

Establishing water quality reference conditions for nutrients, chlorophyll *a* and Secchi depth for 7 typical lakes in arid and semiarid ecoregion, China

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Abstract The increasingly serious lake eutrophication triggers the need for pre-disturbance conditions or historical reference conditions. Establishing nutrient reference condition of lakes in ecoregion is a critical consideration in the development of scientifically defensible aquatic nutrient criteria. Total dissolved solid (TDS) has a significant influence on the growth of algae in arid and semiarid ecoregion (Xinjiang ecoregion) lakes, China. Three methods including lake population distribution, trisection method and multiple regression models were applied to determine reference conditions for seven typical lakes (based on TDS) with respect to total phosphorus (TP), total nitrogen (TN), planktonic chlorophyll *a* (Chl *a*) and Secchi depth (SD). Results show that the first two methods have no significant differences in reference values, and the third method can be used as the validation of the first two methods. The values or ranges considered as nutrients reference conditions are given as follows: TP 0.005 mg/L, TN 0.11 mg/L, Chl *a* 0.86–0.96 µg/L, SD 2.69–3.50 m for freshwater lakes; TP 0.005 mg/L, TN 0.58–0.69 mg/L, Chl *a* 0.64–0.86 µg/L, SD 2.64–3.00 m for saltwater lakes; TP 0.010 mg/L, TN 1.13–1.22 mg/L, Chl *a* 7.00–7.60 µg/L, SD 0.43–0.45 m for brine lakes. Overall, the obtained reference conditions demonstrate that multiple methods can be used to determine reference condition, and reference conditions for various lake types correspond to oligotrophic, oligotrophic, and mesotrophic status, respectively.

Keywords Reference condition · Total dissolved solid · Lake population distribution method · Trisection method · Model prediction

Introduction

At present, eutrophication of surface waters continues to be a major environmental concern in the world, and the major causes are attributed to excess nutrient input and related biological growth (Dodds et al. 2008; Pretty et al. 2002; Xue and Landis 2010). To control eutrophication, it is important to set realistic restoration targets for lakes. Therefore, knowledge of pre-disturbance conditions or historical reference conditions is very urgently needed to establish the lake nutrient reference conditions (Bennion and Simpson 2011).

The reference conditions express the least-impacted conditions, natural background concentrations (Bennion et al. 1996; Paul and Gerritsen 2002; Smith et al. 2003) or the most attainable states (Gibson et al. 2000) if impacts of anthropogenic activities could be minimized. These provide the baseline to determine the changes of the lake state caused by human activity (Solheim 2005). To a certain extent, it would be also possible to predict the potential for future changes (Solheim 2005).

Several methods have been suggested to determine reference conditions (Gibson et al. 2000; US EPA 1998a, b). Two statistically based methods, as reference lake method and lake population distribution method, have been recommended by the US EPA to define a reference condition for any particular nutrient [e.g., total phosphorus (TP), total nitrogen (TN)], within any specific ecoregion or waterbody (Gibson et al. 2000). In regions where few or no minimally impacted lakes are identified, the lower 25th

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percentile of the frequency distribution of the entire lake database has sometimes been equated with the reference condition (Gibson et al. 2000). US EPA developed ambient reference conditions for TP, TN, planktonic chlorophyll *a* (Chl *a*), and Secchi Depth (SD) in the 14 aggregate nutrient ecoregions by this method (Heiskary and Wilson 2005; Paul and Gerritsen 2002; Walker et al. 2007). And the trisection method was recommended for biotic integrity indices (US EPA 1998b) as a better alternative to the lake population distribution. The trisection method has been used to estimate reference conditions when all of the lakes had some degree of disturbance in their watersheds (Dodds et al. 2006). An additional multiple linear regression method applied to lakes considers the statistical relationships to predict Chl *a* and SD values. The reference values of the predictors are used to predict Chl *a* and SD (response variables) reference conditions.

Since the European Commission Water Framework Directive was promulgated, Member States have started to develop lake ecological status assessment systems and finished setting of TP and Chl *a* as reference conditions for European lakes in different lake types and ecoregions (Cardoso et al. 2007; Carvalho et al. 2008; Poikane et al. 2010). In recent years, some researchers have initiated studies on methods of nutrient criteria development in China, and a Regional Nutrient Criteria Research Plan has been carried out in 2008 (Huo et al. 2009, 2012). Xinjiang province, as an arid and semiarid lake ecoregion, is investigated in this study.

Most of the lakes in arid and semiarid ecoregion (Xinjiang lake ecoregion) are inland, and have big differences in total dissolved solid (TDS) for various lakes (Jin et al. 1990). TDS has a significant influence on the growth of algae (Ahmad and Hellebust 1985; Jackson et al. 1987). Hence, it is necessary to classify the lakes based on TDS, and explore the reference conditions of various lake types. The objectives of this study are to (1) investigate the trophic status indicators in seven typical lakes, and (2) test three methods for determining reference conditions for various lake types within the Xinjiang lake ecoregion in China.

