Chin. Geogra. Sci. 2021 Vol. 31 No. 1 pp. 149–166
https://doi.org/10.1007/s11769-020-1170-8

Springer Science Press

Spatial Pattern and Development of Protected Areas in the North-south Transitional Zone of China

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Abstract: The north-south transitional zone in China mainly consists of the Qinling-Daba Mountains. It is the most important West-East geo-ecological space in China, containing protected areas vital for biodiversity conservation and ecological security of China. The protection and rational development of its natural habitat is of great significance to China's ecological security and integration of protected areas based on mountain forest ecosystems on a global scale. In this study, five important types of protected areas in the transitional zone were selected, and their spatial patterns were analysed. Spatial analysis methods, such as kernel density estimation and accessibility analysis, were employed for both point and areal data, and focused on four aspects: land use scale, shift in the centre of gravity, spatial agglomeration, and accessibility. In addition, policy background and evolution of spatial and temporal characteristics of the protected area system in the transitional zone from 1963 to 2017 were also examined. We analysed the characteristics and geographical significance of the West-east corridor using the spatial pattern of the protected area system from the perspective of ecological and economic spaces. We focused on spatial shape, type intersection, and key areas to analyse the spatial overlap of the protected areas. Protected area establishment was divided into three stages: initial (1956–1980), rapid development (1981–2013), and national park transformation (2014–present). These stages reflected the change in the concept of 'simple protection—sustainable use—integration and upgrade' for protected areas of China. The spatial centre of gravity of the protection zone system was located in the west Qinling-Daba Mountains, and its high-density core exhibited a relatively stable N-shaped structure composed of four gathering areas. Affected by factors such as geographic environment and socio-economic development density, the average access time for protected areas was high (1.56 h); wetland parks and scenic areas are located closer to the city centre. As the West-east corridor in the transitional zone extends from west to east, there is a clear spatial dislocation between the development of protected areas and the intensity of human activities. During development, differentiated goal orientation should be adopted based on the idea of zoning and classified governance. With the advancement of the construction of protected areas, the spatial overlap of protected areas in the transition zone has become more prominent. At present, the spatially overlapped protected areas in the transitional zone remain prominent, with inclusion overlap being the most common, and forest parks exhibiting the highest probability of overlap with other protected areas, we should focus on in the integration process of the corridor-type ecological space based on the mountain forest ecosystem.

Keywords: North-south Transitional Zone (NSTZ); protected area (PA); spatial-temporal pattern; accessibility; the West-east corridor; spatial overlap

Citation: LI Xiang, MA Beibei, LU Chunxia, YANG He, SUN Mengyu, 2021. Spatial Pattern and Development of Protected Areas in the North-south Transitional Zone of China. *Chinese Geographical Science*, 31(1): 149–166. https://doi.org/10.1007/s11769-020-1170-8

Received date: 2020-01-06; accepted date: 2020-04-09
Foundation item: Under the auspices of National Science and Technology Basic Resource Investigation Program (No. 2017FY100900)
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1 Introduction

Since the beginning of the 20th century, the need for protected areas (PAs) has increased rapidly globally. Moreover, the number and expanse of PAs have continuously increased and become symbolic of the civilization and progress of a country (Pouzols et al., 2014; Ye et al., 2017). Land protection in China started in the 1950s, after the formation of the starting-stagnation-development process, China has formed two types of protected areas system, including a natural resource system and cultural resource system (Zhu et al., 2017). As of 2017, China had established more than 2000 national nature reserves, forest parks, and other types of PAs (Pan et al., 2018). However, lack of clarity about the rights and responsibilities of the management, overlapping, and protection vacancies in the spaces have restricted the sustainable development of the land system protection in China for a long time. China's north-south transitional zone (NSTZ) is mainly composed of the Qinling and Daba mountains (Peng et al., 2018). It is the most critical geological-ecological transition zone in China and holds considerable significance in the formation of China's geographical pattern, evolution of biological flora, and distribution of natural resources (Zhong et al., 2016). In 2017, the Chinese government issued 'Overall Plan on the Development and Management of National Parks', which marked the formal transformation of China's protected area system from nature reserves to national parks (He et al., 2018). In addition, two of the ten national park pilot projects in this plan are located in the transition zone. In such an area where biological significance and national ecological security significance can not be ignored, what are the characteristics and rules of the space-time pattern of the development of the protection land system under the influence of the national macro policies? What are the characteristics and manifestations of the management and space problems of the protection land system in the NSTZ of China? For developing countries that mostly take the concept of focusing on the coordination of the relationship between protected areas and surrounding stakeholders in the construction of protected areas, what theoretical and political significance does the empirical study of China's north-south transition zone as a typical case have for similar regions in the world? These are all important issues that need to be studied urgently in the national park transformation stage.

The concept of PA was first proposed by UNESCO (United Nations Educational; Scientific and Cultural Organization) in 1962 (Dudley et al., 2010), PAs were considered to be beneficial for the protection of animal and plant habitats, and the natural state of geographical structures while fulfilling the economic and scientific goals for the future of humankind. The idea for establishing protected areas globally has evolved from the original notion of protecting natural spaces to a global PA culture that reflects the relationship between humans and nature. In particular, the research on national parks as an advanced form of protected areas has gradually transitioned from a purely 'biocentrism' concept to an emphasis on the interaction process between national parks and multiple stakeholders (Chen et al., 2019). At present, Western research is mainly concentrated in developed countries such as the United States, Canada, Australia, the United Kingdom, and New Zealand. The relevant results have made great progress in classification systems, development concepts, resource assessment, environmental impact, planning management, and operating models; relatively little research has been conducted in emerging regions and countries (Buckley et al., 2017). Since the construction and management of protected areas and national parks can not be separated from the macro-regional development, there are differences in the concept and focus of the current protected areas in developing and developed countries. Developed countries pay more attention to the use of multiple methods to maintain the integrity of the ecosystem, while developing countries focus more on coordinating the relationship between national parks and surrounding stakeholders (Ceccherelli et al., 2011). At present, the geographical research on protected areas in China has accumulated relatively rich results in the pattern recognition and analysis of the macro-scale, with little attention on local PAs which have undergone rapid growth in the past decade (Fan et al., 2013). In terms of the types of PAs, research has mainly focused on examining the spatial distribution characteristics and influencing factors of one type of PA, there are relatively few comprehensive studies on the integration of multiple types of protected area systems (Ma et al., 2018). Limited by data, in terms of research scale and research thinking, PAs have often been abstracted into point elements for macro analysis, while research on accurate analysis of

PAs on a micro scale has been lacking. To a certain extent, this caused the separation of PA research and regional attribute research (Huang et al., 2019). In terms of research hotspots, the literature analysis result showed that nature reserves are the most concerned type of PAs in existing research (Chen et al., 2019). Geographical studies on PAs often took eco-tourism as the starting point (Ping et al., 2017). Since 2000, national parks have received considerable attention from the Chinese government. Many scholars have discussed the integration of existing PA systems and the pilot model of the national park in China (Chen et al., 2014) based on the experiences of the International Union for Conservation of Nature (Zhang et al., 2015), the United States (Wang et al., 2017), and Japan (Xiao et al., 2017).

By combining existing research, we selected five main types of PAs with the most complete system and highly recognised Chinese spatial scale (Li, 2019; Xu et al., 2019) (i.e. nature reserve (NR), scenic area (SA), forest park (FP), geological park (GP), and wetland park (WP)), and used national and provincial PAs in the transition zone as the research object. According to the spatial performance-element association concept, we explored and discussed the spatial and temporal evolution process, and pattern of the protected area system in the NSTZ, and the characteristics and geographical significance of the 'West-East' corridor, reflected in the two dimensions of ecological space and economic space, with the analysis of face shape element spatial scale. Furthermore, in view of the current multi-management phenomenon of protected areas in China, the spatial overlap of PAs in the study area was analysed in the spatial form, cross-type, and key area system. Based on the regional comprehensive perspective of geography, this article aims to organically link the pattern analysis of protected areas at the phenomenon level with the regional resource ecological foundation and socio-economic development, and promote the development of China's PA research to a more precise, connected, and comprehensive dialectical logic. The research conclusions of this article are helpful to systematically organise the spatial and temporal evolution process and mode of the PA system of China, clarify the main manifestations of the current spatial integration of protected areas in China, and coordinate environmental resources in the construction of PAs systems in China and similar developing countries globally, aim to protect the relationship between local social and economic development, and build a national park management model and provide a scientific basis for the adaptive governance system.

