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Standardized Fuzzy Comprehensive Evaluation Biological Index Method for Ecosystem Health Evaluation in Large Waters of Aquaculture Type

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Abstract: The river ecosystem plays an important role in the material energy cycle in nature and the survival and development of human beings. With the development of human social production and the increasing impact on the environment, the health of rivers has attracted global attention. The purpose of this paper is to evaluate the health status of large-scale aquaculture aquatic ecosystems based on the standardized method of fuzzy comprehensive biological index evaluation. Assessment of the health of aquaculture-type large aquatic ecosystems using the Bioindices method. The comparison of evaluation results shows that the waters P-IBI score calculated by the quadrant method is between 20-34, and the waters P-IBI score calculated by the third method is between 12-25. The situation is relatively consistent, so the quartile method is more suitable for evaluating the aquatic ecological health of aquaculture waters.

1. Introduction

The coastal marine ecosystem is highly productive and rich in resources. As the main area for marine development and utilization, especially the development and utilization of bays, it has become the main production area of fish, shellfish, algae and other seafood, which is affected by natural conditions and man-made. Especially with the rapid economic development in recent years, a series of human activities and natural changes have degraded the Gulf ecosystem, and the ecosystem services in some areas have been reduced [1]. As a big country in marine aquaculture, large-scale aquaculture has brought adverse effects on the health of benthic habitats in coastal waters. Therefore, in order to accurately monitor the health status of large water ecosystems of typical aquaculture types, an attempt was made to evaluate the health of large water ecosystems with the standardized fuzzy comprehensive evaluation biological index method [2].

Many countries have carried out a lot of theory and practice in river health assessment. Khaled used the open source software OpenLCA version 1.5 to study the impact of growing fresh bunch palm oil on human health and ecosystem quality. A life cycle assessment method was used to analyze the investigated impacts. Impacts of land-use change on human health and ecosystem quality were assessed. By adopting the ReCiPe Endpoint method in the life cycle impact assessment phase, the total ecosystem impact is 0.00017 species per year, while the total damage to human health is 0.00146 DALY The results show that land use change affects all impact categories except freshwater eutrophication, freshwater ecotoxicity All have impacts, ozone depletion, terrestrial ecotoxicity, and terrestrial acidification. Furthermore, the analysis showed that the use of fertilizers and pesticides was the main contributor to all impact categories [3]. Eiichiro compared the performance of several macroinvertebrate-based indices to identify one or more indices that were best suited for the Richmond River Catchment (RRC) in northern New South Wales, Australia. The rivers within the RRC are in poor health, with a clear gradient of pollution from the upper to the lower basin. Six common indicators were calculated using household-level identification. Biological assessments support physicochemical results through a gradient of river health from upstream to downstream basins. Household wealth and household wealth percentage are considered the most useful indicators. In studies with limited time, budget and expertise, they will provide accurate but limited information on river health. Due to the overall sensitivity of SIGNAL2 to changes in river health and the level of detail to anthropogenic impacts, SIGNAL2 is considered the most effective indicator for assessing river health. The poor performance of AUSRIVAS, EPT and BCI limits or precludes their use in RRC for river health assessment [4]. Chernomyrdin NV experimentally demonstrates the proposed imaging mode with a resolution of 0.15λ at λ = 500 μm, which exceeds the Abbe diffraction limit and is a large improvement over previously reported SI imaging setups. The proposed technique does not involve any subwavelength near-field probes and diaphragms, thus avoiding THz beam attenuation due to such elements. We have used developed methods for terahertz imaging of various soft tissues: plant leaves, cell spheroids, and ex vivo breast tissue. Our terahertz images clearly reveal subwavelength features in tissue, thus, terahertz SI microscopy has promising applications in biology and medicine [5]. During the years of research and application of river ecosystem health assessment, many scholars have developed many different methods.

In this paper, benthic organisms are used as environmental quality evaluation indicators, and most macrobenthos are used as research objects. These animals are characterized by a wide range of species, relatively fixed activity ranges, and easy sampling; The sensitivity varies greatly, and the change trend of community structure after external disturbance can reflect the nature and degree of disturbance, and can well reflect the health of the environment. development, and they play a very important role in the energy flow of marine ecosystems. Therefore, a detailed study of the community structure and benthic environment quality of macrobenthos in different bays is of great significance for the health assessment of benthic habitats in typical aquaculture bays.

