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Assessment of Water Quality and Fish Species Dominance in the Shatt Al-Arab River by GIS Technique

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Abstract The main objective of this study is to apply the geographic information system (GIS) to assess the spatial and temporal distribution and prediction of water quality and fish dominance in the Shatt Al-Arab River from December 2011 to November 2012. Water and fish samples were collected on monthly basis, from the three stations. Water quality index (WQI) values based on historical studies revealed more acceptable conclusions compared to Iraqi maintenance system of rivers. The minimal value was 50.9 (marginal) encountered in station 3 (Abu Al-Khasib) and the maximal 78.7 (fair) measured from station 1 (Al-Dayr Bridge). According to dominance index (D3), three species formed 61.7% of the total number of species in the River including *Tenualosa ilisha*, *Carassius auratus* and *Planiliza klunzingeri*. *T. ilisha* dominated the fish assemblage of the River. GIS applied in present work showed high accuracy and efficiency to analyze and predict water quality and fish distribution in Shatt Al-Arab River.

Keywords GIS, WQI, Dominance index, Shatt Al-Arab River, Iraq

Introduction

The geographical information system (GIS) can be applied to investigate water quality in rivers, river basin management, national and international protected areas and sanctuaries to assess the suitability of the environment [1, 2]. [3] declares that to assess river water, to manage and restore water resources, temporal and spatial data of the whole water body and more importantly a computer database to store, analyze and manipulate the collected data is required. Over the last 30 years, GIS have been internationally exploited to gather information needed to monitor various water bodies across the world [4]. Several studies were executed to apply GIS to evaluate water quality in different ecosystems included streams, rivers, lakes and groundwater [5-8]. [9] exploited GIS to predict and map the abundance of fish species according to three environmental variables, sea surface temperature, bathymetry and surface chlorophyll-*a*, in south Indian Ocean. [10] developed a database and a public website both containing distributional information on native and introduced freshwater fish and invertebrate species in Western Australia. [2] illustrated the potential application of GIS and spatial analysis techniques to support the fisheries management in Bangladesh.

Only few studies applied GIS to evaluate water quality in Iraq, namely, [11] investigated water quality of Haditha Dam Lake applying remote sensing and GIS techniques, [12] used same techniques to study physical properties of Al-Hammar marsh soil. [13] monitored the changes in marsh areas, south Iraq using remote sensing and GIS applications. [14] Jaber employed GIS facilities to construct map for water resources in Iraq. [15] illustrated the potential application of GIS and spatial analysis techniques to classify spatial and temporal distribution and predictions of some water characteristic of the Shatt Al-Arab River.

No any previous study on fish species or aquatic organisms of the type has been done in Iraq. Therefore, the present work is a pioneer to apply GIS to identify fish species distribution in the Shatt Al-Arab River based on water quality.

Materials and methods

The Shatt Al-Arab River is located at the lower part of the Mesopotamian basin and flows at east south towards the Arabian Gulf. Run about 204 km, and varies in width from 250m at Al-Qurna to more than 2 km at Al-Fao town. Its depth ranged from 4.2 m at Al-Qurna, 8.2 m in Al-Dayr, 9.2 m in Al-Hartha, 15 m in Basrah city to 7m in Al-Fao. It is about 250m wide at Al-Qurna to more than 2 km at Fao district [16]. The River is affected by tidal current penetrating from the Arabian Gulf twice a day.

To execute the work three stations were selected (Fig 1), based on the character of the area that are considered of intensive fishing operations. Station 1 is located near Al-Dayr Bridge (746907 E, 3410824 N meters), station 2 is sited near Ashalha island north of the Sindbad Island (764452 E, 3386729 N meters) and station 3 is located near Al-Sahel Land in Abu Al-Khasib district (786725 E, 3373365 N meters).

