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The research on under water resources supporting capacity restraint in Xi'an city of the water sports

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ABSTRACT

With the rapid, stable, and healthy development of China's economy, sports return to the masses' demands, form a natural concept, and become popular with people. Gradually, water sports become the first chosen leisure and sports for the people in their spare time. Such fitness activities have provided broad development space for the development of national fitness. However, with the development of economy and the deterioration of ecological environment, the utilization of water resources does not accord with the concept of sustainable development. In this paper, the megacity of scarcity of water resources—Xi'an city was taken as the research object, the water resources carrying capacity and its problems were analyzed by building an evaluation system. The study proposes the countermeasures and suggestions on developing water sports by analyzing the water resources carrying capacity. Also, this paper aims to provide theoretical basis for the development and succession of water sports in large and medium-sized cities under drought stress. The results could provide reference for the development of national fitness in the region, and program support for the development of water sports industry to promote water resources protection.

Keywords: Water resources carrying capacity; Environmental protection; Water sports; Xi'an city

1. Introduction

Water resources, a bottleneck restricting the development of human society, have a crucial impact on the development scale or the overall development of a country or a region. With the economic development of the society and the deepening of industrialization, water shortage has become increasingly severe [1]. Initially, developed countries dealt with the problem of urban water resources utilization by combining mathematics with professional knowledge [2]. Subsequently, operations research was also widely used, and the theory of applied systems analysis was eventually formed [3]. Since 1960s, the level of urbanization in our country has gradually increased, but there are some incorrect understandings in the development and utilization of water resources, and the treatment methods are not reasonable. As China is a populous country, the amount of water resources per capita is relatively low, while the demand for water resources is getting higher and higher. Therefore, the rational utilization of water resources should be given a priority [4].

Under the background of adjusting the economic development structure, China listed new energy, environmental protection, culture, and sports as the new motive force for economic development during the 13th five-year plan period, while the sports industry relied on the wellness industry to obtain better policy support. Water sports, in the form of tourism, entertainment, adventure, and competition, are deeply loved by the public and have gradually become an important support for the fitness and leisure industry by relying on such resources as the sea, lakes, and rivers. Water sports industry, involving tourism, leisure, culture, health, and other fields, are the focus of the sports industry. In 2016, the General Office of the State Council promulgated the Guiding Opinions on Speeding up the Development

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of Fitness and Leisure Industry, and listed water sports as an important part of improving the system of fitness and leisure services [5]. Since then, the State Sports General Administration, along with eight ministries, jointly issued "Water Sports Industry Development Plan," which systematically designed the development of China's water sports. After more than 2 years of development, a fitness and leisure industry system led by water, ice, snow, and aviation has been gradually formed, and a scientifically systematic and operable special plan has been formed [6]. As an area with a shortage of water, carrying capacity of water resources is an important factor for the northwest of China because it affects the development of water sports industry. This paper takes Xi'an as the research object and proposes the countermeasures and suggestions on developing water sports by analyzing the water resources carrying capacity. Also, this paper aims to provide theoretical basis for the development and succession of water sports in large and medium-sized cities under drought stress, reference for the development of national fitness in the region, and program support for the development of water sports industry to promote water resources protection.

2. Overview of research area

Xi'an (107° 40′–109° 49′E and 33° 39′–34° 44′N) is located in the central part of the Guanzhong Basin, south to Ankang and Shangluo, with no access to the center, to the north to Xianyang and Tongchuan, to the east Wang Weinan, west Baoji. Xi'an is the political, economic, cultural, and transportation areas of northwest China and Shaanxi province. It is the largest central city in northwest China and Longhai new zone.