Materials and methods

Study area

Xinjiang lake ecoregion is located in the northwest of China, situated in arid and semiarid zones, with an average annual temperature of 6.1 °C (average maximum 43.1 °C in July, and average minimum −42.8 °C in January) (Jia et al. 2004). It is located at the confluence center of inland basin, or tail of the river that is the destination of inland

water system. The total area of lakes in this region is 16,400 km², about 20.1 % of all lake surface area in China. Most lakes in this region are classed as inland drainage lakes, which have no connection with any ocean directly. Because of the arid climate, the water source for the lakes is in short supply; consequently, the lake water is continuously concentrated and salt content is usually high. Except for very few fresh water lakes, most lakes in the region are either salt or brine ones (Jin et al. 1990). Seven typical lakes have been selected to test three methods for determining reference conditions (Fig. 1).

Data sources and data quality

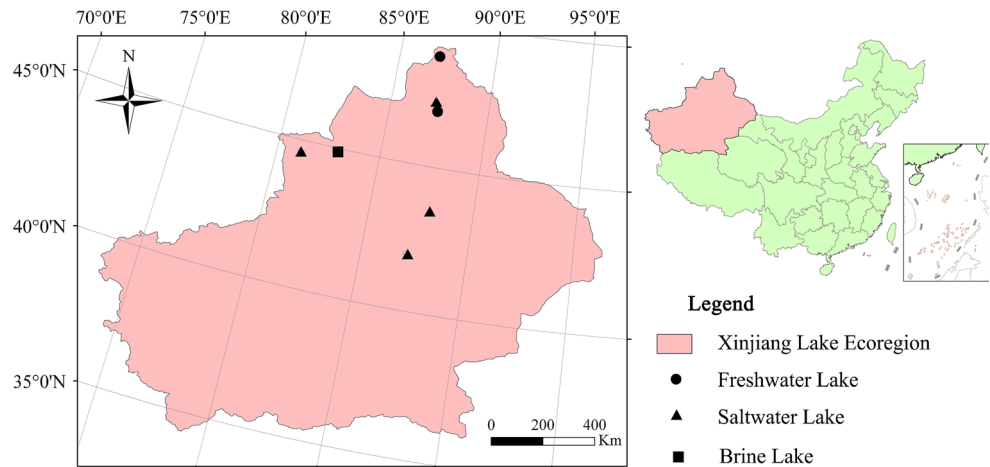
Physico-chemical and biological parameters were studied in this study: dissolved oxygen (DO) as oxygenation conditions, pH as an indicator of acidification status, TDS as an indicator of salinity, nutrients (such as TN and TP) as driver variables, and planktonic Chl *a*, and SD as response variables. Data were collected from lakes across Xinjiang lake ecoregion as part of the ambient monitoring network maintained by the Department of Environmental Protection of the Xinjiang Provinces, China. Data were included from seven lakes that had at least one survey in separate years over this time interval (2005–2010). The DO, pH, TDS, TP, TN, Chl *a*, and SD were measured according to the standard methods (EPA of China 2002).

The minimum reporting limits used for this analysis were 0.01 and 0.1 mg/L for TP and TN, respectively. Observations in the database below detection limits were replaced with values equal to one-half the detection limits since these observations were encountered infrequently (less than 15 % of the total dataset). The method of one-half the detection limit was reported to be sufficiently accurate for determining descriptive statistics like the mean and standard deviation (Dodds et al. 2006; Suplee et al. 2007; US EPA 2006).

Setting of reference conditions

Reference lake method is a common method for establishing reference conditions at present (Gibson et al. 2000; Huo et al. 2012; Poikane et al. 2010). Reference lakes are minimally impacted by human activity and, therefore, represent the least disturbed condition for comparison with other lakes within the region (Angradi et al. 2009). A general rule of thumb for reference sample size could be at least 10 percent of the lake class of concern (Gibson et al. 2000). The 75th percentile of the frequency distribution of these reference lakes can be selected as the reference condition for each variable. Since there is a lack of information on reference lakes in the Xinjiang ecoregion lakes, this method is not an appropriate method for the ecoregion

Fig. 1 The spatial distribution map of lakes and lake types in Xinjiang lake ecoregion



lakes. Therefore, lake population distribution method and trisection method can be as surrogates (Gibson et al. 2000; US EPA 1998a, b).

