

Research

Towards management of sustainable tourism development in coastal destinations of the Bohai Rim: insights from a tourism carrying capacity analysis

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Abstract

The excessive growth and competition of tourism activities often lead to public unhappiness and environmental degradation, and these negative influences may undermine the very basis for destination's attractiveness and the tourism activity itself. In this study, we proposed a methodology that showcases how to measure and evaluate tourism carrying capacity for better management and planning of sustainable tourism. In particular, A Pressure-State-Response framework was firstly used to establish the indicator system, and to illustrate the causal linkages between indicators and components. The index of tourism carrying capacity was then developed as a means for measuring and assessing the tourism development performance in coastal cities in the Bohai Rim. On this basis, the levels of tourism carrying capacity were evaluated and analyzed, and impacts and vulnerabilities in relation to sustainable tourism were identified, proposing development strategy or roadmap for local sustainable tourism. This case study demonstrates the application of the concept of tourism carrying capacity in management practice, highlighting its important role in planning tourism destination development and management of its negative impacts. Conclusively, tourism carrying capacity can be a promising policy tool under the integrative management context to make decisions about measures to control tourism development and growth, and to indicate the pathways and directions that sustainable tourism should follow. By quantifying limits and trade-offs, tourism carrying capacity analysis enable stakeholders to make data-driven decisions for responsible tourism growth. *Clinical trial number:* Not applicable.

Keywords Tourism carrying capacity · Sustainable tourism · Coastal destinations · The PSR framework · The Bohai Rim

1 Introduction

It is evident that tourism development provides considerable prospects for gainful employment and economic opportunities [33], and this is realized by various ways: by providing new jobs and livelihood opportunities, by generating cross-regional business and trading; by improving revenue for local government and communities, etc. However, the paradox of tourism is that the tourism resources and products need to be continuously and intensively protected as it is being developed and marketed, leading to the manifold impacts of tourism development [8, 21, 40]. Unlike other forms of economic activities, tourism is heavily dependent upon in situ resources and facilities, and their attributes, quality and maintenance constitute the pillar of tourism development. As tourism grows, it would exert pressures

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on environmental resources and often alters the socio-economic structures, the characteristics and functioning of destinations and in general affects the life quality of local residents [4, 32]. And thus, excessive and unregulated tourism may endanger and undermine the resources and characteristics of destinations that attracts tourists [29, 38]. In this light, a balance should be maintained between the intensity of tourism activities and the capacity of tourism resources, without impairment or depletion of environment and resources that sustain future development.

The concept of carrying capacity therefore becomes a critical concern in reframing of sustainable tourism. In fact, there are various schools of thought that understand and interpret carrying capacity differently [19, 25]. In its most traditional sense, the concept refers to the maximum number of tourists or tourist use that can be accommodated at the same time, without destruction of physical and socio-cultural environment [24]. O'Reilly [28] demonstrated two schools of thought concerning tourism carrying capacity. The first views tourism capacity as the destination's ability to absorb tourism before negative impacts are perceived by the local community. The second considers tourism capacity as the threshold above which tourist influx will decline because bad experience can be perceived by the tourists themselves and thus the destinations cease to satisfy and attract them. In recognition of its diverse nature, a variety of attributes of tourism carrying capacity (TCC) have been identified, and it gradually evolves so as to incorporate socio-cultural, economic, and ecological aspects [27, 30, 35]. In its broadest sense, tourism carrying capacity could be categorized to three dimensions: social, economic and ecological [4]. Social carrying capacity is a measure of crowding tolerance, such as the overcrowding perception by tourists or local residents [2, 26]. Economic carrying capacity seeks to define the extent to which a region can be altered before the economic activities are adversely affected [5, 43]. Environmental carrying capacity aims to assess the environmental impacts that can be measured in terms of resources depletion, diversity loss or environmental degradation [9, 41].

The challenge in TCC assessment is the establishment of the conceptual framework and actionable methodology that are adaptable to various types of tourism destinations and activities [3, 19, 31]. Researchers have introduced various methods to address the issues of TCC assessment. Shi et al. [34] developed a planimetry method aiming at measuring the eco-tourism carrying capacity of sightseeing spots. Tokarchuk [37] proposed a method for estimating social carrying capacity from the supply side, assuming that the relationship between tourist intensity and residents' satisfaction takes a form of inverted U-shaped curve. Vandarakis [39] proposed a representative indicator set that covers the physical-ecological, social-demographic and political-financial aspects, aiming at best practices for sustainable development. Gomez-Bruna [7] developed the PSR-ti model that provides an easy-to-use management tool for policy makers to assess tourism's impacts and identify the issues related to different stakeholders. These studies proposed a wide variety of limits that describe optimum thresholds for tourism development in terms of volume, density and intensity. However, difficulties with these numerical limits arise when linking them with the management of specific tourism impacts in practice. In order to address this issue, the "load-carrier" perspective approaches were recently by some authors [10, 20], and these approaches attempt to establish the tourism carrying capacity evaluation system based on the dynamic relationship between the carrier and load of tourism elements.

Despite the fact that tourism carrying capacity is an integrative and versatile concept, its application in practice is somewhat limited, because the lack of consistent indicators and methodologies across studies hinder cross-destination comparisons. In addition, overemphasis on ecological impacts and neglecting socio-cultural dimensions may lead to an incomplete understanding and assessment of the overall carrying capacity of a tourist destination. In this study, we aim to provide a better understanding and management of sustainable tourism by coupling a conceptual framework with actionable numerical model, in the context of tourism carrying capacity. To this end, a comprehensive methodological and procedural framework was developed, using the Bohai Rim as a case study. In particular, the Pressure-State-Response (PSR) framework was firstly used to screen the representative indicators, and to identify the causal linkages between these indicators. The index of tourism carrying capacity was then developed to measure and assess the performance of tourism development in coastal cities in the Bohai Rim. On top of that, the levels of tourism carrying capacity were evaluated and analyzed, and impacts and vulnerabilities in relation to sustainable tourism were identified, providing the path and direction of sustainable tourism development. This case study demonstrates the application of the concept of tourism carrying capacity in management practice, suggesting that the proposed methodology can be a promising tool in planning tourism destination development and management of its negative impacts.

