Journal of Landscape Research 2024, 16(6): 69-75

Research Progress of Ecological Environmental Safety Evaluation Indicator System of Health Resorts

GUO Haoqi[1], WANG Xiaobo[1], SHI Guosheng[1], XU Li[2*]

(1. North China University of Technology, Beijing 100144, China; 2. Air Force Medical University, Xi'an, Shaanxi 710032, China)

Abstract The ecological environmental safety of health resorts can prevent premature depletion of medical natural resources and avoid being polluted. In CNKI, Wanfang Database, Google Academic, Web of Science, and Pub Med database, Chinese search terms "health resort", "convalescence", "ecological environment", "ecological safety protection", "evaluation", as well as English search terms "health resort", "convalescence", "ecological environment", "ecological safety and security", and "estimation" were searched, and a total of 33 articles were screened. The basic information of the 33 articles was recorded, and the types of evaluation models, evaluation indicators and indicator thresholds were summarized. The future development direction was proposed, and the enlightenment to the management and protection of health resorts was summarized.

Keywords Health resort, Convalescence, Ecological environment, Ecological safety protection, Evaluation

DOI 10.16785/j.issn 1943-989x.2024.6.013

A health resort is a regional complex with natural convalescent resources as the core, including the surrounding good natural environment and convalescent facilities, or refers to the regional combination of convalescent objects with different convalescent factors and cultural landscapes. Health resorts can meet people's needs for healthy living, achieve sustainable use of ecological resources, and promote the development of local economy.

The ecological environment of a health resort is the natural source carrier of convalescent factors and an important guarantee to ensure the health benefits of natural convalescent factors. To protect the ecological resources of a health resort is to protect the sustainable development of convalescent cause. The ecological environment of a health resort plays an important role in the process of convalescence. The climate, air, water and other natural resources in health resorts are closely related to the ecological environment. The degradation of the ecological environment in health resorts may lead to the loss of functions of health resorts, and outside influences beyond a certain limit may lead to ecological imbalance, and even threaten the health and survival of humans and other organisms[1].

Safe ecological environment in health resorts can prevent premature exhaustion of medical natural resources and avoid being polluted[2]. On the basis of providing a personalized convalescent rehabilitation program, health resorts need to pay more attention to ecological environment and emphasize their ecological safety protection and sustainable development. In this study, the relevant journal articles and standards about the ecological environment of health resorts were sorted out and recorded, and the evaluation model of the ecological environment of health resorts were summarized and analyzed. Besides, the evaluation models and indicators of the ecological environment of health resorts were analyzed, and corresponding suggestions for the management and protection of the ecological environmental safety of health resorts were put forward.

1 Research methods

1.1 Literature sources and search strategies

In CNKI, Wanfang Database, Google Academic, Web of Science, Pub Med Database, the combination of the following keywords and related synonyms were used: Chinese search terms were health resort, convalescence, ecological environment, ecological safety protection and evaluation; English search terms included health resort, convalescence, convalesce, convalescent, ecological environment, ecosystems, ecosystem, ecology, ecological safety and security, ecological defense, ecological safety and protection, ecological security protection, estimation, and evaluations. Boolean logical operators "OR" or "AND" were used to concatenate these terms for retrieval.

1.2 Criteria for literature inclusion and exclusion

The corresponding criteria for literature inclusion and exclusion were formulated according to the research questions. The following types of articles were included: (i) all articles using an indicator system to evaluate the ecological environment with convalescent function, in which the indicator system used was specifically described; (ii) articles constructing or revising the evaluation indicator system of the ecological environment in a health resort independently; (iii) articles studying the feasibility and effectiveness of evaluation indicator system of the environment in a health resort. Exclusion criteria: (i) articles about the ecological environment with little relation to health resorts; (ii) articles downloaded repeatedly; (iii) non-research articles such as news, conference reports and conference notices; (iv) the full text cannot be obtained; (v) non-English articles.

1.3 Records of articles

The criteria for literature inclusion and exclusion were strictly followed. Firstly, the retrieved articles were preliminarily screened according to their title and abstract; secondly, the full text was downloaded for review to ensure that the articles contained relevant information about the ecological environment quality indicator of health resorts, and the basic characteristics and indicator construction of the included articles were statistically analyzed. The basic data of the articles was recorded through excel tables as follows: (i) basic information, including first author, title, publication year, country, and language; (ii) basic information of indicator evaluation system, containing indicator system theory, indicator construction method, indicator selection principle, indicator weighting method, type of health resorts and evaluation method; (iii) evaluation dimension, indicator content and main conclusions of each article.

Received: November 12, 2024 Accepted: December 18, 2024

Sponsored by the National Natural Science Foundation of China: Visual perception based natural intervention for patients in HSCT wards (52278045); Innovative Technology Project of Chinese Rehabilitation Medical Association: Research on the correlation between rehabilitation services and ecological safety in sanatoriums (KFKT-2023-20).