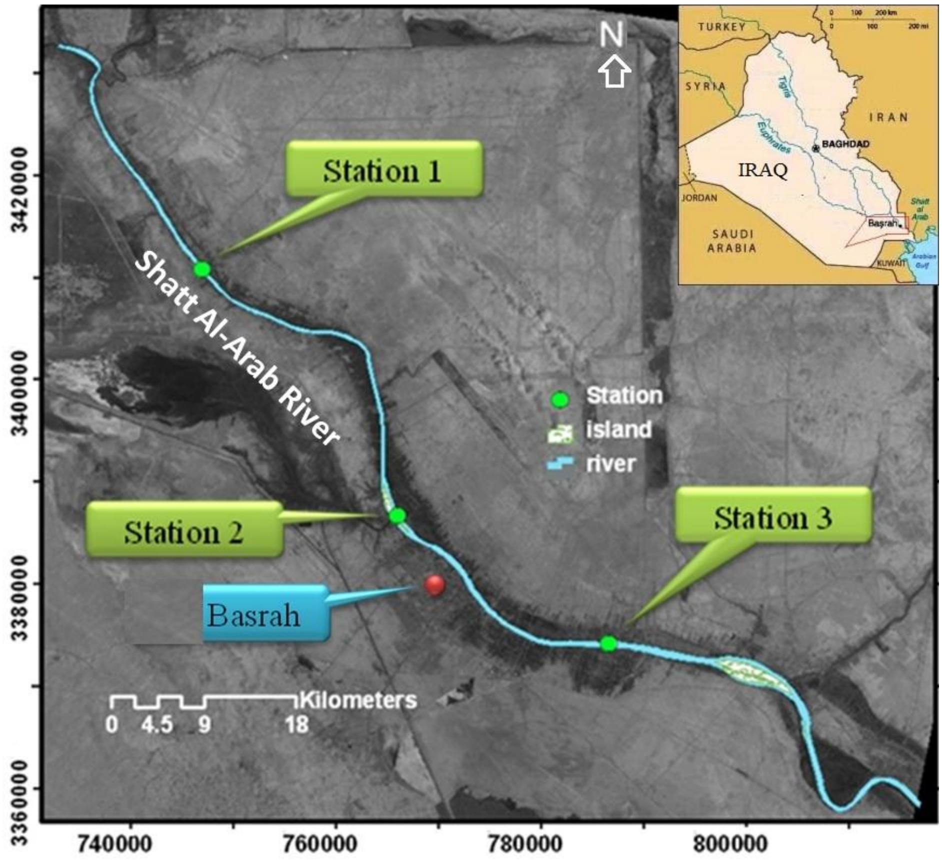

Figure 1: Satellite image of study area in Shatt Al-Arab River captured by satellite Landsat 7, date of capture 2010

Water samples were collected on monthly basis, from the three stations, manually from mid river by dipping sampling bottle at approximately 15-25 cm below the water surface, using a plastic bottle for the period from December 2011 to November 2012. At each location, the GPS waypoint (location is record and store in the device) was collected for spatial reference using GPSMAP 78s model 2010 type Garmin. In-situ measurements were carried out on water temperature, salinity, pH, total dissolved solid (TDS) and dissolved oxygen using YSI 556 MPS models 2005 meter. Transparency of water was estimated by Sechi disk of 25cm in diameter. The water samples were tested for total alkalinity, TDS, biological oxygen demand (BOD_5), nitrate and phosphate following the standard methods [17]. The procedure described by [8] was followed to determine the chlorophyll-a.

The Canadian Water Quality Index (CCME WQI) was applied to assess the water quality of three sampling stations in the Shatt Al-Arab River. Water temperature, salinity, pH, dissolved oxygen, transparency, alkalinity, TDS, BOD_5, nitrate, phosphate and chlorophyll-a were selected to calculate the index. Standards mentioned in the maintenance system of rivers and public water pollution (25) of 1967 were considered in the current study [19] to assess the scope of water quality of the Shatt Al-Arab River. The formulation of the WQI as described in the Canadian Water Quality Index 1.0-technical report [20] was followed. The computed WQI values could be classified as 95-100= excellent; 80-94= good; 60-79 = fair; 45-59 =marginal and 0-44 = poor [20].
Fish samples were regularly collected from each station by using gill nets (100 m to 500 m with 1.5 cm to 15 cm mesh size), cast net (7 m diameter with 2.5cm to 4cm mesh size) and electro-fishing by generator engine (provides 300-400V and 10A). Fish species identified and counted, and classified by consulting [21, 22]. The analysis of the nature of the fish assemblage in the three sites was carried out to determine the three most abundant species according to [23].

