinctly increased under the Conservative, Moderate, and Ambitious targets (Supplementary Table S2). Under the Conservative targets, the global pattern of PA coverage rate varied only slightly, with 31 countries or regions undergoing different degrees of increase and only four (Cook Islands, French Polynesia, Gibraltar, and Reunion) increasing markedly from Class 1 to 4. Under the Moderate and Ambitious targets, the global pattern of PA coverage rate changed noticeably. There were 74 (for Moderate targets) and 87 (for Ambitious targets) countries or regions experiencing different degrees of increase, in which 19 and 21 increased markedly from Class 1 to 4 (Supplementary Table S3 and S4).

The top 10 contracting parties with the highest PA expansion potential included Russia, China, Brazil, the United States (a non-contracting party to the CBD), Australia, Spain, Turkey, Canada, Indonesia, and South Africa (Fig. 6). Overall, these top 10 countries with the largest PA expansion potential contribute 61.91% to the global expansion of PAs under the Ambitious Target. Under the Ambitious target, the top 10 contracting parties (to the Convention on Wetlands or CBD) with the highest PA coverage included Brazil, Russia, China, the United States, Canada, Australia, Algeria, Venezuela, Mongolia, and Indonesia (Supplementary Fig. S6).

Discussion

Currently, most global-scale biodiversity conservation priorities are evaluated on the basis of the biodiversity of all ecosystems combined[41–44], and specific studies on global wetland biodiversity remain scant. This study proposed an assessment model to identify priorities for global wetland biodiversity conservation and proposed targets for PA coverage in three scenarios at both global and national scales. We adopted the consistent conservation target scenario framework with the expansion of the global PA network that is based on cost-effectiveness to ensure the optimization and feasibility of global biodiversity conservation outcomes. Priority assessments of wetland ecosystems have mostly been regional-or national-scale assessment studies, for example, highly prioritized PAs for biodiversity in Patagonian wetlands and the prioritization of wetland conservation in Manawatu Wanganui, New Zealand[45,46]. In addition, conservation priority sites and corresponding prioritization ranks for coastal wetlands in China have been identified by integrating shorebird survey datasets from multiple sources and using the criterion of 1% of the global or flyway population and priority index P-i[47]. In contrast, the current study identified quantitative conservation targets and specific spatial locations of wetlands at

