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Applicability of diatom based indices for Water quality assessment in Iran ecosystems: case study Gorganrood subbasin (NE Iran)

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Abstract

One of the fundamental factors affecting the ecological health of river is water quality. Accordingly, the biological status of diatoms in relation to water quality in rivers, especially in Iran, has received less research attention. Hence, diatom indices (TDI and GDI) in relation to practical water quality indices (IRWQIsc and NSFWQI) were used to assess the ecological status of four major tributaries within the Gorganrood River basin, as a major river system in northeastern of Iran. In this regard, water and diatom samples were collected on a monthly basis interval from August 2013 through May 2014. In total 73 diatom taxa belong to the 30 genera were identified. According to the mean values of TDI, Zarringol and Chehelchay stations categorized in the oligotrophic status with high quality, while Gharachay and Oghan stations categorized in class 2 with good quality. In addition, mean values of the GDI shows that except for Oghan station which categorized in class 1 with high quality, other three stations are classifying in class 2. Also, according to the $IRWQI_{SC}$ and NSFWQI results, almost all stations categorized in the good class. Consequently, results showed that TDI and GDI values are significantly correlated; however, there was no significance relationship between these indices with IRWQIsc and NSFWQI. It seems that further works are needed to clarify the usefulness of diatom indices in relation to water quality assessments in Iran.

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Introduction

Surface water pollution ranks among the most pressing global environmental challenges (Pasand et al., 2019). In response, biological assessment methods have emerged as essential complements to traditional physical and chemical analyses for water quality evaluation (Lobo & Callegaro, 2000). Over recent decades, the scientific community has increasingly adopted integrated approaches that combine chemical parameters with biological indicators (Bate et al., 2004). Among the various bio-indicators employed – including benthic macro-invertebrates, fish communities, and diatoms. Diatoms have proven particularly valuable due to their unique advantages as ecological indicators (Whitton & Kelly, 1995; Hill et al., 2000; Ramos et al., 2012).

Diatoms are a large and diverse group of single-celled algae belongs to the class Bacillariophyceae.; which are distribute all over the world in nearly all types of aquatic systems; in addition, taxonomically diverse with many thousands of taxa having diverse ecological requirements; (Stoermer and Smol 1999). They are sensitive to the stressors and rapidly respond to the environmental changes by change in composition and diversity (Stevenson and Pan 2001).

In many countries, standardized methods based on diatom assemblages have been developed long before (Descy and Coste 1991; Kelly et al. 1998; Stevenson and Pan, 2001); however, in Iran, limited studies have been conducted using diatom indicators to assess the water quality of ecosystems. This may be due to the lack of sufficient data on diatoms. The only study in this trend, has been done by Atazadeh et al (2007) who used TDI (Trophic Diatom Index) in Gharasou River (west of Iran), and concluded that the TDI can use as an indicator of water pollution in Iranian rivers. Gorganrud is one of the main rivers in northeast of Iran which is highly impacted by the land use practices (Heshmatpour et al, 2025). In this regard, water quality of this river can be categorized by using $IRWQI_{SC}$ and NSFWQI indices as studied in these area by some researchers and then linked the results with diatoms indices. Therefore, the aims of this research was to conduct a comparative evaluation of diatom-based indices (GI and TDI) in relation to water quality indices ($IRWQI_{SC}$ and NSFWQI).

Material and Methods

Gorganrood River basin is located northeast of Iran in Golestan Province. The river originates from Aladagh Mountain in Bojnourd City, and after passing 250 km flows to the Gorgan plain and ultimately reaches to the Caspian Sea. Several tributaries join to Gorganrood River from east and south (Arekhi et al., 2022). The study area encompasses four tributaries of the Gorganrood River, includes Zarringol in Aliabad, Gharachay in Ramian, ChehelChay in Minudasht and Oghan Rud in Galikesh (Figure 1).

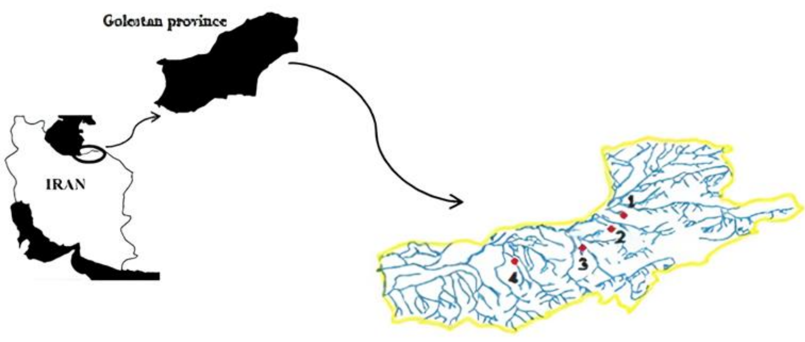

Figure 1. Location of studied rivers (1: Oghan Rood, 2: ChehelChay, 3: Gharachay, 4: Zarringol)