$$D_3 = (\sum_{i=1}^{3} pi) \times 100$$

where: D_3 is the dominance index; P_i is the proportion of the total sample represented by the i^{th} species.
The analyses were executed by using statistical programs (SPSS, version 19) and geographic analyses were carried out in ArcGIS 9.3.

Results

Water quality index (WQI)

The summary results of the physico-chemical analysis of Shatt Al-Arab River are represented in Table 1. The Canadian Water Quality Index (WQI) was applied by consulting two different sources of data, namely the system of river maintenance from pollution, and the historical studies. The index provides minor difference in WQI values between station 2 and the others. Values found to range from 45.9 to 63.2 that categorized as marginal during the whole study period. The lowest value of WQI was 45.9 recorded in station 2 and the highest was 63.2 encountered from station 1 (Figure 2A). WQI values based on historical studies revealed more acceptable conclusions compared to river maintenance system. However, values varied from 50.9 - 78.7 that categorized within category four (marginal) and three (fair) during the study period. The minimal value was 50.9 (marginal) encountered in station 3 and the maximal 78.7 (fair) measured from station 1 (Figure 2B).

Table 1: Summary of physico- chemical characteristics of Shatt Al-Arab River from December 2011 to November 2012 (SD: standard deviation)

Parameter	Station					
	1		2		3	
	Range	**Mean±SD**	**Range**	**Mean±SD**	**Range**	**Mean±SD**
Temperature (°C)	11.3-34.4	22.0±8.19	11.8-35.7	23.3±8.24	10.9-36.9	22.6±9.03
Salinity (‰)	0.75-1.48	1.12±0.19	1.09-2.27	1.69±0.41	1.40-6.19	3.18±1.54
pH	7.41-8.51	7.96±0.31	7.33-8.51	8.04±0.32	6.99-8.28	7.97±0.42
Transparency (cm)	34-76	55.3±12.12	38-81	57.17±13.2	35-71	55.75±11.40
Dissolved oxygen (mg/l)	6.11-9.92	7.50±1.30	5.55-9.50	7.45±1.34	5.76-9.55	7.23±1.12
Alkalinity (mg/l)	121-236	156.6±33.13	125-188	146.9±17.7	131-192	168.0±16.48
Phosphate (µg atom $P\text{-}PO_4$/l)	0.03-1.25	0.26±-0.33	0.06-1.24	0.42±0.33	0.07-1.06	0.28±0.27
Nitrate (µg atom $N\text{-}NO_3$/l)	11.0-56.0	24.0±13.03	6.87-49.9	23.3±13.29	14.28-34.1	24.9±6.30
TDS (mg/l)	1188-1789	1522.1±195	1626-3012	2255.2±463	1985-7131	3768.9±1930
Chl-a (µg/L)	1.82-9.23	5.51±2.55	2.24-8.42	5.13±1.76	2.09-9.58	5.14±3.15
BOD_5 (mg/l)	1.79-4.11	2.74±0.75	1.33-5.54	2.73±1.34	1.73-4.62	3.15±0.88