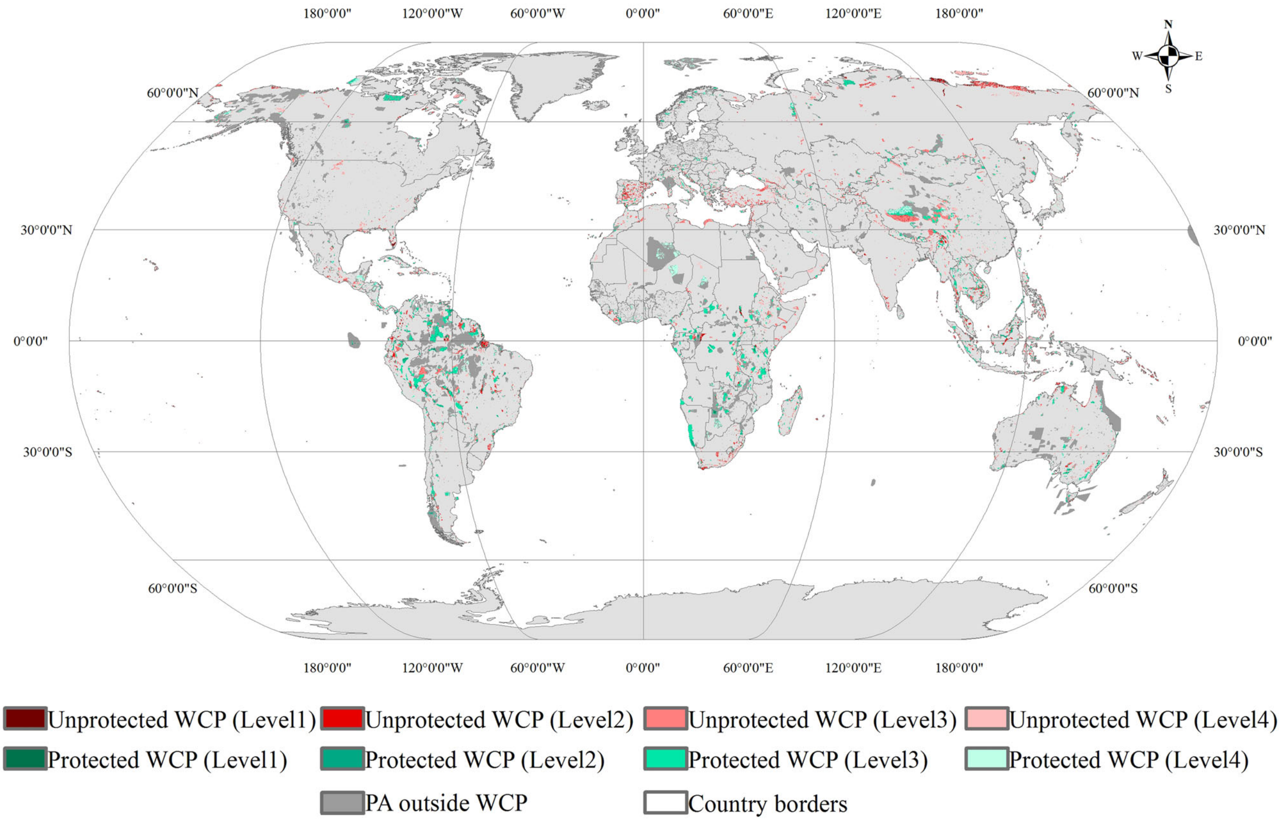
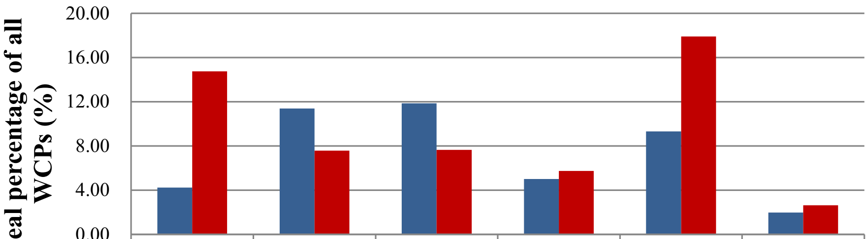


Fig. 2 Global distribution of wetland conservation priorities (WCPs) and protected areas (PAs). The darkest red color represents the unprotected areas of WCPs with the highest priority, while the lightest red color indicates the unprotected areas of WCPs with the lowest priority. The darkest green color shows the protected areas of WCPs with the highest priority, while the lightest green color shows the protected areas of WCPs with the lowest priority.



	Europe	South America	Africa	North America	Asia	Oceania
Protected	4.23	11.37	11.85	5.00	9.30	1.97
Unprotected	14.75	7.58	7.65	5.74	17.90	2.64

Fig. 3 The proportion of protected and unprotected wetland conservation priorities (WCPs) on each continent. Antarctica and Greenland are excluded.

both global and national levels. The proposed prioritization framework and targets under different scenarios will provide technical support and spatially specific target references for contracting parties of the Convention on Wetlands and CBD, which have set up mutually supportive goals and targets, including the Ramsar Strategic Plan, SDGs, and Aichi Targets.

Policy implications for wetland biodiversity conservation at global and national levels. Wetland conservation policies vary across countries and regions. Most countries have no special laws for wetland conservation[48]. Relevant regulations are scattered within the policies of other departments, such as laws pertaining to environmental protection and water resources, but this results in protection gaps or conflicts between different departments[49]. Therefore, guidelines that provide specific targets and locations for wetland conservation at both the global and national levels are crucial for improving wetland conservation policies.