The lake population distribution method does not involve specific identification of reference lakes, but provides a basis for estimating reference condition by the use of all the lake data presently available and selecting percentiles of frequency distribution for each variable in the ecoregion lakes. In areas where few or no minimally impacted lakes are identified, the lower 25th percentiles of TP, TN, and Chl *a*, reflecting high nutrient quality, can be selected as the reference conditions for the ecoregion (Dodds et al. 2006; Gibson et al. 2000). Using the same logic described for SD, the opposite end of the distribution (i.e., upper 25th percentile) is used because greater SD is associated with higher water quality (Gibson et al. 2000).

The trisection method is also a good alternative for determining reference condition in the ecoregion lakes. Some researchers more recently have adopted the trisection method recommended for biotic integrity indices as a better alternative (US EPA 1998b). The trisection method initially considered all the sampled lakes and retained that third with the lowest nutrient or Chl *a* concentrations or with the greatest SD, assuming that the least-impacted water bodies were represented by the best one-third of the distribution (US EPA 1998a, b). The 50th percentile (median) values derived from the best one-third of the data are considered as reference conditions. The problem with this method is its sensitivity to the proportion of impacted sites and the degree of regional impact (Dodds et al. 2006).

The final method for determining reference conditions is to predict Chl *a* and SD using multiple linear regressions. The predictors (independent variables) are selected from a number of chemical and physical indexes, including TP, TN, pH, DO, and TDS. Then reference values of the predictors are used to predict Chl *a* and SD (response variables) reference conditions. Similarly, TP or TN can be

predicted from land use and lake morphometry (Soranno et al. 2008).

It is well known that no single value can represent reference conditions over all types of water bodies. Lake ecosystems are complex and their characteristics mutually vary within large ranges, determined by external and internal factors (Moss et al. 2003). Therefore, the final results of reference conditions were expressed as ranges, not fixed values.

Classification of lakes

Total dissolved solid (TDS) is a measure of the combined content of all inorganic and some small amounts of organic substances that are dissolved in water, including molecular, ionized or micro-granular (colloidal sol) suspended form. It is often used as an indication of salt content in water body and as an aggregate indicator of the presence of a broad array of chemical contaminants.

Salinity is known to be one of the key factors controlling the growth of algae. It had an effect on both split ability and metabolic rate of algae, even influenced the algae aggregate state (Wong and Chang 2000). Algae differ in their ability to adapt to a varied range of salt conditions, and the optimum salinity interval was also very different. When salinity was below or above the optimal range, perhaps through influencing osmoregulation, the absorption ability for salinity was reduced, and photosynthesis and growth of algae were inhibited under these conditions (Vincent 2001; Wiencke and Davenport 1988).

Hence, based on the various concentrations of TDS, seven typical lakes in Xinjiang region were grouped into three different types, including freshwater lakes (TDS ≤ 1 g/L), saltwater lakes (1 g/L < TDS ≤ 35 g/L), and brine lakes (TDS > 35 g/L) (Jin 1995). The spatial distribution map of seven typical lakes in the Xinjiang ecoregion is illustrated in Fig. 1, and the basic information of these lakes is shown in Table 1.

Table 1 The basic information of lakes in Xinjiang ecoregion (Wang and Dou 1998)

Lake type	Lake name	Lake area (Km ²)	Maximum depth (m)	Mean depth (m)	Sampling sites
Freshwater lake	Kanas lake	44.78	188.50	120.10	5
	Jili lake	174.00	14.70	9.90	4
Saltwater lake	Bosten lake	992.20	16.50	8.08	14
	Chaiwopu lake	30.00	6.10	4.18	5
	Sayram lake	453.00	86.00	46.40	5
	Ulungur lake	753.00	12.25	8.00	6
Brine lake	Aibi lake	1,070.00	2.80	1.40	5

Statistical analysis

Values for TN, TP, Chl *a*, SD, TDS, pH, and DO were log₁₀ transformed to accommodate heterogeneity of variance prior to statistical analyses, and all statistical analyses were undertaken on raw survey data. Relationships between the aforementioned variables were initially described by Pearson correlations and inspection of scatter plots. To derive type-specific reference conditions, descriptive statistics were used for TP, TN, Chl *a* and SD (medians, quartiles and percentiles) by each lake type. Linear regression models via stepwise method were used for predicting Chl *a* value and SD.

Results

Lake types analysis

The characteristics of the freshwater lakes, saltwater lakes, and brine lakes are shown in Fig. 2. As shown in Fig. 2, freshwater lakes were characterized by relatively low concentrations of TP, TN, Chl *a* and large SD values, saltwater lakes were characterized by the large TP, TN, Chl *a* concentrations and small SD values, and brine lakes by the largest TP, TN, Chl *a* median concentrations and the smallest SD values. In addition, analysis of Kruskal–Wallis Test demonstrated that there were significant differences in the values of TP, TN, Chl *a*, and SD in various lake types ($p < 0.05$).