2 Research results

2.1 Results of literature screening

According to PRISMA strategy, 2,716 related articles were retrieved. The retrieval sources included Web of Science (951 articles), Pub Med (184 articles), MDPI (126 articles), CNKI (447 articles), Wanfang Database (398 articles) and VIP Database (610 articles). In the preliminary screening, 256 duplicate articles and 2,343 articles inconsistent with the research theme were excluded. According to the criteria in section 1.2, 33 articles were selected, including 22 Chinese articles. The 33 articles were studied and analyzed.

2.2 Basic characteristics of literature

The number of published articles about studies on evaluation indicators of ecological environmental safety in the health resorts increased year by year, and the years of included articles were mainly from 2011 to 2024. The earliest included article was published in *Ecological Modelling* by a Chinese scholar in 2005.

Among these articles, there were 28 articles (84.85%) on Chinese health resorts, and they were mainly concentrated in Guizhou[3-8] (6 papers), Yunnan[4, 9-11] (4 papers), Inner Mongolia[12-14] (3 papers), Fujian[15-17] (3 papers), Anhui[18-19] (2 papers), Qinghai[20-21] (2 papers), Hunan[22-23] (2 papers), and Jiangxi[24-25] (2 papers); there was one article about Sichuan[4], Hubei[26], Hangzhou[27], Jilin[28], and Heilongjiang[29]; there were five articles about foreign resorts in Russia[30], Korea[31], Germany[32], Italy[33] and Spain[34] (1 paper each).

According to the convalescent resources of the health resorts, the included articles were classified. They were about forests[4-6, 8, 15, 17, 20, 22-24, 29, 31, 32] (13 articles), hot springs[6, 8, 10, 11, 15, 30, 35] (7 articles), wetlands[18, 19, 21, 26-28] (6 articles), lakes[9, 25, 33] (3 articles), grassland (3 articles), seawater (2 articles), spring water[29] (1 article), caves (1 article), and deserts (1 article), and the total number was 33, involving 13 provinces and cities in China and 5 foreign countries.

2.3 Composition of literature content

The construction of ecological environment evaluation system of health resorts includes the choice of theoretical model and the method of indicator selection. Due to the difference of natural environment and natural convalescent resources in different regions, the theoretical model and method of indicator selection are different. According to the summary of the included literature, there were 10 theoretical models adopted by various health resorts, including self-construction model (8 articles), driving force-pressure-state-impact-response model (DPSIR) (2 articles), "pressure - state - response" (PSR) indicator system model (5 articles), vitality - organization - resilience (VOR) model (1 article), analytic hierarchy process (AHP) (2 articles), ecological footprint evaluation model (1 article), ecological security evaluation model (1 article), stirring modeling method (1 article), market value method (2 articles), and shadow engineering method (2 articles).

Among the included literature, there are 8 methods of indicators selection in total, namely correlation analysis (2 articles), principal component analysis (2 articles), expert consultation (4 articles), existing indicators of national ecological environment assessment (17 articles), literature research (4 articles), field investigation (2 articles), open interview (1 article), and questionnaire survey (2 articles).

2.4 Analysis of frequency of indicators

Among the 33 articles studied, the frequency of 13 first-level indicators and 25 second-level indicators was high (Table 4).

3 Analysis of literature content

3.1 Analysis of existing models

According to the existing theoretical models, the ecological environment research models of health resorts were summarized (Table 5). Among them, the usage rate of "pressure-state-response" (PSR) indicator system model was the highest, and 5 articles used the model; 2 articles adopted driving force-pressure-state-impact-response model (DPSIR); the market value method (2 articles) and shadow engineering

Table 1 Number and frequency of articles in various regions

Countries	Regions	Number of articles	Frequency//%
China	Guizhou	6	18.18
	Yunnan	4	12.12
	Inner Mongolia	3	9.09
	Fujian	3	9.09
	Anhui	2	6.06
	Qinghai	2	6.06
	Hunan	2	6.06
	Jiangxi	2	6.06
	Sicuan	1	3.03
	Hubei	1	3.03
	Hangzhou	1	3.03
	Heilongjiang	1	3.03
	Jilin	1	3.03
Russia	Caucasus	1	3.03
Germany	Bayern	1	3.03
Korea	Gangwon-do	1	3.03
	Gyeongsangbuk-do		
	Ulsan metropolitan area		
Spain	Galicia	1	3.03
Italy	Province of Catania	1	3.03
	Province of Salerno		

Table 2 Number, frequency and distribution of articles about different types of health resorts in various regions

Convalescent resources	Number of articles	Frequency//%	Regions (number)
Forests	13	39.39	Korea (Gangwon-do, Gyeongsangbuk-do, and Ulsan metropolitan area, 1 article each), Yunnan (1), Guizhou (2), Sichuan (1), Germany (1), Qinghai (1), Hunan (3), Jiangxi (1), and Fujian (1)
Hot springs	7	21.20	Russia (Caucasus, 1), Yunnan (2), Guizhou (2), and Fujian (1)
Wetlands	6	18.18	Anhui (2), Hubei (1), Hangzhou (1), Qinghai (1), and Jilin (1)
Lakes	3	9.09	Yunnan (1), Italy (Province of Catania, and Province of Salerno, 1 each), and Jiangxi (1)
Grassland	3	9.09	Inner Mongolia (3)
Seawater	2	6.06	Spain (Galicia, 1), and Fujian (1)
Spring water	1	3.03	Heilongjiang (1)
Caves	1	3.03	Guizhou (1)
Deserts	1	3.03	Guizhou (1)

method (2 articles) were used in domestic and foreign articles, but they were mainly used for ecological service assessment.