2 Literature review

Tourism carrying capacity is a critical concept in sustainable tourism management, referring to the maximum level of tourism activity that a destination can accommodate without causing significant negative impacts on the environment, society, and economy. The concept of tourism carrying capacity has garnered significant interest due to growing human-induced pressures on ecosystems [16]. Recent focus has centered on the rise in overtourism and its adverse impacts, underscoring the reality that the environment possess a limited capacity to sustain such growth in tourism development [12]. Tourism carrying capacity is particularly important in the coastal destinations which are undergoing rapid change as a result of industrialization and popularization in the context of environmental change [1].

Early TCC analysis emphasized numerical limits, such as visitor numbers or infrastructure capacity. TCC assessment methods have evolved over the years, incorporating various approaches to evaluate the capacity of tourist destinations. Recent research adopts a systems-based approach, recognizing tourism as a complex interplay of ecological, economic, and social subsystems. For instance, Wang et al. [41] conceptualized TCC through fuzzy affiliation models that balance economic gains with environmental sustainability, while Jurado et al. [27] introduced "growth limits" for coastal destinations, integrating weak and strong sustainability scenarios. These methods include index systems, multi-objective optimization algorithms, neural networks, and information monitoring [14, 22]. More recently, a study on the Qinghai-Tibet Plateau developed a model for estimating the TCC of tourism corridors, considering not only road traffic capacity but also the influence of surrounding landscapes, tourist attractions, and tourism infrastructure [42]. This comprehensive approach is essential for accurately assessing the TCC in complex tourism environments. More empirical applications of TCC assessment have been conducted in various regions, providing valuable insights into the practical implementation of TCC assessments. He et al. [11] developed an Urban Tourism Resource Ecological Carrying Capacity (UTRECC) model, evaluating 11 carrier indicators (e.g., air quality, waterbody health) and 5 load metrics (e.g., carbon emissions per tourist) across Chinese cities. Entropy weighting and linear aggregation techniques help normalize disparate data, offering actionable insights for policymakers. Similarly, sentiment analysis of online reviews has enhanced demand forecasting, enabling real-time adjustments to visitor management [13].

Coastal destinations face unique challenges in managing tourism carrying capacity due to their fragile ecosystems, high seasonal demand, and competitive uses (e.g., fishing, recreation, conservation). TCC assessments in these areas prioritize environmental thresholds (e.g., beach erosion, coral reef degradation, water quality), social tolerance (resident dissatisfaction, overcrowding), and infrastructure limits (waste management, coastal development). For example, studies in destinations like Thailand's Phu Yai [18] and Spain's Balearic Islands [15] highlight the need for strict visitor caps, seasonal zoning, and sustainable infrastructure. A recent study on the tourism carrying capacity of Naxos Island in Greece developed a tailored index to assess the impacts of tourism on the island's coastal zones [19]. In this study, the authors used the Pressure-State-Response (PSR) framework to analyze the interactions between tourism and the environment, highlighting the need for integrated coastal zone management. Obviously, effective assessment of TCC in coastal areas requires interdisciplinary collaboration, dynamic policy frameworks, and prioritizing long-term ecological health over short-term tourism gains.

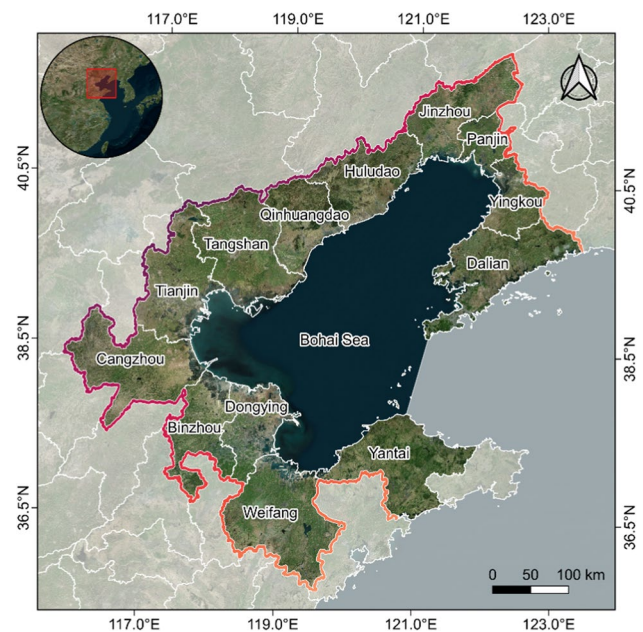
The existing research on TCC assessment has made significant progress, but several gaps remain. These include the need for more comprehensive assessment methods, greater attention to specific tourism forms and regions, optimization of assessment models and parameters, and better integration of management capacities into TCC calculations. Future research should address these gaps to provide a more accurate and holistic assessment of TCC, supporting sustainable tourism development and effective management of tourist destinations.