Reference conditions established by descriptive statistics

Lakes that are known to be severely impaired may be excluded from the sample. The population distribution of each selected variable is determined. The best 25th percentile of the distribution of each nutrient variable is taken as its reference value in seven typical lakes. Reference conditions for TP, TN, Chl *a*, and SD based on the dataset

of all lakes can be seen in Table 2. The reference values determined by the best one-third of lakes (trisection method) are also listed in Table 2.

As shown in Table 2, the values derived from the method of lake population distribution were a little higher than those from trisection method (SD values were opposite), suggesting that the trisection method lends itself to more conservative estimate of reference condition. For freshwater lakes, reference TP and TN values for the trisection method were in accordance with those for the method of lake population distribution (Table 2). Reference SD was 3.50 m for the trisection method and 2.69 m for the method of lake population distribution (Table 2). Finally, median reference Chl *a* values were 0.86 µg/L for the trisection method and 0.96 µg/L for the method of lake population distribution (Table 2). In addition, the analysis of Paired Samples *T* Test revealed that there was no significance difference in reference values derived by lake population distribution and trisection methods ($p > 0.05$).

Moreover, as expected, there were significant differences among various lake types in reference nutrients, Chl *a*, and SD. For example, reference TP values were both 0.005 mg/L for freshwater and saltwater lakes, but 0.010 mg/L for brine lakes. Reference TN values 0.11 mg/L for freshwater lakes, 0.58–0.69 mg/L for saltwater lakes, but 1.13–1.22 mg/L for brine lakes. Reference Chl *a* concentration were 0.86–0.96 µg/L, 0.64–0.86 µg/L, and 7.00–7.60 µg/L, respectively. Finally, reference SD had a value of 2.69–3.50 m, 2.64–3.00 m and 0.43–0.45 m, respectively.

Multiple regression models for reference chlorophyll *a*

Prior to establishing reference conditions, Pearson correlations were computed for each pair of variables to select the potential predictor variables in various lake types (Table 3). In freshwater lakes with extremely low TDS, there were no significant correlations between TDS and other variables; while Chl *a* and TP were both correlated with SD (Table 3). Hence, linear regression models were

