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Application of (TRIX) Index to Evaluate The Trophic Status of The Middle Part of Shatt Al-Arab River, South of Iraq

KEYWORDS

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ABSTRACT *TRIX index , for the first time was used to evaluate trophic status of the Shatt Al-Arab River ,which is the most important source of water at Basrah city. Water samples were collected monthly from December 2012 to November 2013 at five stations along the river . The TRIX index integrates dissolved inorganic nitrogen and phosphorus , oxygen saturation percentage and chlorophyll-a .The TRIX index is scaled from 0 to 10 , the values in this area ranged from 5.74 to 7.12 . The results demonstrate the status of Shatt ranged from moderate quality to poor and degraded quality , eutrophication level ranged from high to elevated (very high).*

Introduction

Shatt Al-Arab is tidal river passed across the Basrah city ,south of Iraq ; their water used for several purposes like drinking ,agriculture, industry ,oil shipping ,and recreation's. Basrah province largely contribute to the economy of Iraq and the region. This river is influenced by freshwater discharge from Tigris and Euphrates rivers agricultural runoff and untreated domestic sewage (Moyle 2010 ; Saleem & Hussain 2013). Nutrient enrichment and eutrophication causes undesirable changes in ecosystem structure and functions (Lin &Yo,2008) . Krivokapic *et al* (2010) showed that one of the principal effects of the enhanced nutrient concentration is a massive increase in primary productivity .

Ecological indicators are commonly used to provide synoptic information about the ecosystem status .Their main attribute is that they combine a range of most important environmental factors in a single value which is thought useful for management and for making ecological quality concepts easily understandable by the general public and mangers (Zoriasatein *et al* , 2013) .

Vollenweider *et al* (1998) introduced a complex trophic index (TRIX) based on physiochemical (oxygen saturation , minirals and / or total nitrogen and phosphate) and biological (chlorophyll-a concentration) parameters . TRIX was easy to calculate and contains useable parameters for describing the trophic state of a system .

The previous studies were limited to that of Al-Abbawy (2012) on assessment of trophic status of the Shatt Al-Arab river used Carlson's index depend on chlorophyll-a concentration , total phosphate , and secchi disc reading .

The aim of our study is to evaluate temporal and spatial trends in water eutrophication and to apply TRIX index to assess the trophic status of Shatt Al-Arab river.

Materials and Methods

Study Area:-

Shatt Al-Arab river pass across Basrah city and Governorate (fig.1) from the confluence at Qurina town to the discharge in the Arabian Gulf, with a length of 195 Km , annually its transports approximately 35.2 Km^3 of riverine water to irrigate the agricultural lands on both sides of the river through countless side canals . The Shatt is subjected to semidiurnal tidal fluctuations and impacted by disposal of untreated wastes from different sources.

Five collection stations were made along the river at the following coordinates: 30.36 623 N and 47.45 662 E(station 1); 30.34 915 N and 47.46 368 E (station 2) ; 30.33 755 N and 47.47 563 E(station 3) ; 30.30 376 N and 47.51 328 E(station 4) ; and 30.27 251 N and 48.02 810 E(station 5) , Fig.(1)

Water samples were collected monthly from the surface layer , during low tide ,from December 2012 to November 2013 with polyethylene bottles .Temperature and salinity were measured in situ using(WTW cond 3110 set 1) and transparency using Secchi disc. The level of dissolved oxygen was measured with modified Winkler method according to Lind(1979), the correlation between water temperature and salinity was used to calculate oxygen saturation rates .Total phosphate (TP), which was digested according to APHA(2005) , and the dissolved inorganic phosphorus (DIP) were determined according to Strickland and Parsons(1972). Nitrate-NO_3 was determined using an ultraviolet(UV) technique , Nitite-NO_2 was determined according to colorimetric method and ammonia N-NH_3 according to titric method that described at (APHA,2005) . The spectrophotometric analysis described in APHA(2005) was used to determine the chlorophyll a , phaeophytein and to calculate the phytoplanktonic biomass.