3 Methodology

3.1 Study area

The Bohai Rim, stretching along thousand-kilometer coastline, manifest diverse cultural traditions, social customs, climatic regimes and natural landscapes that contribute to make it a major region of tourism and sightseeing. In a narrow sense, the Bohai Rim refers to China's Liaodong Peninsula, North China Plain and Shandong Peninsula,

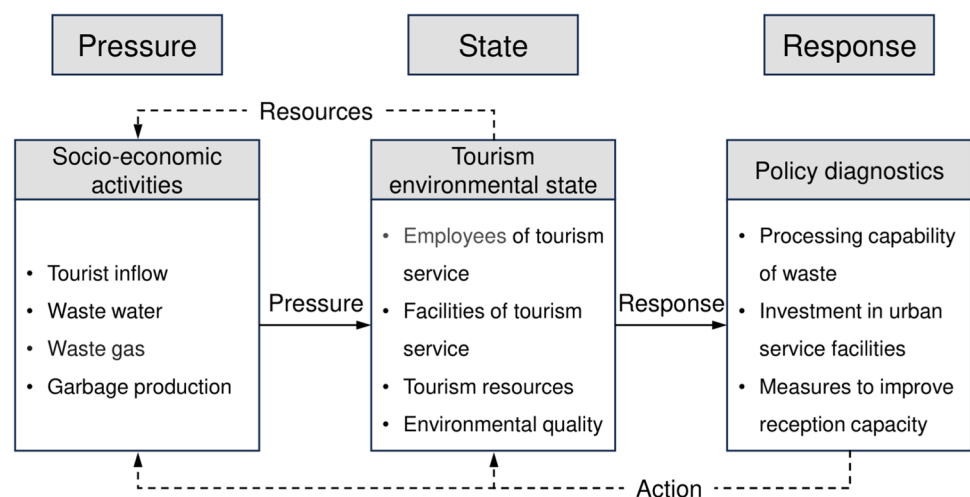
Fig. 1 Location of coastal cities in the Bohai Rim



covering 13 coastal cities around the Bohai Sea (Fig. 1). This study focus on the coastal area of 136,000 km² with a population of 70.59 million residents, and a coastal length of 3800 km. The study area covers 13 municipalities from north to south: Dalian, Yingkou, Panjin, Jinzhou, Huludao, Qinhuangdao, Tangshan, Tianjin, Cangzhou, Binzhou, Dongying, Weifang and Yantai. The Bohai Rim has some of the most diversified landscapes and shorelines in North China, and it harbours various lifestyles, traditions and customs with thousands of years of history. These features, coupled with mild climate and coastal scenery, have contributed to making the tourism industry a significant source of revenue in this region.

The coastal cities in the Bohai Rim have taken advantage of their abundant coastal resources to develop commercial tourism. For example, Dalian holds annual costume festivals, beer festivals and marathon races to attract local and foreign visitors. Tianjin, a city rich in cultural heritage and historic wealth, has developed culture-oriented tourism products, such as historical relics, temples and museums. However, the pressures of population and activities on the natural environment have remained continuously on the rise for the last decades. In addition, the Bohai Rim is home to resource-intensive industries like steel and crude oil, posing potential threats to tourism sustainability both locally and regionally.

Fig. 2 The PSR conceptual framework for developing indicators of tourism carrying capacity



3.2 Indicator system and data collection

The PSR framework was adapted to develop indicator of TCC and incorporate the links between the tourism environment and socio-economy (Fig. 2). The logic underlying this framework is based on a Pressure-State-Response feedback loop, in which anthropogenic activities that exert impact on the environment. State variables represent the status of the tourism environment and resources, and the response indicators describe management policies and actions to for environment change. The PSR-derived indicators provided a systematic framework in which the current state could be characterized and the processes determining resources and environment change examined. A 30-indicator core set was arranged, covering the current state of the system, the potential pressures and responses to it (Table 1).

Socio-economic statistical data used in this study were obtained at the county level from China Urban Construction Statistical Yearbook, China City Statistical Yearbook, and statistical bulletins of each city. Assessments of coastal sea water quality were obtained from Report on the state of China Marine Ecology and Environment. Space-based data (e.g., locations of restaurants, hotels and shopping malls) were acquired from Gaode Map. The tourism data used in this study were from 2019 or 2023 to minimize the disturbance of COVID-19 pandemic.

Table 1 Indicator system of tourism carrying capacity derived from the PSR framework

PSR	Indicator	Unit	Type	Weight
Pressure	Domestic tourist arrivals (P1)	10 ³ person	–	0.059
	International tourist arrivals (P2)	10 ³ person	–	0.060
	Industrial wastewater discharge (P3)	10 ⁴ ton	–	0.051
	Industrial dust discharge (P4)	ton	–	0.049
	Carbon dioxide emission (P5)	10 ⁴ ton	–	0.055
	Domestic garbage treatment amount (P6)	10 ⁴ ton	–	0.059
State	Practitioners of transport and logistics (S1)	10 ⁴ person	+	0.018
	Practitioners of accommodation and catering (S2)	10 ⁴ person	+	0.017
	Practitioners of environment and public facilities (S3)	10 ⁴ person	+	0.023
	Practitioners of culture, sports and entertainment (S4)	10 ⁴ person	+	0.020
	Number of restaurants (S5)		+	0.025
	Number of shopping malls (S6)		+	0.032
	Number of hotels (S7)		+	0.032
	Number of tourist attractions (S8)		+	0.025
	Domestic tourism receipts (S9)	10 ⁵ RMB	+	0.019
	International tourism receipts (S10)	10 ⁵ RMB	+	0.020
	Area of parks and green space (S11)	km ²	+	0.022
	Area of rivers, lakes and reservoirs (S12)	km ²	+	0.034
	Length of coastline (S13)	km	+	0.021
	Concentration of respirable suspended particulates (S14)	µg/m ³	–	0.032
	Environmental quality index of surface water (S15)	–	–	0.040
	Water quality class of coastal sea (S16)	–	–	0.038
Response	Comprehensive utilization rate of industrial solid waste (R1)	%	+	0.043
	Wastewater treatment rate (R2)	%	+	0.034
	Domestic garbage treatment rate (R3)	%	+	0.064
	Harmless treatment capacity of domestic garbage (R4)	ton/day	+	0.018
	Fixed assets investment in urban service facilities (R5)	10 ⁴ RMB	+	0.017
	Number of public lavatories (R6)		+	0.016
	Number of parks (R7)		+	0.025
	Public recreational green space per capita (R8)	m ²	+	0.031

