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Multiscale Spatial Distribution Pattern and Influencing Factors on Inland Fishing Gardens in China

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Abstract: Recently, a significant number of freshwater fishing gardens have sprouted up across mainland China. These recreational facilities are an important component in promoting the upgrading of the fishing industry and rural revitalization, and they are a key component in the high-quality development of rural tourism. This paper uses fishing gardens points of interest (POI) in China as data sources and employs kernel density estimation and geographical detectors to systematically uncover the multiscale spatial distribution pattern of these gardens, as well as the factors influencing their distribution. The results show that: (1) There are 15,090 fishing gardens in inland China. The spatial distribution of Chinese fishing gardens corresponds well with the "Hu-Line", with a greater number of gardens clustered in the southeast and few in the northwest. The density distribution exhibits a polarized pattern with multiple high-density centers. (2) The number of fishing gardens varies significantly across regions, with the eastern > central > western > northeastern; Guangdong has the most fishing gardens. The top five provinces have 43.4% of the total number of fishing gardens in the country. Large-scale fishing gardens are common in developed cities such as the Pearl River Delta, Beijing-Tianjin-Hebei, and the Yangtze River economic belt. (3) In natural environmental factors, land altitude and contour are negatively correlated with the distribution of fishing gardens, whereas winter temperature is positively correlated with the distribution. More than 50% of fishing gardens are located within 6 km of urban built-up areas. (4) GDP, population, and tourism revenue are the most important social development factors influencing the distribution of fishing gardens. The moderate factors are per capita income and the rate of urbanization; the weak factors are fishery output value and freshwater products production. In the discussion, suggestions on how to guide the rational layout and healthy development of the fishing garden industry in the region are put forward. We believe that these suggestions could be part of the pursuit to improve the fishing garden industrial policy in China.

Keywords: recreational freshwater angling; fishing garden; Geo Detector; kernel density estimate; multiscale spatial pattern; rural tourism; inland China

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1. Introduction

Fishing has gradually transitioned from a production activity and transformed into a recreational sport intended for both entertainment and competition as a result of economic development and the improvement of living standards. When compared to fishing in the traditional sense, recreational angling aquatic catches are not intended to meet people's basic physiological needs [1], but rather as an important part of recreational fishery, and they have given rise to the unique culture of fishing tourism. Fishing tourism has become an important industrial sector in some developed countries, with a large number of people participating in recreational angling [2,3]. The number of recreational anglers is growing

in developing countries with a rapidly expanding middle class [4]. China, as one of the fastest-growing developing countries, has a thriving recreational angling sector as a result of the country's consistent economic growth, its large population, and a long tradition of fishing. In recent years, China has seen the emergence of a recreational angling industry with an annual revenue of more than 25 billion CNY [5,6]. Fishing associations and clubs, such as the China Angling Association (CAA) and China Recreational Angling Association (CRAA) at the national level, can be found throughout the country. Every year, the CAA and CRAA hold hundreds of fishing competitions of varying scales, promoting the growth of recreational angling into a commercial and professional sport.

Recreational angling sites are either freshwater or seawater. They also can be either public or private in terms of the ownership of the water body. According to the Chinese Recreational Fishery Development Monitoring Report, recreational angling accounts for approximately 30% of the total recreational fishery revenue, with freshwater angling accounting for 80% of the total recreational angling revenue [6]. The percentages of natural water and private water available in freshwater angling are influenced by a variety of factors, such as the distribution of water area, tourists' affordability to charged fishing prices, government protection strength of natural waters, etc. Due to the lack of natural water bodies and fishing restrictions imposed by the government, more private water bodies are being opened up for fishing to meet people's recreational needs. According to Horváth et al. [7], private ponds have several advantages (e.g., fish abundance, guaranteed fish catching, and reachability) over natural water for fishing, and the number of private ponds in Hungary has been rapidly increasing in recent years. Nonetheless, the above-mentioned factors must be weighed with the number of recreational anglers. China has not implemented a recreational angling licensing system. As a result, determining the exact number of recreational fishing participants in the country is difficult. The numbers estimated using various standards vary greatly and range from 30 million to 100 million [8,9], indicating a large number of people engage in this recreational activity. Furthermore, according to the seventh national census (2020), cities house 63.89% (902 million) of the permanent residents in China. The majority of Chinese cities are densely populated with large areas of ground covered by impervious surfaces. Areas where natural water resources are not available have very limited space for recreational angling. The recent tightening of the fishing policy will further reduce the space for recreational angling. Therefore, many privately-owned ponds and reservoirs, aquaculture farms, agricultural gardens, and rural fish ponds in China have opened fishing sites to meet the demand of a large number of recreational anglers. Recreational fishing sites established by private water bodies charge fees and this is the primary source of revenue for them. The places where people take aquatic products, such as fish, shrimps and crabs, etc., as the angling catches are collectively known as fishing gardens in China.

Recreational angling and its participants are brought together in fishing gardens. Their development provides more economic benefits and job opportunities than the traditional fishing industry [10], relieving damage to natural water bodies and aquatic biological resources from overfishing, at the same time enriching the recreational tourism in rural China. As a result, the development of fishing gardens has received more attention from government agencies in charge of agriculture, fisheries, and environmental protection. Several stimulant policies have been implemented in recent years to encourage the development of recreational angling and fishing gardens. For example, in the Chinese Ministry of Agriculture and Rural Affairs' "Guidelines and Suggestions on Expanding Multi-functional Agriculture and Promoting the High-quality Development of Rural Industries" published in 2021, it has been suggested that recreational angling and fishing gardens should be included as new business sectors and new scenic spots to promote the high-quality development of rural industries and the integrated development of agriculture-related service sectors, to increase the economic benefit and industrial competitiveness. The Chinese Ministry of Agriculture and Rural Affairs (2022) recommends the transformation of traditional fishing industry sites into environmentally friendly, scenic, and leisure revenue by utilizing

resources such as ponds, rivers, lakes reservoirs, and seas, as well as the development of recreational angling business [11]. To summarize, the government hopes to transform recreational angling into a driving force for social development and rural revitalization, as well as to incorporate elements such as work, life, and environmental protection into the function of fishing gardens to achieve a healthy human–environment cycle. However, some areas are already seeing poorly planned massive fishing garden construction and unhealthy competition among similar businesses [6]. At this point, it is critical to determine the spatial distribution pattern of existing leisure fishing sites, so that future industry development can proceed with better business planning.