Xi'an has an obvious landform differentiation. From south to north, there are Qinling mountains, Loess hills, Loess Plateau, piedmont alluvial fan, Weihe River, and tributary terraces and alluvial plain. Qinling mountains, lying in the southern part of the city, are referred as China's geographical boundaries of the south and the north. With an average elevation of 2,000 m or more, Qinling mountains are water resource conservation areas in Xi'an; Loess hilly, with an elevation of 800–1,300 m, distributed in the southeastern Lantian County, Baqiao District, and the junction of Lintong District; Loess Plateau distributed intermittently in the southeast and southern, with an elevation of 680–780 m; piedmont alluvial fans are mainly distributed in the Qinling mountains outside the Meiyukou, with 400–650 m above sea level; alluvial plains are mainly distributed in the Weihe River on both sides of the Taiwan Strait, and its tributaries are generally below 550 m above sea level.

Xi'an is located in the warm temperate semi-humid continental monsoon climate zone. The city's average annual rainfall arrives 561.1 mm, mainly in July–September, accounting for 45%–60% of the annual rainfall. Most of the city belongs to the Weihe River, a tributary of the Yellow River. Among them, there are more than 40 tributaries whose catchment area is more than 50 km^2. There are six catchment areas above 1,000 km^2. The city's total average water resources is 2.347 billion m^3, of which 1.97 billion m^3 are surface water resources, 1.432 billion m^3 groundwater resources, and 1,057 million m^3 surface water and groundwater. The surface water availability in Xi'an is 750 million m^3, the available groundwater resources are 907 million m^3, the overseas passenger water is about 270 million m^3, the out-transfer water is approximately 47 million m^3, the water used for repeated collection and utilization is 63 m^3, 2.037 billion m^3, accounting for 87.20% of the total water resources.

Xi'an has jurisdiction over 11 districts and 2 counties, with a total area of 10,108 km^2, of which 548.6 km^2 metropolitan area. At the end of 2016, the resident population was 8.7506 million, of which 635.68 million was urban residents. With the establishment of Xi'an's cosmopolitan city, the demand for water resources in Xi'an continues to increase. Some studies have shown that the total amount of water resources in Xi'an is not enough and the water shortage has persisted.

3. Methods

3.1. Data sources and selection

Taking Xi'an city as the research object, the related research data are from Shaanxi Statistical Yearbook, Xi'an Statistical Yearbook, Xi'an Water Resources Bureau, China Water Resources Database published from 2005 to 2016, (http://www.data.ac.cn/index.asp), China Regional Natural Resources Database (http://www.data.ac.cn/xb/xb.asp), the State Sports General Administration website (http://www.sport.gov.cn), and China Water Sports Association Annual Report.

3.2. Model building

Once the economic development goals and the urban construction plan are confirmed, the production water level will be determined accordingly. Therefore, the production water can be determined according to the level of economic development, local economic development policies, and urban development plans. To determine the water resources carrying capacity, first, the population and urbanization level should be taken into consideration first to reflect the coordinated development of people and the environment; second, we must consider the water consumption of the ecological environment, and give priority to the protection of ecological water consumption, ecological and social, economic and technological connotation [7]. In addition, the availability of water resources in the upper and lower reaches of the water allocation and reuse of water should also be considered to reflect the water resources carrying capacity of the geographical and technological content [8].

3.2.1. Quantitative calculation model

The optimal level of resource carrying capacity is the result of equilibrium between the increase in population, economic growth, ecological protection, and water resources utilization [9]. As the population is the decisive factor in determining the carrying capacity of water resources, the goal of water sports water resources can be transformed into a certain population target and meet certain living standards.

Suppose the average per capita utility level is Ua, the total utility is U, the population is P, the water level is T, the economic productivity level is Pr, and the available water resource is Wa:

$$\text{Ua} = \frac{U}{P} \tag{1}$$

$$U = f(\text{Wa}, T, \text{Pr}, P^{-1}) \tag{2}$$

The ecological carrying capacity of water sports water resources can be expressed as follows:

$$\text{Pc} = g(\text{Wa}, T, \text{Pr}) \tag{3}$$

where Pc is the ecological carrying capacity of water resources.

