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Biological integrity of fish in Jinan Region, China

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Abstract. To understand biological integrity of fish, in spring (May) and in autumn (October) 2015, 25 sampling sites of Jinan Region was investigated. The score of F-IBI all over the Jinan Region showed positive correlations between spring and autumn. The results of F-IBI showed that spring of Jinan Region was of excellent ecological integrity, while the autumn of Jinan Region were in severe impairment.

1. Introduction

River ecosystem, as a natural ecosystem formed under the interaction of aquatic communities and their living environment, shows significant regional difference. The difference of natural features and influence of human activities are the main factors causing the spatial difference of river ecosystem [1]. As one of the most diversified communities in vertebrates, fish is an important factor in river ecosystem for material cycle, energy flow and information transmission [2]. The community characteristics of fish can reflect the structural diversity and spatial distribution characteristics of fish community [2].

Evaluation on fish index of biotic integrity (F-IBI) has been widely applied in the world [9-11] and become one of main means for evaluating river health globally [3]. However, one-time survey results show great contingency, so sampling surveys conducted in the same region in different seasons can yield evaluation results more realistic [4]. Therefore, this study surveyed fish communities in spring and autumn in Jinan region and evaluated them according to evaluation system of fish communities. The basic information of fishes provides reliable data supports for protecting the health of ecosystem in the region.

2. Materials and methods

2.1. Collection of fish samples

In accordance with the field conditions in Jinan region, 25 sampling points were set in total (Fig.1). Two persons collected fishes in the range 400 meters in the upstream and downstream of each sampling point. In 30 minutes, one was responsible for collecting fishes by using an electric shock instrument, while the other one held a braid and a bucket to collect fish using the braid and putting the fish in the bucket. After collection, the fishes were identified and treated in the field. The species of all fish samples were identified. At sampling points with water depth exceeding two meters, the fish samples were collected by using the hanging net method. In these regions, the hanging nets were hung in different regions of sampling points and then taken back after 30 minutes.



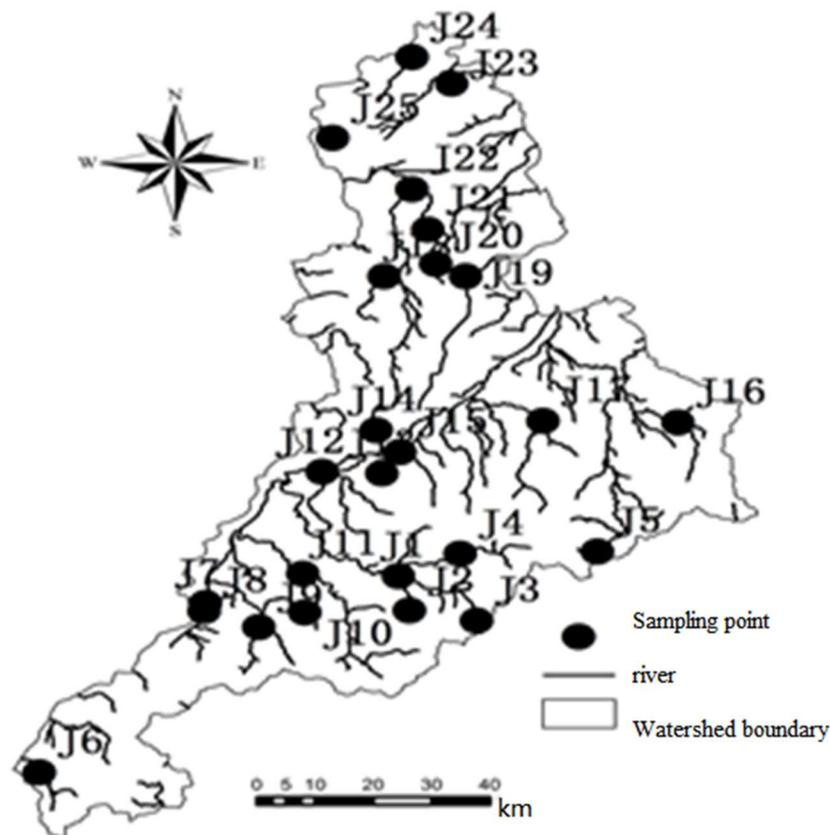


Fig.1 Location map of sample sites

2.2. Data analysis and processing

2.2.1. Structural characteristics of fish community and analysis of water environmental factors. The relevant data, such as species of fishes, density, biomasses and Shannon-Weiner indexes at each sampling point were calculated.

2.2.2. Evaluation system of F-IBI in Jinan region. By using five attributes (species composition and density, feeding habit, pollution tolerance, spawning pattern, and number and distribution), the evaluation system of F-IBI was established. Furthermore, this research used 22 indexes that were sensitive to changes of living environment as candidate indicators [5] and screened 25 candidate indexes [5].

