World Journal of Fish and Marine Sciences 5 (3): 257-262, 2013
ISSN 2078-4589

DOI: 10.5829/idosi.wjfms.2013.05.03.7297

Evaluation of Ecological Quality Status with the Trophic Index (TRIX) Values in Coastal Area of Arvand, Northeastern of Persian Gulf, Iran

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Abstract: Ecological indicators are commonly used to provide synoptic information about the state of ecosystems. Their main attribute is that they combine a range of environmental factors in a single value which is thought useful for management and for making ecological quality concepts easily understandable by the general public. In this study, the trophic status and water quality of Arvand River has been evaluated by using the trophic index TRIX. Water collection has been carried out at 9 sampling stations along the river between 2010 and 2011. The TRIX index integrates chlorophyll a, oxygen saturation, dissolved inorganic nitrogen and phosphorus. The index is scaled from 0 to 10, covering a range of four trophic statuses (high, good, moderate and degraded). The results demonstrate the river is in the first trophic state (0-4) which represents high quality and low trophic level.

Key words: Arvand River · TRIX Index · Trophic Status · Ecosystem

INTRODUCTION

In developing countries, more than 90 percent of wastewater and 70 percent of industrial wastes are discharged into coastal waters without being treated [1]. The entry of wastes into marine environment not only changes water quality parameters but also affects benthic organisms, cause habitat change and increases the risk of eutrophication and, thereby, causes the area to become susceptible [2]. The Urban Wastewater Treatment Directive defines eutrophication as the "enrichment of water by nutrients, especially compounds of nitrogen and/or phosphorus, causing an accelerated growth of algae and higher forms of plant life to produce an undesirable disturbance to the balance of organisms present in the water and to the quality of water concerned. Karydis [3] characterized "Oligotrophic" waters as nutrient poor with low productivity, "Eutrophic" waters as nutrient rich with high algal biomass and "Mesotrophic" waters as moderate conditions. Hypoxia or even anoxia is the last stage of eutrophication [4] and this phase is often characterized as "Dystrophic" [3]. In addition, eutrophication of coastal waters has been considered as one of the major threats to the health of marine ecosystems in the last few decades [5]. The risk of eutrophication may increase or decrease depending on the speed and direction of flow and wind. It can occur as a result of natural processes, for example, where there is upwelling of nutrient rich deep water to nutrient poor but light rich surface of the photic zone of the water column [6].

Various factors may increase the supply of organic matter to coastal systems, but the most common is clearly nutrient enrichment. The major causes of nutrient enrichment in coastal areas are associated directly or indirectly with meeting the requirements and demands of human nutrition and diet. The deposition of reactive nitrogen emitted to the atmosphere as a consequence of fossil fuel combustion is also an important anthropogenic factor [7]. Nutrients are the essential components of life in marine environment. Phosphorus and nitrogen are incorporated into living tissues and silicate is necessary for the formation of skeleton of Diatoms and Radiolaria [8]. In the sea, most of the nutrients are present in sufficient concentration and lack of some of them limits the growth of phytoplankton [9]. While some nutrient

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enrichment may be beneficial, excessive enrichment may result in large algal bloom and seaweed growth, oxygen depletion and the production of hydrogen sulphide, which is toxic to marine life and can cause high mortality, red tide events, decreasing fishery yields and nonreversible changes in ecosystem health [10].

Trophic conditions of coastal waters vary considerably from region to region and within regions. A trophic index (TRIX) characterizing eutrophic levels, was introduced by Vollenweider *et al.* [11]. The European Environmental agency has evaluated this index and suggested that TRIX scale at regional levels should be developed. TRIX values are very sensitive and any slight change of oxygen, Chlorophylla, dissolved inorganic nitrogen and total phosphorus concentrations results in changed index values [12]. This simple index seems to help synthesize key eutrophication variables into a simple numeric expression to make information comparable over a wide range of trophic situations [13].

In recent years, the scientific and technological advances have shown that studying sea and oceans, which cover 70% of the earth, is considerably important. Today in order to meet increasing need for food, the studies on food sources in our seas have gained speed. This study aims to determine the ecological quality of coastal waters in Arvand area, southwest of Iran.

