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Transboundary conservation hotspots in China and potential impacts of the belt and road initiative

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Abstract

Aim: Biodiversity hotspots often span international borders, thus conservation efforts must as well. China is one of the most biodiverse countries and the length of its international land borders is the longest in the world; thus, there is a strong need for transboundary conservation. We identify China's transboundary conservation hotspots and analyse the potential effects of the Belt and Road Initiative (BRI) on them to provide recommendations for conservation actions.

Location: China, Asia.

Methods: We compiled a species list of terrestrial vertebrates that span China's borders. Using their distribution, we extracted the top 30% of the area with the highest richness value weighted by Red List category and considered these transboundary hotspots for conservation priority. Then we analysed protected area (PA) coverage and connectivity to identify conservation gaps. To measure potential impact of the BRI, we counted the species whose distribution range is traversed by the BRI, and calculated the aggregation index, proportion of natural land and night light index along its routes.

Results: We identified 1964 terrestrial vertebrate species living in the border region. We identified four transboundary hotspots and found insufficient PA coverage and low connectivity in three of them. The BRI routes intersected all four hotspots and traversed 82.4% (1619/1964) of the transboundary species, half of which (918) are sensitive to the potential risks brought by the BRI. Night light index increased generally along the BRI. However, the proportion of natural land and the aggregation index near the BRI showed different trends in hotspots.

Main Conclusions: There is an urgent need for conservation action in China's transboundary region. The BRI should put biodiversity conservation at the core of its development strategy. Furthermore, we suggest using the planned BRI as a platform for dialogue and consultation, knowledge and data sharing, and joint planning to promote transboundary conservation.

KEYWORDS

conservation gaps, landscape analysis, priority areas, the belt and road initiative, transboundary conservation, vertebrates

1 | INTRODUCTION

International border areas often harbour rich and endemic biodiversity (Fowler et al., 2018; Huang et al., 2012; Liu et al., 2020). For example, as a politically sensitive area located on the border of North and South Korea, the Korean Demilitarized Zone harbours more than 4000 species (Lee & Miller-Rushing, 2014). Globally, the distribution of 53.8% vertebrates cross international borders (Mason et al., 2020). However, transboundary species face great conservation challenges because international borders often separate wildlife populations artificially, and the creation of physical barriers to separate nations prevents transboundary wildlife movement (Linnell et al., 2016). For example, 1506 native species whose geographical range traverse the US–Mexico border are threatened by the Border Wall (Peters et al., 2018). Furthermore, protected areas (PAs) often stop at political boundaries, thereby failing to safeguard the full distribution of species (Kark et al., 2015). In addition, differences in governance and unequal status of legal protection of nations on either side of the border, makes it hard to control poaching and smuggling (Nijman et al., 2016). For example, 43,399 kg of pangolin material and 518 whole individuals were seized on the border between Myanmar and China between 2010 and 2014 (Nijman et al., 2016).

Consequently, conservation actions that span borders are needed to avoid biodiversity loss. These actions can prevent the isolation of small populations, permit effective combating of poaching (Scholte et al., 2013), coordinate conservation priorities, identify and control extensive and large-scale threats like climate change, and lead to sharing of data and experience to improve protection effectiveness (Kark et al., 2015; Ma et al., 2020). A high-profile example of conservation action along borders is the European Green Belt. This project snakes along the line of the former Iron Curtain and spans 23 countries and six biogeographical regions to improve landscape connectivity and biodiversity conservation effectiveness (Vasilijević & Pezold, 2011).

As one of the most biologically diverse countries (Mi et al., 2021), China is home to four of the world's 36 biodiversity hotspots (Conservation International, https://www.cepf.net/node/1996), and three of them ('Mountains of Central Asia', 'Himalaya' and 'Indo-Burma') extend beyond its borders. China neighbours 14 countries on land, and has the longest land border (22,800 kilometres) in the world. Many conservation flagship species, including Siberian tiger (*Panthera tigris*), Asian elephant (*Elephas maximus*), Snow leopard (*Panthera uncia*) and Cao-vit gibbon (*Nomascus nasutus*) are distributed across China's border and require transboundary conservation efforts (Wang et al., 2021).

The need for increased conservation efforts along China's borders will become more acute because of the Belt and Road Initiative (BRI), which was formally proposed in 2013. This initiative involves over 70 countries and is the most extensive international transportation infrastructure construction project ever developed (https://eng.yidaiyilu.gov.cn/). Construction of infrastructure like road and rail networks is often considered one of the most influential human interventions to the earth's ecosystems (Laurance et al., 2004, 2014; Popp & Boyle, 2017). Historically, large transportation infrastructure projects have had significant negative impacts (Laurance et al., 2001, 2009). Once a road is built, it is almost permanent in the environment, bringing long-term risks to the surrounding ecosystems (van der Ree et al., 2015). This is particularly critical in roadless areas including border regions, because the first cut can bring a rapid increase in human pressure (Laurance, 2015; Selva et al., 2015). The BRI will promote development in border areas so that will also bring conservation challenges to transboundary species. Linear infrastructure of the BRI may hinder the dispersal of species and pose threats such as roadkill, noise and pollutions (Hughes, 2019). The BRI could be accompanied by logging, urbanization or agriculturalization, which can lead the loss of habitat for surrounding species (Hughes, 2019). Furthermore, the growth of human population along with the construction of infrastructure will increase the risk of biological invasion (Liu et al., 2019). Conservation planning in advance is therefore needed to reduce the possible loss of biodiversity caused by the BRI.