The multivariate index of trophic state TRIX (Vollenweider *et al* , 1998) was used to evaluate the trophic state of the river .The following formula was used to quantify the eutrophication :

$$TRIXa = (\log_{10} [chl.a * Ab\ \%O * DIN * DIP] + K) / M$$

or

$$TRIXb = (\log10 [chl.a * Ab\ \%O * DIN * TP] + K) / M$$

Where:-

Chl.a : Concentration of chlorophyll a in mg/m^3

Ab %O: Absolute value of the percentage of dissolved oxygen saturation [Abs(100-%O)]

*DIN : Dissolved inorganic nitrogen =(nitrate-NO_3 +nitrite-NO_2 + ammonium –NH_4), in mg/m^3

DIP :Dissolved inorganic phosphorus in mg/m^3

TP: Total phosphate in mg/m^3

K=1.5 , M=1.2: Are the scale values introduced by authers

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to adjust TRIX scale values with the levels of eutrophication .

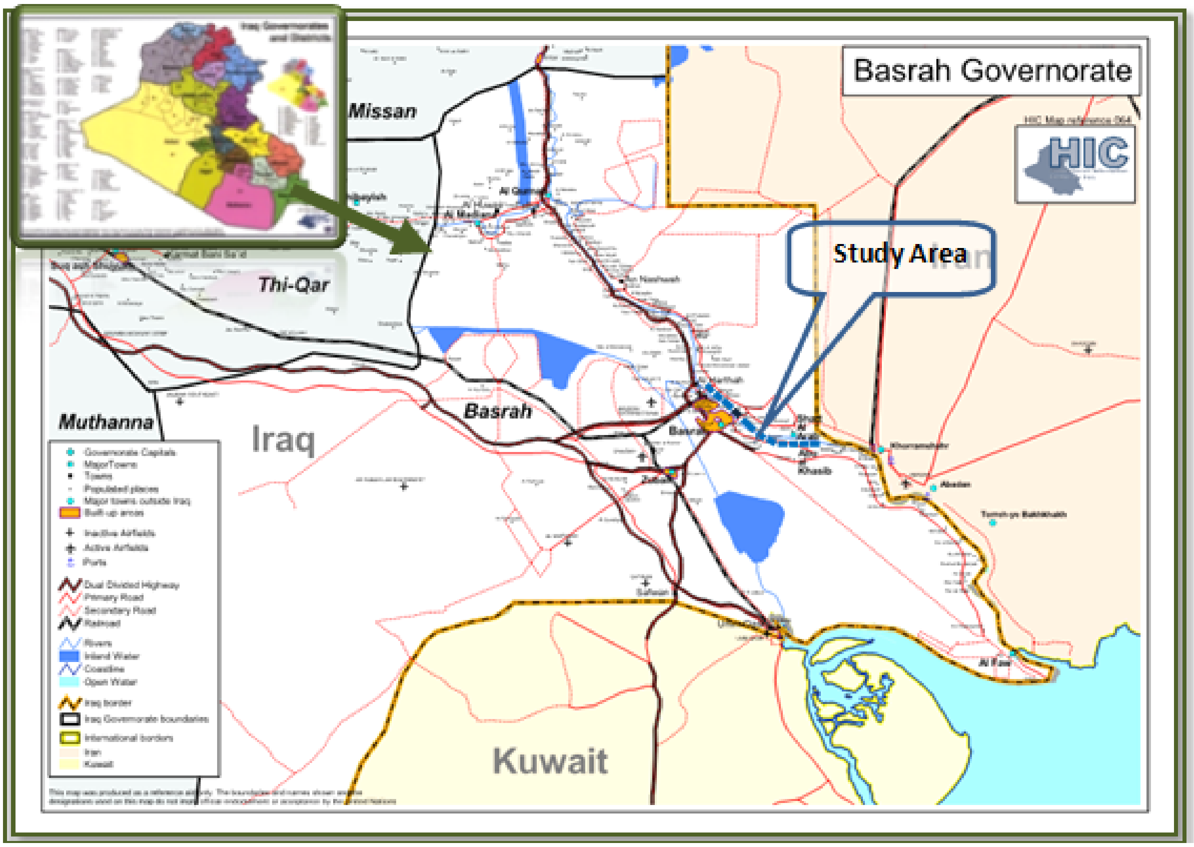
The index scaled from 0 to 10 according to Pettine *et al* (2007) and Karydis (2009) was shown in table (1).