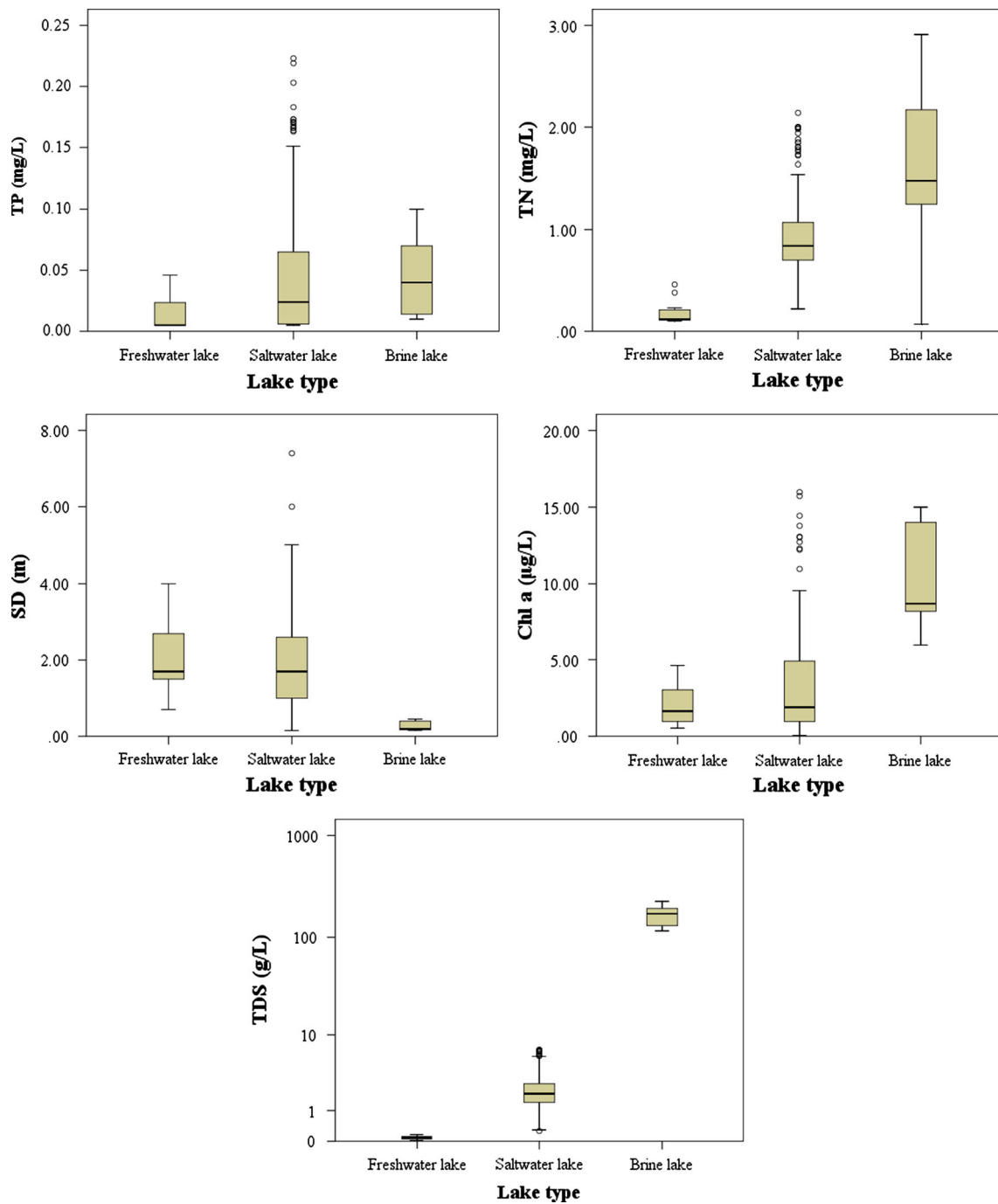


Fig. 2 Box plots of TP, TN, SD, Chl *a*, and TDS for various lake types in Xinjiang ecoregion

only built to predict the values of SD (Table 4) in freshwater lakes.

The values of TDS for saltwater lakes were between 1 and 35 g/L, which were appropriate for algae growth. Algae photosynthesis strengthened, and respiratory function declined with an increase in TDS (Vincent 2001). This is beneficial to the accumulation of organic matter, and facilitates the growth of algae, hence an increase Chl

a concentration and a reduction in transparency. To better understand the relationship between TDS and TN, TP, Chl *a* and SD in saltwater lake, the scatter plots of the variables are illustrated in Fig. 3.

Table 3 and Fig. 3 indicated that significant positive correlations ($p < 0.01$) existed between several of the candidate explanatory variables in simple correlation analysis, especially between TDS and other variables, between

Table 2 Establishment of reference conditions for various lake types using lake population distribution and trisection

Parameters	Lake population distribution (25 %)	Trisection (median)	Parameters	Lake population distribution (25 %)	Trisection (median)
Freshwater lake (TDS < 1 g/L)					
TP (mg/L)	0.005	0.005	SD (m)*	2.69	3.50
TN (mg/L)	0.11	0.11	Chl <i>a</i> (μg/L)	0.96	0.86
Saltwater lake (1 g/L < TDS < 35 g/L)					
TP (mg/L)	0.005	0.005	SD (m)*	2.64	3.00
TN (mg/L)	0.69	0.58	Chl <i>a</i> (μg/L)	0.86	0.64
Shallow and brine lake (TDS > 35 g/L)					
TP (mg/L)	0.010	0.010	SD (m)*	0.43	0.45
TN (mg/L)	1.22	1.13	Chl <i>a</i> (μg/L)	7.60	7.00

* SD: opposite end of the distribution

Table 3 Correlations between enrichment measures and physical variables in Xinjiang ecoregion lakes for various lake types

	TP	TN	Chl <i>a</i>	SD	pH	DO	TDS
Freshwater lake							
TP	1						
TN	0.016	1					
Chl <i>a</i>	0.286	-0.011	1				
SD	0.449*	0.257	0.491*	1			
pH	0.117	0.458	-0.166	0.105	1		
DO	0.008	0.094	0.344	0.249	-0.147	1	
TDS	-0.043	-0.032	-0.054	-0.057	-0.088	-0.109	1
Saltwater lake							
TP	1						
TN	0.467**	1					
Chl <i>a</i>	0.153	0.117	1				
SD	-0.237**	-0.156*	-0.240**	1			
pH	0.279**	0.075	0.150	0.033	1		
DO	-0.098	0.033	-0.112	0.120	-0.073	1	
TDS	0.585**	0.485**	0.397**	-0.417**	0.217**	-0.133*	1
Brine lake							
TP	1						
TN	0.008	1					
Chl <i>a</i>	-0.718*	-0.517	1				
SD	0.709*	0.743*	-0.347	1			
pH	-0.870**	-0.055	0.457	-0.817**	1		
DO	-0.306	0.162	-0.392	-0.376	0.310	1	
TDS	0.741**	-0.260	-0.837*	0.890*	-0.675**	-0.644**	1.000

** Correlation is significant at the 0.01 level (2-tailed)

* Correlation is significant at the 0.05 level (2-tailed)

Chl *a* and SD. In addition, SD was significantly associated with TN and TP ($p < 0.05$).