To advance the understanding of the importance of international borders to conservation globally and to guide regional planning, we compiled a list of transboundary terrestrial vertebrates and identified the hotspots of transboundary conservation in China. We then evaluated whether existing PAs are sufficient to protect these hotspots. Finally, we analysed the potential risks and opportunities brought by the BRI.

2 | METHODS

2.1 | China's transboundary terrestrial vertebrates

We compiled a list of transboundary terrestrial vertebrates in China from the International Union for Conservation of Nature (IUCN) Red List database (https://www.iucnredlist.org/). We downloaded data of all species of mammals, birds, amphibians and reptiles from the database and filtered those living in terrestrial ecosystems. We then filtered these species based on their geographical ranges, to retain species live both in China and other neighbouring countries. Furthermore, we filtered the species by their distribution codes and retained those with codes of 'Extant', 'Possibly Extant', 'Native', and for birds we excluded 'Passage'. The retained species were classified as the transboundary terrestrial vertebrates in China.

2.2 | Mapping transboundary conservation hotspots

We downloaded distribution maps of transboundary species from the IUCN Red List (IUCN, 2021) and BirdLife International and the Handbook of the Birds of the World (BirdLife International, 2018). We then refined the distribution range (R 4.1.0, *terra* package) (Hijmans, 2022b) for each species according to its suitable habitat types (i.e. land cover types) and elevation range, which were obtained from the IUCN Red List. Land cover data were obtained from Jung et al. (2020), which is consistent with the IUCN habitat classification, and elevation data were obtained from WorldClim (https://worldclim.org/) (Fick & Hijmans, 2017). All raster layers were rescaled to a spatial resolution of 1 km and were under spatial reference coordinate system of WGS1984.

We created 10 km, 50 km and 100 km buffer zones on both sides of China's border as border region (made in ArcGIS 10.2.2) for subsequent analysis. We visually checked the results, and found the geographical locations of transboundary conservation hotspot were similar when using different buffer zones (see Figure S2). Finally, we chose to present the 100 km results in this article to cover a larger area for conservation planning. This was also based on the consideration that the dispersal range of most terrestrial vertebrates (Minor & Lookingbill, 2010; Paradis et al., 1998; Saura et al., 2017) is within 100 km. If an individual animal disperses across international borders, most do not extend beyond 100 km.

We used this border region to crop the distribution maps of transboundary terrestrial species in China. Within the border region, each specie has a distribution layer with a value of 0 or 1 in each 1-km^2 cell, where 1 represents presence and 0 represents absence. All species were then weighted by their Red List category, assuming Least Concern (LC) as 1, Near Threatened (NT) as 2, Vulnerable (VU) as 3, Endangered (EN) as 4 and Critically Endangered (CR) as 5 (Balaguru et al., 2006). We valued DD as 3 because DD species are often considered potentially at risk of extinction (Jaric et al., 2016). However, excluding the 65 DD species did not affect the main results. The weighted distribution layers were stacked to obtain a weighted-richness map. Finally, we extracted the top 30% of cells with highest values in the weighted-richness map as conservation hotspots. The 30% was chosen as the threshold because according to the 2030 action target 3 of the 15th meeting of the Conference of the Parties to the Convention on Biological Diversity (COP15) (Convention on Biological Diversity, 2020), it is necessary to protect 30% of land and sea globally by 2030. We aggregated neighbouring cells in the hotspot map into a patch, and patch less than 100 km apart (from their centre points) were further aggregated into a hotspot (R 4.1.0, *grainscape* package, see Figure S1) (Chubaty et al., 2020). Four hotspots were finally identified (Figure 1a).

2.3 | Coverage and connectivity of PAs within the border region

We obtained map layers of PAs in China's neighbouring countries from the World Database on Protected Areas (UNEP-WCMC, 2017) and supplemented China's PAs from Yang, Chen, et al. (2018). For some PAs which are point data in the WDPA dataset, we constructed circles around the points with areas equal to the sizes listed in the attribute table. In each hotspot, we calculated percentage of area in each country and their PA coverages (Table 2). We also calculated PA coverage for each species and compared the differences between Classes using Kruskal–Wallis Test with a post-hoc Conover's all-pairs comparison test (R 4.1.0, *PMCMRplus*, *multcompView* package) (Graves et al., 2019; Pohlert, 2022).

