Evaluation of management effectiveness of nature reserves in the Yellow River Basin of Henan Province based on improved METT

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Abstract. Based on the connotation of nature reserve management effectiveness evaluation, the evaluation index of the Management Effectiveness Tracking Tool (METT) released by WWF was improved, and 11 national and provincial nature reserves in the Yellow River Basin in Henan Province were tracked and evaluated. The research results show that the improved METT evaluation index can comprehensively reflect the management effectiveness of nature reserves in the study area. METT evaluation index among different levels of nature reserves are significantly different ($P<0.05$). Score differences between national and provincial nature reserves are relatively large in terms of management effectiveness. Among the 39 evaluation indicators developed, average scores of legal status, establishment of nature reserve boundaries, nature reserve objectives, nature reserve design, regional cooperation, species status assessment and habitat condition assessment are relatively lower.

Keywords: METT, management effectiveness, nature reserve.

1   Introduction

Nature reserves are an important management tool for protecting biodiversity, maintaining natural capital and ecosystem services, and ensuring the well-being of people in the country and around the world [1]. Research on the evaluation of management effectiveness of nature reserves mainly includes the establishment of evaluation index systems, evaluation frameworks and indicator scoring, and case analysis, etc [2-3]. However, the application scope of management effectiveness evaluation methods in China is relatively small, the application level is shallow, the evaluation indicators still applied mechanically and there is still a lot of room for improving the localization of survey

indexes [4]. In this context, it is of great significance to conduct a practical analysis based on the actual situation of the nature reserves in the Yellow River Basin in Henan Province and to analyze the effectiveness of nature reserve management from different aspects.

METT is a Management Effectiveness Tracking Tool Questionnaire jointly developed by the World Bank and WWF [5] and promoted by funding donors and non-governmental organizations in at least 85 countries. This method is based on the WCPA framework and focusing more on the monitoring of process [6]. It has been widely used in GEF projects involving nature reserves to evaluate the impact of projects on the management effectiveness of nature reserves [7-9], however, research on using the METT tool system to develop an evaluation index system for the management effectiveness of nature reserves and conduct scientific evaluation on them in the Yellow River Basin in Henan has not yet been reported [10].

2   Research Methods

2.1   Modification of METT Evaluation Index System

Based on the actual situation of the Yellow River Basin Nature Reserve in Henan Province, the METT (management effectiveness tracking tool) questionnaire was modified and an evaluation index system including 38 first-level evaluation indicators was developed (Table 2). There are 4 options under each first-level indicator, with scores of 3, 2, 1 and 0 respectively. Additional questions are set for the 7th, 31st, 35th and 36th indicators as references, and then based on management foundation, behavior, Mechanisms, effects and other factors, classification and evaluation were conducted, and the survey results were classified based on the nature reserve level and the average scores of primary and secondary indicators (Table 2).

2.2   Questionnaire Design and Survey

In October 2023, based on the improved METT evaluation indicators, a questionnaire was designed and distributed to 11 nature reserves in the study area (Table 1). The survey targets 1 technical staff and 1 managerial staff from each of 11 nature reserves and a total of 22 questionnaires were collected in the survey, including 10 and 12 from national and provincial nature reserves respectively. The data were classified based on the level of nature reserves, the average score of each section and the number of returned surveys (Table 1).

2.3   Nature Reserve Boundary Data

The boundary data of nature reserves come from the nature reserve platform (http://www.zrbhq.cn/), the Ministry of Ecology and Environment of the People's Republic of China (https://www.mee.gov.cn/), and the National Forestry and Grassland Scientific Data Center (https://www.forestdata.cn/), Henan Provincial Forestry Bureau

(https://lyj.henan.gov.cn/) and documents from other relevant management departments.

2.4   Formula for calculating Entropy Weight Method

Determination of the positivity and negativity of indicators:
   The indicators in this article are all positive indicators.
   Data standardization:

$$X'_{ij} = \frac{X_{ij}}{10^a} \tag{1}$$

$$p_{ij} = \frac{x'_{ij}}{\sum_{i=1}^{n} x'_{ij}} \tag{2}$$

$$e_j = -k \sum_{i=1}^{n} p_{ij} \times \ln(p_{ij}), (j = 1,2,3,\cdots,m) \tag{3}$$

$$k = -\frac{1}{\ln(n)} \tag{4}$$

$$d_j = 1 - e_j \tag{5}$$

$$W_j = \frac{d_j}{\sum_{j=1}^{m} d_j} (j = 1,2,3,\cdots,m) \tag{6}$$

In this formula: X_{ij} represents the indicator j of the sample i; X'_{ij} represents the normalized values of X_{ij}; a represents the minimum integer that satisfied the condition; e_j represents the entropy value of the indicator j; n represents the total number of indicators; p_{ij} represents the probability of the indicator j of the sample i appearing in all samples; K represents a constant; d_j represents the coefficient of difference of the indicator j; W_j represents the weight of the indicator and m represents the number of the sample.