2. Research on the Health Evaluation of Aquaculture Type Large Water Ecosystem by the Standardized Fuzzy Comprehensive Evaluation Biological Index Method

2.1. Fuzzy Comprehensive Rating Method

Fuzzy comprehensive evaluation method is an evaluation method that applies fuzzy mathematics to concrete practice. The establishment of the fuzzy comprehensive evaluation model requires five modules: (1) Establish the evaluation factor set. (2) Establish an evaluation set. (3) Establish a fuzzy relationship matrix. (4) Determination of the weight vector. (5) Establish a fuzzy comprehensive evaluation model [6-7]. The fuzzy comprehensive evaluation model can reflect the ambiguity of the boundary by using the membership degree to describe the evaluation level, and its objectivity and rationality are more obvious in the evaluation. Because the fuzzy comprehensive evaluation reflects the comprehensive influence of different evaluation factors on water quality and avoids the one-sidedness of the single-factor index, it has been used more and more in recent years [8-9].

2.2. Calculation Method of Biological Index

(1) BMWP Index

The index was marked on a scale of 1-10 from least sensitive to most sensitive according to differences in macrobenthos anti-pollution characteristics, and the sum of the family-level sensitivity values for the species at the sample points was the score for the BMWP checkpoint. The higher the value, the smaller the impact of human intervention on the sample. The index uses the species sensitivity value of family-level taxa to reflect the water quality level in a water body, but it needs to be corrected for different family-level sensitivity values of macrobenthos during the application process [10-11].

(2) Macrobenthos Integrity (B-IBI) Index

The B-IBI index is a multi-parameter assessment method, which is widely used in river health assessment in my country. This study also compared the relationship between the BMWP index and the B-IBI index. When calculating the B-IBI index, the basic principle and calculation formula refer to the relevant research data of other scholars in the monitoring area [12-13].

2.3. General Steps for Ecosystem Health Assessment

(1) Steps for establishing the PSR model evaluation system

The steps for establishing the PSR model evaluation system are as follows: ① Determine the research area and research scale (division of the research area), review human activities, and identify the pressure caused by human activities [14-15]. ②According to the characteristics of the study area, analyze the response of the ecosystem to stress (physical, chemical, biological, ecosystem level and ecosystem service functions), select appropriate indicators, and establish an index system; ③Determine the index weights; Assign or normalize the indicators; ⑤ Calculate the comprehensive health index; ⑥ Obtain the health status of the ecosystem in the study area and analyze the research results [16-17].

(2) F-IBI

The steps of fish biological integrity index calculation can be summarized as follows: ① data collection in the survey area, determination of reference sample points and damaged points; ② index selection; ③ index selection; ④ index assignment and calculation of fish biological integrity index [18].

3. Investigation and Research on the Health Assessment of Large Water Ecosystems of Aquaculture Types

3.1. Data Processing

On the basis of the expert questionnaire, the index weight is calculated by the analytic hierarchy process, and the index weight is screened by SPSS software and the abnormal value of the index weight is eliminated, and the weight of each index is obtained.

3.2. Construction of Indicator System

In this study, the PSR model ecosystem health evaluation system was selected to evaluate the water ecosystem of Egong Bay. The index system for the health evaluation of the typical fishery water ecosystem in Egong Bay includes three categories: pressure index, state index and response index. The pressure index includes Organic Pollution (A), Eutrophication (E) and Oil pollution index (PollutionIndex, PI), state indicators include phytoplankton density (cells/m3), zooplankton biomass (mg/m3), benthic biomass (g/m2), swimming biological resource density (kg/m2) km2) and larvae density (cells/m3), response indicators included phytoplankton diversity and benthic biodiversity. On this basis, the structure of the ecosystem health evaluation system of typical fishery waters in Egong Bay is constructed, which are the target layer (layer A), the index layer (layer B) and the sub-indicator layer (layer C). Among them, organic pollution index, eutrophication index and oil pollution index are water quality indexes, and state indexes and response indexes are biological habitat indexes.

Organic pollution index A and its grade division, calculated according to formula (1).

$$A = \frac{C_{COD}}{C'_{COD}} + \frac{C_{DIN}}{C'_{DIN}} + \frac{C_{PO_4-P}}{C'_{PO_4-P}} - \frac{C_{DO}}{C'_{DO}} \tag{1}$$

In the formula, A is the organic pollution index, each numerator is the measured value of COD, DIN, PO4-P, DO, and the denominator is the corresponding evaluation standard value of each detection factor.

