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Functional diversity and some ecological aspects of fish community in Hawr Ad Dalmaj marsh, Southern Iraq

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Declaration

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Abstract

Hawr Ad Dalmaj marsh is a largely isolated marsh located about 65 km north east to Al-Diwaniya City and 35 km southern east of Kut city, at the heart of the Mesopotamian alluvial plain. The length of the Hawr Ad Dalmaj marsh ranges about 50 km and the width is about 10 km. Hawr Ad Dalmaj marsh is one of the most important wetland areas on a global level. Until now no study has been conducted to understand the nature of the ecosystem in it as well as the fish community feeding overlap. So it is necessary to conduct a study to find out the nature of the diversity of fish in the region and effect of some physical and chemical properties of water on the fish community in terms of the number of species and individuals and the total weight of fish and knowing effect of alien species on the endemic species in terms of food and breeding. And it has shown that the composition of community differs from previous studies, revealed that introduced alien small size species and some of the uneconomic species dominated. The samples were caught monthly from January 2017 to December 2017. Two sampling sites were selected, the first site (32˚ 35′ 93.96" N and 45˚ 22′ 38.15" E) was near km 331 of Main Outfall Drain (MOD) channel and the second site (32˚ 13′ 38.32" N and 45˚ 50′ 14.11" E) was located southeast of the first, near km 299 of MOD channel. Some environmental parameters were measured, namely air temperature ranged from 47.6 °C in the second site during August to 10 °C in January in the first site, while water temperature from 37.88 °C in the second site during August to 8.9 °C in January in the first site. Light penetration revealed 40 cm in June and July (site 2) and 89 cm in December (site 1). The pH values tend toward the alkaline, the lowest 6.7 in December in site1 and 8.8 measured in July in site 2; the salinity ranged from 2.3 in February (site 1) to 11.13 in August (site 2), while Dissolved Oxygen from 10.34 mg/L in January (site 1) to 5.58 mg/L in August (site 2). The lowest values of reactive nitrate were recorded (1.56 µg N/L) in August (site 2) and highest (7.89 µg N/L) in May (site 1), however the values of reactive phosphate recorded, the lowest 0.59 µg P-PO_4/L in May (site 2), the highest was 1.11 µg P-PO_4/L in October (site 1). Several fishing tools were used to collected fishes. A total of 16265 individuals were collected during study period represented 730033.23 g included 15 species belong to 7 families of Osteichthyes, cyprinids family occupied first degree in the number of species (7). Positive significant correlation was found between number of species and water temperature (r=0.506). *Planiliza abu*, *Carassius auratus* and *Coptodon zillii* were the most total numerical relative abundance 35.99, 27.75 and 15.86% respectively, *C. auratus*, *S. triostegus* and *C. zillii* were the most total weight relative abundance and composing 22.52, 14.86 and

13.02% respectively in the study area. native species included 9 seasonal species 1 and 5 for rare species. Diversity Index (H) ranged between 0.92 in January to 1.74 in December, Richness Index (D) 1.11 in November and 1.72 in May, Evenness Index (J) recorded 0.4 in January and the highest 0.75 in December. The percentage of similarity among stations by Jaccard Index (Ss%) showed variation uneven during study months. Cluster analysis of species similarity pointed to clumping in groups controlled by temperature. Analysis of food components indicated that *S. triostegus* and *L. vorax* were carnivore, *C. auratus*, *C. carpio* and *C. luteus* were omnivores, whereas *O. aureus* and *P. abu* were detritivores. while *C. zillii*, *M. sharpeyi* were herbivores. Diet overlap varied among the studied species. The present study was showed very high values of diet overlap between *P. abu* and *Oreochromis aureus* 95%, also very high values of diet overlap between *S. triostegus* and *Leuciscus vorax* 93.70%, also between *Carassius auratus* and *Carasobarbus luteus* 98.9%. All species reproduced in Hawr Ad Dalmaj marsh. All species possessed a long reproductive season except *L. vorax*. Total sex ratio was in favour of females. The impact of alien species direct effects during destruction of nest and reproductive ground especially eggs which lie on a plant for native species and hybridization between alien and native species, and indirect effects by competition on food, ecological space, environment destruction and aggressive behaviour.

INDEX

	PAGE
PART I	
1. INTRODUCTION	11
1.1 Classification of Marshlands	11
1.2 The Mesopotamian Marshlands	12
1.3 Functional Diversity of the Iraqi Marshlands	14
1.3.1 Production function	16
1.3.2 Regulation function	17
1.3.3 Habitat function and biodiversity	25
1.3.4 Information function	26
1.4 Ecological factors	27
1.4.1 Water temperatures	28
1.4.2 Hydrogen ion concentration	30
1.4.3 Salinity	32
1.4.4 Dissolved oxygen	35
1.4.5 Turbidity	36
1.4.6 Phosphate	38
1.4.7 Nitrate	40
1.4.8 Composition of the fish community	42
1.4.9 Life characteristics of fish	44
1.4.10 Nature of fish food	60
1.4.11 Food interaction	62
1.5 References	64
PART II	
2. AIMS OF THE STUDY	94
3. MATERIAL AND METHODS	96
3.1 Area of the study	96
3.2 Climate of the study area	99
3.3 Fieldwork	99
3.4 Laboratory Work	102
3.5 Fish sampling analyses	103

3.6 Statistical Analysis 108
4. REFERENCES 110

PAPER 1 113
PAPER 2 138
PAPER 3 159
PAPER 4 174
5. General Conclusions & Recommendations 193
APPENDIXES 195
ACKNOWLEDGMENT 199

LIST OF TABLES

		Page
Table 1	Effect of pH values on the fish (Swingle et al., 1969).	31

LIST OF FIGURES

		Page
Figure 1	The Mesopotamian Marshlands in Southern of Iraq (Studio Galli Ingegneria).	13
Figure 2	Stages of the marshes draining until 2010 (Canadian-Iraq Marshlands Initiative, 2010).	14
Figure 3	Relationship between wetland functions and economic values (Turner et al., 2000, in Lambert, 2003).	15
Figure 4	Interactions among hydrology, physiological environment, and biota in wetlands. (NRC, 1995).	17
Figure 5	Flow of carbon (CO_2) pathways and methane (CH_4) in the wetland (Mitsch et al., 2013).	22
Figure 6	Relationship in the food chain between five levels foods for the common fish in the Al-Chybayish marsh (southern Iraq), during the period 2005-2006 (Mohamed et al., 2012).	25
Figure 7	Predictive effect of changing rainfall ratios increased degree of temperatures and increased evaporation value on the diversity and the abundance of fish species. Change = Δ, increase = ↑ (Pankhurst & Munday, 2011).	30
Figure 8	Relationship of dissolved O_2 saturation (mg/L) in water column (m) and temperature (°C) (Eaton et al., 1995).	36
Figure 9	Conceptual model summarizing the effects the turbidity in the ecosystem of the marsh (Scheffer et al., 1993).	37
Figure 10	Conceptual model summarizing the phosphorus cycle in the marsh (Mitsch & Gosselink, 2000).	39
Figure 11	Conceptual model summarizing the nitrate cycle in the marsh (Mitsch & Gosselink, 2000).	41
Figure 12	Distribution of endemic fish in Al- Hammar, Al- Huwaizah, and the Central Marshes (IUCN, 2010).	44
Figure 13	Common carp (*Cyprinus carpio*).	46
Figure 14	Gold fish (*Carassius auratus*).	48
Figure 15	Hishni (*Planiliza abu*).	49
Figure 16	Himri (*Carasobarbus luteus*).	50
Figure 17	Shilik (*Leuciscus vorax*).	52
Figure 18	Bonni (*Mesopotamichthys sharpeyi*.	54
Figure 19	*Tilapia zillii* (left) and *Oreochromis aureus* (right).	58
Figure 20	Jirri (*Silurus triostegus*).	59

Figure 21	Layout of the MOD, after the directorate of the MOD.	96
Figure 22	Location and physiography of Hawr Ad Dalmaj marsh captured by the satellite Landsat 7 (year of capture: 2018).	97
Figure 23	The Site 1 of the samplings of the current study.	98
Figure 24	The Site 2 of the samplings of the current study.	98
Figure 25	Etrex GPS utilised for localization of the sampling sites.	100
Figure 26	Etrex YSI sension 156 Multi-Parameter Meter utilised for water parameter analyses.	100
Figure 27	Measurement of the water quality parameters during the samplings in the Hawr al-Dalmaj marsh.	101
Figure 28	Collection of fish samples in the study area.	102

PART I

1. INTRODUCTION

The ecosystem is a dynamic complex of plants, animals, microorganisms and non-living communities. The interaction between these communities works as one functional unit (Millennium Ecosystem Assessment, 2005). Wetland is not literally considered a water body because water often does not cover all land. It is also not land in the conventional sense because water covers most of the land (Keddy, 2010). This homogeneity between soil and water formed unique environmental properties that differ from those of other regions on the Earth (Gibbs, 2000). The term "wetlands" is a comprehensive word that refers to a variety of inlands, coastal and marine ecosystems. This comprehensiveness has led to a confusion in understanding the concept of wetlands, making difficult to obtain an universal agreement but the most widely accepted definition of wetlands is the following: *''areas of marsh, fen, peat land or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six meters*" (Ramsar, 2005).

Wetlands constitute less than 3% of the Earth's surface area, and they are one of the most productive areas on Earth (Ratner, 2003; Ferreira & Lacerda, 2016). Wetlands contain approximately 40% of all species in the world (Keddy, 2010; Rebelo et al., 2015) and, despite their importance, more than half of the world's wetlands are deteriorating. It is recognized that the wetland deterioration is accompanied by the decline or extinction of some species (Muhamad et al., 2010; Huo et al., 2013; Sankura et al., 2014; Krüger et al., 2015).

1.1 Classification of Marshlands

Marshlands are classified as wetlands, which are covered seasonally or permanently by shallow water, or land where the water depth level is near or on the surface. The groundwater is wetting the soil and allowing aquatic plants to grow (Naumburg et al., 2005). Wetlands include the transitional range between the terrestrial environment and the aquatic environment (Mitsch & Gosselink, 2000).

There are four types of wetlands (Young et al., 2002):

Swamps. Wetlands that are characterized by the profuseness of trees and shrubs with static water and limited drainage, often with moderate or weak acidic soil.

Marshes. Wetlands that are almost permanently submerged and characterized by a mixture of cattails, cane and other aquatic plants. Iraqi marshlands fall under this category.

Bogs. Wetlands containing peat plants that restrict rain as the only water source and often have acidic soils and contain mostly *Sphagnum*.

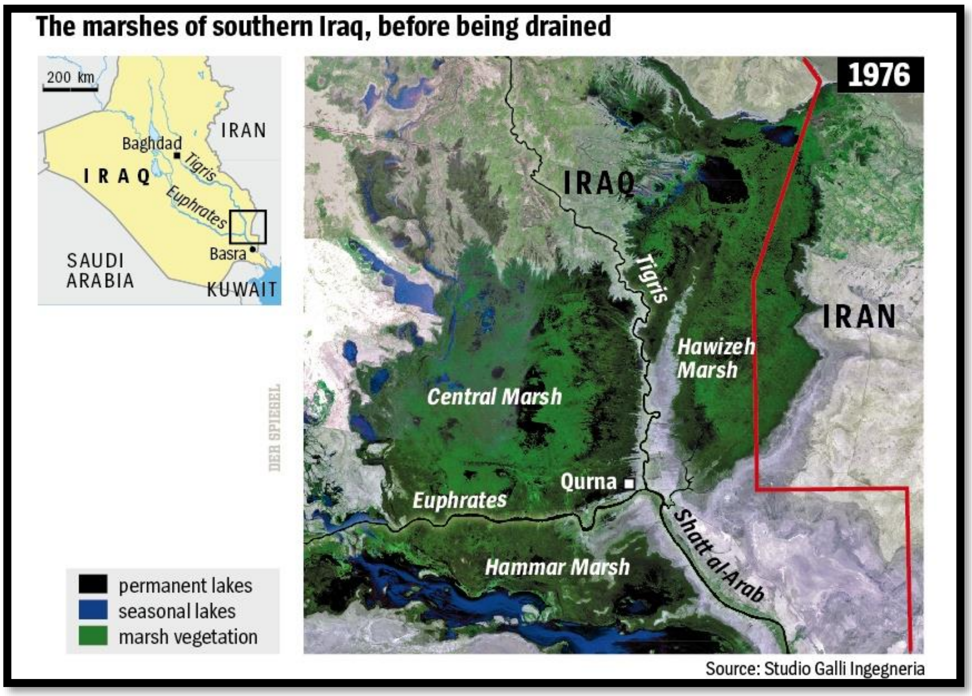
Fens. The land that contains concentrations of peat and groundwater is the main source of water. A variety of plant species grow in these kinds of wetlands.

1.2 The Mesopotamian Marshlands

Iraq is located in the Middle East with a total area of 438320 km^2 (Al-Ansari & Knutsson, 2011). Iraq is surrounded by six countries, namely: Turkey to the north, Iran to the east, Kuwait and Saudi Arabia to the south and southwest, and Jordan and Syria to the west; besides its outlet to the Arabian Gulf to the southeast. The marsh area is located in the southern part of the country, on the confluence of Tigris and Euphrates rivers. The marsh area has unique properties that are hard to be found in any other place on the planet, which makes it one of the most important wetlands at the global level (Partow, 2001). The dominant environment of the area varies depending on several factors among which water temperature, water salinity, water availability and nutrients availability (Richardson & Hussain, 2007). Iraqi marshes are mainly fed from Tigris and Euphrates, which are originated from Turkey. The wrong water policy adopted by the former Iraqi regime has led to water scarcity, which affected the marshes and converted most of the marshes areas to dry land during the 1990s. The dried marshes transformed into barren lands covered with salt. The destruction reached humans, animals, and plants living in the marshes (UNEP, 2001; Ghadiri, 2006). This loss was not limited only to the species loss, but also to the loss of the genetic diversity, the functional communities and the interactions among the living organisms in the area (Naeem, 2006). Such catastrophic results provoked the attention of the environmental experts and Human Rights activists from all over the world (Maltby, 1994) along with the UNEP. The issue was brought up in the European Parliament in several occasions (Brasington, 2002). Upon governmental and non-governmental efforts for over a decade, three sites in the marshes were chosen (i.e., Al-Hammar, Al-Hawizeh and Central Marshes) for the World Heritage List (Cave & Negussie, 2017), that represents an international recognition of their global value according to United Nations Environment Program (UNEP, 2001).

Mesopotamian marshes are the largest inner of wetland systems in extremely hot and dry environments on the Earth (Schaaf & Rodrigues, 2016).

Figure 1. The Mesopotamian marshlands in southern of Iraq (Studio Galli Ingegneria).

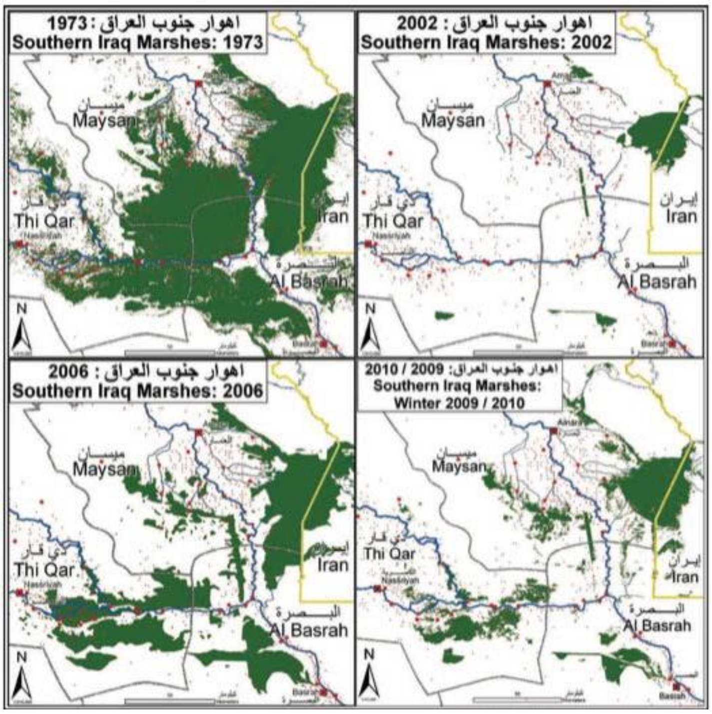


The Marshlands were at great risk during the Saddam regime. Saddam Hussein's regime conducted the draining of the marshes in 1991. The total area of the marsh survived during this campaign about 7% only (Brasington, 2002). Al- Hammar Marsh was completely disappeared between 1992 and 1994 (Figure 2) shows the stages of the deterioration of the reality of the marshes of 1973 until 2010.

This drying process coincided with an aggressive operation against the Marsh Arabs (Ma'dan). Ma'dan are perceived as the descendants of the Sumerians and they are the living connection between the Iraqis of today and the ancient Sumerians (Al-Zahery et al., 2011). Thousands of Ma'dan were killed and displacements and arrested tens, besides other catastrophic changes that blew the area’s ecosystem. Such sabotage included fisheries and fishing quantities, which deteriorated due to the draining of the vast water bodies along with the oppression against people in that period (Mitchell, 2002). Also, the deliberate draining of the marshes resulted in an almost total loss in the biological diversity of the occurring non-aquatic species of plants, birds, invertebrates.

After the departure of Saddam Hussein in 2004, the Italian Ministry for the Environmental and Territory and the Iraqi Ministry of Environment measured the area of water surfaces of all large marshes. The area of water surfaces of the Central Marsh resulted 3121 km², having 700 km² of natural lakes with a flow rate of about 100 to 800 m³/s and an average depth of 1.75 m. The salinity ranges from 0.2 to 1.5 ppt. The estimated area of Al-Hawizeh Marsh resulted of about 3500 km², being characterized by 650 km² as a permanent marsh with an average depth of 2.5 m and salinity ranges from 0.3 to 2 ppt. During the flood season, it is estimated that the area of Al-Hammar Marsh reaches 3000 km² with the total storage of 5 billion m^3 of water, while in the dry season the area of the water surface of Al-Hammar Marsh is 600 km² and the total storage capacity is approximate 0.18 billion m^3, with the salinity ranging from 0.5 to 10 ppt (Khulood, 2012). This problem due to the decrease in water quantities in the Tigris and Euphrates rivers and also because of high temperatures.

Figure 2. Stages of the marshes draining until 2010 (Canadian-Iraq Marshlands Initiative, 2010).

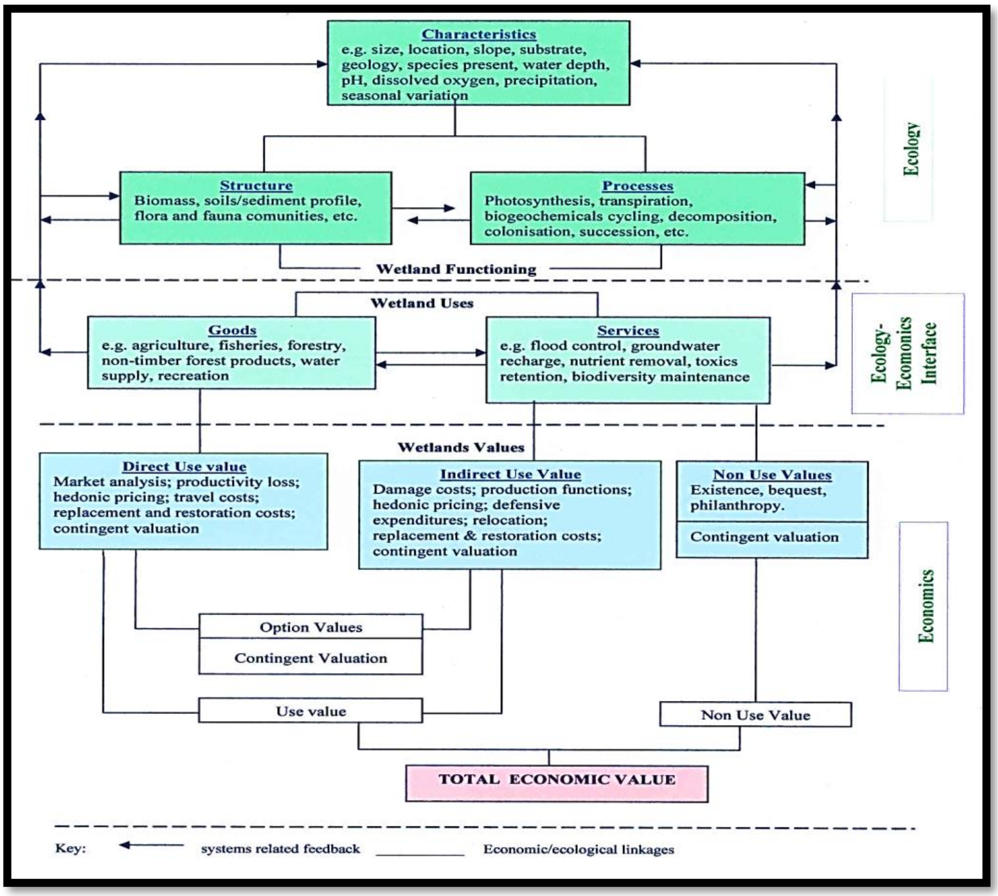


1.3 Functional Diversity of the Iraqi Marshlands

Wetlands function as the most specific point for maintaining ecosystem balance (Richardson, 1981) and their functional diversity can be summarized in how wetlands can affect neighbouring environments (Bush, 1997). It is defined by Novitzki et al.

(1997) as a process or series of biological processes that are being taken place within wetlands. No wetland can perform all functions at a high level because many functions are operated by nature in opposite directions (Hansson et al., 2005; Adamus et al., 2009; Acreman & Holden, 2013). The location and size of wetlands determine the nature of the functions they will perform. The functions of wetlands vary from region to another and the geographical location plays a major role in determining their own functions, such as hydrological and water regulation functions (Reed, 1993).

Figure 3. Relationship between wetland functions and economic values (Turner et al., 2000, in Lambert, 2003).



The function quality of wetlands depends on many factors such as climatic conditions, quantity and quality of water entering wetlands, disturbance within the wetlands or the surrounding ecosystem. Wetland disturbance is usually caused by natural conditions such as drought or by human activities, such as landfilling, water change and / or introduction of non- native species (Mitsch & Gosselin, 2000). Data on functional diversity helps to give an economic evaluation of wetland goods and services, and an inseparable part of the cost and benefits of development projects (Lambert, 2003). Moreover, this information is very important to determine the amount of wetland resources which contribute to the country's total national production (Torell & Salamanca, 2003). Turner et al. (2000) summarized the nature of the relationship between goods and services which were provided by wetlands with the economic values of these functions, as shown in Figure 3.

The marshes in southern Iraq have many major and minor functions. The physical, chemical and ecological properties of freshwater wetlands, in general, and the Mesopotamian marshes, in particular, can be classified into four levels of functional diversity: i) production function, ii) regulation function, iii) habitat function and iv) biodiversity and informations function (Novitzki, 1978; Luecke, 1993; Costanza et al., 1997; Tiner, 2005; Mitsch & Gosselink, 2000; Ramsar, 2004; Hassan et al., 2005; Verhoeven & Setter, 2009).

1.3.1 Production function

The ecosystem of wetlands, with all its components, performs a crucial role by conversion of solar energy to other types that result in the production of edible materials for plants and animals (De Groot et al., 2002). Human societies, since the start of humankind, have used renewable resources in nature; these resources have a value known as "*existence value*" (Selassie et al., 2006). The function of production is determined by wetlands natural resources. Accordingly, the production function in wetlands is divided into several levels, the most important of which are:

Raw materials

Wetlands provide a suitable environment for animals to graze, produce wood for fuel, as well as raw materials for industries such as warehouse equipment like mats, trays, baskets. They also provide raw materials used in the paper industry (Newcome et al., 2005). The most common plant species in Iraqi marshlands are reed *Phragmites australis* and reed mace *Typha domengensis* (Hamdan et al., 2010), and they are usually used in industry. A report by the United Nations Environment Program (UNEP, 2001) refers to the use of these plants in building houses by local people as an inherited Sumerian tradition. Iraqi marshland plants have been used as a primary material in local industries of paper production (Bedair et al., 2006).

Food production function

Wetlands are considered as the basic conservation of fish resources (Newcome et al., 2005). Fisheries of Iraqi marshes have an exceptional importance because they are one of the main economic foundations of the traditional culture of the marshlands. According to a study by Jawad (2006), there are 14 fish species of economic importance in Iraqi marshes. Abd & Rubec (2009) identified four additional species of high economic importance. In 1990, the FAO estimated the fishing in Iraqi inland waters to reach 23,600 tons, and more than 60%; that amount came from marshlands (Partow, 2001). The amount of the catch in Iraq during the 1970s and 1980s was likely to be greater, than that of the 1990s (Maltby, 1994).

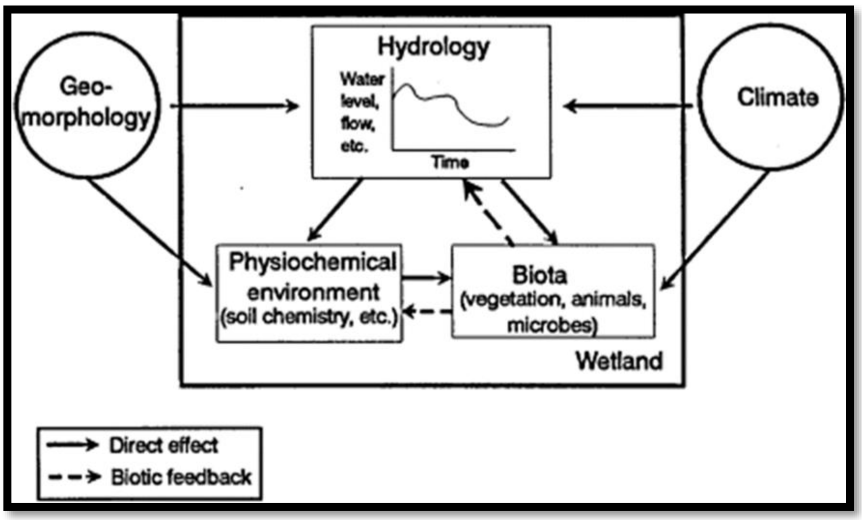
1.3.2 Regulation function

Wetlands perform regulatory functions that constitute processes essential to ecosystems, through bio-geochemical cycles and other biosphere processes (De Groot et al., 2002). These processes have direct benefits in maintaining ecological balance and species productivity (Elliott & Elliott, 2010). The regulatory functions of wetlands are of two kinds: hydrological and biological (De Groot et al., 2002).

Hydrological functions

The hydrological properties of wetlands are the most important factor in the development of the ecosystem functioning of these areas (Reed, 1993; Mitsch & Gosselink, 2000). Maltby (2009) demonstrated that the hydrological properties of wetlands affect the soil and the nature of vegetation (Figure 4).

Figure 4. Interactions among hydrology, physiological environment, and biota in wetlands. (NRC, 1995).



Hydrological functions of wetlands were classified into several levels: flood control, water supply, water storage, and erosion control (Olde Venterink et al., 2006; Rebelo et al., 2015; Moor et al., 2017).

Flood control

Wetland ecosystems are linked to a variety of complex direct and indirect functions depending on the type of wetlands, soil, water characteristics and associated biological effects (Mitsch & Gosselink, 2000). One of the most common hydrological functions of wetlands is the flood reduction. Wetlands store water during rainy periods, and the stored water is released during dry periods (Bucher et al., 1993). Devito et al. (1996) found that the wetlands in Canada play a major role in floodwaters and rainwater discharge. This process is the basis for most hydrological models of rainwater in areas containing wetlands (Beven & Kirkby, 1979; Moore, 1985). Bullock & Acreman (2003), who reviewed the function evidence for wetlands in flood control, found that about 80% of the relevant studies concluded that wetlands reduced the harmful effects of flooding. Iraqi Marshlands are characterized by their dry desert climate, where water levels decrease in summer season due to lack of rain and low water imports. The marsh areas in southern Iraq is somewhat larger in winter when water imports are available and surface water is stored at a depth of up to 4 m in some occasions (Hussain, 2014). However, it seems that the function of flood control in Iraqi marshes is rare, especially considering the current water situation in Iraq, which does not predict the occurrence of floods in this region, especially with the increasing number of dams, which were established and the planned to be established on Tigris and Euphrates (Al Obaidy & Al-Khateeb, 2013; Issa et al., 2013).

Water supply

Wetlands perform functions such as water preservation and storage (Ramsar, 2004). Middle East countries are considered as arid or semi-arid, with an average annual rainfall of 166 mm (Rogers & Lydon, 1994; Al-Ansari & Knutsson, 2011). Water resources scarcity in the Middle East, particularly in Iraq, is a critical factor in the stability of the region and a key element in the economic development (Naff, 1994; Al-Ansari, 2005). About 75 billion m^3 of water come to Iraq from Tigris and Euphrates. Iraqi marshes account for about 44% of the total inland waters of Iraq (Jones et al., 2008). Therefore, the Mesopotamian marshlands are the strategic reservoirs of the water supply used in agricultural and industrial purposes before being discharged into the Persian Gulf (Al Obaidy & Al-Khateeb, 2013; Issa et al., 2013).

Groundwater

Water is usually infiltrating into soil cavities among soil grains, through small areas called small micropores spaces, and through networks of cracks, roots and channels known as macropore (Beven & Germann, 1982), or larger cavities known as soil pipes (Jones, 2010). The speed of water flowing within the soil varies, and the speed of water movement through small area networks tends to be greater than that of micropore networks within soil (Bromley et al., 2004). Therefore, the speed of water infiltration into the soil depends on the abundance of networks of both kinds (Jones, 1997, 2010).

Groundwater in Iraqi marshlands area is of an air origin. Meaning, it is caused by the penetration of rainwater and floods into the ground. (Haddad, 1978). The suitability of water in general and groundwater in particular for using depends on its quality (Boyd, 2000). The nature of underground water storage in all Iraqi marshlands is of semi-open area type. Groundwater flows according to the hydraulic gradient from high-pressure zones to low-pressure zones, depending on the topography of the region (Al-Asadiy & Atiaa, 2007). The groundwater levels in the middle of the marshlands reach shallow depths that do not exceed 1 m above sea level in some areas. The amount of water that can be discharged from the wells in the area is between 400 and 900 m^3 s/day. However, groundwater is rarely used to fill the marshes because of their low quality which may cause economic and environmental damage (Al-Sudani, 2017).

Corrosion function

Without plant cover, the soil erosion rates increase. Many countries, especially those in tropical areas, lose large amounts of soil because of the erosion. Globally, 11 million km^2 of land (equivalent to the United States of America and Mexico combined) are affected by the high erosion rates (Millennium Ecosystem Assessment, 2005). Each year, about 75 billion tons of soil are believed to be eroded from earth ecosystems, 13 to 40 times faster than the average required for soil creation (Pimentel & Kounang, 1998). Pimentel et al. (1995) stated that, according to the estimates of the second half of the twentieth century, the quality of one third of arable land in the world has deteriorated due to erosion and this means that economic and environmental losses are expensive and difficult to compensate (Myers,1997). Plants in wetlands play a key role in preserving the soil from erosion, whether these coastal wetlands or inland wetlands (Halle et al., 2004). Reppert et al. (1979) stated that the greater the area of coastal wetlands are, the greater will be the protection of shore from erosion. Wetlands loss leads to significant losses of lands due to erosion (Zinn & Copeland, 1982; Gellis et al., 2009), since wetlands and their plant cover play a major role in reducing dust storms (Kemp, 2008).

Iraqi marshes are characterized by their geographical location because they are surrounded by arid lands (Schaaf & Rodrigues, 2016) and, consequently, Iraqi marshes play a major role in protecting the soil from erosion. The functional role of Iraqi marshes was obvious when Saddam Hussein's regime committed the crime of draining the marshes during the 1990s. The dust storms increased, and rising dust appeared because of drying of marshes and exposure of large areas of soils and the loss of plants in those areas (UNDP, 2004).