Many studies on the leisure angling sites have been conducted, including angler location preferences [12,13], the ecological response of the angling site to angling activity [14–16], and the evaluation of the angling site value [17–19]. These studies are primarily concerned with natural water bodies, with less emphasis placed on freshwater angling and the comprehensive distribution of angling sites. However, freshwater angling is the most popular type of angling in China, and fishing gardens differ greatly from natural water bodies, making it difficult to apply findings from previous studies. The problem we face is fishing gardens will become more common in China as the fishing industry undergoes structural reform, but conducting theoretical studies on the spatial distribution of leisure angling sites in China will not suffice to address the aforementioned issues. For starters, existing studies in China have largely focused on coastal areas [20–22], with results that have limited their applicability to inland regions. Second, several studies, but only in specific areas, focus on urban planning [23], tourism development [24], and operation and management [25]. Third, because it is difficult to obtain spatial data on fishing gardens, very few empirical analyses are conducted at the regional scale, resulting in limited research scope and scale. As a result, while studying the spatial distribution of fishing gardens in China and the influencing factors, data source innovation and the involvement of interdisciplinary fields are required. Large geospatial datasets are included in the Point of Interest (POI) data. They have played an important role in the empirical study of the spatial structure of industries and facilities, because of their high accuracy, wide-coverage, quick update, and ease of acquisition [26–28]. Fishing gardens are classified as a sub-category of recreational places due to their strong commercial aspect. This classification makes it easier to determine their number and distribution in China. Geo Detector models could identify the spatial heterogeneity among factors, recognize the relationships between multiple factors, and explain the driving force behind them. They have been widely applied in geospatial analysis [29–31].

The freshwater fishing gardens in 31 provinces (cities) of China are used as the POI, and GIS tools are used to empirically study their number, pattern, and density on multiple spatial scales. Point space analysis and Geo Detector models are used to explore the impact of natural environmental factors and social development factors on the spatial distribution of fishing gardens. Suggestions are made for the rational development of fishing gardens as an industry, which will serve as a reference for the management of government departments and the operation of business owners.

2. Materials and Methods

2.1. Extraction and Processing of Fishing Garden Data

The POI data used in the study were obtained from the open platform of Gaode Map (https://lbs.amap.com/, accessed on 21 December 2021). The platform's API port was used to extract the coordinates, details, and reviews of fishing gardens in China for December 2021. All POI entries had timestamps that were later than November 2021 and were current. The POI data were inspected one by one using their attached information and Google images, duplicates were removed, sorted, and classified. Errors in data were corrected. The spatial distribution of fishing gardens on land in 31 provinces of China was determined. Land-based seawater fishing gardens were also found. Sea fish are raised in these gardens in the seawater that has been transported over. Following data processing, 316 such fishing

gardens were discovered, accounting for 2.05% of China's inland fishing gardens. The majority of seawater fishing gardens are found along the coasts of northern to southern China, with a distinct linear distribution; the remainder are concentrated within 100 km of the Pearl River Delta coast. Inland seawater fishing gardens are expensive to build, there are only a few of them. Given the current situation of China and its inland rural areas, only freshwater fishing gardens were studied in this paper.

2.2. Spatial Data Sources

Administrative division of the study area (2019) and DEM data (240 m) were obtained from the Geospatial Data Cloud (http://www.gscloud.CN/, accessed on 1 November 2021). Geomorphologic data (1:1 million) were obtained from the Resource and Environmental Science and Data Center (https://www.resdc.CN/, accessed on 3 November 2021) of the Chinese Academy of Sciences' Institute of Geographic Sciences and Natural Resources Research. Waterbody data were extracted from global 30 m land-cover datasets using the fine classification system V1.0 for the period of 1985–2020 [32]. The January (2015–2017) national average temperature was calculated using China's 1 km-resolution monthly average temperature dataset (1901–2017) [33]. The data on urban built-up areas of major cities (with a population >300,000) came from the dataset on urban built-up areas of China (2020) [34]. The data on ecosystem type were taken from the 1:100,000 spatial distribution data for ecosystem types of China (2010) [35].

2.3. Official Data

Population data were derived from the results of China's seventh national census (2020). Data on the fishing industry were obtained from the previous five years' annual national fishery statistical reports and recreational fishery monitoring reports. Local statistical reports and national economic and social development bulletins were used to compile the statistical data on the economy, resident income, freshwater aquatic product output, and urbanization rate in 2020. To minimize the deviation among the conditions of the local tourism industry caused by COVID-19-related damages, the total tourism revenue was taken from the 2019 figure.

2.4. Study Methods

2.4.1. Kernel Density Estimate

Kernel density estimation (KDE) is a non-parametric method that is widely used for point space analysis [36–38]. The attenuation effect of distance on the service provided by a facility to its surrounding locations is also taken into account. KDE makes use of the information contained in the data and avoids prior knowledge that is skewed by the subjectivity of the researcher. As a result, it can perform the best approximation on sample data. The calculation formula is:

$$f(x) = \sum_{i=1}^{1} \frac{1}{nh} k\left(\frac{dis}{h}\right) \quad (1)$$

where f(x) denotes the kernel density calculation function at the spatial position x; h is the distance attenuation threshold (i.e., bandwidth); n denotes the number of elements whose distance from position x is less than or equal to h; and the k function represents the spatial weight function. Since the choice of bandwidth has a significant impact on the result of the kernel function estimation method, this paper uses the KDE tool of ArcGIS 10.2 software to perform multiple tests and determine whether when the bandwidth is set to 30 km, it can better reflect the density difference.

2.4.2. Geographic Detectors Model

Geographic detectors (Geo Detector) model is a statistical model for spatial data analysis [39] that can test the spatial differentiation of a single variable or detect the possible

causal relationship between two variables by testing the coupling of two variables' spatial distributions. Four detectors, including factor detection, detection of interactions, risk detection, and ecological detection are among the model results [40,41]. Only Factor detection is used to analyze the influencing factors. To find the optimal result, the conventional model must divide the number of independent variable layers many times. As a result, this paper employs the optimal parameters-based Geographic detectors model [42] provided by the "GD" package in R software to automatically layer the independent variable data.

Factor detection: This is used to determine to what extent do independent variables X affect the dependent variable Y. Power of determinants is computed using a q-value, and it is calculated as follows:

$$q = 1 - \frac{SSW}{SST},\ SSW = \sum_{h=1}^{L} N_h \sigma_h^2,\ SST = N_\sigma^2 \quad (2)$$

where h is the index to denote each of the strata related to the dependent variable Y as well as the independent variables X; N_h and N are the units of stratum h and whole areas, respectively, and similarly in the following for the variances of ${\sigma_h}^2$ and σ^2; SSW and SST are the sum of intra-layer variances and the total variances of whole areas, respectively; q-statistic is [0, 1], and the greater the q-statistic, the stronger the explanatory power of the independent variables X to the dependent variable Y.

2.4.3. Factors Affecting the Heterogeneity of Fishing Gardens

Fishing gardens, as a type of space, are bound to be constrained by natural conditions. At the same time, as a type of industry, they are influenced by social and economic factors. As a result, to analyze the influencing factors of fishing gardens, this paper selects 11 potential indicators from the two dimensions of the natural environment and social development. The four natural environment indicators, including altitude, landform type, winter temperature, and distance from main city, are all spatially available data. Each indicator can be spatially coupled with the fishing gardens directly. Then, using buffer analysis, superposition analysis, and shortest path methods, in conjunction with the distribution characteristics, density characteristics and location characteristics of the fishing gardens can be found. The influence of different social development factors on the distribution of fishing gardens is detected using official data at the municipal level and the geographic detector method. Social development factors are composed of GDP, population (POP), per capita disposable income (PCI), urbanization rate (UR), fishery output value (FOV), freshwater products production (FPP), and tourism revenue (TR). FPP is the sum of freshwater aquaculture products and freshwater capture products, including fish, crustaceans (shrimp, crab), shellfish, algae, etc.

