# The rating mode of eutrophication in Dalinuoer Lake

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**Abstract.** The Logistic Curve eutrophication level comprehensive evaluation model was used to generate model samples and verification samples based on the evaluation grade criteria and uniform random numbers and was solved using an accelerated genetic algorithm. The water quality monitoring indicators in July, August, September and October of 2017 were selected to evaluate the water environment quality of Darinol Lake and determine the eutrophication level. The results showed that the degree of eutrophication in Darinol Lake is close to five extremely eutrophic state, and the eutrophication grades in July, August, September and October showed a slowly decreasing trend.

## 1. Introduction

Dalinuoer Lake is the second largest freshwater lake in Inner Mongolia. It is known as "China Swan Lake". It is the largest migration route for migratory birds in northern China and one of the most important migratory birds distribution center in Northeast Asia.

Dalinuoer Lake is located in the western part of the Keshiketengqi, Chifeng City, Inner Mongolia, east longitude 116 ° 29 '~ 116 ° 45', north latitude 43 ° 13 '~ 43 ° 23', is a typical northern drought area with a lacus area of about 228km$^2$, water storage of about 1.6 billion cubic meters, the maximum depth of about 13m, the average depth of about 6.7m, its geographical location shown in Figure 1. Dalinuoer Lake has four supply rivers: the Gonggeer River, Shali River, Haolai rivers and Liangzi River, respectively, all inland rivers. The annual river supply is about 60.9 million cubic meters. Precipitation recharge of 0.714 cubic meters, groundwater recharge of 1152 cubic meters, higher water quality alkalinity, as a closed half brackish water [1-2]. The lacus is rich in Crucian carp and Archangel fish, is the largest fishery base of the Keshiketengqi. There are 160 species in 16 orders and 36 orders in Nature Reserve of Dalinor Lake [3]. Among them, there are 8 species of national protected birds such as red-crowned cranes, white


**Figure 1.** Dalinore Lake location picture.

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storks, white-naped cranes and black storks, 18 species of secondary protection birds such as gray crane, Xie Yi crane, big swan.

Dalinuoer Lake belongs to a closed plateau lacus, the flow of water into the lacus has decreased over the years, the evaporation is on the rise, the water is not exported, the lacus is shrinking year by year, combined with the intensification of human activities, the pollutants into the lacus cannot be discharged. These questions make the lacus salinity gradually increase and the water environment continues to deteriorate. Mastering Darunor Lake Eutrophication is of great significance for the sustainable utilization of the aquatic resources, the protection of wetland ecological functions and the comprehensive management in Dalinuoer Lake.

## 2. Establishment of eutrophication rating model

Comprehensive evaluation of water eutrophication level, using some water quality indicators and the establishment of mathematical models to comprehensively evaluate water eutrophication level, provide a scientific basis for water pollution prevention and protection. At present, the models for water environment quality assessment mainly include Sheperd similarity evaluation model [4], fuzzy neural network evaluation model [5], projection pursuit evaluation model [6] and Logistic Curve evaluation model [7]. Since evaluation results of some models have many discrete water quality ratings, they are semi-quantitative and their resolution is too coarse. Even though they belong to the same water body, their corresponding water quality indicators often differ significantly, and Logistic Curve evaluation model can overcome the above shortcomings and achieved good results in the application [7-8]. Therefore, Logistic Curve evaluation model is used to evaluate the eutrophication level of Dalinuoer Lake.

### *2.1. Evaluation standard*

Selection of evaluation criteria of water quality, evaluation level is divided into extremely poor nutrition, poor nutrition, nutrition, rich nutrition, extremely rich nutrition. See Table 1 for details.

**Table 1.** Water quality evaluation standards of lacus.

| **Water quality indicators** | **Water quality level** | | | | |
|---|---|---|---|---|---|
| | **1 extremely poor nutrition** | **2 poor nutrition** | **3 nutrition** | **4 rich nutrition** | **5 extremely rich nutrition** |
| transparency (/m) | >37 | 12 | 2.4 | 0.55 | 0.17 |
| Oxygen consumption (mg/L) | <0.09 | 0.36 | 1.8 | 7.1 | 27.1 |
| Total nitrogen (mg/L) | <0.02 | 0.06 | 0.31 | 1.2 | 4.6 |
| Total phosphorus (μg/L) | <1 | 4 | 23 | 110 | 660 |

### *2.2. Evaluation factors*

Water quality data use the average monitoring results at various monitoring points in Daloreau Lake in July, August, September and October in 2017. Evaluation factors include: transparency, oxygen consumption, total nitrogen and total phosphorus.

### *2.3. Establishment of Logistic Curve eutrophication rating model (L-C model)*

#### *2.3.1. L-C model.*

$$z = \frac{N}{1+e^{c+\sum_{i=1}^{n} c_i x_i}} \tag{1}$$

In the formula: $z$ is calculated value of eutrophication level model
$N$ is the highest level of water quality
$x_1, x_2, \Lambda, x_n$ are the indicators of eutrophication evaluation is the number of indicators

n is the number of indicators
$c_0, c_1, c_2, \Lambda, c_n$ are the model parameters

*2.3.2. Generation of modeling samples.* Using uniform random number between [0, 1] and evaluation criteria of eutrophication level applying formula (2) [9] to produce random 25 modeling samples. Table 2 shows the L-C model modeling samples.

