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**Impact of forest fragmentation on river water quality: an example from a typical subtropical hilly basin**

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## Part 1. Water quality evaluation methodology

In this study, China's Environmental quality standard for surface water (GB 3838-2002) was adopted for the evaluation of individual water quality parameters, as shown in Table S1. Class Ⅰ is mainly applicable to source water and national nature reserves; Class Ⅱ is mainly applicable to the primary protection area of the surface water source of concentrated drinking water, the habitat of rare aquatic organisms, the spawning ground of fish and shrimp, and the feeding ground of young and young fish. Class Ⅲ is mainly applicable to the secondary protection area of surface water source of centralized drinking water, the winter farm of fish and shrimp, the migration channel, aquaculture area and other fishery waters and swimming areas. Class Ⅳ is mainly applicable to general industrial water areas and recreational water areas where the human body is not in direct contact; Class Ⅴ is mainly applicable to agricultural water use areas and general landscape waters.

**Table S1** Basic limits for six water quality indicators in environmental quality standards for surface waters.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| WQI | Class Ⅰ | Class Ⅱ | Class Ⅲ | Class Ⅳ | Class Ⅴ |
| PI | 2.0 | 4.0 | 6.0 | 10.0 | 15.0 |
| COD | 15.0 | 15.0 | 20.0 | 30.0 | 40.0 |
| BOD5 | 3.0 | 3.0 | 4.0 | 6.0 | 10.0 |
| NH3-N | 0.15 | 0.5 | 1.0 | 1.5 | 2.0 |
| TP | 0.02 | 0.1 | 0.2 | 0.3 | 0.4 |
| TN | 0.2 | 0.5 | 1.0 | 1.5 | 2.0 |

The Canadian Council of Ministers of the Environment Water Quality Index (CCMEWQI) is grounded in an index formulated by the Ministry of Environment, Lands and Parks of British Columbia, Canada. This index is primarily predicated on a composite evaluation that integrates three fundamental factors: Scope, Frequency, and Amplitude. These dimensions collectively facilitate a comprehensive assessment of water quality, enabling the identification of trends and the effective communication of water condition to stakeholders. By incorporating these multifaceted criteria, the CCMEWQI provides a robust framework for evaluating and managing aquatic ecosystems (Hurley et al., 2012; Lumb et al., 2006), the categories and detailed meaning of CCMEWQI values are shown in Table S2. The calculation method is as follows:

F1 (Scope) represents the percentage of parameters that do not meet their guidelines at least once during the time period under consideration, relative to the total number of parameters measured:

$F1=\frac{Number of failed parameters}{Total number of parameters}×100\%$ (1.1)

F2 (Frequency) represents the percentage of individual tests that do not meet guidelines:

$F2=\frac{Number of failed tests}{Total number of tests}×100\%$ (1.2)

F3 (Amplitude) represents the amount by which failed test values do not meet their guidelines. F3 is calculated in three steps.

⑴The number of times by which an individual concentration is greater than (or less than, when the guideline is a minimum) the guideline is termed an “excursion” and is expressed as follows. When the test value must not exceed the guideline:

$excursion\_{i}=\frac{FailedTestValue\_{i}}{Objective\_{j}}-1$ (1.3)

For the cases in which the test value must not fall below the guideline:

$excursion\_{i}=\frac{Objective\_{j}}{FailedTestValue\_{i}}-1$ (1.4)

⑵The collective amount by which individual tests are out of compliance is calculated by summing the excursions of individual tests from their guidelines and dividing by the total number of tests (both those meeting guidelines and those not meeting guidelines). This parameter, referred to as the normalized sum of excursions, or *nse*, is calculated as:

$nse=\frac{\sum\_{i=1}^{n}excursion\_{i}}{Total number of tests}$ (1.5)

⑶F3is then calculated by an asymptotic function that scales the normalized sum of the excursions from guidelines (nse) to yield a range between 0 and 100.