At the global level, our research can provide technical support for the post-2025 Strategic Framework for Global Wetland Conservation and Development and can also guide wetland conservation related to SDG 6.6 (protection and restoration of water-related ecosystems). Expanding PAs based on WCPs can help in the development of wetland conservation targets at the global level[50]. The WCPs may be valuable for locating PA expansion areas, which can be beneficial for preventing further loss of wetland biodiversity. At the national level, countries and regions play different roles in the projected global PA expansion, especially the contracting parties to the Convention on Wetlands and CBD. This study can inform policy development related to wetland conservation in various countries. There may be great differences in the national responsibilities for global wetland

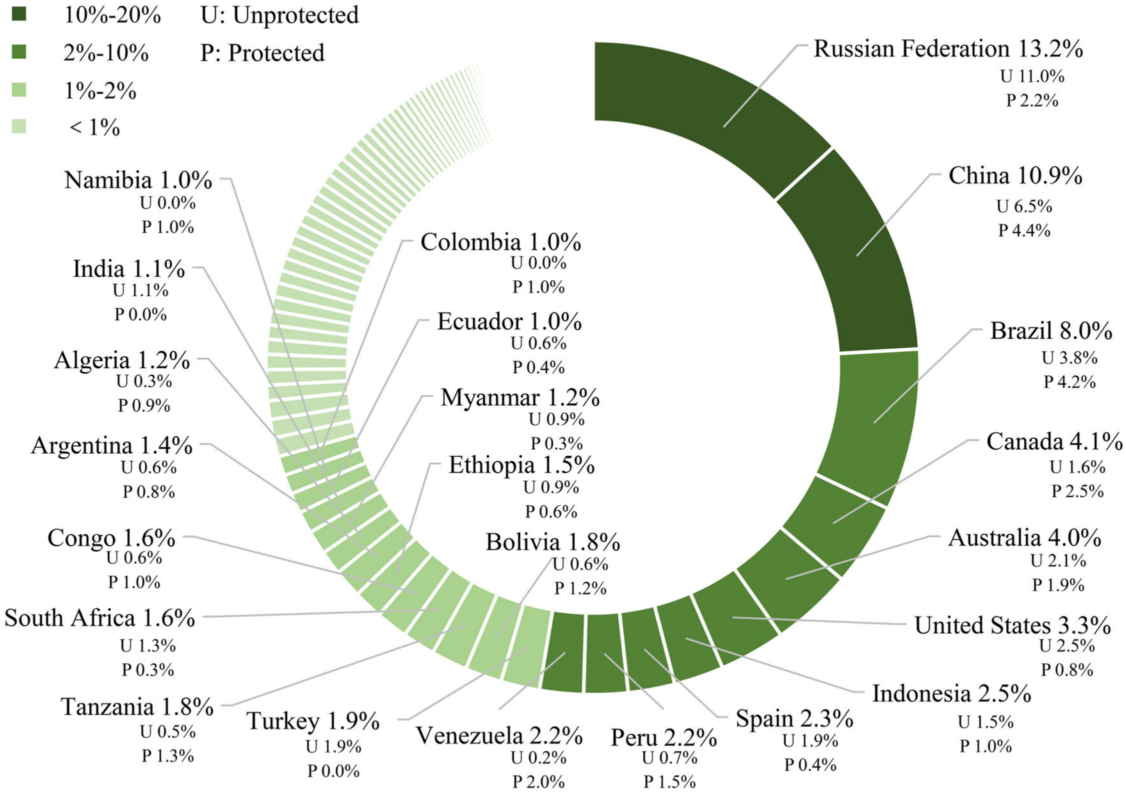


Fig. 4 The contributions of individual countries and regions to global wetland conservation priorities (WCPs). Values for all countries and regions (excluding Antarctica and Greenland) were calculated. The names and proportions of the 23 countries that contribute more than 1% of global WCPs are shown.