Biological functions

Primary productivity

Primary productivity is the process of converting the solar energy to chemical energy by plants (Browne, 1981). Gross primary productivity is the total net of daytime photosynthesis and respiration of plants at night in a given environment (Walker, 2008). Primary productivity is an important tool for determining the state of nutritional levels and the potential for fish production in any aquatic ecosystem (Mohanty et al., 2014), and it is an essential tool for understanding the dynamics in ecosystems. Thus, it can be considered as a determinant of many ecosystem functions (Cho et al., 2007; Moeckel et al., 2017).

The primary productivity of marshlands is affected by soil properties such as pH, availability of calcium, magnesium, and possible condition of hypoxia (Bertness, 1985; García et al., 1993). In general, freshwater marshes associated with rivers are highly productive ecosystems (Mitsch & Gosselink, 1986), and the Iraqi marshes do not differ from this hypothesis. The increase in the primary productivity within the Iraqi Marshlands environment is due to the weak water currents, leading to increased growth of aquatic plants and algae (Hussain, 2014). The Iraqi Marshland Restoration Program (IMRP) reported that the initial productivity of phytoplankton in Iraqi marshes ranged from.1-12.5g/m^3/h at surface and 9.37-37.5 g/m^3/h (IMRP, 2006), consequently the Iraqi marshes have timings to start the prosperity and increase primary productivity, and there are timings for a decrease in the total number of phytoplankton species. Hammadi et al. (2007) indicated that the total number of phytoplankton species decreased during the summer months and during winter, particularly in December and January. Aquatic plants have significant primary productivity and are considered as a source of dissolved oxygen sources in water during the daylight hours (Green &

Galatowitsch, 2001; Jeppesen et al., 2012; Katende, 2004). Emergent plants in the Iraqi marshes are habitats for many living organisms, since the decomposition of these plants creates organic pathways, which are the key for the energy cycle in these regions (Njau & Maly, 2003). In addition, the plants play an important role in reducing the speed of the water currents, thus facilitating the deposition of suspended particles in the water (Whitney et al.,1981). In an integrative role, submerged plants absorb nutrients and particulate which are deposited in the water column and increase the activity of photosynthesis in the whole water body (Firestone, 1982). *Phragmites australis* is one of the most common aquatic plants in the Iraqi marshes, followed by the *S. litoralis* and thirdly by *T. domingensis* (Al wan, 2006).

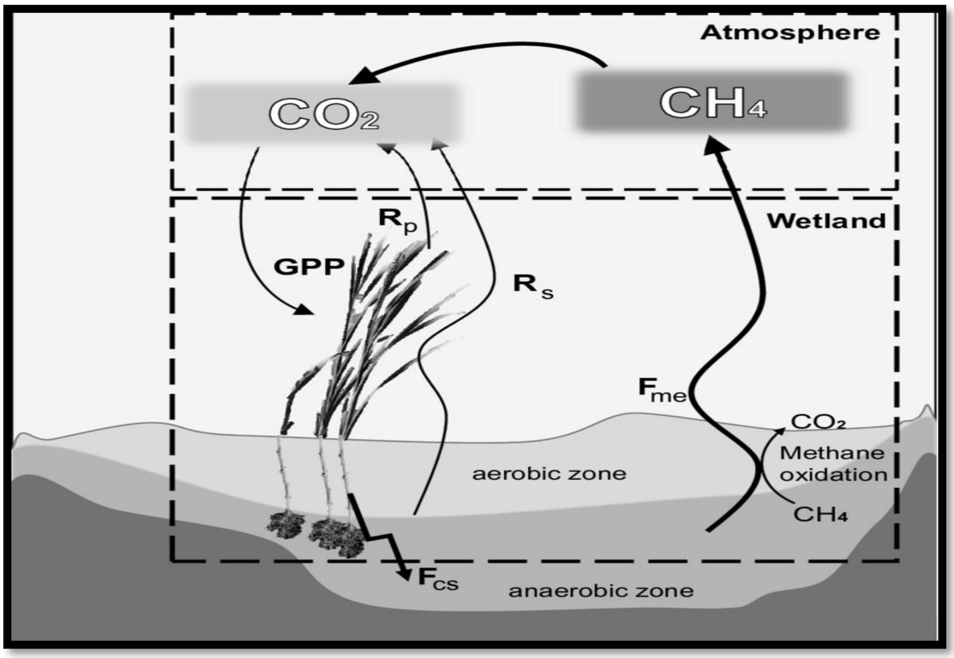
Function of carbon sequestration

Wetland ecosystems regulate carbon sequestration from the atmosphere, which helps in reducing the damage caused by global warming (Spaninks & Van Beukering, 1997). Plants absorb CO_2 during their growth process and then store it in underground plant biomass as sediments (Turpie et al., 2000). Carbon cycle is usually associated with microbiological cycles that produce the energy necessary for chemical transfers of nitrogen, sulphur and other compounds (Hagen et al., 2012). The activity of microorganisms is originally represented by a series of oxidative and reduction reactions that affect the outcome of bio-geochemical processes in wetlands (Mitsch et al., 2013; Johnston, 2014). The quantitative contribution of the microorganisms affects the bio-geochemical processes of wetlands and then of the flows of carbon and of other nutrients (Montoya et al., 2012). In fact, carbon dioxide emissions result from plant respiration and soil activity while methane emissions are produced only from soil activity (Bridgham et al., 2013), as shown in Figure 5. However, the total CO_2 and CH_4 emissions improve ecosystems، assuming that the presence rates of these gases affect the process of global warming. On the other hand, the emission of these gases is influenced by several factors, which are the same as those that control plant productivity within wetlands. They include microorganisms' community, diversity and abundance of plant community, biomass, salinity, wetland age, and water immersion ratio and soil nutrient contents (Blume & Schlichting, 1985; Inamori et al., 2007).

Carbon flow and greenhouse gases production in wetlands are affected by water salinity (Blume & Schlichting, 1985; Nyman et al., 1993). There is a general decline in methane flows with increased salinity in freshwater and saline swamps (Olsen et al., 1996; Poffenbarger et al., 2011). This decrease is due to large quantities of sulphate which prevent methane generation, and lead to lower methane emissions for the upper layers

(Bartlett et al., 1987). Al-Hammar Marsh is the saltiest among the Iraqi marshes, and the carbon cycle dominates the cycles of other elements (Hussain, 2014).

Figure 5. Flow of carbon (CO_2) pathways and methane (CH_4) in the wetland (Mitsch et al., 2013).



Water quality improvement

Wetlands are used as natural filters to improve water quality by reducing the quantity of suspended material (Kadlec & Knight, 1996; Mitsch et al., 2013; De Groot et al., 2002). Wetlands have been used in many countries of the world for water treatment, and more than 500 water treatment of marshes in Europe and 600 in marshes in Central America, Eastern Europe and Asia are registered (Aquarec & Wintgens, 2003). The use of aquatic plants in the treatment of water in the United States of America in the nineties of the last century has been improved since a number of wetlands was made. In addition, the use of aquatic plants to treat industrial water as well as domestic and agricultural wastewater was increased and improved (Sauer & Kimber, 2001). Jin et al. (2006) stated that the use of aquatic plants improves water quality, restores water bodies and controls pollution in many places in China, especially in Wuli Lake. Aquatic plants were considered the best technique for treating household wastewater in Toscana, in Italy (Conte et al., 2001). In Canada, 120 species of aquatic plants have been planted for water treatment (Eddy, 1991; Merz, 2000). Both Greenway & Woolley (1999) and Maine et al. (2006) clarified the different mechanisms for wastewater treatment by aquatic plants, such as reducing the speed of water flow, favouring the deposition of suspended particles and then reducing water turbidity. Emergent plants perform well for these processes with some submerged plants. The emergent plants have the ability to remove soluble inorganic nutrients (ammonium, nitrite, nitrate and phosphate) and heavy materials by absorption or direct introduction of the water column through stems of these plants, while their roots remove these materials from the bottom. Algae, floating and submersible plants remove pollutants directly from water column. The Iraqi marshlands play the role as a natural refinery to free Tigris and the Euphrates from waste and contaminants. This property of marshes is due to the slow flow of water through the thick plants as reed (*P. australist*) and reedmace (*T. domingensis*), which work to filter the water of some contaminants and reduce pollution of water flowing to the Persian Gulf (Maltby, 1994). The studies which are dealt with the treatment of water by aquatic plants in the Iraqi marshes are very few. Aziza et al. (2006) considered the reed and reedmace as a good vital evidence of the possibility offered by the environmental treatments because of their ability to accumulate trace elements such as copper, lead and zinc. Awad & Abdulsahib (2007) studied mercury concentrations in Al-Amara and Al-Basra marshes and Shatt Al-Arab in 13 species of aquatic plants, water column and precipitation. The highest concentration was found in *P. pectinatus* in Al-Hwizeh marshes. Mercury concentrations were higher in aquatic plants than in precipitation and water. Eddy (1991) and Sooknah (2000) demonstrated that the reduction of organic substances is carried out by the bio-oxidation process performed by the bacteria which were found on the thin capillaries of biofilms, formed on the stems and roots of the aquatic plants. Decomposers destroy organic substances and transform them into simple materials that can be absorbed directly by plants. Bacteria use organic materials to produce energy and form new cells. This biochemical interaction requires the existence of electron-receptors to oxidase organic substances. This interaction uses free oxygen as transporters of the electron provided by the aquatic plants in these areas, as shown in the following equation:

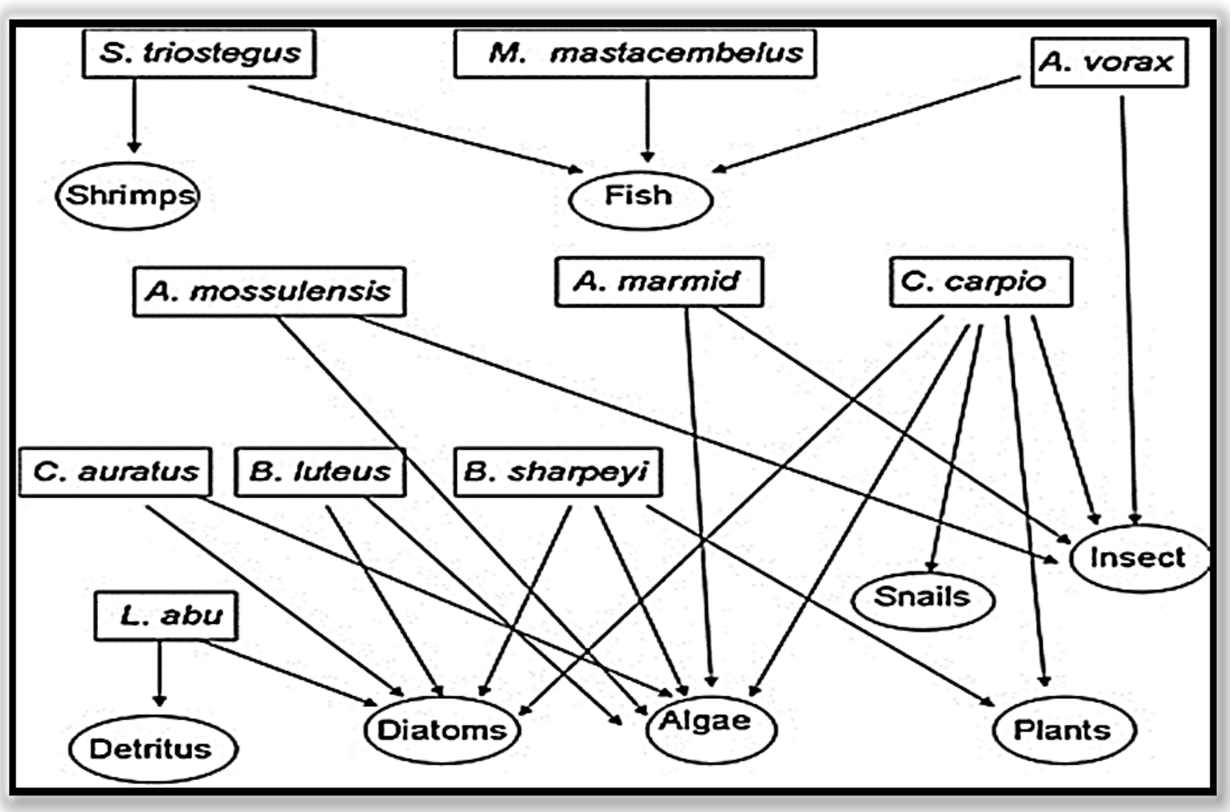
$C_2H_7O_2N + 5O_2 \longrightarrow 5CO_2 + NH_3 + 2H_2O + \text{energy}$ (Appels et al., 2008).

Food chains

"*Food web is a map that describes which kinds of organisms in a community eat other kinds*" (Pimm et al., 1991). Food studies in estuaries are often driven by the desire to understand the nutrition sources that support fisheries production (Bouillon et al., 2011). Organisms differ in their location on food webs, and this location depends primarily on the nature of nutrient interactions for each of the categories of this network (Rosemond et al., 1993; Osenberg & Mittelbach, 1996). Relationships among the different species in the food network can be represented hierarchically; the order of species starts from the bottom (bottom level of the food network) to the highest producers. The category of producers mostly consists of living beings including green plants and algae, as well as blue bacteria (Scott & Marcarelli, 2012). Autotrophs use a process called photosynthesis. In this process, carbon dioxide is used in the presence of sunlight and water to produce glucose ($C_6H_{12}O_6$) and release oxygen (Smith et al., 1987; Whitton, 1992; Scott & Marcarelli, 2012). Consumers represent the highest nutritional levels in the hierarchy of food networks; they do not produce their own food, but rather they feed on producers (McQueen et al., 1986; Moss et al., 1996). Accordingly, predators are at the top of the pyramid in food chains (Brose et al., 2005); the presence of predators is determined by several factors, including the properties of water and the abundance of habitats (Scheffer, 1991; Vanni et al., 1997; Jeppesen et al., 1990). Originally, changes in each food level are an opposite response to the next nutrient level; in other words, the effect of the higher level at the lower level (Jeppesen et al., 1990; van Donk & Gulati, 1995). Thus, the reduction of carnivorous predators allows the increase of animals with herbivores and so on (Carpenter & Kitchell, 1996; Lampert & Sommer, 2007). Competition within a single food level is a type of indirect food interaction known as a negative effect of one species on the rate of population growth or the abundance of another (Strauss, 1991; Wootton, 1994). Batzer et al. (2004) demonstrated that food webs in wetlands are mainly dependent on aquatic plants and organic detritus. Therefore, animal communities without predators do not suffer from shortage of food sources due to the abundance of these foods in wetlands (Neill & Cornwell, 1992; Bunn & Boon, 1993; Batzer & Wissinger, 1996).

Aquatic plants, large benthic algae, and phytoplankton are the main base in Iraqi marshes as primary producers (Al-Handal & Hashim, 1990). Aquatic plants, large benthic algae, and phytoplankton are consumed by animals, i.e. large herbivores, birds, large and small invertebrates and first-class herbivorous fish (primary consumers) (Plaziat & Younis, 2005; Ali et al., 2007). The marshes in southern Iraq are known for the largest group of detritivorous fish (Mitsch & Gosselink, 2000). Algae, diatoms and aquatic plants appear to be of great importance in these marshes. In these areas, 9 fish species feed on algae, diatoms and aquatic plants, while 6 species of fish feed on diatoms only (Mohamed & Hussain, 2012). Mohamed et al. (2012) described the nature of the food web of fish in Al-Chybayish Marsh, in the South of Iraq, during the period 2005-2006 (Figure 6).

Figure 6. Relationship in the food chain between five levels foods for the common fish in the Al-Chybayish marsh (southern Iraq), during the period 2005-2006 (Mohamed et al., 2012).



1.3.3 Habitat function and biodiversity

Parker (1989) defined the habitat as "*part of the physical environment in which plants and animals live*". Instinctively, living organisms require environments in which they find enough food, water, shelter, breed and escape potential predators (Marczak et al., 2010). Therefore, the vital role played by wetlands in maintaining the overall health of this specific ecosystem has become clearer over the past three decades: they provide big living environments for different species of flora, fauna, and biodiversity (Thompson & Luthin, 2010). Several definitions of the term 'biodiversity' have led to significant confusion in its meaning (Hamilton, 2005). Biodiversity can simply be defined as the "*number of taxa within a defined geographic range*" (Begon et al., 1986). The nature of inter-biotic relationships divides biodiversity into three levels (Alpha, α;

Beta, β; Gamma γ) (Sepkoski, 1988). The diversity of alpha type is the biodiversity within a site; it measures the species diversity or the variability in a selected area, community or a gathering. It is often measured using alpha diversity indicators, such as the Shannon Wiener index and Fisher's alpha (Magurran, 2013). Therefore, the H-index is used in most community studies to clarify and emphasize that the community has an equivalence in the appearance of species and the degree of similarity of species compared with other societies (Kobingi et al., 2009). Beta diversity is based on the study of diversity or heterogeneity rate for ecological communities between individual sites within a given area. It is measured in different ways, including Jaccard index (Hall et al., 2006), that is used to determine the similarity between sites in terms of the presence or absence of individuals in the area. It differs from the Shannon index, which compares existing species (Whittaker, 1960; Wilson & Shmida, 1984; Anderson & Cribble, 1998; Tuomisto, 2010). Finally, gamma diversity is a general biodiversity level; it measures biodiversity between two distant regions (e.g. two continents), and it is produced from alpha and beta diversity (Arellano & Halffter, 2003). Biodiversity greatly influences the stability of ecosystem functioning and the response to the environmental changes (Cleland, 2012).

Baiser et al. (2011) noted that change in species abundance affects population dynamics, resistance to invasions of uncommon species and stability of ecosystem functions, including carbon emissions, primary productivity and food webs. It is agreed that each organism varies in its interaction with other organisms and effects within the overall performance of the ecosystem, whether it is dominant in the community or not. The loss of any of these organisms will lead to the environmental disturbance (Naeem et al., 2012).

The marshes in southern Iraq have an exceptional biological diversity, they are among the 100 global sites in the list (Olson & Dinerstein, 2002) and have been identified as endemic birds' area (Salim, et al., 2009; BirdLife International, 2010), in addition, they contain a Ramsar site (Stattersfield et al., 1998).

1.3.4 Information function

Ancient human often used rivers and lakes as habitats. Wetlands provide drinking water and food (such as fish and birds), as well as pastures and transport (Evans, 2002), they have witnessed civilizations of peoples and constituted an important part of their cultural heritage, including the mythology, arts and religion (Barbier et al., 1997).

Accordingly, wetlands are an essential source of information. The information function can be classified into many levels.

Scientific research

Wetlands are a source of information about aquatic organisms, bird species, habitats, ecosystem functions, and natural biological processes and relationships among them (Turpie et al., 2010). Iraqi marshes have been fertile ground from various study aspects, cultural, historical, water, biological, as well as the taxonomic aspects of the biota in the Mesopotamia region related to microorganisms (Annandale, 1918; Al-Qarooni, 2005), plants (Blakelock, 1957; Al-Hilli et al., 2009), fish (Khalaf, 1961; Coad 1991, 1996, 2010), birds (Sharpe, 1886; Salim et al, 2010), mammals (Hatt,1959; Al-Robaae & Kingswood, 2001) and reptiles (Boulenger, 1918; Haas & Werner, 1969; In-den-Bosch, 2003).

Entertainment and aesthetic features

Wetlands are unique landscapes that do not exist in other environments and offer opportunities for recreational activities such as camping, fishing and bird watching (De Groot et al., 2002). Scott & Evans (1994) presented a general primary list of elements of the landscape which form the marsh scene of fresh, permanent freshwater lakes with dense growth of submerged aquatic plants and narrow lanes within the large promontory plants of reed and papyrus and the sloping mud banks. Many sources, which are taken from travel books and reports that have dealt with many Iraqi Marshlands testify about their beauty and uniqueness (Maxwell, 1957; Young, 1977). There is also a reference to the Mesopotamian marshes in Sumerian literature (Young, 1977). Thesiger (1954) described his first experience of visiting the marshes in the 1950s as follows:

"*Memories of that first visit to the Marshes have never left me: firelight on a half-turned face, the crying of geese, duck flight in to feed, a boy's voice singing somewhere in the dark, canoes moving in procession down a waterway, the setting sun seen in crimson through the smoke of burning reed beds, narrow waterways that wound still deeper into the Marshes*".

1.4 Ecological factors

Physical and chemical properties of water are the determining factors for the spread of aquatic organisms and fish, in particular through their impact on metabolic activities, growth, nutrition, reproduction, diversity and migration behavior (Lowson, 2011).

Galacatos et al. (2004) pointed out that the physical and chemical factors have direct effects on the biological diversity of fish in the aquatic ecosystem. The low water levels in any water body increase the salinity values, electrical conductivity and hardness, and decrease dissolved oxygen and pH values leading to a decrease in the species number. Therefore, it seems that the biological diversity of fish communities is unstable due to the changes in physical and chemical characteristics of the ecological habitats. Dike et al. (2004) reported that the alteration in physical and chemical properties of water in any water surface for long periods may result in undefined changes in the biodiversity of fish. They added that water characteristics are specific and determinant to the quality and performance of wetlands' functional diversity (Mitsch & Gosselink, 2000).

1.4.1 Water temperatures

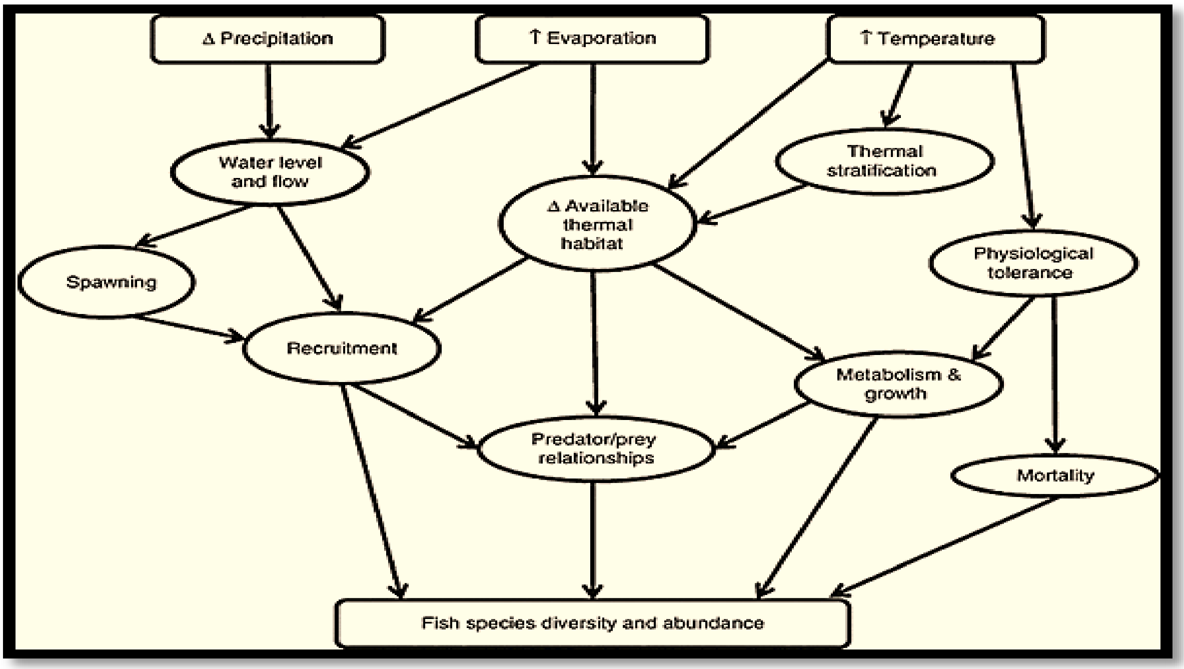
The water temperature (WT) plays an important role in the chemical reactions in aquatic environment through its effect on the metabolism of organisms and their ability to compete each other (Welcomme, 1979; Tiwari et al., 2006). Most of the studies and researches related to the physio-chemical factors that affect the nature of aquatic bodies, demonstrated that temperature is one of the most important properties, due to its capacity of interfering with many other physical and chemical factors in water, which is reflected on the functional role of water bodies (Weiner, 2000; Kieffer & Cooke, 2009). Water temperatures are effective in many water properties such as solubility of gases, salts, viscosity, density, electrical conductivity and surface tension, as well as in their identification of aquatic organisms' activity capacity. Some species of fish suffer more than others, due to the scarce ability to realize anatomical, physiological and behavioural adaptations to environmental changes. The more adaptive the features of this capacity by the fish, the better adaptations they have to the changes in temperature (Rivers-Moore et al., 2012).

Temperature is a key factor of water density, which is directly related to salinity that determines the distribution of organisms in the water body (Geyer et al., 2011). Grossman & Ratajczak (1998) stated that temperature is one of the most important physical factors affecting water quality in any water body. Despite the homogeneity of temperature within the water column in shallow water bodies, deep water bodies show variations in their water temperatures. Temperature affects the physiology and behaviour of aquatic organisms, particularly of fish (Bannon, 2006). This effect is directly reflected in the diversity of the fish community (Figure 7). On the other hand, high temperature affects the solubility of gases. Plants shading water surface reduces the temperature and increases the concentration of oxygen (Poole & Berman, 2001). In a related context, moderate temperatures during spring and autumn seasons increase the amounts or numbers of fish due to feeding availability and breeding, and their movement is a reason to be caught during these seasons (Scott & Poynter, 1991). Fish, like other exothermic organisms, have a temperature directly dependent on the surrounding water, so when the temperature of the external environment changes, it reflected directly on the temperature of the fish body (Isyagi et al., 2009). Hölker (2003) noted that the increase in temperature would increase the chemical reactions within the body of the organism, and thus accelerate the processes of metabolism and breathing and growth. The temperature should be within the optimal ranges for each species and physiological phase within the species, and within endurance limits. But, if these creatures cannot regulate their vital activities under these conditions, it will happen a delay in growth. Because of the reduced energy available due to the stress processes that regulate the new conditions, each fish species has an ideal temperature for the performance of its physiological functions.

Coutant (1975) identified the Low Thermal Response (LTR) as the internal ability of fish to detect deadly heat. Small fish show high sensitivity to changes in water temperature, so their body temperature reaches equilibrium more quickly than large fish (Jobling, 1981).

It is generally accepted that a fish has a high sensitivity to temperature fluctuations. It pursues a definitive behaviour in dealing with temperature, and the most famous behaviour is the phenomenon of thermal avoidance (Boubee et al., 1991), that means the ability of the fish to avoid high temperatures when adapted to preferred temperature (Coutant, 1987). Based on this behavioural adjustment, fish will instinctively choose the space that provides them with the optimum temperature to efficiently perform all their life functions (Richardson et al., 1994). The ability of fish to tolerate heat varies depending on the temperature, age, and sex of the fish. The same tolerance decreases with the reduction of oxygen concentration in the water (Boubee et al., 1991). On the other hand, the temperature plays a key role in fish maturity and reproductive characteristics, such as early maturity and high fertility (Viravong, 2006). In addition, the survival rate of fish eggs also depends on water temperature (Jobling, 1981). Therefore, the temperature of water unquestionably affects fish distribution systems and species abundance in any water body (Clarke, 2003). Understanding the various effects of temperature on fish helps to rationalize the behaviour of fish in migration, the abundance of species, and the nature of fish nutrition in water bodies.

Figure 7. Predictive effect of changing rainfall ratios increased degree of temperatures and increased evaporation value on the diversity and the abundance of fish species. Change = Δ, increase = ↑ (Pankhurst & Munday, 2011).



1.4.2 Hydrogen ion concentration

The acidic function (pH) is defined as the negative logarithm of hydrogen ions concentration (Stone & Thomforde, 2004). The acidity and alkalinity of water is determined by the concentration of hydrogen ions (H^+). Acidic water contains a higher concentration of hydrogen ions than hydroxyl ion (OH^-), while alkaline water contains a higher concentration of hydroxyl ions than the hydrogen ones (Dickson, 1984). The term "pH" has been proposed since 1909. It has been expressed that the value of pH is equivalent to the negative logarithm of positive hydrogen ions, i.e.:

$pH = - Log [H^+]$ or $pH = Log 1 / [H]$ (Culberson, 1981).

In fresh water bodies, pH values fluctuate significantly. These fluctuations are usually due to the plant photosynthesis and the respiration of aquatic animals. Carbon dioxide (CO_2) is produced through the respiration process by animals and this gas has an acidic effect in the water (Fulazzaky, 2009). This hypothesis can give an acceptable explanation for the observed low pH values in water during the summer season. In summer, two important factors are overlapped, which are the length of lighting period and the rise of temperature (Singh et al., 2002; Alabaster& Lloyd, 2013). The value of the acidic function decreases at dawn and then rise at noon with an increased photosynthesis in some cases (Abdel-Tawwab et al., 2010). On the other hand, the increase in organic and inorganic elements leads to rise in pH values in water (Bates & Vijh, 1973). This is evident in the rainy season, where the values of the acidic function increase because of the increase in organic elements, sediment deposits and sediments washed by the rain (Allan & Castillo, 2007). High pH values lead to disturbance in the biological balance, through elimination of bacteria and microorganisms, as well as algae. This in turn disrupts the food chain of fish, and thus affects the functional diversity of aquatic organisms, increases the competition among fish and causes declines in the fish numerical abundance (Dodds, 2002). On the other hand, the decrease in pH values helps the activity and reproduction of certain species of bacteria and fungi, which secrete compounds that lead to the water toxicity (Morris, 1978). The values of the acidic function also affect the organ performance. The increase of the acidic function or the decrease of the acidic function will lead to imbalance in fish bodies (Kiran, 2010).

Table 1. Effect of pH values on the fish (Swingle et al., 1969).

pH	**Effect on fish**
4	Acid death point
4 to 5	No reproduction
5 to 6.5	Slow growth
6.5 to 9	Desirable ranges for fish reproduction
9 to 10	Slow growth
≥11	Alkaline death point

The average known pH of fish blood is 7.4 (Heath, 1995; Roberts, 2012). The optimum pH range for fish life is 7.0 to 8.5 (Seker et al., 2003). Fish can become tense in water with a pH ranging from 4.0 to 6.5 and 9.0 to 11.0, and the death is almost certain at a pH less than 4.0 or greater than 11 (Ekubo & Abowei, 2011). Swingle et al. (1969) summarized the effect of pH values on fish, as shown in Table 3. This preference for fish for appropriate pH values in aquatic environments has a crucial role in the formation of fish community (Lowe-McConnell, 1975). During the life cycle of fish, each age stage has optimal pH values (Ferreira et al., 2001; Parra & Baldisserotto, 2007).

1.4.3 Salinity

Salinity is a term given to the total concentration of dissolved salts in water (Buttner et al., 1993), or it is the total concentration of ions in freshwater (Teillet et al., 2010). Salinity is a source of concern around the world. The consequences of salinization are often severe, partially because they are associated with significant changes in the hydrology and ecology of water bodies (Salcon, 1997; Nielsen et al., 2003). As a result, the increased salinity changes the structure and functions of freshwater systems (Bailey & James, 2000; Blinn et al., 2004). Several studies indicated that the increased salinity in freshwater ecosystems is associated with the reduction of the species abundance and of productivity of some species (Nielsen et al., 2003). Salinity is associated with a reduction in the abundance of phytoplankton species and large aquatic plants; it has a significant impact on plant root areas, as it can reduce the ability of plants to absorb water through their roots by osmosis. This causes necrosis and creates imbalances in nutrition that leads to poor growth or mortality (Beek et al., 1980). These interrelated environmental impacts of salinity have made it one of the most important determinants of the functional role of the ecosystem (Nielsen et al., 2003).

