Research on the Route Selection of Transmission Lines Crossing Rivers in the Yangtze River Basin (Hubei section) Based on Ecological Sensitivity Evaluation

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Abstract: Studies on ecological sensitivity mainly focused on the sensitivity of a wide range of ecosystems to changes in the external ecological environment. In recent years, more and more assessments have been made on urban ecological sensitivity, but few studies have focused on the ecological sensitivity of river basins. Due to the length and the complicated terrain of the transmission line, it was unavoidable to cross the Yangtze River. So far, there are few studies combined the ecological sensitivity of river basins with large transmission lines. Ecologically sensitive areas along the Yangtze River restrict transmission line channel selection from engineering safety, law and ecological space control. Our study focused on the Yangtze River (Hubei section), by collecting the data of ecologically sensitive areas along the Yangtze River (Hubei section), the spatial distribution characteristics of ecologically sensitive areas along the Yangtze River (Hubei section) were analyzed by ArcGIS spatial analysis method among different cities. The results showed that the highest total ecological sensitivity index was 0.88 in Huang Shi. The total ecological sensitivity index of the main stream of the Yangtze River (Hubei section) was 0.41, indicating moderate ecological sensitivity of the Yangtze River (Hubei section). There were spatial differences in the ecological sensitivity along the Yangtze River. When the transmission line crosses the main stream of the Yangtze River (Hubei section), there was little difference in spatial ecological sensitivity among different cities, due to the large slightly sensitive and insensitive ecological sensitivity index area of each city.

1. Introduction

Since the first Yangtze River crossing - Wuhan Zhuankou 220kV Yangtze River crossing in 1959, China has designed hundreds of great spans in the Transmission line domain [1]. In the past 65 years, although Transmission lines in China have accumulated a lot of experience in the design of transmission line large span, many problems still need to be studied, discussed and practiced. When the transmission line crosses a river, it is necessary to pay attention to the selection of guide ground, anti-vibration and anti-dance, insulator, pole and tower and foundation [2], Attention should also be paid to the ecologically sensitive areas distributed along the Yangtze River ((Hubei section). China issued the Outline of the Yangtze River Economic Belt Development Plan in September 2016, applied the Yangtze River Protection Law in March 2021 and the Yellow River Protection Law in April 2023, which further strengthened the ecological and environmental protection in the Yangtze and Yellow River basins [3]. Thus, more stringent requirements were put forward on river basin ecological environment protection and high-quality development. Furthermore, it further restricted the selection of transmission lines with large spans by the law and space control.

On August 11, 2024, the Central Committee of the Communist Party and The State Council issued the Opinions on Accelerating the Comprehensive Green Transformation of Economic and Social Development, proposing to accelerate the delivery of clean energy in the northwest, which meant that there would be more transmission lines inevitably across the great rivers [4]. The transmission lines cover a wide area, and the distance of UHV transmission lines was long, thus the important channels were densely arranged with multiple circuits, resulting in the safety of power grid operation finally [5]. The national energy strategy also put forward the requirement to avoid the occurrence of UHV transmission dense channels. Therefore, how to choose a reasonable channel to cross large rivers has become an urgent problem for transmission lines.

Steiner proposed that environmentally sensitive areas were important for the long-term conservation of biodiversity, soils, waters, and other natural resources at site and regional scales [6]. Still now, there were a few researches on the analysis of ecological environment-

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sensitive factors and sensitive areas of river basins, which mainly focused on the discussion of urban planning [7-9]. Ecological sensitivity research methods mainly include the comprehensive index method, fuzzy comprehensive evaluation method, analytic hierarchy process, principal component analysis and other traditional evaluation and analysis methods. Recently, the single factor analysis and multi-factor comprehensive evaluation based on GIS platform have become the main stream, and the combined application of multiple evaluation methods combined with the GIS technology has become the development trend of watershed ecological sensitivity research [10]. This paper took the Yangtze River main stream (Hubei section) as the research object, taking into account the needs of ecological environmental protection and the selection of cross-river transmission line routes, by studying the spatial distribution and ecological sensitivity of ecologically sensitive areas along the Yangtze River main stream (Hubei section), to provide important reference for the rational spatial layout of river conservation and transmission line crossing.