2.5   Data Analysis

The improved METT evaluation index summary and variance analysis were conducted by using SPSS.

3   Results and Analysis

3.1   Analysis of the Overall Score of the Improved METT Evaluation Index

After statistical analysis of the score characteristics of management effectiveness evaluation indicators in the collected questionnaires, it was found that the average index scores of the 5 national nature reserves and 6 provincial nature reserves participating in the survey were 102.40 points and 89.50 points separately. The results of single - factor analysis of variance among 38 evaluation indicators show that significant differences

between national and provincial nature reserves existed (*P<0.05*), indicating that the level of nature reserve is significantly related to the management effectiveness score.

Table 1. Comprehensive evaluation scores of nature reserve management effectiveness tracking tool evaluation.

Name of nature reserve	Level of nature reserve	average score
Henan Funiu Mountain National Nature Reserve	National level	86.50
Henan Xiaoqinling National Nature Reserve	National level	97.00
Henan Taihang Mountain Macaque National Nature Reserve	National level	98.50
Henan Yellow River Wetland National Nature Reserve	National level	122.00
Xinxiang Yellow River Wetland Birds National Nature Reserve	National level	108.00
Liuyuankou Provincial Wetland Nature Reserve in Kaifeng, Henan	provincial	84.50
Xiong'er Mountain Provincial Nature Reserve in Luoyang, Henan	provincial	94.50
Henan Qingyaoshan Provincial Nature Reserve	provincial	83.50
Henan Puyang Yellow River Wetland Provincial Nature Reserve	provincial	87.50
Lushi County Giant Salamander Provincial Nature Reserve	provincial	91.50
Yellow River Wetland Provincial Nature Reserve in Zhengzhou, Henan	provincial	95.50

As can be seen from Table 1, the number of nature reserves shows a clear downward trend as the score level increases or decreases. The average score of the management effectiveness evaluation of the 11 nature reserves is 95.36 points; there are a total of 9 nature reserves with an average score below 100, accounting for 81.81% of the total number of surveys. In the Henan Yellow River Basin Nature Reserve Management Effectiveness Evaluation, both of the number of nature reserves with scores ranging from 86-91.5 points and 92-97.5 points are 3, accounting for the largest proportion. This shows that the management level of Henan Yellow River Basin Nature Reserve is at a medium level.

3.2 Analysis of Score Characteristics of Each Evaluation Indicator of The Improved METT

Statistical analysis and data classification were conducted on the evaluation results of the management effect of the Nature Reserves in the Yellow River Basin in Henan Province (Table 2). Among the first-level indicators, the highest proportion is management effect, and the lowest proportion is management behavior. After further comparison of management behavior, it is found that both of national nature reserves and provincial nature reserves have poor performance in fund management, carbon cycle, and tourist facilities and services, the low scores of these indicate that Henan Yellow River Basin Nature Reserve still has major problems in fund management, carbon cycle, tourist facilities and services, and urgent improvement in management behavior is needed.

The average score of national nature reserves in terms of basic management indicators is 1.19 points, among which the legal status and establishment of nature reserve boundaries are relatively weak, with scores of 0.00 and 0.02 respectively. The average score for the management mechanism indicator is 1.89. Among them, Nature reserve objectives and nature reserve design are relatively weak, with scores of 0.01 and 0.02 respectively. The average score of management behavior indicators is 3.58 points, which is relatively high. And we find regional cooperation, legislation and law enforcement are relatively weak, with scores of 0.02, 0.04 and 0.04 respectively. The average score of management effect indicators is 2.65. Among them, the scores of business tourism contribution are relatively good, which shows that tourism has initially achieved results.

Table 2. Evaluation indicators and their scores.