The "pressure-state-response" (PSR) indicator system model is the most commonly used theatrical guiding model of evaluation indicator, and is currently considered by many governments and organizations as the most effective evaluation model for environmental indicator organization and environmental status report[20]. It better reflects the relationship among the pressure caused by human activities on the ecological environment, the change of ecosystem state and the response of human to the change of ecosystem state[19]. PSR indicator system model divides the environmental system into three levels: pressure factor, state indicator and response measures. Among the evaluation criteria of stress level, population density was taken as the evaluation indicator in all five articles[16, 19, 20, 26, 28]. In the evaluation criteria of state level, no evaluation indicators coincided, but the evaluation was basically centered on the quality of natural environment (air, water, noise and human environment). In the response level, the evaluation mainly focused on the management level of health resorts and the enforcement of policies.

The evaluation of the above evaluation indicators can be well applied to the evaluation of the service function of the ecological environment (state), the carrying capacity of the ecological environment (pressure), and the safety protection and sustainable development (response) of health resorts[28].

DPSIR model, which consists of "driver", "pressure", "state", "impact" and "response", is generally applicable to environmental assessment and governance, and can help policy makers and managers understand the root causes of environmental problems[9], so as to take effective response measures. The evaluation indicators can be weighted usually combining with AHP. DPSIR model can cover social, economic, environmental and other factors, and can represent the impact of social, economic and human activities on the ecological quality of a basin. The evaluation results are accurate and effective.

Market value method uses the change of regional output or profit caused by the change of environmental quality to measure the economic benefit or loss caused by the change of environmental quality, and considers the exchange value of commodities or tangible commodities, while the value of ecological services generated is actually ignored. Therefore, the results may be relative[18]. Shadow engineering method can be used to estimate the value of flood control and water storage[27]. The combination of market value method and shadow engineering method is suitable for the ecological security assessment of coasts, wetlands, lakes and other health resorts, and has certain limitations for the assessment types of health resorts.

Ecological footprint analysis refers to the area of productive land and water required to support regional populations, and the land required to absorb the waste generated by these populations. This approach provides a simple but comprehensive measure to assess the direct and indirect impact of human consumption on regional regenerative capacity[12]. Then, by comparing it with the existing biological capacity, it is possible to judge whether the development pattern of the area is in a sustainable state.

Agitation modeling is used to analyze the relationship between population, economy, technology and environment. However, it views population, economy, technology, and environment as changing relationships of equal proportions, which is inconsistent with reality[12].

Vitality-organization-resilience (VOR) model can carry out regional ecological health assessment from a quantitative and objective perspective, and the vitality, organization and resilience are state values. It is more reasonable and effective for small areas.

Each method or model has its own characteristics and scope of application. The selection of an appropriate evaluation method or model needs to determine the scientificity and practicability of the evaluation results according to specific evaluation purpose and content. At the same time, attention should be paid to the updating and optimization of evaluation methods and indicators to adapt to the changing environment and needs.

However, model evaluation indicators

Table 3 Statistics of characteristics of literature content

Characteristics of the content	Total number of articles	Proportion of total articles//%	Number of Chinese articles	Proportion of Chinese articles//%	Number of English articles	Proportion of English articles//%
Indicator theoretical models						
Self-construction model	8	24.24	8	100	0	0
DPSIR model (driving force-pressure-state-impact-response model)	2	6.06	0	0	2	100
"Pressure-state-response" (PSR) indicator system model	5	15.15	5	100	0	0
Vitality-organization-resilience (VOR) model	1	3.03	1	100	0	0
Analytic hierarchy process (AHP)	2	6.06	2	100	0	0
Ecological footprint evaluation model	1	3.03	0	0	1	100
Ecological security evaluation model	1	3.03	0	0	1	100
Stirring modeling method	1	3.03	0	0	1	100
Market value method	2	6.06	1	50	1	50
Shadow engineering method	2	6.06	1	50	1	50
Methods of indicators selection						
Correlation analysis	2	6.06	0	0	2	100
Principal component analysis	2	6.06	0	0	2	100
Expert consultation	4	12.12	3	75	1	25
Existing indicators of national ecological environment assessment	17	51.52	14	82.35	3	17.65
Literature research	4	12.12	3	75	1	25
Field investigation	2	6.06	0	0	2	100
Open interview	1	3.03	1	100	0	0
Questionnaire survey	2	6.06	2	100	0	0

are generally determined by expert evaluation and literature review, and there are relatively subjective factors, which leads to the arbitrariness and subjectivity of the selection and attribution of various variable indicators. This suggests that it is urgent to develop new screening methods to avoid single subjective screening indicators, such as how to use big data and artificial intelligence methods to select key indicators.