F-IBI was calculated by using the score ratio method. The specific method is shown as follows: for biotic indexes which are lower under stronger disturbance, 95% quantile is the optimal expected value and the index scores of each sampling point equal to the values obtained by dividing the index value by 95% quantile. For indexes that the stronger the disturbance is, the higher the values, 5% quantile is the optimal expected value and its calculation formula is presented as follows:

$$Bi_{mn} = (X_{max} - X_m) / (X_{max} - X_{0.05})$$

Where, $Bi_{m,n}$, X_{max} and X_m represent the calculated score of biotic index of the m th sampling point, the maximum biotic index value in m sampling points and the biotic index value of the m th sampling point, respectively; $X_{0.05}$ indicates the biotic index value of 5% quantile in m sampling points.

Table 1. Evaluation system of F-IBI in Jinan region and parameter description

Attribute	No.	Parameter index	Response to disturbance
Species composition and density	F1	Number of species	Decrease
	F2	Shannon-Weiner index of fishes	Decrease
	F3	Evenness index of fishes	Decrease
	F4	Proportion of Gobioninae	Decrease
	F5	Proportion of Cyprininae	Increase
	F6	Proportion of Cobitidae	Decrease
	F7	Proportion of Leuciscinae	Decrease
	F8	Proportion of Gobiidae	Decrease
	F9	Proportion of pelagic fishes	Decrease
	F10	Proportion of demersal fishes	Decrease
	F11	Proportion of fishes in middle and lower layers	Increase
Feeding habit	F12	Proportion of carnivorous fishes	Decrease
	F13	Proportion of herbivorous fishes	Decrease
	F14	Proportion of omnivorous fishes	Increase
Pollution tolerance	F15	Proportion of pollution-tolerant fishes	Increase
	F16	Proportion of pollution-sensitive fishes	Decrease
Spawning pattern	F17	Proportion of fishes with pelagic eggs	Decrease
	F18	Proportion of fishes with demersal eggs	Decrease
	F19	Proportion of fishes with viscid eggs	Increase
	F20	Proportion of fishes with special eggs	Increase
Number and distribution	F21	Number of individual fishes	Decrease
	F22	Proportion of cosmopolitan species	Increase

Finally, the reference points for evaluating fish ecology in Jinan region were selected to be J1, J3, J4, J7 and J11 [5,6].

2.2.3. *Data analysis.* SPSS 18.0 was used for correlation analysis of data and box diagram was analyzed through Origin Pro 7.0. 0.

3. Results

By analyzing each box diagram, five parameters were selected. There are four in spring and five in autumn. Three indexes, i.e. the number of fish species, Shannon-Weiner index of fishes and individual species of fishes were commonly selected. Based on Pearson correlation test, three parameters, i.e. the number of fish species, widespread fish species and diversity index of fishes were finally selected in spring. In autumn, four parameters, i.e. Shannon-Weiner index of fishes, percentage of pollution-sensitive fishes, percentage of carnivorous fishes and individual species of fishes were selected as core parameters of the evaluation system.

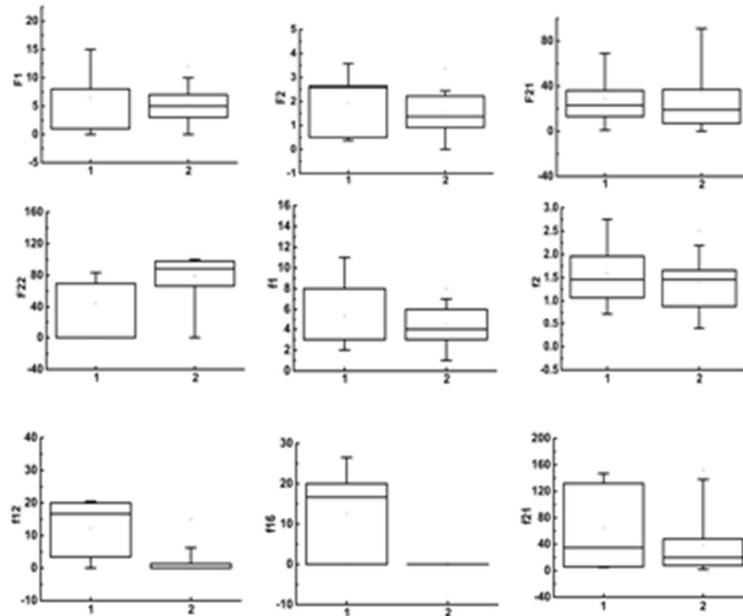


Fig.2 Box-plots of 9 candidate metrics between reference and impaired sites in Jinan Region
 1:Reference sites;2:impaired sites;F:wet season;f:dry season

Through calculation and analysis, the standards for F-IBI in spring are shown as follows: in the ranges of 0~16.66, 16.66~33.33, 33.33~50.00 and larger than 50.00, the river ecosystem is separately considered to be extremely unhealthy, unhealthy, moderately healthy and healthy. In autumn, the river ecosystem is extremely unhealthy, unhealthy, moderately healthy and healthy when the F-IBI scores are in the ranges of 0~10.31, 10.31~20.62, 20.62~30.93 and larger than 30.93.