**Table 2.** Randomly generated L-C model modeling samples.

| Serial number | Trans-parency | Oxygen consumption | Total nitrogen | Total phosphorus | Standard grade | Calculatione grade |
|---|---|---|---|---|---|---|
| 1 | 46.62 | 0.051 | 0.015 | 0.559 | 1 | 1.013 |
| 2 | 89.617 | 0.034 | 0.009 | 0.106 | 1 | 0.26 |
| 3 | 45.867 | 0.061 | 0.01 | 0.978 | 1 | 1.032 |
| 4 | 55.149 | 0.051 | 0.015 | 0.646 | 1 | 0.791 |
| 5 | 99.746 | 0.056 | 0.01 | 0.078 | 1 | 0.185 |
| 6 | 23.709 | 0.133 | 0.042 | 2.821 | 2 | 1.867 |
| 7 | 16.26 | 0.176 | 0.02 | 1.426 | 2 | 2.15 |
| 8 | 19.699 | 0.098 | 0.035 | 1.947 | 2 | 2.022 |
| 9 | 14.496 | 0.195 | 0.04 | 2.79 | 2 | 2.261 |
| 10 | 18.619 | 0.356 | 0.049 | 3.862 | 2 | 2.104 |
| 11 | 3.252 | 1.479 | 0.145 | 9.171 | 3 | 2.965 |
| 12 | 8.979 | 1.308 | 0.29 | 16.739 | 3 | 2.939 |
| 13 | 7.487 | 0.583 | 0.305 | 4.379 | 3 | 2.939 |
| 14 | 10.476 | 0.879 | 0.149 | 18.998 | 3 | 2.688 |
| 15 | 5.647 | 1.611 | 0.159 | 22.001 | 3 | 2.948 |
| 16 | 1.038 | 5.341 | 0.606 | 93.002 | 4 | 4 |
| 17 | 1.715 | 5.229 | 0.684 | 104.886 | 4 | 4.082 |
| 18 | 0.655 | 3.409 | 0.794 | 52.709 | 4 | 4 |
| 19 | 1.961 | 5.678 | 0.799 | 64.253 | 4 | 4.049 |
| 20 | 1.413 | 4.582 | 1.004 | 49.799 | 4 | 4.16 |
| 21 | 0.263 | 8.747 | 3.879 | 359.852 | 5 | 4.989 |
| 22 | 0.267 | 17.778 | 3.764 | 222.285 | 5 | 4.982 |
| 23 | 0.222 | 21.613 | 2.287 | 401.613 | 5 | 4.962 |
| 24 | 0.213 | 22.129 | 2.319 | 605.647 | 5 | 4.984 |
| 25 | 0.512 | 11.198 | 1.626 | 267.201 | 5 | 4.831 |

Note: The upper level of the selected transparency level is 100.

$$X(i,j)=y(i,j)\big(a(i,j)\big)-b(i,j)+a(i,j) \quad (2)$$

In the formula: $X(i,j)$ is the jth level sample value of the ith indicator
$y(i,j)$ is a uniform random number between [0, 1] of the jth level sample of the

ith indicator generated
a(i,j) is the upper bound of the jth grade of the ith index
b(i,j) is the lower bound of the jth grade of the ith index

*2.3.3. Solve the model.* Currently, there are many methods for solving the LC model, such as the successive search method [10], the four-point average method [11], the orthogonal design method [12], the Macquarite method, the enumeration optimization method [13] M (1,1) model method [7] and other conventional methods, the above methods in the parameter optimization are computationally heavy, complex operation, but compared with other methods, the genetic algorithm in the literature [7], [14] to solve LC model have achieved good results, so this study selects the genetic algorithm for parameter optimization.

Model parameter estimation use accelerated genetic algorithm, the establishment of the following objective function:

$$\min f(c_0, c_1, c_2, \Lambda, c_n) = \sum_{i=1}^{m} |z_1 - z_1'| \tag{3}$$

In the formula: $z_1, z_2, \Lambda, z_m$ are the calculated value of m modeling samples respectively
$z_1', z_2', \Lambda, z_m'$ are rank value of m modeling samples respectively

In order to eliminate the influence of the dimension and to facilitate the calculation, modeling and validation samples normalization processing performed - equation (4) [9]:

$$X'(i,j) = \frac{1}{M(i)} X(i,j) \tag{4}$$

In the formula: $X'(i,j)$ is the normalized sample value of the jth level of the i–th indicator
M(i) is the maximum value of the ith indicator standard grade

Using accelerated genetic algorithm to solve equation (3) [9], the results of the model parameters and accelerated genetic algorithm related parameters are listed in Table 3.