The United States Geological Survey has classified the water based on the saline content into three categories: *i)* brackish water, which has a salt concentration of about 0.1 to 1.0 g/L; *ii)* moderate saline water with a salt concentration from 1 to 10 g/L; *iii)* severe saline water with the salinity range from 10 to 35 g/L (Rzóska, 2012; Anati, 1999).

The salinity is measured by calculating the extent of electricity transmission across water, i.e. by its conductivity (Lewis, 1980). The ratio of ions to water quality standards affects some of the physico-chemical properties of total and basic precipitation, electrical conductivity, alkalinity, acidity, water viscosity and surface stress. This, in turn, affects the distribution and spread of aquatic organisms, particularly fish (Grzesiuk & Mikulski, 2006).

Water in which the fish live is not entirely pure. It is a good solvent for many ions (Sabri et al., 1993), that give to the water body a balance of ionic balance. In contrast, fish are trying hard to maintain a certain balance of ionic concentrations in their body fluids and the state of ionic equilibrium within the body (Benli & Yildiz, 2004). However, the problem with fish lies in the fact that the internal ionic equilibrium does not appear to be compatible with the external aquatic environment in most species. Thus, fish adopt a specific physiological mechanism to maintain the internal ionic balance, known as ion regulation. It is well known that both freshwater and saline water do not have a similar ionic balance. Although fish seek to achieve a state of tight stability, the environments inhabited by fish are often different in their ionic balance and these physiological problems have been associated with the evolution of fish over millions of years. If we are to agree that the basic laws of physics in the universe have worked towards creating a balanced and harmonious environment, then it is the nature of water that has contributed to the success of fish and to their ability to overcome these osmosis problems (Evans et al., 2005). Although, each type of fish has a specific range of environmental variables in which it can live, fish can get used to a certain limit of these environmental variables by their physiological responses to altering their internal environment over time in the long term (Carneiro & Urbinati, 2001). Most freshwater inhabitant fish are saline moderate-tolerant fish because they do not tolerate high saline and suffer major losses when they undergo a sudden change in the saline level of the environment in which they live. These losses result from the occurrence of so-called osmotic shock (Geddes, 1979).

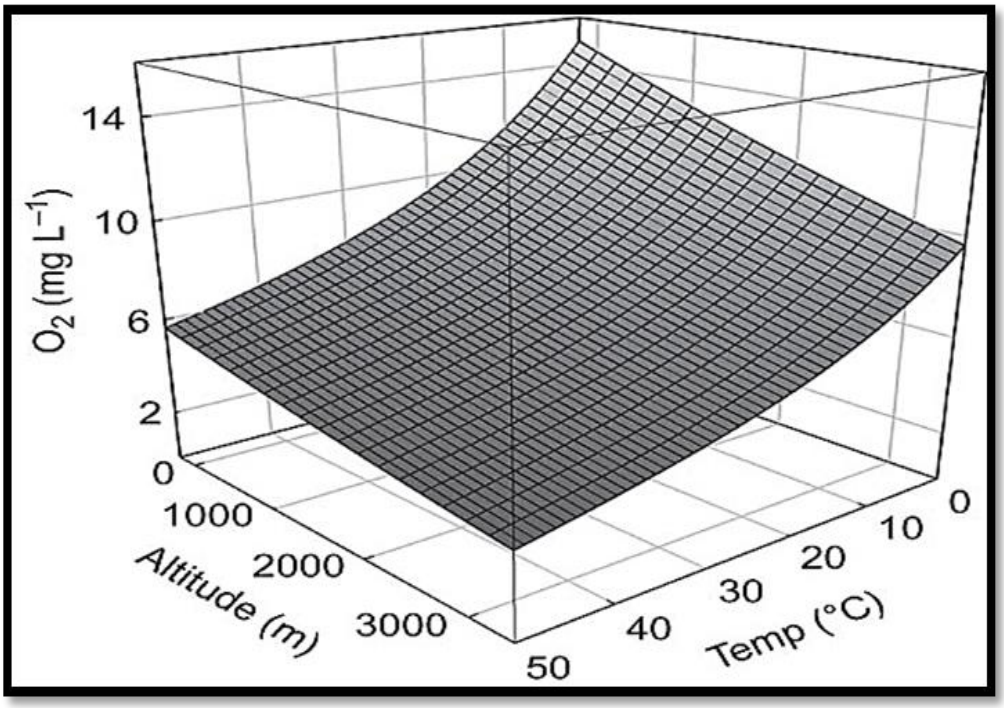
The increasing salinity of freshwater bodies is a serious environmental problem due to the negative impact of high salts on the survival of aquatic organisms in general and of freshwater fish, in particular (Williams, 1987). The question by recent research on this subject is why cannot some species tolerate the maximum saline content? Some scientific explanations may help to providing a small part of the answer: first: the loss of the aquatic environment and other environmental factors to the conditions at maximum salinity site، second: the geographical distribution of these species may be limited to specific areas with low salinity or high salinity that may have a direct or indirect effect on changing other factors that determine the distribution of species. Moreover, the presence of one or more species within a particular salinity does not necessarily mean that they can complete there their life cycle. Salinity also affects the rate of oxygen consumption in different ways. This is represented in a U-shaped curve where the high oxygen consumption is in high or in low osmotic environments, while the low consumption rate is observed in the medium or equal osmotic environment (Laiz-Carrión et al., 2005). High oxygen consumption resulted from fish exposure to salt strain may in turn indicate the ingression of energy consumption also metabolic rates and associated blood glucose use. Most fish exposed to salinity follow these physiological responses (Hattingh, 1977). Blood sugar levels are often elevated consequently to higher salinity in the ocean to meet the increasing need for energy for osmosis and ionic regulation resulting from different salinity levels (De Boeck et al., 2000; David et al., 2005).

Salinity and temperature are important environmental factors that have a significant impact on fish survival, growth and distribution. Salinity affects growth by affecting fish appetite, food intake, and food movement through the digestive canal (Boeuf & Payan, 2001). Many studies have highlighted the effect of salinity on the growth of several species of fish. These studies do not represent a fixed base on the effect of different saline concentrations on the growth achieved by fish and this is due to two reasons, the first is the difference in the salinity effects according to the species and their age ranges, while the second is the difficulty to determine the optimal salinity for the growth of a particular species of fish (Boeuf & Payan, 2001). The fish appetite is negatively affected by the increase in salinity values. The efforts in the process of azimuth regulation and high blood pressure lead to confusion in digestion and loss of appetite (Arnesen et al., 1993). Digestibility is one of the important measures by which food items can be recognized and determined by nutritional value (Jobling, 1986). The digestion of food and its passage through the fish digestive canal are affected by factors such as temperature, fish size, composition and intake of food, and health status of fish (Hepher, 1988). Salinity affects the digestibility of food in fish indirectly through its effect on the food movement through the digestive tract (Jobling, 1983). At least in theory, fish with a wide range of tolerances are often used as a model to compare fish from freshwater and fish from brackish water in determining the digestibility of food because the entrails operate differently in both environments (Evans, 1994). Nielsen et al. (2003) referred to the threat of salinity in Australian fresh water, where they demonstrated the effect of groundwater and the effect of increasing salinity on aquatic organisms when salinity exceeds 1000 mg/L, as well as the effects of this increase on the physical environment of water and the consequent effects on functional diversity of water systems. In the USA, researchers found that salinity has a strong association with the biological functions of wetlands, such as the spatial distribution of fish populations (Series, 1992; Gelwick et al., 2001). The salinity system also affects the habitat function of species living in the marshes assuming that wetlands provide an appropriate habitat for aquatic organisms. Therefore, the salinity effect on the presence of species and brooding cycles in these environments undoubtedly affects the habitat of these species (Minello et al., 2003). In Europe, studies on this subject are relatively few, even though salinity is an important environmental factor that regulates wetland communities and affects the use of marshes by species that inhabit or visit these areas (Mathieson et al., 2000).

1.4.4 Dissolved oxygen

The amount of dissolved oxygen (DO) per liter of solution is called dissolved oxygen (Maulood & Boney, 1981). Xiao-Jun & Ruyung (1992) reported that ponds and lakes cannot support the life of organisms when oxygen is down starting from fish to aquatic insects and microorganisms. Therefore, it is important to understand the behaviour and distribution of oxygen in the natural environment to give a close perception to the extent of the effects produced by dissolved oxygen on aquatic ecosystems. The quantity of O_2 dissolved in water is a function of many factors, including the abundance and diversity of species (Bergheim et al., 2006). Being a gas, oxygen has low dissolution in water, and water ecosystem, by nature, imposes types of interference among environmental factors. The percentage of oxygen dissolved in water is often affected by the surrounding temperature in a predictable manner, as shown in Figure 8. The relationship between temperature and dissolved oxygen fundamentally affects the functional diversity of lakes and ponds and it is agreed that all organisms living in such type of water need mainly appropriate rates of DO and suitable temperatures for living (Kelly & Linda, 1997). Weiner (2000) stated that the dissolved oxygen in water has an important effect on some of the chemical reactions that take place in the water column and in sediments of the water body. The increase in oxygen dissolved in water environments results from many ways, including wind and water waves as well as by the photosynthesis activity realized by the aquatic plants. Several other factors may affect the decrease in dissolved oxygen in the water, including the high temperature, salinity and groundwater currents, as well as the topographic locations of the water body. Flody (2005) clarifies that the decrease in dissolved oxygen levels by depletion has a significant and direct effect on the availability of fish. The variation in the DO demand among fish depends not only on species but also on fish activity and weight. Flody (2005) explains that most fish require between 6 and 5 mg/L to grow naturally but, if the level of DO reaches 4-3 mg/L, the fish will stop feeding and, if the concentration of DO arrives to 1 mg/L, most fish will die.

Figure 8. Relationship of dissolved O_2 saturation (mg/L) in water column (m) and temperature (°C) (Eaton et al., 1995).



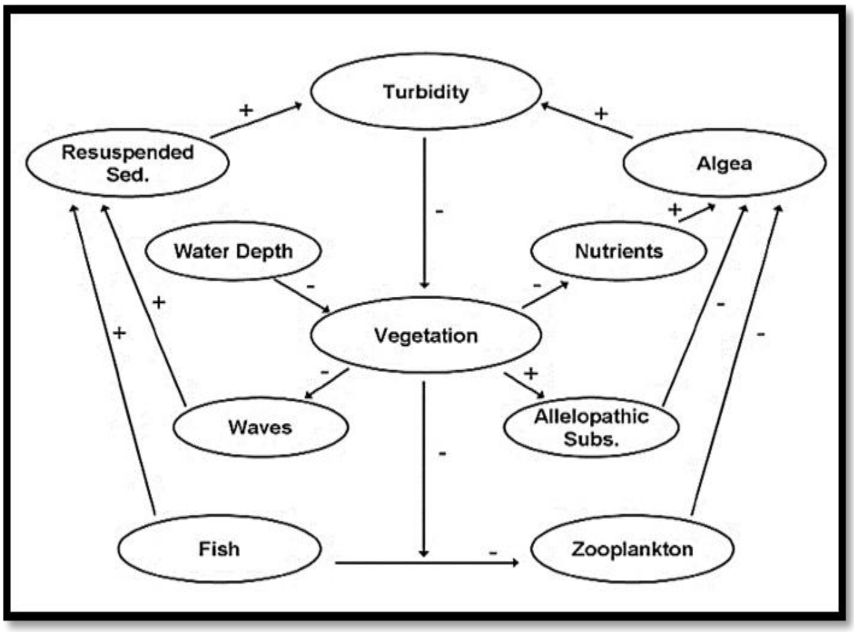
Fish, like other animals, breathe by inhaling oxygen and exhaling carbon dioxide and the process is performed using gills in almost all fish (Svobodová, 1993). It is believed that fish, in the lack of oxygen in the aquatic environment, usually tend to go towards the surface of water as a last resort and a way of breathing; then, they start unusual hibernation and stop feeding, perhaps because they do not have enough energy for swimming and nutrition (Yovita, 2007). The metabolic rate is strongly affected by the concentration of oxygen in the aquatic environment, which is reflected on the rate of growth and the risk of disease. As a result, dissolved oxygen directly affects the diversity and abundance of species which, in turn, is reflected in the functional role played by water bodies (Boyd, 1982; Crampton et al., 2003; Nordgarden et al., 2003).

1.4.5 Turbidity

The turbidity reflects the loss of transparency in liquid (Mishchenko et al., 1999). Water has the ability to scatter the light passing through it; the light is absorbed by water particles and suspended particles. Concentration of these substances and their type, color and size indicate the degree of turbidity in water (Mortimer, 1971). The suspended solids mostly consist of silt, mud and tiny particles of organic compounds and microorganisms (Bouffard & Hanson, 1997). Suspended materials, whether organic or inorganic, are deposited when the water movement stops or weakens, leading to known differences in the turbidity of the water of streams, rivers, ponds, lakes, and other still and moving water bodies (Tanner & Jackson, 1948). The presence of turbidity in the water leads to multiple damage, especially with the increase in temperature and the lack of saturation ratios in oxygen and the deposition of sediments in the bottom of the water and its effect on some of the benthic organisms in it (Wenz, 1992; Hanson & Butler, 1994).

High values of turbidity can reduce primary productivity by acting as a shade on algae, leading to the almost total elimination; in addition, the suspended solids can have adverse effects on aquatic animals through the intervention on reproduction, transfer of the respiratory O_2, gill health, nutrition and habitat abundance (Hynes, 1970; Waters, 1995). The high level of turbidity often leads to the reduction of animal biomass (Lougheed et al., 1998), affecting some biological functions of wetlands, including food chains. In addition, it has a direct impact on the diversity and abundance of the fish community, as shown in Figure 9.

Figure 9. Conceptual model summarizing the effects the turbidity in the ecosystem of the marsh (Scheffer et al., 1993).



The increase in total suspended solids affects the diversity of fish by gathering on fish gill and reduction of the respiratory efficiency, thus, the rate of growth and the resistance to diseases are reduced and negative effects can be found also in the evolution of eggs and their larvae (Galacatos et al., 2004). Moore et al. (2008) studied the deadly ranges of turbidity and their effects on groups of common freshwater fish and invertebrates in the Auckland Rivers. They found the guide lines for each of these organisms and the expected effects of high concentrations of turbidity on the longevity of these organisms. Suspended solids are natural parts in all freshwater environments. However, human activities such as agricultural and urban drainage water often lead to increased levels of suspended solids in many habitats as well as the expected effects of aquatic plants on turbidity (Forman & Alexander, 1998).

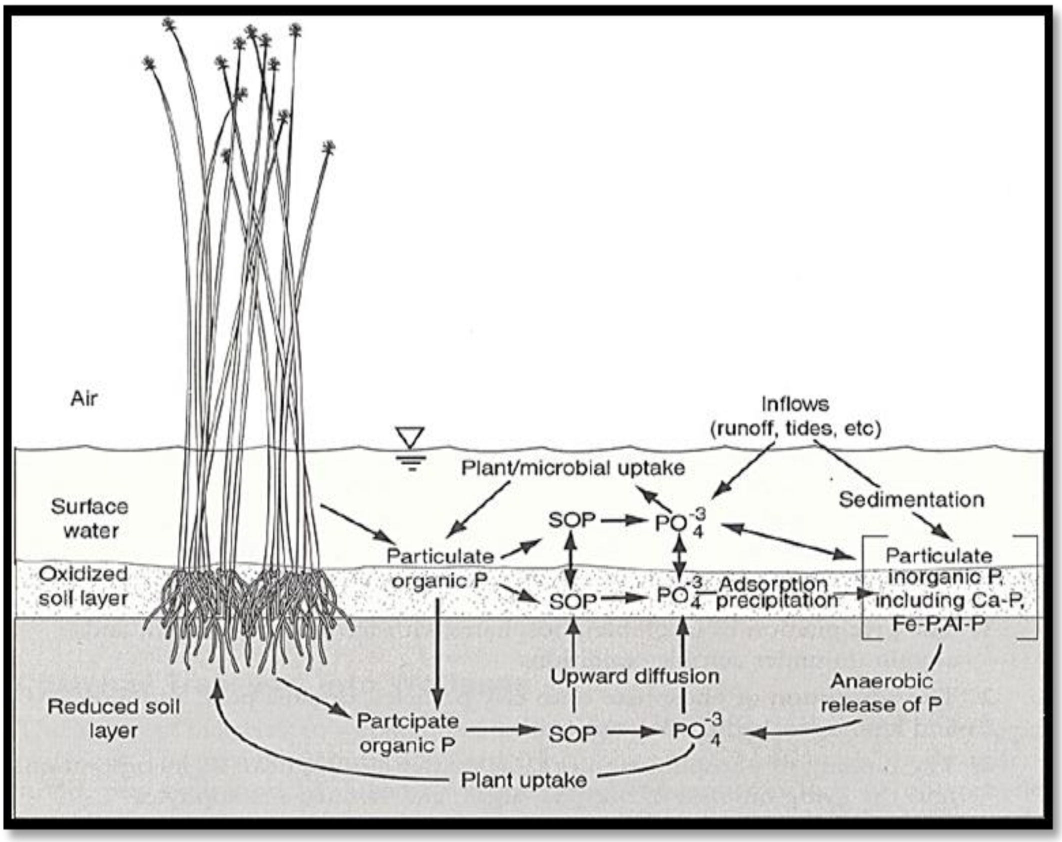
1.4.6 Phosphate

Water quality attributes, such as nutrient concentration, biomass and turbidity are often used in lake classification systems to document the nutrient status of lakes and reservoirs (Carlson, 1977; Goldman, 1988). The nutrient status of the lakes is usually identified by several alternative measurements, such as the Secchi disk and the phosphorus concentration (Carlson, 1977), that is one of the essential nutrients for the life on this planet (Pasek, 2008).

A phosphate is a form of phosphorus in the natural water (Stumm,1973); it is a subsurface resource, usually found in soluble form or suspended in a water medium and can also be found in benthic deposits as well (Colman & Holland, 2000). Phosphate is classified into three forms (orthophosphate, condensed phosphate, organic bounded phosphate), and the ionic formula of phosphate depends on the temperature and the concentration of the hydrogen ion (Wetzel, 2001). Phosphate as soluble is founded in a few concentrations since aquatic plants absorb it, and its concentration in water varies according to the population density, agricultural activity and soil characteristics (Dawood, 1980). The analytical separation between soluble and insoluble phosphates is done through filter paper, since dissolved phosphates pass through filtering paper with 0.45 μm porosity and the insoluble phosphates cannot (Thompson & Yeung, 1982).

Phosphate rocks are considered as the primary source of phosphorus in the soil and are usually found in forms of different compounds, but the compound that is used by living organisms is called “reactive phosphate”, characterized by its low solubility in water (Hem, 1985), as shown in Figure 10. In water, the main source of phosphorus compounds is represented by the washing powders and by what is carried off with soils because of agricultural activities (Svendsen et al., 1995).

Figure 10. Conceptual model summarizing the phosphorus cycle in the marsh (Mitsch & Gosselink, 2000).



The phosphate level strongly affects productivity and thus the structure of the ecosystem functions (Paytan & McLaughlin, 2007). Also, it is recognized that the phosphorus cycle affects the role of other key elements, such as carbon and oxygen (Berner, 1986; Colman & Holland, 2000). It is accepted that phosphate itself has no toxic effect in the environment, however, the problem comes from phosphorus as such, since it is an important nutrient of aquatic plants, and consequently it plays a key role in the process of photosynthesis, making algae and plants grow abnormally in water. This last phenomenon significantly affects the concentration of dissolved oxygen in the water (Schulz & Jørgensen, 2001) which, in turn, affects fish life and the construction of their population. Also, phosphate deposits can contain large amounts of heavy metals, found naturally in water. Also, mining operations that deal with phosphate rocks can leave behind high levels of cadmium, lead, nickel, copper, chromium and uranium, which, if not managed efficiently, can leak heavy metals into adjacent groundwater or swamps. Plants and fish consume those substances, which can lead to high levels of toxic metals in the superposition of these organisms (Schulz & Jørgensen, 2001; Diaz & Rosenberg, 2008).

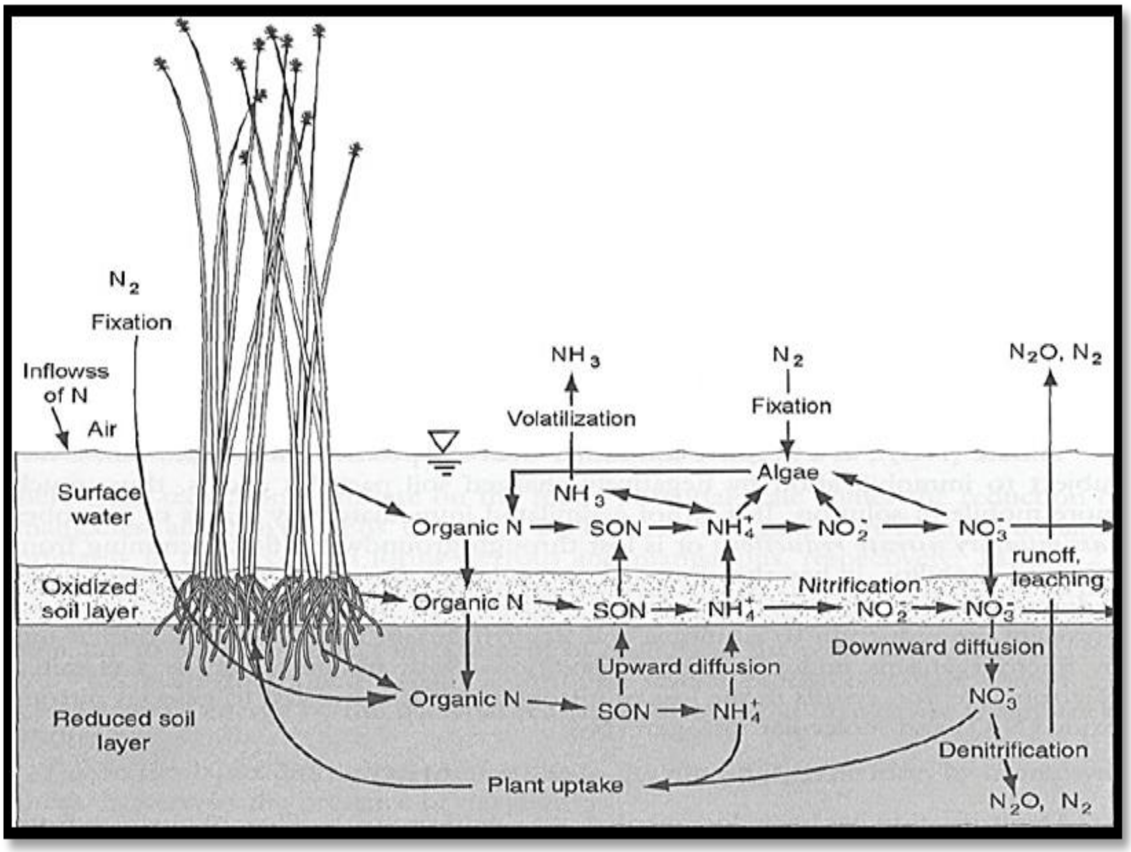
1.4.7 Nitrate

The functions realized by ecosystems in wetlands are undoubtedly influenced by human activities, that often have a negative impact on the functions of these systems. Plant nutrients such as nitrite and nitrates have an obvious importance. By knowing their concentrations, it is possible to predict the extent of their environmental effects, since their reduction determines the productivity of that environment (Hutchinson, 1957). The increase in their levels causes pollution and becomes poisonous to fish and human, because they are soluble and do not be adsorbed on minerals or the surface of the soil (Warren, 1971). Most nitrates in natural water are organic or chemically obtained from agricultural and industrial waste. There are amounts of nitrates that come from the oxidation of nitrogen gases (Smith et al., 1987). Nitrogen enters the wetlands in organic and inorganic forms. The product of organic form analysis is NH_4^+ and NO_3^-. Non-organic nitrogen is dissolved (NO_2-N and NO_3-N) or is associated with suspended sediments in water (NH_4-N). The molecular state is deposited and buried with the bottom deposits as shown in Figure 11. Therefore, nitrate is the oxidized form of nitrogen and when it is reduced, it turns into nitrite.

Many types of bacteria in the aquatic environment (the most important is *Nitrosomonas* spp.) convert ammonia into nitrite which, in turn, is transformed in nitrate by another group of bacteria, mainly *Nitrobacter* spp. (Brinkhurst, 1975). Whereas in anaerobic mediums, a reduction process occurs where nitrates are converted into nitrite by bacteria, the most important of which are *Pseudomonas* spp., then to the nitrogen gas which rises in the air (Krenkel, 2013).

The increased concentration of phosphates and nitrates in the bodies of water causes an enormous growth of plants, especially algae, because the plants absorb most of the nitrates immediately after their liberation by the bacteria. Therefore, it seems logical to note that water bodies that do not contain plants have a high nitrate concentration because the nitrate ion is unstable and is not adsorbed and deposited and can only be extracted by organic activities or evaporation (Rodvang & Simpkins, 2001). Water retaining of nutrients varies depending on how long does nutrient stay in water, saturation and water characteristics. The nutrients retaining is different in rivers compared to lakes and ponds (Khuhawar & Mastoi, 1995).

Figure 11. Conceptual model summarizing the nitrate cycle in the marsh (Mitsch & Gosselink, 2000).



Nitrates are present in rainwater at rates of 0.1-0.3 mg/L and over (600 mg/L) in groundwater affected by agricultural fertilizers (Davies & Dewiest, 1966). Surface water has a concentration of nitrates between 0 and 18 mg/L and non-contaminated natural water has a concentration of 5 mg/L (Hamil & Bell, 1986). The acceptable limits of nitrates concentrations in water are 45 mg/L and the increase in the concentration of nitrates leads to the formation of compounds that prevent oxygen from passing through haemoglobin in fish (Kendall, 1991). This has negatively effects on the physiological activities, leading to a decline in growth or mass death of fish (Cushing, 1975). On the other hand, Nixon (1982) noted that there is a direct relationship between the perfect limits of primary productivity and nutrients and the abundance of fish. The same concept is referred to by Caddy (1993), who built his hypothesis that the forms of fisheries for marine or freshwater water depend on food pathways and primary productivity. This hypothesis was strengthened by providing further evidence of this phenomenon by Oczkowski & Nixon (2008) who found a positive relationship between the levels of nitrogen, and the benthic and total productivity in the aquatic environment.

They pointed out that this relationship continues in this way until reaching a critical point, after which the relationship takes another direction.

1.4.8 Composition of the fish community

Fish is one of the most diverse vertebrates' groups, includes 64 order, 549 families, 5054 genera and 33200 species (Froese & Pauly, 2015). Freshwater fish includes nearly 15,000 species, which are richer than the sea fish according to volume unit. There is one species per 15 km^3 of freshwater compared to the same number per 100,000 km^3 in marine waters. The fresh water fish include 7,956 species of 6 families that make up to 24% of all existing species. These families are, Cyprinidae (containing 2420 species), Gobiidae (1950 species), Cichlidae (1350), Characidae (962), Loricariidae (684) and Balitoridae (590 species) (Ormerod, 2003; Wiley & Johnson, 2010; Reid et al., 2013). Discussing the difference in the distribution of living organisms is a fundamental issue in ecology, and several factors determine the nature of the life diversity. In internal environments, the species abundance in the fish communities is ruled by many biotic factors and their interactions, which include competition and predation. The overlap of environmental needs also plays a large and influential role in the species diversity (Oberdorff et al., 1998). It is recognized that the structure of the fish community in the aquatic ecosystem is largely affected by the water quality standards (Carol et al., 2006), although fish tend to keep a stable species composition within the fish community (Gomes et al., 2001).

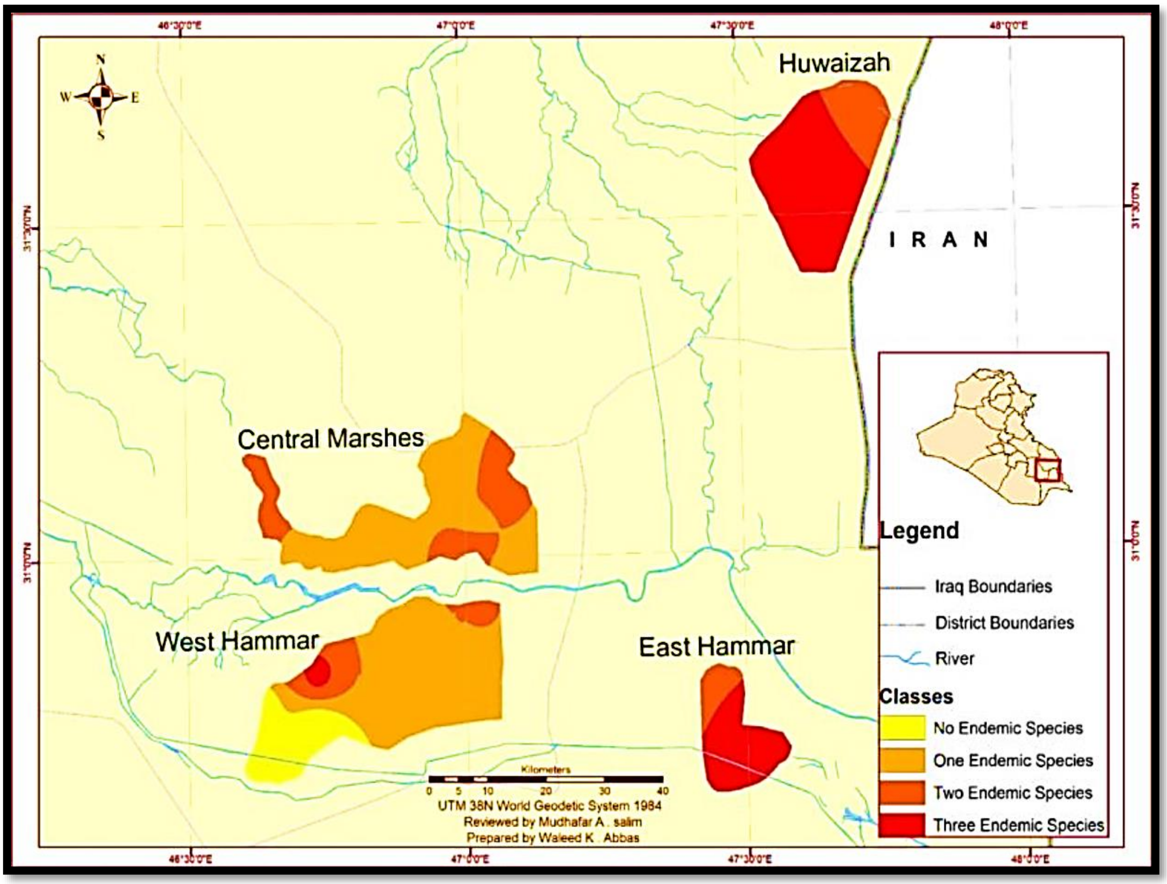
The population is defined as a group of individuals belonging to the same species that occupy a certain place in a certain period. The population has a statistical nature, which does not appear in any individual member of certain species by itself (Chong et al., 2010). The fish community consists of a large number of species that vary in abundance; every community has its own structure and the species diversity is the main indicator of the community structure (Žiliukas, 2005). The description of fish community composition depends on the use of environmental evidence for diversity, including the richness guide, which expresses the richness of the study area in terms of the numerical abundance and fish species. Diversity refers to the abundance of species in terms of number, weight, and evenness and the evenness index value is associated with diversity. The highest value of diversity is achieved when there is no sovereignty, relative abundance, and similarity, which are used to calculate the degree of similarity in the qualitative composition of fishing samples (Ludwig et al., 1988; Hubbell, 2001; Pihl & Wennhage, 2002). This evidence is the basis for such studies in different aquatic environments, through the analysis of complex data and their conversion into understandable values. Moreover, they give a precise description of the state of the community and they are useful in knowing the differences among fish groups. This evidence is also used in community analysis, knowledge of sovereignty and diversity. On the other hand, living and non-living environmental factors must be linked with groups to understand the relationship between these factors and the composition of the community (Lima-Junior et al., 2006; Leitão et al., 2007; Leonardos et al., 2008).