$F3=\frac{nse}{0.01nse+0.01}$ (1.6)

The divisor 1.732 normalizes the resultant values to a range between 0 and 100, where 0 represents the “worst” water quality and 100 represents the “best” water quality.

$CCMEWQI=100-\left(\frac{\sqrt{F1^{2}+F2^{2}+F3^{2}}}{1.732}\right)$ (1.7)

**Table S2** General description of the CCMEWQI index.

|  |  |  |
| --- | --- | --- |
| Categories | Value | Implication |
| Excellent | 95-100 | water quality is protected with a virtual absence of threat or impairment; conditions very close to natural or pristine levels. |
| Good | 80-94 | water quality is protected with only a minor degree of threat or impairment; conditions rarely depart from natural or desirable levels. |
| Fair | 65-79 | water quality is usually protected but occasionally threatened or impaired; conditions sometimes depart from natural or desirable levels. |
| Marginal | 45-64 | water quality is frequently threatened or impaired; conditions often depart from natural or desirable levels. |
| Poor | 0-44 | water quality is almost always threatened or impaired; conditions usually depart from natural or desirable levels. |

**Part 2. nonparametric change-point analysis (nCPA)**

The nonparametric change-point analysis (nCPA) has been widely used in ecology. It is very effective for evaluating the location of the independent variable mutation point that causes the dependent variable mutation (Huo et al., 2015). Here, we use this approach to explore thresholds for landscape forest fragmentation indicators that lead to abrupt water quality changes. nCPA was calculated as follows:

The deviance value was calculated, as:

$D=\sum\_{k=1}^{m}(y\_{k}-μ)^{2}$ (2.1)

where *D* is the deviance, *n* is the sample size, and *μ* the average of the m observations yk.

Next, the deviance redundancy ∆*i* of *i*th interval point between the two groups was calculated using formula (2). The ∆*i* of each probable changepoint *t* (1 ≤*t* ≤n) was always greater than or equal to 0. Finally, the *i* th value, at which maximum ∆*i* was achieved, was identified as the abrupt change-point *t*.

$∆i=D-(D\_{\leq i}+D\_{>i})$ (2.2)

where D, D ≤ *i*, and D > *i* are the deviance of the data *y1*, *y2*, …*yn*, *y1*, *y2* …*yi*, and *yi+1* …*yn*, respectively.

The actual observation data is usually very limited. Therefore, the nCPA was combined with the bootstrap method to calculate the probability of the positions at which the abrupt changes occurred. We extracted 1000 random samples from the raw water quality parameter-landscape metric data set using the bootstrap simulation method.