Table (1) :The TRIX index scaled .

TRIX value	State water quality	Level of eutrophication
0<TRIX≤4	high- quality	low
4< TRIX≤5	good	medium
5<TRIX≤6	moderate	high
6<TRIX≤10	poor and degraded	elevated

Statistical Analysis:

ANOVA- one way was used to identify the existence of significant differences in the eutrophication levels among months and among stations. The relationship between the index and parameters were tested using the Pearson's correlation coefficients ,while the correlation between the parameters and the evolution of eutrophication was evaluated using Principal Component Analysis (PCA) with Conoco program ver.4.5



Fig(1): The map of Basrah Governorate ,showing the study area.

Results

Temperature changes during the studied period with minimum value measured in January (13.0 ^{0}C) at station 2 and maximum in September (33.4 ^{0}C) at station 3. ANOVA test shown no significant differences (P>0.05) within stations . Salinity was lower in September with minimum value (0.8 PSU) at station 1 and maximum value (6.1 PSU) which recorded during March at station 4. Transparency, which measured as Secchi disc, shown minimum and maximum values of (0.3m) in December at station 5 and (1.5m) in February at station 1 respectively . The phytoplankton biomass was found to vary in time , the highest value (3220.02mg/m^3) was detected in May at station 5 ; while , the values were undetectable in December at stations 2,3, and 5. In contrast , the highest values of phaeophytine (11.84 mg/m^3) were in December at station 3 and the lowest values (0.053 mg/m^3) were in May at station 4. The oxygen saturation rate showed highest values (99.62) at station 4 during November , and minimum values(98.76) at station 2 during March.

TRIXa values obtained were ranged from (5.74) in September at station 1 to(7.12) in April at station 4 , demonstrate the river is ranged from high to very high eutrophication , while TRIXb values obtained were ranged from (6.60) in July at station 1 to (8.02) in May at the same station , demonstrate the river is elevated and very high eutrophication . The values of the parameters described above are shown in the table(2).

Table(2): Means, ±SD and ranges values of some ecological variables at the studied stations.

Variables	Station 1 Means±SD (range)	Station 2 Means±SD (range)	Station 3 Means±SD (range)	Station 4 Means±SD (range)	Station 5 Means±SD (range)
Temperature(^{0} C)	23.77± 5.49 (13.5 - 29.9)	23.83±5.49 (13.0 -30.5)	23.98±5.89 (13.2 – 33.4)	23.28±5.18 (13.8 -29.7)	22.78±5.33 (13.3 – 29.2)