Several studies have been conducted to describe fish communities in different water bodies. Brosse et al. (2001) studied the abundance, diversity and composition of freshwater fish communities in the Taieri River, in New Zealand, and recorded six species. *Rutilus rutilus* was the most abundant of these species and the average diversity index (H) in this river was 2.45. Green et al. (2006) studied the demographics of fish in the Taylor and Shark rivers in South Florida, USA, where 29 fish species were found in the first river and 26 species were found in the second river. The highest number of specimens belonged to the species *Lucania parva* in the Taylor Rivera and to *Gambusia holbrooki* in the other river. Lima-Junior et al. (2006) described the fish gathering in the Corumbatai River, in Brazil, where there were 39 species and the numerical sovereignty was for *Hypostomus strigaticeps*, the Diversity Index (H) was 2.18 and the Evenness Index (J) was 0.51. A fish survey was carried out by Carol et al. (2006) in 14 water reservoirs in Spain and 20 different species were found, with common carp that was the most abundant among these species. The average Diversity Index was 1.275 and the Richness Index (D) was 5.7. Hoagstrom (2006) described the composition of the fish community in the Missouri River, USA, finding 96 species and the highest number of specimens was for *Thymallus arcticus*. López-López et al. (2009) conducted a fish survey in the Rao River, in Mexico, and found 53 species, 26 of which were marine and 27 were freshwater fish species. The average Diversity Index was 2.21.

With the near-complete destruction of the Marshes in the Southern of Iraq during 1990s, the status of most of the species currently remains unclear since they have not been evaluated as globally endangered species and they are often species of economic importance (IUCN, 2010).

Mohamed et al. (2012) described the status of the fish community in Al-Chybayish Marsh, where 14 fish species were recorded related to 7 families through the period considered. Al-Noor et al. (2010), analysing the fish community in the lower Euphrates at Qurna, found 21 species and 14 of them were freshwater species. In a study performed by Mutlak (2012), in the East Al-Hammar Marsh, 47 species belonging to 20 families were found.

Figure 12. Distribution of endemic fish in Al- Hammar, Al- Huwaizah, and the Central Marshes (IUCN, 2010).



1.4.9 Life characteristics of fish

The study of life characteristics of fish is an approach to get the information required for planning the correct management, and to improve, sustain and maintain the stock of fish for its preservation (Garcia & Rosenberg, 2010). Díaz et al. (2006) and Hooper et al. (2005) noted that the life characteristics and biodiversity of fish communities are affected by the capacity of the systems and their responsiveness to environmental changes. Most relevant studies tend to prove that a community that relies on diversity of a large number of species is more stable than those that contain one or a limited number of species (Dulvy et al., 2004; Hilborn et al., 2003), on the assumption that the abundance of species in a community gains resistance to climate change (Yachi & Loreau, 1999; Hilborn et al., 2003), and large water bodies such as large marshes and rivers are more diverse than the small ones (Rahel & Hubert, 1991; Newall & Magnuson, 1999).

Studies on life characteristics of Iraq's fish communities are limited (Jawad, 2003) and it is recognized that in Iraq the fish belong to 68 species, most of them are of economic importance (Al-Daham, 1982), since they meet the consumer taste and are accepted by a large number of consumers, especially in Southern Iraq (Al-Nasiri & Hoda, 1975).

Common carp, *Cyprinus carpio* (L. 1758)

The common carp belongs to Cyprinidae family. Its body is compressed from the sides, the nose is flattened and round, and the mouth (in terminal location) contains a couple of barbels (Al-Daham, 1982; Coad, 2010), as shown in Figure 15. Two carp fish species were introduced to the Iraqi water for breeding in 1955. The first species was brought from Indonesia and the second was from the Netherlands into Zaafaraniya fish farm, in Baghdad, and then released into water bodies (Al-Hamed, 1966). This fish species is economically important in Iraqi waters for its high growth rates, resistance to harsh environmental changes, the easiness of breeding, and the wide feeding spectrum (Lowe et al., 2000; Koehn, 2004). The relationship between the height and the total weight is an important biological indicator about the development of the fish resources in any water body. This relationship determines the nature of the fish growth; if it is isometric, it indicates that the environment is suitable for the growth of the fish species hence the value of the coefficient b is equal to 3. When the value of b shifts to the length or weight, the relationship is asymmetric (allometric) (Schreck & Moyle, 1990). Several studies examined the value of the b coefficient for *C. carpio*. Jasim (1980) indicated that the standard value of b for *C. carpio* ranged from 2.95 to 3.05 in Lake Habbaniyah (Iraq).

The fish fertility is defined as the number of mature eggs produced in the female ovaries that are ready to be released during the spawning period. The success of reproductive process lies in passing the genes to subsequent generations that, in turn, pass through to subsequent generations (Mohammad & Pathak, 2010). Gonad Somatic Index (GSI), which is one of the important biological indicators, is utilised to understand and know the effectiveness of reproduction, which ensures the survival of the common carp. Zainudin (2005) noted that common carp grows during March and early summer and also during autumn and the late winter in some Lake Victoria locations. Lazard & Dabbadie (2009) found that the breeding period in Europe extends from May to June, and in the south of the United States, it extends from February to June. Epler et al.

(2001c) explained that carp puts the eggs in May in Lake Habbaniya (Iraq) and there is no rest for carp gonads.

Figure 13. Common carp (*Cyprinus carpio*).

Phylum: Chordata

Class: Osteichthyes

Order: Cypriniformes

Family: Cyprinidae

Genus: *Cyprinus*

Species: *C. carpio*

Gold fish, *Carassius auratus* (L. 1758)

In Iraqi water, the goldfish *Carassius auratus* is an invasive species, coming from Turkey, Syria and Iran through the Tigris and the Euphrates rivers and their tributaries. It has become a widespread species in the internal water bodies, competing with the endemic species for food and habitats (Coad, 2010). Tarkan et al. (2010) showed that there were 6 age groups of goldfish in the Epping Forest, in Britain. The researcher pointed out that goldfish females reach the stage of sexual maturity in the first, year at the length of 5 cm, in the northeast of Britain, while in Italy, females of that species reach the sexual maturity at the age of 2 years, at a length of 13.9 cm. Lorenzoni et al. (2010) studied age and growth of *C. auratus* in the Lake Trasimeno, in the Central Italy, funding that the maximum length of the fish was 43.19 cm at the age of 8 years. The researcher reported that the *C. auratus* female lays their eggs from January to May and reaches the sexual maturity in the first year, at the length of 10 cm for females and 9.9

cm for males. It is generally accepted that the fertility differs from one species to another, being a characteristic of each species. It is used to estimate the size of fish stocks, for aquaculture and fisheries management (Mohammad & Pathak, 2010). Aho & Holopainen (2000) noted that the females release their eggs at two paces in eastern Finland. Scholz (1983) explained that *C. auratus* lays eggs in the form of batches where the first batch is filled with yolk with larger volume and sizes than the subsequent batches. Laurila & Holopainen (1990) clarified that the fish of this species lay their eggs in 2 to 3 batches from May to July. It is definite that this species can crossbreed with *C. carpio,* and the hybrids derived are important for fish farms in central Europe, because the second-generation individuals are characterized by rapid growth, resistance to pollution, high productivity and excellent survival rates of juveniles (Skora & Erdmanski, 1985). The golden fish belongs to the genus *Carassius*, which has mostly two species in the Iraqi waters, namely *Carassius carassius* and the golden fish, *C. auratus*. The two species are different from common carp, since both species do not have barbells, and can be distinguished by a number of features, including

1. the number of scales in the lateral line, that are more than 31 in the first species, while in the second species are less than 31;
2. the dorsal fin is convex in *C. carassius,* while it is slightly concave in *C. auratus*;
3. the first beam of the dorsal fin is light in *C. carassius,* while it is coarsely serpentine in *C. auratus*;
4. the number of gill rakers ranges from 26 to 30 in *C. carassius,* while they are more than 39-50 in *C. auratus* (Berg, 1962; Wheeler, 1978).

Many researchers in Iraq have studied the life of the golden fish, *C. auratus*. Al-Noor (2010) showed that the maximum length of *C. auratus* in Al-Hammar marsh was 31 cm at seven years old. In the same Marsh, the growth was standard, and the b coefficient was 2.98. Wahab (2006) showed that there are two peaks of the Gonado-Somatic Index (GSI) for females and males of *C. auratus*, the first peak (with the value of 14.59) is in March and the second (with the value of 7.46) is in August, while Al-Noor (2010) noted that the function of the offspring of *C. auratus* females amounted to 8.94 in February. Al-Amari (2011) clarified that the highest value of GSI for male and female goldfish were 9.22 and 13.83 in May and February, respectively, and the lowest values recorded for males and females were 0.74 and 1.59 in October and September, respectively. Epler et al. (2001c) reported that the laying eggs period starts from the end of February or early March in Lake Habbaniyah (Iraq), at a temperature of 14-13 °C, with the males mature in the third year and the females in the fourth year.

Figure 14. Gold fish (*Carassius auratus*)

Phylum: Chordata

Class: Osteichthyes

Order: Cypriniformes

Family: Cyprinidae

Genus: *Carassius*

Species: *C. auratus*

Hishni, *Planiliza abu* (Heckel, 1843)

Planiliza abu is an important species of Mugilidae family, which is a relevant component of the Iraqi water resources, particularly in the central and southern regions of the Country (Al-Daham, 1982). This species was described by Misra (1947) and Khalaf (1961) as follows: *P. abu* is gray at the upper half of the body and abdomen, and the abdominal surface is more curved than the dorsal surface. The number of scales in the lateral line ranges from 42 to 46 and the caudal fin is slightly concave (Khalaf, 1961). It is found in the Syrian basin (Beckman, 1962) and in the waters of the Tigris River, near Mosul (Coad, 2010) and Salah Adin province, it is found in the little Zab River (Al Rawi et al., 1978) and in Diyala river and in various other areas of Iraq (Khalaf et al., 1986). Hussain & Saoud (2008) pointed that this species is dominant in the Marshes of southern Iraq, having a wide range of tolerance for living in different environments, ranging from brackish freshwater to rivers and ponds (Mohamed et al., 2009).

Figure 15. Hishni (*Planiliza abu*)

It is one of the favourite fish for most of the low-income Iraqi consumers. The reproduction and spawning period of *P. abu* was studied in different environments of inland waters. *P. abu* is characterized by high fertility (Coad, 2010), and this last characteristic in some fish species is due to the high mortality rate. The number of eggs released by the fish differs according to the breeding strategy and the ovulation system. Fish that spawn in open water produce high number of eggs, that may reach up to millions. Fertility is lower in fish that build nests and/or exercise parental cares or are ovoviparous. Ünlü et al. (2000) demonstrated that the spawning of *P. abu* in the Tigris river in Turkey is in March. Khalaf et al. (1986) studied the sex ratios and the maturity age of *P. abu* in the Diyala river while Epler et al. (2001c) reported that this species spawn period takes place during May in Al-Habbaniyah and Al Tharathar lakes, although some fish spawn in early of this timing.

Phylum: Chordata

Sub Phylum: Vertebrata

Super Class: Pisces

Class: Osteichtheys

Sub class: Actinoptergii

Order: Perciformes

Sub order: Mugilidei

Family: Mugilidae

Genus: *Planiliza*

Species: *Planiliza abu*

Himri, *Carasobarbus luteus* (Heckel, 1843)

The species *Carasobarbus luteus*, formerly known as *Barbus luteus*, is characterized by the head somewhat small and tapered from the front; it has a pair of short barbells on jawbone. The body is about 30 cm in length and covered with large scales. The color of the dorsal surface is dark-brown, the abdominal surface is light yellowish, and the fins are gray (Beckman, 1962). It is found in big numbers in various areas of the Iraqi waters, especially in the southern and central regions (Al-Daham, 1984). *C. luteus* is widely distributed in inland waters and is one of the most widely accepted species by consumers (Al-Daham, 1979; Khalaf, 1961). A report by the Food and Agriculture Organization of the United Nations (FAO) noted that *C. luteus* formed about 43.6% of the fish total number in 7 major fish markets in Iraq (Andersskog, 1966).

Figure 16. Himri (*Carasobarbus luteus*)

Many studies have been conducted on *C. luteus* to clarify the life aspects of this species. A study by Al-Mukhtar (1982) regarding the life of *C. luteus* and *L. vorax* species in Al-Hammar Marsh. Al-Daham & Bhatti (1979) identified five maturity stages of this fish and Biro et al. (1988) studied the phenomenon of the slow growth of *C. luteus* in the Diyala river showing that, in this polluted river, the maximum length of this species of fish was 173 mm, while Polservice (1984) reported that the maximum length of the *C. luteus* fish was 720 mm in Lake Razzaza and 820 mm in the Lake Al- Tharthar.

Phylum: Chordata

Sub Phylum: Vertebrata

Class: Actinopterygii

Order: Cypriniformes

Family: Cyprinidae

Subfamily: Barbinae

Genus: *Carasobarbus*

Species: *Carasobarbus luteus*

Barak & Mohamed (1983) focused on the physical measurements of this fish and highlighted that the maximum age reached by this fish was 6 years and the maximum length 234.4 mm. Daoud & Qasim (2000) pointed out that this species reaches the sexual maturity when is 120 mm long for males and 135 mm for females and explained that the relative fertility is between 29 and 47 eggs/g.

Shilik, *Leuciscus vorax* (Heckel, 1843)

The endemic species *Leuciscus vorax* belongs to the Cyprinidae family and spreads in Syria, Iraq and Iran (Coad, 2010). Many researchers have been interested in studying the life cycle of *L. vorax* for its economic importance and many studies examined the relationship between height and total weight. Oymak et al. (2011) indicated that the maximum length of females is 86.3 cm at nine years old at Ataturk Dam, in Turkey in Euphrates River. The maximum male length is 80.1 cm at the age of 8 years. In a study conducted in the channel of Shatt al-Basra, Al-Dabical & Al- Daham (1995) clarified that the maximum length of *L. vorax* is 104.11 cm. It is recognized that the age groups of fish vary according to water bodies. Biro & Furesz (1976) pointed that the age of the specimens of this species reached eleven years in Lake Balaton. Epler et al. (2001b) found six age groups in the Lake Al-Habbaniyah, but in Lake Al-Tharthar, the same Authors found seven age groups. The researchers pointed out that the females of *L. vorax* reach the first sexual maturity in Lake Al-Habbaniyah and Al-Tharthar at the length of 47.2 cm and 44.2 cm, respectively, and Szypula et al. (2001) mentioned that the maximum length of fish was 63.6 cm at seven years old in Lake Al-Tharthar. In the Al-Razazah Lake, the maximum length registered was 53 cm, at five years old, while in the Lake Al-Habbaniyah the maximum length was 58.5 cm at six years. Many studies have considered the GSI of *L. vorax*, and the highest value for GSI was 12.08 for females and 10.08 for males, in March in Poland rivers (Kompowski & Neja, 2004), while Epler et al. (2001c) found that the highest value of GSI was 17.31 for females in January, and 11.90 for males in February. The females of *L. vorax* begins the laying eggs at the end of February and continues until the beginning of March, when the temperature of water is about 13-14 °C. Al-Saleh et al. (2012) studied the GSI of this species in the Euphrates basin, in Syria, finding that the highest GSI of females was 5.29 in the first half of March and for males was 1.83 in the second half of March. The lowest value recorded for GSI of females was 0.34 in July and for males was 0.36 in June. Oymak et al. (2011) indicated that the highest value of GSI was in March, April and June for both females and males, highlighting that the females of *L. vorax* begin laying eggs in April and continue until the end of May, in the northern part of the Euphrates river (in Turkey), when the temperature of the water is between 14 and 18 °C. Instead Al-Saleh et al. (2012) found the highest value of GSI of 5.3 in the Euphrates river, in Syria, in February and March and the lowest in April, in both females and males. The same Authors reported that *L. vorax* females lay eggs in February until the end of March and that females and males of this species reach the stage of the sexual maturity in the second year, reaching its peak in the third year.

Figure 17. Shilik (*Leuciscus vorax*) (https://www.fishbase.sinica.edu.tw).

Several studies were conducted on *L. vorax* life in Al-Hammar Marsh before its drying in 1991 (Al-Mukhtar, 1982; Hussein & Al-Kanaani, 1989). Jasim (1980) noted that the highest growth period for this species, in Lake Al-Habbaniyah, was during the summer when the water temperature was 25 °C. Szypula et al. (2001) compared the age and the growth of 3 species, i.e. *L. vorax*, *C. luteus* and *P. abu* in Al-Habbaniyah, Al-Tharathar and Al-Razzaza lakes. AI-Rudainy et al. (2006) considered the scales and frequency of length as the estimation of the age of *L. vorax*, describing the growth near the hot flows at the Euphrates river and observing a significant increase in the weight of its spawn from August to December.

Phylum: Chordata

Class: Osteichthyes

Order: Cypriniformes

Family: Cyprinidae

Genus: *Leuciscus*

Species: *Leuciscus vorax*

Bonni, *Mesopotamichthys sharpeyi*

This species is characterized by its green or golden-brown color with white to silver or yellowish-brown abdomen. The color of its eyes is either brown orange or golden (Al Hakeim, 1976), the body is spindle, and the mouth is terminal, the lips are slightly developed but they are not thick, the lower lip is split from the middle. The dorsal fin contains four long elastic and un-branched rays. The pharyngeal tooth structure is 2,3,5-5,3,2. Sometimes, only four teeth are in the main row, but the front teeth are missing in all small and big fish (Coad, 2010). The lateral line contains 29-37 scales (Al-Hamed, 1972). *M. sharpeyi* belongs to order Cypriniformes, family Cyprinidae, that is one of the most spread fish families in fresh Iraqi water (Coad, 2010). *M. sharpeyi* is one of the most economically important fish in Iraq (IUCN, 2010). It spreads in Iraq, Syria, Egypt and Turkey (Coad, 1995; Kahkesh et al., 2010) and, in the 1970s, this species was the most spread across Iraqi marshes, however, its number has declined gradually. Nowadays, *M. sharpeyi* is almost missing in Iraqi waters, representing only 0.05% of all catches in Al-Hammar Marsh (Richardson, 2008). This Cyprinidae is found in considerable quantity in Hawr Ad Dalmaj Marsh, which makes it possible to restore this species in all Iraqi Marshlands. Several studies have focused on *M. sharpey* (Al-Hamed, 1966; Al Jerian, 1974; Yesier, 1988; Al-Daham & Jasim, 1993). Al-Hadithi & Jawad (1975) studied the physical appearance of this fish in Basra Governorate water; Al Hakeim (1976) examined the physical appearance and the sexual maturity of *M. sharpey* in Al-Razazza lake; Mohamed & Barak (1988) studied the growth and the state coefficient in Al-Hammar Marsh finding for this species the maximum length of 750 mm. Jasim (1988) studied the breeding activities and the relationships among the fish length, the weight and of this species in southern of Al-Hammar Marsh. Abed (1989) made a comparative study between the age and the growth of *M. sharpey* in Al-Hammar Marsh and Shatt Al-Arab and found the maximum length of females and males were 618 mm and 473 mm, respectively, in Al-Hammer Marsh while, in Shatt Al-Arab, the maximum length of females and males were 555 mm and 470 mm, respectively. Mohamed & Ali (1994) compared the growth of 4 different species from Cyprinidae family with that of the species *M. sharpeyi*. Hussein (2000) compared the growth of this species in five Iraqi aquatic environments. Backiel et al. (1984) reported that the maximum length recorded in Al-Tharthar lake was 720 mm. Mohamed et al. (2012) found that algae constitutes 50%, diatoms 27%, and plant tissue 12% of the total food for this species in Al-Chybayish Marsh.

Figure 18. Bonni (*Mesopotamichthys sharpeyi*)

Kingdom: Animalia
Phylum: Chordata
Class: Actinopterygii
Order: Cypriniformes
Family: Cyprinidae
Subfamily: *Barbinae*
Genus: *Mesopotamichthys*
Species: *M. sharpeyi*
Synonym(s): *Barbus sharpeyi*

Tilapia

Tilapia are a freshwater group of fish species originating exclusively from Africa (excluding Madagascar) and from Palestine (Jordan Valley and coastal rivers) (Pullin & Lowe-McConnell, 1982). They are distributed all over Africa, except the Northern Atlas Mountains and South-West Africa (McAndrew, 2000); outside Africa, they are also widely distributed in South and Central America, southern India, Sri Lanka (Pullin & Lowe-McConnell, 1982) and in the Lake Kinneret (Israel). These fish are also highly adaptable to the environment, as reflected by their tolerance to a wide range of different environmental conditions, such as temperature, salinity, dissolved oxygen and ammonia (Pullin & Lowe-McConnell, 1982). *Coptodon zillii* (in formerly, this species was known as *Tilapia zillii*) and *Oreochromis aureus* are the most famous species of the tilapia family.

The body is laterally compressed, covered with relatively large, cycloid scales, which are not easily dislodged (Ross, 2000); the dorsal and anal fins have hard spines and soft rays, the pectoral and pelvic fins are large and in an advanced position, as shown in the Figure 21. This character provides the fish with great control over swimming and manoeuvring and cichlids have red muscles designed for relatively low-speed but continuous movements (Ross, 2000). Tilapias have fairly conventional skin, which are generally characterized by vertical bars, with relatively subdued colors and with little contrast over the body colours. This provides the fish a modest ability to change their colours, in response to stress, by controlling skin chromatophores. Tilapia has well-developed sense organs, represented by prominent nares and a clearly visible lateral line; the eyes are also relatively large, providing the fish an excellent visual capability. The increasing importance of tilapia as aquaculture candidate makes necessary to understand their food preferences and feeding regimes in their natural habitats. Tilapias are generally herbivorous/omnivorous, i.e. they are low on the aquatic food chain (Grover et al., 1989). *Coptodon zillii* feeds on macrophytes, blue-green and green algae, organic debris, zooplankton, aquatic insects and insect larvae and pupae, rotifers, diatoms, benthic invertebrates, and arthropods. Plant materials are more preferable foods for this fish than the animal sources. It is worth mentioning that the feeding for this species varies by seasons (Spataru, 1978; Buddington, 1979; Odedeyi et al., 2007). As for *O. aureus,* it feeds on phytoplankton, zooplankton, detritus, and plant residues (Spataru & Zorn, 1978; Jiménez Badillo & Nepita Villanueva, 2000). The time of year may also have an influence on tilapia feeding habits. Spataru (1978) found that *C. zillii* in Lake Kinneret, in Israel, had great variations in the food eaten in relation to season of the year. In winter and spring, Chironomida pupae (Diptera) was prevalent in fish stomachs, while zooplankton was dominant in summer and autumn. Spataru & Zorn (1978) also found that *O. aureus* in the same lake fed more intensely on zooplankton in spring, when zooplankton forms are more abundant. Nile tilapia also showed seasonal variation in feeding activity in Bangladeshi fish ponds (Dewan, 1979). The feeding activity was greater in summer than in winter. Greater amounts of phytoplankton were recorded in fish stomachs during winter, while debris was more consumed during summer. From the above discussion, it appears that tilapia has irregular feeding patterns, depending, as mentioned earlier, on fish species and size, season of the year, time of the day, photoperiod, water depth, geographical location and type of habitat.

C. zillii is among the most salinity tolerant tilapia species (Bailey & Hatton, 1979). it can spawn several times a year in suitable environmental and culture conditions. In these multiple spawning fish, the ovaries contain oocytes at different developmental stages. Coward & Bromage (1998) found that up to 20% of the immediately post-spawned *C. zillii* ovary was occupied by unspawned mature eggs. Residual eggs that progress into atresia have also been reported in post-spawned *O. niloticus* ovaries (Aravindan & Padmanabhan, 1972; Peters, 1983). Immediately after spawning, the tilapia ovaries are regenerated very rapidly and previtellogenic stages are recruited into vitellogenic and late vitellogenic stages in as little as 1 week (Coward & Bromage, 2000). As a result of different gonadal developmental stages in tilapia, spawning intervals are expected to vary considerably among species, and even within the same species. These intervals are influenced by fish size, stocking density, sex ratio, nutrition status, culture conditions and environmental factors. For example, Siraj et al. (1983) found that first- and second-year classes of Nile tilapia spawned at short intervals (7-12 days), while third-year class fish spawned at longer intervals (10-20 days).

The impacts of tilapia introductions on native populations vary with species and geographical locations. Generally, introduced tilapia is known to adapt easily to their new habitats, while native species are forced to contend with environmental changes and competition by the exotic species. These impacts range from little or slight to devastating. However, there is still a wide debate over the environmental impacts of tilapia introductions in many parts of the world; the introduction of tilapia in India has led to a significant reduction in the yield of the native species, such as Indian carp, pearl spot and mirror carp in many reservoirs (Natarajan & Aravindan, 2002). The decrease in the yield of these fish has been attributed to the prolific breeding nature of introduced tilapia. The introduction of *Oreochromis spilurus niger* and *Oreochromis esculentus* into the Lake Bunyoni (Uganda) has failed but, on the other hand, the introduction of Nile tilapia into the same lake was successful but had considerable impacts, including hybridization with the other two introduced species (Lowe-McConnell, 1958). Nile tilapia populations have also exhibited retarded growth and are subjected to infestation by parasites and poor fishery yields. It has also been suggested that the disappearance of *O. spilurus* from the Lake Naivasha and *O. esculentus* and *Oreochromis variabilis* from the Lake Victoria was related, partially, to their hybridization with the introduced species (Ogutu-Ohwayo & Hecky, 1991). In Australia, the competition between *Oreochromis mossambicus* and the indigenous species for food and breeding sites in the Darling river could have devastating impacts on indigenous fish populations (Arthington & Bluhdorn, 1996). In contrast, *O. mossambicus* supported the fisheries on the Sepik river flood plain (Papua, New Guinea) without affecting the indigenous species (Coates, 1987). Habitat alterations/destruction by tilapia have been reported mainly for macrophyte feeders, such as *Oreochromis aureus*, *Tilapia rendalli* and *C. zillii*, which are highly destructive for the native indigenous vegetation (Pullin & Lowe-McConnell, 1982). *C. zillii*, when introduced in new environments, has also been reported to be subjected to the competition by the endemic *O. variabilis* in Lake Victoria, leading to severe harm to that species (Welcomme, 1988). The introduction of *T. rendalli* in Madagascar and Mauritius has also caused serious disturbance to the indigenous fauna and flora in the lakes, rivers and reservoirs of those countries (George, 1975). Tilapia introductions also led to changes in the biology of native species; Moreau (1983) reported that the littoral native species present in the Lake Kyoga (Africa) began to migrate to open water after the introduction of tilapia into the lake. Tilapia has been found to migrate into the lower Colorado river mainstream in North America from irrigation canals in which they had been stocked for the aquatic weed control (Fitzsimmons, 2001). Tilapia, along with other exotic species, was introduced as fish for sport activity and completely changed the native fish communities in the river, to the extent that the native species are endangered. In some parts of the river, tilapia represented about 90% of the biomass. It is clear from the above examples it is highlights that the introductions and transfers of tilapia into new habitats can be supportive or destructive for the environment. This means that any introductions of tilapia should be preceded by a complete environmental impact assessment (EIA). One of the major risks of tilapia introductions is their ability to interbreed with closely related domestic species. Such uncontrolled hybridization is likely the cause of the loss of genetic variability. As a result, the loss of pure tilapia species is gradually increasing. Unlimited numbers of hybridizations have been reported in both cultured and wild tilapia. In most cases, hybrids have characteristics morphometrically and biologically different from those of their parents. Natural hybridization between related tilapia species (either introduced or native) is also possible. For example, hybridization between *O. spilurus niger* and *Oreochromis leucosticte* (Lake Naivasha), between *O. spilurus niger* and *Oreochromis niloticus* (Lake Bunyoni) and between *Oreochromis macrochir* and *O. niloticus* has been reported (Moreau, 1983). The first recorded the presence of these two species in Iraq 2007. In Hawr AdDalma marsh, the first recording for the two species *C. zillii* and *O. aureus* was at 2008 and 2010 respectively (Al-Zaidy, 2013a, b).

Figure 19. *Tilapia zillii* (left) and *Oreochromis aureus* (right)

Class: Actinopterygii

Order: Perciformes

Family: Cichlidae

Subfamily: Pseudocrenilabrinae

Genus: *Oreochromis*

Species: *Oreochromis aureus* (Steindacher, 1864)

Synonyms: *Chromis aureus* Steindacher, 1864

Chromis nilotica Gunther, 1869

Tilapia niloticus Tristram, 1884

Tilapia aurea Trewavas, 1965

Genus: *Coptodon*

Species: *Coptodon zillii* (Gervais, 1848)

Synonyms: *Acerina zillii* Gervais, 1848

Chromis andreae Gunther, 1848

Chromis microstomus Lortrt, 1883

Tilapia magdalalenae Vinciguerra, 1926

Jirri, *Silurus triostegus* (Heckel, 1843)

Asian catfish belongs to the Siluridae family, which includes 16 *genera*. These species live in freshwater and are spread in Europe and Central and Southwest Asia. They are characterized by the absence of fatty fins, lack of dorsal spine, long anal fin, and a body without scales (Kottelat & Freyhof, 2007). In Iraq, there are only two species of catfish: The European catfish (*Silurus glanis*) and the Asian catfish (*Silurus triostegus*), diffused along the Tigris, the Euphrates, Shatt al-Arab rivers and the southern marshes (Coad, 2010). The common name of these fish is jirri (Al-Daham, 1984). Most of these species, whether wild or cultivated, have been exposed to many problems, including competition, parasitism and predation (Nikolsky, 1963). This fish is of economic importance in Iraq, since it is consumed by humans or manufactured as animal food or exported. Studies and researches on this fish were limited to the classification aspects.

Figure 20. Jirri (*Silurus triostegus*).

The availability of these species in the Iraqi internal waters varies, representing 8.6% of the total catch in the Iraqi marshlands (Das et al., 1978) while Mohamed et al. (2008) reported that *S. triostegus* constituted about 1.99% of the number of fish caught from Haweezah Marsh. Oymak et al. (2001) demonstrated that the highest GSI values for *S. glanis* caught in the Ataturk tank on the Euphrates river is in May. Van den Eelaart (1954) clarified that the spawn in the Euphrates river begins in March, which is different from what happens in Turkey. Oymak et al. (2001) revealed that the reason for this is due to the high temperature in the Euphrates river running through Syria, compared to the Euphrates river passing through Turkey.

Kingdom: Animalia

Phylum: Chordata

Class: Actinopterygii

Order: Siluriformes

Genus: *Silurus*

1.4.10 Nature of fish food

Fish food consists mainly from plants and animals living in or near the water. The food types provide fish with proteins, fats, carbohydrates and vitamins as well as minerals in different quantity and relationships. The diversity of fish species in aquatic environments reflects food resources availability and variety. The nature of nutrition in fish depends on the initial productivity that, in turn, is based on the amount of nutrients available, the level of degradation and the quality of the dominant food chains which determine the shape and nature of the food pyramid. The nutrition environment varies by species. Some species feed on shallow banks of aquatic plants, other in the water column, a third group prefers deep-water recharge, the fourth feed on the water surface and the fifth in the bottom (De Silva, 1973). The study of the food interactions among species is an important mean of determining the distribution of communities in aquatic environments and improving the level of management (Oscoz et al., 2006; Ramírez-Luna et al., 2008). Hyslop (1980) stated that studying fish food helps to understand the functional role of the fish communities and of the environment they live in. The Author noted that the proliferation and distribution depend on the availability and productivity of food in the specific aquatic environment. The nutrition and the nutritional relationships change when the available items change. It depends on the productivity of the region and the nature of the distribution in the aquatic environment (Bagenal, 1978). The nature of fish feeding is influenced by the interaction between predator and prey, the quantity of food sources available and the food specialization of species and by the development stage which the ontogeny undergoes from egg to adulthood (Werner & Hall, 1988).