Because when the water resources reach the ultimate load status, a balance between supply and demand will be achieved. Therefore, the total water consumption Wd does not appear in the expression of water resources ecological capacity Pc:

$$\text{Wd} = \text{Wa} \tag{4}$$

The total amount of water used to carry out water sports is generally comprised of the domestic water consumption, production (including industrial and agricultural) water consumption, and ecological water:

$$\text{Wd} = \text{Wdd} + \text{Wdi} + \text{Wda} + \text{Wde} \tag{5}$$

where Wd represents total water consumption; Wdd represents domestic water consumption; Wdi represents industrial water consumption; Wda represents agricultural water use; and Wde represents ecological water consumption.

For the region as a whole, the ecological water consumption Wde and the agricultural water consumption Wda basically do not vary with the population, while domestic water consumption Wdd and industrial water consumption Wdi change with the population changes.

$$\text{Wdd} = P\{r\text{Pddu} + \text{Pdda}(1-r)\} \tag{6}$$

$$\text{Wd}r = P * \text{Pddi} \tag{7}$$

Hereby, Pddu represents urban domestic water standard; r represents urbanization rate; Pdda represents rural domestic water standard; and Pddi represents per capita industrial water consumption.

The combined Eqs. (2.3) and (2.5) give the quantitative equations of the ecological carrying capacity of water sports water resources as follows:

$$\text{Pc} = \frac{\text{Wa} - \text{Wde} - \text{Wda}}{r^{*}\text{Pddu} + \text{Pdda}(1-r) + \text{Pddi}} \tag{8}$$

Among them, Pddi is the per capita industrial water consumption, which can be determined according to the planned industrial added value, the unit of industrial added value water consumption and the planned population.

3.2.2. Key factor of ecological carrying capacity of water resources

3.2.2.1. The amount of water available The amount of available water depends on three aspects: the local natural renewable water resources Wdr, the transit water resources Wex and the water reuse Wre. The calculation of available water resources is an important basic work in the evaluation of water resources carrying capacity, which determines the success or failure of the whole water resources work. Water sports can use water resources according to the following formula:

$$\text{Wa} = \text{Wdr} + \text{Wex} + \text{Wre} \tag{9}$$

where Wa is available water resources (m^3); Wdr is locally available water resources (m^3); Wex is transit available water resources (m^3); and Wre is water reuse.

3.2.2.2. Ecological water consumption Assuming a certain amount of water quota, ecological water consumption is calculated according to different types of ecosystems using direct or indirect methods. The amount of water used in the terrestrial ecosystem is similar to that of agricultural water, and the calculation process can be cross-referenced. Using direct calculation method, the calculation formula of natural ecological water consumption is as follows:

$$\text{Wde} = \sum_{i=1}^{n} \text{RdaAi}\alpha\text{i} \tag{10}$$

where Ai is the area of the type i land area in units of "667 m^2", αi is the type of land area i, $i = 1, 2, ..., n$, n is the number of land types, and Rda is the average per 667 m^2 of agriculture water consumption standards, unit: m^3/667 m^2.

3.2.2.3. Production water consumption The differences among the standard areas for production water use are relatively obvious, are among the most consumable agriculture water, which are related to local rainfall, topographic and geological conditions, main crop types, irrigation, and water saving levels, so the actual situation should be taken into consideration. According to water sports agricultural water standards and the planning period of the total population, the agricultural water consumption specific calculation method can be defined as follows:

$$\text{Wda} = \text{RdaAi} \tag{11}$$

where Ai is the agricultural irrigation area, unit: 667 m^2.

3.2.2.4. Population and urbanization level The number of urban population and the determination of the number of agricultural population vary according to the trend of urban development, so the level of urbanization should be determined first. The number of urban population and the number of agricultural population are generally the corresponding ratio, set the rate of urbanization r, then the number of urban population Pr, and agricultural population P(r–1).