In brine lakes with extremely high TDS, algae photosynthesis weakened and respiratory function enhanced with an increase of TDS (Wiencke and Davenport 1988). This is adverse to the growth of algae; hence decrease Chl *a* concentration and increase transparency. As shown in Table 3 and Fig. 4, significant correlations ($p < 0.05$) existed between TDS and Chl *a*, SD, TP; between SD and TN, TP; and between

Chl *a* and TP. In addition, TDS was no significantly associated with TN.

In terms of the significant correlation between Chl *a*, SD and other variables, multiple linear regression models via stepwise method were built to predict Chl *a* and SD using all the available lake data from the three lake types (Table 4). Variables were listed in the order in which they explain model variance, and the p values were less than 0.05 for each model. Then reference values were used for the independent variables to predict the Chl *a* and SD

Table 4 Multiple linear regression models to predict chl *a* and SD from TP and TDS for various lake types in Xinjiang ecoregion lakes

Models	<i>F</i>	<i>p</i>	<i>R</i> ²	Predicted values
Freshwater lakes				
lg(SD) = 0.229 * lg(TP) + 0.711	5.801	0.024	0.201	1.53 m
Saltwater lakes				
lg(Chl) = 0.786 * lg(TDS) + 0.0086	19.700	<0.001	0.131	1.71 μg/L
lg(Chl) = -0.008 * lg(TP) + 0.781 * lg(TDS) - 0.012	10.134	<0.001	0.130	1.69 μg/L
lg(SD) = -0.192 * lg(Chl) + 0.230	10.151	0.002	0.067	1.75–1.85 m
Brine lakes				
lg(Chl) = -0.527 * lg(TP) + 0.350	7.452	0.029	0.516	25.35 μg/L
lg(SD) = 2.485 * lg(TDS) - 5.989	15.162	0.017	0.791	0.360 m

associated with those concentrations. The predicted values from the linear regression were inferior to the values derived directly from the statistical distribution, with higher Chl *a* (1.69–1.71 μg/L for saltwater lake, 25.35 μg/L for brine lake) and lower SD (1.53 m for freshwater lakes, 1.75–1.85 m for saltwater lakes, 0.36 m for brine lakes). This may be attributed to some environmental factors, such as suspended particle, dissolved color, which may potentially confound the relationship between driver variables and response variables. These models should be validated with future reference lake data, but the modeling method holds promise as a potential tool for predicting Chl *a* reference targets and certainly supports the reference targets derived directly from the statistical distribution of Chl *a* and SD.

If one method may yield an unexpectedly high or low reference value, such a value can be checked using the other methods or explained (Huo et al. 2012). Thus, the values and ranges considered as nutrients reference conditions for seven typical lakes in Xinjiang ecoregion are