Nikolsky (1963) classified fish based on feeding ranges. Thus, there is the large-scale (*euryphagic*) feeding fish, which feed on different types of food; *stenophagic* fish, which feed on specific types of food, and *monophagic* fish, which feed on one type of food. Depending on the nature of the food, Das (1955) divided fish into three groups:

1. Carnivorous: Predatory fish that have adapted teeth for biting, shredding, holding, crushing or keeping prey. The fish of this group have a real stomach, but the intestines are short, rubbery with thick walls.

2. Herbivorous: Toothless fish that have a sophisticated gill-like device that can extract microorganisms from water. It is also found that these fish lack of a real stomach but have long, thin-walled intestines.

3. Omnivorous: These fish feed on many nutrients including plants, aquatic animals, aquatic invertebrates and organic crumbs of an appropriate size. De Silva (1973) explained that food habits include the diet composition and the special importance of each diet constituent. Feeding habit means the behaviour or method represented by the feeding activity (percentage of feeding fish) and feeding intensity (activity rate per fish).

Several studies have examined the food nature of fish and the content of the gastrointestinal tract in general. Opiyo & Dadzie (1994) showed that there is a type of fish in the lake of Guinea Basin (Graham) that for its feeding depends mainly on green algae and green vegetables as well as on a diet with a small number of zooplanktons. Vörös et al. (1997) also explained that *Hypophthalmichthys molitrix* (Silver carp) found in Hungary water is selective for the size of algae, which reaches to 10 μm. Saint-Jacques et al. (2000) found that *Castomus mersoni* (White Sucker) in the waters of North America is carnivorous, feeding insects and invertebrates. Miho et al. (2005) found 95 species of diatoms in the content of the gastrointestinal tract of *Baraus meridionalis*, in the Albanian Shkumbini river. Also, in a study by Awasthi et al. (2006) algae formed the highest percentage of the food content in the digestive tract of this fish as well as different proportions of insects and other aquatic plants. Dadebo et al. (2014) found that the food of green tilapia consists of upper plants, organic substances and phytoplankton. Agbabiaka (2012) found that, in the Otamiri river (Nigeria) the green tilapia combines plants and animal components as food and adult diet consists of 50% and 47.61% for the same substances. Several studies have been conducted to analyse the content of gastrointestinal tract in Iraqi fish. Many researchers in Iraq have found differences in the food taken by common carp (*Cyprinus carpio*) in different seasons and the dominance of animal food was in autumn (Al-Shammaa et al., 1996). Ciepielewski (2001) clarified that there is a difference in the nutrition of common carp during different stages of growth. Epler et al. (2001a) explained that the plant component was 51.7% of the carp food in Al- Habbaniyah lake (western Iraq). All studies carried out on shilik (*L. vorax*), in different parts of Iraq, have shown that they are carnivorous (Shafi & Jasim, ١982; Epler et al., 2001a) and this was also confirmed by Al-Shamma'a (2006) when studied the species *S. triostegus* in Al- Hammar marsh, near Al- Fohood area in southern Iraq. He noted that jirri (catfish) is a carnivorous species because fish are their main diet, followed by shrimp and aquatic insect larvae. However, the lack of frogs in the components may be due to the nature of the region and of the environment (Baras et al., 1998). Al-Mukhtar (1982) clarified that himri (*C. luteus*) is omnivorous, depending mainly on algae and higher aquatic plants, animals and organic matter. Salman et al. (1993) and Ciepielewski et al. (٢٠٠١) found that aquatic plants formed the main food of this species. Ahmad & Hussain (1982) noted that hishni (*Planiliza abu*) feed mainly on phytoplankton and both Wahab (1998) and Epler et al. (2001a) noted that organic substances represent high proportion of the food lists for this fish. The study of consumption of small fish by large fish was estimated at 0.8, 25 and 30% in the lakes of Al-Tharthar, Al- Habbaniyah and Al- Razza, respectively. Among the predatory fish, there are *Barbus esocinus*, *Leuciscus lepidus*, *Aspius vorax* and *Silurus triostegu*; among the small fish there is *Planiliza abu* (Al-Shammaa et al., 1996), while the bunni (*Barbus sharpeyi*) is a herbivorous fish, as confirmed by all the studies performed in different parts of Iraq (Epler et al., 2001b).

1.4.11 Food interaction

Food relations among fish are one of the main challenges to the environmental role in which fish can coexist in the same community and share the available food sources. Competition for food and space is one of the most important factors that have a part in the abundance of fish groups (Connell, 1975). It is easy to divide food sources for co-existence within the fish community through the equal distribution of the consumption of all kinds of prey among predators and the division of the consumption of environments at different times by fish. This division reduces intraspecific interaction among individuals of the different groups of species, reduces the chances of the availability of a type of food at the expense of the other, and allows more species to coexist (Wheeler & Allen, 2003). The study of food interaction among species provides a clear view of dietary strategies among interspecific individuals and intraspecific individuals and the possibility of interaction (competition and predatory) and the movement of energy in the natural network. Also, the study of food interactions among species is an important way of determining the distribution of communities in the aquatic environment and improving the level of management (Ramírez-Luna et al., 2008). Masilya et al. (2011) assessed the food interaction and the competition between the species *Lamprichthys tanganicanus* that was newly introduced to Lake Kivu in East Africa and the species *Limnothris samiodon*, which is one of the main fishes settled in the lake. The food interaction between the two species was high in the shore area of the lake and the predominant food was represented by the medium-sized zooplankton, while the food interaction in the far-from shore areas was little. Oscoz et al. (2006) studied the nutritional relationship of two species of freshwater fish, *Phoxinus phoxinus* and *Gobio lozanoi* (Cyprinidae), caught in Iberian river in northern Spain; the results showed that the two species mainly fed on larvae of *Chironomidae* and *Trichoptera* and ground invertebrates and that the food interaction between them was high. Hussain & Ali (2006) studied the nature of nutrition and food relationship of 11 species in Al-Hammar marsh fish in southern Iraq and found that there are 11 food interaction out of 55, that little specialization and overlap indicated a large amount of available food sources and environmental division among the existing species. Hussain et al. (2009) examined the specialization, competition and food interaction of fish populations in three re-irrigated marshlands located in southern Iraq. The study showed that most fish were specialized in food and found four positive cases of food competition, three nutrition groups contained several species (carnivorous, omnivorous and herbivores), two groups have single kinds (crumbling and benthic). Taher (2010) studied the specialization and the extent of food interference of 13 small marine species in Shatt Al-Basrah canal, finding seven species of carnivorous fish, three herbivorous species and one piscivorous species. Also, he found six high-specialty behaviour and five low-specialty behaviour with a wide food range and two types of general feeding. In addition, the study recognized a significant food interaction between the green mullet and the mudskipper (0.97) and there were no overlaps in 13 cases. Hussein & Attee (2000) examined dietary relationships and dietary interactions of four Cyprinidae species in Al- Hammar marsh (*M. sharpeyi*, *C. luteus*, *L. xanthopterus* and *C. carpio*) and the highest significant dietary interaction was found between the common carp and *L. xanthopterus* (87.5%). Ali et al. (1998) studied the food relationship of fish populations in the northwest of the Arabian Gulf, with the highest overlap between *Chirocentrus dorab* and *Otolithes ruber* (96%). Taher (2007) conducted a study on food relations and dietary interaction of fish in Iraqi marine waters in the northwest of the Arabian Gulf, describing the food relationship of thirteen types of carnivorous fish, finding the highest overlap (96%) between *Johnieops sina* and *Otolithes ruber*. For biological factors, the interaction among species includes the competition. Predation and environmental interdependence play an important and influential role in the species diversity and abundance (Hughes & Oberdorff, 1997).

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PART II

2. AIMS OF THE STUDY

Water bodies are spread in different parts of Iraq, extending from north to south. The inland waters cover 600-700 thousand hectares; natural lakes constitute 35.4%, dams, and reservoirs 13.3%, rivers and their branches 7.3% and marshes 44%, in addition to the Iraqi marine waters, in the north-west Arabian Gulf (FAO, 2006). Iraq has 43 species of freshwater fish, ten alien species and 53 marine species (Coad, 2010). The South-eastern Iraqi Marshlands represent one of the largest wetland ecosystems in all of Asia and covered about 15,000 km^2. Marshes region lies in the southern part Iraq depression alluvial plain between latitude 29°55’00” N to 32°45’00” N and longitude 45°25’00” E to 48°30’00” E. These marshes were formed by the confluence of the Tigris and Euphrates Rivers. Iraqi Marshlands has unique environmental features that rarely meet in the other region of the world (Partow, 2001). Also, these marshes are known for its high productivity; they are a natural shelter, and the main source of fishing for local fisheries Iraq. The biodiversity of fish in water bodies is affected by internal problems such as poor fishing management, overfishing and the use of illegal fishing methods. Consequently, a need has arisen for the rational development and management of these resources. An understanding not only of the biology of the organisms involved but also of the environments in which the fisheries are practiced dictates essential basis for the formulation of any management and development policies. It is known that patchy distributions of organisms and changing environmental conditions are characteristic traits of aquatic environments. Moreover, the Changes in the quantity and quality of water entering water bodies can lead to displacement and/or destruction of the fish community. Such disruptions can be of either short or long duration, depending upon the nature of the imposed stress and the recovery process. This means that the distribution and growth of fish are functional responses to local habitat conditions. Hawr Ad Dalmaj marsh is one of the most important wetlands in Iraq. Located between 32.20 degrees north and 45.30 degrees east longitude, to occupy an area of nearly 100,000 hectares. Little long-term information is available on the physical, chemical and biological characteristics of this marsh, where most of the studies have been limited in scope. There is no study was carried out in this water body to determine their ecosystem or to describe the spatial distribution of fish fauna while simultaneously measuring the environmental parameters.

First, the current study aims at assessing fish stock in Hawr Ad Dalmaj marsh to the definition of the factors that affect the fish community of food, environmental factors.

Subsequently, understanding the relationship and the functional diversity between the types of fish and maintaining fish stocks. Moreover, to achieve the so-called the optimized exploitation, as well as showing off the size of the changes that have occurred on that structure in light of climate change

Second, establish a database capable of providing the necessary advice to the concerned authorities to ensure the protection for this wealth and developing it.

3. MATERIAL AND METHODS

3.1 Area of the study

Hawr Ad Dalmaj marsh is one of important waterbodies in Iraq. It is located 40 km south west of Kut city, Wasit Governorate. A length of approximately about 50 km long with an average width of about 10 km. Its feeders are the overflow of the irrigation canals and floodwater of the Tigris river during the wet year and mainly from the Main Outfall Drain (MOD) through the feeding channel with a control structure of a maximum capacity of 53 m^3/s. Hawr Ad Dalmaj marsh circulates its water into the MOD again through a controlled escape structure of a maximum capacity of 46 m^3/s, towards Al- Hammar marsh in the city of Nasiriyah (Khulood, 2012), as shown in Figures 21 and 22. This area reaches its maximum extends during the period from March to May and reduces its extension due to evapotranspiration rates during the period from July to September. The average water depth within the lake varies between 0.5 to 2.5 m with total storage which is 429 million m^3 (Russian, 1984).

Figure 21. Layout of the MOD, after the directorate of the MOD.

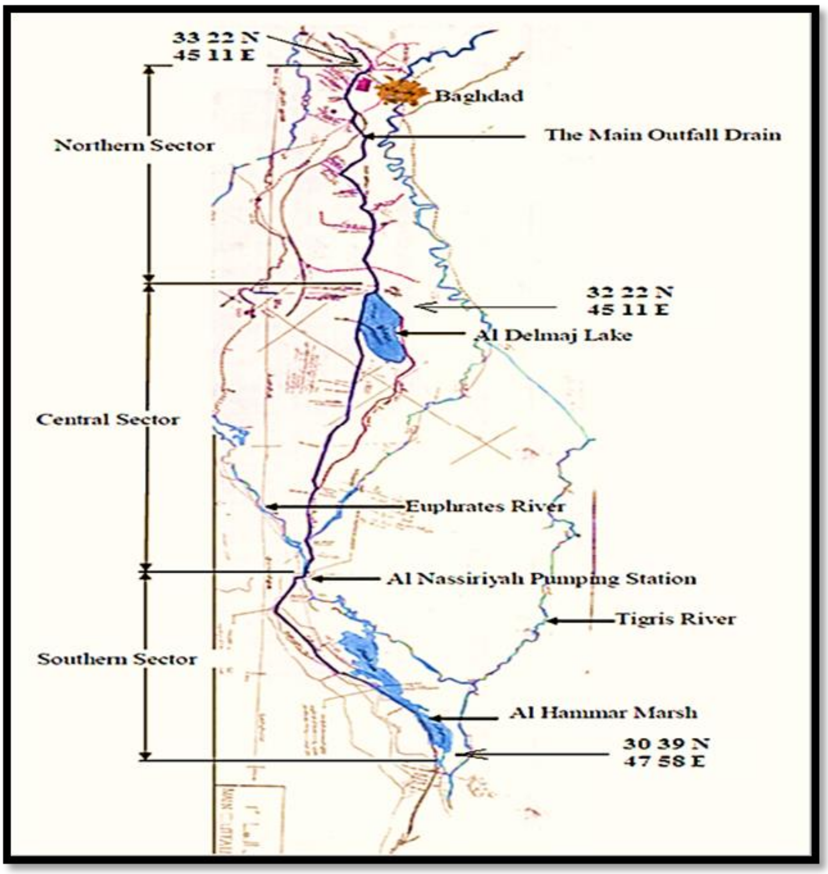
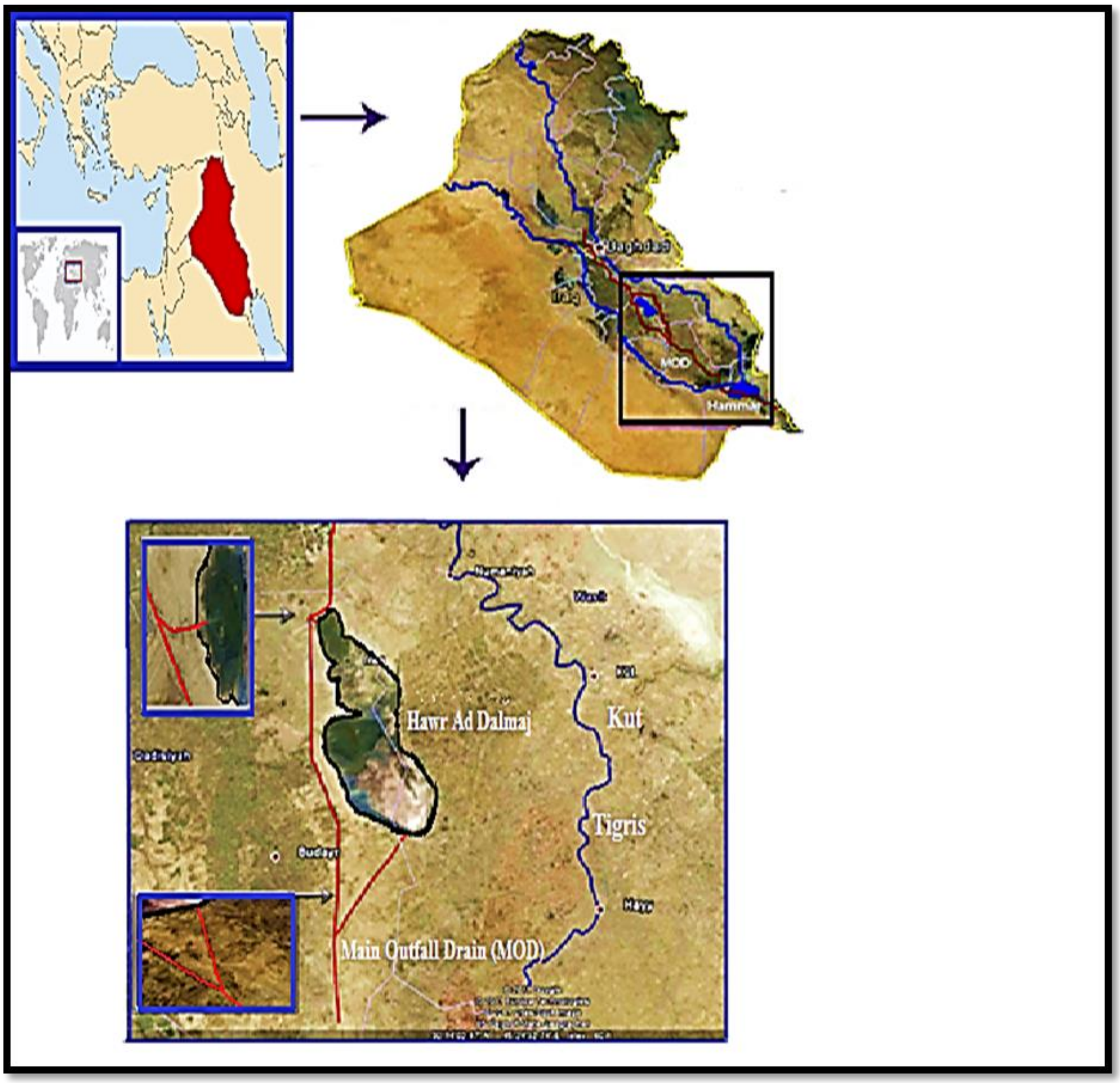


Figure 22. Location and physiography of Hawr Ad Dalmaj marsh captured by the satellite Landsat 7 (year of capture: 2018).

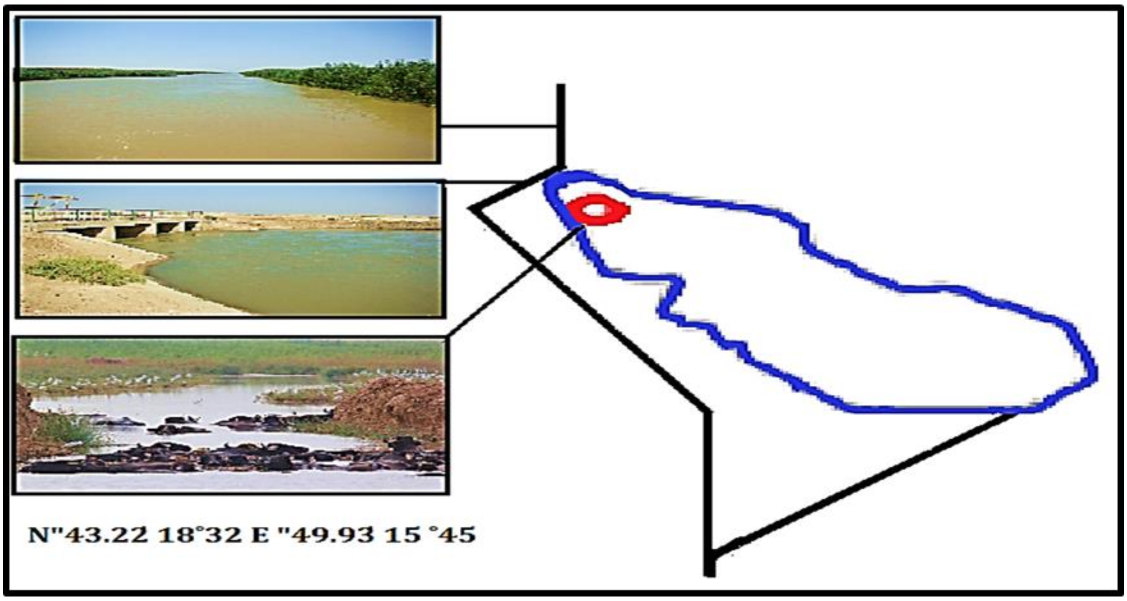


To execute the present study, two stations were selected for sampling, based on the character of the topography of the region.

First site (Site 1)

Located at 32° 35′ 93.96" N and 45° 22′ 38.15" E, near the km 331 of the MOD channel, this place is considered as the main source for the processing water into the water body, as described in Figure 23. The reason of choosing this area is to know the characteristics of the water before its entry into this water body as well as to characterize the number of fish species in the fish community in this site. This area is inhabited, and some food crops are cultivated in the nearby territories to it, as well as some activity of breeding of the fish and livestock can be found.

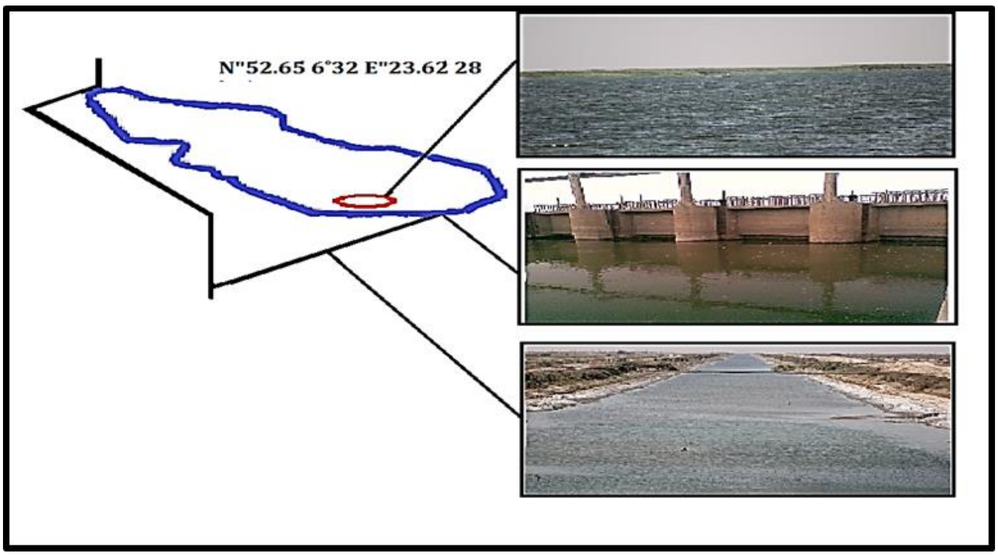
Figure 23. The Site 1 of the samplings of the current study.



Second site (Site 2)

Located at 32˚ 13′ 38.32" N and 45˚ 50′ 14.11" E, at southeast of the first location, near the km 299 of the MOD channel (Figure 24).

Figure 24. The Site 2 of the samplings of the current study.



The reason for choosing this area is that it is the only place for this water body drainage, therefore, this site can be retained as ideal for sampling and identifying changes in the water quality and the components of the fish community. About the specific features of this location, it is fully open and almost devoid of population, fishing operations, as well as hunting of the birds and breeding of buffalos are performed in this area.

3.2 Climate of the study area

The climate of the study area analysed in this study is classified into dry and semi-dry, a climate condition that has its implications on the hydrological characteristics such as the water levels of this marsh. The length of the summer season, that is accompanied by the total dryness with a total loss of rainfall, in addition to the high temperatures and evaporation significantly affect the water balance and the physical and chemical properties of the marsh waters. This type of climatic region also determines the qualities of the ecosystem. Therefore, this ecosystem is one of the ecosystems most exposed to deterioration and the most fragile, as its characteristics change rapidly according to climate changes (Issar & Zoha, 2004).

The soil adjacent to Hawr Ad Dalmaj marsh is characterized by high salinity, slow slope and poor drainage that lead to high salinity and groundwater approach from the surface, tends to darken in the surface layer due to the presence of high ratio organic matter. Hawr Ad Dalmaj marsh soil cultivar was treated as clay alluvial and slime, with varying percentages of amount and type of clay. The sand ratio ranged between 14 and 20%, the alluvial between 40 and 5% and the clay between 31 and 45%. These soils are considered appropriate to grow of reed plant (AL-Saaidi, 2014). Hawr Ad Dalmaj marsh is surrounded by arid and semi-desert areas that consist of sand dunes, it is a unique feature in the Mesopotamian marshes, which is the presence of marshes near the sand dunes is an unique feature in the Mesopotamian marshes, hence Hawr Ad Dalmaj is unique compared to the rest of the Iraqi marshes (Al-Farajii, 2000).

3.3 Fieldwork

Water characteristics

Some environmental characteristics were measured in conjunction with the fishing operations from the selected sites after locating the coordinates of the two stations using Garmin GPS-126 (GARMIN Corporation, Hsin-Tien, Taiwan; Figure 25). Field measurements included both air and water temperatures, salinity (Sal), pH and Dissolved Oxygen concentration (DO), measured using the YSI sension 156 MUL TI

METER (Hach Company, Loveland, Colorado, USA; Figures 26 and 27), which was usually calibrated before fieldwork. The water transparency was measured using the Secchi disc, that is a 30 cm diameter metal disc usually painted in black and white and divided into four intertwined parts, attached to a long, measurable rope. The measurement, which results are expressed in cm, is done by lowering the disc slowly into water vertically until it disappeared, then looking at the rope and registering that depth as D1 and then slowly withdrawing the rope until it reappears and then recording that depth as D2. The average of the two readings is taken to represent the light transmittance and the output is represented in cm:

$$\text{Light transmittance (cm)} = (D1 + D2) / 2$$

Figure 25. Etrex GPS utilised for localization of the sampling sites.

Figure 26. Etrex YSI sension 156 Multi-Parameter Meter utilised for water parameter analyses.

The level of the nutrients nitrate (NO_3) and phosphate (PO_4) was measured in manually collected water samples from approximately 15-25 cm deep from the surface of the water. Plastic bottles of 1.5 L of volume were used to save the samples of the water collected in samplings conducted from 9 am to 11 am. The collected samples were stored in a cooling box, after their stabilization obtained using drops of chloroform for laboratory analysis. Upon arrival to the laboratory, the samples of water were directly filtered using Millipore filter paper, with the diameter of the holes of 0.45 μm, then the filtered was frozen until chemical analyses were performed.

Figure 27. Measurement of the water quality parameters during the samplings in the Hawr al-Dalmaj marsh.

Fish samplings

Fish samples were collected during the period from January to December 2017, within the last third of each month. The fish samples were collected monthly by two to three field trips per month, in coordination and cooperation with fishermen of the region, in order to cover as much of the environmental study as possible, to achieve random collection of samples and the wide representation of the fish species and their lengths within the fish community. The net seine was used eight times per day in the second site, while it was not used in the first site because of the density of aquatic plants, the nature of the bottom and the shallow water level. The length of the net was 120 m and the size of the openings at the sides was 10 × 10 mm and in the centre was 5 × 5 mm, with its upper rope on the rafts and its lower rope on some iron chains.

It took about 20-30 minutes to collect water samples, depending on the wind speed in the fishing area (Figure 28). Gill nets were used extensively in all areas, especially in the first site. Gill net length ranged between 50 to 100 m with 1 to 7 cm mesh size.

These nets are usually loose on one side and they are irregular in the water because of they have been affected by the current of water.

Cast nets were used in both of two sites, especially in places where the bottom was full of dense plant and it was the hiding place of large fish, including *C. carpio*, *S. triostegus* and *L. vorax*. The electric catch in all regions is the most utilised method for research purposes in environments with high- and medium-depth plant densities, based on the use of a power generator (providing 300-400 V and 10 A). This method of fishing affects a surface of about 1 m^2. The hook and line were also used to catch some fish using shrimp as bait. The samples of fish that were harvested by various tools were stored in plastic containers and in nylon bags containing crushed ice until they reached the laboratory (Figure 28). The purpose of using a variety of means of fishing is to avoid the selectivity that may be inherent in each method of fishing, the use of multiple means of fishing contributes to the acquisition of random and unbiased samples of the particular type community in the environmental studies. The ratio of each fishing type was calculated, according to the following equation:

$$\text{number of species} / \text{total number of species} \times 100$$

Figure 28. Collection of fish samples in the study area.

3.4 Laboratory Work

Water tests

Reactive Nitrate. Nitrate (NO_3^{2-}) was measured by the method of reducing nitrate to nitrite by using the cadmium column according to the method described in Parsons et al. (1984) where 100 mL of the sample were treated with 2 mL of NH_4Cl, passed through a cadmium column, and after collecting 50 mL of the passing sample in the cadmium column, sulphanilamide solution was then added; the resulting compound interacts with N-(1-naphthyl) ethylene diamine dihydrochloride. The light absorbency was recorded by the UV-visible spectrophotometer Helios Aqua Mate (Spectronic Unicam, Cambridge CB5 8HY, UK) at a wavelength of 543 nm. Results were expressed by the unit of measurement µg of nitrogen atoms/L, as average of three readings per sample.

Reactive Phosphate. This parameter was analysed by using the Murphy and Riley (1962) method described in Parsons et al. (1984) by adding one drop of the alvinonfthaline to 50 mL of the filtered sample. When the pink color appears, the concentrated sulphuric acid is added in drops until the color disappeared and then treated with the mixed reagent and 10 minutes later. The density was measured by using a spectrophotometer at a wavelength of 885 nm and measure was represented in the unit of µg of phosphorous atom/L as average of three readings per sample.

3.5 Fish sampling analyses

Classification

Frozen fish were washed, dried with a piece of cloth then they were classified based on species and families according to a variety of sources consulted (Khalaf, 1961; Beckman, 1962; Coad, 1996, 2010).

Occurrence

The species were divided into three groups according to their repeated appearance in the monthly samples based on Tyler (1971): *i*) common or regular fish species, it is meant that the fish species emerged in the fish samples from 9 to 12 months during the period considered for the study; *ii*) seasonal or immigrant fish species, including species that were found as present in the samplings performed in6 to 8 months; *iii*) occasional fish species, that appeared in the samplings performed from 1to 5 months during the year.

Ecological characteristics

Ecological Indexes. In this study the Ecological Indexes considered were the following:

- Richness Index
- Diversity Index

- Evenness Index
- Jaccard's Index

Richness Index (D). The degree of richness and richness of the region, in terms of numerical and qualitative abundance, is used to illustrate the relationship between the number of species and the number of individuals. This parameter does not have a limited value, but the variable depends on the number of species, used here for a comparison between sites (Kocataş, 1992). It was measured according to the equation developed by Margalefe (1968) as follows:

$$D = (S - 1) / \ln N$$

where

D = Richness Index.

S = number of species in the sample

N = total number of individuals in the sample.

Diversity Index (H). This parameter is based on measuring the distribution of the number of individuals among different species, and it was derived from a mathematical formula utilised by Shannon (1949) (Mandaville, 2002), which is the most preferable among other diversity indexes proposals. The values of this index range from 0.0 to 5.0, and the generally accepted results are between 1.5 and 3.5; values above 3.0 indicate that the environment is stable and balanced while values under 1 indicate contamination and degradation of the environment. The value of the Diversity Index was calculated by the following equation (Shannon & Weaver, 1949):

$$H = - \Sigma (ni/N) \ln (ni/N)$$

where

N = density of all species in the considered station.

ni = density of one species.

Evenness Index (J). This parameter was derived from the Shannon Index by Pielou (1966). The values of this Index range between 0 and 1. When a value is closer to 1, it means that individuals are distributed evenly among species (Pielou, 1966). It was calculated according to the following equation (Pielou, 1977):

$$J = H/\ln S$$

where

H = Shanon – Weaver Diversity Index

S = number of species

Jaccard's Index (Ss %). This index is used to make comparisons between species in two samples from two different stations or two samples collected in two different time periods. The index is obtained by the following equation proposed by Jaccard (1908):

$$Ss\% = (A/A + B + C) \times 100$$

where

A = number of conjoint species between Site 1 and Site 2

B = number of species which appeared in Site 1 and not found in Site 2

C = number of species appeared in Site 2 and not found in Site 1.

Biological characteristics

Length. Total length (measured from the tip of the snout to the tip of the longest caudal fin ray) of each fish was measured to the nearest mm by using metric ruler. Fish were separated into length groups (1 cm between each length and other). The percentage occurrence of each length group was calculated monthly.