3. Results

3.1. Multiscale Spatial Characteristics of Fishing Gardens in China

3.1.1. Spatial Distribution Characteristics of Fishing Gardens in China

According to the POI sorting results, there are 15,090 fishing gardens in inland China, distributed across 31 provinces (cities). The average nearest neighbor tool in ArcGIS 10.2 was used to analyze the spatial structure status of all points, and the results show that fishing gardens have significant spatial agglomeration characteristics on a national scale (Z-score: −171.32, p = 0), and the spatial distribution is extremely uneven. The spatial distribution of fishing gardens on a national scale (Figure 1) is characterized by more in the southeast and less in the northwest, which closely corresponds to the population distribution pattern. It is primarily distributed to the east of China's population boundary—the Hu line [43,44] accounting for 97.1%. The Pearl River Delta, Haihe River Basin, the lower reaches of the Yellow River, the middle and lower reaches of the Yangtze River, and the eastern part of the Sichuan basin are among them. Due to the high priority of economic development in Yunnan, Guizhou, Shaanxi, and northeast China, fishing gardens are concentrated and distributed in provincial capital cities. Fishing gardens in the west of

the Hu line are limited and dispersed, accounting for only 2.9% of the country. They are primarily found in the Yinchuan Plain, Hetao Plain, Huangshui Valley in the Yellow River middle and upper reaches, as well as the southern edge of the Jungar basin and Bosten Lake. The distribution characteristics are that fishing gardens are primarily concentrated around major cities, with a few scattered along major highways in the form of threaded beads.

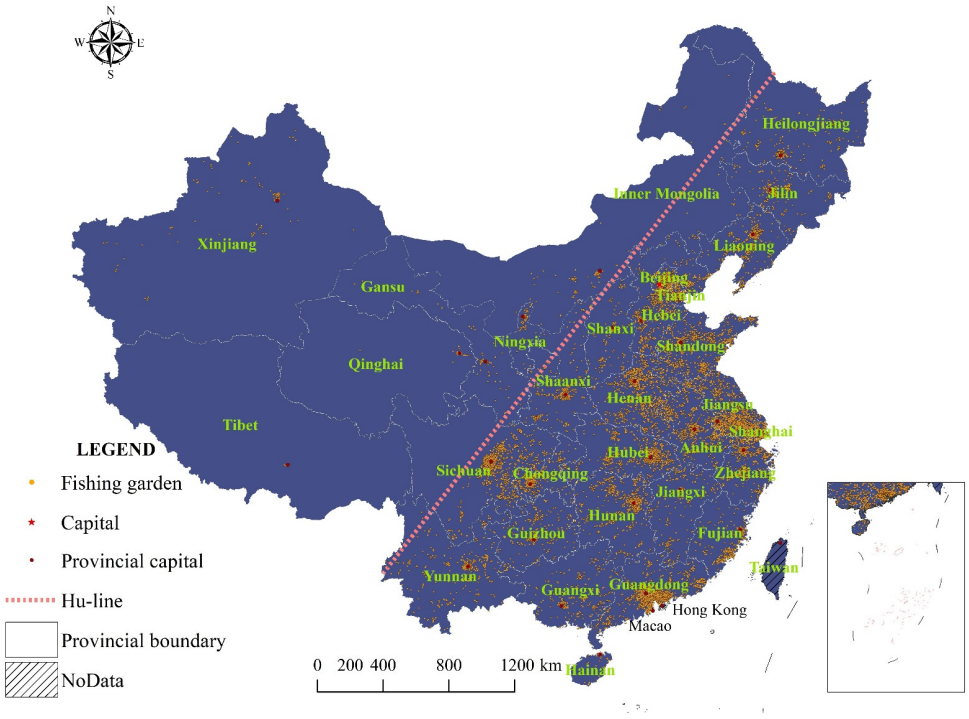

Figure 1. Spatial distribution of fishing gardens in inland China.

3.1.2. Spatial Density Characteristics of Fishing Gardens in China

Figure 2 depicts how the kernel density of China's inland fishing gardens varies significantly across the country, exhibiting the characteristics of "one pole and multiple cores". With a maximum density of 0.151–0.287 per km^2, the pole centers with the highest distribution density of fishing gardens are in Dongguan and Guangzhou and spread in circles around it to the core area of the Pearl River Delta. There are several secondary centers in Chengdu and its surrounding areas, Wuhan, Beijing, Shanghai, southern Jiangsu, Hangzhou, and Nanjing, with a maximum density of 0.066–0.15 per km^2. At the same time, high-value areas have emerged around western Chongqing, Xiamen, Changsha, Nanning, Kunming, Jinan, Zhengzhou, Xi'an, Tianjin, Shenyang, Harbin, Changchun, Urumqi, Yinchuan, and Jinhua, with maximum densities ranging from 0.025 to 0.067 per km^2. Furthermore, the triangular area formed by Beijing, Changsha, and Shanghai contain a large area of lower-density areas with a density of less than 0.025 per km^2. Other places have a low overall density value.

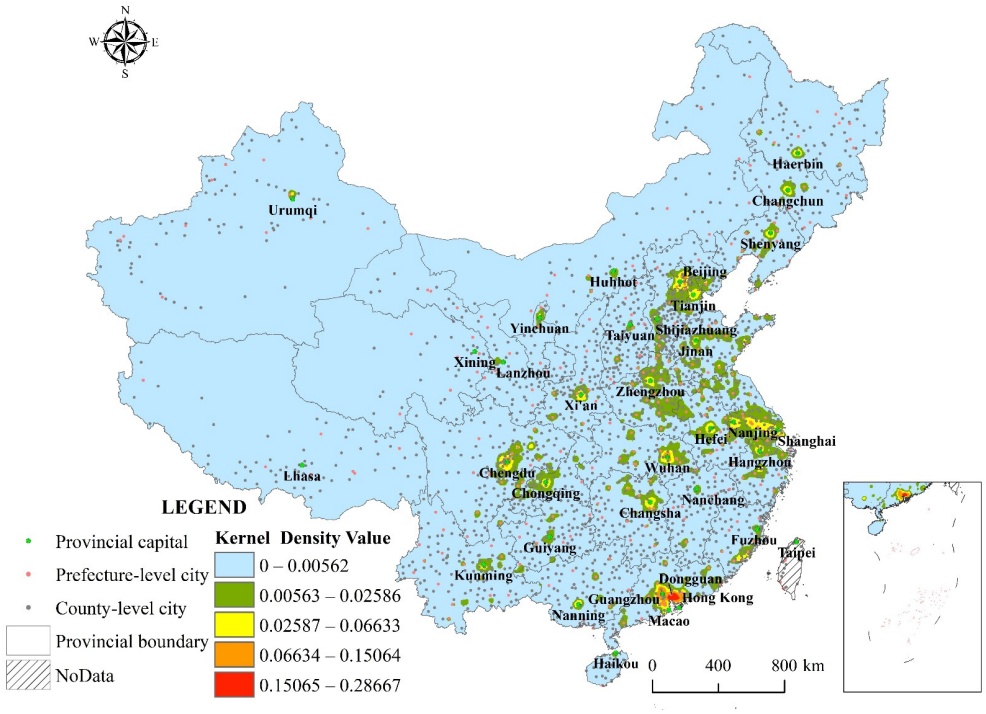

Figure 2. Kernel density of fishing gardens in China.