2 Materials and Methods

2.1 Study area

The NSTZ geographically lies between the warm-temperate and subtropical areas of central China, serving as a dividing line between the Yellow and Yangtze river basins (Fig. 1). It is also the only ecological corridor connecting east and west China (Zhang, 2019).

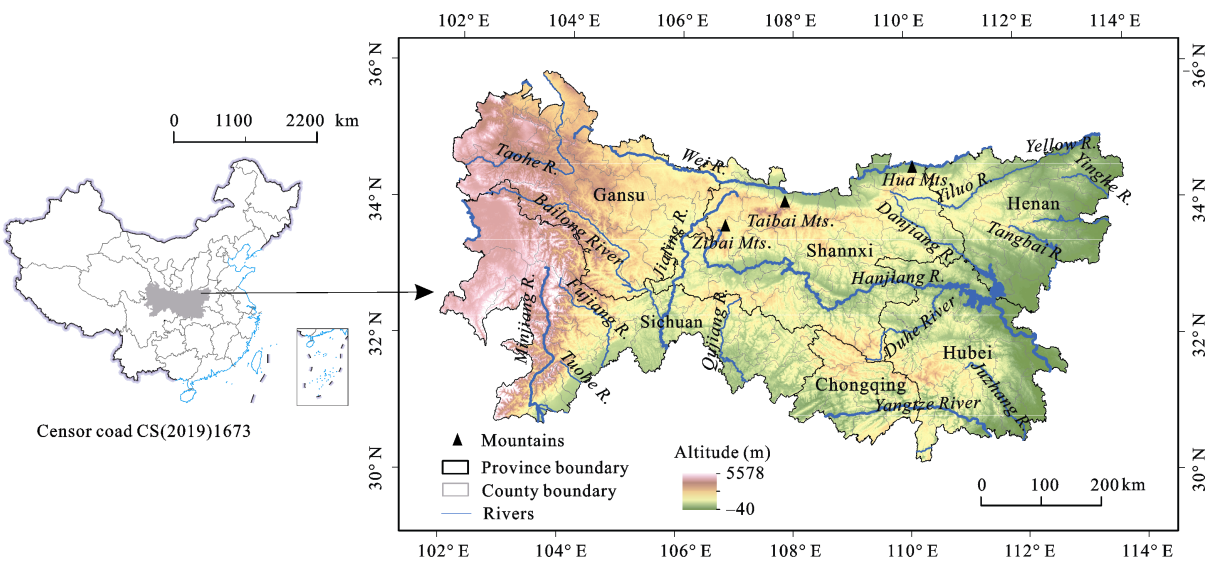

Fig. 1 Location of the North-South Transitional Zone of China

According to the National Basic Resources Investigation Program 'Integrated Scientific Investigation of the North-South Transitional Zone', the NSTZ includes 176 counties/districts in Henan, Hubei, Chongqing, Sichuan, Shaanxi, and Gansu provinces/municipalities, with a total area of 421 865 km^2 and total population of 83.59 million in 2017 (NBSC, 2018). NSTZ is one of the largest contiguous poverty-stricken areas in China. In 2017, its GDP accounted for 33.21% of the total national GDP of China; however, its per capita GDP was 39515 yuan (RMB), only 66.80% of the national average (NBSC, 2018).

2.2 Data sources

The data for this study, such as location, area, type, and protection objectives of national and provincial PAs, were collected from the official websites of China, including Ministry of Ecology and Environment of the People's Republic of China (http://www.mee.gov. cn), National Forestry and Grassland Bureau (http://www.forestry.gov.cn/), Ministry of Housing and Urban-Rural Development of the People's Republic of China (http://www.mohurd.gov.cn/fjms/), and the official websites of the individual PAs. In 2017, the number of PAs in the NSTZ was 401, which included 139 nature reserves, 127 forest parks, 38 geological parks, 59 Scenic area, and 38 wetland parks (Table 1). PA relevant administrative agencies of China and their functioning significantly changed in 2018. Therefore, for 2018, the centralized management departments of different types of PAs areas are discussed separately in Table 1.

The images from Google Maps and the latest planning maps were used to digitise the boundaries of the above-mentioned 401 PAs to obtain their surface information. Subsequently, they were calibrated according to the latitude, longitude, and area of the PA. Circular shapes were used for the PAs with missing planning maps (mostly at the provincial level) according to their published latitude and longitude ranges.

2.3 Methodology

2.3.1 Spatial centre of gravity

To analyse the overall characteristics and evolutionary trajectories of the spatial distributions of the PAs located in the NSTZ, the spatial centre of gravities of the distributions of the PAs after the abstract treatments of the centre of masses were calculated by taking the PA area as the weight and using the geometric tool of ArcGIS10.2 (Gong, 2002). The formula is as follows:

$$G(x,y)=\left(\frac{\sum_{i=1}^{n} w_i x_i}{\sum_{i=1}^{n} w_i}, \frac{\sum_{i=1}^{n} w_i y_i}{\sum_{i=1}^{n} w_i}\right) \quad (1)$$

where G is the spatial centre of gravity, x and y are the longitudes and latitudes of the spatial centre of gravity, respectively, x_i and y_i are the longitudes and latitudes of i PA's geocentric protection after the abstract processing, respectively, w_i is the area of i PA, and n is the number of PAs in the NSTZ.

Table 1 Classification and management of the protected areas in the north-south transitional zone of China

Type	Centralized management		Number	Proportion of the total area of China (%)
	Before 2018	Since 2018		
Nature reserve (NR)	More than a dozen departments, including forestry, agriculture, land, environmental protection, ocean, housing construction, and water conservancy	National Forestry and Grassland Bureau Nature Reserve Management Division	139	5.05
Forest park (FP)	State Forestry Administration	National Forestry and Grassland Bureau Forest Resources Management Division	127	8.44
Scenic area (SA)	Ministry of Housing and Urban-Rural Development of China	National Forestry and Grassland Bureau	59	5.61
Geological park (GP)	Ministry of Land and Resources	National Forestry and Grassland Bureau	38	11.79
Wetland park (WP)	State Forestry Administration	National Forestry and Grassland Bureau Wetland division	38	2.24

Notes: Due to lack of data on the number of provincial-level geological parks in China, the number of geological parks in the study area only represents the proportion of national-level geological parks

2.3.2 Kernel density estimation

In this study, the kernel density estimation (KDE) method, using ArcGIS10.2, was utilised to analyse the spatial agglomeration characteristics of the PAs (O'Brien, 2012). In KDE, the probability of occurrence of the geographical practices at different locations is considered to be different. The probability of occurrence of events in areas with dense points is high (McCloud, 2020). The formula is as follows:

$$f(x)=\frac{1}{nh}K(\frac{x-x_i}{h}) \tag{2}$$

where $f(x)$ is the kernel function, n is the number of PAs in the NSTZ, $K(\ )$ is the kernel function, h is the bandwidth, namely the radius of the circle domain, and $x–x_i$ is the distance from the evaluation point to the output grid.

2.3.3 Accessible time

To reflect the strength of socio-economic links between the PAs and their region, the shortest driving time from the administrative centre to the central point abstracted from each PA was calculated using Amap (Chinese MapQuest https://www.amap.com/) to represent the accessible time of each PA (Williams et al., 2019).

2.3.4 Area coverage

To analyse the distribution characteristics of the PAs in the West-East corridor of the NSTZ, the area coverage rate of the protected land in 176 counties falling in the study area was calculated using the following formula:

$$P=\frac{\sum_{i=1}^{m}S_{pi}-\sum_{i=1}^{m}S_{oi}}{S_a} \tag{3}$$

where P is the area coverage rate of the PAs in the county, m is the number of PAs in the county, S_{pi} is the area of the i protected area of the county, S_{oi} is the overlapping area of the i protected area, and S_a is the administrative area of the county.