METHODS AND MATERIALS

Study Areas: Arvand River with about 200 km lengths is located in Iran and Iraq as part of their border in southeastern side of Iran, this river is continuation of Tigris and Euphrates Rivers with joint together at al-Gurna, but there is another territory that makes water for Arvand Rood, it is Karun River that comes from Iranian side (Fig. 1). Arvand River flows in the Township of Khoramshahr, Abadan and to west of Mino Island. The border between Iraq and Iran down to the mouth of the river as it discharges in to the Persian Gulf. The width is varying from about 350m at Basra to 1600m at its mouth.The water carries very large amounts of mud and sediments so that the river should be dredged frequently to keep enough depth for ships to move along the river. Beside most important economic activities such as agriculture and heavy industries around river shipping oil from Iraq and Iran and large scale date productions is so valuable for both countries. The two major cities of the river are Abadan and Khoramshahr in Iran and Basra in Iraq.

Water Sampling: Sampling was done from nine sites, during four seasons, summer, autumn, winter and spring (2010-2011). The results have been summarized as an average. Samples are collected in sterile capped containers following the methods as described by APHA 14]. To avoid contamination, disposable gloves washed in 1N HCl were worn during water sampling. Sampling bottles were kept in large, airtight plastic ice-cold containers at 4°C and were transported to laboratory within 6h of their collection for further processing. Water temperature, PH, Turbidity, Electrical conductivity and Salinity were measured immediately after each sampling with water quality electrode (Hurbio-U10). Total dissolved solids (TDS), chemical oxygen demand (COD), biochemical oxygen demand (BOD), dissolved oxygen (DO), Sulphate (SO_4), Nitrate (NO_3) and ammonium (NH_4) by following the methods as described by APHA [14].

Fig. 1: Topography of the sampling site, Arvand River in Khuzestan province

Phytoplankton Sampling: Phytoplankton was taken from 2m water column seasonally from the stations, using Niskin bottles water samplers. The samples for qualitative analyses were preserved in 4% formaldehyde solution immediately after collection. Later on in the laboratory the preserved samples were left to stand for 24h in order to achieve sedimentation of the algal cells. After sedimentation the samples are concentrated first. The remaining water (50 ml) was centrifuged for 20s at 4000 rpm. The liquid phase was then immediately removed and remaining pellet r from preserved samples suspended in approximately 10 drops of sample water with Pasteur pipette. When the exact identification of genus proved impossible, fresh samples were used for assistance. Abundance of phytoplankton was estimated [15].

$$N = \frac{A*c*100}{v*f*l}$$

N = No. of plankton cells or units per liter of original water
F = Number of field counted
A = Total no. of plankton counted L=Volume of original water in liter
C = Volume of concentrated of sample in ml V=Volume of field in cubic mm

Statistical Analysis: Trophic index (TRIX) values were calculated in order to determine the eutrophication level of the sampling area and the quality of waters [11]. The index is given by:

TRIX= [log 10(chl a. D%O.N.P)+1.5]/1.2

Chl a= chlorophyl a, D%O= oxygen as an absolute deviation (%) from saturation, N=Dissolved inorganic nitrogen N-No_3 + No_2, P=total phosphorus p-po4. Ammonium values were not used in nutrients ratios and calculation of TRIX, because NH4 –N values were not measured in this paper. TRIX was scaled from 0 to 10, covering a range of four trophic states(0-4 high quality and low trophic level; 4-5 good quality and moderate trophic level; 5-6 moderate quality and high trophic level and 6-10 degraded and very high trophic level)[16,17].

Pearson correlation coefficient was used to detect any correlation among biotic (chlorophyll a) and abiotic variables (TRIX, DO and nutrients).

RESULTS

The chlorophyll a concentration over the entire period is shown in Fig. 2. The highest value (15.1) was determined at station 9 in summer. The lowest value (0.97) was detected at station 4 in winter. The high concentrations occurred during the growing season (summer).

Nutrient concentrations are shown in Fig. 3. and Fig.4. Maximum nitrogen concentrations were observed in summer and highest amount of phosphorus concentrations were measured in fall. The maximum amount belongs to station 1(0.0799) in fall and lowest content was detected at station 7(0.0097) in winter.

The dissolved oxygen concentrations are shown in Fig. 5. The highest DO value (9 mg) was measured in winter at station 4 and the lowest value (3 mg) was observed in fall at station 9. The oxygen concentrations