3.1.3. Provincial-Level Characteristics of Fishing Gardens

Table 1 shows that the eastern region has the most fishing gardens, with 7332, accounting for 48.6% of the country; the central region has slightly more than the western region, with 3410 and 3338, accounting for 22.6% and 22.1% of the country, respectively; and northeastern China has the fewest, with 1013, accounting for 6.7% of the country. In terms of provinces, there are three provinces with more than a thousand fishing gardens, eight provinces with between five hundred and a thousand, and twenty provinces with fewer than five hundred gardens. Guangdong has the most fishing gardens, 2439, which is 1104 more than Jiangsu, which ranks second and accounts for 16.16% of the country. The two provinces with the fewest fishing gardens are Tibet and Qinghai, both of which are located in Qinghai–Tibetan plateau. The top five provinces account for 43.4% of the country's total number of fishing gardens, with significant provincial differences.

Table 1. The number of fishing gardens in various regions of China.

Region	Provinces	Number	Percentage of the Total %	Region	Provinces	Number	Percentage of the Total %
Eastern	Hainan	40	0.27	Western	Tibet	2	0.01
	Tianjin	266	1.76		Qinghai	19	0.13
	Shanghai	284	1.88		Ningxia	87	0.58
	Fujian	337	2.23		Gansu	99	0.66
	Beijing	482	3.19		Xinjiang	120	0.8
	Zhejiang	617	4.09		Inner Mongolia	132	0.87
	Hebei	692	4.59		Guizhou	285	1.89
	Shandong	837	5.55		Chongqing	352	2.33
	Jiangsu	1335	8.85		Guangxi	371	2.46
	Guangdong	2439	16.16		Shaanxi	381	2.52
	subtotal	7329	48.57		Yunnan	444	2.94
					Sichuan	1046	6.93

Table 1. *Cont.*

Region	Provinces	Number	Percentage of the Total %	Region	Provinces	Number	Percentage of the Total %
Central	Shanxi	142	0.94	Northeastern	subtotal	3338	22.12
	Jiangxi	227	1.5				
	Hunan	629	4.17		Heilongjiang	292	1.94
	Anhui	713	4.72		Jilin	315	2.09
	Hubei	807	5.35		Liaoning	406	2.69
	Henan	892	5.91		subtotal	1013	6.71
	subtotal	3410	22.6				
Total	-	-	-	-	-	15,090	100

3.1.4. Municipal-Level Distribution Characteristics of Fishing Gardens

It is convenient for central government to find cities with a developed fishing industry to carry out pilot work if the research scale is refined to the municipal level. The number of fishing gardens in each city reflects the region's industrial scale, which is divided into five levels based on the natural breakpoint method. Figure 3a depicts the distribution of fishing gardens in three hundred and thirty-three prefecture-level cities and four municipalities directly under the central government. The findings indicate that the scale of each city varies greatly and that the characteristics of uneven spatial distribution persist at the municipal level. There are fishing gardens in 323 of the 337 cities, covering almost every city in China except the Qinghai–Tibetan Plateau, but only four cities have more than four hundred fishing gardens, namely Dongguan, Beijing, Guangzhou, and Chengdu. In stark contrast, 207 cities have fewer than 34 fishing gardens, 75 cities have 34–86 fishing gardens, 27 cities have 87–173 fishing gardens, and 10 cities have 174–357 fishing gardens. The number of different scale levels of fishing gardens can be seen to have a "pyramid" distribution. The majority of urban fishing gardens are on a small scale, and the larger the scale level, the fewer the corresponding cities. The scale of fishing gardens in developed cities such as the Pearl River Delta, Beijing, Tianjin, Hebei, and the Yangtze River economic belt is large in terms of urban clusters. Furthermore, the scale of fishing gardens ranks first in the province not only in the northeast, but also in many provincial capital cities such as Hubei, Hunan, Anhui, and Yunnan, etc. In addition to large cities, fishing gardens in some small and medium-sized cities, such as Jinhua, Xinxiang, Lu'an, Fuyang, Zhumadian, Changde, Huanggang, Linyi, and other places, have grown in size and merit the attention of the management department.

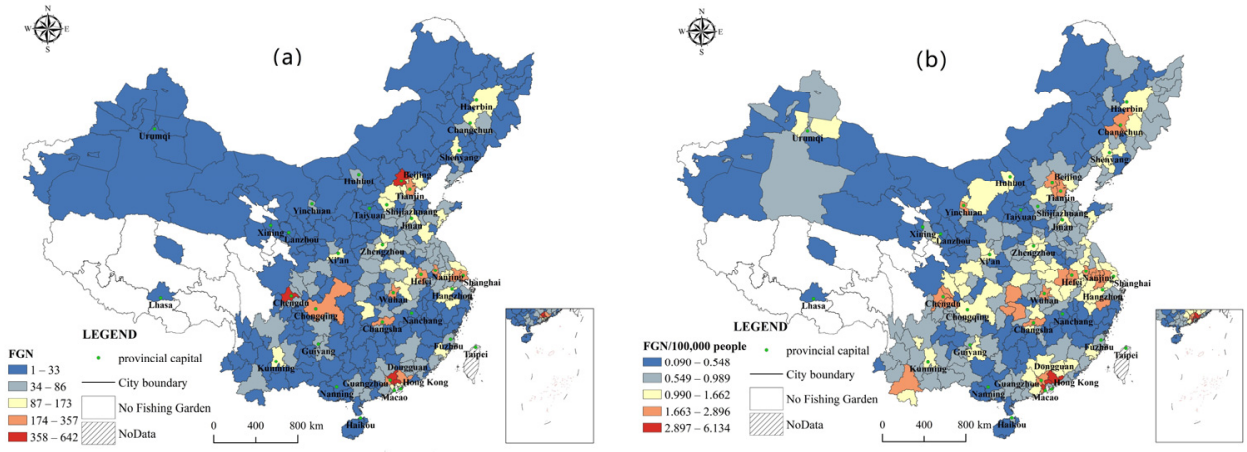

Figure 3. Fishing gardens are distributed at the municipal level. (**a**) The number of fishing gardens (FGN), and (**b**) the FGN per 100,000 people.