Following Saura et al. (2017), we calculated the connectivity of PAs in each hotspot, using the Confer 2.6 software (Saura & Torné, 2009). The connectivity index of PAs, ProtConn index, represents the proportion of connected PAs to the study area. First, we calculated the area of each PA in the hotspot (a). Then we made buffer zones of 500 km for each of the above-mentioned PAs to capture possible 'springboard' PAs (T) following Saura et al. (2017). The area of springboard PAs was set at 0. Next, we calculated distances (x) between pairs of these PAs, and these distances were then converted by negative exponents (formula 1) as the probability of direct movement between the two PAs (Pij).

$$Pij = e^{-2d/D} \tag{1}$$

In this formula, D is a predefined dispersal kernel, which is set at 100 km, also known as the dispersal range of most terrestrial vertebrates.

Finally, the connectivity index of the PA—ProtConn was calculated according to the following formula (2):

$$ProtConn = 100 \times \frac{\sqrt{\sum_{i=1}^{n+t} \sum_{j=1}^{n+t} a_i a_j p_{ij}^*}}{A_L} \tag{2}$$

In this formula, a_i and a_j are the area of PA i and j in the hotspot (L). p_{ij}^* is the maximum probability of movement between two PAs including the probability of movement connected by 'springboard' or other PAs. A_L is the area of the research area, which is the area of the hotspot in this analysis (Saura et al., 2017). All raster layers were rescaled to a spatial resolution of 500 m under coordinate system of EPSG:32648—WGS 84 / UTM zone 48 N (R 4.1.0, *raster* package) (Hijmans, 2022a).

2.4 | Assessing the threats brought by the BRI

We downloaded a map layer of the BRI routes from the World Bank database (https://databank.worldbank.org/) (Reed & Trubetskoy, 2019). Six economic corridors that cross China's borders are planned along the BRI (https://eng.yidaiyilu.gov.cn/), where infrastructure construction will likely to be the largest and cause the highest human pressures. We retained the routes belonging to each economic corridor according to the attributes of the routes. We also downloaded a published map of the BRI (Geographic Data Sharing Infrastructure, College of Urban and Environmental Science, Peking University, http://geodata.pku.edu.cn) to complement routes belonging to the economic corridors.

We overlaid the BRI routes (spatial lines) with refined distribution maps of all transboundary species, to identify the species whose distribution is traversed by the BRI (*terra* package, R 4.1.0). Because the BRI may have different impacts on different taxa, we further obtained threat information of transboundary species from the IUCN Red List database. We grouped these threats into three categories to match the environmental impacts that