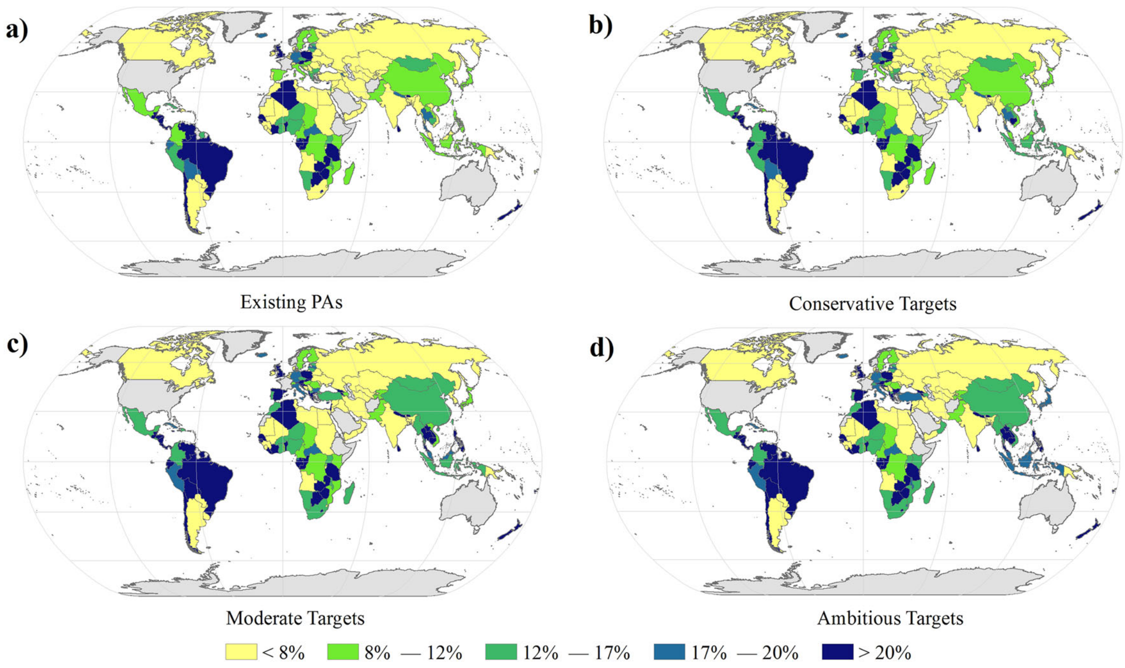
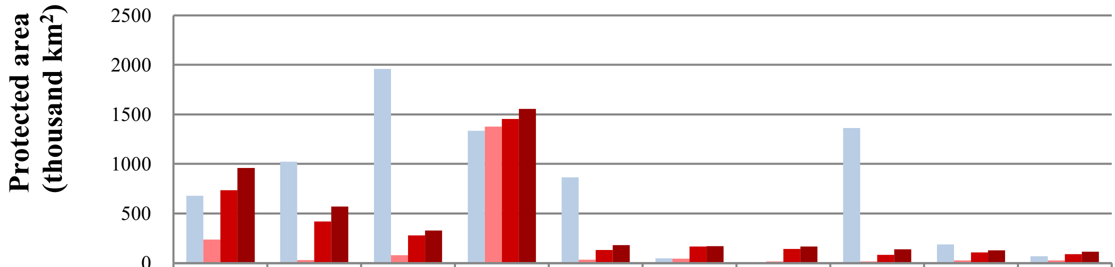


Fig. 5 The global pattern of protected area (PA) coverage rate under the existing conditions and the three scenarios. Countries and regions were grouped into five classes (Class 1: < 8%, Class 2: 8–12%, Class 3: 12–17%, Class 4: 17–20%, Class 5: > 20%) according to the range of PA coverage rate under the three targets. The darker the color, the higher the PA coverage rate in one country. A represents the rate of existing PA coverage, B is the rate of PA coverage under the Conservative target scenario, C indicates the rate of PA coverage under the Moderate target scenario, and D denotes the rate of PA coverage under the Ambitious-target scenario.