To eliminate the impact of population size differences, each city's fishing gardens are standardized based on the number of people. The number of fishing gardens per 100,000 people can reflect the region's fishing garden supply capacity as well as the competitive pressures of tourists, and is divided into five levels according to the above method. Figure 3b depicts that areas with a high per capita availability of fish gardens are more widespread than those with large-scale fishing gardens. In contrast to the regional characteristics of the number of fishing gardens, many cities in the central and western regions have a high level of per capita availability. High-value areas are no longer restricted to large cities, and per capita availability in small cities surrounding large cities is also very high. Dongguan has the most per capita availability, with 6.134 fishing gardens per 100,000 people, followed by Huizhou and Zhongshan. These cities, which have a large population and an active economy, are all located in the Guangdong–Hong Kong–Macao Greater Bay Area. Fishing gardens in this area not only serve the locals, but also attract visitors from Hong Kong and Macao. Using Anselin Local Morans I tool in ArcGIS 10.2 further analyzes the local Moran index of per capita availability of fishing gardens in various cities. According to the findings, cities in the Pearl River Delta, Taihu Lake Basin, Wuhan, and Hefei have High-High clusters (p = 0), indicating that the large cities in these areas, as well as the surrounding small cities, have a high per capita availability of fishing gardens and show a trend of spatial agglomeration at the municipal level.

3.2. Natural Environment Factors Influencing on Spatial Heterogeneity of Fishing Gardens

As shown in Figure 4a,b, the distribution of fishing gardens is closely related to the altitude. The number of fishing gardens is negative correlated to altitude, i.e., fewer fishing gardens are present in higher-altitude regions. The number decreases even more significantly as the altitude increases. Specifically, 67.56% of the fishing gardens in China are located below a 200 m altitude, 14.63% at 200–500 m, 5.4% at 1000–1500 m, and 2.98% at 1500–2000 m. Although 31% of the total land of China is above a 2000 m elevation, only 2.17% of fishing gardens are located in highly elevated areas. The majority of the low-laying areas in China are located on the alluvial plains of eastern China, where rivers are dense and interconnected and the population and cities are concentrated. Fishing gardens are thus abundant and widely distributed in these places. The areas of east China to the south of the Great Wall, while they are low-altitude regions the same as northeast China, have a greater number and denser distribution of fishing gardens than the latter.