2. Method

2.1. Spatial distribution of eco-environmental sensitive areas in the main stream of Yangtze River ((Hubei section)

The national parks, nature reserves, wetland parks, forest parks, scenic spots and aquatic germplasm resources reserves in the main stream of the Yangtze River (Hubei section) were identified. The background data of nature reserves were obtained from the National List of Nature Reserves (2009) compiled by the Department of Natural Ecology of the Ministry of Environmental Protection [11]. By using the method of graph overlay, data collation and statistical analysis, the ecological sensitive factors and ecological sensitive areas in the main stream of the Yangtze River (Hubei section) were analyzed. Finally, the ecological sensitive factors and ecological sensitive areas of the main stream of the Yangtze River (Hubei section) were recognized as a whole. Then the distribution maps of various ecologically sensitive areas such as nature reserves, scenic spots, forest parks and geoparks in the Yangtze River Basin were made by using MapGIS software.

2.2. Ecological sensitivity analysis of the Yangtze River main stream (Hubei section)

According to the functional zoning of nature reserves, the Hubei section of the Yangtze River was divided into highly sensitive, moderately sensitive and mildly sensitive and insensitive sections. According to the distribution of functional zones in the ecological sensitive area, the classification criteria and classification of ecological sensitivity degree were proposed, as shown in Table 1. If an area belong to multiple ecologically sensitive areas with different protection levels, it was graded according to the control requirements with higher sensitivity levels.

Table 1. Ecological sensitivity level classification table

Ecologically sensitive area	Sensitivity classification			
	Highly sensitive	**Moderate sensitivity**	**Mild sensitivity**	**Insensitive**
National park	Core protected area	General control area	/	/
Nature reservation	Core region, Buffer area	Experimental plot	Outer protection zone	/
Scenic spot	Core scenic spot(Primary protected area)	Secondary protected area	Tertiary protected area	/
Wetland park	Conservation area, Restoration area	Rational utilization area	Others	/
Forest park	/	Core scenic spot, Ecological conservation area	General recreation are, Management service area	/
Geopark	/	Primary protected area	Secondary protected area, Tertiary protected area	/
Conservation area for aquatic germplasm resources	/	Core region	Experimental plot	/
Others	/	/	/	Ordinary stream

Note: - Indicated that there was no sensitivity rating.

2.3. River ecological sensitivity index

We calculated the proportion of the total length of the ecologically sensitive area on the regional reach to the total length of the regional river and computed the total index of the ecological sensitivity of the reach through the spatial distribution map of the ecological sensitivity on different reaches [12-13]. According to the proportion of the total length of high, medium and low sensitivity river in the whole length of the region, the high, medium and light sensitivity index of the regional reach were calculated.

3. Results and analysis

3.1. Spatial distribution of eco-environmental sensitive areas in the main stream of Yangtze River (Hubei section)

There were 12 sensitive ecological and environmental areas in 6 categories along the main stream of the Yangtze

River (Hubei section), no national parks, 6 nature reserves (including nature mini-reserve) and 6 nature protection areas. See Table 2 for details, and see in figure 1.

Table 2. Status of ecologically sensitive areas in the northern reaches of the Yangtze River

Ecologically sensitive area name	Rank	Administrative region	River length involved(km)
Three Gorges National Geopark	National	Yichang	96
Yangtze Three Gorges national scenic spot	National	Enshi, Yichang	100
Huangzhou Binjiang Provincial wetland Park	Provincial	Huanggang	9.3
Wuxue Yangtze River Bund provincial wetland Park	Provincial	Huanggang	27
Siguyu national aquatic germplasm resources Reserve in Huangshi Section of Yangtze River	National	Huangshi	70
Siguyu national aquatic germplasm resources Reserve in Jianli section of Yangtze River	National	Jingzhou	115
Three Gorges Reservoir area aquatic life nature reserve	Provincial	Enshi	16
He Wangmiao Yangtze finless porpoise provincial nature reserve	Provincial	Jingzhou	30
Hubei Swan River white-flag dolphin National Nature Reserve	National	Jingzhou	47
Hubei Xinluo section of the Yangtze River white-flag dolphin national Nature Reserve	National	Jingzhou, Xianning	122
Silingpo egret nature protection community	Provincial	Yichang	2.8
Yangtze River Hubei Yichang Chinese sturgeon provincial nature reserve	Provincial	Yichang	58