3 Results

3.1 PA system development in the NSTZ

3.1.1 Development history

The development and evolution of the PA system in the NSTZ can be divided into three stages based on the number and structure of different PAs: initial stage, rapid development stage, and national park transformation stage (Fig. 2). In the initial stage (1956–1980), the number of PAs grew slowly, consisting of only one type of PA (i.e. NR). For more than 20 yr, only eight national nature reserves, including Sichuan Wolong National Nature Reserve, and two provincial nature reserves were established. The total planned area of the PAs was approximately 7187 km^2 (Huang et al., 2018). In the rapid development stage (1981–2013), 351 national and provincial PAs were added in the NSTZ, accounting for 86.35% of the total area of the existing PAs, with the total planned area increasing to 76 909 km^2. Additionally, in this stage NRs dominated the PA system in the NSTZ, with the newly added proportion reaching to 35.06%, followed by FPs with a proportion of 34.47%. The development of WPs and GPs started in 2000, with a relatively small number, respectively accounting for 7.00% and 8.00%. During the national park transformation stage (since 2014), the PA system in the NSTZ exhibited stable and optimized development characteristics. In this stage, only 55 PAs were added, and WPs exhibiting the fastest growth rate with 18 new additions, followed by NRs with five new additions.

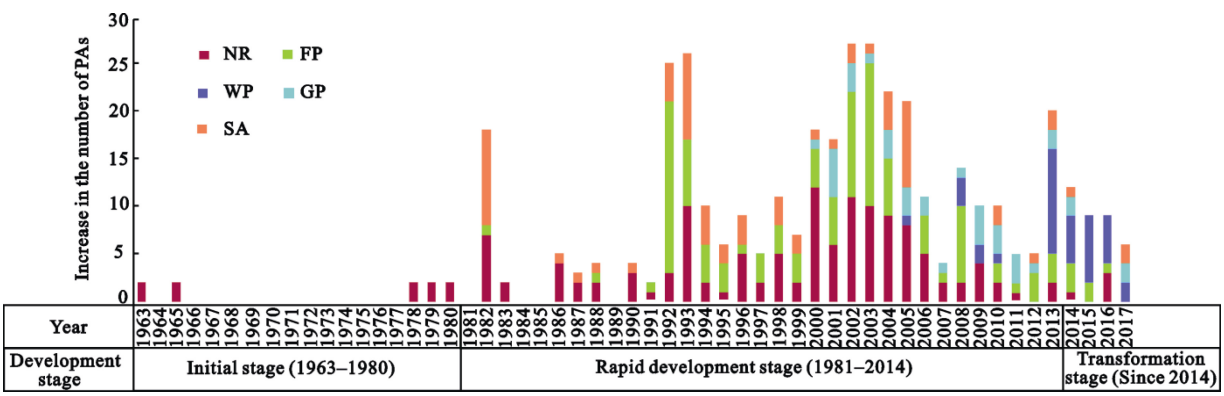

Fig. 2 Number of authorized protected areas (PAs) per year in the North-South Transitional Zone of China (1963–2017). NR: Nature reserve; SA: Scenic area; FP: Forest Park; GP: Geological Park; WP: Wetland Park

3.1.2 Policy background of the evolution of PAs

The evolution and characteristics of the protected land system in the NSTZ were directly affected by the changes made in relevant policies, regulations, and management modes in China.

During the initial stage (1956–1980), the PAs in China were mainly formed for 'preserving the original growth state of plants driven by various places and 'rescuing and protecting the natural environment seriously affected by human production and life' (Huang et al., 2018). However, due to interference from political movements, especially the Cultural Revolution, the number of PAs established in the NSTZ increased slowly, with many periods when no PAs were established.

During the rapid development stage (1981–2013), under the dual influence of economic reforms and international environment, the guiding ideology for establishing PAs in China changed to maintaining the ecology and biodiversity while considering tourism development to better utilise the economic, social, cultural, and educational benefits of the PAs (Duan et al., 2015). Accordingly, the protection zone system in the NSTZ rapidly expanded and entered a new stage with the establishment of different types of PAs, with NRs as its main component (Li et al., 2001). Two distinct peak periods occurred in this stage. The first period occurred from 1992 to 1993, guided by the government's 'Decision to Accelerate the Development of the Tertiary Industry' and 'Encourage Provinces and Cities to Accelerate the Development of Tourism' (Sheng et al., 2019). The NSTZ strongly impacted tourism development, with the number of leading SAs and FPs significantly increasing and accounting for 74.50% of the newly added PAs in the NSTZ during this period. The second peak occurred from 1999 to 2005, when the Chinese government paid more attention to the protection of forest habitats and wild plants. A total of 53 FPs and 24 NRs, mainly for protecting forest ecosystems and rare plants, and 6 SAs, mainly for protecting the forest landscape, were established along the NSTZ. The newly established PAs during this period accounted for 57.24% of the total land area of NSTZ.

In the national park transformation stage (since 2014), many issues arose during the establishment and management of the PAs, such as intersecting management, unclear confines between rights and liabilities, and overlapping and protection vacancies (Wang et al., 2019). This was due to the increase in the number of PAs in China as well as the diversification of the PA types. These issues weaken the ability of the PAs to maintain ecosystems, provide high-quality ecological products, and support regional sustainable development. Therefore, National Park Reform policy was formally proposed in 2014 to improve the existing PA system and promote its sustainable development in China. Subsequently, the Chinese government issued the 'Overall Plan for Establishing a National Park System' in 2017, and a National Park Administration was established in 2018 to bring all nature reserves within the pilot scope of a unified management. Shennongjia and Giant Panda national parks situated in the NSTZ were selected among the 10 national park pilots established in 2017.

3.2 Spatial characteristics of the protected zone system

3.2.1 Land use scale characteristics

The total land use of various PAs in the NSTZ is 86 769 km^2, accounting for 20.57% of the total area of the NSTZ. The average area of all types of PAs is 216 km^2, but the types exhibited significantly non-equilibrium characteristics (Fig. 3). The NRs dominate the PA system, having the largest total land use and average area for a single park. Although the number of FPs accounts for 31.67% of the total number of PAs in the NSTZ, the total and average areas of a single park is often small. Furthermore, the average area of the SAs and geoparks is large. However, as the number of SAs and geoparks is small, their total area is small. The WP, a type of protected land, occupies the least area in the NSTZ, with total and average land areas of 1.35% and 14.68%, respectively, of the average value of the protected land in the NSTZ.

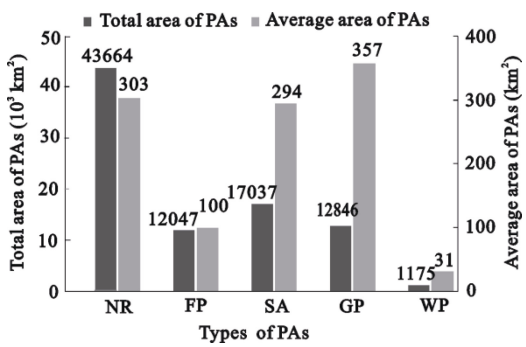

Fig. 3 Total and average areas of different types of protected areas (PAs). NR: Nature reserve; SA: Scenic area; FP: Forest Park; GP: Geological Park; WP: Wetland Park

3.2.2 Characteristics of the movement of the centre of gravity

The movement trajectory of the spatial centre of gravity of the protection centres obtained through area weighting indicated that most of the spatial centre of gravity of the protection centres in the NSTZ underwent a displacement path of northeast, followed by northwest, but it was always located in the west of Qinling (west side of Zibai Mountain). Regarding the type differentiation, only the spatial centre of wetland parks moved 35 km southeast in Baihe and Yunxi counties at the junction of Shaanxi and Hubei provinces. Other types of PAs contained smaller centre of gravities migration distances, and the centre of gravity was always distributed in Shiquan County (centre of GPs), Ningqiang County (centre of NR), Lueyang County (centre of FPs), and Shao Huahua (centre of gravity of SAs).

The movement of the centre of gravity of the PAs was mainly affected by the conditions of resources and environment. PAs located in the western part of the NSTZ were mainly the type with larger areas, such as NRs and SAs. In NSTZ, the size of an individual PA located in the west was generally larger than of one located in the east. Simultaneously, PAs in the western part of the NSTZ were mostly established earlier, which, to a certain extent, resulted in more contiguous PAs in the western Qinling-Daba region. Although in recent years, WPS and other types of PAs have been rapidly established in the eastern part of the NSTZ, their spread has been limited due to increased human activities, thus, forming large-scale contiguous PAs has been difficult. Therefore, the spatial centre of gravity of the protected zone system in the NSTZ has always been located in the west of Qinling-Daba Mountains.