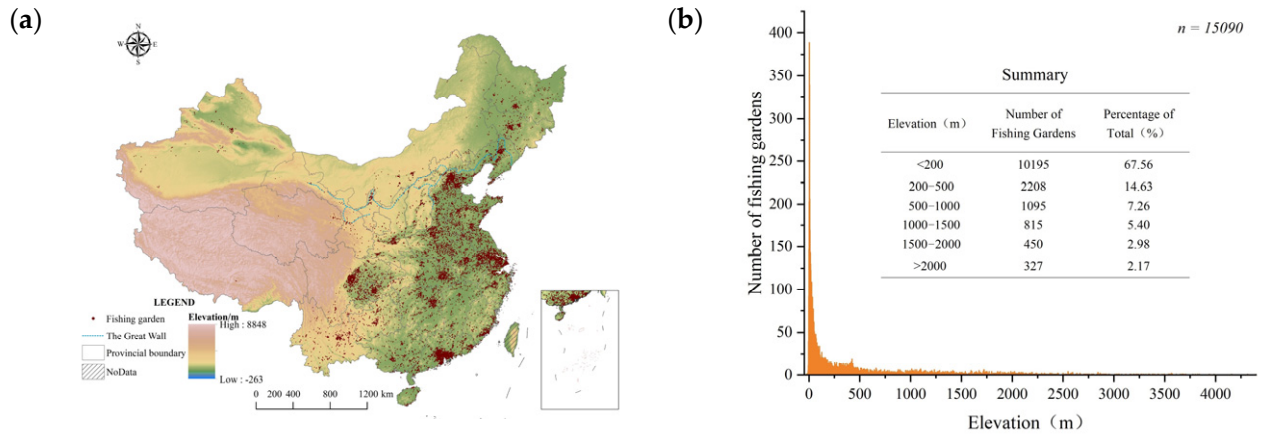

Figure 4. *Cont.*

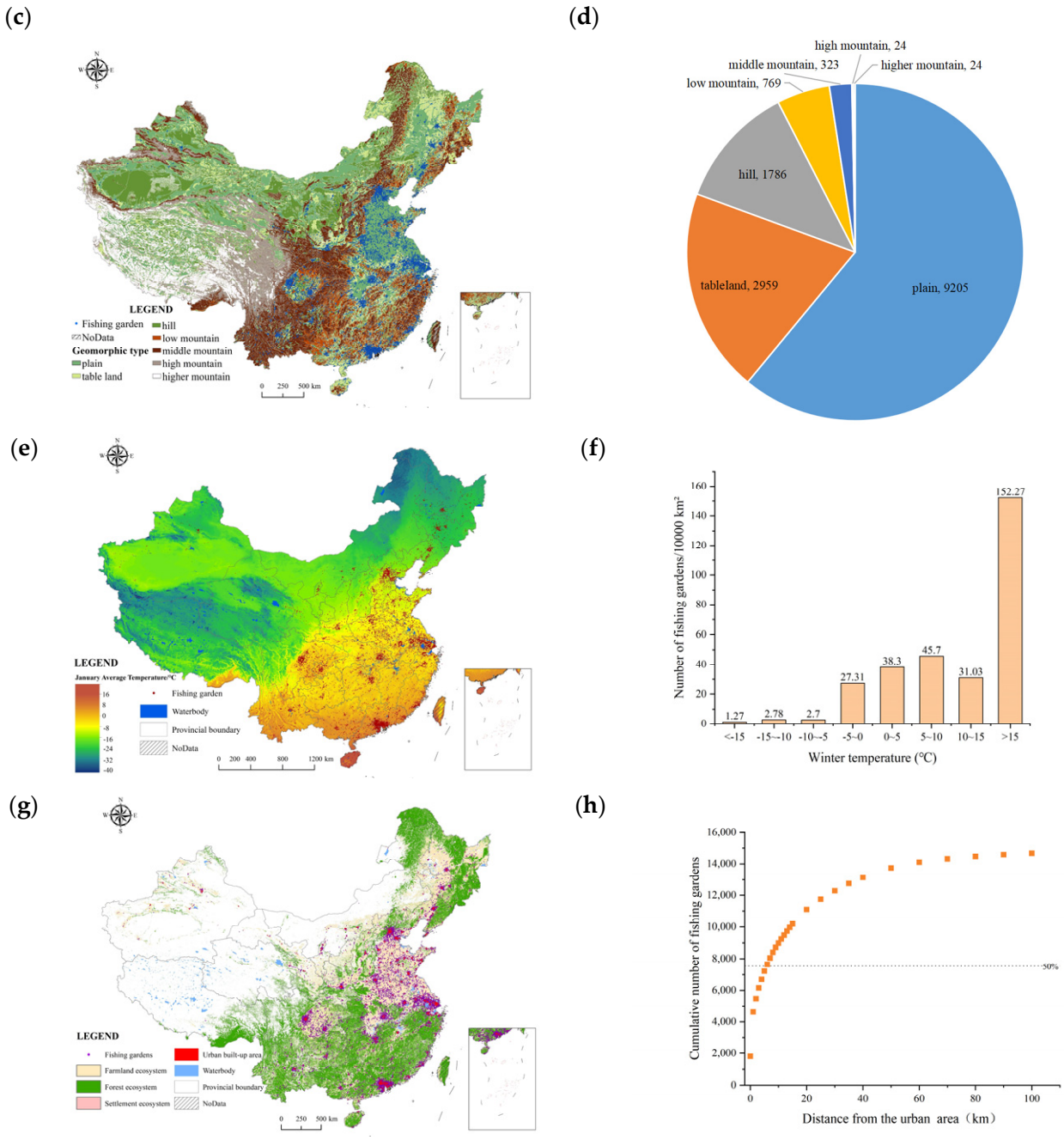

Figure 4. Spatial coupling between fishing gardens and natural environmental factors (**a**) DEM, (**b**) distribution of fishing gardens with respect to altitude, (**c**) landform map, (**d**) distribution of fishing gardens with respect to landform, (**e**) average temperature in winter (January), (**f**) FGN per unit area in different temperature zones, (**g**) urban built-up areas and terrestrial ecosystems, and (**h**) FGN in terms of their distance from urban built-up areas.

As shown in Figure 4c,d, the highest number of fishing gardens are found on plains (61%), followed by tableland (19.6%). The number of fishing gardens on hills, low mountains, and moderately high mountains accounts for, respectively, 11.8%, 5.1%, and 2.1% of the national total, while those on high and very high mountains account for only 0.16% of the total. This is an indication that the number of fishing gardens is negatively correlated to land contour, i.e., fewer fishing gardens are found on an uneven and rugged land surface. Large differences in the number are present between plains, hills, and mountains. Even in mountainous areas with a small total number of fishing gardens, the number follows

the trend of low mountains > mid-height mountains > high mountains. On the one hand, the influence of altitude is strong in areas of the same landform type, and a much higher number of fishing gardens are found on low-altitude plains than mid- and high-altitude plains (the same applies for tablelands and hills). On the other hand, the low-altitude hilly areas of southeast China, though having fewer cities and being less populated than the neighboring plain areas, are still considered densely populated regions. However, due to landform factors, the density of fishing gardens in these areas is much lower than the surrounding.

The spatial coupling (Figure 4e) between the fishing garden distribution and winter temperature (January) reveals that low-temperature regions have fewer fishing gardens in winter than high-temperature regions. For places with temperatures below −10 °C, only Heilongjiang, Jilin, eastern inner Mongolia, and northern Xinjiang have very few fishing gardens. The number in each temperature zone is further analyzed. To eliminate the influence of area size, the number of fishing gardens in each temperature zone is standardized in terms of the area of the region (Figure 4f). The results show great variation in the number of fishing gardens per unit area (10,000 km^2) across the temperature zones. Areas with an average winter temperature of above 15 °C could have as many as 152.27 fishing gardens, while those with an average winter temperature below −15 °C have only 1.27 fishing gardens. This in general shows that regions with a lower winter temperature tend to have fewer fishing gardens, especially for areas below −5 °C in winter. This is because fishing is an outdoor sport and is affected to a considerable extent by temperature. At exceedingly low temperatures, the comfort level of participants is poor. In addition, fishing becomes more difficult as the water surface freezes. Though ice fishing is a tradition in cold regions of China, the number of participants are greatly reduced in winter. As such, fishing gardens in high-latitude areas are faced with the problem of long freezing periods in winter and the low number of tourists. Lower-latitude regions, on the other hand, tend to experience a higher winter temperature, shorter freezing period, and less impact from cold weather. The low temperature in winter is, therefore, a limiting factor on the development of fishing gardens in high-latitude areas.

The spatial coupling between fishing gardens and the 433 urban built-up areas in China with a population of above 300,000 reveals the presence of fishing gardens in the vicinity of major cities of China (Figure 4g). Larger cities have more fishing gardens, which are present in high density and with a high level of clustering. This is particularly true in east China, where the areas around urban clusters are also the places showing a high level of fishing garden clustering. Many fishing gardens are also found to be evenly distributed in the space between cities. The distance between each fishing garden and the built-up area of the nearest city is computed by buffer analysis (Figure 4h). The results show that as the distance increases, the cumulative growth in the number of fishing gardens slows down, which means more fishing gardens are present per unit of distance as one approaches the built-up area of a city. Major cities in China are usually more than tens of kilometers apart. In contrast, more than 40% of fishing gardens are located within 3 km of the urban built-up area, and more than 50% of them are located within 6 km. This means that most fishing gardens are concentrated close to major cities. Cities are typically densely populated and scarce in the natural water available per capita. The close proximity of fishing gardens in economically developed areas help to attract more tourists who take part in recreational angling. Hence, the size and location of cities, especially major cities, strongly affect the number and distribution of fishing gardens. Looking further into the ecosystem around the fishing gardens, one could see that most of the existing fishing gardens are located in areas comprising mostly of cultivated land, and largely rely on highly-fragmented and small patches of water bodies. This situation makes it difficult to realize large-water-body fishing. A small number of fishing gardens are located in areas with mainly forests, and they have the potential to develop into multi-functional venues. Only very few fishing gardens are close to large water bodies.

3.3. Assessing the Influence of Social Development Factors on the Spatial Heterogeneity of Fishing Gardens

As shown in Table 2, all influencing factors pass the significance test. Taking into account the exploratory data analysis results obtained previously, it can be seen that the seven factors all have a positive impact on the spatial homogeneity of fishing gardens, but the explanatory power of the factors varies. Of all the social development factors, GDP, POP, and TR are best at explaining the spatial homogeneity in the distribution of fishing gardens, while FPP and FOV are lower in their explanatory power.

Table 2. Detected results of social development factors in the distribution of fishing gardens.

Parameters	GDP	POP	TR	PCI	UR	FOV	FPP
q-statistic	0.651	0.644	0.507	0.393	0.258	0.122	0.075
p-value	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

GDP has the most explanatory power among all factors (q = 0.651). As an important indicator of the economic scale in a region, a high GDP value indicates a high overall level of urban economic development, while a rapid rise in the local economy is an indispensable factor behind the large-scale emergence of the recreational fishing industry and recreational angling. On the spatial distribution map of social development factor categories (Figure 5a), most of China's high-GDP cities are located on the East Coast and are provincial capitals. As previously mentioned, these cities are also on low-altitude plains and enjoy good natural conditions. Overall, GDP decreases from the southeast to the northwest, which agrees with the spatial trend of fishing garden distribution. Therefore, cities with a high GDP are more likely to have a greater number of fishing gardens. The optimal layers of each social development factor are shown in Figure 5. The numbers in the legend of each graph represent the various levels of the variable, and the larger the number, the higher the factor value.