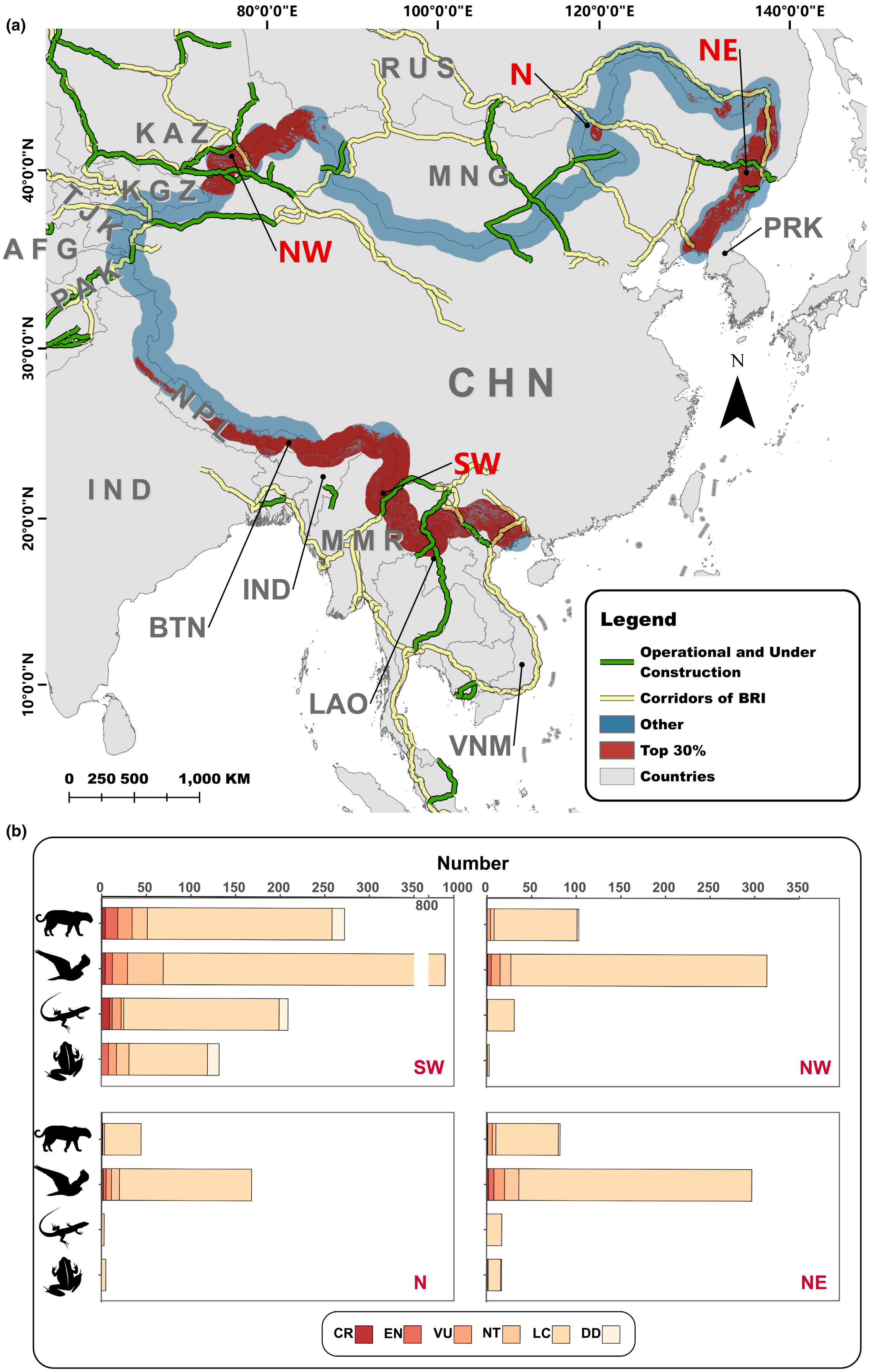

FIGURE 1 (a) China's transboundary hotspots and routes of the belt and road initiative and (b) number of species in each hotspot. Coordinate system is WGS_1984_UTM_Zone_48N.

TABLE 1 Group the threats to species to the three levels of risks brought by the BRI

Potential BRI impacts	Threats to species (from IUCN red List)
Direct risks	4.1 Roads & railroads
	4.2 Utility & service lines
	4.3 Shipping lanes
Accompanying risks	5.1 Hunting & collecting terrestrial animals
	5.2 Gathering terrestrial plants
	5.3 Logging & wood harvesting
	5.4 Fishing & harvesting aquatic resources
	8.1 Invasive non-native/alien species/ diseases
	8.2 Problematic native species/diseases
	8.3 Introduced genetic material
	8.4 Problematic species/diseases of unknown origin
	8.5 Viral/prion-induced diseases
	8.6 Diseases of unknown cause
Long-term risks	1.1 Housing & urban areas
	1.2 Commercial & industrial areas
	1.3 Tourism & recreation areas
	2.1 Annual & perennial non-timber crops
	2.2 Wood & pulp plantations
	2.3 Livestock farming & ranching
	2.4 Marine & freshwater aquaculture
	3.1 Oil & gas drilling
	3.2 Mining & quarrying
	3.3 Renewable energy
	6.1 Recreational activities
	6.2 War, civil unrest & military exercises
	6.3 Work & other activities
	7.1 Fire & fire suppression
	7.2 Dams & water management/use
	7.3 Other ecosystem modifications
	9.1 Domestic & urban waste water
	9.2 Industrial & military effluents
	9.3 Agricultural & forestry effluents
	9.4 Garbage & solid waste
	9.5 Air-borne pollutants
	9.6 Excess energy
	11.1 Habitat shifting & alteration

Abbreviations: BRI, Belt and Road Initiative; IUCN, International Union for Conservation of Nature.

the BRI may bring (Table 1). The potential impacts of BRI could be roughly divided into three levels from specific to extensive or from immediate to long term (Hughes, 2019). The first is the direct impact of transportation infrastructure itself, such as the risk of road kill, electrocution or habitat loss. The second are the risks accompanying road operations, such as poaching and logging, as well as biological invasion and disease transmission. The third type is long-term risk. Due to the economic development brought by convenient transportation, the surrounding areas may be urbanized or agriculturalized after road construction. Mining and development of wind power and hydropower may also happen. This will cause a series of human disturbances, such as pollution and natural land changes. Such risks are most widespread at both spatial and temporal scales.

To further assess the potential impacts of the BRI, we selected routes that are identified as 'under construction' and 'operational' (Reed & Trubetskoy, 2019), because they already have an impact on their surrounding environment. We made a 2 km (on both sides) buffer zone along selected routes, which was termed as 'road-effect-zone' in road ecology and often span from several hundred meters to 3.5 km (Forman & Alexander, 1998; Husby, 2017). We then calculated three indexes (the proportion of natural land, fragmentation index of natural land, and nighttime light) in the road-effect-zone in each hotspot. Land cover data were obtained from a reclassified MODIS product (resolution 500 m, University of Maryland (UMD), https://earthdata.nasa.gov), in which 'Croplands', 'Urban and Built-up Lands' and 'Cropland—Natural Vegetation Mosaics' were classified as human modified land and the remains as natural land. Proportion of natural land was calculated in R using the package *Landscapemetrics* (Nowosad, 2019). We used the aggregation index to measure fragmentation of natural land (He et al., 2000). Aggregation index ranges from 0 to 100, with a higher value indicating a lower level of landscape fragmentation. To measure human pressure, we downloaded the night light data from Chen et al. (2020). We calculated the average values of the night light index in each buffer zone, of which the higher value indicates higher human pressure. Finally, we used Wilcoxon Signed Rank Test to compare values of indexes before and after the proposal of the BRI (2001–2012 vs. 2013–2019, the BRI was proposed in 2013) to investigate the change of habitat condition and human pressure. At the same time, we calculated the aggregation index, proportion of natural land and night light index in the whole border region as a background value to better understand the impacts of the BRI. All raster layers had a resolution of 500 m under coordinate system of EPSG:32648—WGS 84/UTM zone 48 N.