**Table 3.** AGA solves model parameter results.

| Acceleration frequency | 26 | | The best objective function value | | 3.542 |
|---|---|---|---|---|---|
| Optimize variables | $c_0$ | $c_1$ | $c_2$ | $c_3$ | $c_4$ |
| Initial interval | [-10, 10] | [-10, 10] | [-10, 10] | [-10, 10] | [-10, 10] |
| Parameter result | -0.263 | -2.729 | -0.66 | 3.545 | -4.896 |

In this way, an eutrophication rating model of L-C is established - equation (5) [9]:

$$z = \frac{5}{1+e^{-0.263+3.545x_1-0.66x_2-4.896x_3-2.729x_4}} \tag{5}$$

In the formula: $x_1$, $x_2$, $x_3$, $x_4$ are the normalization of transparency, oxygen consumption, total nitrogen, and total ph osphorus respectively.

**Table 4.** Randomly generated L-C model validation samples.

| Serial number | Total phosphorus | Oxygen consumption | transparency | Standard grade |
|---|---|---|---|---|
| 1 | 0.658 | 0.059 | 60.594 | 1 |
| 2 | 3.225 | 0.349 | 24.079 | 2 |
| 3 | 20.269 | 1.681 | 2.606 | 3 |
| 4 | 106.776 | 5.898 | 0.993 | 4 |
| 5 | 281.502 | 22.646 | 0.317 | 5 |

*2.3.4. Model verification.* As with the modeling samples,using uniform random number between [0,1] and evaluation criteria of eutrophication level applying formula (1) [9] to produce random 5 validated samples. Table 4 gives the validation samples, eutrophication levels and calculated levels of L-C models. As can be seen from Table 2 and Table 4, the LC model determines the level of calculation of the sample and depicts the effect of the number of differences of eutrophication indicators on the determination of eutrophication level with finer resolution. Compared with the standard grade, calculating the grade is reasonable .Therefore, the established L-C model can be used to evaluate the water quality of Dalinore Lake.

## 3. Evaluation results

According to the analysis of the individual indicators of transparency, oxygen consumption, total nitrogen and total phosphorus in July, August, September and October in 2017 in Darylor Lake, in addition to the total nitrogen in October between grade IV and grade V water quality standards in 'The Surface Water Environmental Quality Standards' (GB3838-2002), in other time periods, total nitrogen, total phosphorus and oxygen consumption exceeded the grade V water quality standard in 'The Surface Water Environmental Quality Standards' (GB3838-2002). The evaluation indexes are normalized and put into the eutrophication level evaluation model (formula 5). The evaluation results showed that although the eutrophication level of Darinor Lake decreased slowly from July to October, the overall eutrophication level is close to levels five extremely rich nutrition. The curve of eutrophication level of Dalinor Lake in 2017 is shown in Figure 2.

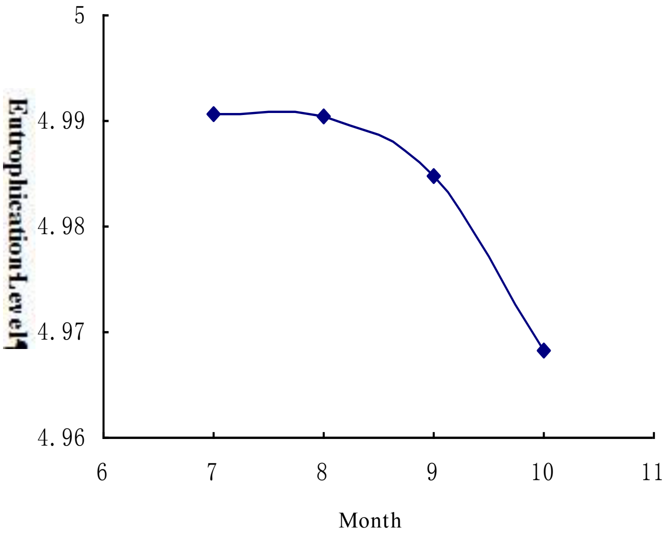


**Figure 2.** Eutrophication level changes in 2017, Darinor Lake.

## 4. Conclusion

Using evaluation model of Logistic Curve (LC) eutrophication, rating criterion and uniform random numbers to generate modeling and verification samples and real code accelerated genetic algorithm to solve evaluation model, finally, evaluate the eutrophication level of Dalinuoer Lake. The results show that Dalinuoer Lake eutrophication levels close to levels five extremely rich nutrition, eutrophication levels showed a gradual downward trend in July, August, September and October.

Dalinuoer Lake belongs to a closed plateau lacus, the main source of supply includes the four rivers into the lacus and atmospheric precipitation, the drainage of lacus has only evaporation. In recent years, the evaporation in the lacus area has been increased, the flow into the lacus has been reduced, pollutants entering the lacus have been increasing and accumulating, and human activities have been exacerbated. Total nitrogen, total phosphorus and salt content in lakes have been continuously increasing. Water quality is changing from freshwater → brackish water → salt water → salt lake. In the future, we should step up the monitoring of water quality in Dalinuoer Lake and take active management measures.

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