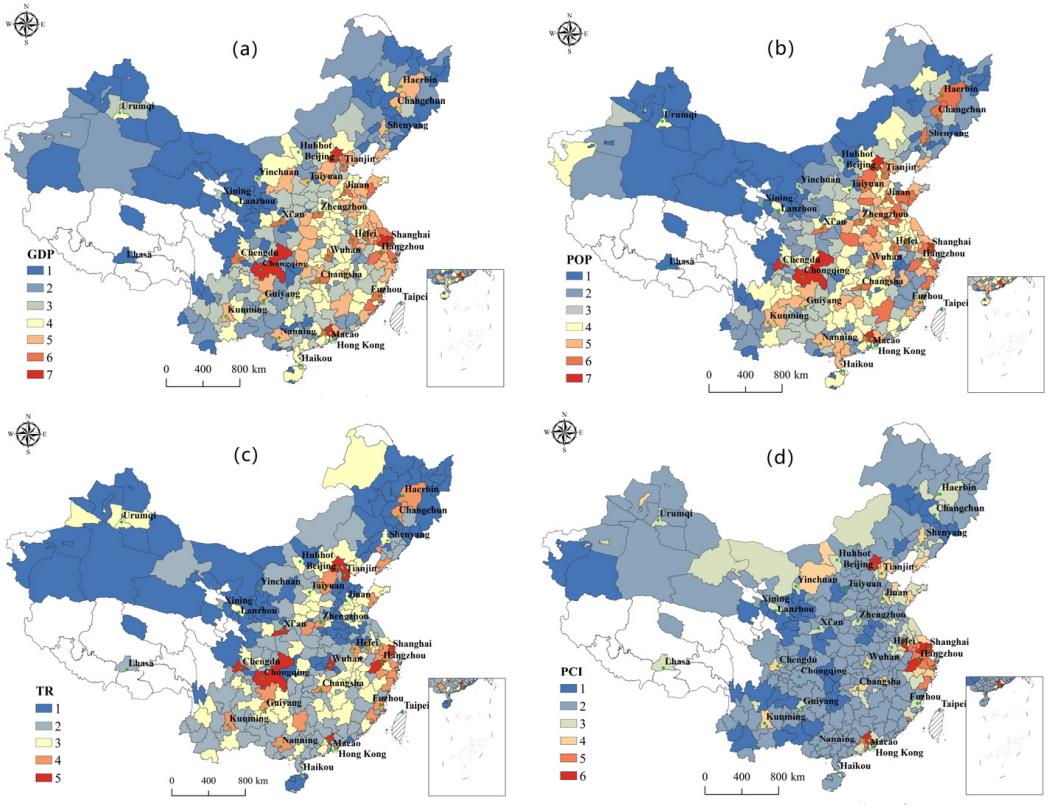

Figure 5. *Cont.*

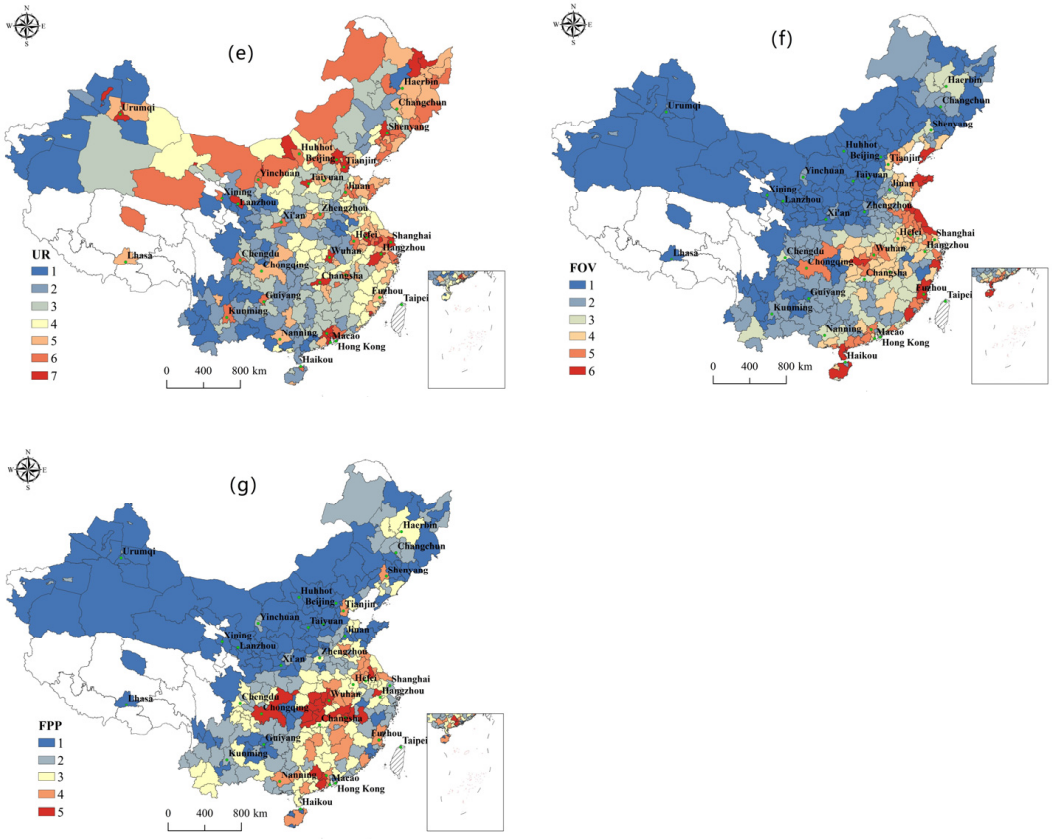

Figure 5. Social development factor categories spatial distribution. (**a**) GDP, (**b**) POP, (**c**) TR, (**d**) PCI, (**e**) UR, (**f**) FOV, and (**g**) FPP.

POP ranks the second in explanatory power (q = 0.644). Population affects the total number of anglers and the total GDP in a region, and is thus related to GDP distribution (Figure 5b). There is some collinearity between the two, but differences also exist. Many cities in central China are highly populated, but have a much lower total GDP than the coastal cities. These places are major suppliers of the labor force in China. Laborers not only flow between cities, but also from villages to cities. Many rural areas thus become empty nests due to the seasonal exodus of their population. The significant reduction of the permanent resident population limits the development of fishing gardens in central China, particularly in the small cities and rural areas. Overall, population affects, to a great extent, the number of fishing gardens. Without a large population base, there will not be sufficient anglers to support the operation of the fishing garden industry. Such is the case for many cities in the vast northwest and on the land border of China.