3.3 Data normalization

Due to the usual inconsistency of the indicator measures used, it is necessary to eliminate the effects of different measuring units and avoid meaningless aggregations by normalization of the raw dataset. By normalization, different indicators were converted to dimensionless measures that can be combined for a consistent interpretation. A linear Min–Max standardization method was used to transform all the positive and negative indicators, and the equation can be written as follows:

$$x_{ij}^* = \begin{cases} \frac{x_{ij} - \min(x_{ij})}{\max(x_{ij}) - \min(x_{ij})}, & \text{if } x_{ij} \text{ is a positive indicator} \\ \frac{\max(x_{ij}) - x_{ij}}{\max(x_{ij}) - \min(x_{ij})}, & \text{if } x_{ij} \text{ is a negative indicator} \end{cases} \quad (1)$$

where x_{ij}^* and x_{ij} are the normalized value and original value of the j -th indicator respectively; $\max(x_{ij})$ and $\min(x_{ij})$ are the maximum and minimum values of x_{ij} . Note that after this transform, all indicators take values are rescaled in the [0, 1] range and are of the “more is better” type, with a value of 1 representing the best possible outcome for each indicator.

3.4 Weighting the indicators

The importance of each indicator can be estimated by assigning weights, and the weights to indicators can be assigned in different ways. The entropy weight method was herein used for weight calculation. In this way, the probability theory is used for computing entropy, and the objective weights of the indicators were established without considering any thoughtfulness of the preference of the decider [17]. The information entropy of each indicator was calculated with Eq. (2).

$$e_j = -k \sum_{i=1}^n \frac{x_{ij}^*}{\sum_{i=1}^n x_{ij}^*} \ln \left(\frac{x_{ij}^*}{\sum_{i=1}^n x_{ij}^*} \right), \quad (2)$$

where $k = 1/\ln(n)$ is a stable expression, n denotes the number of assessment subjects and e_j is the entropy value of the j -th indicator with a range of [0, 1].

The underlying logic is: the smaller the entropy value of a indicator, the greater the degrees of data divergence; and thus, the more important the role that indicator would play in the overall assessment, leading to a higher weight. The weight of each indicator was calculated by Eq. (3).

$$w_j = \frac{1 - e_j}{\sum_{j=1}^m (1 - e_j)}, \quad (3)$$

where w_j is the weight of the j -th indicator, and m denotes the number of indicators.

3.5 Overall evaluation of TCC

The linearly weighted average method was used to aggregate the normalized indicators and corresponding weights, providing an overall assessment of tourism carrying capacity for each city. The comprehensive evaluation value of TCC was calculated by Eq. (4).

$$TCC_i = \sum_{j=1}^m w_j \cdot x_{ij}^*, \quad (4)$$

where w_j is the weight of the j -th indicator, and x_{ij}^* denotes the rescaled dimensionless value of each indicator.