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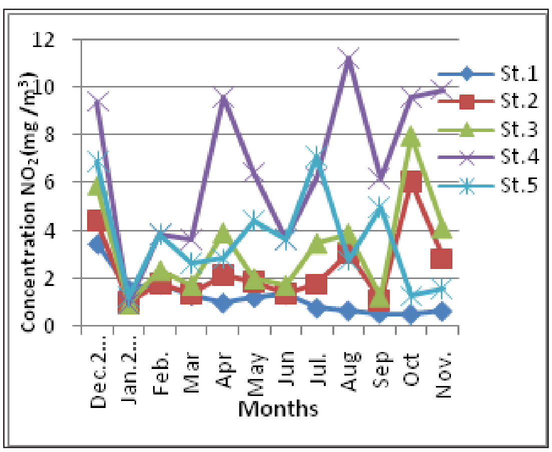
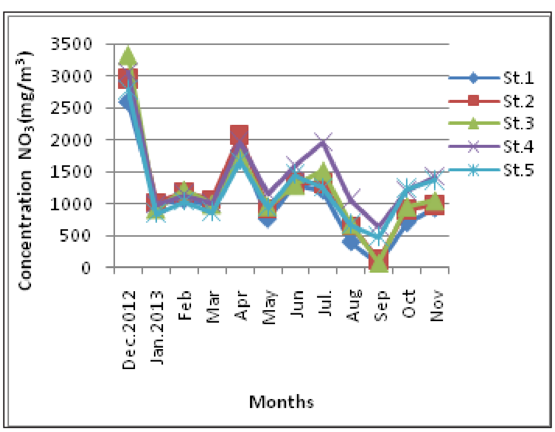
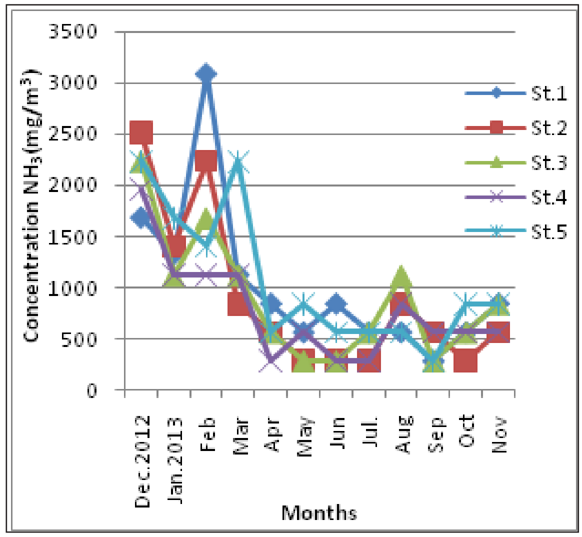
Salinity (PSU)	1.23±0.44 (0.8 -2.1)	1.81± 1.13 (0.9 -4.3)	2.08±1.28 (0.9 – 4.8)	2.64±1.59 (1.1 -6.1)	2.78±1.11 (1.6 – 5.0)
Transparency (Secchi Disc(m))	0.94±0.27 (0.55 – 1.5)	0.91±0.22 (0.7 -1.35)	0.93±0.20 (0.75 -1.45)	1.00±0.21 (0.8 – 1.48)	0.63±0.16 (0.3 -0.85)
Biomass(mg/m^3)	464.9±392.6 (173.17 -1663.68)	348.8±209.5 (ND -810.91)	392.1±277.7 (ND -1014.31)	530.9±468.7 (78.35 -1466.54)	858.4±866.2 (ND -3220.02)
Phaeophytein (mg/m^3)	3.60±2.38 (0.08 – 8.09)	4.13±1.94 (0.94 – 7.56)	4.70±3.16 (1.88 – 11.84)	4.09±2.56 (0.05 -8.64)	5.39±2.18 (2.82 – 8.42)
Abs. O%	99.13±0.086 (98.92 – 99.22)	99.23±0.169 (98.76 – 99.40)	99.25±0.153 (98.83 – 99.39)	99.43±0.130 (99.21 – 99.62)	99.22±0.060 (99.14 – 99.34)
TRIXa	6.26±0.27 (5.74 -6.81)	6.34±0.13 (6.08 – 6.52)	6.40±0.25 (5.86 – 6.67)	6.71±0.33 (5.93 – 7.12)	6.45±0.19 (6.24 – 6.83)
TRIXb	7.13±0.36 (6.60 -8.02)	7.16±0.19 (6.80 – 7.38)	7.06±0.25 (6.67 – 7.45)	7.24±0.35 (6.64 -7.78)	7.40±0.24 (6.91 – 7.74)

PSU : Practical Salinity Units , ND : undetectable

Concerning the data used in the construction of TRIX index and the model for the eutrophication state used to evaluate the studied area, the nutrient concentrations varied considerably during the studied periods and stations , nitrite concentration were ranged from(0.515 mg/m^3) in October at station 1 to (11.256 mg/m^3) in August at station 4. The highest concentration of nitrate concentration (3330 mg/m^3) was in December at station 3 , while the lowest concentration (60 mg/m^3) was detected in September at station 1 . The ammonia concentrations ranged from (280 mg/m^3) in varied periods at all stations to (3080 mg/m^3) in February at station 1 . The trophic state is the concentration of dissolved inorganic nitrogen (DIN), also evaluated with maximum value (5575.943 mg/m^3) in December at station 3 and minimum value (340.549 mg/m^3) in September at station 1. Fig.(2).