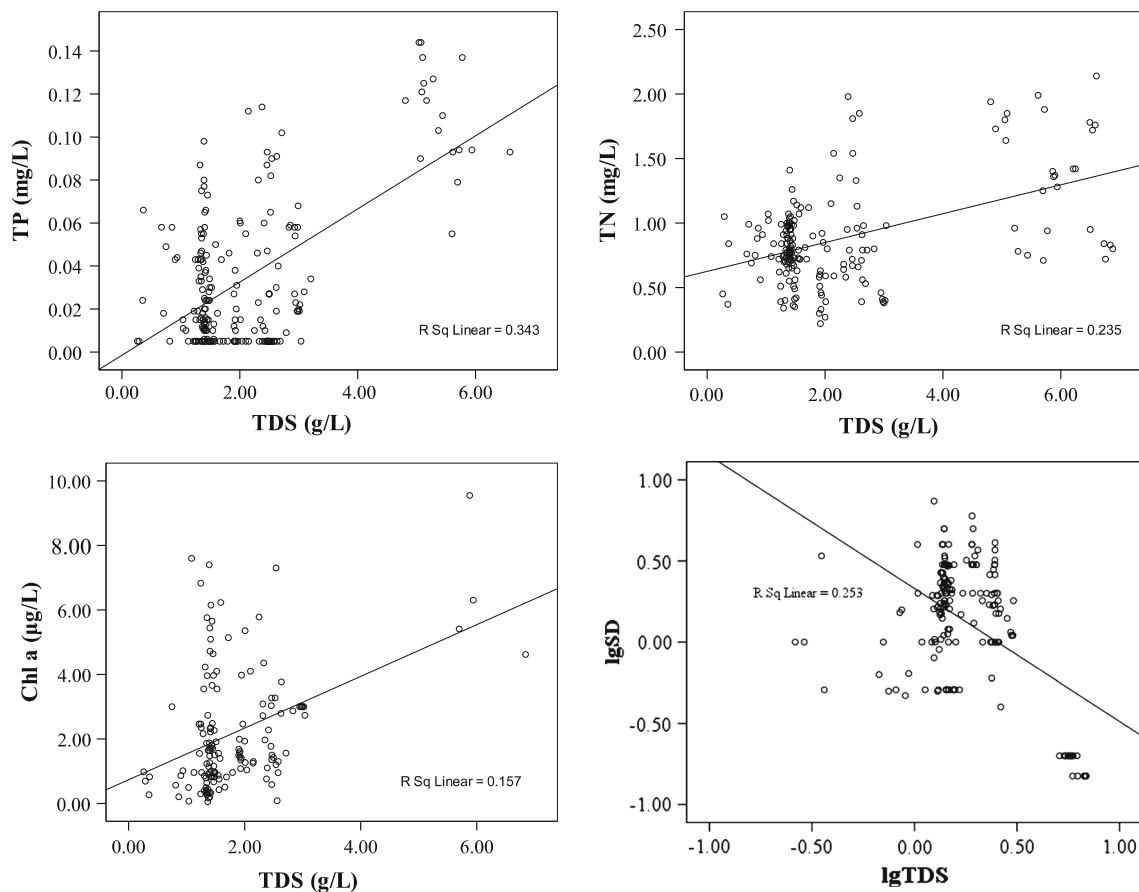


Fig. 3 Scatter plots of SD, Chl *a*, TP, TN, and TDS for saltwater lakes

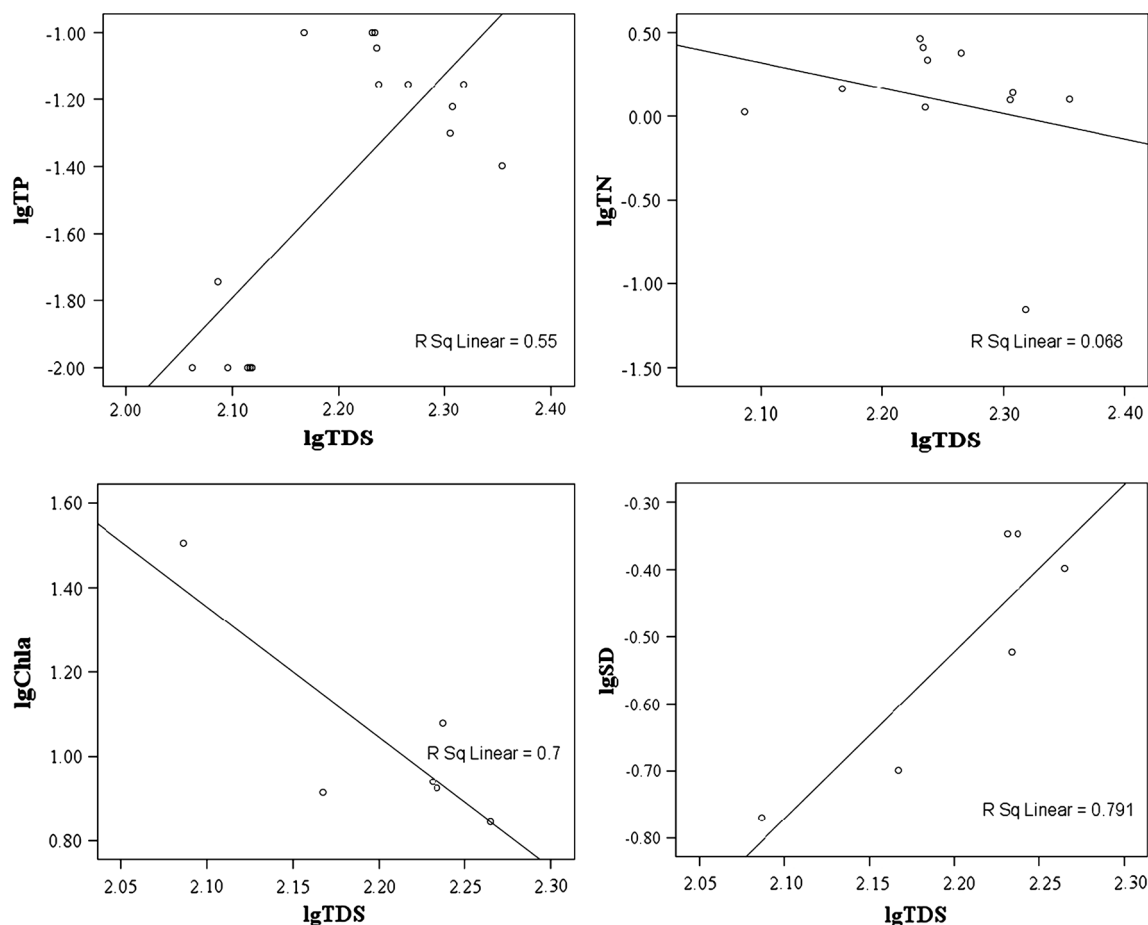


Fig. 4 Scatter plots of SD, Chl *a*, TP, TN, and TDS log₁₀ transformed for brine lakes