3.2 Analysis of existing evaluation indicators

3.2.1 Composition of the existing indicator system. The ecological environment assessment indicators of health resorts in 33 articles were summarized and classified. The selected indicators were also different because of the different emphasis in the ecological environmental safety assessment of different health resorts. After the screening of indicators, the evaluation indicators with the highest correlation degree and reference rate were obtained (Table 4). Among them, the first-level indicators infrastructure, biodiversity, forests, water body and air appeared more frequently, meaning that the above indicators were the core indicators in the study, and they were also important first-level indicators to evaluate the ecological environment status of health resorts.

The second-level indicators related to the first-level indicator "infrastructure" include service facilities (8 articles), medical and nursing facilities (4 articles), construction facilities (5 articles), road facilities (3 articles), and leisure facilities (3 articles). As the service basis of health resorts, service facilities directly affect the quality of experience of tourists or users, and good service facilities can enhance the overall attraction of the bases[5]. As an important part of convalescent resources, medical service facilities include but are not limited to blood pressure, blood sugar, heart rate monitors, etc., and are of great significance for enhancing convalescent effect and improving people's physical and mental health[23]. The characteristics of building facilities, such as building area, plot area, use conditions, heritage value and distance from the sea, will affect the evaluation of the ecological environment of health resorts[34]. Roads and road networks are the criteria for measuring accessibility within a health resort, and require a walkable and diverse path network within the resort. Especially in forest convalescence, accessible paths must be provided to meet higher safety expectations[32].

The second-level indicators related to the first-level indicator "biodiversity" are biological richness index (15 papers), habitat index (3 papers), and plankton biomass (3 papers). The frequency of biological richness was the highest. Relevant studies show that it can enhance the resistance of the ecosystem to natural and human interference, so as to protect the environmental quality of health resorts, and also indicates that health resorts have relatively rich animal and plant resources and good landscape resources. The biodiversity assessment in the literature mainly referred to the *Standard for the Assessment of Regional Biodiversity* (HJ 623) published by the Ministry of Ecology and Environment of the People's Republic of China, and the biodiversity was scored according to different criteria[15]. As an important indicator to measure biodiversity, biological richness index takes into account the contribution of different land use types (such as woodland, grassland, waters, cultivated land, construction land and unused land) to biodiversity[13]. Biodiversity is usually included in the indicator group of ecological environment quality (state) of scenic spots. It includes the quality and diversity of biological species, and each aspect is divided into different grades. Ecological security degree is calculated according to the corresponding scores[14]. Biodiversity is regarded as the key indicator of ecological environment evaluation of many convalescent wetlands, and is used to reflect the organizational structure and complexity of wetland ecosystems[26].

The second-level indicators related to the first-level indicator "forests" include forest coverage rate (10 articles), canopy density (4 articles), and forest quality (3 articles). These second-level indicators are mainly used to evaluate the diversity of forests, ecological balance and convalescence effect in forest or comprehensive health resorts[15, 24].

The second-level indicators related to the first-level indicator "water body" are water quality (13 articles), and water system richness (3 articles), which are mainly used to evaluate hot springs, wetlands, lakes, seawater, spring and other health resorts. In seawater therapy, good water quality is one of the evaluation

Table 4 Ecological environmental safety evaluation indicators of health resorts and their citation frequency

First-level indicators	Second-level indicators	Frequency	References
Forests	Forest coverage rate	10	[14], [22], [25], [32]
	Canopy density	4	[22], [25]
	Forest quality	3	[22]
Vegetation	Vegetation coverage rate	4	[4], [7], [20], [29]
	Vegetation richness	3	[21], [25]
Land quality	Soil quality	4	[12], [19], [25]
Water body	Water quality	13	[3], [11], [12], [19], [26], [29], [33]
	Richness of water system	3	[4], [15], [16]
Sea	Visible sea area	1	[11]
	Environmental quality of offshore waters	1	[16]
Biodiversity	Biological richness index	15	[13], [20], [26], [15], [28]
	Habitat index	3	[18], [27], [28]
	Ephemerfly biomass	3	[33]
Ecological resistance surface	Water proximity	6	[3]
	Road proximity	3	
Air	Air quality	7	[5], [14], [6], [10], [16]
	Negative oxygen ion level	6	[14], [23], [25, 31]
	Oxygen concentration	2	[31], [27]
	Nitrogen concentration	1	[9]
Temperature	Temperature	5	[13], [4], [23], [11]
Humidity	Humidity	4	[4], [14], [23]
Wind speed	Wind speed	1	[14]
Noise	Noise environmental quality	8	[5], [6], [16], [17]
Patches	Patch area ratio	5	[9, 16]
Pollution discharge	Quantity of pollutant discharged	6	[9]
	Pollution treatment rate	4	[16]
Infrastructure	Service facilities	8	[5], [6], [23], [10], [35]
	Medical and nursing facilities	4	[23]
	Building facilities	5	[9], [34]
	Road facilities	3	[10, 32]
	Leisure facilities	3	[10]