At different stages of development, the leading forces responsible for the movement of the spatial centre of gravity of a PA, within the NSTZ, differed (Table 2). In the rapid development stage, the movement of the spatial centre of gravity of the PAs in the NSTZ was mainly affected by the national-level PAs. In the national park transformation stage, the newly added areas of the provincial-level PAs was approximately 1.45 times that of the national-level PAs; thus, the overall direction of gravity of the PAs was closer to the provincial-level PAs.

3.2.3 Spatial clustering characteristics

The rapid development stage was the main period of growth of PAs in the NSTZ of China. Therefore, the bandwidth in this study was selected to highlight the agglomeration of the rapid development stage. After repeated estimations and debugging, the bandwidth was set as 0.6 km (McCloud et al., 2020). Overall, the high-density core of the PAs in the NSTZ exhibited a relatively stable N structure (Fig. 4). It was mainly concentrated in the following four areas: eastern Sichuan Province (Anzhou, Mianzhu, Shifang, Pengzhou, and Dujiangyan), southern Shaanxi Province (Zhouzhi, Taibai, and Chang'an), western Henan Province (Gongyi, Xinmi, Fuyang, and Dengfeng, and Neixiang and Xishan), and northwest Hubei Province (Fangxian, Baokang, and Gucheng). In particular, the spatial high-density core positions in the latter two stages mainly overlapped. However, the maximum kernel density in the national park transformation stage increased by 23.93%, compared to the rapid development phase. This indicated that during the transition of the PA system to national parks in China, the spatial accumulation pattern of the PAs within the NSTZ was consistently strengthened.

Table 2 Movement direction and distance of the centre of gravity of the protected areas in the North-South Transitional Zone of China

Stage	Level	Coordinate	Direction	Distance (km)
Initial (1956–1980)	National and provincial	105°23′24″E; 32°13′48″N	/	/
	National	105°23′24″E; 32°13′48″N	/	/
Rapid development (1981–2013)	National and provincial	106°25′48″E; 32°52′48″N	northeast	120.80
	National	106°22′12″E; 33°5′24″N	northeast	/
	Provincial	106°24′36″E; 32°31′12″N	/	/
National park transformation (since 2014)	National and provincial	106°25′12″E; 32°52′48″N	northwest	0.90
	National	106°27′36″E; 33°4′12″N	southeast	8.51
	Provincial	106°16′12″E; 32°34′12″N	northwest	15.67

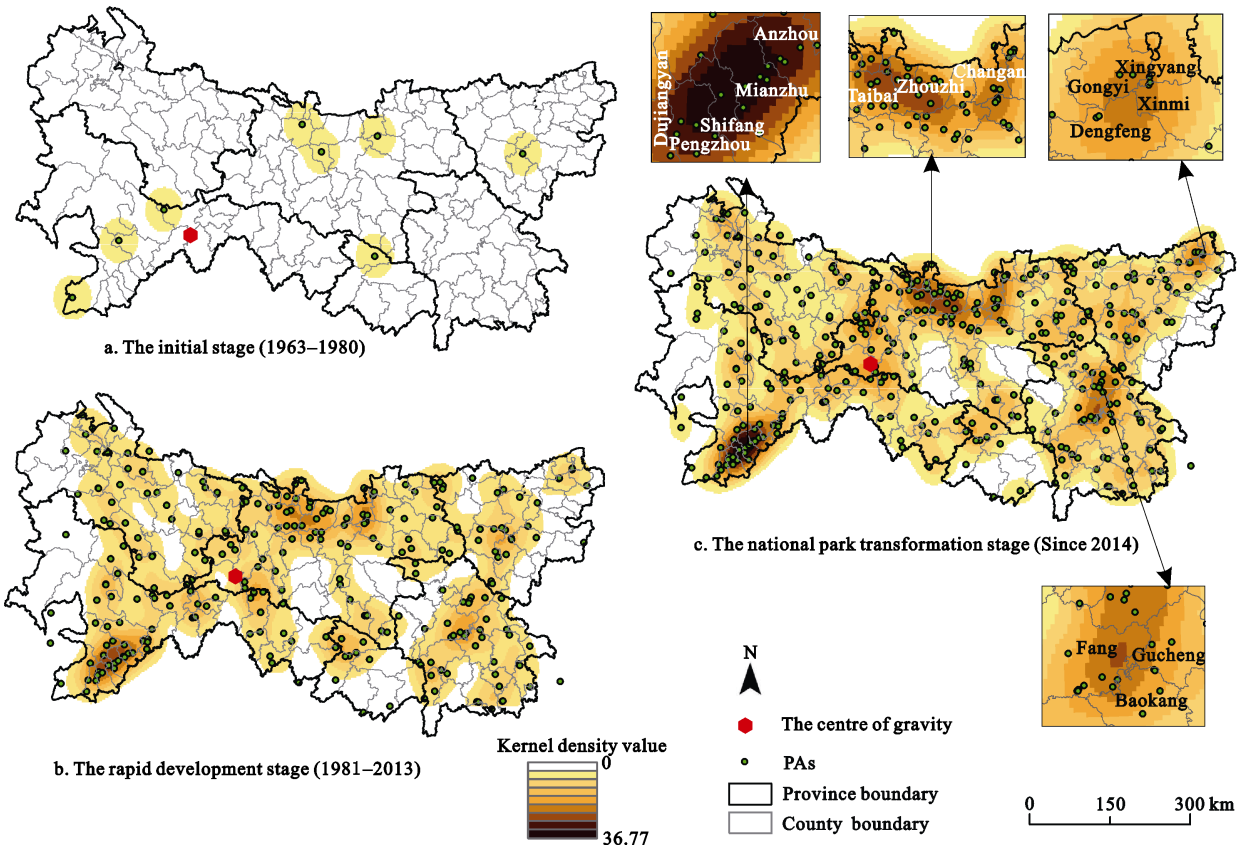

Fig. 4 Knernel density distribution and the centre of gravity of protected areas (PAs) in the North-South Transitional Zone of China in 1963–2017

FPs had four cores consisting of one big and three small cores (Fig. 5). Meanwhile, the remaining types of PAs only had a single-centre structure. FPs are mainly concentrated in the southern part of Shaanxi Province (Zhouzhi, Huyi, and Ningshan). Three small agglomeration cores were located in the western part of Henan Province (at the junction of Dengfeng, Gongyi, Fuyang, and Xinmi) and eastern Sichuan Province (Mianzhu, Shifang, Pengzhou) and north-eastern Sichuan Province (Wanyuan, Hanxuan). The core of the NR is located in the south of Shaanxi Province (Taibai, Zhouzhi, Yangxian, and Foping); The core of the SA is located in the east of Sichuan Province (Mianzhu, Shifang, Pengzhou, Anzhou); The core of GP is located in the east of Sichuan Province (Nanjiang, Nanzheng, Wangcang); The core of the WP is located in Hubei Province (Nanzhang, Yicheng, and Xiangyang).

3.2.4 Accessible time

Accessible time is one of the critical indicators for describing the characteristics of a PA (Pan et al., 2018). It also provides a visual representation of the strength of social and economic links between the PA and region. In this study, using the Amap data, we calculated the shortest driving time between the provincial-level (prov'l) and national-level (nat'l) PAs located in the NSTZ in 2017 and the administrative centre (district and county government seat) (Fig. 6).