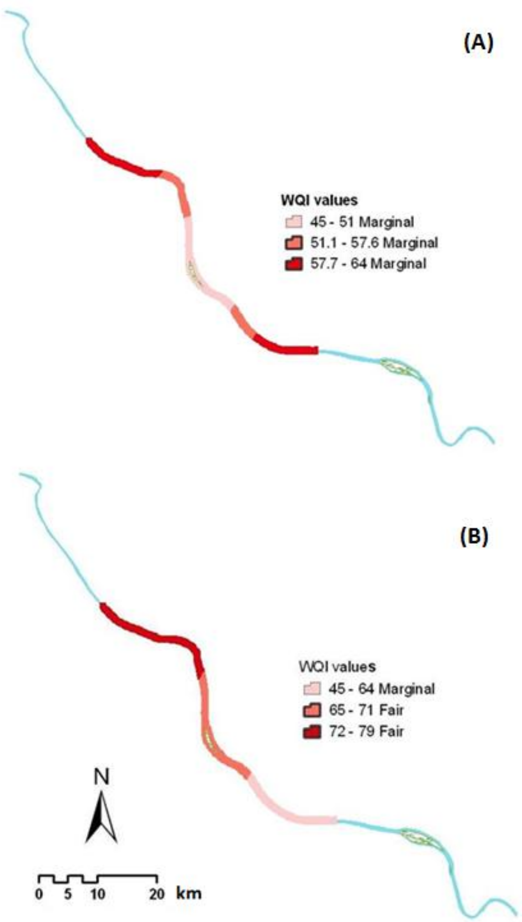

Figure 2: The pattern of WQI values in the Shatt Al-Arab River. (A) by applying the system of river maintenance from pollution and (B) relying on the historical studies

Fish dominance index (D3)

A total of 58 fish species belonging to 46 genera and 27 families were collected from the study stations in Shatt Al-Arab River. Table 2 shows the relative abundance of the most abundant fish species (>2%) in the study stations during 2011-2012. *Carassius auratus* was the most abundant species in station 1, comprised 27.2% of the total number, followed by *Coptodon zillii* 21.7% and *Planiliza klunzingeri* 14.9%. Also, *C. auratus* was the most abundant species in station 2 constituted 25.9% of the total catch, followed by *P. klunzingeri* 22% and *C. zilli* 11%. *Tenualosa ilisha* was the most dominate species in station 3, formed 43.1% of the total number, followed by *C. auratus* 21.6% and *P. klunzingeri* 5.4%.

Table 2: Relative abundance of the most abundant fish species (>2%) in the study stations

Fish species	Stations		
	1	2	3
Carassius auratus	27.2	25.9	21.6
Planiliza klunzingeri	14.9	22	5.4
Coptodon zillii	21.7	11	4.6
Planiliza abu	11.6	8.6	3.8
Tenualosa ilisha	4.2	6.7	43.1
Carasobarbus luteus	5	-	-
Cyprinus carpio	2.6	-	4
Poecilia latipinna	-	5.7	-
Gambusia holbrooki	2.2	3.6	-
Thryssa whiteheadi	-	3.1	2.2
Thryssa hamiltonii	-	2.2	-
Acanthopagrus arabicus	-	2	3.7

According to dominance index (D3), three species formed 61.7% of the total number of species in the Shatt Al Arab River including *T. ilisha*, *C. auratus* and *P. klunzingeri*. Figure 3 shows the relative abundance of *T. ilisha* in the Shatt Al Arab River during the study period. It has been found that the fish assemblage was dominated by *T. ilisha* (27.4%), it varied from 0.1% in March to 73.8% in May. *C. auratus* comprising 23.7% of the assemblage, it fluctuated from 7.1% in May to 87.6% in March (Figure. 4). *P. klunzingeri* was formed 10.6% and relative abundance ranged from 0.3% in June to 33.8% in July (Figure 5).