indicators used to measure the availability of seawater, which is the basis of seawater therapy activities[34]. The quality of water body is one of the elements of the convalescent hot spring landscape, and especially in the aspect of sensory experience, the quality of water body is directly related to the tactile experience of hot springs and the perception of the body impact of hot springs. Improving the quality of water body and ensuring the cleanliness and comfort of water body can enhance the convalescent effect of hot springs[10]. Water quality and water ecological logic factors are important reflections of ecological health status. Indicators of water quality can be obtained through routine water monitoring, including coverage area of aquatic plants, zooplankton biomass, etc. Water ecological indicators can reveal the status of communities and systems[9].

The second-level indicators related to the first-level indicator "air" contain air quality (7 articles), and negative oxygen ion level (6 articles). Air quality directly affects the convalescent environment and the health of tourists, and is an important factor to evaluate the quality of forest convalescent bases[6]. Among them, the negative oxygen ions in the air have the function of dust reduction and sterilization, can regulate the physiological function of the human body, and has a health care effect on human health. In the grassland environment, the concentration of negative oxygen ions directly affects the suitability of convalescent activities[14].

The first-level indicators "temperature, humidity, wind speed, and noise" are the basis for measuring the climate comfort of health resorts. The environmental microclimate composed of temperature, humidity, wind, wind speed, noise environmental quality constitutes the climate environment that people rely on for survival. An appropriate microclimate has the effects of regulating body and mind, eliminating fatigue, curing diseases, and enhancing physical fitness, can promote human health, and then affect climatic comfort[14]. Oxygen concentration has been included as one of the evaluation indicators for the "forest air" category. Oxygen concentration is regarded as a key factor in assessing the suitability and quality of a forest convalescent environment[31].

The second-level indicators related to the first-level indicator include pollution emission (6 articles) and pollution treatment rate (4 articles). A higher pollution treatment rate means that more pollutants are effectively treated, and pollution to the natural environment is reduced, which helps to maintain the health of ecosystems. It is an important indicator to measure whether health resorts can achieve sustainable development[16].

3.2.2 Review of existing indicators. In the existing literature, there are multi-dimensional differences in the level of ecological security evaluation indicators of different health resorts, and the first- and second-level indicators are confused. After summary, if convalescent resources are classified, the indicators include forests, hot springs, and ocean. If attribute levels are classified, the indicators include connectivity, accessibility, temperature, humidity, and slope. According to the type of health resorts, indicators that can influence the evaluation of forest heath resorts include forest coverage rate, canopy, forest quality, vegetation coverage rate, vegetation richness, soil quality, air quality, negative oxygen ion level, oxygen concentration, ammonia concentration, temperature, humidity, etc. The indicators related to water convalescence such as hot springs, lakes, seawater, springs and wetlands contain water quality, water system richness, biological richness index, habitat index, mayfly biomass, etc. The indicators related to grassland convalescence include air quality, negative oxygen ion level, oxygen concentration, nitrogen concentration, temperature, humidity, wind speed, patch area ratio, etc. The indicators related to cave convalescence include air quality, negative oxygen ion level, oxygen concentration, nitrogen concentration, temperature, humidity, wind speed, etc.

There are a large number of existing rating indicators and various names of indicators, which are easy to dazzle readers and researchers. This suggests that it is needed to establish a unified evaluation indicator system scientifically and rigorously as soon as possible to facilitate the ecological environmental safety assessment of health resorts, which is also the development direction of ecological environmental safety

Table 5 Summary of models for research on ecological environment of health resorts