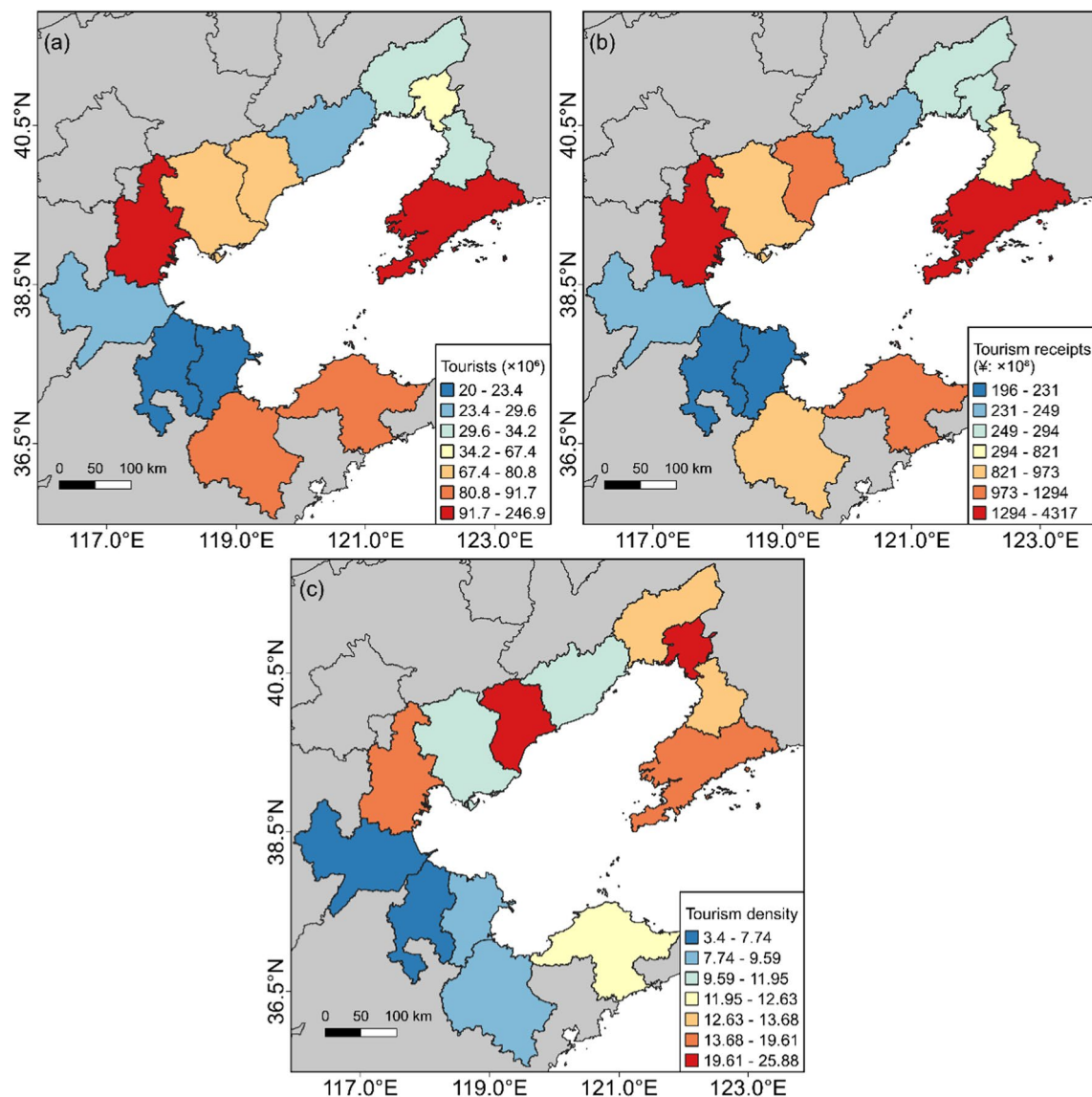


Fig. 3 The spatial distribution of tourist arrivals (a), tourism receipts (b), and tourism density (c) in coastal cities in the Bohai Rim. Note that tourists include both domestic and international tourist arrivals

4 Results

4.1 Spatial pattern of tourism activities

Tourist development is a driving force that may exert significant impacts on the environment, social and economic structures and dynamics. Figure 3 highlights the spatial distribution of two key pressure-related indicators (e.g., tourist arrivals and tourism receipts) and tourism density among the coastal cities in the Bohai Rim. As can be seen, the top two cities that enjoyed the largest tourist arrivals were Tianjin and Dalian, both of which are popular tourist destinations in China. Tourist arrivals in the northern and southwestern cities of the Bohai Sea were at relatively low levels, ranging from 20 million (in Binzhou) to 36 million (in Panjin). Tourist receipts generally shared a similar spatial pattern with tourist arrivals. However, it is noted that Qinhuangdao surpassed Weifang in tourist receipts (ranking

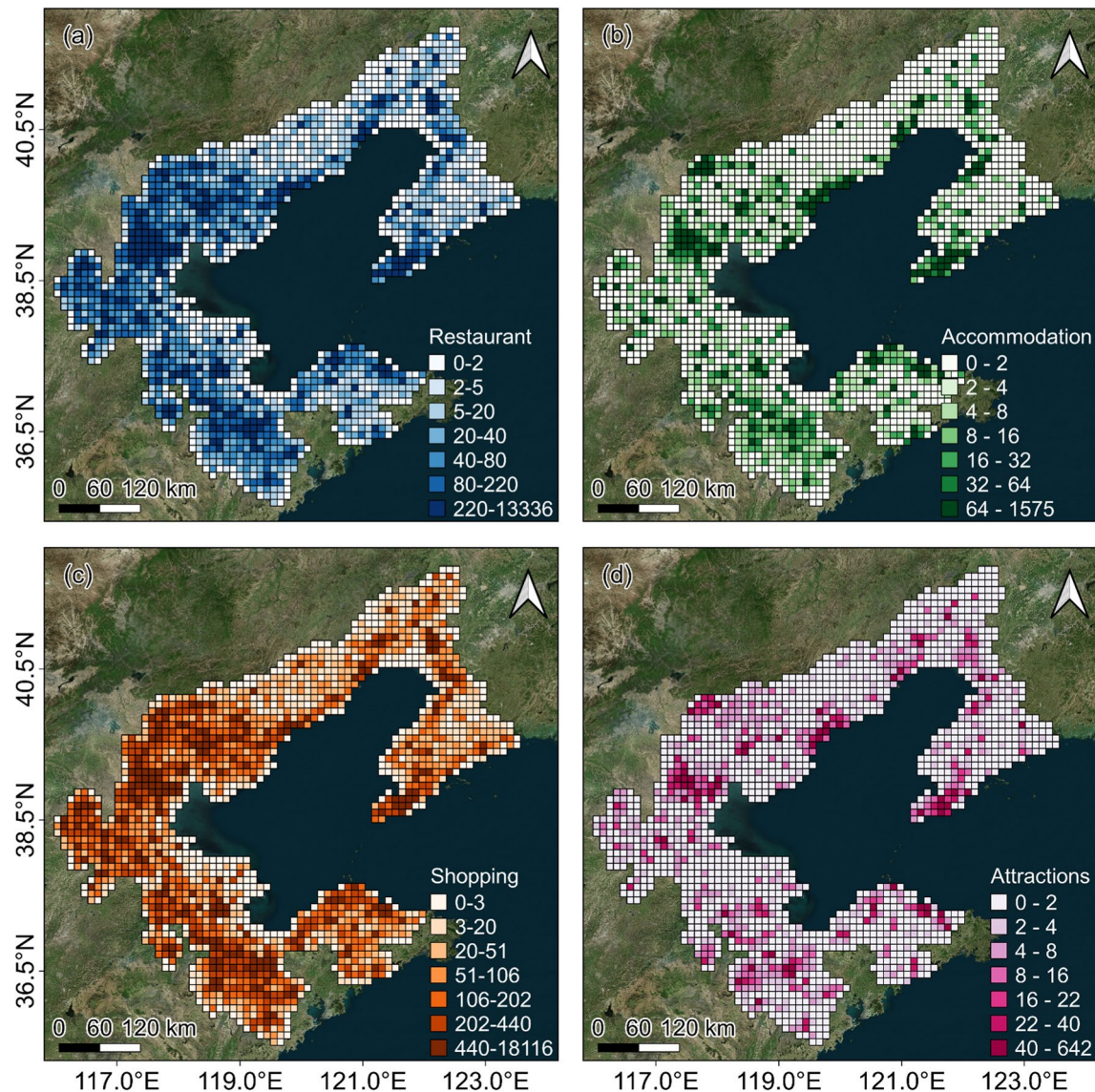


Fig. 4 The spatial distribution of restaurants (a), accommodations (b), stores (c), and tourist attractions (d) in coastal cities in the Bohai Rim