Water and diatom samples were collected monthly from August 2013 to May 2014 from four stations (Oghan, Chehelchay, Gharechay, and Zarringol) in the Gorganroud River. According to Kelly et al. (1998), five rocks were collected from the rocky beds at each station, and epilithic diatoms were separated using a toothbrush and preserved in 3% formalin according to Ahmadi-Musaabad et al., 2019; Panahi-Mirzahasanloo et al., 2021, 2024. Then, organic matter was removed by oxidation with hot HNO3, and permanent diatom slides were prepared using Naphrax (three slides for each sample). Diatom species were identified using a light microscope (with 1000x magnification) based on the diatom flora (Krammer and Lange-Bertalot 1986, 1988, 1991a, 1991b). To calculate the relative abundance of each species, at least 400 valves were counted. Analysis of the relationship between water quality and diatom distribution was carried out according to Kent and Cocker, 1975, using the DCA classification method and CANOCO-5 software. Shannon-Wiener indices (1998) were used to measure species diversity, and Pielou index (1966) was used to measure species evenness, and the diatom trophic index (TDI) and diatom generic index (GI) were used to express the ecological status of the river with the help of biological indices.

TDI was calculated based on weighted average equation of Zelinka and Marvan (1961) according to Kelly et al. (2001; 2014). Other index used to characterize the diatom community was generic diatom index (GI) which is based on genera (Coste and Ayphassorho 1991). The water quality classes and ecological status based on these two indices were used according to classification presented in Noga et al. (2014).

River water samples were collected, transported, stored, and then the necessary tests were performed using the standard method (APHA, 1999): Temperature ‹DO (Dissolve Oxygen), (Biological Oxygen Demand) BOD, (Chemical Oxygen Demand) COD, (Electrical Conductivity) EC, (Total Dissolve Sediment) TDS, (potential Hydrogen) PH, (Total Hardness) TH, NH4 (Nitrate), (Phosphate) PO4, Fecal coliform, Turbidity.

In order to investigation of the applicability of diatom based indices for water quality analysis, two water quality indices ($IRWQI_{sc}$ as a local index and NSFWQI as reference index) were selected. Many studies in Iran have applied $IRWQI_{sc}$ index to assess water quality across different ecosystems (Hamedi et al. 2015; Samadi 2016; Bagherpour et al. 2017; Makhlough et al. 2017; Aghayi et al., 2019, Ebraheim et al. 2020, Heshmatpour et al. 2025). Also, NSFWQI water quality index is one of the most important indices widely used for water quality assessments (Ghaziyani et al., 2020, heshmatpour et al. 2025). The parameters involved in these indices and their weights were presented by Aghayi et al., (2019) and Heshmatpour et al., (2025). The indices were calculated according to following equations:

$$NSFWQI = \sum_{i=1}^{n} I_i W_i$$

Where the I_i is the sub-index value of each parameter, W_i is the parameter's weight score and n is the number of parameters (Oram 2007).

$$IRWQI = \left[\prod_{i=1}^{n} I_i^{W_i} \right]^{1/\gamma}$$

Where $\gamma = \sum_{n=1}^{n} W_i$, I_i and W_i are the sub-index value and weight scores of the parameter I respectively and n is the number of parameters (Hashemi et al., 2011; Ebraheim et al., 2020).

After testing for data normality, Spearman's correlation coefficients were used to analyze the relationships between water quality indices and diatom-based indices. In addition, one-way analysis of variance (ANOVA) followed by Tukey's multiple comparison test (SPSS 16) was used to examine differences in species diversity, evenness, and richness among stations.

Results

In total, 73 diatom taxa belong to the 30 genera identified. In 4 sampling stations, the highest abundance belonged to the species *Achnanthidium minutissium*. The results of DCA classification to investigate the relationship between epilithic diatom assemblage and physicochemical factors of the water quality are shown in Figure 2.