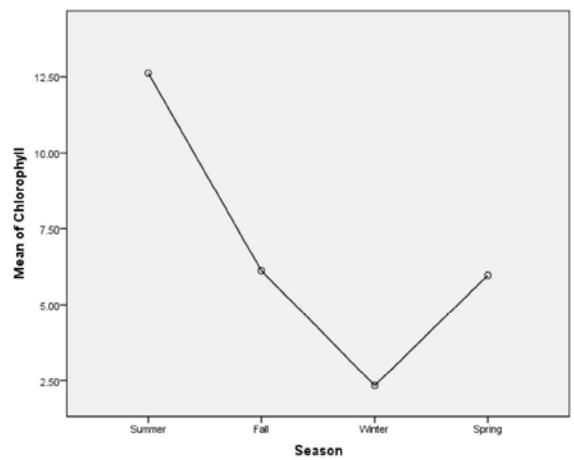

Fig. 2: Chlorophyll a concentration in different seasons

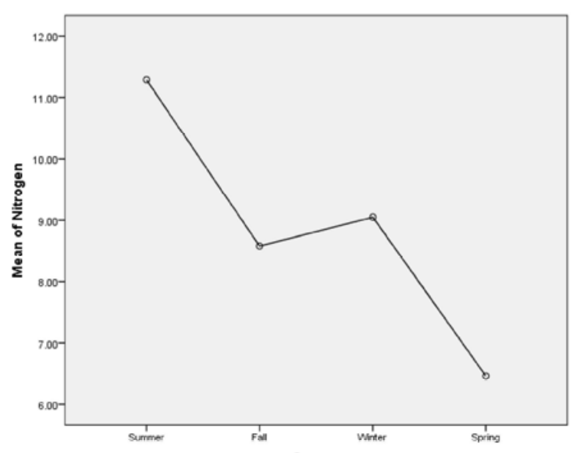

Fig. 3: Nitrogen content (mg/L) in different seasons

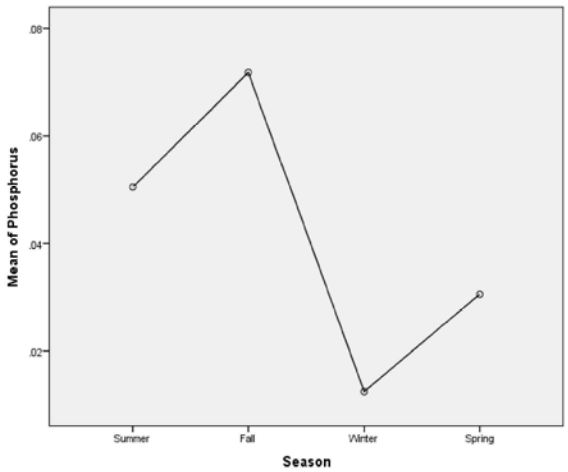

Fig. 4: Phosphorus content (mg/L) in different seasons

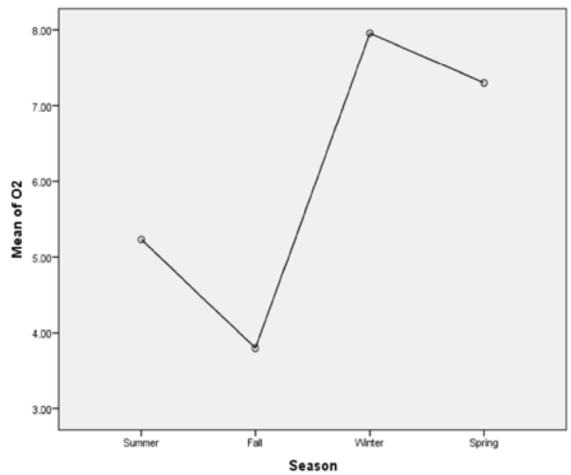

Fig. 5: Oxygen concentration (mg/lit) in different seasons

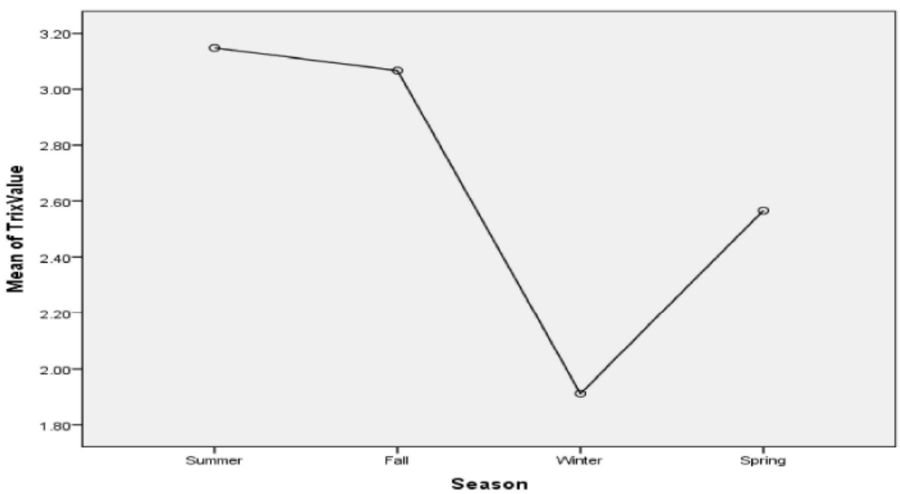

Fig. 6: Trix values in different seasons

(Fig. 5) remained virtually always within the high-quality standard set by WFD in winter and spring (seasonal mean measured 7.95 mg and 7.3 mg respectively) which represent the limits above most biological requirements are satisfied [18]. However, the mean concentrations in summer and fall show conditions of deficiency (< 6 mg) according to OSPAR [19].