3 | RESULTS

3.1 | China's transboundary terrestrial vertebrates

We identified 2185 transboundary species in China, including 1217 birds, 476 mammals, 306 reptiles and 186 amphibians (Appendix S1). Among these species, 23 were CR, 61 were EN, 100 were VU, 112 were NT, 1824 were LC and 65 were DD. According to the IUCN Red List, populations of 808 species (37.0%) were in decline, 493 species (22.6%) were unknown, 773 species (35.4%) were stable and 111 species (5.1%) were increasing. In total, we obtained distribution

TABLE 2 Four transboundary hotspots: Their flagship species, protected area (PA) coverage and connectivity

Hotspot	Species	Flagship species	Countries	Proportion of the hotspot area	PA coverage	Connected-PA coverage (ProtConn)
Southwest (SW)	1542	*Nomascus concolor, Nomascus nasutus, Neofelis nebulosa, Rhinopithecus strykeri, Panthera uncia, Panthera pardus, Panthera tigris, Ursus thibetanus*	China	40.5%	10.9%	1.68%
			Myanmar	19.3%	8.9%	
			India	13.0%	11.4%	
			Vietnam	9.8%	6.1%	
			Nepal	7.3%	20.7%	
			Laos	5.2%	15.3%	
			Bhutan	4.3%	32.0%	
			Total	100.0[a]%	12.2%	
Northwest (NW)	451	*Panthera uncia, Falco cherrug, Ranodon sibiricus*	China	43.3%	6.2%	4.51%
			Kazakhstan	54.2%	20.6%	
			Russia	1.4%	54.7%	
			Total	100.0[a]%	14.7%	
North (N)	220	*Grus japonensis, Falco cherrug*	China	98.6%	63.7%	100% (Only one protected area)
			Russia	1.2%	0.0%	
			Total	100.0[a]%	63.1%	
Northeast (NE)	413	*Panthera pardus, Panthera tigris, Ursus thibetanus*	China	51.7%	16.7%	2.21%
			Russia	29.6%	15.8%	
			North Korea	18.3%	2.6%	
			Total	100.0[a]%	14.2%	

[a]Since the grids on which the border line located were not assigned to either country in calculation, the sum would be slightly <100%.

maps for 2116 species (Appendix S1). Among them, there were 1964 species living within China's border region (100 km along both sides of the border).

3.2 | Transboundary conservation hotspots, PA coverage and connectivity

We identified four transboundary hotspots, that is, the southwest (SW), northwest (NW), north (N) and northeast (NE) (Figure 1a). The four hotspots support various transboundary species (1542—SW, 451—NW, 413—NE and 220—N), including different flagship species (Table 2, Figure 1b). In total, they harbour 1900 of the 1964 (96.7%) transboundary vertebrates living in China's border region (Appendix S1). PA coverages in the four hotspots averaged 13.6% (63.1% in N, 14.7% in NW, 14.2% in NE and 12.2% in SW). The N hotspot is small with only one PA—China Hulun Lake National Nature Reserve. PA connectivity index (ProtConn) of the other three hotspots were 4.51% in NW, 2.21% in NE and 1.68% in SW. In total, there were 1473 transboundary species having a PA coverage lower than the Archi target 11 (17%) within the border region. PA coverage of reptiles is significantly lower than that of birds, and there were no significant differences in PA coverage between other Classes (Table S1, Figure S3 and Figure S4).

3.3 | Potential impacts of the BRI

Routes in the BRI corridors traversed all four transboundary hotspots (Figure 1a) and intersected distribution ranges of 82.4% (1619/1964) of the transboundary species (Appendix S1). More than half (918) of these species are sensitive to ecological risks posed by the BRI. Compared to direct risks, accompanying and long-term risks will affect more species (Figure 2). Although distributions of more species of birds are traversed by the BRI (984), they are the least sensitive to the BRI risks (215). Amphibians have the highest proportion of species exposed to at least one risk (0.87, 87/100), followed by reptiles (0.69, 134/194) and mammals (0.44, 150/341). Mammals (0.27, 41/150) are the most sensitive to direct risks, followed by reptiles (0.23, 31/134) (Figure 2).