4th to Weifang's 5th) as compared to that of tourist arrivals, indicating visitors in Qinhuangdao may be more readily able to shop and spend than in Weifang. Unlike the patterns of tourist arrivals and tourism receipts, Fig. 3c highlights the spatial imbalance of tourism density (measured as tourist arrivals/local residents). As can be seen, the tourism density was not equally distributed among the coastal cities, with the highest tourism density achieved in two interior cities (Panjin and Qinhuangdao). The interpretation can be twofold: this could be an indicator of policy effectiveness of regional tourism development, making these cities more accessible and popular with visitors; nevertheless, it could also be a tendency to overcrowding perception, as residents in less populated area may be less tolerant to visitor influx.

Figure 4 shows the spatial distribution of reception capacity (represented with the number of restaurants, accommodations, shopping restores, and tourist attractions) in the Bohai Rim. As can be seen, there is a good agreement between the pattern of these four variables, and the two groups of cities can be established in terms of their spatial patterns. The first group is cities with their tourism supplies stretched along the coastal zone, and the typical cities are Dalian, Huludao, Qinhuangdao and Yantai. In these cities, most of the settlements and tourist attractions are concentrated in the narrow coastal strip, where attractive natural features are densely located. Tour operators packaged tourism products (particularly tour routes and accommodations) have made seaside tourism more accessible and affordable to travelers, who are often

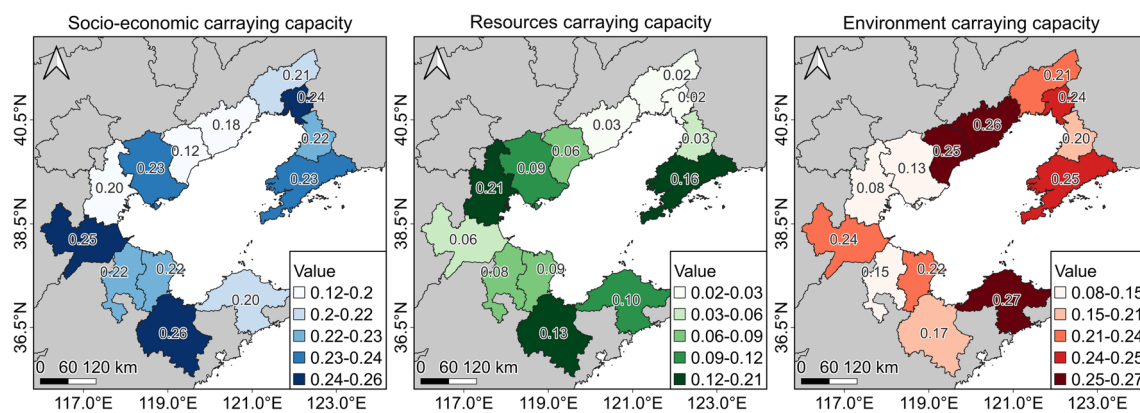
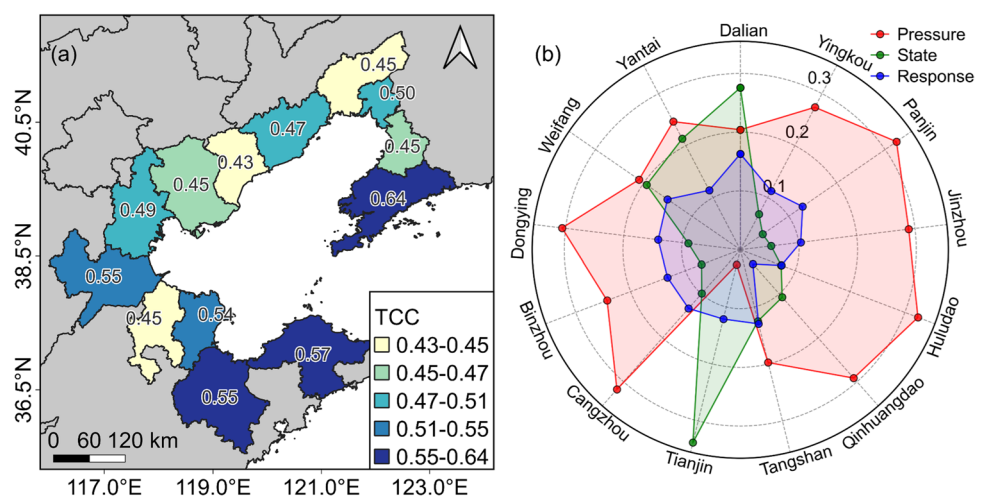


Fig. 5 Assessment of tourism carrying capacity in terms of three dimensions: **(a)** Socio-economic carrying capacity; **(b)** Tourism resources carrying capacity; **(c)** Tourism environment carrying capacity

Fig. 6 Performance of tourism carrying capacity in coastal cities in the Bohai Rim. **a** Overall assessment of TCC; **b** Assessment of tourism carrying capacity in terms of the pressure, state, and response component, respectively



attracted by the offering of “sunshine, sand, and sea”. This results in the destinations of these cities often be characterized by high tourist influx in summer, leading to seasonal variability of tourism activities in the coastal zone. In contrast, the second group is cities with most of their tourism supplies patchily distributed in the inland rural regions, and the typical cities are Tangshan, Tianjin, Dongying, and Weifang. This is mainly due to two reasons: most of destinations in these cities (such as natural parks, archaeological sites, and recreational spaces) are located in the interior area; in addition, most of coastal zones in these cities are mud flats that are unfriendly to tourism activities, and are often heavily affected by neighboring development activities (e.g., shipping ports or sea farming). Some of these cities have managed to produce year-round tourism by providing incentives relating to their cultural heritage and unique folk-custom. In this way, these destinations have spanned their tourism across different seasons, travel forms and visitor motivations.