Models	Model application method	Type of applicable regions	References
DPSIR model	DPSIR model, an environmental management and decision support tool, analyzes and evaluates environmental issues through the interaction of five elements: driving force (D), pressure (P), state (S), impact (I) and response (R).	The current international research focus on marine and coastal ecosystems, biodiversity, decision-making system construction and so on	[9], [13]
"Pressure-state-response" (PSR) indicator system model	The environmental system is divided into three levels for comprehensive evaluation: pressure factor, state indicator and response measure	PSR model can be applied to the study of various environments and ecosystems	[20], [26], [19], [16], [28]
Vitality-organization-resilience (VOR) model	VOR model carries out regional ecological health assessment from a quantitative and objective perspective, and vitality, organization and resilience are all state values	The evaluation results of small areas are more reasonable and effective	[21]
Ecological footprint assessment model	The area of biologically productive land and water required for an area is calculated to assess the resources consumed and waste generated in the area	This model is suitable for comprehensive areas, and can be used to evaluate system stress and state, and ecological equity, and as a reference for ecological compensation decision-making	[12]
Ecological security evaluation model	Ecological deficit/surplus (ED/ES), ecological stress index (EPI), ecological coordination coefficient (ECC) and ecological footprint diversity index (EFDI) are calculated to analyze and evaluate the ecosystem environment	Ecological security assessment model is suitable for ecologically fragile areas, such as grassland, forests, wetlands and other areas with sensitive ecosystems, and they have obvious responses to environmental changes	[12]
Stirring modeling method	IPAT (environmental impact, population, affluence and technology) model is used to analyze the relationship between population, economy, technology and environment	It is applicable to the study of the impact of population, environment and technology on the environment	[12]
Market value method	Market value method uses the change of regional output or profit caused by the change of environmental quality to measure the economic benefit or loss caused by the change of environmental quality	It is suitable for ecosystem service function evaluation of ecological scenic spots or health resorts	[18], [27]
Shadow engineering method	Shadow engineering method is used to measure the cost of repairing a natural environment damaged by environmental pollution, and the maintenance cost is used to estimate the degree of environmental pollution or damage	It is used to estimate the loss caused by water pollution and the value of forest ecological function	[18], [27]

assessment of health resorts in the future.

3.3 Analysis of the thresholds of existing evaluation indicators

The range of evaluation indicators that can be quantified and widely recognized by national standards in evaluation indicators of the 33 articles was sorted out and summarized (Table 6).

3.4 Future research direction

In the future, it is necessary to explore interdisciplinary research, adaptive management and dynamic evaluation mechanism. Efforts should be made to develop multi-scale comprehensive assessment models for ecological security assessments from regional to global scales. This will involve interdisciplinary collaboration, combining expertise in ecology, environmental science, social science and economics to increase the comprehensiveness and scientific nature of assessment results. By analyzing the dynamic characteristics of space and time, a perfect and scientific evaluation system is constructed. In addition, it is needed to pay attention to multi-source data fusion, adopt cutting-edge remote sensing technology and in-depth big data analysis, and build accurate models to monitor and predict the evolution of ecological environment of health resorts in real time. Multiple sources of data should be integrated to provide a better understanding of the complexity and diversity of ecosystems and then more insightful assessments. Future research should focus more on practical applications to ensure that research results can provide practical recommendations and solutions for policy makers and ecological environment managers. Theoretical framework should be combined with practical operation to improve indicators and models and adapt to the complexity of ecological environment assessment of health resorts.

4 Conclusions

4.1 Research summary

Through the reading, recording and analysis of 33 articles on the ecological environment of health resorts, the existing evaluation models were sorted out, and the evaluation methods and applicable range of each model were summarized. However, the model evaluation cannot avoid human subjective factors. In future research, it is needed to pay attention to the integration of multiple disciplines and develop new screening methods, such as how to use big data and artificial intelligence methods to select key indicators. By the analysis of evaluation indicators in the existing models, the 30 indicators that are highly related to the evaluation of health resorts and have the highest mention rate were summarized, which can clearly reflect the hot spots of concern in the environmental evaluation of health resorts at home and abroad. However, the first- and second-level indicators are confused, and there is no unified evaluation standard at present. This suggests that a unified indicator system should be established scientifically, rigorously and comprehensively as soon as possible to point out the direction for future the safety environment assessment of health resorts. At the same time, the future research should pay attention to the exploration of interdisciplinary research, adaptive management and dynamic evaluation mechanism. Theoretical framework should be combined with practical operation to improve indicators and models and adapt to the complexity of ecological environment assessment of health resorts.

4.2 Enlightenment to the management and protection of health resorts

(1) Raising awareness of ecological safety protection and promoting sustainable development. It is needed to adhere to the concept that "lucid waters and lush mountains are invaluable assets", actively promote the awareness of ecological safety protection of health resorts, improve the awareness of environmental protection of convalescent institutions, promote the sustainable development of health resorts, and ensure the convalescent quality of health resorts.

(2) Clarifying the responsibilities of departments and strengthening the supervision and implementation of relevant departments. Due to historical reasons, the ownership, contract right, use right and management right of health resorts in China are more complicated. In the fields of convalescent institutions and tourism, it involves multiple management of tourism departments, ecological environment departments, health departments, civil affairs departments, traditional Chinese medicine departments, etc., which inevitably leads to the increase of administrative costs and low management efficiency. The responsibilities of various departments should be sorted out in a timely manner, and relevant departments and local enterprises should test in time and formulate corresponding systems and regulations.

(3) Exploring regional resort resources and building a unique convalescent brand. It is needed to conduct a full investigation and research on convalescent resources, excavate convalescent resources regional characteristics, classify convalescent resources according to functional zones, highlight the characteristics of health resorts and regions, and build a unique convalescent brand.