Weight. The body weight was also determined to the nearest (0.01) g recorded by using a balance (BL 15oos 13801194; Sartorius AG Gottingen, Germany). Fish were separated into weight groups and the percentage of occurrence of each weight group was calculated monthly.

Length-Weight Relationship and Condition Factor. To study Length-Weight Relationship, the standard length of each fish was measured to the nearest mm and the body weight was also determined to the nearest 0.1 g and the values were recorded. Length-Weight Relationship of the species was estimated by using the following equation proposed by Le Cren (1951):

$$W = aL^b$$

where

W = weight of fish (g)

L = observed total length (cm)

'a' = the regression intercept on the x-axis

'b' = the regression slope.

The Condition Factor (K) or Fulton's condition factor was calculated according to Htun-Han (1978) equation as per formula given below:

$$K = \frac{W}{L^\wedge 3}\, x\, 100$$

where

W = weight of fish (g)

L = length of fish (cm).

Food and feeding habits of fish

Stomach content analyses

To study food item, two methods were used based on the nature of the food points (P%) and the frequency or occurrence (F%) methods. Accordingly, the point and frequency methods were adopted to analyse the food components avoiding the use of the Volumetric method, because the results obtained using the two abovementioned methods are accurate enough to dispense with the use of the Volumetric method (Holden & Raitt, 1974). Since the species of the Cyprinidae family do not have a real stomach, foregut (i.e., the anterior part of the digestive canal) was removed. The gut or intestines were divided by their filling degree: half-filled, semi-full, three-quarters filled and full, giving the points 0, 5, 10, 15 and 20, respectively. Each gut was preserved in 10% formalin solution for latter examination. The point assessment method was carried out. Each stomach was washed by the water, opened and its content was moved into a Petri dish and examined under a low power binocular microscope (zoom Force ×40). Food items were taxonomically identified, as far as possible, and classified into nine main groups: i) mollusca, 2) crustacea, 3) aquatic insects, 4) organic crumbs, 5) diatoms, 6) plants and seeds, 7) algae, 8) worms and 9) fish. This classification was done according to Hadi (1984), Sheath & Wehr (2003) and Coad (2010). The points were distributed to various food items and the points were collected for each food component and the percentage of the total points was calculated. The method of frequency of occurrence is summarized in the determination of the number of the stomachs or intestines which repeated in them the occurrence of one or more food ingredients, and then expressed as the percentage formula, of the intestine containing that food item. The Index of Relative Importance (IRI%) was calculated according to the following formula (Pinkas, 1971):

$$IRI\% = [P\% \times F\% / \sum P\% \times F\%] \times 100$$

where

P%= percentage of each food component

F%= percentage of frequency of each component

Feeding activity and Feeding intensity

To study feeding activity and feeding intensity, all the examined stomachs were assessed first based on the visual estimation of their distension and the relative amount of food contained in them. The examined stomachs were classified into 5 groups according to the following method utilized by Geevarghese (1976):

1. *Heavy*: the stomach was gorged with food and the wall was fully distended.
2. *Good*: the stomach was almost full, and the distension of the wall was quite evident.
3. *Medium*: the stomach was nearly half full, and the wall was slightly distended.
4. *Poor*: the stomach contained little quantity of food, but the distension of the wall was not evident.
5. *Empty*: the stomach contained nothing, and no distension of wall was evident.

The percentage of occurrence of the 5 categories for the stomachs, in each length group, was calculated and stomach fullness was estimated on a 0-20 points scale (Hyslop, 1980). The percentage of occurrence of the stomachs classified as heavy, good and medium which was truly reflective of well condition in each season was determined to assess the feeding activity.

The feeding activity and the feeding intensity were calculated according to the following equations proposed by Gordan (1977):

$$\text{Feeding activity} = \frac{\text{Number of stomachs containing food}}{\text{Number of stomachs examined}} \times 100$$

$$\text{Feeding intensity} = \frac{\text{Sum of the total points given to stomach fullness}}{\text{Number of stomachs containing food (point/fish)}} \times 100$$

Food Overlaps between the species

The amount of dietary interference (degree of overlap) between species was determined using the equation developed by Pianka (1974):

$$O_{jk} = \frac{\sum_{i} P_{ij} P_{ik}}{\sqrt{\sum_{i}^{n} P_{ij}^2 \sum_{i}^{n} P_{k}^2}}$$

where

OKJ = degree of overlap between the J, K

Pij, Pik = proportions of the i the resource used by j the and k the species.

About the value of this parameter, it can be said that, when the overlap degree is 0.6 or more, the overlap will be considered as significant (Moyle & Senayake, 1984).

Gonado-Somatic Index (GSI)

To determine the maturity stage reached by the fish, the gonads were extracted from each specimen after the dissection, then they were wet weighed to the nearest 0.01 g. The stages of maturity were divided according to the appearance of the reproductive organs, which included the color of the organs, the presence of sweating, the extent of the egg's eyes, in addition to the amount (%) of the body that occupied by the gonads, according to Nikolsky (1963). The value of the Gonado Somatic Index (GSI) was calculated for males and females according to the following equation (Webber & Giese, 1969).

$$\text{GSI} = \frac{gonad\ wet\ weight\ (g)}{fish\ wet\ weight\ (g)} \times 100$$

Impacts of the alien species on native species

The impact produced by the alien species was determined based on the number extracted on a monthly basis, and their proportion on the total catches was calculated, by using appropriate tables for their identification.

3.6 Statistical Analysis

The results were statistically analysed according to the statistical program SPSS (Statistical Package for Social Science-ver. 17, 2011). All data were treated with the Analysis of Variance (ANOVA) and Least Significant Difference (LSD) to detect the variations of different variables at two locations. T-test was used to the investigation of significance between the groups. The mean, standard deviation and the significance at the probability (0.05) of each data were calculated. Also, the values of correlation coefficient were calculated to show the correlation among variables, also between species groups with the environmental factors throughout the study period by using Canonical Correspondence Analysis (CCA).

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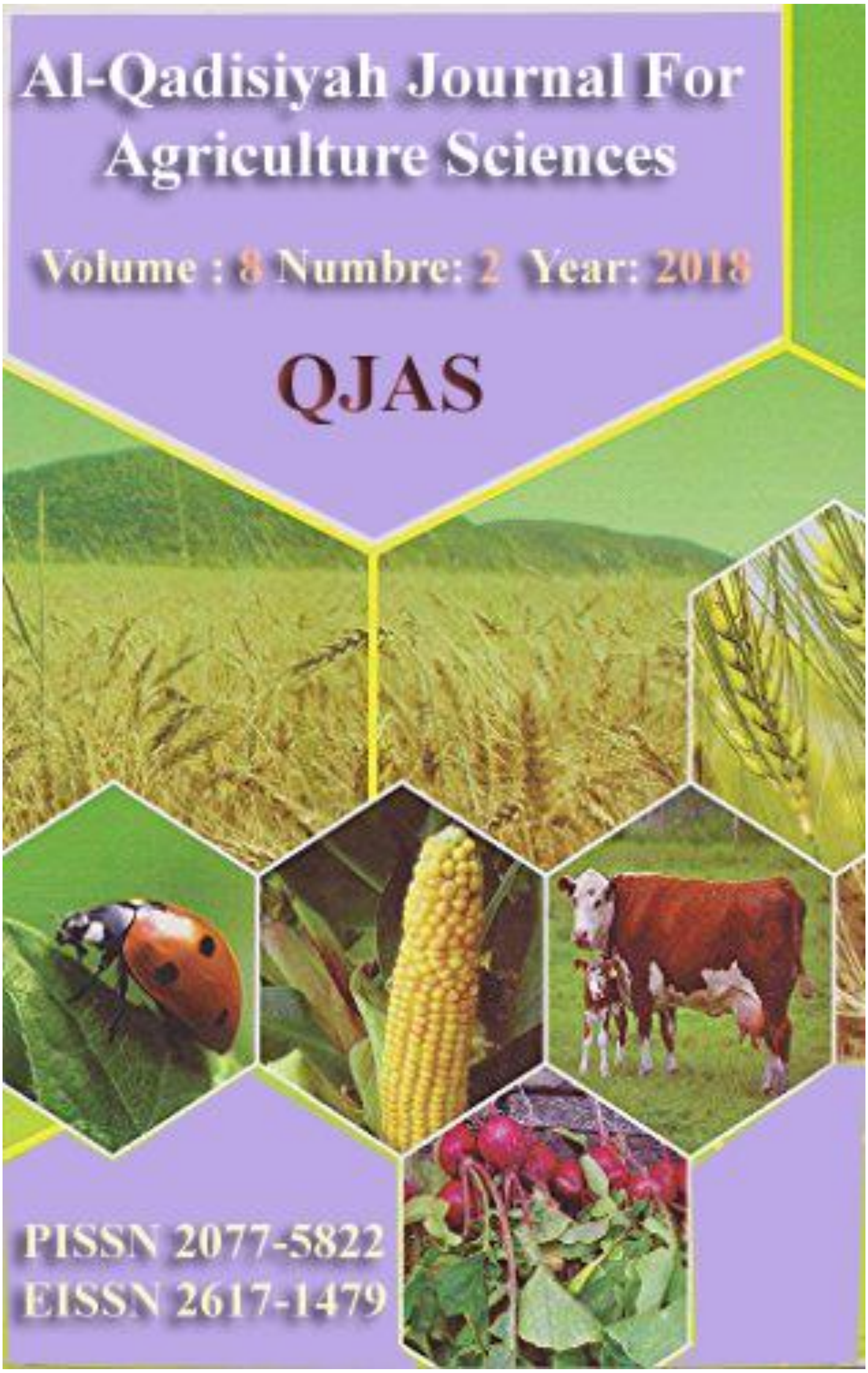
PAPER 1



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Re Extrapolation For The Iraq Marshes Which Falling Within The World Heritage List(A Literature Review)

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Abstract

The Mesopotamian Marshlands or The Garden of Eden, lies in the southern part of Iraq with estimated area of 15000-20000 km^2. Historically, the area had pioneering role in the human civilization for over 5000 years. The indigenous people of the area are called "Marsh Arabs" or "Ma'dan" who are the descendants of the Sumerians and Semitic people. The former Iraqi regime (Saddam Hussein) had violently led an aggressive campaign to drain the marshes in 1991. Only %7 of the total area survived this campaign, which caused a mass destruction of the ecosystem and dwellers' displacement. In 2003, water started to flow back to the area. Yet, the reflooding did not restore the whole former area of the wetlands. Moreover, the new ecosystem influenced the diversity and characteristics of the co-existing species in the area. In 2016, due to the importance of the Mesopotamian Marshlands, the International Union for Conservation of Nature (IUCN) listed three marshes from the area as World Heritage Sites requiring conservation, namely: Hammar, Hwezeh and Central Marshes. The aim of this study is to re-evaluate the ecosystem of those three sites from a biological perspective by examining some challenges that should be dealt with to restore stability to this multi-thousand-year-old system.

Introduction

Iraq lies in the Middle East with a total area of 438320 km^2(1). It is surrounded by six countries, namely: Turkey to the north, Iran to the east, Kuwait and Saudi Arabia to the south and southwest, and Jordan and Syria to the west; besides its outlet on the Arabian Gulf to the southeast. The marsh area lies in the southern part of the country on the juncture of Tigris and Euphrates Rivers. The marsh area has unique properties that are hard to be found in any other spot on the planet, which makes it one of the most important wetlands on the global level (2). The dominant environment of the area varies depending on several factors among which water temperature, water salinity, water availability and nutrients availability (3). The marshes are mainly fed from Tigris and Euphrates which are originated from Turkey. The wrongwater policy adopted by the former Iraqi regime has led to water scarcity, which affected the marsh area and rendered most of the area dry during the 1990s. The dried marshes transformed into barren lands covered with salt. The destruction reached human, animal and plant lives in the marshes (4). This loss was not limited to only species lost, but also the genetic diversity, the functional communities and the interactions among the living organisms in the area (5). Such catastrophic results provoked the environmental experts and Human Rights activists all over the world (6) along with the UNEP. The issue was brought up in the European Parliament in several occasions (7). Upon governmental and non-governmental efforts for over a decade, three sites in the marshes were chosen (Hammar, Hwezeh, and Central Marshes) for the World Heritage List (8). The UNESCO had adopted in November

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Abstract

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Keywords: *Iraq, Mesopotamia, Cultural Heritage, Biological Diversity, Invasive Species.*

Introduction

Iraq lies in the Middle East with a total area of 438320 km^2 (Al-Ansari and Knutsson, 2011). It is surrounded by six countries, namely: Turkey to the north, Iran to the east, Kuwait and Saudi Arabia to the south and southwest, and Jordan and Syria to the west; besides its outlet on the Arabian Gulf to the southeast. The marsh area lies in the southern part of the country on the juncture of Tigris and Euphrates Rivers. The marsh area has unique properties that are hard to be found in any other spot on the planet, which makes it one of the most important wetlands on the global level (Partow, 2001). The dominant environment of the area varies depending on several factors among which water temperature, water salinity, water availability and nutrients availability (Richardson and Hussain, 2007). The marshes are mainly fed from Tigris and Euphrates which are originated from Turkey. The wrong water policy adopted by the former Iraqi regime has led to water scarcity, which affected the marsh area and rendered most of the area dry during the 1990s. The dried marshes transformed into barren lands covered with salt. The destruction reached human, animal and plant lives in the marshes (UNEP, 2001). This loss was not limited to only species lost, but also the genetic diversity, the functional communities and the interactions among the living organisms in the area (Naeem, 2006). Such catastrophic results provoked the environmental experts and Human Rights activists all over the world (Maltby, 1994) along with the UNEP. The issue was brought up in the European Parliament in several occasions (Brasington, 2002). Upon governmental and non-governmental efforts for over a decade, three sites in the marshes were chosen (Hammar, Hwezeh, and Central Marshes) for the World Heritage List (IUCN, 2016c). In November 1972, UNESCO adopted a convention to protect the cultural and natural heritage, to aid the efforts of the international community for the conservation of sites of global value as they belong to the future generations. Signatories to this convention were 192 countries. The list attached to the convention included many unique sites from all over the world. The inclusion to the list means that the site is belongs to many unique other sites. The southern marshes of Iraq were included in July 17th, 2016. This represents an international recognition of their global value according to United Nations Environment Programme (UNEP, 2001). As one of the largest inland systems in the globe under such sever heat and dryness (IUCN, 2016b), its recognition from the IUCN is a kind of fairness which could represent a new stage for a civilization that lived for over 5000 years. This requires preserving the area as a joint responsibility that is accomplished by international cooperation (IUCN, 2016b).

The evolution of the Mesopotamian Marshlands

Many studies have discussed the origin and evolution of the Mesopotamian Marshlands, and perhaps the most acceptable theories relevant to the subject are those which indicate that the marshlands formed at the end of the Pleistocene Age (20000-37000 years ago). During that age, some kind of a Tsunami stroke due to an elevation of sea level (Less & Falcon, 1952). The area faced a second era represented by climate changes in the northern polar regions of Europe, Asia and North America some 12000 to 17000 years ago. Such changes led to a decrease in oceanic level of about 130 m. This resulted in a severe decline in the levels of coastal basins to become dry lands, like the transformation of the Persian Gulf area into an almost dry land and the ancient rivers at that time (Tigris, Euphrates and Karon) became directly pouring out in Oman Gulf. This helped form fresh water ecologies. Accordingly, wetlands formed in the depressions about 11000 to 13000 years ago (Sanlaville, 2001). The third era took place in the end of the Pleistocene Age, about 10000 years ago. Here, another significant marine swift happening took place, which formed the coastal line of the Arabian Gulf with the spread of river-based freshwater marshes. This continued until 9000 years ago. The coastal line of the Arabian Gulf and the southern part of Mesopotamia formed in the Post-Ice Age. Aqrawi (1995) has identified four climatic stages of the marshes in the last 10000 years:

The last 7000 years: semi-dry area characterized by saline lake formations.

The last 6000 to 7000 years: wet area characterized by heavy rain and high sea level (floods).

The last 4000 to 6000 years: semi-dry area characterized by water level retreat and the reshape of the marshlands.

The last 3000 years: dry area with characteristics as seen today.

The precipitation of the organic materials in the Mesopotamian Marshlands through the ages helped the human settlement as there is a significant connection between the environmental factors that formed the marshes and the use of these marshes by man as a means of living (Soltysiak, 2006), especially with the existence of the desert formation surrounding the marshes (Kliot, 1996).

Cultural Heritage

The use of the term Mesopotamia is related to the concept of the marshlands. Mesopotamia, a Greek word indicating to the land between two rivers (McCarthy, 2001). Hence, the term points out to all the lands between the two rivers including the

southern marshlands. The inhabitants of Mesopotamia are habituated to live next to water, therefore the marshlands represent the ideal environment of living on and benefit from its natural resources (Scoones, 1999). Thus, the discussion about the history of Mesopotamia normally implies the cultural heritage of the marshlands, which are historically known as Garden of Eden (in the Holy Scriptures) or the land of Abraham or the land of Sumer. Pottery relics found in Tel Ubaid- Eridu indicate the Sumerians settled in the marshlands 5000 years ago (Al-Jwaybirawhie, 1993). There is an indication to the marshlands in the Sumerian literature (Young, 1977), which is the first example of written literature in the history of mankind (Hallo, 2010). The Sumerians had their own language, which was not connected to any other linguistic family and was considered one of the most ancient languages on earth (Al-Zahery et al., 2011). Besides that, the Sumerians were founders of the urban civilization along with their abilities in breeding animals and doing agriculture activities and first of the invention of writing; also, they had the world's oldest examples of water engineering for agriculture purposes (Ionides, 1937; Lloyd, 1943; Adams, 1958; Haigh, 1951; Lees & Falcon, 1952; Lees, 1955; Buringh, 1957; Harris & Adams, 1957; De Vaumas, 1955, 1958; Nelson, 1962; Adams & Nissen, 1972; Rzóska, 1980; Wagstaff, 1985; Naff & Hanna, 2002; Green, 1980). Their remains are still land marking their great civilization and cities on the edges of the marshlands like Lagash, Ur and Uruk (Soltysiak, 2006). Marsh dwellers lived and a somehow buffered environment and conserved their original lifestyle through the centuries (Kliot, 1996). The present marsh dwellers (Marsh Arabs or Ma'dan) are the descendants of the Sumerians and they are the living connection between the Iraqis of today and the ancient Sumerians (Al-Zahery et al., 2011). Ma'dan (Shiite Muslims) live on the edges of the marshes or in small artificial isles made of reed within the marshes (UNEP, 2001) and their lifestyle significantly resembles that of the ancient Sumerians (Al-Hilli, 1977) as they still depend on hunting/fishing, buffalo milk products and the use of reed for building houses. The famous reed guesthouse (Mudheef), built in the same Sumerian layout surviving 5000 years (Figure 1), represents the peak of the social and cultural system of the Ma'dan (UNEP, 2001).
Additionally, there is remarkable resemblance between the traditional clothing style of the Ma'dan with the fashion style of the ancient Sumerians indicated in their relics (Figure 2).

This unique social texture suffered greatly upon Saddam's campaign to drain the marshes in 1991 and the consequential aggressive displacement and genocide of thousands of the Ma'dan (Nicholson & Clark, 2002). This campaign was considered one of the greatest crimes in Iraq modern history. The UNEP launched the project of "Support of the Environmental Management of the Iraqi Marshlands" in 2004 funded by the USA, Italy and Japan, with the aim of supporting the restoration of the Marshlands as a glimpse of hope to regain their lives and marshes, for those who were displaced.

Figure 1. The *mudheef* in southern Iraq (on the left) and a Sumerian reed hut or *mudheef* before 3,000 year ago (on the right) (UNEP, 2001).

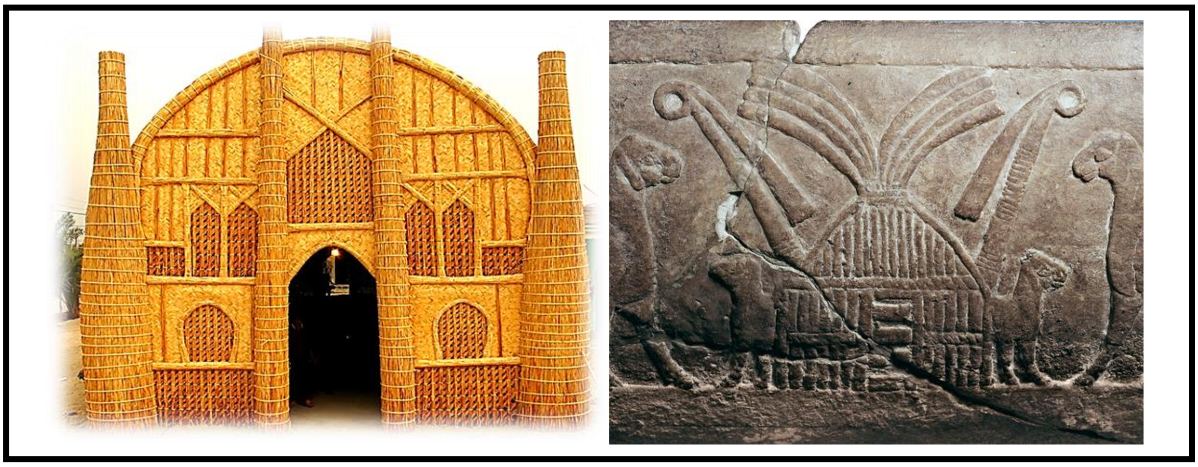

Figure 2. Sumerian statuette of a female covering her head in a headdress in the southern Iraq style. Museum of Fine Arts, Boston (on the left). Female of southern Iraq (on the right). http://tammuz.tumblr.com/post/19178715516/statuette-of-a-female-wearing-a-headdress-in-the

Geographical Location

The marshes of southern Iraq form an aquatic triangle with its head in Amara city and its base extending between Basra and Nasiriyah cities and expanding northward to Kut city, including marshes like Shwecheh, Hawr Ad Delmaj and Afaq (Scott & Evans, 1993). Hammar and Hwezeh marshes and the Central Marshes lie in the Lower Mesopotamian Basin in southern Iraq (Al-Ansari & Knutsson, 2011), as shown in Figure 3 (where the three-dimensional diagram represents the topographical nature of the Iraqi Marshlands in the central and southern Iraq) and in Table 1. Tigris and Euphrates rivers represent the main water sources feeding the marshes (Al-Ansari et al., 2012). Water level of the marshes varies from 1 to 2 m above sea level and about 22 m above sea level near the borders with Iran. Water depth in the marshes does not exceed 2 m in most marsh sites, but it sometimes reaches 7 m as in Hwezeh marsh (Islam, 1982121). The marsh area is a depression, as it is evident in the 3D graphic of the area represented in the Figure 3. Hammar marsh lies to the south of Euphrates and extends from Nasiriyah city at the west to the outskirts of Basra city at the east.

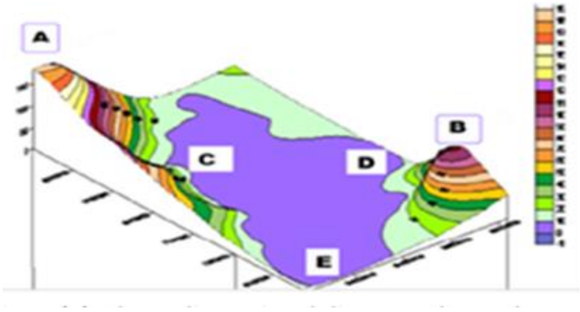

Figure 3. The 3D graphic of the Marshland area. A: Plateau Samawa; B:Iranian territory; C: Nassiriya; D: Amara; E: Qurnah (Al-Manssory, 2008).

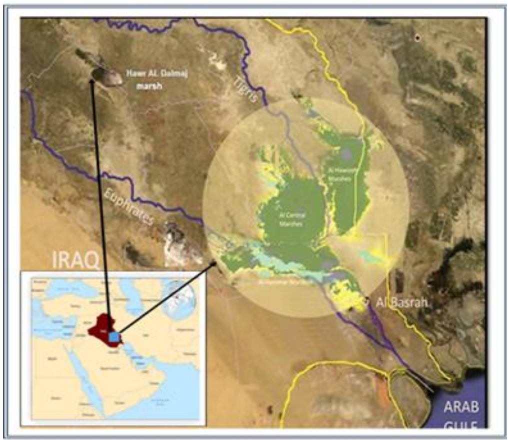

Figure 4. The major Iraqi Marshlands.

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The total area of this water body is about 2800 to 4500 km^2 in the flood season and water depth ranges from about 1.8 to 5 m (Maltby, 1994). The supply of water to the Hammar Marsh originates by Euphrates with less water quantities deriving from Tigris (Awad & Abdulsaahib, 2007). The Central Marshes (Qurnah), located in the juncture of Tigris-Euphrates, are the heart of the southern marshes. The water flows to the Central Marshes through several tributaries of the Tigris. The total area of the Central

Marshes is about 3000 km^2 reaching up to 4000 km^2 in flood season and the water depth is about 3 m (UNEP, 2006). Hwezeh Marsh lies to the east of Tigris and is divided by the Iraq-Iranian borders; its main freshwater supplies are Msharrah and Kahla rivers and Sannaf Marsh, while Kassarah and Sweb rivers are the main drainage. Hwezeh Marshes cover an area of about 3000 km^2 reaching up to 5000 km^2 in flood season, with depth of about 7 m (Evans, 1994).

Table 1. Geographical subdivision and terminology used for the three marshes with the subdivisions proposed by various authors.

Location (IUCN, 2016c)	Governorat (IUCN, 2016b)	Coordinates[1] (BirdLife International, 2010)	Approximate area (IUCN, 2016a)		CIMI (2010)	Marshes affiliated the main marsh		
			Property (ha)	Buffer zone (ha)		New Eden Project (2010)	Abed (2007)	BirdLife International (2010)
The Huwaizah Marshes	Maysan	N 31 33 44 E 47 39 28	48131	42561	Hawizeh	Hawizeh	Hawizeh	Haur Al-Hawizeh
					Majnoon			Haur om am Nyjah
					Al-Sanaaf			
The Central Marshes	Maysan, Dhi Qar	N 31 05 07 E 47 03 15	62435	83958	Chibayish	Central		Haur Uwainah
					Al-Islah			
					Dawaya	Abu-Zirig		Haut Al Rayon & Um Osbah
					Prosperity River			Haur Auda
					Glory River			
The Hammar Marshes	Al Basrah (East Hammar)	N 30 44 21 E 47 26 19	20342	12721	East Hammar	Hammar	East Hammar	Haur Hammar
	Dhi Qar (West Hammar)	N 30 50 30 E 46 41 03	79991	68403	West Hammar		Suq Shuyukh	
								Haur Chubaisah

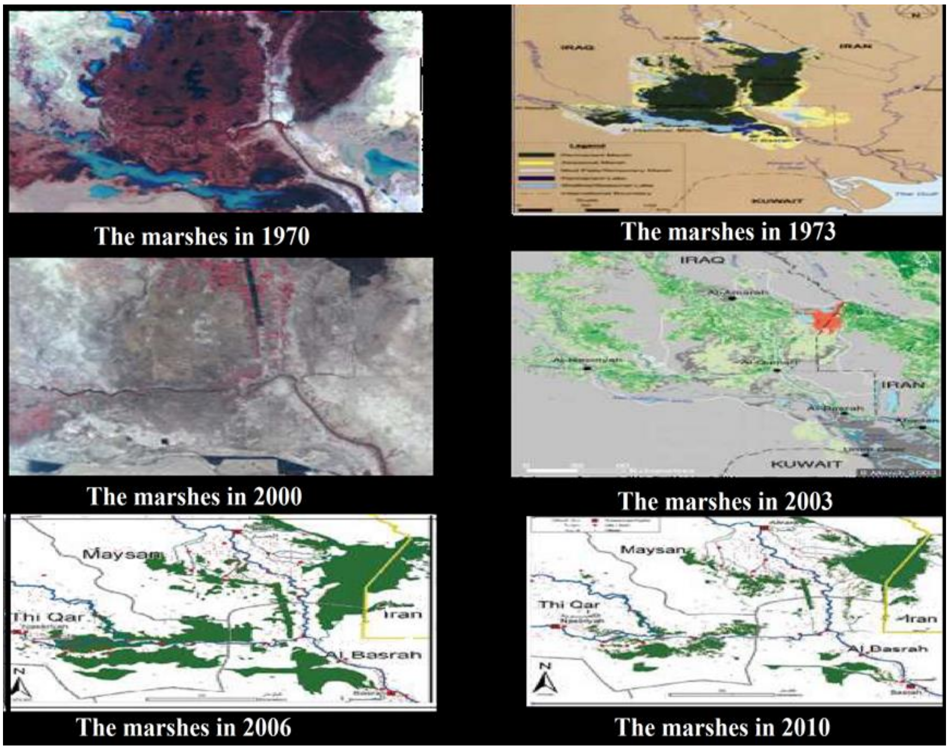
[1]At the central point.

The Draining of the Marshes

Saddam regime conducted the draining of the marshes in 1991 via separating and blocking Tigris tributaries flowing Al-Hwezeh Marshes in Amara city (Dempster, 2007). Two embankments were built to form an artificial canal of 1200-2000 m width and 90 km length (Al-Rubaie, 2008) beginning from Al-Salam Sub-district in Amara city and southward to Qurna city to drain in Euphrates (Schwartzstein, 2015). Another embankment was built to divide the marshes into smaller areas for practicality reasons in terms of gaining less evaporation times or water draining. This method was used in all marsh areas (Partow, 2001; Pearce, 1993). In addition, the Euphrates was diverted to the MOD (Main Outfall Drain) course at about 5 km to the east of Nasiriyah city. This operation made change to the historical and natural course of Euphrates with the purpose of eliminating of the river's feed to Hammar Marsh (Naff & Hanna, 2002). Hammar Marsh was completely disappeared between 1992 and 1994 with all its former length of about 120 km (Munro & Touron, 1977).

Figure 3 shows the stages of the marshes draining until 2010, when the total area decreased to only 7% of the historical area (Brasington, 2002).

Figure 3. The stages of the marshes draining until 2010 (Garstecki et al., 2010; UNEP-GRID-Arendal Maps and Graphics Library, 2009).



The division of the marshes was accomplished when water flow was eliminated. The draining project was accompanied by aggressive campaign of arrests, killings, household burnings and displacements of the endogenous marsh dwellers in thousands, by throwing napalm bombs in different parts of the marshes (Sluglett, 2003) and, in addition, by using chemicals weapons, artillery and minefields (UN, 2002). Over 75000 people of the Ma’dan population fled to Iran and lived in refugee camps for more than a decade (Nicholson & Clark, 2002). The number of the Ma’dan living in the marsh areas significantly decreased during the 1990s, besides other catastrophic changes that blew the area’s ecosystem.

Table 2 shows some of the changes produced in the marsh population, total areas, plan populations, and fishing quantities before and after the draining campaign. Soil salinity in the drained areas dramatically increased due to the over-evaporation of water which was originally saline (Hassan & Kubaisi, 2002).

Table 2. Changes in some traits of the marshes people and characteristics before and after the drying.