	Russia	China	Brazil	America	Australia	Spain	Turkey	Canada	Indonesia	South Africa
ExistingPAs	678	1021	1960	1334	866	48	2	1361	187	70
Conservative target	237	30	78	1376	34	43	15	16	29	26
Moderate target	735	419	278	1453	132	167	141	84	108	89
Ambitious target	961	570	329	1555	182	169	166	139	129	113

Fig. 6 The top 10 countries with the largest protected area (PA) expansion potential under the ambitious target. The terrestrial areas of all countries and regions (excluding Antarctica and Greenland) are calculated.

biodiversity conservation, the need for and suitability of areas for PA expansion, and levels of threatened biodiversity, because many important natural and social issues need to be considered at the national level[51,52]. Setting biodiversity conservation targets for wetlands at the national level with the global conservation targets as a framework will be conducive to updating national biodiversity strategies and action plans under a harmonized legal and regulatory regime at different scales and jurisdictions.

In addition to numerical targets, target areas for PA expansion have also been identified using scenarios with clear boundaries and priority conservation levels. It should be noted, however, that the targets proposed for each country in this study are indicative rather than mandatory, and they are intended to provide numerical and spatial references for contracting parties of the Convention on Wetlands and CBD to set their own formal targets. When actually implemented, these targets should be further downscaled by incorporating more accurate datasets to help local governments develop detailed implementation plans.

Importance of wetland ecosystem and biodiversity conservation in different countries. Based on the contribution to global WCP conservation, the contribution to the global PA system, and the urgent need to improve national PA efficiency in different countries, the following three categories of countries require special attention.

(1) Mega-WCP countries: These countries have the widest distribution of WCPs and are critical for the global conservation of wetland ecosystems and biodiversity. A few WCP-concentrated countries (China, Brazil, the Russian Federation, Australia, Indonesia, Venezuela, Peru, and the United States) can contribute significantly to global wetland biodiversity conservation. These countries play an indispensable role in the protection of wetland ecosystems and biodiversity. They should thus enhance the protection of WCPs and strive to achieve ambitious conservation targets as much as possible; otherwise, major losses to global wetland biodiversity could result.

(2) Countries with great WCP contributions to the global PA system: These are countries with the largest area of unprotected WCPs, such as the Russian Federation, China, Brazil, the United States, Australia, Spain, Turkey, Canada, Indonesia, and South Africa. These countries have the potential to contribute greatly to global PA expansion (up to 61.91%). They are crucial in improving the global PA system for wetland biodiversity conservation. Even though a margin of error in the area of unprotected WCPs exists in each country (owing to the exclusion of national wetland parks and important wetlands from WDPA), giving conservation priority to WCPs in these countries can quickly improve the wetland biodiversity conservation efficiency of the global PA system.

(3) Countries needing to improve national PA efficiency: These countries have a large distribution of WCPs, yet only a small percentage is protected. This suggests that national PA networks are not sufficiently focused on wetland biodiversity, and that national or regional PA networks need to be expanded to protect more wetland ecosystems and biodiversity. There is an urgent need for further conservation. For example, the Russian Federation and Mexico have large areas covered by PAs, while only 16% and 24% of WCPs are protected. Of the top 20 countries in terms of PA coverage, approximately one-third have less than 50% of their WCPs protected.

In summary, the five countries that should prioritize global wetland biodiversity conservation are Russia, China, Brazil, the United States, and Australia. It should also be noted that five countries, namely French Polynesia, Micronesia, the Cook Islands, Anguilla, and Aruba, which are mostly archipelagos, have many of their WCPs unprotected (more than 10% of their land area), and conservation should be strengthened.

The effective implementation of the CBD and the development of the SDGs' targets require clarification of each country's responsibilities, rights, and obligations in the conservation of various ecosystems and their biodiversity. The current study informs the responsibilities of each country in achieving its wetland biodiversity conservation targets. Countries with high PA coverage may limit their economic development if they are to protect more areas with wetland biodiversity potential, which will pose a substantial challenge for countries that have high levels of biodiversity but poorer economies[53]. A concerted international effort is required to tackle the dilemmas faced by these types of countries that take on a disproportionate share of responsibility for wetland biodiversity conservation. Therefore, there is an urgent need for a global collaborative mechanism that weighs the benefits of expanding PAs versus managing existing ones[54,55], to significantly improve the effectiveness of global biodiversity conservation through multilateral global action[56], sharing knowledge, good practices, and resources.