(4) Timely monitoring and adjusting the ecological safety pressure of health resorts. Health resorts have certain vulnerability, but have certain ability to self-repair. The ecological safety pressure of health resorts should be monitored in time, and the flow rate of convalescents should be adjusted accordingly to ensure the moderate development and sustainable development of health resorts.

(5) Carrying out multidisciplinary integration development and formulating scientific and systematic convalescent projects. According to the existing environment resources, landscape resources, local medicine and food resources and cultural resources, they should be integrated with preventive medicine, clinical medicine, rehabilitation medicine, health care, traditional Chinese medicine and health care medicine.

Table 6 Thresholds of ecological environmental indicators of health resorts

Indicators	Range	Standards
Air quality	Grade 3 and above	*Ambient Air Quality Standards* (GB 3095-2012)
Surface water quality	Class III and above	*Environmental Quality Standards for Surface Water* (GB 3838−2002)
Noise environmental quality	Class 0	*Environmental Quality Standards for Noise* (GB 3096−2008)
Soil quality	Class II and above	*Environmental Quality Standard for Soils* (GB 15618−2018)
Comprehensive sewage discharge standard	Needing to meet the standard standards	*Integrated Wastewater Discharge Standard* (GB 8978−2002)
Climatic comfort Index (S)	S≤4.55 means very comfortable (VC); 4.55 < S ≤ 6.95 means comfort (C)	*Quality Standard of Forest Based Health and Wellness Base* (LY/T 2934−2018)
Temperature (T)	The optimum temperature is 18−24 ℃	*Quality Standard of Forest Based Health and Wellness Base* (LY/T 2934−2018)
Wind speed (V)	About 0.3 m/s	*Quality Standard of Forest Based Health and Wellness Base* (LY/T 2934−2018)
Relative humidity (RH)	The optimum healthy humidity is 45%-65%	*Quality Standard of Forest Based Health and Wellness Base* (LY/T 2934−2018)

The characteristic areas of health resorts are combined with the types of convalescent activities, integrate the theoretical knowledge of various disciplines, and develop scientific and systematic convalescent projects.

References

[1] Zhang, K. R., Zhang, X. Q. & Li, Q. et al. (2023). Near-natural precise restoration of degraded ecosystems: Nature-based solutions. *Plant Science Journal, 41*(6), 751-758.

[2] Wang, Y. Y., Xu, L. & Zhang, J. Q. et al. (2022). Qualitative study on the value of regional natural resources analysis in different convalescent areas for plateau personnel. *Chinese Convalescent Medicine*, *31*(5), 449-455.

[3] Ying, B., Liu, T. & Ke, L. et al. (2023). Identifying the landscape security pattern in karst rocky desertification area based on ecosystem services and ecological sensitivity: A case study of Guanling County, Guizhou Province. *Forests*, *14*(3), 613.

[4] Li, W., Jian, J. & Lu, K. (2024). Spatial-temporal characteristics analysis and ecological environment quality evaluation of forest health care bases in Yunnan, Guizhou and Sichuan provinces. *Heliyon*, *10*(8), 29644.

[5] Pu, Y. C., Zhang, X. Q. (2020). Resource status and evaluation of Longyan Lake provincial forest therapy Base in Bozhou. *Forest Inventory and Planning*, *45*(5), 80-84.

[6] Peng, C., Xiang, Y. H. (2024). Evaluation of forest health base in Jianhe Hot Spring City, Guizhou Province based on AHP. *Journal of Green Science and Technology*, *26*(1), 169-175.

[7] Jia, Z. Z., Li, Y. W. & Gao, Z. D. et al. (2019). Research on composite evaluation index of karst cave health effects: A case study of Tianyuan cave in Hongguoshu area of Guizhou. *Carsologica Sinica*, *38*(5), 815-822.

[8] Zhang, M. (2021). Resource status and evaluation of Xifeng Hot Spring Provincial Forest Health Base in Guizhou. *Guizhou Forestry Science and Technology*, *49*(1), 56-60, 64.

[9] Wang, Z., Zhou, J. & Loaiciga, H. et al. (2015). A DPSIR model for ecological security assessment through indicator screening: A case study at Dianchi Lake in China. *PLoS One*, *10*(6), 0131732.

[10] Long, Z. H., Gao, C. G. (2020). Study on elements of landscape environment and quality evaluation of healthcare-type hot spring. *Hunan Agricultural Sciences*, (5), 61-65.

[11] Liu, Y. (2011). *Study on spatial structure and integrated development of tourist hot springs in central and eastern Yunnan* (Doctoral thesis). Retrieved from China National Knowledge Infrastructure.

[12] Guo, S., Wang, Y. (2019). Ecological security assessment based on ecological footprint approach in Hulunbeir Grassland, China. *International Journal of Environmental Research and Public Health, 16*(23), 43-51.