Results indicated the average access time for the PAs as 1.56 h, which was 0.56 h longer than that of the national nature reserves of China (Xu et al., 2019). According to the standards issued by the National Bureau of Statistics in 2003, the study area was located in the NSTZ of central and western China, with the area of the western region accounting for 71.42%. Due to factors such as the physical and geographic environment, and the density of social and economic development, the accessibility of PAs in western China has been found to be generally lower than in central and eastern regions of China (Xu et al., 2019). Regarding the level, although the number of provincial-level PAs (186) in the NSTZ was less than the national-level PAs (215), the average access time for the provincial-level PAs was 0.27 h less

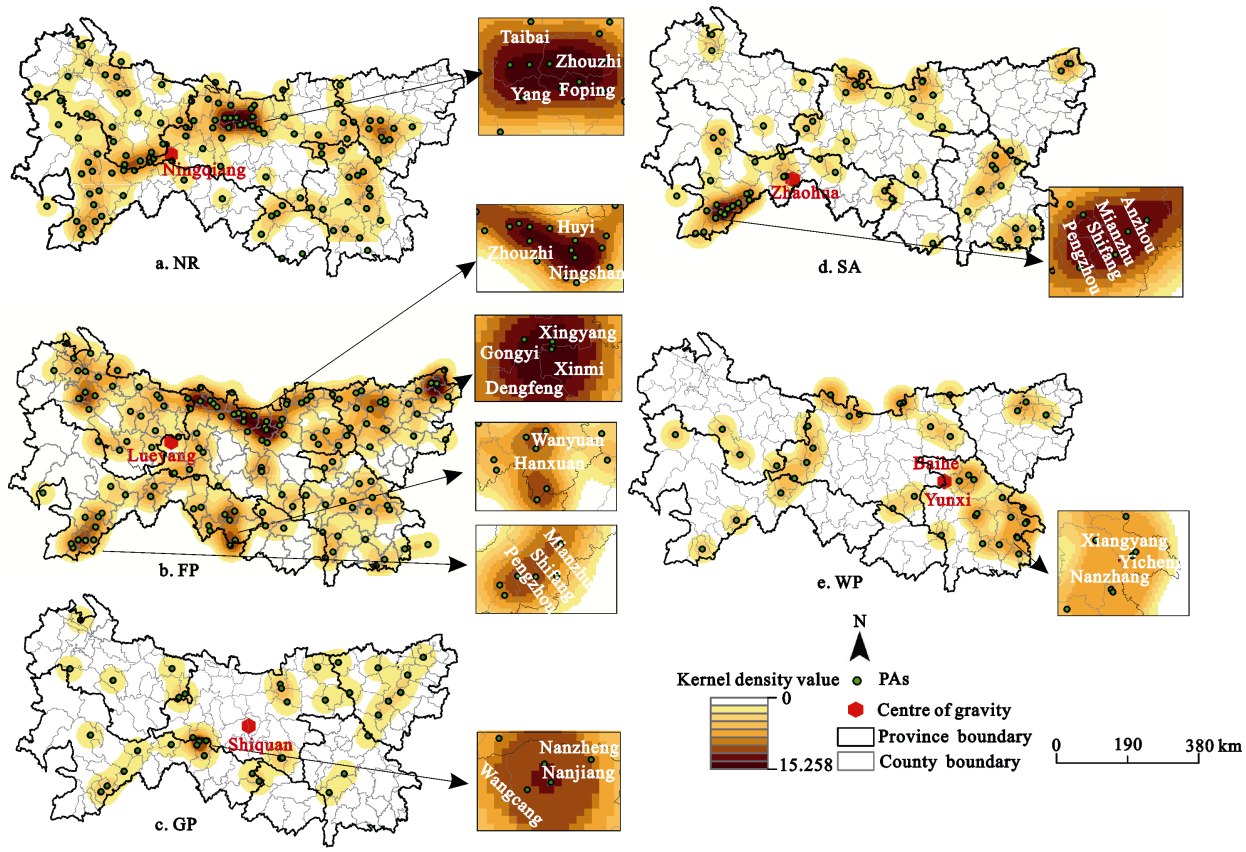

Fig. 5 Kernel density analysis and the centre of gravity of different types of protected areas (PAs) in the North-South Transitional Zone of China in 2017. NR: Natural Reserve; SA: Scenic area; FP: Forest Park; GP: Geological Park; WP: Wetland Park

than that for national-level PAs. This was mainly due to the larger average size of national PAs, with an average area of approximately 1.3 times of the provincial PAs. Therefore, centroid abstraction produced a long distance.

The five types of PAs were categorised into two types: near-city and far-city. Near-city types included WPS and SAs, with an average access time of approximately 1.0 h, and 36.67% of WPs were located within 0.5 h, which was consistent with the maximum living radius of residents with cars in China (Ni, 2013). The accessibility advantage of near-city type PAs fulfilled the original intention of establishing these PAs, i.e., to provide a recreational space for citizens while protecting the ecological environment. In particular, since the transformation of national parks, WPs became the fastest growing PAs. WPs are usually located in areas with a high concentration of human production and living spaces, such as river basins and its vicinities (Guo et al., 2019); thus, the distance to the urban built-up areas is short.

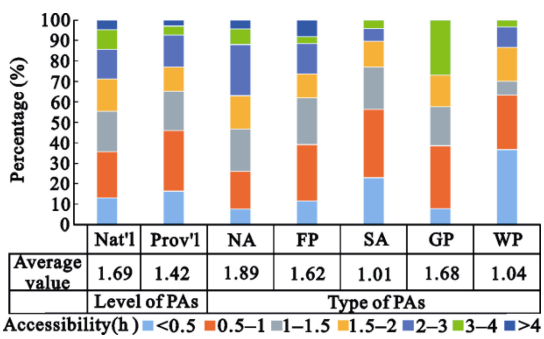

Fig. 6 The reachable time of various types and grades of the protected areas (PAs) in the North-South Transitional Zone of China in 2017. NR: Natural Reserve; SA: Scenic area; FP: Forest Park; GP: Geological Park; WP: Wetland Park,prov'l: provincial-level, nat'l: national-level

3.3 Characteristics of the West-east corridor distribution of the PAs in the NSTZ

3.3.1 Characteristics of the West-east corridor distributed in the ecological space

The NSTZ is the most important large-scale West-East

ecological corridor of China and is of great significance for studying the biodiversity and unique diffusion pathways of China. Zheng (2008) categorised the ecological geography of China into 49 natural areas based on a combination of natural factors, such as temperature, moisture, and landform. Per this categorisation, 11 types of natural areas were found to be distributed along the NSTZ from west to east, from the coniferous forest steppe area in the Qilian Qingdong Alpine Basin to the artificial vegetation area in the North China Plain (Fig. 7). The forest ecological zone, which was dominated by deciduous broad-leaved forest areas (IVA2) in the Qinba Mountains, had the largest area, accounting for 65.11% of the total NSTZ area. This natural habitat background promoted the formation of protection features by protecting the forest ecosystem as a core function in the NSTZ. FPs accounted for 31.67% of the total PA system and the proportion of other types of PAs, with forest ecosystem as the main protection object, was 10.69%.

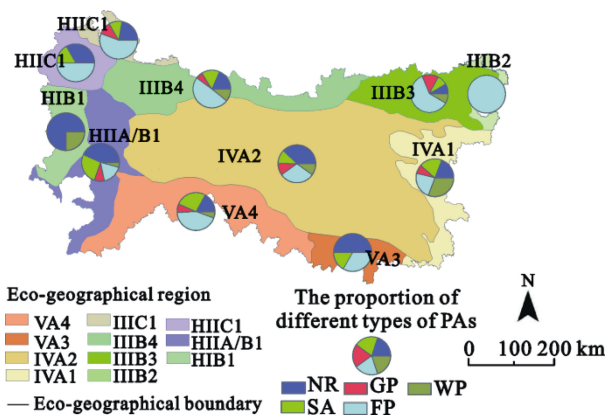

Fig. 7 Spatial distribution of the classification of protected areas based on the eco-geographical region in the North-South Transitional Zone of China in 2017. HIB1: Guoluo-Naqu plateau mountain alpine shrub-meadow region; HIIA/B1: western Sichuan and eastern Xizang high mountain and deep valley coniferous forest region; HIIC1: Qilian Mountains of eastern Qinghai high mountain and basin coniferous forest region; IIIB2: North China Plain cultivated vegetation region; IIIB3: North China mountain deciduous broadleaved forest region; IIIB4: Fenhe and Weihe river basins deciduous broadleaved forest and cultivated vegetation region; IIIC1: northern and middle Loess Plateau steppe region; IVA1: Mid-lower reaches plain of Changjiang River and Dabieshan Mountain evergreen and deciduous broadleaved forest mixed region; IVA2: Qinling and Bashan mountains evergreen and deciduous broadleaved forest mixed region; VA3: Hunan and Guizhou mountains evergreen broadleaved forest region; VA4: Sichuan Basin evergreen broadleaved forest and cultivated vegetation region. NR: nature reserve; SA: Scenic area; FP: Forest Park; GP: Geological Park; WP: Wetland Park