4.2 Dimensions of tourism carrying capacity

There are basically three dimensions (social, economic, and environmental) in tourism carrying capacity assessment [4]: social dimension can be assess in terms of psychological and sociocultural aspects, economic in terms of monoculture, unemployment, or loss of activity diversity, environmental in terms of physical and ecological parameters. In this section, the tourism carrying capacity was categorized to three dimensions, and each dimension was assessed in terms of socio-economic, resources and environment carrying capacity, respectively. The assessment of each dimension was achieved by calculating the linearly weighted average of their corresponding dimensional indicators.

As presented in Fig. 5, the spatial patterns of each dimension varied widely between the coastal cities, and some cities showed a considerable discrepancy in dimensional assessments. In the socio-economic dimension, Panjin, Cangzhou, and Weifang presented highest socio-economic carrying capacity with values ranging between 0.24 and

0.26, due to their relatively higher scores in reception capacity and environmental facilities. With the exception of Qinhuangdao, the less developed tourism cities were more likely to host lower socio-economic carrying capacity, which may be mitigated by measures to encourage local management and operation of tourist services and environmental facilities. In the resources dimension, it is clear that Dalian, Tianjin, and Weifang ranked the top three cities that presented highest resources carrying capacity, which were mainly due to their better performance in tourism resources (e.g., longer coastline or larger green space). In the environment dimension, Huludao, Qinhuangdao, and Yantai presented highest environment carrying capacity with values ranging between 0.25 and 0.27. These cities are primarily oriented towards beach tourism, and good environmental conditions and rich marine biodiversity give them a competitive advantage. The environmental concerns are of outmost importance for these cities to be line with The battle for the comprehensive management of Bohai Sea launched in 2018, and these cities have experienced notable improvement of environmental quality over the last five years.

4.3 Overall assessment of tourism carrying capacity

Figure 6 shows the overall evaluation of tourism carrying capacity in coastal cities in the Bohai Rim. As can be seen, Dalian, Weifang, and Yantai ranked the top three cities with the overall assessment of TCC ranging between 0.55 and 0.64. It seems that these three cities had more balanced performance in terms of the pressure, state, and response components, after a closer examination in Fig. 6b. And it is noted that although Tianjin attained a relatively high overall performance of TCC, the assessment of the PSR components showed a polarized pattern, with lowest pressure component score and highest state component score among all coastal cities. Qinhuangdao followed a similar polarized pattern to that found in Tianjin, with the lowest pressure component score registered, which led to a relatively poor overall performance of TCC. From the above, it may be noted that the key role in precisely defining the carrying capacity and accordingly deciding upon the direction of tourism development, is played by use of the component which registers the lowest values. And thus, more attention should be paid to these components, since they define the room for improvement and the final level of tourism carrying capacity.

5 Discussion

5.1 Tourism development and sustainability in the Bohai Rim

Tourism in the Bohai Rim has developed rapidly in the last decades, and has been incontestably a critical economic activity for many cities in this region. It is estimated that tourism resource of the provinces in the Bohai Rim account for about thirty percent of the total tourism resource in China [36]. There are 5 world natural and cultural heritage sites, 14 national scenic areas, 21 national nature reserves, and 53 national forest parks in this region. Tourist arrivals in the 13 cities in the Bohai Rim amounted to more than 860 million in 2019 and tourism receipts reached 11.7 billion RMB. Many destinations are facing the pressures of tourism and the pressures are likely to increase in the context of anticipated tourism growth in Bohai Rim. The emergence of new visitor attractions is likely to intensify pressures on existing destinations to enhance their competitive advantages. In fact, many cities have already taken measures to diversify their tourism products in order to keep or even extend their market share. For example, Dalian has recently aimed to develop from beach-oriented summer recreation destination, to a dynamic four-season and full-domain tourism destination. To this end, Significant facility and amenity expansion to satisfy the demands of tourists was encouraged and designed, such as developing night vista, hot-spring leisure, and ice-snow recreation.

It is apparent from the previous analysis that TCC may play a significant role in the planning and management of sustainable tourism in the Bohai Rim. This is because tourism revenue is one of the economic pillars in many cities of the Bohai Rim. The assessment of TCC provides parameters relative to desirable and acceptable tourism development which serves for planning the development of traffic routes, infrastructure, and communications. In addition, as the Bohai Sea is a semi-enclosed and ecologically sensitive system, it is necessary to harmonize integrated coastal zone management with the tourism planning process. This is especially true under the context of growing environmental pressure, since contemporary trends in tourism require well protected and attractive environments. In the long run, it is essential for the saturated and potentially saturated destinations to achieve the appropriate balance between

the social, economic, and environmental contexts, which form the very basis of tourism carrying capacity assessment in the Bohai Rim. TCC may act as a management tool for policy-makers to reconsider the direction and path that sustainable tourism should follow.