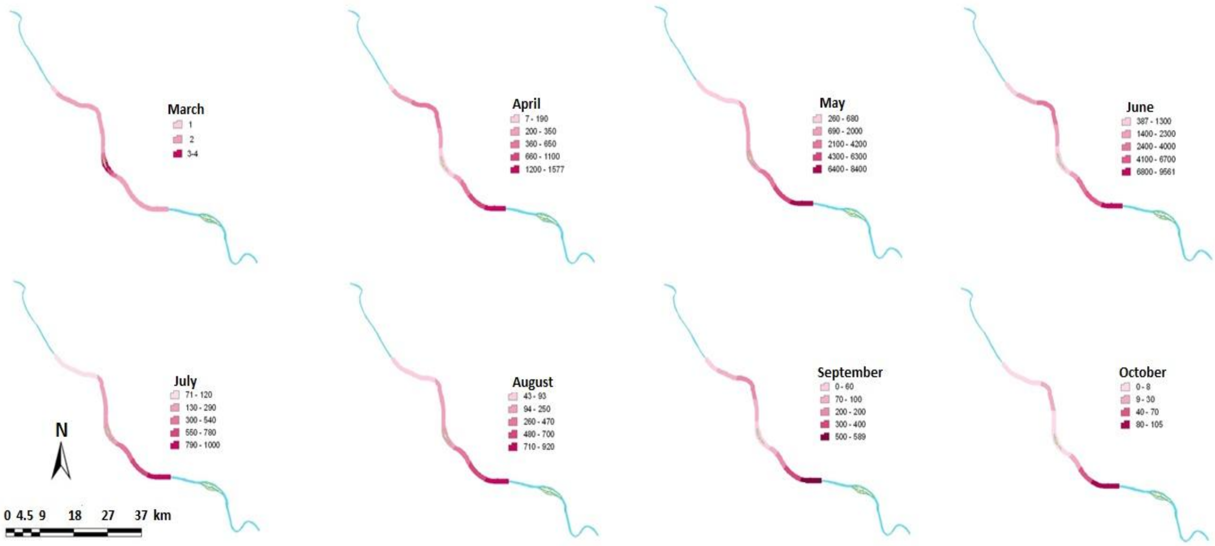

Figure 3: Monthly distributions of T. ilisha individuals in the Shatt Al-Arab River from March to October 2012

Figure 4: Monthly distributions of C. auratus individuals in the Shatt Al-Arab River from December 2011 to November 2012