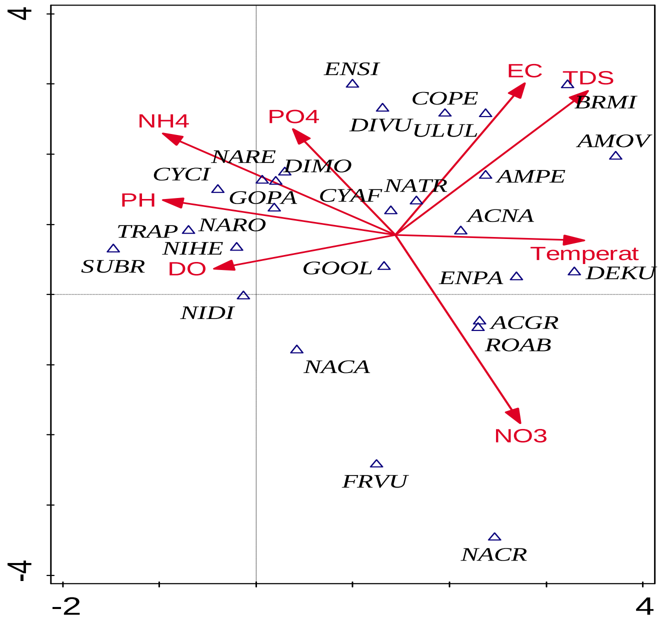

Figure 2. DCA classification diagram using epilithic species abundance data and water quality parameters at the study stations during the sampling period

According to the Figure 2, the most important influencing parameters are NO3, TDS, EC and NH4. In addition, *Achnanthidium gracillimum* (ACGR) and *Rhoicosphenia abbreviata* (RHAB) shows positive correlation with NO3, *Brachysira microcephala* (BRMI) with TDS and *Cocconeis pediculus* (COPE), *Navicula tripunctata* (NATR) and *Ulnaria ulna* (ULUL) with EC. In addition, *Diatoma moniliformis* (DIMO) shows positive correlation with PO4, *Gomphonema parvulum* (GOPA) and *Navicula reichardtiana* (NARE) shows positive correlation with NH4. Also, *Navicula rostellata* (NARO) and *Nitzschia incospicua* Grunow (NIIN) show positive relation with PH and DO respectively.

According to the formula in the references, the values of TDI, GI, Shannon diversity, Simpson diversity, Pielou Evenness, NSFWQI, and $IRWQI_{SC}$ indices calculated, and their averages are presented in Table 1.

Table 1: Mean value and standard deviation for measured indices

Index	Zarringol	Gharachay	Chehelchay	Oghan
TDI	28.71± 15.15	41.56±28.44	33.78±14.05	40.65±19.03
GI	15.87±2.37	14.52±1.73	17±2.08	17.42±2.17
Shannon diversity	1.3±0.46	1.66±0.47	1.55±0.33	1.48±0.33
Simpson diversity	0.56±0.15	0.71±0.15	0.64±0.21	0.67±0.08
Pielou Evenness	0.4±0.43	0.5±0.33	0.57±0.56	0.31±0.05
NSFWQI	73.4±29.41	73.5±42.19	72.5±95.36	73.3±30.59
$IRWQI_{SC}$	73.5±58.17	84.8±91.67	82.6±46.13	85.5±83.78

Based on the mean value of TDI, Zarringol and Chehelchay stations categorized in the oligotrophic status with high quality, while Gharachay and Oghan stations categorized in the oligo-mezotrophic with good quality. On the other hand, mean value of the GI shows that except for Oghan station which categorized in the high quality class, other three stations are classifying in the good quality class. Also, differences values of the TDI and GI between months were shown in Figure2 a, b. In addition, the values of the NSFWQI and $IRWQI_{SC}$ of four stations (Table 1) were categorized in good class and differences between data measured in various months were shown in Figure 2 c, d.