To explore the West-East corridor effect of the PA system in the NSTZ from a macro perspective, the change law of the area coverage of the PAs in each zone and county along the longitude was analysed using ArcGIS 10.2. The method included calculating the distance of the central point of 176 districts and counties after abstracting the centroid from the reference line using the geodetic projection coordinates at the westernmost edge of the NSTZ as the vertical reference line. The distance from the west reference line was used as the horizontal axis and the protective ground space coverage was plotted on the vertical axis. The average of the horizontal and vertical coordinates was used as a reference to draw the secondary coordinate axis. The graph is divided into four quadrants (Fig. 8). Results indicated a gradual decrease in the distribution characteristic of the coverage of the PAs in all districts and counties as the NSTZ extended from west to east. On the eastern side, the proportion of districts and counties, with the coverage of PAs below the average of NSTZ, was as high as 40.7%. The Shennongjia Forest District exhibited the highest spatial coverage and was selected as a pilot national park pilot. It is located in the western Hubei Province, with a spatial coverage of 99.9%, followed by Li County in the Aba Tibetan Autonomous Prefecture in eastern Sichuan and Tibet. Yaluo provincial NRs and SAs had a PA coverage of 85.4%.

3.3.2 Characteristics of the West-east corridor distributed in the economic space

In 2011, the State Council of China issued the 'Major Function Zoning', which divided China's land space into four categories: optimized development zone, major development zone, restricted development zone, and

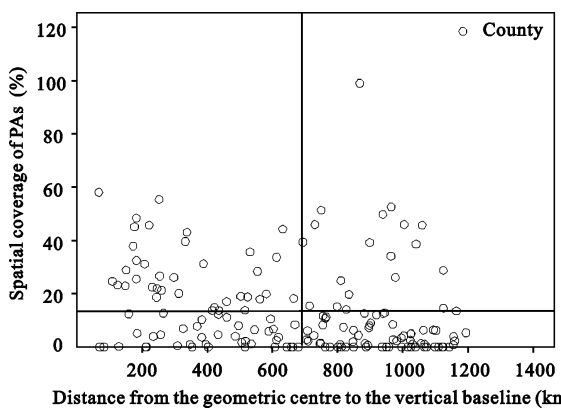

Fig. 8 The 'West-East' change of spatial area coverage of the PAs in each county in North-South transition zone of China in 2017

prohibited development zone (Fan, 2015). PAs are in a restricted development zone, the delineation of PAs will mostly restrict the expansion of construction land, urbanization processes, and regional economic development. Alternatively, PAs also have higher values in terms of viewing, recreation, and popular science, resulting in the development of local tourism and related service industries (Cao et al., 2012). Thus, to explore the economic significance of the spatial distribution of the PA system in the NSTZ, the distance from the west reference line was used as the horizontal axis and GDP of the county was plotted on the vertical axis (Fig. 9).

Results indicated that the GDP of all districts and counties displayed a periodic increase as the NSTZ extended from west to east. Within 0–220 km from the western edge (from Sichuan Luqu to Sichuan Jiuzhaigou), the GDP of each district and county rapidly increased from west to east, within 220–880 km (from Sichuan Shifang to Hubei Shennongjia Forest Area), the GDP of each district and county remained relatively stable with a significantly small difference, and for a distance >880 km (from Hubei Fang to Henan Xinzheng), the GDP of each district and county rapidly increased from west to east and formed a High GDP area on the east side of the NSTZ.

3.4 Spatial overlap in the PAs in the NSTZ

Different types of PAs have fallen under the jurisdiction of different management departments in China for a long time, thus creating a significant spatial overlap in the existing PA system. This leads to further problems, such as the problems of multiplemanagement and unclear responsibilities (Wang et al., 2019). In the rapid development stage, with the diversification of PA types, the spatial overlap of the PAs in the NSTZ became more prominent. By 2014, the proportion of PAs with spatial overlap accounted for 29.17% of the total number of PAs in the NSTZ. By 2017, the proportion had increased to 33.53%, which implied that 9 of the 28 newly added PAs were established during the national park transformation stage. To further study the current situation of the spatial overlap in the PA system in the NSTZ, spatial forms, intersection types, and key areas were analysed to provide a basis for the spatial integration and optimization of the PA system in the NSTZ.

3.4.1 PA overlap based on spatial morphology classification

The spatial overlap of the PAs in the NSTZ was divided into three types based on spatial forms: complete overlap, inclusion overlap, and crossed overlap (Table 3).

Complete overlap implied multiple hanging brands at the same place. This type of PA usually contained excellent natural conditions and geographical location, which met the evaluation criteria of different types of PAs. Therefore, the same functional area was used to declare different types of PAs and was approved by relevant state departments. In 2017, 21 PAs with an overlap problem were located in the NSTZ (Table 4, Fig. 10), accounting for 18.26% of the total.

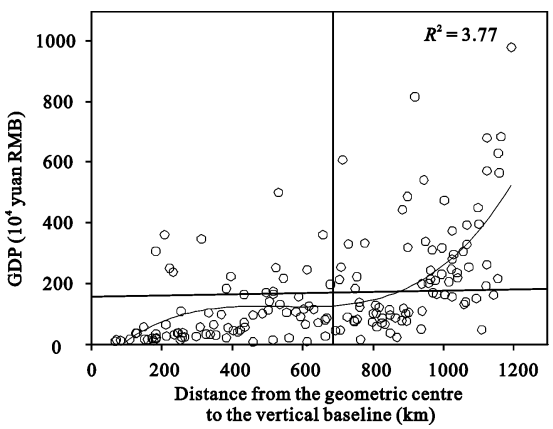

Fig. 9 The 'West-East' change of GDP of the North-South transition zone of China in 2017

Table 3 Types and evolution of spatial overlap of protected areas in the North-South transition zone of China

Year	Number	Percentage (%)	Complete overlap		Inclusion overlap		Crossed overlap	
			Number	Percentage (%)	Number	Percentage (%)	Number	Percentage
1980	0	0	0	0	0	0	0	0
2014	105	29.17	19	18.10	77	73.33	9	8.57
2017	115	33.53	21	18.26	83	72.18	11	9.57

Table 4 Completely overlapped protected areas located in the North-South transition zone of China

Administrative Region	Completed Year	Name
Xingyang County	1988	Huancuiyu Provincial Forest Park
	1988	Huancuiyu Provincial Scenic Area
Luoning County	2002	Henan Shenlingzhai National Forest Park
	2005	Luoning Shenlingzhai National Geological Park
Fang County	2003	Savage Valley Provincial Nature Reserve
	2002	Fang County Savage Valley Provincial Geological Park
Zhouzhi County	1992	Louguantai National Forest Park
	1993	Louguantai Provincial Scenic Area
Langao County	2002	Nangongshan National Forest Park
	1993	Nangongshan Provincial Scenic Area
	2009	Nangongshan National Geological Park
Wudu District	2005	Wanxiang Cave Provincial Geological Park
	1999	Nangongshan Provincial Scenic Area
Dangchang County	2014	Nangongshan National Geological Park
	2003	Wanxiang Cave Provincial Geological Park
		Wanxiang Cave Provincial Scenic Area
Hezheng County, Kangle County	1992	Guangegou National Geological Park
	2002	Gansu Guangegou National Forest Park
	2002	(Named Daheba Provincial Forest Park in 1999–2003)
Zhuoni County	2005	Gansu Songmingyan National Forest Park
	2003	Gansu Yeliguan National Forest Park