Limitations and future research. There are inevitably some limitations associated with this study, including uncertainties related to data quality and the weighting process. Although the best currently available data were used in this study, there were still differences in data quality across countries[57,58]. Therefore, it is necessary to further validate and optimize our approach at the national level when setting conservation targets in practice. It should be noted that understanding how to monitor and predict wetland biodiversity after the establishment of PAs remains a challenging issue. In future research, more impacts of human activities and climate change on wetland biodiversity should be included[59,60]. A predictive model of wetland biodiversity linking human-induced land use change, hydrological disturbances, footprints, and climate change is needed to improve the wetland biodiversity conservation and monitoring system. It is also necessary to quantify wetland biodiversity threats at the global and national levels (including threats from anthropogenic disturbance and climate change) to provide an additional reference for national wetland biodiversity conservation targets in the context of global change.

Conclusions

The aim of our paper was to propose a cost-effective assessment model for wetland conservation, identify global wetland conservation priorities (WCPs), and provide three target-setting scenarios for current PA expansion. The present assessment model advances a systematic framework for comprehensive evaluation of wetland conservation that considers multiple aspects such as wetland ecosystems, biodiversity, ecological zones, population density, land for construction, and human impacts. The identified global WCPs clarify the quantity and spatial location of wetlands that need priority for protection globally. If the Ambitious target can be achieved, the expanded PA system can fully protect global WCPs and substantially improve the wetland conservation efficiency of the PA system.

This paper contributes to theory and methodology by offering an approach to the assessment and prioritization of global wetland conservation, which remain underexplored in extant studies. By introducing two main groups of factors affecting the global prioritization of wetland conservation, our review of the relevant global products adds to the relevant body of knowledge. Furthermore, the assessment model integrates sub-indicators of these factors into an implementable evaluation tool. Our study has important practical implications as well. The global scale and spatially specific wetland conservation priorities and targets can contribute to bridging the gap between conservation science and the political theory required for the post-2025 Strategic Framework for Global Wetland Conservation and Development. As the requirements of global wetland sustainable development become increasingly multi-target specific, further work will focus on a prioritization system that integrates conservation, monitoring, and prediction to provide more comprehensive quantitative targets for the contracting parties of the Convention on Wetlands.

Methods

Data sources and processing. After reviewing the relevant global products, we chose eight global-scale wetland-related datasets, six biodiversity templates, and three human-impact datasets to calculate the sub-indicators for assessing and prioritizing wetland conservation (Table 1). These templates and datasets were selected because: (1) they identify important spatial information in consideration of at least one facet of wetland biodiversity; (2) they are robust and widely used in global wetland and ecoregions identifying and biodiversity evaluation; and (3) the data are relatively reliable and accessible. All the wetland-related datasets adopt the widely accepted Ramsar Convention definition for wetlands. The wetland types include natural wetlands (marine/coastal wetlands, inland wetlands) and artificial wetlands.

The dataset of global glaciers was selected to refine the WCPs. The WDPA was used to identify conservation gaps by overlaying the PA layer with WCPS. The GADM was used to calculate the conservation target of each country. All these templates and datasets are available online. To ensure spatial consistency, all data used the same projection and were transformed into a raster format at a resolution of 1 km.

Assessment model for wetland conservation and prioritization. To identify cost-effective, comprehensive global conservation priorities for wetland biodiversity while balancing the impacts of human activities, we established a two-level index system to assess and prioritize wetland conservation value. The index system includes two primary indicators (wetland conservation value and human activity intensity) and six sub-indicators (importance of wetland ecosystem (IWE), importance of species (IS), importance of ecological zone (IEZ), population density (PD), land for construction (LC), and human impact (HI)) (Table 2).