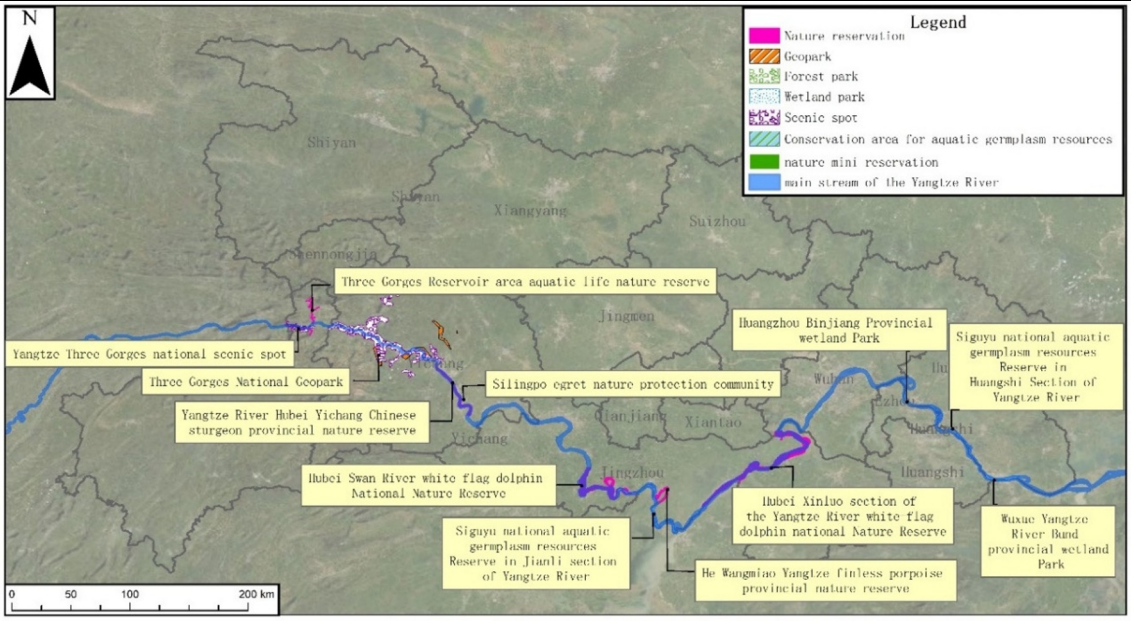

Figure 1. Map of the Spatial Distribution of Ecologically Sensitive Areas along the Main Stem of the Yangtze River (Hubei section)

3.2. Analysis of distribution characteristics of ecologically sensitive areas

There were 6 types of 12 ecologically sensitive areas distributed in 7 cities and states in the main stream of the Yangtze River (Hubei section), among which Huanggang, Jingzhou and Yichang have more ecologically sensitive areas, and the scope of each ecologically sensitive area overlap, and the cross length was longer in Yichang. In the ecologically sensitive areas, there was no national parks, mainly consist of nature reserves and protected areas. The ecologically sensitive areas were distributed along the main stream of the Yangtze River, among which the Three Gorges scenic area was large, spanning Enshi Prefecture and Yichang from east to west. The Baiji National Nature Reserve of the new Luohe section of the Yangtze River in Hubei Province spaned Jingzhou and Xianning from east to west, while the scope was large.

3.3. Analysis of ecological sensitivity index

There were 8 cities (prefectures) along the main stream of the Yangtze River (Hubei section), and Wuhan and Ezhou have no ecological sensitive area distribution, with the lowest ecological sensitivity index. The total ecological sensitivity index of Huangshi was 0.88, indicating that Huangshi has the highest ecological sensitivity of the Changjiang River. According to the classification of ecological sensitivity levels, the ecological sensitivity of the Yangtze River main stream (Hubei section) was generally moderate and mild, the high ecological sensitivity index of the Yangtze River main stream (Hubei section) was less than 0.5, and the moderate ecological sensitivity index of 0.5 and above was only in Huangshi. The ecological sensitivity index of the Yangtze River main stream (Hubei section) was mainly related to the distribution density of the ecologically sensitive areas along the Yangtze River and the length of the river in the city (prefecture). As shown in Figure 2 and Table 3.