given as follows: TP 0.005 mg/L, TN 0.11 mg/L, Chl *a* 0.86–0.96 µg/L, SD 2.69–3.50 m for freshwater lakes; TP 0.005 mg/L, TN 0.58–0.69 mg/L, Chl *a* 0.64–0.86 µg/L, SD 2.64–3.00 m for saltwater lakes; TP 0.010 mg/L, TN 1.13–1.22 mg/L, Chl *a* 7.00–7.60 µg/L, SD 0.43–0.45 m for brine lakes.

The analysis of trophic state indices (Carlson 1977) showed that TSI (SD) were much larger than TSI (Chl *a*) in most lakes of Xinjiang ecoregion. This indicated that under the hot and dry weather, suspended particles (may not contain phosphorus) were much gathered in water, greatly reducing the water transparency (Carlson and Havens 2005). In addition, the correlation between Chl *a* and TDS (seen in Table 3; Figs. 3, 4) significantly existed in saltwater and brine lakes ($p < 0.05$), demonstrating that TDS had a great impact on the concentration of Chl *a*.

The obtained values of reference condition can be transformed into the TLI (Σ) (Jin and Tu 1990). It is calculated that the TLI (Σ) range of lake reference condition is from 19 to 21 for freshwater lakes; 25–28 for saltwater lakes and 47–48 for brine lakes. It shows that the trophic states of reference condition for various lake types

in Xinjiang ecoregion correspond to oligotrophic, oligotrophic, and mesotrophic, respectively.

Discussion

Results showed that there were significant differences in the reference conditions of three type lakes for seven typical lakes in Xinjiang ecoregion. Brine lakes generated larger values for nutrients and Chl *a*, and lower values for SD than the other two lake types. This is because the sample of brine lakes has a high proportion of shallow lakes (see in Table 1) influenced by salinization, which generally have high nutrient concentration and low transparency (SD: 0.43–0.45 m) due to wind and wave action in these shallow lakes. The vast majority of fresh and saltwater lakes are deep (see in Table 1), which favors long-term stability and lower nutrient concentrations. Hence, the reference conditions of freshwater and saltwater lakes were characterized by lower nutrient concentrations and higher transparency compared to those of brine lakes. This illustrated that the differences of reference conditions among

various lake types had a strong correlation with the value of salinity. The determination of reference conditions for the special-type lake provided a support for nutrient criteria, and avoided the under-protection of lakes.

These three methods are not exclusive; all methods could be used simultaneously to provide different values for comparison. Where undisturbed or nearly undisturbed conditions are difficult to identify, and sufficient data are available in a region, both population distribution and trisection methods could be given preference for determining the regional reference condition. The trisection method can act as a surrogate for identifying reference lakes, but it is not recommended for regions with widespread anthropogenic impacts (Dodds et al. 2006). If degraded conditions prevail and appropriate data exist to adequately quantify the relationship of variables, the multiple regression models would be preferred to provide a statistically defensible method.

In USA, nutrient reference conditions of ecoregion III (Xeric West) were determined using lake population distribution method (US EPA 2001). Although the ecoregion is classed as the same climate zone (temperate continental climate) as Xinjiang ecoregion, their reference values have large differences. The ecoregion III (mainly freshwater lakes) is composed of unforested basins and plateaus with scattered mountains and buttes, and has high concentrations of dissolved solids, nitrite plus nitrate (Gibson et al. 2000; Rohm et al. 2002). In ecoregion III, areas of high human population density occur along with associated nutrient inputs (Gibson et al. 2000), leading to water quality serious deterioration. The TP and Chl *a* criteria of ecoregion III, hence, were larger than those of freshwater lakes and saltwater lakes in Xinjiang ecoregion. These results illustrated that the establishment of lake nutrient reference conditions is a critical consideration in the development of scientifically defensible aquatic nutrient criteria.

Conclusions

In this study, nutrient reference conditions for seven typical lakes in Xinjiang ecoregion were established by the methods of lake population distribution and trisection. Additionally, regression models were developed for estimating reference Chl *a* concentration and SD, successfully for various lake types. The results of different methods for setting reference conditions using at least three potential available methods may make the reference values more credible and defensible. Any one method may yield an unexpectedly high or low reference value, but such a value can be checked by the other methods. Available data suggest that the reference conditions of freshwater lakes,

saltwater lakes, and brine lakes in Xinjiang ecoregion correspond, respectively, to oligotrophic, oligotrophic, and mesotrophic status. The attempts and application of setting reference conditions would provide an experience support for nutrient criteria development in China.

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