Trait studied		Before drying the marshes in 1991	After drying the marshes in 1991
Number of the Arab marsh		300,000-500,000 (Young, 1977; Coast, 2002)	75,000-85,000 (DAI, 2004)
Water discharge, m^3/s (Hassan et al., 2012)	Al-Hawizeh	145	81
	Al- Hammar	231	21
	The Central Marshes	253	0.97
Total wetlands area, km^2 (UNEP, 2001)		8,926	1,296.9
Dominant plants (Al wan, 2006)		18	7
Catch of fish, tons (Tkachenko, 2003)		13200 in 1989	2000 in 1993

Such sabotage included fisheries and fishing quantities, which deteriorated due to the draining of the vast water bodies along with the oppression against people in that period (Mitchell, 2002). The deliberate draining of the marshes resulted in an almost total loss in species, populations and habitats of birds, as the marshes were and are vital resting areas for migrant birds in the route between West Asia and East Africa (Mitchell, 2002). As well as this area was extremely polluted as a result of the use of army munitions and poison gas and of the destroying activity realized (Al-Ansari et al., 2012; Benvenisti, 2003). Several mammal species were dramatically affected by the draining, as Scott & Evans (1993) mentioned, since the deliberate draining of the marshes led to global extinction of *Nesokia bunnii* sp. and *Lutrogale perspicillata maxwelli* spp. The draining project damaged the biological diversity of the occurring non-aquatic species of plants, birds, invertebrates, in addition to the destruction of the biological diversity of the aquatic species like fish and amphibians (UNEP, 2001).

Biological diversity

Life came back to the drained marshes in 2003 yet in in the anisotropic form. Most plants, fisheries and waterfowls were restored but in less number that those existing before the draining (IMRP, 2006). The numbers of species of insects reached 45 on the year 2006 (Richardson & Hussain, 2006), while they were about 104 before the draining (Scott, 1995). Table 3 shows the biological diversity in the marshes in the period 2005-2012. More than 100 invertebrate species were found in the restored marshes along with fish, amphibians, birds, mammals, and reptiles (UNEP, 2010).

Health and integrity of any environment is measured by the occurrence of resident rare, not common, species. Accordingly, as an optimistic indicator of the marsh recovery, the Euphrates soft-shell turtle (*Rafetus euphraticus*), among the rare amphibian marsh species indicating the marshes health, was found in the restored marshes although registered as endangered species. Additionally, 9 resident or visiting marsh bird species were recorded, though being marked globally vulnerable (IUCN, 2010). These numbers might be increasing with the improvement of the environmental status in the restored marshes. Bird communities in the marshes consist of resident, summer/winter visitor and passing birds. In terms of populations, they are either common or rare, including the species region-restricted to the marshes. Salim et al. (2009) recorded 151 bird species in southern Iraq, 53 of which were breeding, 10 possibly breeding, 44 residents, 110 winter visitors from their breeding areas in Europe and Asia. The pygmy cormorant (*Phalacrocorax pygmaeus*) is dominant in Hwezeh marshes as resident bird species, while little egret (*Egretta garzetta*) dominates Hammar Marsh along with gulls and terns (Hussain, 2014). The importance of the marshes increases due to the occurrence of the migrant and waders as they play an important environmental role transporting nutrients from one place to another, and their faeces are also nutrition sources for the plants besides their role as primary and secondary consumers of seeds, aquatic plants, tiny invertebrates, fish, frogs, snakes (Mitsch & Gosselink, 2000).

Table 3. The biological diversity in the Iraqi marshes.

Biogenic group	Huwaizah Marshes	West of Hammar	East of Hammar	Central Marshes	Total number	References
Bacteria	4	3	7	#	7	Al-Taee et al. (2006)
Fungi	10	-	67	13	90	Abdullah et al. (2010)
Phytoplankton	92	89	64	74	132	Hassan et al. (2011)
Aquatic plants	36	24	28	33.3o	51	Al wan (2006); Hussain (2014)
Zooplankton	49	43	42	-	87	Al-Sodani et al. (2007)
Oligochaete	20	2	10	8	26	Jaweir & Al-Janabi (2012)
Fish	17	14	39	17	41	Hussain et al. (2012)
Amphibians	2	2	2	#	2	ARDI (2006)
Reptiles	3	2	3	#	3	ARDI (2006)
Birds	62	53	77	#	159	ARDI (2006)
Mammals	10	2	16	9	18	Al-Sheikhlym & Nader (2013)

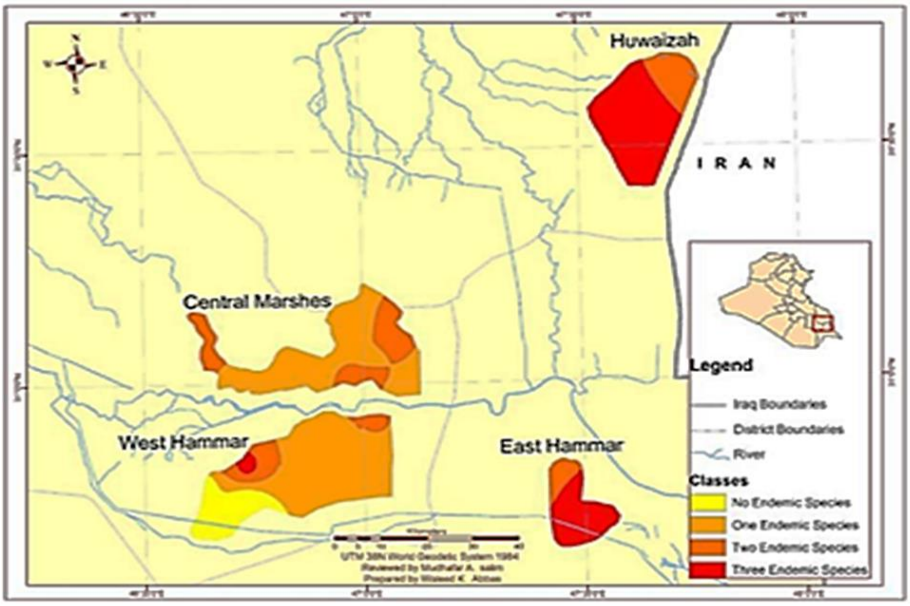
No data available

Fish communities

Conditions like dissolved oxygen, water depth, pH, salinity, temperature, etc.; influence distribution and occurrence of fisheries in the freshwater systems (Van dear Valk, 2006). Coad (2010) stated that there are 44 fish species recorded in the Mesopotamian Marshlands, of which 14 are resident, 24 are freshwater species and 20 are marine species, and most of fish species occur in the Hammar Marsh. Hwezeh Marshes include 17 freshwater fish species and no marine fish species while the Central Marshes include 14 freshwater fish species.

In the Figure 4, the distribution of fish communities in the three marshes is shown. Fish community in East Hammar Marsh, which is fed by Euphrates and Shat Al-Arab rivers, differs from that of the other marshes and this explains the regular occurrence of marine and mixed fish species along with the original and alien freshwater fish species (Hussain et al., 2006). Therefore, Hammar Marsh is of vital importance for fish species, due to the tidal dynamics existing between the marsh and the Gulf waters. This character supports fish movements between the marsh and the Gulf, which in turn provides the environmental corridor to many marine species for hatching periods, nutrition and shelter inside the marsh area. Consequently, Hammar Marsh plays an important role in the breeding of fish coming from the Gulf, which significantly contribute to the total fishing quantities all over the Gulf area (Al-Dubakel, 2011).

Figure 4. Distribution of the endemic fish in the three marshes (IUCN, 2010).



The Iraq Marshes include many economic fish species. Abd *et al*. (2009) mentioned 18 fish species of economic importance in the marshes: *Barbus barbulus*, *Barbus esocinus*, *Arabibarbus grypus*, *Mesopotamichthys sharpeyi*, *Luciobarbus xanthopterus*, *Carasobarbus luteus*, *Leuciscus vorax*, *Carassius auratus*, *Ctenopharyngodon idella*, *Cyprinus carpio*, *Hypophthalmichthys molitrix*, *Tenualosa ilisha*, *Planiliza abu*, *Nematalosa nasus*, *Silurus triostegus*, *Alburnus mossulensis*, *Mugil dussumieri* and *Acanthopagrus latus*.

Fish species included in the fish community in the restored marshes can be described as limnophilic; they come from the lower parts of Tigris and Euphrates and they prefer the quiet environment of the marsh with less water current. They are river species, not the original marsh species which existed and adapted to the area for thousands of years yet lost forever. Many studies were conducted to examine fish communities in the post-draining marshes. Hussain *et al.* (2008) realized a comparison of fish communities in three marsh sites of the southern Iraq: Soog Al-Shiyookh, Hwezeh and East Hammar. The researchers pointed out that these marsh sites included equal populations of the original species, but the East Hammar marsh was distinguished for including the largest population of the original species due to the occurrence of marine species. The species *Planiliza abu* dominated the southern marshes followed by *Carassius auratus*, for the availability of suitable conditions and nutrient sources like organic materials, aquatic plants and algae, these being the main food for them. The former species is resident, and the latter is alien to the Iraqi environment (Hussain et al., 2008). Hussain et al. (2009) showed that 31 species were found in Hammar marsh belonging to 14 families and the dominance was held by Cyprinidae in terms of the number of species, while *P. abu* was dominant in terms of population as it was 35.85% of the total collected sample. Fish were divided into three categories: resident (45.1%), alien (19.4%) and marine (35.5%). Fish occurrence differed as 10 species were resident and 5 were seasonal, as well as there were 16 rare species. Mohamed et al. (2009) studied the nature of fish community in Hwezeh marshes in the period 2005-2006. The total number of the species was 15, with the dominance of *P. abu* (37.1%) followed by *Carasobarbus luteus* (29.4%), *Carassius auratus* (15.3%), *Alburnus mossulensis* (4.88%) and *Leuciscus vorax* (4.14%). The post-draining stage in the marshes included difference in the nutrition system for some fish species. Hussain *et al*. (2006) mentioned the changed in nutrition of some fish species in Hammar Marsh and indicated that change happened for *C. luteus* from herbivorous to omnivorous. The same applies to *C. carpio*, from omnivorous to carnivorous and, in addition, *Silurus triostegus* and *L. vorax* completely changed their feeding system to be totally predatory to small fish. Such change was also found for *M. mastocemblus*, which opted to become fish predator. These changes can be related to the evolved environment as well as to the food scarcity manifested after many years of draining. The co-occurrence of varied fish communities (herbivorous, carnivorous, omnivorous, detritivorous and predators) in one ecosystem, though in various rates, indicates that the food hierarchy is disordered and abnormal in that ecosystem (Hussain, 2014). Thus, some determinants for the environmental stability and balance off the marshes should be addressed, especially those which contribute to the rehabilitation of the marshes, like salinity level and invasive species occurrence.

Water status in the marshes

The key and determinant factor in the restoration of the marshes, including people communities and biological diversity, is the availability of incoming water to the marshlands, mainly via Tigris and Euphrates. This in turn depends on the upstream countries of the two rivers (Turkey, Syria and Iran). Turkey built on Tigris 17 dams with a storage capacity of 25.3 billion m^3, and those built on Euphrates are 40 with storage capacity of 95 billion m^3 (Ozis, 1983). For example, in 1998, the Ataturk's dam was built in Turkey as part of the South-East Anatolia Irrigation Project (Great Anatolia Project = GAP), with a storage capacity of over 307 billion m^3 of water flowing annually from Turkey to Iraq via Euphrates and it can be said that this dam alone could dry out Euphrates (Partow, 2001). In Syria, 4 dams were built with the storage capacity of 16.1 billion m^3. So, in 1972, Tigris and Euphrates flows witnessed decreases of 15% and 43%

of the original quantities, respectively (University of Victoria, 2010). This could in future lead to lessen the average annual flow of the two rivers up to 52 billion m^3 per year in 2020 (Nomas, 2005). If the same rate of inflow decrease continues in the next years, Tigris and Euphrates there would be no more by 2040 (UN, 2010).

It is retained that the water requirements to restore the marshes to their former shape and extension of the 1980s (12900 km^2) are about 42 billion m^3 per year (Polservice, 1979). Since water demands from Tigris and Euphrates for the coming periods in terms of agricultural, service and industrial uses would rise to about 70.6 billion m^3 per year, a water deficit of 8.6 billion m^3 per year would strike taking into account groundwater resources that give 1.2 billion m^3 per year, i.e. 2% of the total water resources in Iraq (World Bank, 2006). Therefore, this issue needs a re-consideration in the water plans and programs to be efficiently used according to the strategic importance. The use of the MOD water to stabilize Hammar Marsh and the Central Marshes might be one of the reasonable solutions, especially with the suitable quantities of water in the MOD in terms of discharge, corresponding to 220 m^3 per second (Al-Mahmood, 2009).

Salinity

Salinity is one of the most important environmental factors influencing fish survival, development and distribution (Holliday, 1969). Environmental disturbs resulting from water quality influence the quality of the biological productivity. This leads to alter the structure and the nutrition behaviour of the biological communities, reducing the native species populations (that are more sensitive to the environmental condition and water quality) and increasing the presence of the alien species (Raderr et al., 2001). Consequently, salinity increases contribute directly to population decreases in the aquatic environment (Hussain et al., 2012). It is well-known that salinity in Tigris and Euphrates increases southward (Al-Lami *et al*., 1996) and this aspect negatively reflects on the biological diversity in the southern marshes (Nielsen et al., 2003).

The salinity increases in soil due to the deliberate draining campaign led to impose extra loads on water inflows from the two rivers (Tahir et al., 2008) which are already not enough to cover the actual demand for the restoration of the marshes (University of Victoria, 2010). It is important to accurately systematically think to this deteriorating situation. The investment in drain water for irrigation and re-fertilizing lands to reach soil salinity balance or upon mixing drain water with freshwater are applicable solutions. The soil cleanse with drain water then with river water saves 20-30% of cleansing freshwater (Nomas, 2005). The fundamental resolution of salinity problem is no easy task, and efforts should be intensified to study the impact of salinity acclimatization on the local fish communities for having not negative reflects on the fish status in the Iraqi marshes. Most inhabitant freshwater fish are categorized as stenohaline fish, as they cannot tolerate high salinity range variations and there are testimonies of enormous mortalities when salinity crosses the tolerable boundaries (Jackson, 1981). However, several studies confirmed the potentiality of solving this issue and enhancing salinity acclimatization of fish via using salt feeding technique that refers to incorporating certain salt amounts in the food fed to those fish (Lawson & Alake, 2011), given that the local fish general exposure to high salinity in their natural environment is not confined to specific ages, but all age groups from egg to adult are exposed to this condition.

Invasive species

Biotic factors like interspecies interactions including competition, predation and environmental interdependence needs play important and influential role in the species diversity and richness (Oberdorff & Hughes, 1998). Invasive species contribute to many negative environmental impacts that are not easily discovered and lead to great loss in the local biological diversity, due to the direct environmental interactions among species, let alone the genetic overlap when they mix with local species (Saunders et al., 2002). Many invasive species invaded the Iraqi marshes before and after the draining process like *Cyprinus carpio*, *Ctenopharyngodon idella* and *Carassius carassius*, which came to be second in dominance following *P. abu*, in the southern marshes. The dominance of invasive fish species in the Iraqi marshes is due to i) their ability to use the available diet sources, ii) that they are not recognized by the enemies of the local fish species like waterfowl, predator fish and reptiles, and iii) their ability to tolerate disturbed conditions (Van dear Valk, 2006). Invasive fish species compete with local species if they fed the same diet components or occupy the same territory leading to the displacement of each of them (Hussain et al., 2009). Hussain (2014) described the types of food overlapping between local and alien fish species, showed in Table 4. Eight out of 12 fish species with low food overlapping were included in the study. Also, there is considerable food overlapping among 4 local and alien species, besides the overlapping between alien species like *Cyprinus carpio* and *Carassius carassius*. Accordingly, immediate management interference is required to uplift and stabilize the productivity of the food chain on the long run, and then ensuring the stability of fish diversity in the aquatic environment (Dudgeon et al., 2005).

Table 4. Food overlap between the local and alien species in the marshes using Morisita Index (Hussain, 2014).

The scientific name	The overlap weak (≤ 50)	The overlap median (50-69)	The overlap high (≥70)
Carassius carassius × *Cyprinus carpio*	21		
Cyprinus carassius × *Acanthobrama marmid*	22		
Carassius carpio × *Alburnus mossulensis*	39		
Alburnus mossulensis × *Carasobarbus luteus*	35		
Carassius carpio × *Carasobarbus luteus*	41		
Carassius carpio × *Alburnus mossulensis*	41		
Acanthobrama marmid × *Alburnus mossulensis*		51	
Carassius carpio × *Luciobarbus xanthopterus*		69	
Carasobarbus luteus × *Carassius carpio*			90
Silurus triostegus × *Leuciscus vorax*			90

Conclusions

From the examination of the current conditions and from the comparison with the situation pre-existing the drying up of these wetlands' areas of southern Iraq, the following conclusions can be drawn:

Iraqi southern wetlands play an important role in keeping the regional and global biological diversity;

the draining of the marshes has been an organized crime that led to complicated issues of damaging effects to the natural and social aspects of the environment;

Iraq faces drastic water shortage coinciding with the completion and operation of water projects upstream of the Tigris and Euphrates rivers, causing severe decline in the river flows;

the draining operations impacted the ecosystem, in general, and the species populations and the food behaviour of the fish communities, in particular;

the salinity increase in the southern marshes is a serious threat to the biological diversity in general and to fish species, in particular;

the marshes suffer from shortage in water inflows and experience ongoing deterioration due to the absence of short-term or long-term strategies to deal with such issues. Then it is very urgent to intensify the future studies and researches through different disciplines concerning wetlands management.

Recommendations

Activating the international agreements to ensure enough water inflows in Tigris and Euphrates and monitoring water quality and water pollution.

Developing informed programs for the optimal use of the water resources with the aim to rehabilitate the Iraqi marshes.

Conducting regular survey for the populations and species of wetland communities of fish, birds and plants.

Engaging relevant NGOs in the programs of the preservation of the biological diversity and educating marsh locals about coping with the environmental s*tatus quo* without exhausting the niches characterizing those areas.

Developing future programs by the governmental agencies and NGOs for the professional and craft development for the population of the marsh to maintain in those areas the human communities.

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اعادة استقراء للاهوار العراقية التي تقع ضمن لائحة التراث العالمي (دراسة مرجعية)

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الخلاصة :

تقع اهوار بلاد ما بين الرافدين أو جنة عدن، الجزء الجنوبي من العراق، وتحتل مساحة ١٥-٢٠,٠٠٠ كم^2. تاريخيا، كان لهذه المنطقة دورا رائدا في الحضارة الإنسانية يمتد لأكثر من ٥٠٠٠ عام .يسكن الاهوار اقوام يطلق عليهم "عرب الاهوار" او" المعدان" ، الذين هم ورثة السومريين وشعوب السامية . قاد صدام حسين بهمجية حملة شرسة على هذه المناطق في عام ١٩٩١، ادت الى تجفيف الاهوار. لم يسلم من هذا الدمار سوى ٧٪ من المساحة الكلية للأهوار . تسبب هذا الفعل في تدمير شامل للنظام الإيكولوجي، وتهجير سكان الأهوار . في عام ٢٠٠٣، بدأت المياه بالتدفق من جديد إلى هذه المناطق. اعادة الاغراق، لا يضمن استعادة جميع مناطق الأراضي الرطبة في جنوب العراق كما في الوضع السابق .كما ان النظام البيئي الجديد اثر على تنوع وخواص الانواع المتعايشة في تلك المناطق. في عام ٢٠١٦ وبالنظر لأهمية اهوار بلاد ما بين النهرين، ادرجت منظمة (IUCN)ثلاثة من الاهوار العراقية وهي هور الحمار ،هور الحويزة واهوار الوسط ضمن لائحة التراث العالمي كارث حضاري يجب المحافظة علية .الهدف من هذه الدراسة، هو إعادة تقويم النظام البيئي في هذه المناطق الثلاث من منظور البيولوجي ومن خلال استعراض بعض التحديات التي يجب التعامل معها لاسترداد الاستقرار إلى نظام البيئي يمتد لآلاف السنين .

PAPER 2

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Dear Sir/Madam,

I am pleased to inform you that your paper on " ***The fish community and food habits of fish species in Hawr Ad Dalmaj marsh*" By Kadhim J.L. Al- Zaidy ; Giuliana Parisi / Università di Firenze, Italy, and S M. J. Y. Al-Amari /University of Babylon – Baghdad, Iraq,** has been accepted for publication in ***Biochem. Cell. Arch.*** Your Paper will appear in **Vol. 19, No. (Issue 2), November 2019.**

Sincerely yours

(P R Yadav)

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The fish community and food habits of fish species in Hawr Ad Dalmaj marsh

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Abstract

This study was conducted from January to December 2017 in Hawr Ad Dalmaj marsh, which is located 40 km southwest of Kut city, Waist Governorate southeast Iraq. The fish samples were collected, and water temperature and salinity were measured monthly. Water temperature ranged from 37.54 °C during August to 9.15 °C in January; salinity ranged from 2.68 g/l in February to 10.91 g/l in August. Fifteen species of fish were collected, belonging to 7 families and all of them were freshwater fish. Resident species, seasonal species, and occasional species formed 60% (9 species), 6.67% (1 species) and 33.37% (5 species) of the total ichthyofauna, respectively. The dominant species were *Planiliza abu*, *Carassius auratus* and *Coptodon zillii* with a relative abundance 35.99%, 27.75% and 15.86% respectively. The highest monthly similarity was found in March (91.67%) and lowest in May (69.23%). Food items varied among fish species and *Silurus triostegus* and *Leuciscus vorax* resulted highly specialized, while *Planiliza abu*, *Coptodon zillii*, *Oreochromis aureus*, *Cyprinus carpio* and *Mesopotamichthys sharpeyi* showed less specialization. *Carassius auratus* and *Carasobarbus luteus* were non-specialized species based on their food components.

Keywords

Fish community, alien species, food habits, Hawr Ad Dalmaj marsh.

1. Introduction

Mesopotamia is a Greek word which refers to the land between two rivers (McCarthy, 2001), hence, the term points out to all the lands between the two rivers Tigris and Euphrates including the southern marshlands. Mesopotamian marshes are the largest inner of wetland systems in extremely hot and dry environments on the Earth (Schaaf & Rodrigues, 2016). Tigris and the Euphrates represent the main sources of water feeding these marshes (Al-Ansari *et al.*, 2012). The present marsh dwellers (Marsh Arabs or Ma'dan) are the descendants of the Sumerians, and they are the living connection between the Iraqis of today and the ancient Sumerians (Al-Zahery *et al.*, 2011). Ma'dans (Shiite Muslims) live on the edges of the marshes or in small artificial isles made of reed within the marshes (UNEP, 2001). Their lifestyle significantly resembles that of the ancient Sumerians (Al-Hilli, 1977). Saddam Hussein regime conducted the draining of the marshes in 1991 when the draining project was accompanied by an aggressive campaign of arrests, killings, household burnings and displacements of the endogenous marsh dwellers in thousands. The effects produced to this environment and ecosystem were dramatic and the damage included the fishing activity and the quantities fish caught in these wetlands characterizing the southern Iraq, which were enormously deteriorated in that period (Mitchell, 2003). After 2003, water returned to the Iraqi marshes but only relatively. The study of the life characteristics of fish is an approach to get the information required to plan, manage, improve, sustain and maintain the stock of fish present in a given environment and for its preservation (Garcia & Rosenberg, 2010). Hawr Ad Dalmaj marsh is one of the important waterbodies in Iraq; it is located 40 km southwest of Kut city, Waist Governorate. Its length about 50 km with an average width of 10 km. Its feeders are the overflow of the irrigation canals and floodwater of Tigris River during the rainy years and mainly from the Main Outfall Drain (MOD). The average water depth within the marsh varies from 0.5 to 2.5 m. The total storage capacity of Hawr Ad Dalmaj marsh is 429 million m^3 of water (Russian, 1984). Carp (1980) listed this marsh as a moist land of international importance. Despite the global importance of this area, unfortunately at the moment it is not protected (Scott, 1993) and no study has been carried out in there to analyse its ecosystem, the fish species composition and fluctuation during the year.

The aim of this study was to describe the temporal distribution of fish community present in Hawr Ad Dalmaj marsh area for 1 year, and to know and elucidate the relationships among the invasive species and the local species of fish, highlighting the food utilized by different species of fish during the year.

2. Materials and Methods

2.1 Study area and water quality

To execute the present study two stations were selected for sampling, based on the character of the topography of the area examined, as shown in Figure 1, the first located at 32˚ 35′ 93.96" N and 45˚ 22′ 38.15" E (near kilometre 331 of the MOD channel) and the other one located at 32˚ 13′ 38.32" N and 45˚ 50′ 14.11" E (southeast of the first location, near kilometre 299 of the MOD channel). The field measurements included water quality, that were measured monthly by using the YSI sension 156 MUL TI METER (Hach Company, Loveland, Colorado, USA). The water transparency was measured using the Secchi disc. NO_3 and PO_4 were measured as shown in Parson et al. (1984).

2.2 Fish sampling

Fish samples were collected monthly during the period of the study, lasting from January 2017 to December 2017. The fish were caught by several fishing methods, such as the seine net, whose length was 120 m and the size of the openings was 10 × 10 mm at the sides and 5 × 5 mm in the centre, and the gillnets, whose length ranged from 50 to 100 m with 1 to 7 cm mesh size. The fish collected were counted and identified for their classification by family, genus and species, by consulting a variety of bibliographic sources (Beckman, 1962; Coad, 1996, 2010).

The fish were classified based on the frequency or occurrence (F%) method, according to Tyler (1971), that classified the species in three categories, as the following: i) common species, that were found in monthly catch samples from 9 to12 months; ii) seasonal species, that appeared in the monthly catch samples from 6 to 8 months; iii) occasional fish species, that were caught from 1 to 5 months. The relative abundance was calculated according to Krebs (1974):

Relative abundance % = (ni / N) * 100

ni = number of individuals of species in the sample.

N= total number of individuals of all species.

Jaccard's Index (Ss %) was studied, to know the similarity in structure of the fish community in Hawr Dalmaj marsh, the value Jaccard's Index (Ss %) was calculated according to Jaccard (1908):

$$Ss\% = (A/A + B + C) \times 100$$

where

A: Number of conjoint species between Station 1 and Station 2

B: Number of species which appeared in Station 1 and don't found in Station 2

C: Number of species appeared in Station 2 and not found in Station 1.

Finally, for classification of fish in categories, a method based on the nature of the food points (P%) was utilized. To analyse the food eaten by the fish, the digestive canal of each fish was individually separated, washed by the water, opened and its content was moved into a Petri dish and examined under a low power binocular microscope (zoom Force ×40). Food items were then taxonomically identified, as far as possible, and classified into 9 main groups: i) mollusca, 2) crustacea, 3) aquatic insects, 4) organic crumbs, 5) diatoms, 6) plants and seeds, 7) algae, 8) worms and 9) fish. This classification was done according to Hadi (1984) and Coad (2010).

the Index of Relative Importance (IRI%) was also calculated according to (Pinkas, 1971):

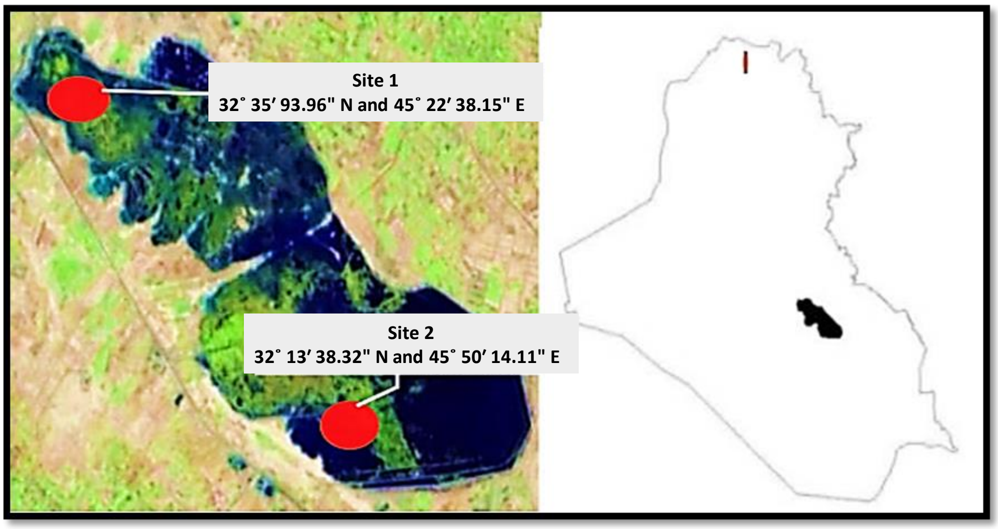
$$IRI\% = [P\% \times F\% / \sum P\% \times F\%]\ 100$$

where

P%= percentage of each food component.

F%= percentage of frequency of each component.

Figure 1. Map of the Hawr Ad Dalmaj marsh with the two Sites of the study.

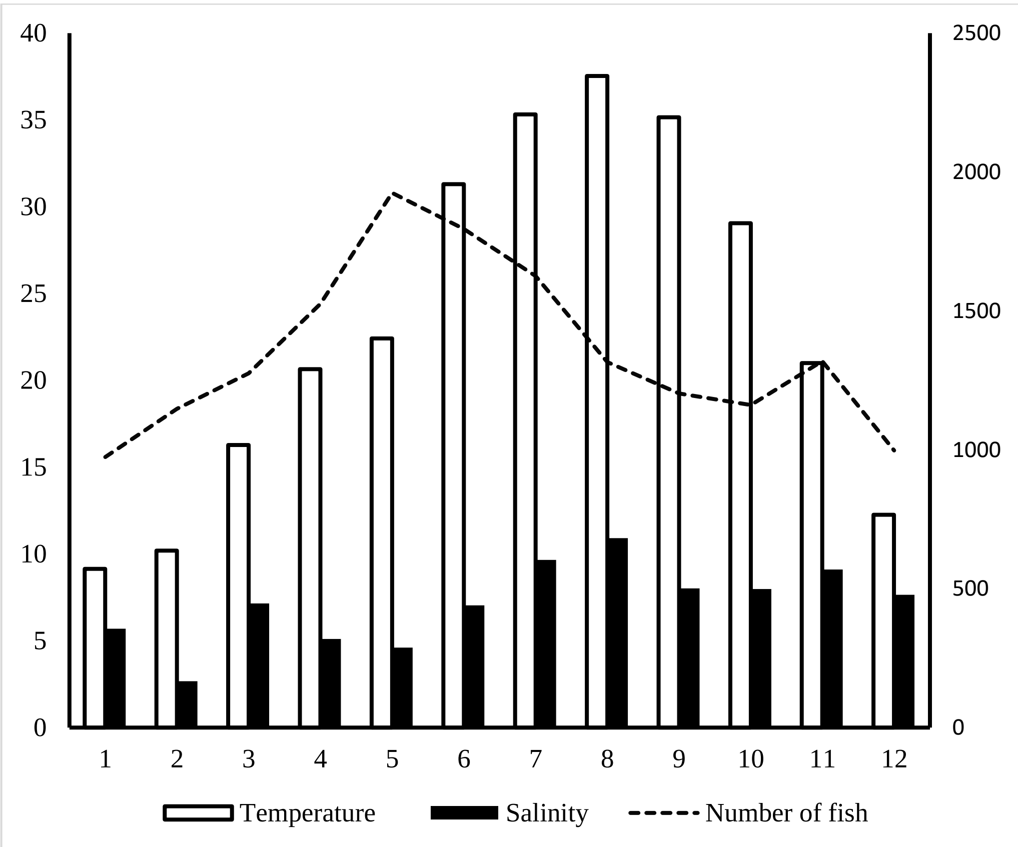


3. Results

3.1 Water quality

In the current study, the water temperature showed clear monthly variations. The highest values were recorded during August (37.54 °C), and the lowest during January (9.15 °C). The salinity as well showed clear monthly variations and the values registered during the study period were between 2.68 g/l in February and 10.91 g/l in August (Figure 2).

Figure 2. Monthly variations in water temperature and salinity (y axis on the left) and the total number of individuals caught (y axis on the right) in the Hawr Ad Dalmaj marsh in the study period.