Eutrophication index E and grade division, calculated according to formula (2).

$$E = \frac{C_{COD} \times C_{DIN} \times C_{PO_4-P}}{4500} \times 10^6 \tag{2}$$

In the formula, E is the eutrophic index, and each molecule is the measured value of COD, DIN, PO4-P, and DO, respectively.

3.3. Ecosystem Health Evaluation Criteria

The plankton integrity index value at the reference point is obtained by adding up the index scores calculated at the reference point. The health standard of the evaluation system is divided according to the 25% quantile value of the plankton integrity index value at the reference point, and the distribution range value of the quartile is less than the 25% quantile value. Health evaluation criteria (see Table 1).

Table 1. P-IBI indicator system health evaluation criteria

Health grading	Healthy	Sub-health	Good	Poor	Very poor
Rule of thirds	>25	20-25	15-21	5-15	0-5
Quartile	>26	20-26	14-20	6-14	0-6

4. Analysis and Research on the Health Assessment of Large Water Ecosystem of Aquaculture Types

4.1. Screening for the Discrimination Ability of Biological Indicators

Pearson correlation analysis was performed on 8 biological indices with strong discrimination after screening, as shown in Table 2.

Table 2. Person correlation analysis among biomarkers

Biological parameters	Cyanobacterial abundance	Phytoplankton diversity index	Phytoplankton evenness index	Zooplankton diversity index	Zooplankton richness index
Cyanobacterial abundance	1	-0.164	-0.213	-0.352	-0.452
Phytoplankton diversity index	-0.164	1	0.791	0.368	0.384
Phytoplankton evenness index	-0.213	0.791	1	0.320	0.194
Zooplankton diversity index	-0.352	0.368	0.320	1	0.234
Zooplankton richness index	-0.452	0.384	0.194	0.234	1

The correlation between cyanobacterial abundance, zooplankton diversity index, zooplankton richness index, number of phytoplankton species, and number of zooplankton species $|r|<0.7$ can be directly used as an evaluation index. The correlation between phytoplankton diversity index and phytoplankton evenness index was 0.792, and only one index was selected to avoid information duplication among biological indices. After correlation analysis, it was determined that five indices including cyanobacteria abundance, zooplankton richness index, phytoplankton species number, zooplankton species number, and zooplankton diversity index were suitable for the health assessment of plankton aquatic ecosystems in waters.

4.2. Calculation of Plankton Integrity Index

(1) Rule of thirds

According to the method of thirds, the statistical distribution of the five biological indicators constituting the plankton integrity index value at the reference point was firstly calculated, and the scoring standards of the evaluation indicators were determined (see Table 3 for details). Among the 7 indicators, for the indicators whose value increases with the greater the pollution, the 75% quantile is used as the cut-off point, and the index value below the 75% quantile is the ideal value, and is assigned a value of 5 points, if it is greater than 75 The index value of the % quantile is divided into two equal parts, the lower part is assigned 3 points, and the upper part is assigned 1 point; for the index whose value decreases with the increase of pollution, the 25% quantile is used as the cut-off point, and the lower part is lower than 25%. The value of the quantile is an ideal value, and the value is assigned as 5 points. The value greater than 25% of the quantile is divided into two equal parts. The upper segment is assigned 3 points and the lower segment is assigned 1 point.

Table 3. Distribution of index values in reference points

Parameter index	Minimum	25% quantile	50% quantile	75% quantile	Maximum value
Cyanobacterial abundance	0.012	0.033	0.035	0.061	0.179
Phytoplankton Diversity Index	1.85	2.29	2.78	3.22	3.98
Phytoplankton Evenness Index	0.98	1.21	1.39	1.57	1.99
Zooplankton Diversity Index	2.41	2.64	2.88	2.98	3.2
Zooplankton Richness Index	2.14	2.34	2.65	2.75	2.97

According to the three-point scoring standard, the 7 plankton integrity indices were scored for the measured values of the 3 water indicators in Reservoir A, and then the 7 index scores were accumulated, and finally the total plankton integrity index scores of the 3 waters were obtained. .

(2) Quartering

According to the statistical distribution of the seven biological indicators constituting the plankton integrity index value in the reference point by the four-point system, the scoring standards of the evaluation indicators were determined. For the indicator with stronger pollution and smaller value, the 95% quantile is the expected value, and the distribution range less than this value is divided into 4 equal parts, and recorded as 6 points, 4 points, 2 points and 0 points in order from large to small; For the indicators with stronger interference and larger value, take the 5% quantile as the expected value, divide the difference between the expected value and the maximum value into 4 equal parts, and record them as 6 points, 4 points, 2 points in order from small to large points and 0 points.