With a q-value of 0.507, TR ranks the third in explanatory power. It is considered to possess a high level of explanatory power in terms of the physical meaning of a geographical detector. TR indicates the scale of the local tourism industry, and will undoubtedly affect the recreational activity and tourism structure at the local level. As fishing gardens are tourism destinations, their distribution is strongly affected by the activity of the tourism market in the region (Figure 5c). A more prosperous tourism market and a greater number of tourists mean more potential customers to the fishing gardens, supporting the establishment of more fishing gardens. Some fishing gardens are located on the premise of grade A scenic sites. The interconnection between tourism and the fishing garden industry has been seen again during the recent event of COVID-19, when the impact of the pandemic on tourism has caused the temporary or permanent closure of many fishing gardens.

Figure 5d shows the PCI grade of cities in China. PCI is a more useful indicator for living standards than GDP, and is considered the most important and determining factor of consumer spending. The explanatory power of PCI on fishing garden distribution is 0.393.

A higher income level means a greater ability to participate in tourism activities and pay for fishing garden expenses. Hence, PCI impacts on the distribution of fishing gardens. UR is the fraction of urban permanent residents in the total permanent resident population of the region. It has a q-value of 0.258. Cities with a high proportion of urban population may give rise to more suburban fishing gardens to meet the short-term travel needs of residents highly concentrated in the urban area. This leads to the establishment of fishing gardens at a close proximity to urban areas. In recent years, with the support of policies, many large-scale autonomous cities for ethnic minorities in China have experienced a very high urbanization rate (Figure 5e). However, the number of fishing gardens in these places has yet to rank at the top, owing to some of the aforementioned factors. This affects the q-value obtained in the global model. In addition, the spatial distribution of highly urbanized cities is consistent with the spatial distribution of cities that have high numbers of fishing gardens.

FOV indicates the level of development of the local fishing industry. Its impact on fishing garden distribution is analyzed here in terms of fishing conditions. Many coastal cities have a solid foundation in the fishing industry (Figure 5f) and many business participants. They were among the first to open up fishing gardens. However, the FOV of coastal cities is comprised of the outputs of both the marine fishing industry and freshwater fishing industry, resulting in the poor explanatory power of this indicator for the distribution of just inland fishing gardens. Nevertheless, FOV still has a positive impact on fishing garden distribution, and its explanatory power is 0.122.

China's FPP indicates the production of freshwater products, mainly in the form of fish (>85%) [45]. It signifies the impact of the fish supply on fishing gardens. This indicator, however, has the lowest explanatory power in the global model. This is because, compared to the amount of freshwater products consumed, the demand of recreational angling is not high, and most regions have the ability to supply enough fish for recreational angling. However, by comparing Figures 3a and 5g, we found that cities with a low FPP have the lowest number of fishing gardens. Additionally, it turns out that FPP affects fish prices and thus the operation cost of fishing gardens, and the diversity of local freshwater products determines the fish diversity in local fishing gardens. As such, it is a factor that should receive the attention of business operators of fishing gardens.

4. Discussion

China's urbanization has moved a large number of people from rural areas to the cities and separated them from their land and water. Economic development has led to the flourishing of domestic tourism with recreational angling being widely featured on the Internet. A sizable number of fishing gardens have appeared in inland China under this background. Just as the overall social development is important to the growth of recreational fisheries in China [46], the regional economic level and residents' income greatly affect the distribution of fishing gardens, and differences in population and fishery bases further lead to the unbalanced development of the recreational angling industry. Natural conditions directly limit the places and total number of fishing gardens that could be constructed, and affect the population, socioeconomic development, and fishing industry status of the region. For this reason, natural environmental factors have a profound and multi-fold impact on the distribution of the fishing gardens. Although recreational fishing is still a small industry in China, it is a green and less wasteful industry [47], and is supported by the large population of the country. It could become a new way for rural populations to earn a life. However, the blind construction of fishing gardens and immature management result in the rapid growth of fishing gardens in some places at the expense of quality. The careful monitoring and management of government in this industry are thus necessary, so that recreational fishing could be a positive driving force for the society and the environment [48]. Three suggestions are made here based on the results of this study and the existing problems of the fishing garden industry in China.

(1) As observed in their spatial distribution, fishing gardens are densely distributed in the east, and are growing in number in the provincial capitals of other regions. These cities should lead the formulation of industry standards and issue preferential policies that give timely support to the financial and land needs of the fishing garden industry. As part of the fishing withdrawal and resettlement project, fishermen could be encouraged to participate in the operation of fishing gardens or related services. In the large expanse of rural inland China, traditional rice field fish breeding could be used to foster an extended industrial chain built on the rice fields–fish ponds–fishing gardens–agritainment model, creating new growth potential for rural leisure and tourism. The natural conditions of China make it difficult for most fishing gardens to support and operate large stretches of water. Thus, it is important to make full use of sites that could provide large areas of water for recreational fishing, thus establishing fishing tourism brands and driving fishing gardens with small water bodies to seek a more diversified and individualized development in their fishing mode, fish type, and site scenery.

(2) China's fishing gardens are growing rapidly in number. Fishing gardens of different sizes are emerging in great numbers in places suitable for their development, but are sparse or not present at all in other places, falling short to the needs of local fishing fans. In cities on the Pearl River Delta, Yangtze River Delta, and Beijing–Tianjin–Hebei Metropolitan Region where fishing gardens are highly concentrated, the government should steer local fishing gardens toward high-quality development in its approval of fishing garden projects. In hilly and mountainous areas, the government should encourage business owners to make use of the varied agricultural modes of these places to develop multi-functional, integrated fishing gardens. In other regions, priority should be given to places close to the urban area and scenic spots, and the local economic status and population size should be taken into consideration to rationally plan the location of fishing gardens.

(3) China's fishing garden industry started late and is mostly found in the suburbs and rural areas. The knowledge and service skill of some employees fall short of the industry standard. They are not very conscious of water environment protection [49], and their fish breeding skills need to be improved. The government should provide corresponding training programs to help improve the professional skill and service standard of these employees. Government bureaus should also supervise the fishing gardens to implement safety facilities and medical emergency equipment, so that situations such as drowning and injury could be dealt with in a timely manner. This will ensure a safe and comfortable fishing environment for the visitors, help to create high-quality rural tourism attractions, and draw more people to participate in fishing.

5. Conclusions

This paper studies the spatial distribution pattern and influencing factors of freshwater fishing gardens in inland China based on POI data and GIS tools, making up for the shortcomings of traditional monitoring methods. This is of great value to China, which has not yet established a comprehensive monitoring system for recreational fishing gardens. This method provides a reference for leisure tourism research in other regions, especially in developing countries with an imperfect monitoring system. In addition, this study considered the distribution of fishing gardens from a quantitative point of view, but in fact, the scale and development levels of each fishing garden are not consistent, and in-depth research on this needs to be supported by detailed field research and land-use data. Further research on fishing gardens can be carried out based on multi-period data from the perspective of "quantity-area-quality".

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