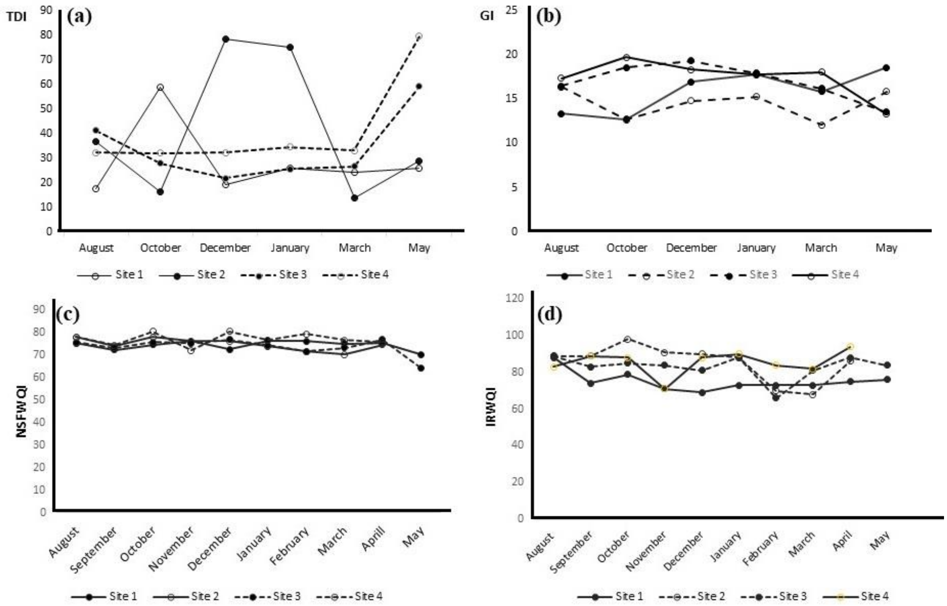

Figure 2. Monthly variation of TDI values (a), GI values (b), $IRWQI_{SC}$ (c) and NSFWQI (d) at the four sampling sites

Shannon diversity index ranged between 0.88 and 2.28 and Simpson index 0.4-0.84. Both indices showed highest values in Chehelchay station in August and the lowest value observed in Zarringol station in May. The highest evenness observed in Chehelchay station in May (0.68) and the lowest value observed in Zarringol station in January (0.16). The highest number of taxa was determined in the Gharachay station (23 taxa), while, the lowest number obseved in Chehelchay station (10 taxa) (Figure 3).

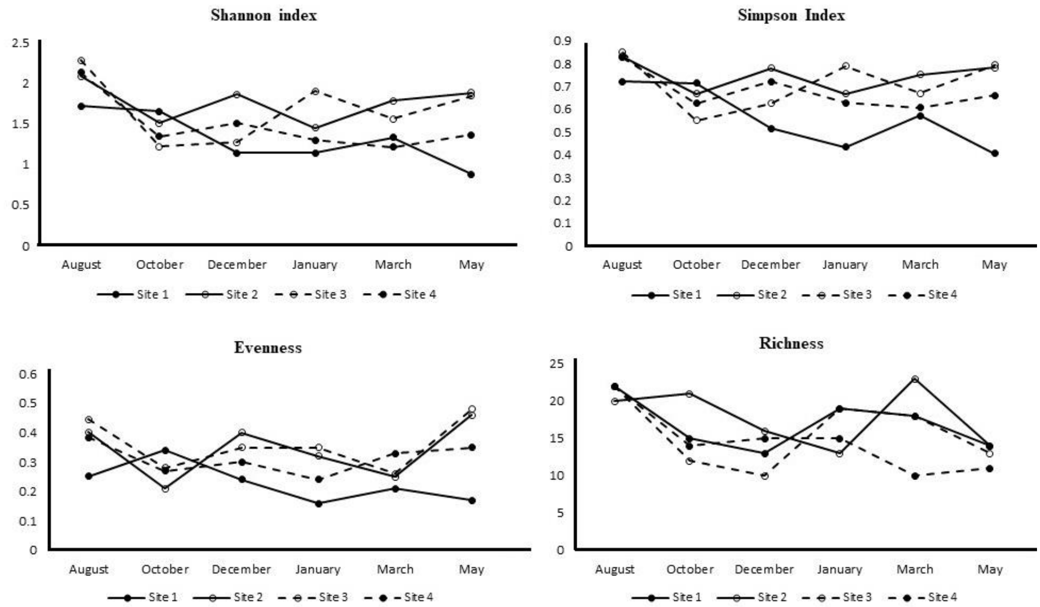

Figure 3. Values of the diversity indices during sampling period

Spearman's correlation coefficients showed that TDI and GI values are significantly correlated; however, there is no significance correlation between TDI, GI, Shannon diversity, Simpson index, Pielou evenness index and richness index with $IRWQI_{sc}$ and NSFWQI (Table 2).

Table 2. Spearman's Correlation coefficients between measured indices

Indicator species	TDI	GI	NSFWQI	IRWQI	Shannon	Simpson	Evenness	Richness
TDI	1.000	0.426*	0.185	0.210	0.263	0.341	0.610**	-0.310
GI	0.426*	1.000	0.094	-0.164	-0.430*	-0.396	-0.106	-0.362
NSFWQI	0.185	0.094	1.000	0.551**	-0.075	-0.107	-0.107	-0.016
IRWQI	0.170	-0.185	0.551**	1.000	0.250	0.250	0.250	0.197
Shannon	0.263	-0.430*	-0.075	0.250	1.000	0.978**	0.695**	0.584**
Simpson	0.341	-0.396	-0.107	0.250	0.978**	1.000	0.762**	0.493*
Evenness	0.610**	-0.106	-0.080	0.120	0.695**	0.762**	1.000	-0.128
Richness	-0.310	-0.362	-0.016	0.197	0.584**	0.493*	-0.128	1.000

* Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed).