There was a slight but significant decline in the aggregation index and the proportion of natural land after the proposal of the BRI in the whole border region (Figure 3). Trends of the indexes are different in the four hotspots (Figure 3). In the NE and SW hotspots, natural land proportion significantly increased. In the NW hotspot, natural land proportion and the aggregation index significantly decreased (Figure 3a,b). The night light index significantly increased after 2013 in the whole border region, indicating an overall increase in human pressure in the border region. Worryingly, the night light index increased more rapidly in the four hotspots (Mean value: NE 0.370–0.926, NW 0.069–0.465, SW 0.201–0.530) compared to the whole border region (0.014–0.035) (Figure 3c, Table S2).

4 | DISCUSSION

Our compilation of China's transboundary species and identification of the four transboundary hotspots along the border highlight the importance of transboundary conservation action. All four hotspots identified have high transboundary conservation value, even the smallest N hotspot contains 220 transboundary species. Three hotspots (SW/NW/NE) have insufficient PA coverage and low PA connectivity. Insufficient PA coverage is universal for transboundary species, and reptiles received less PA coverage compared to birds. Increasing coverage and connectivity of PAs in the border region are necessary to protect the majority of transboundary species in China.

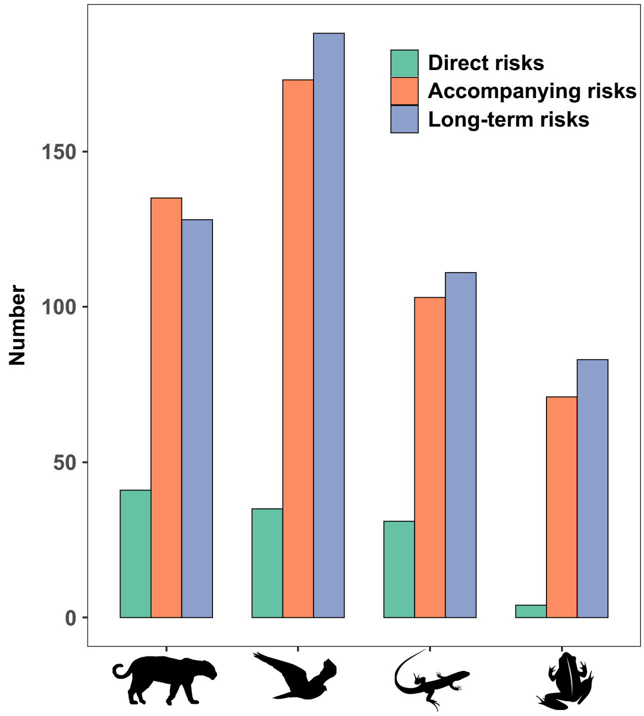

FIGURE 2 Number of transboundary species in the four classes that may be affected by the BRI.

The SW hotspot harbours the highest number (1542) of transboundary species. Many transboundary species, including the Myanmar snub-nosed monkey (*Rhinopithecus strykeri*, <950 individuals in China and Myanmar, Yang, Tian, et al., 2018), the newly discovered skywalker hoolock gibbons (*Hoolock tianxing*, <150 individuals in China, Zhang et al., 2020) and Cao-vit gibbons (*Nomascus nasutus*, 107–136 individuals in China and Vietnam, Ma et al., 2020) are endemic to this area and each has a tiny population. Without effective transboundary conservation, poaching and habitat loss and degradation will be difficult to regulate (Trinh-Dinh et al., 2022; Wang et al., 2021). Also, the SW hotspot has insufficient PA coverage (12.2%) and low connectivity (ProtConn 1.68%), especially in China, Myanmar and India (Table 2). Both China and Myanmar should make efforts to increase PA coverage and curb rampant wildlife smuggling across the border (Nijman et al., 2016; Tan et al., 2022). Although transboundary conservation cooperation between China and Myanmar may be difficult because of the unstable regime in Myanmar, this does not make the need any less important. After the outbreak of COVID-19, China built a border fence of about 500 km in Yunnan province along the border with Myanmar to stop illegal immigration, which may pose long-term negative effects on transboundary species conservation (https://new.qq.com/omn/20210828/20210828V03IZ000.html). A cooling of China–India relations in recent years has also raised concerns about the impact on