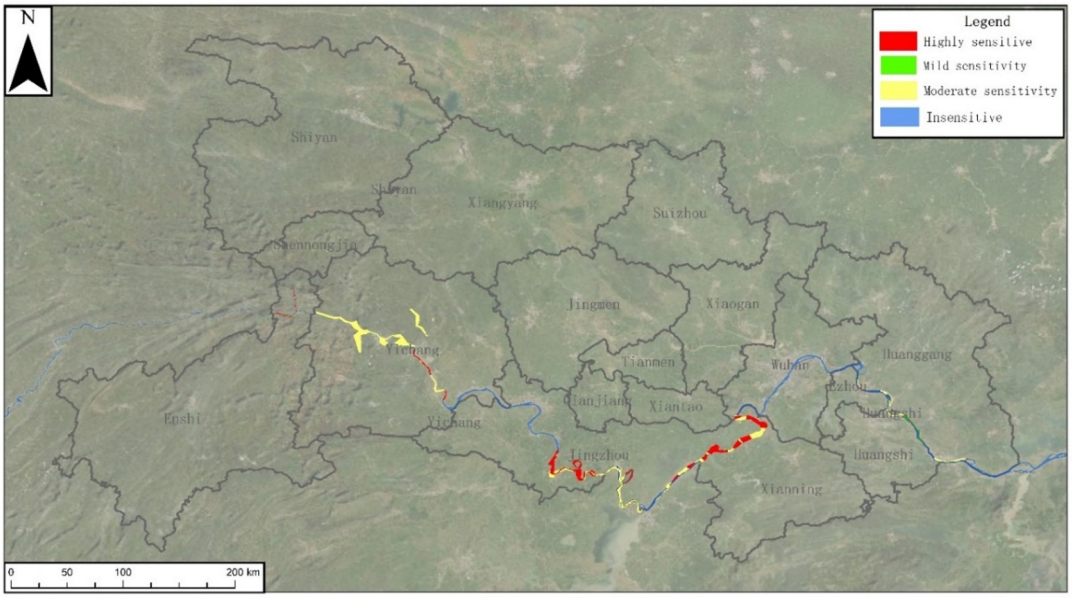

Figure 2. Map of the Spatial Distribution of Ecologically Sensitive Areas along the Main Stem of the Yangtze River (Hubei section)

Table 3. Results of ecological sensitivity index in the main stream of Yangtze River (Hubei section)

River reach	River length (km)	Ecologically sensitive areas involved	length of ecologically sensitive areas(km)/Index				Total length of ecologically sensitive areas(km)/Index
			Highly sensitive	Moderate sensitivity	Mild sensitivity	Insensitive	
Yichang	232	Three Gorges National Geopark, Three Gorges National scenic Spot, Silingpo Egret nature protection community, Yangtze River Hubei Yichang Chinese sturgeon provincial nature reserve	36/0.16	26.3/0.11	46.7/0.2	123/0.53	109/0.47
Enshi	39	Three Gorges National scenic Spot, Three Gorges Reservoir area aquatic life nature reserve	16.7/0.43	0	0	22.3/0.57	16.7/0.43
Huanggang	106	Huangzhou Binjiang Provincial Wetland Park, Wuxue Yangtze River Bund provincial wetland Park	36.6/0.35	23/0.22	1.8/0.02	44.6/0.42	61.4/0.58
Huangshi	31	Siguyu national aquatic germplasm resources Reserve in Huangshi Section of Yangtze River	0	17.8/0.54	9.5/0.31	3.7/0.12	27.3/0.88
Jingzhou	458	Hewangmiao Yangtze Finless porpoise Provincial Nature Reserve	102.1/0.22	59.8/0.13	0	296.1/0.65	161.9/0.35
Xianning	118	Hubei Xinluo section of the Yangtze River white-flag dolphin national Nature Reserve	33.2/0.28	27.5/0.23	0	57.3/0.49	60.7/0.51
Total	1061	/	224.6/0.21	154.4/0.15	58/0.05	547/0.51	437/0.41

3.4. Spatial layout analysis of transmission lines crossing the main stream of the Yangtze River (Hubei section)

The total ecological sensitivity index of the main stream of the Yangtze River (Hubei section) was 0.41, the overall sensitivity was moderate, and there were spatial differences in the ecological sensitivity of each section. When the transmission line crossed the main stream of the Yangtze River (Hubei section), the principle of ecological protection was given priority. When the transmission line crossed the main stream of the Yangtze River (Hubei section), the transmission line location can be selected from the order of ecological insensitivity, light, moderate and high. The results showed that there was little difference in spatial ecological sensitivity among different cities when the transmission lines crossed the main stream

of the Yangtze River (Hubei section), and there were large river sections in each city with mild and insensitive ecological sensitivity index.