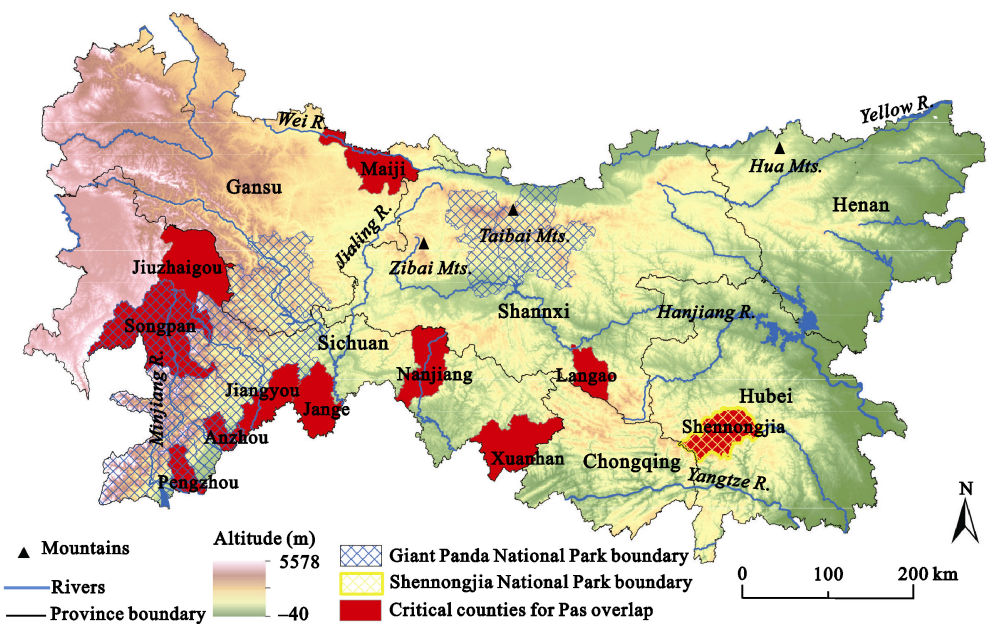

Fig. 10 Distribution of the critical areas with overlapped protected areas (PAs) in the North-South transition zone of China

Inclusion overlap implied that one type of PA contained other types of PAs within the functional zone. It was the most common type of spatial overlap in the NSTZ. By 2017, 73 PAs were of this type, accounting for 63.48% of the total number of overlaps in the NSTZ. Based on the reasons for forming an overlap in the PAs,

these were divided into two types: integrated- and expanded-type. Integrated-type referred to the standard of the original PAs to achieve a higher level of protection, and the integration of resources based on the existing PAs. However, before integration in the original PA, a phenomenon called multi-brand hanging in the same place occurs. This creates the issue of spatial overlap between the new PA and the original PA. There were relatively less of these types of PAs in the NSTZ. By 2017, only seven integrated-type PAs existed in the NSTZ, such as the Sichuan Guangwushan-Nuoshuihe SA. Expansion-type included establishing other types of new PAs within the established PAs, to include the scope of new PAs in the original PAs or expand the scope of original PA planning by incorporating the new PA. This type was mainly formed for two reasons. One is due to the principle of sustainable development to establish other types of PAs reasonably and appropriately in nature reserves. The other is based on the principle of protection, to establish nature reserves in SAs or other types of PAs. Within the open areas, such as FPs and WPs, nature reserves were planned to limit human activities, such as in Savage Valley Geopark and Savage Valley Nature Reserve located in Fang County.

Crossed overlap implied no apparent inclusion relationship between the overlapping PAs and only a certain degree of functional division being crossed. This type of overlap was relatively small (only 11) in the NSTZ. Examples of this type of overlap are Jiangyou National Geological Park and Guanwushan Provincial Nature Reserve, located in Sichuan Province. The functional areas of the two PAs crossed in Guangwu Mountain.

3.4.2 PA overlap based on type classification

Understanding the spatial overlapping characteristics and laws of different types of PAs is extremely important. Statistics on the types of PAs with spatial overlapping in the NSTZ indicated 12 types of overlapping combinations (Fig. 11). Among these, meeting the assessment criteria for multiple PAs were mostly subordinate forest ecosystems, the probability of overlap between FPs and other types of PAs was the highest type, accounting for 56.41%. This is consistent with the natural ecological background with forest ecosystems as the main component. Forest parkhas the maximum cross management problems with other types of protected areas. It is suggested that relevant departments should focus on resolving and integrating these types of PAs when implementing a unified authority and hierarchical management system during the transformation of national parks.

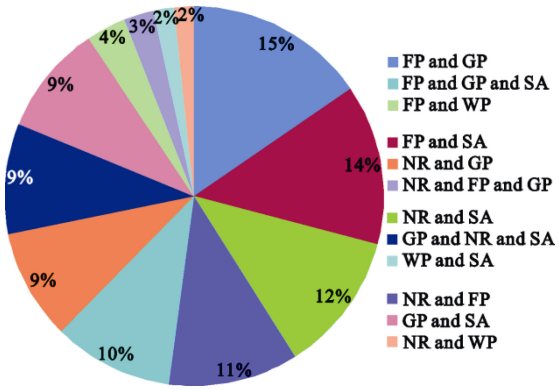

Fig. 11 Distribution of the spatial overlap of protected areas in the North-South transition zone of China. NR: nature reserve; SA: Scenic area; FP: Forest Park; GP: Geological Park; WP: Wetland Park

3.4.3 Key overlapped PAs

In order to clarify the areas with serious spatial overlap of PAs in the NSTZ, we counted the counties with more than three overlapping protected areas (Table 5). Results indicated that in the NSTZ, there were 11 counties where the number of overlapping protected areas exceeds three, which were distributed in the south of Qinling Mountains, except Maiji District in Gansu Province (Fig. 10). Among these, overlapped PAs in Sichuan Province were most prominent, with 72.70% critical overlapping counties located in this province.

At present, there are two national park pilots (Giant Panda National Park and Shennongjia National Park) established in the NSTZ. These national parks are located in the counties with the most prominent overlapping of PAs in the NSTZ (Fig. 10). In 2016, Shennongjia National Park became the second national park pilot after Sanjiangyuan National Park. It integrated five PAs in the Shennongjia Forest Area in Hubei province, forming a complex overlap type in space. According to the Panda National Park Development Plan (Draft for Comment) released in 2019, Giant Panda National Park will span three provinces: Sichuan, Shaanxi, and Gansu, including three garden districts: Minshan mountain, Qionglai mountain-Mingsan mountain, Qingling, and Baishuijiang.The Panda National Parkhave a total area of 27 134 km^2 and cover 77 nature reserves. They cover four counties with serious PA overlap problems (Anzhou District, Jiuzhaigou City, Pengzhou County, and Songpan

Table 5 Protected areas with seriousoverlapping problems in the North-South transition zone of China

Administrative region	Number overlapped protected areas	Overlapped protected areas
Xuanhan County	5	Sichuan Dabashan National Geological Park, Bailixia Provincial Nature Reserve, Han Xuan National Forest Park, Sichuan Yucheng Zhuhai Forest Park, Sichuan Guanyinshan Forest Park
Shennongjia Forest District	5	Hubei Shennongjia National Nature Reserve, Hubei Shennongjia National Geological Park, Hubei Shennongjia National Forest Park, Hubei Longmen River National Forest Park, Hubei Jiu Dahu National Wetland Park
Pengzhou County	4	Sichuan Baishuihe National Forest Park, Sichuan Baishuihe National Nature Reserve, Sichuan Longmenshan National Scenic Area, Sichuan Longmenshan National Geological Park
Anzhou District	3	Sichuan Mianyang Bioreef National Geological Park, Sichuan Anzhou District Sponge Reef Nature Reserve, Sichuan Baishui Lake Provincial Scenic Area
Jiangyou County	3	Sichuan Jiangyou National Geological Park, Sichuan Guanwushan Provincial Nature Reserve, Sichuan Dou Tuanshan-Foye Cave Provincial Scenic Area
Jiange County	3	Sichuan Jianmen Shu Road National Scenic Area, Sichuan Jianmenguan National Forest Park, Sichuan Jiange Jianmenguan Provincial Geological Park
Nanjiang County	3	Sichuan Nuo River National Scenic Area, Sichuan Nuoshuihe National Geological Park, Sichuan Shenmen Provincial Scenic Area
Songpan County	3	Sichuan Huanglong National Geological Park, Sichuan Huanglongsi Provincial Nature Reserve, Sichuan Huanglong National Scenic Area
Jiuzhaigou County	3	Sichuan Jiuzhaigou National Geological Park, Sichuan Jiuzhai National Forest Park, Sichuan Jiuzhaigou National Scenic Area
Lanzhao County	3	Miaoshan National Geological Park located in the southwest Shaanxi Province, Miyayama National Forest Park located in the southwest Shaanxi Province, and the provincial-level scenic spot located in the southwestern part of Shaanxi
Maiji District	3	Gansu Tianshui Maiji Mountain National Geological Park, Gansu Maiji National Forest Park, Gansu Tianshui Maiji Mountain National Scenic Area

County). The Giant Panda National Park integrates 20 protected areas in the transition zone with spatial overlap problems, accounting for 17.40% of the total overlapped area in the NSTZ. Therefore, considering the typical nature and complexity of the natural habitat value and spatial overlap in the NSTZ, the overlapped PAs in China are expected to provide better solutions and experience for exploring the two national park pilots mentioned above.