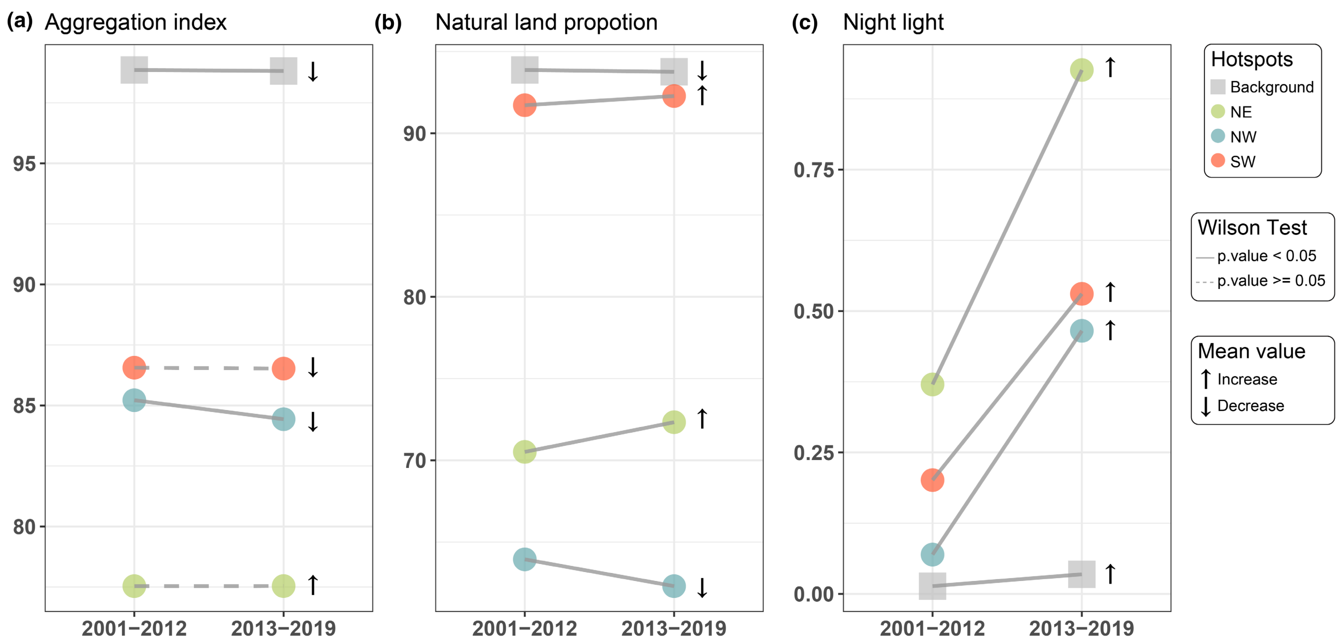

FIGURE 3 Wilcoxon test to compare each index within 2 km buffer zone of the Belt and Road Initiative (BRI) before and after the proposal of the BRI (2001–2012 vs. 2013–2019). The N hotspot has no BRI projects in operation or under construction, so is excluded from this analysis.

transboundary conservation. Existing cooperation platforms can be helpful to develop dialogue and cooperation among countries. For example, in the Hindu Kush Himalayas region, the International Centre for Integrated Mountain Development that involves eight member states including Afghanistan, Bangladesh, Bhutan, China, India, Myanmar, Nepal and Pakistan, has made great efforts in transboundary landscape conservation, promoting community participation and serving as a bridge for solving transboundary issues (https://www.icimod.org/).

The NW hotspot also has low PA coverage (14.7%) and connectivity (ProtConn 4.51%). China and Kazakhstan need to advance conservation cooperation along their border, and China (PA coverage 6.2%) needs to establish more PAs to conserve transboundary species. The China–Kazakhstan border area includes precious and fragile wetlands and arid and semi-arid habitats, and harbours threatened species such as the snow leopard and goitered gazelle (*Gazella subgutturosa*). The rising use of ecosystem services, like water resources, in both China and Kazakhstan has led to environmental deterioration (Imentai et al., 2015). Also, fences along this border likely divide wildlife populations (Rosiere & Jones, 2012). All these issues require international cooperation and coordinated management to resolve. Recently, government leaders and researchers from China and international organizations have jointly issued 'Declaration on Protecting Biodiversity and Building a Community of Life in Arid Areas', which could be a good start for transboundary conservation cooperation.

In the N and NE hotspots, termed the Amur basin, China, Mongolia and Russia have reached a series of transboundary conservation cooperation agreements since 1956 (Simonov & Egidarev, 2018). The N hotspot is small but harbours 220 transboundary species. Most of the N hotspot (63.1%) were covered by China's Hulun Lake National Nature Reserve, which is currently threatened by human activities and climate change (Zheng et al., 2016). The Hulun Lake basin is a Ramsar PA, and it is an important breeding ground for rare transboundary wading birds, such as red-crowned crane (*Grus japonensis*), white-naped crane (*Antigone vipio*) and Baer's pochard (*Aythya baeri*). Lake levels and water quality are declining, and species living on wetland are further threatened by climate change, overgrazing and overuse of water resources (Zheng et al., 2016).