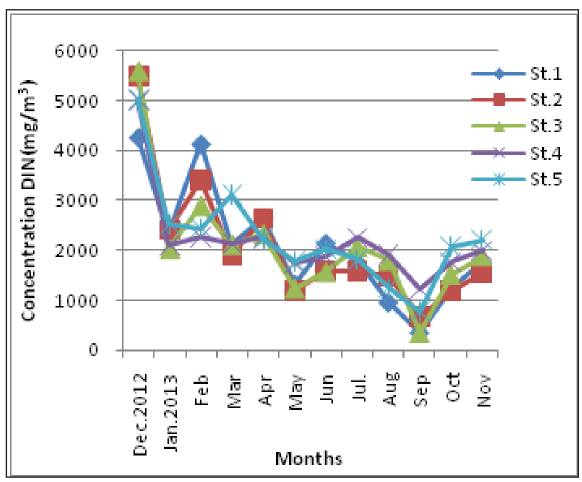


Fig.(2): Concentrations of nitrate(NO_3) , nitrite(NO_2) ,ammonia (NH_3) and DIN=(NO_3+NO_2+NH_3) at the studied stations.

The minimum value of dissolved inorganic phosphorus (DIP) (0.328 mg/m^3) was in May at station 5 , while the maximum value (8.045 mg/m^3) was in December at station 4 . Total phosphate concentrations were ranged from (3.238 mg/m^3) in March at station 1 to (52.164 mg/m^3) in November at station 5, chlorophyll a concentrations were often enhanced after rainfall , the highest value (48.06 mg/m^3) in May at station

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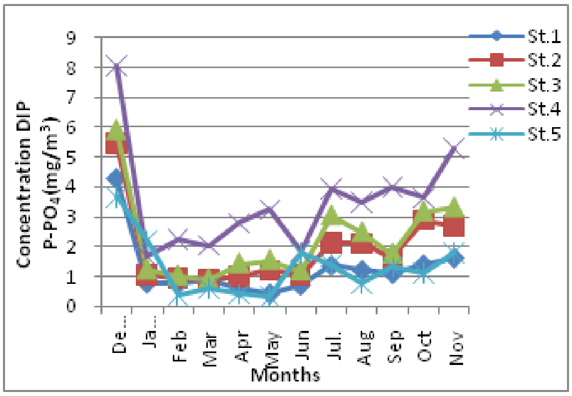
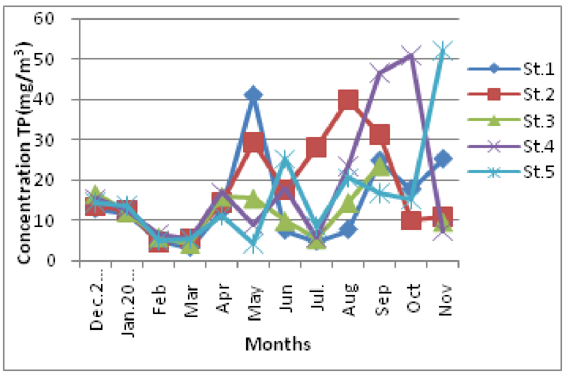
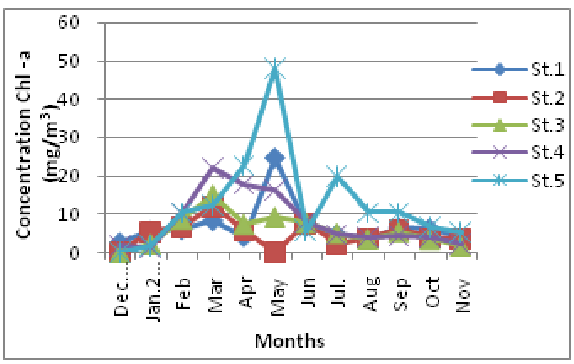
5 , and the lowest value were undetectable in December at stations 2,3 and 5. Highest dissolved oxygen value(10.4 mg/l) was detected in March at station 2 ,while lowest value(3.1 mg/l)was in September at station 4. Fig.(3).