5.2 Challenges of sustainable tourism in the Bohai Rim

Against the backdrop of the sluggish economy, some changes and emerging features in tourist preference have been observed, causing problems to the development of tourism in the Bohai Rim. For example, tourism in the Bohai Rim have experienced the imbalance of regional development both spatially and temporally. Some areas have witnessed excessive development of tourist infrastructure and high level of tourism activities, whilst others are still rarely-explored or pristine land. The socio-economic marginalization of the low-income groups is aggravated by the increasing growth in developed tourism areas, accompanied by a rise in the cost of property and price of goods or services [6]. These developed tourism areas are heavily dependent upon tourism receipts, and the development of other industries may be restricted due to the incompatibility between tourism and other development activities. In addition, by its very nature of seasonal pulse, coastal tourism activities in the Bohai Rim converge in the summer months, which results in most of the coastal destinations being characterized by high levels of tourist influx and touristic activity in summer, leading to the seasonal pulse of tourism industries. This is especially true in cities exposed to large amount of cruise ships, such as Dalian and Yantai. Some destinations such as water-affinity shores and entertainment spots shut down in winter months and re-open in summer, often leading to unemployment or underemployment of local tourism practitioners during the low season. This seasonal reoccurrence of overcrowding or overtourism inevitably results in both socio-economic and environmental pressures.

Some destinations have attempted to create four-season tourism, by expanding the choice of tourism products including business, leisure, culture, sport and health spas. Niche markets are being developed by providing particular tourism products for young people, senior visitors, and those who travel for specific purposes such as exploration, sport and health reasons. In this light, it can be inferred that travel intensity may largely increase as people are more readily able to travel and their trips are expected to shorter and more frequent. As a consequence, it is likely that overtourism induced pressures, such as overcrowding or congestion, would become more intensive, extensive and recurrent. The increased visitor abundance and tourism density are likely to expand the social and environmental footprint of tourism activities, expanding the patchy distribution of visitors and enhancing the hub position of some destinations. This thus further increases the tourism influx and pressures, and the popular tourism attractions may experience high saturation level, leading to negative feelings of visitors as well as dissatisfaction of local residents.

The practical value of TCC analysis lies in its ability to ensure sustainable tourism development by balancing environmental protection, socio-cultural preservation, and economic benefits. By quantifying limits and trade-offs, TCC analysis enables stakeholders to make data-driven decisions for responsible tourism growth. As for the Bohai Rim, possible pathways to achieve tourism sustainability may include community involvement, ecotourism, cultural heritage preservation, low-impact infrastructure, etc. These pathways intersect and reinforce each other, requiring holistic implementation. Success depends on collaboration among travelers, businesses, communities, and governments to prioritize long-term sustainability over short-term gains.

5.3 Implications and limitations

It is evident from the above discussion that the assessment of tourism carrying capacity is essentially aimed at defining the level of tolerance or compatibility between tourism demand and the socio-economic, cultural, and ecological support system to meet those demand. The significance of tourism carrying capacity as a conceptual framework is that it can be used for policy making, as a basis for coordinating tourism development and growth at different scales. For example, in venue management and crowd control, it can help to make control measures of tourist flow. In the design and planning of tourism destinations, TCC can be used for planning benchmark or scenario, with which the acceptable level of tourism activities may be projected. In this regard, tourism carrying capacity assessment may serve as a management tool for policy-makers to adjust the path and direction that sustainable tourism development should follow. By integration with scenario analysis of future development, TCC may help to indicate which is the more appropriate and desirable development pattern to choose. Exceeding the tourism carrying capacity would

inevitably result in decreased economic interests accruing to the destinations, increased environmental degradation, and social issues.

In the light of the above, it can be concluded that tourism carrying capacity is a relatively versatile concept and as such it can be oriented towards a variety of functions in planning and decision making. In spite of its versatility, its application in management practice is somewhat limited and sometimes problematic. Firstly, these are methodological difficulties in measuring and assessing social parameters. Compared with economic and ecological parameters, demographic and socio-cultural indicators are difficult to measure and monitor. Additionally, There is still no wide agreement on what socio-demographic, political and economic parameters should be considered in the assessment of tourism carrying capacity. There are varying interpretations of sustainable development, depending on the perspectives that tourism-related goals, objectives and measures are defined in relation to their impacts and interactions. Secondly, tourism carrying capacity is not necessarily fixed in time [23]. Because of its dynamic nature, TCC can often be altered by management practices, such as improvement of recreational service and facilities. It can also alter in response to the ever-changing environmental status, whereby variations in coastal water quality could affect the ecological carrying capacity. This would complicate management practices and urge efforts to measure parameters in a more detailed manner, which would inevitably increase the cost of time and manpower.

6 Conclusions

In this work, we proposed a methodological and procedural framework which contributes to a more systematic understanding of tourism carrying capacity assessment, as well as to its analysis and application within the integrative management context. In particular, the PSR framework was used to screen the proper indicators and recognize the causal links within the indicator system. On that basis, the entropy weight method and linearly weighted average method were used to calculate the levels of tourism carrying capacity. From the key issues discerned from the tourism carrying capacity assessment, it can be concluded that TCC could serve as a systematic, integrative and dynamic policy tool in the management practice, rather than as a unique number that is static and unalterable. It is worth noting that the method may be readily adapted to other areas experiencing similar tourism issues depending on their needs and conditions, making the proposed methodology more versatile and replicable.

Tourism carrying capacity still faces many challenges when it is put into management practices. For example, there are methodological difficulties in measuring complex social and cultural issues, political difficulties in accepting limits to development, fragmentation of decision-making and difficulties in policy coordination and integration [4]. Due to the complexity of both tourism activities and environmental responses, an integrated management framework is needed to both maximize economic benefits, and to minimize ecological degradation.

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Data availability The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate Not applicable.

Consent for publication Not applicable.

Competing interests The authors declare no competing interests.

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