The results of F-IBI in Jinan region are displayed in Table 3. F-IBI results demonstrate that there are nine healthy sampling points, five moderately healthy ones and nine unhealthy ones, while there are relatively less extremely unhealthy sampling points, only two in spring. In autumn, six healthy sampling points, two moderately healthy ones and four unhealthy ones are found, while there are a larger number of extremely unhealthy sampling points, 13 in total. In southern mountain area of Jinan, the representative points, such as Liujiabao bridge, Bingdukou and Huangchao reservoir show a high health degree of water ecosystem. The regions with lower or the lowest health degree of water ecosystem are mainly located in the central and northern regions of Jinan. F-IBI scores of fish communities in spring and autumn in Jinan region show an obviously positive correlation ($P < 0.05$), indicating that fish communities in large-scale range of the region exhibit same biotic integrity characteristics in different seasons (Table 2).

Table 2. Result of Jinan Region

Site	Spring score	Spring health	Autumn score	Autumn health	progress	Integrated health
J1	71.65	healthy	89.25	healthy	—	healthy
J2	14.46	extremely unhealthy	4.01	extremely unhealthy	—	extremely unhealthy
J3	50.15	healthy	36.40	healthy	—	healthy
J4	55.77	healthy	51.11	healthy	—	healthy
J5	50.00	healthy	7.80	extremely unhealthy	↓	moderately healthy
J6	22.92	unhealthy	14.96	unhealthy	—	unhealthy
J7	43.86	moderately healthy	23.86	moderately healthy	—	moderately healthy
J8	50.00	healthy	0.89	extremely unhealthy	↓	unhealthy
J9	22.37	unhealthy	10.05	extremely unhealthy	↓	unhealthy
J10	44.08	moderately healthy	20.46	moderately healthy	—	moderately healthy
J11	55.87	healthy	43.00	healthy	—	healthy
J12	32.86	unhealthy	1.78	unhealthy	↓	extremely unhealthy
J13	34.24	moderately healthy	8.92	unhealthy	↓	unhealthy
J14	31.96	unhealthy	10.70	unhealthy	—	unhealthy
J15	8.59	extremely unhealthy	1.78	extremely unhealthy	—	extremely unhealthy
J16	38.78	moderately healthy	0.89	extremely unhealthy	↓	unhealthy
J17	60.59	healthy	0.89	extremely unhealthy	↓	unhealthy
J18	22.74	unhealthy	5.13	extremely unhealthy	↓	unhealthy
J19	26.18	unhealthy	10.23	extremely unhealthy	—	unhealthy
J20	21.59	unhealthy	0.45	extremely unhealthy	↓	unhealthy
J21	31.13	unhealthy	2.45	extremely unhealthy	↓	unhealthy
J22	74.13	healthy	33.09	healthy	—	healthy
J23	44.39	moderately healthy	13.06	unhealthy	↓	unhealthy
J24	19.75	unhealthy	9.14	extremely unhealthy	↓	unhealthy
J25	55.36	healthy	35.29	healthy	—	healthy

4. Discussion

In F-IBI evaluation across the world, one-time evaluation or annual tracking evaluation is generally conducted only [5-7], while the researches at the same sampling points and seasons are rare. In this survey, large differences are found in F-IBIs of some sampling points, while the fish communities exhibit consistent integrity characteristics in the whole region, indicating that health of river ecosystem is not affected by water environmental factors [8-10]. The number of fish species, Shannon-Weiner index of fishes and individual species of fishes are indexes selected in the two seasons. Therefore, it is speculated that these three indexes are most stable in Jinan region and can be used as the main indexes

for evaluation. In F-IBI evaluation, 13 sampling points without changes of grade account for 52.00% of the total sampling points and fish communities at these sampling points are not influenced by seasons (spring or autumn). There are 12 degraded sampling points, accounting for 48.00% and basically distributed in the central and northern areas. In the central area of Jinan, due to a lot of human activities and great emissions of industrial waste water and sanitary sewage, river is polluted seriously. Therefore, it is suggested that the government should strengthen management on ecosystem of central and northern areas and control exploitation of underground water and emissions of industrial waste water and sanitary sewage, so as to finally build a harmonious and stable river ecosystem in Jinan region.

5. Conclusion

In Jinan region, F-IBI scores of fish communities in spring and autumn show an obviously positive correlation, indicating that fish communities show consistent characteristics of biotic integrity in large-scale range of the region. In spring, there are nine healthy sampling points, five moderately healthy ones and nine unhealthy ones. Moreover, extremely unhealthy sampling points are less and only two are found. In autumn, there are six healthy sampling points, two moderately healthy and four unhealthy ones, with a larger number (13 in total) of extremely unhealthy sampling points. In the southern mountain area of Jinan, the health degree of water ecology is high. The regions with lower or the lowest health degree of water ecosystem are mainly distributed in central and northern areas of Jinan.

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