Table 4. Distribution table of transmission lines crossing the main stream of the Yangtze River (Hubei section) based on ecological sensitivity

River reach	Length and index of ecologically sensitive area		Transmission line location layout
Yichang	Highly sensitive	36/0.16	Priority air crossing for avoidance
	Moderate sensitivity	26.3/0.11	The distribution of the moderately sensitive areas was long, and the distribution of the surrounding sensitive areas was dense and deep along the vertical sides of the Yangtze River, which was difficult to cross in one step, thus the priority was to avoid.
	Mild sensitivity	46.7/0.2	Priority layout segment
	Insensitive	60.7/0.26	Priority layout segment
Enshi	Highly sensitive	16.7/0.43	Priority air crossing for avoidance
	Insensitive	22.3/0.57	Priority layout segment
Huanggang	Highly sensitive	36.6/0.35	Priority air crossing for avoidance
	Moderate sensitivity	23/0.22	Harmless air crossing
	Mild sensitivity	1.8/0.02	Priority layout segment
	Insensitive	44.6/0.42	Priority layout segment
Huangshi	Moderate sensitivity	17.8/0.54	On the north side, there were Cehu Pelteobagri Buteobuta National aquatic germplasm resources Reserve and Wangtian Lake Jiaozui national aquatic germplasm resources Reserve, on the south side, there were Cihu Scenic area and Huama Lake national aquatic germplasm resources Reserve. The distribution of ecologically sensitive areas around was dense, thus it was recommended to avoid.
	Mild sensitivity	9.5/0.31	Priority layout segment
	Insensitive	3.7/0.12	Priority layout segment
Jingzhou	Highly sensitive	102.1/0.22	Priority air crossing for avoidance
	Moderate sensitivity	59.8/0.13	Priority air crossing for avoidance
	Insensitive	296.1/0.65	Priority layout segment
Xianning	Highly sensitive	33.2/0.28	Use large span air harmless crossing
	Moderate sensitivity	27.5/0.23	Priority air crossing for avoidance
	Insensitive	57.3/0.49	Priority layout segment

4. Conclusion

With a length of more than 6,300 km, the Yangtze River was the longest river in China. The main stream of the Yangtze River (Hubei section) belonged to the middle and upper reaches of the Yangtze River, with a total length of 1,062 km. It crossed Hubei Province from east to west and was an important industrial corridor of Hubei Province [14]. Li Dewang et al. analyzed the spatial pattern of ecological sensitivity in the upper reaches of the Yangtze River, and the results showed that the insensitive, mildly sensitive, moderately sensitive, highly sensitive and extremely sensitive areas accounted for 74.14%, 6.76%, 8.25%, 4.93% and 5.93% of the total area of the upper reaches of the Yangtze River, respectively. The ecologically sensitive areas in the Yangtze River Basin are mainly distributed in the upper reaches[15]. The river direction of the Yangtze River main stream (Hubei section) was generally east-west, and the long-distance and north-south transmission lines were often difficult to avoid. In order to reduce the ecological impact of the transmission lines on the Yangtze River main stream (Hubei section), it was particularly important to select the right crossing point for the transmission line selection[16].

This study sorted out the ecologically sensitive areas along the main stream of the Yangtze River (Hubei section). There were 12 ecologically sensitive areas of 6 categories along the main stream of the Yangtze River (Hubei section). There were no national parks, 6 nature reserves (including the nature mini-reserve) and 6 nature protection areas. Among them, Huanggang, Jingzhou and Yichang have a large number of ecologically sensitive areas, and the scope of each ecologically sensitive area overlaps, and the cross length is longer in Yichang. The number of nature reserves and nature protected areas was large, and the ecologically sensitive areas were distributed in a band along the main stream of the Yangtze River. The total ecological sensitivity index of Huangshi was 0.88, indicating that the ecological sensitivity of Huangshi River was higher. The total ecological sensitivity index of the main stream of the Yangtze River (Hubei section) was 0.41, the overall sensitivity was moderate, spatial differences were exist in the ecological sensitivity of each section. The result was consistent with Li Dewang's. When transmission lines were selected to cross the main stream of the Yangtze River (Hubei section), there was little difference in spatial ecological sensitivity among

different cities, and a large river section in each city had the mild and insensitive ecological sensitivity index. When transmission lines were selected to cross the main stream of the Yangtze River (Hubei section), it was recommended to adopt the mode of air crossing in one step and select the narrow part of the river for crossing, which can minimize the ecological environment impact of the line on the main stream of the Yangtze River (Hubei section).

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