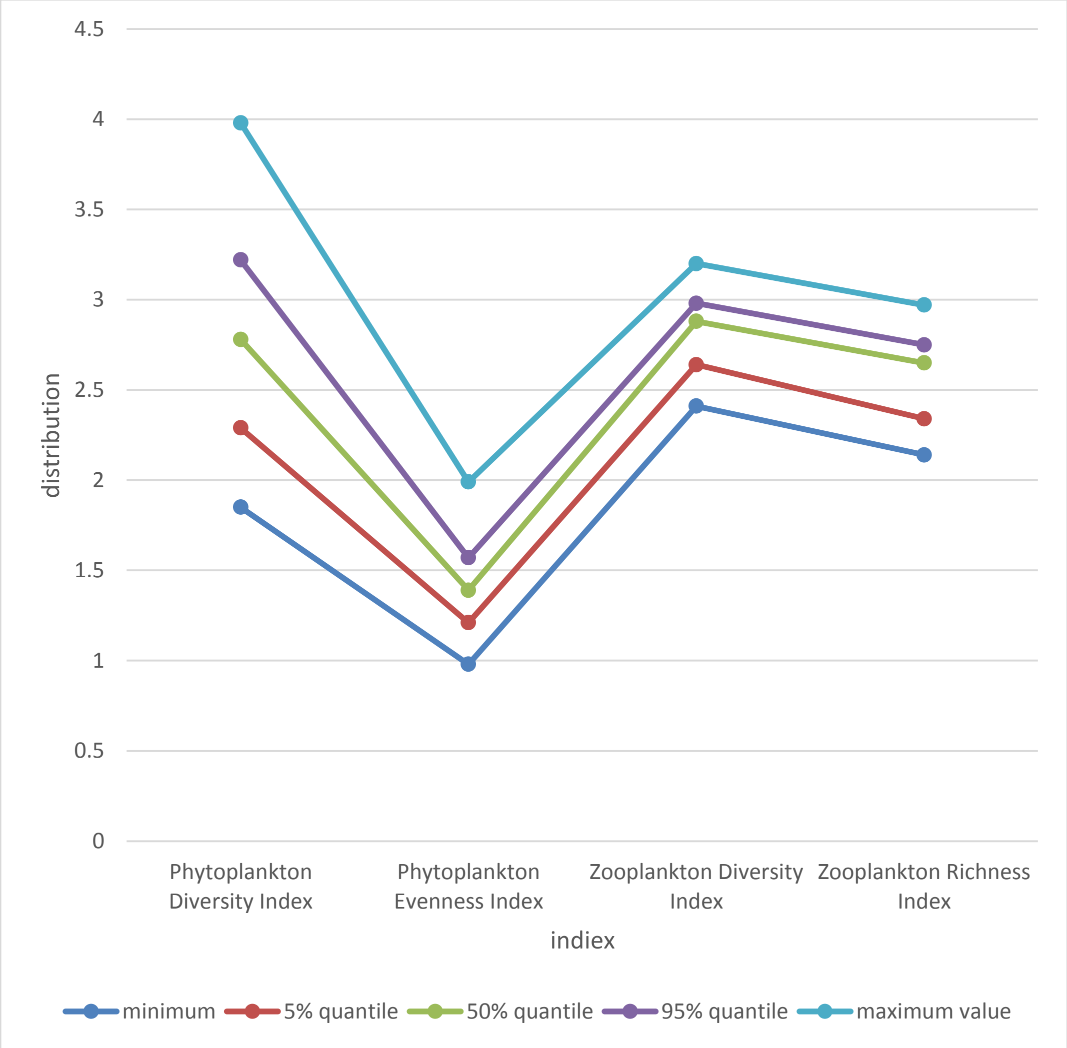

Figure 1. The distribution of index values in the reference point

As shown in Figure 1, according to the four-point scoring standard, five plankton integrity indices were used to score the measured values of the three water indicators in Reservoir A, and then the five index scores were accumulated to obtain the plankton integrity of the three waters. Sex index total score.

4.3. Comparative Analysis of Plankton Integrity Index Evaluation Results

According to the above-established plankton integrity index scoring standard, the scores of the three waters of Reservoir A were calculated, and on this basis, the health of the aquatic ecosystems in different periods of the three waters of Reservoir A was evaluated. The evaluation results of the three-point method and the four-point method are shown in Figure 2, respectively.