[13] Dong, Z., Zhang, J. & Tong, Z., et al. (2022). Ecological security assessment of Xilingol grassland in China using DPSIRM model. *Ecological Indicators*, 143.

[14] Dong, S., Zhang, X. W. & Su, D. R. et al. (2023). Study on environmental impact factors on the grassland's function to wellness service industry: A case in the grassland of Huihe Nature Reserve in Inner Mongolia. *Acta Agrestia Sinica*, *31*(8), 2287-2304.

[15] Li, Y. L. (2021). *Research on the planning and design of Qingliu Gaorai Hot Spring Forest Health Base in Fujian Province based on forest health base quality evaluation* (Master's thesis). Retrieved from China National Knowledge Infrastructure.

[16] Lin, M. T., Yu, J. H. & Huang, J. C. et al. (2012). Landscape ecological health assessment of tourist islands: A case of Meizhou Island,the Mazu Holy Land of Fujian Province, East China. *Chinese Journal of Ecology*, *31*(7), 1846-1854.

[17] Chen, R., Zhang Y. L. (2023). Construction of suitability evaluation index system for county-level forest-based health care: A Case study of Jiangle County, Sanming City. *Journal of Chinese Urban Forestry*, *21*(3), 155-160.

[18] Li, T., Gao, X. (2016). Ecosystem services valuation of lakeside wetland park beside Chaohu Lake in China. *Water*, *8*(7), 301.

[19] Liu, H. (2020). Research on influencing factors of tourism ecological security in Huaibei mine wetland and the construction of its evaluation model. *Journal of Zunyi Normal University*, *22*(5), 51-55.

[20] Han, R. Y. (2015). Ecological security assessment and regulation of Yaozigou scenic area in Datong National Forest Park. *Southern Journal*, (3), 92-94.

[21] Sun, W. J., Qiao, B. & Yu, H. Y. et al. (2024). Ecological health assessment of the alpine wetland landscape in the Heihe River source area based on vigor,organization,and resilience. *Arid Zone Research*, *41*(2), 301-313.

[22] Deng, H. B. (2023). *Research on planning evaluation system of forest health bases in Hunan Province* (Master's thesis). Retrieved from China National Knowledge Infrastructure.

[23] Tian, G. (2024). *Research on the evaluation of health resources and habitat quality in Chuanyanshan National Forest Park under the background of health tourism* (Master's thesis). Retrieved from China National Knowledge Infrastructure.

[24] Pan, Y. L. (2019). *Research on the evaluation index system of forest resources based on health function* (Master's thesis). Retrieved from China National Knowledge Infrastructure.

[25] Feng, F. (2023). *Research on the planning and design of lake-type tourism resorts under the concept of ecological health* (Master's thesis). Retrieved from China National Knowledge Infrastructure.

[26] Jiang, W. G., Pan, Y. Z. & Hou, P. et al. (2009). Assessment and analysis of wetland ecosystem health in Dongting Lake. *Geographical Research*, *28*(6), 1665-1672.

[27] Ning, X., HU, M. M. & SHAO, X. X. et al. (2017). Assessment of coastal wetland ecosystem services in the south of Hangzhou Bay. *Ecological Science*, *36*(4), 166-175, 184.

[28] Zheng, X. J. (2014). *Research on wetland ecological security assessment and wetland ecological park planning in the lower reaches of the Tumen River* (Master's thesis). Retrieved from China National Knowledge Infrastructure.

[29] Wang, H., Wang, B. & Niu, Xiang. (2021). Evaluation and functional zoning of ecological healthcare resources endowment in scenic spots based on NDHI index and SRP model. *Terrestrial Ecosystem and Conservation*, *1*(2), 11-23.

[30] Povolotskaya, N. P., Slepykh, V. V. & Reps, V. F. et al. (2024). Natural health-improving potential and pathogenic risks of the climate and urbanization of the Caucasian Mineral Waters Resorts. *Russian Meteorology and Hydrology*, *49*(2), 168-75.

[31] Kang, J., Choi, J. & Lee, K. (2024). Development of an evaluation index for forest therapy environments. *International Journal of Environmental Research and Public Health*, *21*(2), 136.

[32] Immich, G., Robl, E. (2023). Development of structural criteria for the certification and designation of recreational and therapeutic forests in Bavaria, Germany. *Forests*, *14*(6), 1273.

[33] Xu, F. L., Zhao, Z. Y. & Zhan, W. et al. (2005). An ecosystem health index methodology (EHIM) for lake ecosystem health assessment. *Ecological Modelling*, *188*(2-4), 327-339.

[34] Crecente, J. M., Santé, I. & Díaz, C. et al. (2012). A multicriteria approach to support the location of thalassotherapy (seawater therapy) resorts: Application to Galicia region, NW Spain. *Landscape and Urban Planning*, *104*(1), 135-47.

[35] Zhu, D. G. (2006). *Research on the development of hot spring tourism in China* (Master's thesis). Retrieved from China National Knowledge Infrastructure.