4. Prediction of ecological carrying capacity in Xi'an

4.1. Main indicators

Based on the actual situation of water use of various departments in Xi'an and the related water supply special planning research, this research systematically analyzes the water quota standards of all relevant cities in China and abroad. On the basis of this, it analyzes the domestic water consumption standards, water consumption standards, ecological water consumption, and other indicators for analysis and prediction.

4.1.1. Amount of water available

The amount of water resources available in Xi'an in 2016 is shown in Table 1.

4.1.2. Population and urbanization rate

According to the "Xi'an City Master Plan" and relevant data, the population and urbanization rate in Xi'an in 2016 is shown in Table 2.

4.1.3. Production water

In 2016, the total water consumption in Xi'an was 1.847 billion m^3, and the per capita water consumption was 198.6 m^3 by the resident population. Considering the production water sector, the agricultural water consumption in 2005–2016 is the largest, varying from 849 million m^3 in 2005 to 560 million m^3 in 2016, with a 34.04% reduction in water consumption, which shows a decreasing trend. Among them, the Agricultural Irrigation Projects Renewal and Improvement of Agricultural Irrigation contributed a lot. Industrial water consumption dropped from 542 million m^3 in 2005 to 369 million m^3 in 2016, with water use decreasing by 31.92%, showing a trend of slow increase after the fluctuation has dropped. The reduction of industrial water consumption is related to the industrial development policy of strictly restricting the development of high-water-consumption industries, increasing the reuse rate of industrial water and increasing the capacity of wastewater treatment and reuse. Overall, the production water decreased at first, then stabilized, and then slowly increased. Such changes are not only contributed by the construction of a water-saving society in Xi'an but also affected by the expansion of the scale of the industrial area.

Table 1
The amount of water resources available in Xi'an in 2016 (10,000 m^3)

Types of water supply		Output of supplying water
Surface water	Water storage project	51,847
	Diversion works	26,384
	Lifting project	3,828
	Other	0
	Subtotal	82,059
Groundwater	Shallow groundwater	87,629
	Deep water	1,643
	Mildly brackish water	337
	Subtotal	89,609
Other water		13,009
Total water supply		184,677

4.1.4. Ecological water consumption

Ecological water consumption generally includes natural ecological water and human ecological water. From 2005 to 2016, with the construction of ecological projects such as Da Shui Da Luan, Ba Shui Yun Xi, and other ecological projects represented by the Bahe River Rehabilitation Project in Qionglai eco-district, the water consumption for eco-environment increased from 43 to 198 million m^3. The amount of water used in ecological environment shows a sudden soar, which significantly improves the urban ecology and landscape of Xi'an.

4.2. Predicted results

Water production and population size is estimated according to the situation of water resources carrying capacity of Xi'an. With reference to the data of 2016 and based on the above calculation and analysis methods, the relevant indicators of production, ecology, and domestic water use are determined. Based on the priority to meet the water demand for ecological environment construction, the scale of the population that can be carried in Xi'an is 481-6790000 in 2020. Specific indicators are shown in Table 4. The total amount of water resources in Xi'an changed from 19.04 to 30.89 billion m^3, the available water resources varied from 19.90 to 20.37 billion m^3, and the total water consumption varied from 15.56 to 18.44 billion m^3. It is estimated that, in 2020 and 2030, "leading Hanjiwei" project will diverse 443 and 602 million m^3 water to Xi'an; recycled water will be 0.424 billion m^3, and the water reuse rate is low. The comprehensive evaluation of water resources carrying capacity in Xi'an is concluded as medium level. According to the classification and evaluation of water resources carrying capacity, it is concluded that the carrying capacity of water resources in Xi'an is characterized by high carrying capacity of resources and water, high carrying capacity in production and consumption, low load level and low level of ecological breeding bearing capacity. Problems in water resources