The NE hotspot provides habitat for important large predators, including Siberian tiger and Amur leopard (*Panthera pardus*). Conservation of these large predators requires large and well-connected habitats. More than 95% of the Siberian tiger population lives in the Sikhote-Alin Mountains in Russia (Miquelle et al., 2006). However, additional habitat which could support larger numbers of tigers is still available on the China side (McLaughlin, 2016). Dispersal of Siberian tigers is limited by urbanization and railway and highway construction (Ning et al., 2019). PA coverage of China, Russian and North Korea in this hotspot (16.7%, 15.8% and 2.6%) is insufficient, and PA connectivity was only 2.21%. Expanding existed PAs and restoring habitat at the landscape scale is of vital importance for this region (Ning et al., 2019). As an effective practice of transboundary conservation, Northeast Tiger Leopard National Park of China and Land of the Leopard National Park of Russia built a platform for transboundary conservation. Monitoring data showed that Amur leopard and Siberian tiger had increasing populations and had expanded their habitat range (Xu et al., 2021). This successful conservation experience should be replicated to protect more transboundary threatened species.

We found that the six main economic corridors of the BRI traversed all four hotspots and traversed the distribution range of 82.4% transboundary species within the border region. Mammals and reptiles are sensitive to direct risks (Figure 2), so we need to design species-specific conservation actions during the planning of the BRI routes. It is better to circumvent their active areas. Alternatively, the combination of well-designed ecological corridors and road fences can minimized the risk of road kill (Weller, 2015). Birds and amphibians are sensitive to accompanying risks and long-term risks, which means as roads are built and operated, more species in these two Classes may be at risk. Therefore, long-term adaptive management is more important for them, such as continuous monitoring of forest and water resources, and adaptation of PAs to climate change (Li et al., 2015; Li & Gao, 2020).

Human pressure (indexed by night light) increased significantly after the proposal of the BRI in the whole border area, especially in the four hotspots. Increasing human pressure could bring more conflicts between humans and wildlife in the future. Increase movement of people will also likely increase the risk of biological invasion (Laurance & Burgues Arrea, 2017; Liu et al., 2019). To prevent these effects, it will be important to establish sufficient transboundary PAs. Fortunately, the BRI showed some positive impacts on landscape in the NE hotspot (Figure 3), which may be attributed to successful habitat restoration projects in these areas (http://www.brigc.net/zcyj/yjkt/202011/t20201125_102825.html). In fact, conservation has been put at the core of the BRI since 'The Green Belt and Road' construction was proposed in 2015. Four Chinese ministries and commissions jointly released specific guidelines on The Green Belt and Road in 2017 (https://eng.yidaiyilu.gov.cn/). However, as the BRI expands and begins to operate, habitat restoration will become an enormous challenge. Conservation planning and design in advance could be more cost-effective.

It is likely that the full extent of the impacts of the BRI will take a long time to measure due to the time lag between large-scale infrastructure construction and its environmental impact (Ascensão et al., 2022; Ng et al., 2020). Besides, negative effects on the individual or population scale of one specie need to be measured at a fine spatial scale (Fahrig & Rytwinski, 2009), which requires detailed long-term study. Many other groups of taxa like insects and plants were not included in this research, but they may face similar impacts with vertebrates from the BRI and also need transboundary conservation. For example, *Magnolia grandis*, a critically endangered tree species that is distributed in the Sino-Vietnamese border region, was predicted to shift their distribution across the border, which called for transboundary cooperation (Blair, Galante, et al., 2022; Blair, Le, & Xu, 2022). Hopefully, these less charismatic species can also benefit from conservation suggestions of this study. In any case, ecological infrastructure

(Li & Shvarts, 2017) and strategic environmental impact assessment and ecological protection planning (Blair, Galante, et al., 2022; Blair, Le, & Xu, 2022; Laurance & Burgues Arrea, 2017) will be necessary for transboundary species conservation in the hotspots.

In addition to reducing the potential negative impacts of the BRI itself, we suggest conservation efforts take advantage of opportunities brought by the BRI. By connecting more than 71 countries (https://eng.yidaiyilu.gov.cn/) and about 2/3 of the world's population (World Bank, https://www.worldbank.org/), the BRI can be an extremely wide platform for dialogue and consultation, for knowledge and data sharing, and for joint planning. Such dialogue is particularly important today given the political instability in Myanmar and Afghanistan, the cooling of China–India relations, and the conflict between Russia and Ukraine, all of which may affect the transboundary cooperation on biodiversity conservation. The BRI also brings economic prosperity and cultural exchange (Liu & Dunford, 2016), which can reduce ideological gaps and build common conservation goals. Countries that earn dividends from the BRI are obliged by multilateral environmental agreements, like the Convention on Biological Diversity, to maintain ecological services along the routes. It is important that development brought by BRI be part of an explicit strategy to promote transboundary conservation cooperation. Policymakers and conservationists in the Belt and Road member countries have to reach a consensus by putting biodiversity conservation at the core (Lechner et al., 2018).

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CONFLICT OF INTEREST

The authors declare no competing interests.

DATA AVAILABILITY STATEMENT

Additional supporting information may be found in the online version of this article. Some data used for the analyses are freely downloadable online; two datasets, including the heatmap and hotspots of transboundary species, the rasterized protected area layers in research area, are available on the Dryad repository at: https://doi.org/10.5061/dryad.573n5tb9x.

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BIOSKETCH

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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