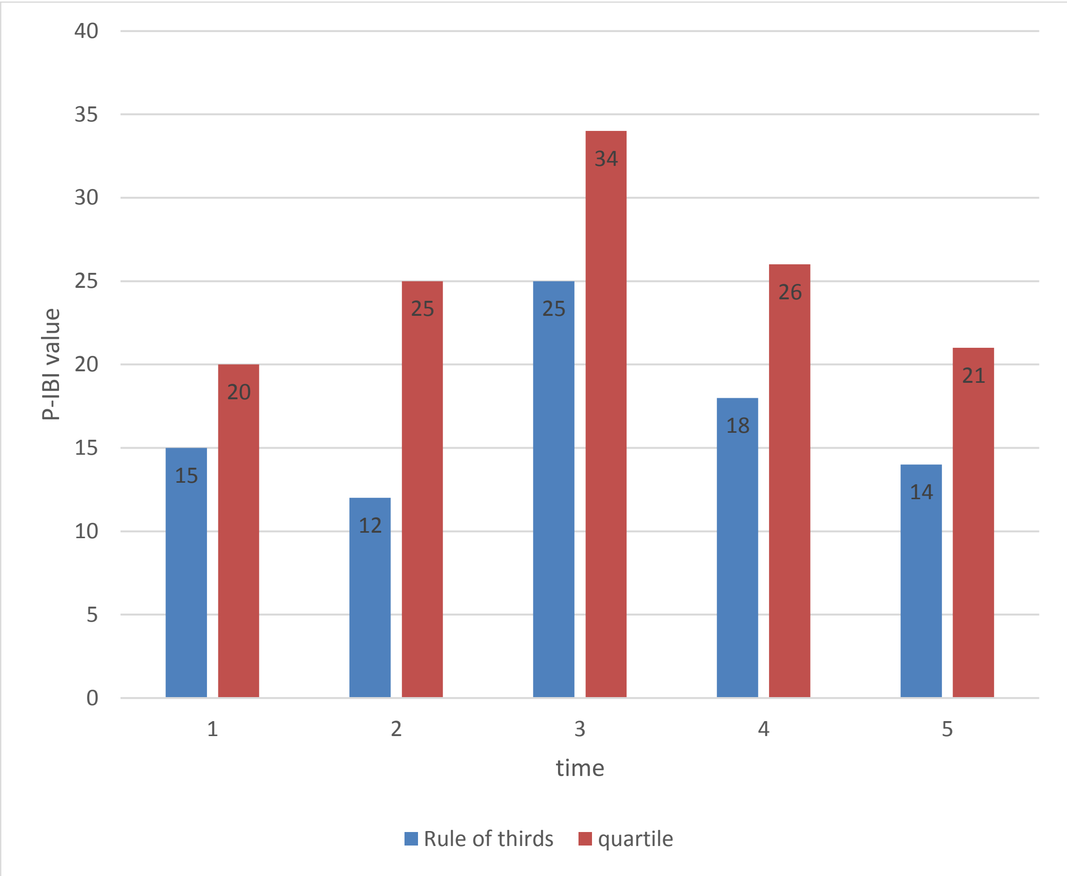

Figure 2. Comparison of P-IBI values and evaluation results

As shown in Figure 2, the P-IBI score of the waters calculated by the quartile method is between 20-34, and the P-IBI score of the waters calculated by the method of thirds is between 12-25, and the results obtained by the quartile method are generally high Compared with the three-point method, and its evaluation results have a good similarity with the grey relational evaluation results, the four-point method is more suitable for the aquatic ecological health evaluation of the three aquaculture types of Reservoir A.

5. Conclusion

In this paper, macrobenthos were used as biological indicators to comprehensively analyze the temporal and spatial variation characteristics of macrobenthos community structure and benthic structures in different aquaculture areas in Jiaozhou Bay, Laizhou Bay, Xiaoqing Estuary nearshore waters, and Sanggou Bay using various indices. Habitat health status provides data support for in-depth understanding of benthic habitat health status of typical aquaculture bays. A comprehensive evaluation method for ecosystem health of typical aquaculture bays was preliminarily established, and the method was used to evaluate the health status of the ecosystems in the coastal waters of the Xiaoqing River estuary in Laizhou Bay, and to determine the ecosystem health evaluation indicators of the aquaculture bays with ecosystem structure and function as the main body, to provide a reference for the construction of the health evaluation system of aquaculture ecosystems.

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Data Availability

Data sharing is not applicable to this article as no new data were created or analysed in this study.

Conflict of Interest

The author states that this article has no conflict of interest.

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