4 Discussion

4.1 Disequilibrium and misalignment characteristics of the PAs in the NSTZ

As the only large-scale West-East ecological corridor of China, the NSTZ not only links the north and south of China, but also is the only large-scale ecological corridor of China (Ma et al., 2004). Due to lack of macro planning based on national ecosystem or resource-based service functions during the initial stage, problems such as uneven distribution of existing PAs in the NSTZ (Xu et al., 2019) and space vacancies became prominent (Huang et al., 2018). The results shows that, the development of protected area system in the NSTZ has the characteristic of 'strong in the west and weak in the east' in the west-east direction. In addition, a more obvious spacial mismatch also exists in the regional development background such as the population distribution, economic growth and infrastructures of the NSTZ. As a whole, on the west side of the NSTZ, the distribution of protected land is relatively concentrated with larger scale and better integrity, while the regional economic growth and the level of population agglomeration often tend to be lower. As the NSTZ extends from west to east, the coverage rate of protected area in the county gradually reduces whereas its fragmentation increases, nevertheless, larger economic scales and population density are the main feature of the district and county in the region. The mismatch between the development of protected area and the level of regional development has seen stronger universality in the construction of protected area in developing countries (Lal et al., 2017). Compared with the U.S. and Japan and other developed countries (Wang et al., 2014), restricted by factors fea-

turing the ecological background of regional resource, development stage, financial strength, planning level and local government capacity, developing countries represented by China are facing a more intense game between 'instrument rationality' and 'value rationality' in the process of construction of protected area (Wang et al., 2019). For the larger-scale ecological zone as the NSTZ, which possesses the corridor form and transitional nature, should be adjusted locally through adopting partition and classified governance based on different development characteristics and regional development level of protected area on the east and west side of the zone, as well as on the representative development model of national parks (American wilderness model, European model, Australian model and British model) in a global context. On the west side of the NSTZ, areas with stronger development of protected area and weaker human activities focus on the concept of ecosystem orientation, and can be used as a priority area for the integration of nature reserves in the transition stage of national parks. Moreover, areas with relatively higher intensity of human activities on the east side focus on the development-oriented concept, which can be used as a potential reserve in the integration of national parks to make an empirical exploration of the Chinese model of interaction and coordination between the protected area and the regional, local and community levels.

4.2 Spatial overlap of the PAs in the NSTZ and their policy significance

In the protection land system, with nature reserves holding primary position, resolving the problem of unsuitability of the management system of the PAs is difficult due to cross-regional and cross-departmental issues (Wang et al., 2014). Overlapping of PAs results in management related confusion, unclear management responsibilities of different departments, and several other problems, which affect the protective effect of the PAs. The establishment of national parks can confirm and register the rights of PAs in a territory and assign them to national park management (Zhong et al., 2016), which can solve the problem of overlapping management and space in the PAs. However, at present, the protected land system of China is in the early national park transformation stage (Xu et al., 2019), and its management effectiveness remains to be proven. Through systematically sorting out the evolution characteristics of the spacial and temporal pattern of protected area of the NSTZ, this paper finds that with the development of the system of our country's protected area, the problem of spacial overlap is becoming more and more salient. Although the spacial overlap of protected area reflects its value, it also results in management conflict, barriers and the waste of human resources in practice. Deguignet et al, who have sorted out the overlapping names of reserves in 219 countries around the world based on the database World Database on Protected Areas (WDPA), find that 36 out of 219 countries have adopted the model of single agency management, thus problems caused by overlapping management of departments within the country are avoided (Deguignet et al., 2017). In recent years, our country's pilot projects of the national park aims to resolve the issue of overlapping management and spacial overlap of protected area through unified right confirmation and registration for protected area (Zhong et al., 2016). Nevertheless, the system of our country's protected area is in the early stage of national park transformation (Xu et al., 2019), and such key issues as the transformation of path, model and effectiveness need to be further explored. In the study region of this paper, the NSTZ is of great significance of ecological corridor, and the spacial overlap of system of internal protected area has the characteristics of typicality and complexity. Most of the protected areas with overlapping phenomena in the NSTZ are attached to forest ecosystem, which is also the most abundant resource protection type in China's nature reserves (Huang et al., 2018). Therefore, the study on spacial form, types and key areas of spacial overlap of the system of protected area in the NSTZ, especially the study on two national parks with pilot significance, is beneficial to the provision of experience accumulation with reference significance for the construction of protected area dominated by forest ecosystem and the transformation of national parks for our country and across the globe.

5 Conclusions

Based on the idea of 'spatial representation' and 'relevance of elements', this paper explored the spatial and temporal evolution process and pattern of the protected area system in the NSTZ of China and discussed its 'West-east' corridor characteristics and geographical

significance reflected in the ecological and economic space. Moreover, based on the spatial perspective, we systematically analysed the phenomenon of multi-management of PAs in China. The results show that NSTZ has the typical characteristics of a corridor-type mountain forest ecological zone. The development status of protected areas and the coupling relationship with regional development have significant west-east and north-south differences; the characteristics of the construction and management of protected areas in the region are different. The problem is typical in the construction of protected areas in developing countries, and its research has a good reference significance for the establishment of suitable national park development models and adaptive governance in China and similar regions. The main conclusions of this study are as follows:

Based on the numbers and structures of different types of PAs, the development and evolution of the PA system in the NSTZ was divided into three stages: initial (1963–1980), rapid development (1981–2013), and national park transformation (2014–present). The characteristics of this staged evolution were closely related to the changes in the PA policy of 'simple protection—sustainable use—integration and upgrade' in China. At present, the PA system in the NSTZ is in the development stage of integrating nature reserves into national parks, with the slowing down of overall growth in the numbers of PAs. Regarding the level and type, provincial-level PAs were established faster than national-level PAs and WPs exhibited rapid establishment in recent years.

Regarding the spatial characteristics, the spatial centre of gravity of the protective zone system in the NSTZ was always located in the west of the Qinling-Daba Mountains (at the junction of Sichuan and Shannxi provinces), and its high-density core presented a relatively stable N-shaped structure composed of four cluster areas, i.e. eastern Sichuan, southern Shaanxi, western Henan, and north-western Hubei provinces. In terms of type differentiation, except for the forest park that formed four aggregate cores (one big core and three small cores), the other type of PAs exhibited a more obvious single-centre structure.

The average access time for the PAs located in the NSTZ was found to be higher (1.56 h) due to several factors, such as geographic environment and socio-economic development density. The accessibility of the PAs at the lower local level was better than that at the national-level, and WPs and SAs are located closer than other PA types to the city centre. As the transition zone extends from west to east, there is a relatively obvious spatial dislocation between the development of protected areas and the intensity of human activities. The PA coverage for all districts and counties gradually decreased, with the GDP exhibiting from fast growth to stable to rapid growth characteristics.

At present, the spatial overlap of the PAs in the NSTZ remains prominent. According to the spatial form of the overlap of protected areas, the spatial overlap of protected areas can be divided into three types: complete overlap, inclusion overlap, and crossed overlap, and inclusion overlap is the most common overlap pattern in the NSTZ. In terms of the type, FPs exhibited the highest overlap probability with other PA types, which should pay more attention to the process of rationalizing and integrating multi-management and unclear responsibilities. Regarding the key areas, the southern side of the NSTZ exhibited a frequent occurrence of spatially overlapped PAs, especially in the northern Sichuan Province. At present, the two national park pilots in the NSTZ signify typical areas with overlapping spaces. Their establishment and development are expected to provide high-value experience and paths for the transformation of national parks in the PAs of China.

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