Each sub-indicator was spatialized by further processing the products introduced in the data sources. We overlaid the eight global wetland products (GLWD, PDGW, GMFAGB, MFDW, GLC_FCS30, GlobCover2009, GLC2000, and GWVS) to derive the IWE. We assumed that the higher the number of overlaps, the greater the potential distribution probability of wetlands and the higher the importance of the wetland ecosystem. Similarly, we obtained the IEZ by overlaying four sets of key biodiversity and ecoregion-related templates (KBAs, BHs, 3Cs, and Global200), with a higher number of overlaps representing higher conservation value in terms of biodiversity and ecological processes. We obtained the IS by integrating waterfowl distribution data and information on endangerment levels (from the GBIF and IUCN Red List of Threatened Species). The human impact-related sub-indicators PD, LC, and HI were obtained by directly ranking the datasets of GHS_POP, GHS_SMOD, and LIAs. To quantify the importance or impact of these indicators, a value from 60 to 100 was assigned to IWE and IEZ according to the number of overlaps, to IS based on the endangered category, and to PD, LC, and HI based on the degree of impact of human activities. The specific details of value assignment are shown in Supplementary Table S5.

The weights of each indicator were obtained according to the analytic hierarchy process (AHP), in which a questionnaire administered on a scale of 1 to 9, was used to compare the relative importance of the indicators mentioned. The 20 experts consulted included research-oriented scholars and management experts in wetlands, nature conservation, biodiversity, and other related fields. The Consistency Ratio ($CR = 0.026$) of the importance matrix of the sub-indicators is less than 0.1, indicating that the importance matrix has an inconsistency degree within the allowable range and passes the consistency test[61]. The weighting of the indicators is shown in Table 2. We used a dataset of wetland reserves in China to validate the WCPs because it is the most detailed dataset available (Resource and Environment Science and Data Center, https://www.resdc.cn/). The validation index was the ratio of wetland reserves overlapped by the WCPs. A ratio of over 75% indicates a high WCP reliability.

Identification methods for wetland conservation gaps. To analyze the conservation efficiency of the global PA network for wetland biodiversity, we spatially overlaid the global WCP classification results and the global PA database to calculate the currently protected/unprotected proportion of global WPCs. Then, we identified wetland biodiversity gaps in the global PA network by clarifying the spatial location and boundaries of the unprotected WCPs. The mapping intervals of wetland biodiversity gaps were categorized as follows: Level 0: background value [0, 60], Level 1: Medium [60, 70]; Level 2: High [70, 75]; Level 3: Very high [75, 80]; Level 4: Extremely high [80, 100].

Table 1 List of data sources.

ID	Name of database	Year	Resolution	Data download links
1	Global Lakes and Wetlands Database, GLWD[62]	2000	1 km	http://www.wwfus.org/science/data.cfm; https://doi.org/10.1016/j.jhydrol.2004.03.028
2	the Potential Distribution of Global Wetlands, PDGW[31]	2015	1 km	https://doi.org/10.1016/j.scitotenv.2017.02.001; https://doi.org/10.6084/m9.figshare.24646248
3	The Global Mangrove Forest Aboveground Biomass, GMFAGB[63]	2004	250 m	http://www.3decology.org; https://doi.org/10.3390/rs12101690; https://doi.org/10.3390/rs12101690
4	Mangrove Forests Distributions of the World, MFDW[64]	2000	1 km	https://sedac.ciesin.columbia.edu/data/set/lulc-global-mangrove-forests-distribution-2000; https://doi.org/10.1111/j.1466-8238.2010.00584.x
5	a Global 30 m Land-Cover Classification with a Fine Classification System, GLC_FCS30[65]	2020	30 m	https://zenodo.org/records/4280923; https://doi.org/10.5194/essd-13-2753-2021
6	the Global 300 m Land-Cover Products in 2009, GlobCover2009[66]	2009	300 m	http://due.esrin.esa.int/page_globcover.php
7	the Global 1 km Land Cover 2000, GLC2000[67]	2000	1 km	https://forobs.jrc.ec.europa.eu/glc2000; https://doi.org/10.1080/01431160412331291297
8	a Database of Global Wetland Validation Samples, GWVS[38]	1980-2013	1 m	https://doi.org/10.1007/s11434-014-0717-4; https://doi.org/10.6084/m9.figshare.24646305
9	distribution data of waterfowl in the Global Biodiversity Information Facility, GBIF[68]	-	-	https://www.gbif.org/occurrence/search
10	IUCN Red List of Threatened Species[69]	-	-	https://www.iucnredlist.org
11	Biodiversity Hotspots, BHs[25]	-	-	https://www.iucn.org/resources/key-biodiversity-areas; https://www.keybiodiversityareas.org/
12	Key Biodiversity Areas, KBAs[26,27]	-		https://doi.org/10.1038/35002501; https://doi.org/10.6084/m9.figshare.24646320
13	Three Global Conditions for Biodiversity Conservation and Sustainable Use, 3Cs[28]	-	1 km	https://naturebeyond2020.com/3conditions/; https://doi.org/10.1093/nsr/nwz136
14	Global 200 Ecoregions, Global 200[29,30]	-	-	https://www.feow.org/ecoregions/interactive-map;https:/https://doi.org/10.1046/j.1523-1739.1998.012003502.x; https://doi.org/10.2307/3298564
15	GHS_POP and GHS_SMOD[70]	2015	1 km	https://data.jrc.ec.europa.eu/collection/GHSL
16	Global Areas of Low Human Impact ('Low Impact Areas,' LIAs)[32]	2019	1 km	https://datadryad.org/stash/dataset/ https://doi.org/10.5061/dryad.z612jm67g; https://doi.org/10.1038/s41598-019-50558-6
17	Randolph Glacier Inventory: A Dataset of Global Glacier Outlines: Version 6.0, RGI 6[71]	2021	-	https://nsidc.org/data/nsidc-0770/versions/6
18	World Database on Protected Areas, WDPA[72]	2021	-	https://www.protectedplanet.net/en
19	Database of Global Administrative Areas, GADM[73]			http://www.gadm.org