**Part 3.**

Table S3 January and July water quality data from 15 stations in the upper Ganjiang River basin.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Monitoringsite | PI | COD | BOD5 | NH3 | TP | TN | TIME |
| S01 | 2.1 | 9.5 | 1.2 | 0.11 | 0.036 | 1.32 | 202107 |
| S02 | 2.3 | 8.3 | 1.2 | 0.22 | 0.051 | 1.57 | 202107 |
| S03 | 2.3 | 8.2 | 1 | 0.1 | 0.026 | 0.76 | 202107 |
| S04 | 1 | 5 | 0.5 | 0.02 | 0.05 | 1.12 | 202107 |
| S05 | 2.4 | 9 | 0.2 | 0.12 | 0.043 | 1.11 | 202107 |
| S06 | 1.6 | 9 | 0.2 | 0.05 | 0.034 | 1.97 | 202107 |
| S07 | 2.3 | 6 | 0.8 | 0.09 | 0.039 | 0.86 | 202107 |
| S08 | 2.4 | 11 | 0.2 | 0.05 | 0.03 | 1.34 | 202107 |
| S09 | 2.3 | 11 | 0.7 | 0.08 | 0.063 | 1.44 | 202107 |
| S10 | 2.7 | 13 | 0.6 | 0.02 | 0.03 | 0.58 | 202107 |
| S11 | 2.4 | 10 | 0.7 | 0.02 | 0.08 | 1.67 | 202107 |
| S12 | 1.3 | 11 | 1.1 | 0.1 | 0.047 | 0.64 | 202107 |
| S13 | 1.5 | 9 | 0.9 | 0.13 | 0.046 | 0.5 | 202107 |
| S14 | 2.9 | 2 | 1.6 | 0.14 | 0.096 | 1.31 | 202107 |
| S15 | 2.1 | 2 | 0.7 | 0.22 | 0.12 | 1.04 | 202107 |
| S01 | 1.3 | 13 | 1.1 | 0.95 | 0.036 | 2.54 | 202101 |
| S02 | 2 | 6 | 1.1 | 1.28 | 0.041 | 3.24 | 202101 |
| S03 | 2.3 | 5.7 | 1.4 | 0.07 | 0.021 | 0.5 | 202101 |
| S04 | 1.1 | 15 | 1.1 | 0.33 | 0.09 | 2.23 | 202101 |
| S05 | 2.1 | 5 | 0.6 | 0.27 | 0.054 | 1.3 | 202101 |
| S06 | 1 | 9.5 | 1.2 | 0.14 | 0.038 | 3.17 | 202101 |
| S07 | 1.7 | 5 | 0.7 | 0.03 | 0.013 | 1.26 | 202101 |
| S08 | 2 | 2 | 1.2 | 0.03 | 0.04 | 2.99 | 202101 |
| S09 | 1.6 | 11 | 1.3 | 0.07 | 0.032 | 2.17 | 202101 |
| S10 | 2.2 | 11 | 1.6 | 0.02 | 0.06 | 1.76 | 202101 |
| S11 | 2.1 | 11 | 1.9 | 0.5 | 0.11 | 3.51 | 202101 |
| S12 | 0.7 | 2 | 1.2 | 0.12 | 0.057 | 0.93 | 202101 |
| S13 | 1.1 | 5.5 | 1.5 | 0.14 | 0.039 | 0.76 | 202101 |
| S14 | 2.1 | 5 | 1.3 | 0.06 | 0.08 | 1.81 | 202101 |
| S15 | 4.5 | 16 | 2.9 | 0.25 | 0.1 | 1.45 | 202101 |

Table S4 Proportion of major land-use types in 15 sub-basins of the upper Ganjiang River basin.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Monitoring site | Cropland | Forest | Grassland | Water | Impervious |
| S1 | 18.14 | 78.07 | 0.07 | 0.74 | 2.96 |
| S2 | 18.87 | 77.76 | 0.06 | 0.67 | 2.62 |
| S3 | 12.05 | 85.30 | 0.06 | 0.94 | 1.52 |
| S4 | 5.64 | 92.58 | 0.02 | 0.33 | 1.43 |
| S5 | 7.20 | 90.77 | 0.28 | 0.42 | 1.30 |
| S6 | 16.68 | 80.42 | 0.04 | 0.52 | 2.34 |
| S7 | 18.63 | 77.97 | 0.36 | 0.09 | 2.95 |
| S8 | 13.47 | 84.24 | 0.04 | 0.05 | 2.19 |
| S9 | 14.18 | 83.15 | 0.05 | 0.44 | 2.17 |
| S10 | 11.54 | 86.39 | 0.04 | 0.34 | 1.68 |
| S11 | 19.31 | 75.76 | 0.02 | 0.48 | 4.41 |
| S12 | 23.03 | 73.77 | 0.08 | 0.75 | 2.35 |
| S13 | 23.61 | 73.06 | 0.13 | 0.88 | 2.29 |
| S14 | 16.23 | 81.40 | 0.05 | 0.32 | 1.98 |
| S15 | 24.56 | 69.34 | 0.03 | 0.60 | 5.48 |

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