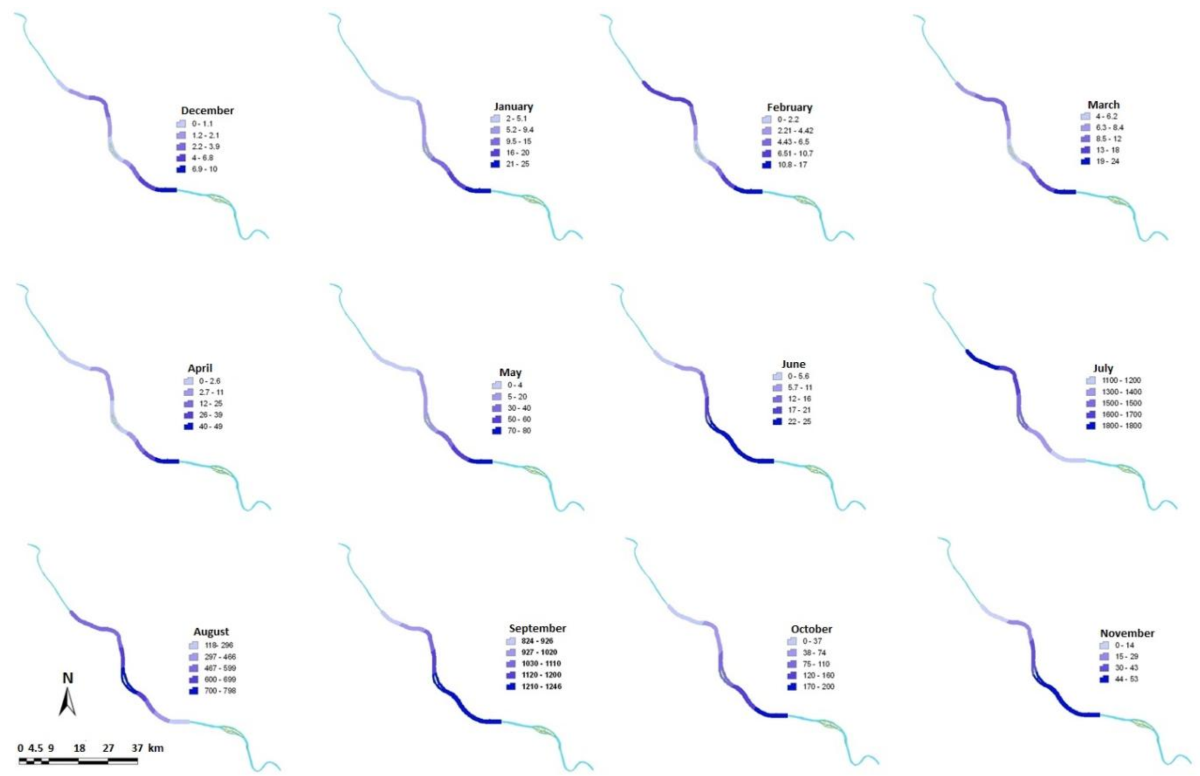

Figure 5: Monthly distributions of P. klunzingeri individuals in the Shatt Al-Arab River from December 2011 to November 2012

Discussion

Water quality index provides vital information for the well-being of a water body. This index is adopted to find out if the quality of water is good enough for drinking, recreation, irrigation, or to support aquatic life [7]. During the last few years, the Shatt Al-Arab River suffered from massive regression in water quality related to the decline in rates of discharge of the Tigris and the Euphrates Rivers due to construction of many large dams, particularly those recently built in the headwater region of Turkey, the Southeast Anatolia Project basin [24], and diverted the Karun River towards Iranian lands during 2009 [25].

Water analysis deduced a clear spatial change in values of water quality (WQI) according to system of river maintenance of pollution. Station 2 was more deteriorated than others and categorized as marginal during the whole study period. This may relate, in general, to low water levels and increase phosphate concentrations. Water quality at station 3 was relatively better than station 2. This may refer to relative decline in phosphate concentrations. Station 1 was the best in water quality due to low phosphorous levels by all means furthermore; it is low in salinity values compared to other stations. WQI calculations based on historical studies also exhibit spatial changes. Station 3 was more deteriorated than others for locating within category four (marginal). This may attribute to the influence of salty seafront penetrating from the Gulf during ebb period, which enrich the location with high concentrations of salts [26]. As well as, receiving some organic pollutants from adjusted agricultural and industrial sites that led to increase nitrate and reduce dissolved oxygen potential during some months [27]. However, station 1 revealed increase in WQI value, and is categorized as fair throughout the whole study period. This refers to decline of salty seafront and also interpreted the lower values of most variables. WQI values based on historical studies offer more acceptable values compared to river maintenance system. This may relate to varies number of variables and objectives adopted to calculate WQI. In addition, the objectives of historical studies reflect the real status of the river.

The freshwater fish species, like *C. auratus* was the most abundant species in the upper reaches of Shatt Al-Arab River which characterized by low values of salinity, whereas *T. ilisha* dominated the fish assemblage in the lower reaches of the River. Several authors stated that marine species are limited to the middle and the lower reaches of the Shatt Al-Arab River, but their numbering decreased leading to the upper reaches of the river, whereas freshwater fish fauna exhibited a reverse trend of distribution in the river [28-29]. According to dominance index (D3), *T. ilisha* dominated the fish assemblage in the Shatt Al-Arab River. *T. iIisha* is an anadromous species ascend during spring and early summer to the upper reaches of the Shatt Al-Arab River for a spawning migration [30-32].

One of the major applications for GIS in fish population dynamics is in the identification of habitats that are important for spawning or nursery grounds for commercially or environmentally critical species [33, 34]. [35] deduced that an additional capability of a GIS for stream analyses is to examine spatial and temporal variation in environmental variables and fish assemblages. Moreover, the associated fish assemblages are predicted to change with this ecological variation [36]. Other potential uses of a GIS approach to examine fish assemblages are testing for spatial patterns of individual occurrences [34].

Conclusion

GIS applied in present work showed high accuracy and efficiency to analyze and predict water quality and fish populations, due to high response of GIS to every temporal and spatial change in water quality, types and numbers of fish during the study period.

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