Table 2 Indicator system for global wetland conservation assessment and indicators' weights.

Target	System	Weight 1	Indicator	Weight 2	Composite weights
Indicator system for the global wetland conservation assessment	Wetland conservation value	83.6%	Importance of wetland ecosystem (IWE)	41.4%	34.6%
			Importance of ecological zones (IEZ)	29.7%	24.8%
			Importance of species (IS)	28.9%	24.2%
	Human activity intensity	16.4%	Population density (PD)	38.1%	6.2%
			Distribution of land for construction (LC)	30.3%	5.0%
			Level of human impact (HI)	31.6%	5.2%

The proportions of WCP Levels 1–4 protected or not protected by PAs were further analyzed to prioritize wetland biodiversity conservation and for the future development of action strategies.

Target-setting methods for wetland conservation. Based on the relationship between the PA network and the various levels of WCPs, conservation gap analysis was performed to determine the global and national biodiversity conservation targets for wetlands under different scenarios. Three conservation target scenarios were included: (1) the Conservative target, which required only unprotected Level 1 and 2 of WCPs to be incorporated into the PA network; (2) the Moderate target, which required unprotected Level 1, Level 2, and Level 3 of WCPs to be incorporated into the PA network; and (3) the Ambitious target, which required all unprotected WCPs to be incorporated into the PA network. The three conservation target scenarios can serve as phased goals (i.e., immediate, mid-term, and long-term planning targets) for global wetland biodiversity conservation. The conservation target equations for scenarios 1, 2, and 3 are as follows:

$$T_C = \frac{PA + WCP_{l1} + WCP_{l2}}{A} \tag{1}$$

$$T_M = \frac{PA + WCP_{l1} + WCP_{l2} + WCP_{l3}}{A} \tag{2}$$

$$T_A = \frac{PA + WCP_{l1} + WCP_{l2} + WCP_{l3} + WCP_{l4}}{A} \tag{3}$$

where T_C stands for Conservative target, T_M stands for Moderate target, and T_A stands for Ambitious target; WCP_{l1}, WCP_{l2}, WCP_{l3}, and WCP_{l4} are the total areas of unprotected WCPs at Levels 1, 2, 3, and 4, respectively; A is the area of the statistical unit, either the total area of wetlands globally or the total area of wetlands in each country for the calculation of global or national targets.

Data availability

All data for WCP assessment model are available with their access information listed in Table 1. The resulted WCP dataset in tiff format is available at 10.6084/m9.figshare.24630717.

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The authors declare no competing interests.

Additional information

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