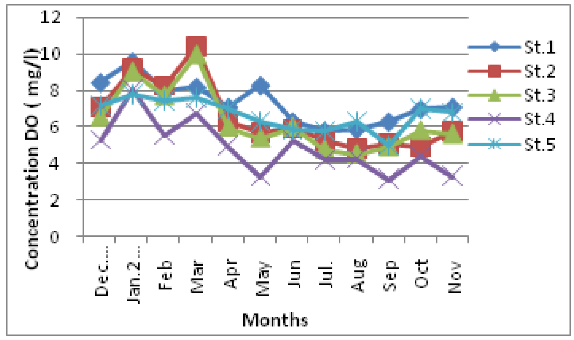


Fig.(3): Concentrations of dissolved inorganic phosphorus(DIP as P-PO$_4$), total phosphate(TP), chlorophyll-a(Chl-a) , and dissolved oxygen(DO) at the studied stations.

TRIXa values in this area ranged from 5.74 to 7.12 . The results demonstrate the river is in (moderate – poor and degraded) water quality where eutrophication level is high – elevated. While TRIXb values in this area ranged from 6.60 to 8.02 demonstrated that the river is in poor an degraded quality with elevated eutrophication .

The results of Pearson's correlation coefficients were employed to explain the relationship between the ecological parameters in the river .Positively correlations was found between NO_2, NO_3 and DIP . Negatively correlations between dissolved oxygen and temperature , and also negatively correlations between Chl-a and DIP , but no significant correlations was found between Chl-a and DIN(NO_2, NO_3 or NH_3). Positively correlations between TRIXa and each of NO_2, NO_3, DIN ,DIP and chl-a ,while positively correlations between TRIXb and each of total phosphate and chl-a . table (3).

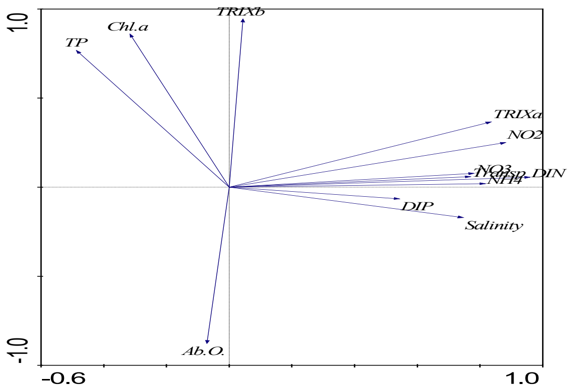
Table(3): Pearson's correlation coefficients between the different variables measured in Shatt A-Arab River.

Variable	Temp.	Salin.	Trans.	N-NO$_2$	N-NO$_3$	N-NH$_3$	DIN	DIP(P-PO$_4$)	TP	Chl-a	Phaeo.	Biom.	DO	Ab.%O$_2$	TRIXa	TRIXb
Temp.	1															
Salin.	-0.36^{**}	1														
Trans.	-0.46^{**}	$+0.35^{**}$	1													
N-NO$_2$	$+0.06^{ns}$	$+0.15^{ns}$	-0.14^{ns}	1												
N-NO$_3$	-0.39^{**}	$+0.10^{ns}$	0.00^{ns}	$+0.39^{**}$	1											
N-NH$_3$	-0.70^{**}	$+0.30^{*}$	$+0.41^{**}$	0.00^{ns}	$+0.42^{**}$	1										
DIN	-0.64^{**}	$+0.24^{ns}$	$+0.24^{ns}$	$+0.23^{ns}$	$+0.85^{**}$	$+0.84^{**}$	1									
DIP(P-PO$_4$)	-0.10^{ns}	-0.11^{ns}	-0.05^{ns}	$+0.69^{**}$	$+0.60^{**}$	$+0.21^{ns}$	$+0.49^{**}$	1								
TP	$+0.33^{*}$	-0.41^{**}	-0.36^{**}	$+0.09^{ns}$	-0.16^{ns}	-0.29^{*}	-0.26^{*}	$+0.12^{ns}$	1							
Chl-a	$+0.19^{ns}$	$+0.43^{**}$	-0.03^{ns}	0.00^{ns}	-0.19^{ns}	-0.18^{ns}	-0.22^{ns}	-0.42^{**}	-0.16^{ns}	1						
Phaeo.	-0.50^{**}	$+0.40^{**}$	0.00^{ns}	$+0.04^{ns}$	$+0.38^{**}$	$+0.30^{*}$	$+0.41^{**}$	$+0.18^{ns}$	-0.03^{ns}	0.00^{ns}	1					
Biom.	$+0.19^{ns}$	$+0.43^{**}$	-0.03^{ns}	0.00^{ns}	-0.19^{ns}	-0.18^{ns}	-0.22^{ns}	-0.42^{**}	-0.16^{ns}	1.00^{**}	0.00^{ns}	1				