First level indicator	Serial number	Secondary indicators	Weights of each evaluation indicator(%)	Average score of secondary indicators		Average score of first level indicator	
				National nature reserve	Provincial nature reserve	National nature reserve	Provincial nature reserve
management basis	Q1	Legal status	0.00	0.00	0.00		
	Q6	Establishment of nature reserve boundaries	0.16	0.02	0.03		
		Number of employees					
		Current funding				1.19	1.05
	Q10	Equipment and facilities	2.64	0.25	0.28		
	Q12		4.99	0.45	0.37		
	Q15		4.66	0.47	0.37		
management mechanism	Q2	Nature reserve objectives	0.09	0.01	0.02		
		Nature reserve design					
	Q5	Management plan	0.16	0.02	0.03		
		Periodic management plan					
	Q7	Resource survey	1.01	0.27	0.30		
	Q8	Employee training	0.37	0.05	0.07		
		Patrol management system					
	Q9	Employee safety and security	0.70	0.08	0.10		
	Q11	Monitoring and evaluation	0.64	0.07	0.09	1.89	2.08
	Q17	Local residents	1.08	0.13	0.16		
		Local community					
	Q18		0.88	0.11	0.14		
	Q20		2.09	0.27	0.30		
	Q30		4.17	0.40	0.40		
	Q31		2.19	0.47	0.48		
management behavior	Q3	Legislation	0.28	0.04	0.05	3.58	3.32
	Q4	Regional cooperation	0.16	0.02	0.03		

	Q13	Reliability of funding sources	4.84	0.61	0.48		
		Fund management					
	Q14	Law enforcement	6.74	0.64	0.61		
	Q16	Research	0.28	0.04	0.05		
	Q19	Resource management	2.16	0.24	0.27		
	Q21	Climate response plan	0.81	0.11	0.12		
		Carbon cycle					
	Q22	Ecosystem services	3.32	0.40	0.40		
		Education and dissemination					
	Q23	Government departments and business part-	7.20	0.58	0.47		
	Q24	ners	7.20	0.72	0.65		
	Q25	Commercial tourism operation	1.76	0.19	0.20		
		Visitor facilities and services					
	Q26		6.78	0.75	0.58		
	Q28		5.33	0.67	0.51		
	Q29		6.97	0.66	0.59		
	Q27	Business tourism contribution	5.86	0.67	0.56		
		Economic benefits					
	Q32	Threat elimination	3.50	0.42	0.33		
	Q33	Functional connectivity	0.58	0.07	0.07		
	Q34	Natural value status	7.44	0.74	0.41		
		Current status of cultural values				2.65	2.13
Management effect	Q35	Species status assessment	1.74	0.48	0.47		
	Q36	Habitat condition assessment	0.77	0.20	0.21		
	Q37		0.22	0.03	0.04		
	Q38		0.22	0.03	0.04		

The average score of provincial-level nature reserves in terms of management basis indicators is 1.05 points. Among which, the legal status and establishment of nature reserve boundaries are relatively weak, with scores of 0.00 and 0.03, respectively. The average score of management mechanism indicators is 2.08 points, among which nature reserve objectives, nature reserve design, periodic management plan, employee training and other aspects are relatively weak, with scores of 0.02 points, 0.03 points, 0.07 points, 0.09 points, etc. Respectively. The average score of management behavior indicators is 3.32 points, among which legislation, regional cooperation and law enforcement are relatively weak, with scores of 0.03 points, 0.05 points and 0.05 points, respectively. The average score of management effect indicators is 2.13 points, among which threat elimination, species status assessment and habitat condition assessment are relatively weak, with scores of 0.07 points, 0.04 points, and 0.04 points respectively.

4   Conclusion

After years of construction and development, the Yellow River Basin Nature Reserve in Henan Province has achieved certain protection results. However, this area has a large population, diverse types of nature reserves, and complex community relations. It faces multiple pressures such as population development, production and livelihood, and ecological protection. This article conducted a survey and research on national and provincial nature reserves in this region to identify weak aspects in the development process, such as community relations, fund management, law enforcement, construction of tourism supporting facilities, and carbon cycling, which are common and need to be taken seriously. Exploring a harmonious development model for nature reserves and communities, scientifically managing various funds, strengthening law enforcement construction in nature reserves, and improving the level of infrastructure in nature reserves will provide long-term guarantees for the sustainable and healthy development of nature reserves, which is conducive to common development of ecological protection and people's livelihoods in the region.

Acknowledgments

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