The TRIX values obtained were always lower than 4, indicating a high-quality condition and hardly varied amongst zones except during the latter stations (8 and 9). The maximum and minimum values were obtained in summer and winter respectively. The value was determined to range between 1.58 and 3.23. An increase was observed in TRIX values with the increase in concentrations of nitrogen and chlorophyll a in summer. The TRIX values are shown in Fig. 6.

Table 1: Pearson correlation coefficient to correlate among ecological variables in Arvand kenar

	O_2	N	P	Cl a	Trix
O_2	1	-0.26	-0.837	-0.441	-0.8
N	-0.26	1	0.168	0.348	0.236
P	-0.837	0.168	1	0.466	0.843
Cl a	-0.441	0.348	0.466	1	0.786
Trix	-0.8	0.236	0.843	0.786	1

The results of Pearson correlation coefficients were employed to explain the relationship among the ecological parameters in the river. TRIX results were positively correlated with nutrients in the system and negatively with oxygen and also it demonstrates significant relation with cl a (Table 1)

The TRIX trophic state index is a multivariate tool used to characterize systems with anthropogenic enrichment. The trophic status of a system depends on the availability of nitrogen and phosphorus for primary production, the determination of the phytoplankton biomass (cl-a) and the saturation of dissolved oxygen [20].

DISCUSSION

Rivers are of the most important renewable and vital resources of fresh water consumed for agricultural, industrial and drinking purpose [21-22]. Water quality is the main factor controlling healthy and diseased states in both humans and animals. Surface water quality is an essential component of the natural environment and matter of serious concern today [23, 24]. Chlorophyll-a is the main photosynthetic pigment in many phytoplankton and Trophy Index in aquatic [25]. Planktonic algae have very short generation times; they also react rapidly to shifts in the environment [26]. Based on the combination of the variables used to obtain TRIX index, this study showed the trophic state and the water quality of collection stations located in Arvand kenar coastal regions was in low trophic level with high quality.

Rather high oxygen concentrations were observed in winter and spring. However, in fall the condition showed deficiency in oxygen concentration. Excessive bacteria and animal activity due to increased phytoplankton biomass and high organic loads in eutrophic systems can lead to oxygen depletion [3]. The fate and behavior of DO is of critical importance to marine organisms in determining the severity of adverse impacts [18]. When they DO falls below 5mg, sensitive species of fish and invertebrates can be negatively impacted and the DO levels below 2.5 mg most fish are negatively impacted [27]. Best *et al*. [18] provided DO thresholds in accordance with 5 ecological categories (>5.7mg high; >4.0 <5.7mg good; >2.4 <4.0 mg moderate; >1.6 <2.4 mg poor; <1.6 mg bad.) In our study, high and good quality statuses were detected in selected stations during all seasons.

Chlorophyll a production and nutrient availability are closely associated with eutrophication [7-28]. Chlorophyll a distribution depend on hydro-chemical conditions, namely nutrient availability, temperature changes, light conditions, water turbulence etc [29, 30]. In this study, the highest chlorophyll a values were generally determined in summer period in all stations. There was positive correlation between chlorophyll a and Nitrogen and Phosphorus In sampling stations. The significant positive relationships between phosphorus and chlorophyll a might indicate that Arvandkenar River has not reached the saturation level, which has an enhanced effect on primary productivity. Jannus [31] asserted that phosphorus was more important on primary production in coastal areas rather than Nitrogen when a positive correlation between phosphorus and chlorophyll a was detected.

TRIX results were positively correlated with phosphorus and chlorophyll a in the system and negatively with oxygen. Calculated Trix values without NH_4 could cause to obtain low values. Therefore, in order to determine the water quality of the environment not only physical and chemical studies but also biological studies that will show the organisms communities in the environment and their abundance should be conducted. Low TRIX values, as defined in this paper, indicate poorly productive waters corresponding to high water quality in Arvand kenar coastal area

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