In addition, the ANOVA followed by Tukey's multiple comparison test of diversity, evenness, and richness among stations indices showed no significant differences between sites ($p>0.05$).

Discussion

The main objective of this study was to evaluate the applicability of some biotic indices based on diatoms for water quality analysis in Gorganrood River. Therefore, TDI, GI, Shannon Index, Pielou evenness index and richness index, $IRWQI_{SC}$ and NSFWQI calculated for the study stations during the sampling period.

$IRWQI_{SC}$ is a national index confirmed as a reliable index for water quality assessment (Pourshahabi et al. 2018, Heshmatpour, et al. 2025). Also, NSFWQI is among the widely used indices for water quality analysis. Aghai et al. (2019), Ebraheim et al. (2020) and Heshmatpour et al. (2025) declared that to have a more comprehensive assessment of surface waters in Iran both indices are required. In this research results shows that a significant correlation between $IRWQI_{SC}$ and NSFWQI. Also, according to these indices, all stations located in good class of the water quality.

Kelly and Whitton (1995)'s TDI for monitoring the trophic status of the Gorganrood River was applied. TDI values showed a temporal variation in all studied sites and Kelly et al. (2008) have confirmed such variation in his study, therefore, they suggested repeated sampling in order to provide a firm basis (i.e. three per year for two years). They declared that greater sampling might be at risk of 'pseudo-replication'; hence, in our study excluded additional data. Atazadeh et al. (2007) used TDI index for water quality assessment in Gharasou River in west of Iran and found it useful for monitoring ecological conditions in streams. Although, according to the results of TDI index, our stations were in the high and good quality, however we found no correlations between TDI with $IRWQI_{SC}$ and NSFWQI indices. In comparison with TDI, GI values were more even in all stations during study period; however, as for TDI there was no significant correlation between GI with $IRWQI_{SC}$ and NSFWQI. In our study, GI positively correlated with TDI, similar results observed by Maraşlioğlu et al. (2020). The advantage of GI index is need for identification to the generic level.

Diversity indices commonly utilized in diatom studies (Ndiritu et al. 2006; Kupe et al. 2008; Jüttner et al. 2012). It has been demonstrated that heavily polluted waters always support low diversity and species richness in diatom assemblages (Lobo and Kobayasi 1990), however factors other than pollution can also affect the species diversity (Lobo et al. 1995). Assemblages, which have low diversity usually dominated by only a few species (low evenness). Shannon values range from 0 to 5, usually ranging from 1.5 to 3.5 and rarely exceed 4.5 (Magalef 1972). In our study, values mainly varied between 1 and 2 during the study period. Simpson index varies from 0 (low diversity) to 1 (Magurran 2004). Results of the Simpson index mostly were between 0.5 to 0.8 and showed high diversity than Shannon index. This is because, the Shannon index is strongly influenced by species richness and by rare species, while the Simpson index gives more weight to common species and is sensitive to abundant taxa (Magurran 2004). There were strong correlations between diversity indices. This is not surprising as they represent aspects of the same phenomenon. According to the ANOVA test, there were no significant differences among diversity indices between sites ($p>0.05$). Similar results also observed in Jüttner et al. (2012). Heino et al. (2009) related it to the insufficient environmental gradients and weakness of differences between water chemistry, which in turn reflected by no clear differences in species diversity components.

Conclusions

Many authors studied applicability of diatom indices to water quality assessment and confirmed that the indices are applicable to their regions because of many widely distributed diatom taxa with similar environmental tolerances recorded elsewhere (Bere and Tundisi 2011; Bere 2016). On the other hand, some other authors considered that diatom indices were developed for a particular region may not be suitable for evaluation of water quality in other regions (Pipp 2002). In our study, although results of the diatom indices and water quality indices was rather similar (Except for some instances, in general, all measured rivers had good quality); however, we found no significant correlations and relationships between indices. Whereas most of the dominant taxa are cosmopolitan taxa. It seems more works and additional data from other regions needed to clarify the usefulness of diatom indices in water quality assessments in Iran.

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Conflict of interest

The authors declare that they have no conflict of interest.

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