Table 2
The population and urbanization rate in Xi'an in 2016

Permanent resident population (10,000)	883.21
Urban population (10,000)	648.54
Urbanization rate (%)	73.43

Table 3
The total water use in Xi'an in 2016 (10,000 m^3)

Production water	123,952
Domestic water	40,910
Ecological water	19,815
Total	184,677

Table 4
The predicted results water resources carrying capacity of Xi'an in 2020

Types	2020
The amount of water resources available (100 million m^3)	19.04–30.89
Ecological water (100 million m^3)	2.42
Domestic water (m^3/people)	143
Production water (100 million m^3)	6.26
Water resources carrying capacity (10,000 people)	481–679

carrying capacity in Xi'an can be included as insufficient water resources and long-term water shortage.

5. Conclusion

(1) The state of urban water resources is the key to affecting the urban scale. Especially in western China, where water resources are insufficient, water resources are the main factor that restricts urban development. Under the background of national development in the western region and the start of the "One Belt and One Road", Xi'an has ushered in a period of rapid development, putting more pressure on the supply of water resources and paying particular attention to the protection of water resources. Therefore, promoting improving and governing water conservation of all regions should be treated as a prerequisite to meet citizens' need for enjoyment of water sports. At the same time, we must actively promote water resources and the general public's ecological environment, water conservancy construction and management, leisure and cultural life cross-border integration and development.

(2) Based on the current situation of Xi'an water sports industry development, the current scale of water sports industry is gradually expanding, especially the growing demand for sports is promoting the diversified development of water sports industry, such as water sports and leisure, health tourism industry, water sports performances, and others. Also, water sports that can be carried out in different waters such as river freshwater and city lakes are included. Research shows that at present, Xi'an has a relatively high water resources carrying capacity to meet the demand of water sports development in the current period of time. However, in the long run, the existing water resources are still insufficient and there may exist even more severe shortage problems. Therefore, it is entirely possible to conduct appropriate development without undermining the existing water resources, that is, to parallel the protection and development. Also, it is important to insist on the principle of comprehensive utilization of water resources in the research and design of water resources utilization. In the process of water cycle purification, rainwater classification and collection utilize concepts such as "green, science and technology, and humanities," we advocate the development of water sports with small resource consumption, slight pollution, and zero damage so that the water sports can achieve a healthy and rapid development with a harmony of tourism, ecology, and culture.

(3) The development of water sports industry form a cross-border with the transportation, water resources, national land, urban construction, environmental protection, finance, tourism, and other fields. From the perspective of public governance and industrial integration, a mechanism of government coordination among top-down government departments should be established. Especially in the initial stage of the development of water sports industry in China, it is necessary to establish collaborative governance in the aspects of water resources protection, sports ship docks construction, water sports events establishment, and water tourism resources development. In the principle of integrating water sports resources, adjusting to local conditions, and scientific planning, it is important to reduce the cost of resource development, give full play to the advantages of resource aggregation, reduce administrative barriers, and establish the governance model of China's water sports industry. All departments should give specific implementation plans in the aspects of promoting the development planning of water sports industry, water area management, financial support, equipment manufacturing, etc. Government departments should also focus on service, supervising, and evaluating water sports infrastructure plans, urban master plans, land plans, water conservancy plans, and other docking problems such as regional integration and reconstruction of the integration and development.

(4) Recycling of urban rainwater and wastewater is an effective way to solve the shortage of urban water resources and reduce urban floods. In terms of water sports wharves, stadium facilities, facilities in sports and tourism fitness and recreation, hotels and other construction projects, we will adhere to the equal emphasis on technical and non-technical measures, pay attention to the use of rainwater and wastewater recycling, advocate the use of renewable energy sources and clean energy sources. In order to reduce the burden on water resources, cut down the short off, reduce the burden of municipal drainage system, we should choose the appropriate and advantageous way, take into consideration the economic, environmental, and social benefit, to improve the city ecology.

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