DO	-0.64^{**}	$+0.32^{*}$	$+0.35^{**}$	-0.56^{**}	$+0.04^{ns}$	$+0.49^{**}$	$+0.31^{*}$	-0.44^{**}	-0.30^{*}	$+0.09^{ns}$	$+0.41^{**}$	$+0.09^{ns}$	1			
Ab.% O_2	$+0.29^{*}$	-0.25^{ns}	-0.18^{ns}	$+0.63^{**}$	$+0.09^{ns}$	-0.25^{ns}	-0.09^{ns}	$+0.58^{**}$	$+0.22^{ns}$	-0.24^{ns}	-0.27^{*}	-0.24^{ns}	-0.92^{**}	1		
TRIX a	-0.13^{ns}	$+0.53^{**}$	$+0.19^{ns}$	$+0.59^{**}$	$+0.58^{**}$	$+0.15^{ns}$	$+0.47^{**}$	$+0.41^{**}$	-0.16^{ns}	$+0.37^{**}$	$+0.08^{ns}$	$+0.37^{**}$	-0.18^{ns}	$+0.24^{ns}$	1	
TRIX b	$+0.08^{ns}$	$+0.25^{ns}$	-0.13^{ns}	$+0.16^{ns}$	$+0.20^{ns}$	-0.05^{ns}	$+0.09^{ns}$	-0.20^{ns}	$+0.44^{**}$	$+0.55^{**}$	$+0.10^{ns}$	$+0.55^{**}$	$+0.04^{ns}$	-0.12^{ns}	$+0.47^{**}$	1

**** : Significant correlation at P<0.01 ; * : Significant correlation at P<0.05 ; ns: No significant correlation**

An extremely important correlation , concerns the TRIX value in each station and the parameters that compose it, was observed when PCA analysis used . highest correlation was observed between TRIXa and NO_3 ,NH_3,DIP and salinity at all stations , while a smaller correlation was observed between TRIXa values and NO_2 . Highest correlation was observed between TRIXb value and Chl-a ,TP Fig.(4).



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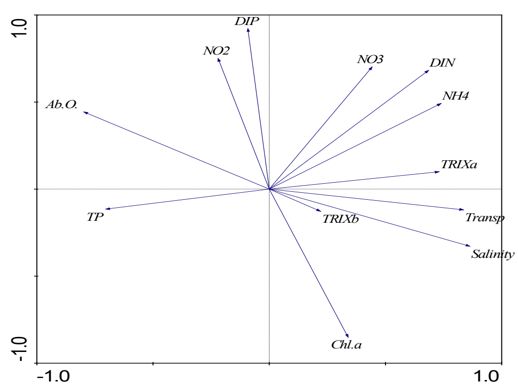

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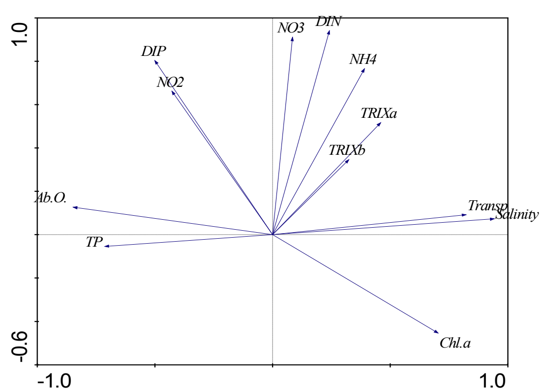

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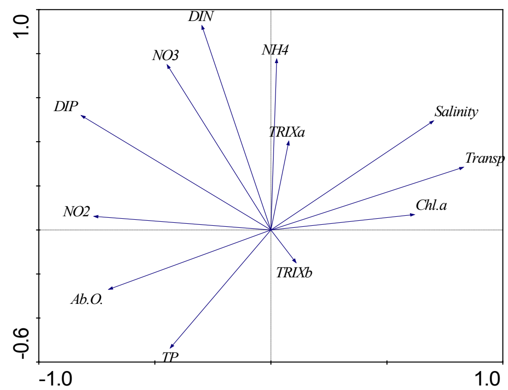

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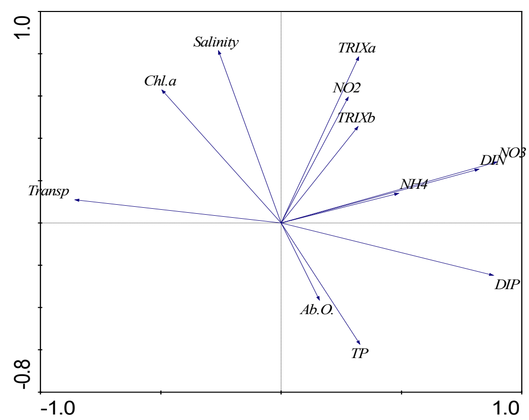

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Fig(4): PCA analysis between TRIX and parameters composed it at stations 1(A) , 2(B), 3(C) , 4(D) , and 5(E).

Discussion

Shatt Al-Arab river is well oxygenated due to continuous diffusion ,daily tidal mixing, the role of phytoplankton, and diversity of different macrophytes species occurred in riparian side marshes (Al-Saadi,2009). Dissolved oxygen variations could be explained by daily and seasonal variations of water temperature in such subtropical region . The reduced of dissolved oxygen at some stations especially at station 4 was due to increase in the untreated domestic sewage effluent (Saleem &Hussain,2013) which polluted the water with reduction substances (nitrite and ammonia) or due to organic pollutants which fasten the consumption of dissolved oxygen (BOD) in water during warm months . Salinity values increased gradually from the upstream to the downstream of the river , as result of decrease riverine discharge from the Tigris and the Euphrates rivers and the progressive advance of the salt wedge front from the Arabian Gulf to the northern reaches of Shatt Al-Arab river (Moyle & Hussain in press)

High levels of dissolved inorganic nitrogen(DIN) in water col-

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umn can be a result of runoff and leaching from agricultural lands ,which they related to the increase in irrigated lands , in the amount of agricultural fertilizers used , untreated wastewater runoff , and atmospheric loading (Dodds ,2006).

Phosphorus is important to all living organisms , however, excessive phosphorus causes micro and macro-organisms' in nuisance quantities, which are harmful to most aquatic organisms .They may cause a decrease in the dissolved oxygen level of water and in some cases temperature rise (Bakan *et al* , 2010). High concentration of total phosphate and dissolved inorganic phosphorus (DIP) may be related to soil fertilization with phosphate compound fertilizers and/or to the domestic sewage which discharged directly through many canals at Basrah city into the Shatt Al-Arab river .

Saleem and Hussain (2013) illustrated that Shatt Al-Arab river was poor by applying organic pollution index(OPI), as well as climatic changes reduce freshwater income to the river resulted in alteration in nutrients concentrations (Hameed & Aljorany , 2011).

Chlorophyll a concentrations , as an indicator of phytoplankton biomass , are often higher after rainfall, particularly if the rain has flushed nutrients into water (Krivokapic *et al* ,2011) .the variations of chlorophyll-a could be explained by variations in nutrient concentrations especially DIP , this finding is in agreement with (Nalamutt and Karmakar , 2014) who showed that algae density can be controlled by the limiting nutrients which typically in freshwater systems is phosphorous that limits the productivity in system . however, the environmental factors (temperature and salinity) could be responsible for additional variations which effect the phytoplankton community (Hameed & Aljorany , 2011).

Dodds (2006) showed that average reference nutrient concentration lead to sestonic chlorophyll concentrations above those considered typical of eutrophic lakes (>8 mg/m^3) less than half the time.

According to the results obtained, TRIXa values demonstrated good efficiency, rather than TRIXb , in using this index to evaluate eutrophication state of the Shatt Al-Arab estuarine river and contradicting with previous study of Al-Abbawy (2012) indicated mesotrophic conditions of Shatt river. Nutrient have the greatest influence on the trophic status, mainly dissolved inorganic nitrogen (DIN) and dissolved inorganic phosphorus (DIP).

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