3.2 Species composition and occurrence

During this study, in the area of Hawr Ad Dalmaj marsh 16265 individuals were caught by different fishing gears, belonging to 16 species and 7 families. Cyprinidae family members dominated the caught fish community with 8 different species, as shown the

Table 1, followed by Cichlidae family, which accounted for 2 species, i.e. *Coptodon zillii* and *Oreochromis aureus*. Mugilidae family was represented only by 1 species, which was *Planiliza abu*, and the same applies on the other 3 families, which were represented only by one species each. The Mugilidae family was represented by 5853 individuals; Cyprinidae ranked second with 5807 specimens caught, and *C. auratus* species ranked first for this family. Cichlidae family ranked third, as it shown in Figure 3. About the Jaccard's Index of the similarity in structure of species in the fish community in Hawr Ad Dalmaj marsh, when the base sample of January with the subsequent month samples was compared, it was noted that the similarity rates were fluctuating among months, with values ranging between the lowest values (69.23%) in May and the highest (90.91%) in December, as is evident in Figure 4.

Figure 3. Number of individuals sampled by Family in Hawr Ad Dalmaj marsh during the study period (from January to December 2017).

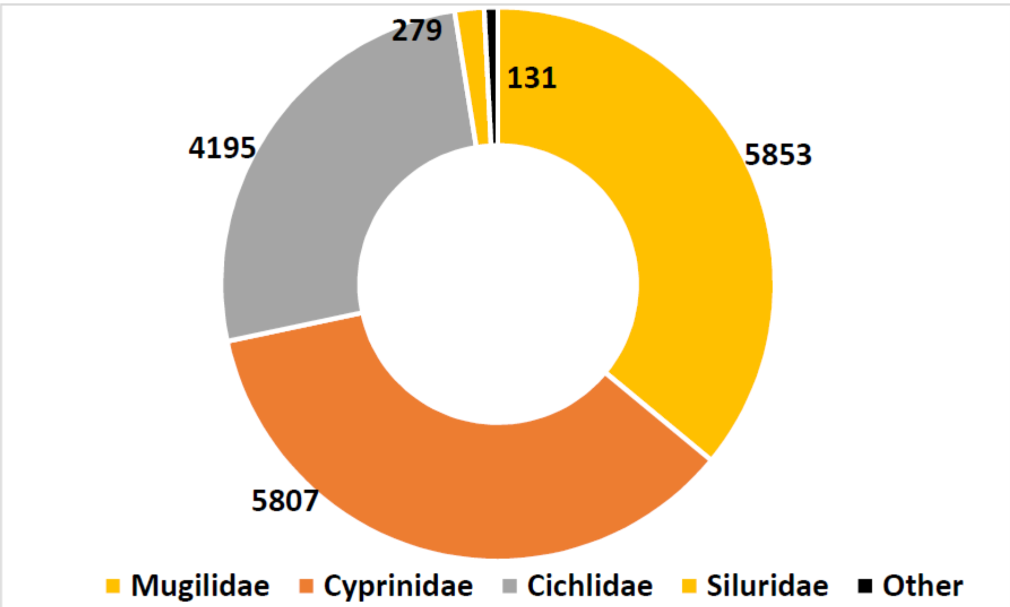
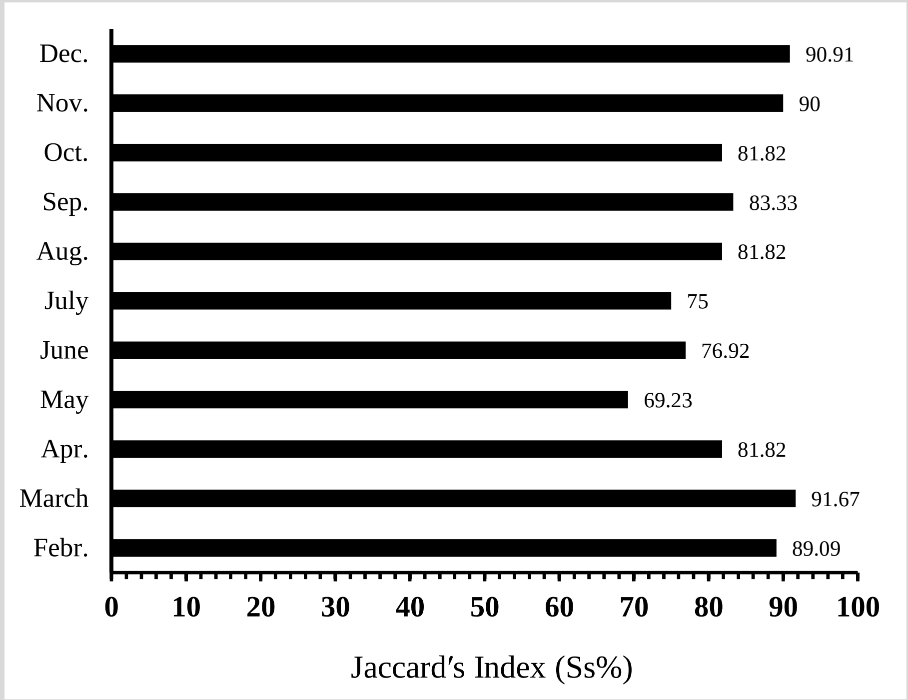


Figure 4. Monthly variations of similarity of species in Hawr Ad Dalmaj marsh during the study period.



The results highlighted a weak positive correlation between water temperature and the number of individuals (r=0.444; P<0.05) and it is showed a negative correlation between the salinity and the number of individuals (r = 0.15; P<0.05).

3.3 Fish species presence

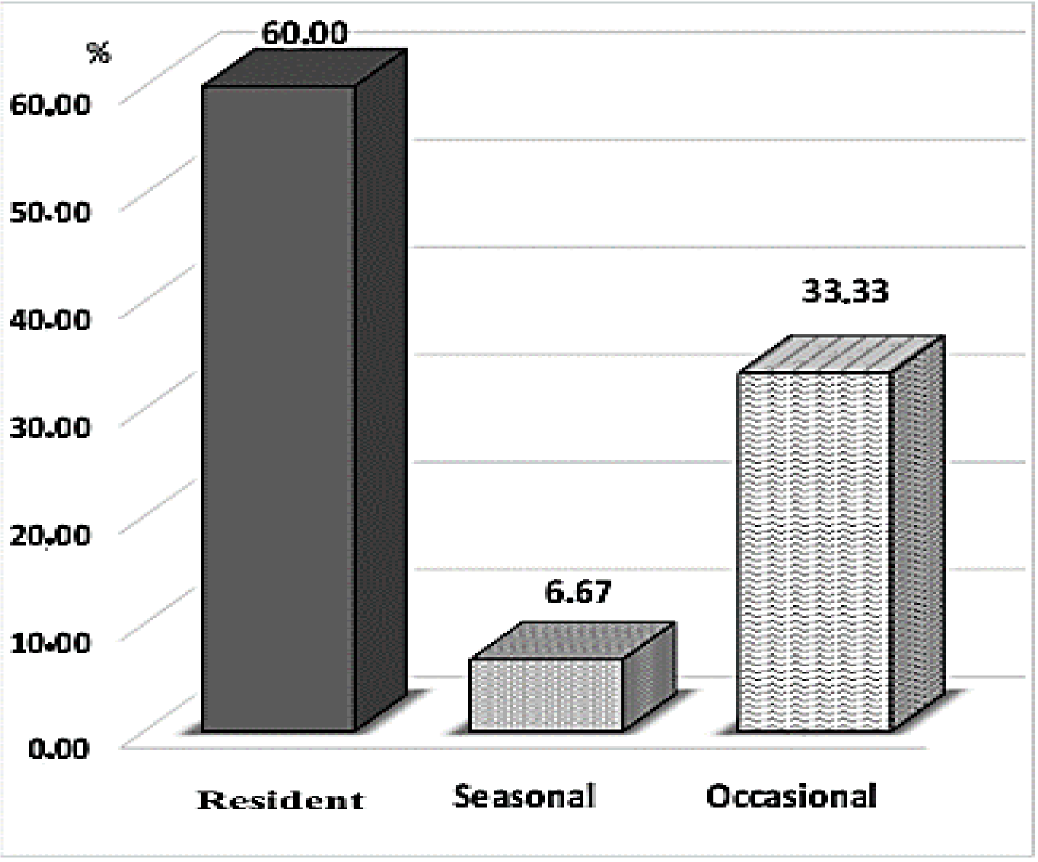
Fish species were divided into three groups according to their presence in the caught samples (frequency or occurrence). The first group included the common fish species; it was represented by the most dominant group and contained 9 different species, that constituted the 60% of the total number of species. The second group was represented by the seasonal fish species, and this group included only 1 species, corresponding to 6.67% of the total number of fish species. The third group was represented by the occasional fish species, which included 5 species and constituted the 33.33% of the total number of species that were caught during the study period (Figure 5).

Table 1. Monthly variations in relative abundance (%) of fish species caught in Hawr Ad Dalmaj marsh from January to December 2017.

Family	Fish Species	Month												Total
		Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	
Mugilidae	***Planiliza abu +***	1.72	2.21	2.50	3.23	4.91	4.47	3.89	3.02	2.66	2.77	3.18	1.43	35.99
Cyprinidae	***Carassius auratus*+***	1.86	2.11	2.13	2.94	2.53	3.14	2.45	2.36	2.10	1.92	2.23	1.98	27.75
	Cyprinus carpio*+	0.10	0.15	0.22	0.17	0.28	0.24	0.26	0.22	0.18	0.20	0.18	0.14	2.34
	Mesopotamichthys sharpeyi+	0.10	0.18	0.23	0.16	0.30	0.21	0.24	0.14	0.15	0.08	0.13	0.12	2.04
	Carasobarbus luteus +	0.05	0.07	0.12	0.17	0.23	0.23	0.19	0.15	0.14	0.17	0.15	0.12	1.80
	Leuciscus vorax +	0.07	0.11	0.06	0.10	0.17	0.14	0.14	0.06	0.07	0.06	0.05	0.06	1.08
	Arabibarbus grypus +	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02
	Luciobarbus xanthopterus+	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
	Acanthobrama marmid +	0	0	0.15	0	0	0.23	0.21	0	0.08	0	0	0	0.67
Cichlidae	***Coptodon zillii *+***	1.24	1.22	1.33	1.65	1.87	1.09	1.48	1.28	1.06	1.06	1.36	1.21	15.86
	Oreochromis aureus*+	0.68	0.79	0.82	0.89	1.12	1.03	0.95	0.67	0.71	0.76	0.69	0.82	9.93
Siluridae	***Silurus triostegus +***	0.06	0.12	0.13	0.07	0.22	0.25	0.20	0.11	0.14	0.10	0.14	0.18	1.72
Bagridae	***Mystus pelusius +***	0.10	0.09	0.14	0.00	0.17	0.00	0.00	0.07	0.10	0.00	0.00	0.08	0.76
Heteropneustidae	***Heteropneustes fossilis*+***	0.00	0.01	0.00	0.01	0.01	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.04
Mastacemblidae	***Mastacembelus mastacembelus +***	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Total catch		974	1147	1275	1526	1925	1795	1626	1316	1203	1161	1319	998	16265
Total no. of species		10	11	11	10	14	11	10	10	10	10	9	10	15
No. of native species		6	6	7	5	9	6	6	6	5	5	4	6	10
No. of alien species		4	5	4	5	5	5	4	4	5	5	5	4	5

*Alien sp.
+Freshwater sp.

Figure 5. Percentage of the composition of fish categories in Hawr Ad Dalmaj marsh in the overall sample caught during the investigation period (from January to December 2017).



3.4 Food composition

The kinds of food utilized by the specimens of fish of the different species analysed during this study are detailed in Table 2 and in Figure 6 that details the Relative Importance Index (IRI), a parameter that expresses the importance of different foods in the diet, defined solely in terms of their frequency, number and bulk, rather than to be referred to the nutritional or other characteristics. For these reasons IRI is considered as a satisfactory index for most descriptive studies about diets.

P. abu was detritivore, adapted to feed on diatoms, algae and organic crumbs. The food of *C. auratus* was composed of plants and seeds, algae, crustacean, aquatic insects and Mollusca, in decreasing order; while *C. zillii* was adapted to feed on plants and seeds, algae, organic crumbs, aquatic insects, diatoms and crustacean. *C. carpio* fish depended on four food items, *i.e.* plants and seeds, algae, crustacean, aquatic insects and diatoms. The major food items for *M. sharpeyi* consisted of algae, diatoms, plants and seeds. The foods of *C. luteus* were plants and seeds, algae, crustacean, aquatic insects and mollusca. The basic food item for *S. triostegus* and *L. vorax* was represented by fish with the percentage reached 96.44% and 92.48%, respectively.

3.5 water quality and the functional characterization

The studied water quality characteristics showed a contrast in the values of the rates during the study period, as showed in the table 3. Also, table (3) shows changes in the values of the Percentage for the functional characterization to analyze food ingredients for the fish community of the study period. Were the highest value of the detrivore, omnivore and piscivore in the summer and the highest value of the herbivore and carnivorous were in the spring.

Table 2. Percentages of food items and the specialization of food of the common fish species found in Hawr Ad Dalma marsh during the study period (from January to December 2017).

Species	Specialization of food			Main food items
	High level (0.0-0.25)	**Low level (0.26-0.46)**	**Non-specialized (≥ 0.50)**	
C. auratus			0.859	plants and seeds 26.19%, algae 24.46%, crustacean 20.9%, aquatic insects 12.63%, diatoms 8.12% and mollusca 7.7%.
C. luteus			0.639	plants and seeds 23.06%, algae 21.85%, crustacean 19.74%, aquatic insects 13.81%, mollusca 13.29%, diatoms 7.29% and organic crumbs 0.04%.
P. abu		0.268		diatoms 47.01%, algae 34.68%, organic crumbs 13.01%, crustacean 2.16%, worms 2.05% and mollusca 0.27%.
C. zillii		0.253		plants and seeds 61.81%, algae 23.02%, organic crumbs 6.11%, aquatic insects 5.75% diatoms 1.9% and crustacean 1.41%.
O. aureus		0.316		diatoms 45.46%, algae 29.69%, plants and seeds 18.11%, organic crumbs 4.67% aquatic insects 0.51 and mollusca 0.02%
C. carpio		0.450		plants and seeds 26.19%, algae 24.46%, crustacean 20.9%, aquatic insects 12.63%, diatoms 8.12% and mollusca 7.7%.
M. sharpeyi		0.296		algae 40.78%, diatoms 28.05%, plants and seeds 24.01%, organic crumbs 4.03%, aquatic insects 1.47%, crustacean 1.07% and other 0.59%.
S. triostegus	0.040			Fish 96.44%, crustacean 3.54% and aquatic insects 0.02%.
L. vorax	0.053			Fish 92.48 %, crustacean 3.75%, mollusca 2.27%, aquatic insects 1.48% and algae 0.02%.

Figure 6. Relative Importance Index (IRI) of items in the diet of the common fish species found in Hawr Ad Dalmaj marsh during the study period (from January to December 2017).

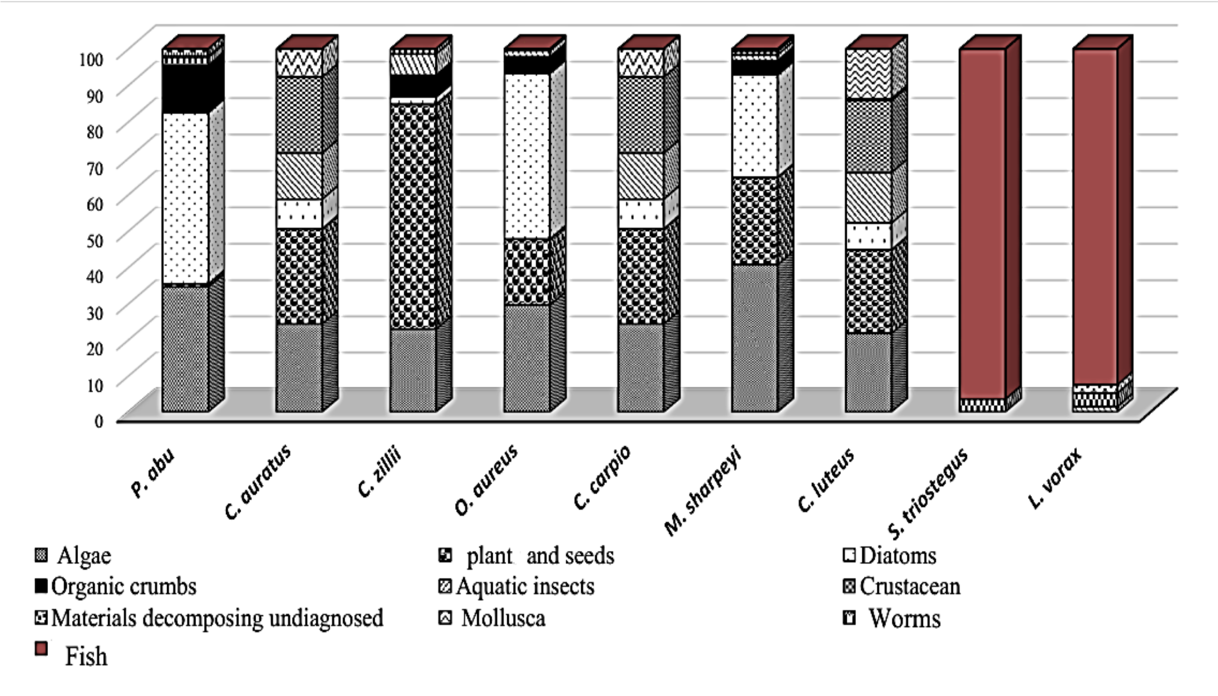


Table (3): The Seasonal averages for the physical and chemical properties of the water and the percentage for the functional characterization to analyze food ingredients for the fish community in the Hawr Ad Dalmaj marsh through the study period

Trait studied		Winter	Spring	Summer	Autumn
Water quality	Temperature of water ºC	10.53 ± 1.72	19.78 ± 2.64	34.72 ± 2.82	28.40 ± 6.75
	Ph	7.31 ± 0.44	8.2 ± 0.2	8.58 ± 0.12	7.70 ± 0.59
	Salinity ppt	5.34 ± 2.31	5.62 ± 1.53	9.20 ± 1.71	8.37 ± 0.73
	(DO) mg/l	9.54 ± 0.33	8.32 ± 0.37	6.31 ± 0.24	8.13 ± 0.53
	Turbidity	10.72 ± 0.78	15.53 ± 1.22	16.97 ± 0.68	12.92 ± 0.78
	Light penetration cm	78.17 ± 6.33	58.17 ± 2.33	42.83 ± 1.17	55.33 ± 8.16
	NO_3 µg N /L	7.01 ± 0.43	3.41 ± 0.55	2.05 ± 0.36	5.23 ± 0.76
	PO_4 µg N /L	1.04 ± 0.08	0.79 ± 0.09	0.72 ± 0.02	0.96 ± 0.09
The functional characterization to analyze food ingredients.	Detrivore	871	1730	1851	1401
	Omnivore	103	222	282	179
	Herbivore	1035	1361	1154	977
	Carnivorous	43	51	12	17
	Piscivore	99	125	146	92

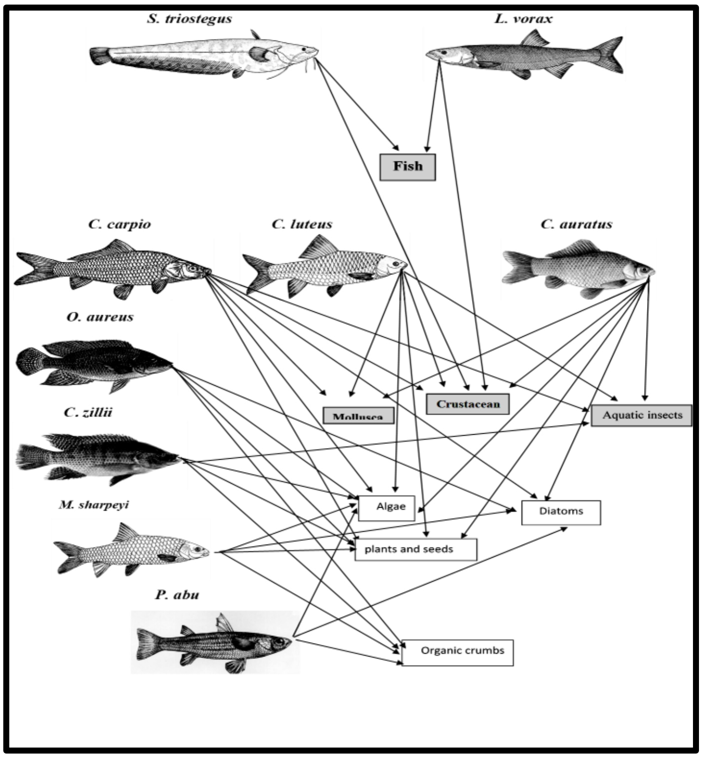
4. Discussion

The fish community structure is widely considered as an integrative indicator of the ecological status of water bodies and its analysis can be a very useful tool. The fish community in a water body is submitted to a dynamic structure because of biotic and abiotic factors in each environment considered that affect the specific biodiversity. The planned desiccation realized in the southern marshes during the nineties determined dramatic consequences on the flora and fauna pre-existing in this area, in addition, affected the climate condition determining changes in temperature and in salinity levels. These environmental and water condition changes produced relevant effects on native fish species. Petihakis *et al*. (1999) indicated that the temperature of water is one of the most important environmental factors. The study results showed a significant correlation between water temperature and the number of individuals. This explains the realized increase in numbers during the months with high temperature, and this is consistent with Hussain *et al*. (2009), but the number of species found in the samplings performed and the number of specimens caught decreased dramatically during the summer months. The salinity showed a weak negative positive correlation with the number of individuals caught and this is consistent with the Al-Shammary (2008) which reached to the same conclusion in a study carried out in the east of Al-Hammar Marshes. The number of species identified during the samplings results very reduced compared with those found by Mohamed *et al.* (2013) in the Shatt Al-Arab River in the year 2011-2012 that amounted at 58 .In the past years, several studies were carried out on southern marshes focusing on nature of fish assemblage (ARDI, 2012; Mohamed et al. 2013), after the drowning in 2003, and the study we have performed is the first and unique research carried out for characterizing the fish community in the Hawr Ad Dalmaj marsh during a year of samplings.

The *Planiliza abu* was the most abundant species found in the samples carried out monthly and its family ranked first in this study. This local native species was found to be the most abundant species also in other studies performed in different areas of marshland. According to Coad (2010), *P. abu* is considered the most abundant species in the marshes in the 1980s and in the recovering marshes in southern Iraq in the year 2005-2006. The reason of the contraction of the specimens sampled in winter months can be explained by the habit of this species that, in December-January, enters rivers and deeper waters, especially when the temperatures are very low. Cyprinidae Family was that second for number of the specimens caught but the first for the variety of species, confirming the dominance of this family in the marsh ichthyofauna, in agreement with what it was recently found by Abdullah (2019) in the Al-Chibyaish marsh and previously by other authors in other wetlands of the southern Iraq. About 72% of the native fish in Iraq belong to this Family (Coad, 2010). The individuals of this family prefer warm water because the high temperature suits with their physiological and vital activities (Al-Daham, 1982; Hussain *et al.,* 2009).

The results of the analysis performed showed the presence of four species of alien fish species (i.e. *C. auratus, C. carpio, C. zillii* and *O. aureus*) the main species. The alien species found during the period of sampling represented on average the 33.33% of the total number of species sampled in the period and this range resulted very close to that found by Hussain *et al.* (2013) in a study performed in three southern marshes (Al-Huwayza, Suq Al-Shuyukh and East Hammar) in the years 2005 and 2006. The prevalence of the alien species may due to their ability to endure sever environmental conditions, in addition, they eat a wide range of food items, making them able to quickly adapt to the environment (Younis, 2005; Mohamed *et al.,* 2013). *Carassius auratus* was the second species for number of the sampled individuals and was regularly caught throughout the year, confirming Coad (2010) results. This alien species colonizes the marshes with great success, also in the most critical periods of the years, because of their short life cycle and high fecundity (Al-Noor, 2010) and the absence of its natural enemies and local diseases in this habitat (Hussain *et al.*, 2013). This species shows a high capacity to tolerate harsh environmental conditions, markedly greater than that shown the other exotic Cyprinidae introduced and widely spread in the Iraqi freshwater, i.e. *Cyprinus carpio*. Among the species of tilapia, *C. zillii* and *O. aureus* are the most tolerant to the salinity levels, and they are also superior to the local fish in the adaptation to the salinity, as well as these fish are able to reproduce more than once a year, condition that leads to the rapid spread of these species and to a rapid adaptation to new environments (Ridha, 2006). The high invasion capacity of *O. aureus* in the new habitats can be also attributed to its own unique reproductive strategy, based on providing protection and parental care to the larvae and post larvae. Additionally, these abovementioned species breed in shallow areas, and this leads to the destruction of breeding areas for the native species.

Figure 7. Principal pathways of energy flow in the food web of fish in Hawr Ad Dalmaj marsh.



The species varied in their feeding behaviour, despite the involvement of the alien species and of the local ones in the same feeding sources. The two species *C. zillii* and

O. aureus are herbivorous fish and it means that these fish destroy the vegetation by the feeding on aquatic plants and the algae growth areas. They have strong teeth for eating plants and algae. Thus, these species destroy the places selected by the native species for reproduction, with possible relevant consequences for native species. As well as, the feeding behaviour for these species increases the turbidity of water, which in turn affects the proportion of hatching eggs of the local fish species by depositing clays on the eggs and consequently reducing the reproduction and fertility of the local species communities (He & Kitchell, 1990). The pathways of energy flow in the food web of the fish community in the Hawr Ad Dalmaj marsh, described based on the results obtained in this study, can be synthetized as shown in Figure 7.

Temperature is a key factor of water density, which is directly related to salinity that determines the distribution of organisms in the water body (Geyer et al., 2011). It is apparent that the functional characterization to analyze food ingredients for the fish of detrivore, omnivore and piscivore showed positive correlation with the water temperature. while the temperature does not show the same effect on the species of herbivorous and carnivorous. Therefore, it seems that the biological diversity of fish community in this area is unstable due to the changing physical and chemical characteristics of the ecological habitats. This means that there is a disturbance in the functional diversity of this water body as a result of changing water quality. Dike et al., (2004) reported that the alteration in physical and chemical properties of water in any water surface for long periods may result in not clear landmarks changes in the biodiversity of fish. and then on the functional diversity of the fish community.

5. Conclusion

The present study concludes that temperature, salinity and number of the fish of the Hawr Ad Dalmaj marsh vary depending on the time of collection. Rapidly increase in the number of alien species and the presence of high food overlap between them and the local species. The composition of fish community suffered clearly changes compared to previous studies as a result of the high proportion of alien species recorded in this study. very useful the continuation, permanence in the continuously monitoring of the Hawr Ad Dalmaj marsh, with estimate to the fish community and its integrity with ecosystem.

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PAPER 3

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Dear Sir/Madam,

I am pleased to inform you that your paper on " ***Some Aspects of the Biology of Planiliza abu Heckel, 1843. from Hawr Ad Dalmaj marsh***" **By Kadhim J.L. Al- Zaidy ; Giuliana Parisi / Università di Firenze, Italy, and S. A. Al-Shawi/University of Baghdad – Baghdad, Iraq,** has been accepted for publication in ***Biochem. Cell. Arch.*** Your Paper will appear in **Vol. 19, No. (Issue 2), November 2019.**

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Some Aspects of the Biology of *Planiliza abu* Heckel, 1843 from Hawr Ad Dalmaj marsh

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Abstract

The main objective of this study was to screen and identify some aspects of the biology of *Planiliza abu* species that are found in Hawr Ad Dalmaj marsh southern Iraq, as a basis for conservation programs on fish community in this area. Five hundred and fifteen specimens of *P. abu* species were caught on Hawr Ad Dalmaj marsh through January to December 2017 and then and then analysed for their length, weight, size, sex, and stomach contents to assess their diet. Results of the current study found that the maximum total length for *P. abu* was 20.9 cm whilst minimum total length was 3.7 cm; the maximum total weight was 122.22 g while the minimum total weight was 2.98 g. Length-weight relationship for females was $W= 0.010 \times L^{2.87}$ and for males was $W= 0.013 \times L^{3.04}$. The sex ratio was most favourable of females that showed values of 1:1.25. The gonado-somatic index (GSI) values for the females were between 0.99-12.81, while for the males were in the range 0.8-10.3.

Keywords

Planiliza abu, length-weight relationship, feeding habits, gonado-somatic index, Hawr Ad Dalmaj marsh.

Introduction

Water bodies are spread in different parts of Iraq, extending from north to south. The inland waters, covering 600-700 thousand hectares, are represented by natural lakes constitute (35.4% of the total inland waters), dams and reservoirs (13.3%), rivers and their branches (7.3%) and marshes (44%) (FAO, 2006). For its peculiarities, the marshlands should be considered as an ecosystem unique, which for more than a decade had been deliberately dried up with, resulting in the whole ecosystem demolition. The process of restoring the marshes started since the year 2003. To evaluate the effect of the restoring process, the continuous monitoring and ecological studies realization were among the main tools to follow up the restoration process and the successive improvement of the status of the area.

In Iraq, the ichthyofauna is represented by 43 species of freshwater fish, 10 alien species and 53 marine species (Coad, 2010). For the ichthyofauna present in it, the Hawr Ad Dalmaj marsh is one of the most important wetlands in Iraq; this marsh is located upstream of Al- Hammar Marsh and it is the last healthy stock found in southern Iraq containing the bunni fish, *Mesopotamichthys sharpeyi*, in addition to other important species of fish. The Hawr Ad Dalmaj marsh fish community is scarcely known even if the biodiversity studies of the fish communities of a waterbody is of relevant ecological interest providing a clear picture of the nutritional mutual relationships, the nature and seasons of breeding, the assessment of pollution levels in the considered area (Balirwa, 1995; Kang *et al.*, 2009; Kumar Sarkar *et al.*, 2013). *Planiliza abu*, which English common name is abu mullet, is an important species of the Mugilidae family, which represents an important part of the Iraqi water fish resources, particularly in the central and the southern regions (Al-Daham, 1982). An accurate taxonomical study on *Planiliza abu* collected in Qarmat Ali River (North Basrah, Iraq), based on morphometric and meristic characters and electrophoretic analysis has been recently published by Abdul-Razak (2018), that clearly identified the differences of abu mullet from others of the same Family. This species can be found in rivers flowing to the northern and eastern Persian Gulf, far upriver in Syria and Turkey, within the Tigris and Euphrates system, and is most common in Iran, Iraq, and Pakistan. Hussain & Saoud (2008) pointed that *P. abu* is dominant in the marshes of southern Iraq. Another species found in big numbers in various areas of Iraqi waters, especially the southern and central regions (Al-Daham, 1984), is *Carasobarbus luteus*, a species of Cyprinidae family, that was formerly known as *Barbus luteus*.

P. abu has a wide range of tolerance for living in different environments ranging from brackish freshwater to rivers and ponds (Mohamed *et al.,* 2009); it occasionally enters estuaries, preferring salinities lower than 2‰ but can tolerate salinities up to 30‰ if the change is gradual (Ahmed et al., 2002, cited in Coad, 2012). *P. abu* is characterized by high fecundity (Coad, 2010); the relative fecundity of fish from Iraq ranges from 359,873 to 756,118 eggs for fish of age groups 1+ to 3+ (Epler *et al.*, 1996), while in other geographical areas, a lower fecundity is reported, like in populations from Turkey (Ünlü *et al.*, 2000).

Objective of this study was to investigate the *Planiliza abu* distribution and diet in the Hawr Ad Dalmaj marsh, a waterbody located in the south-east of Iraq, in relation to size class, fish sex, habitat and seasonality.

Materials and methods

Samples were collected from two locations in Hawr Ad Dalmaj marsh, which is situated between Wasit and Al-Diwaniya Provinces (Iraq), from January to December 2017. The samplings were performed in two different sampling sites, the first one located at 32˚ 35′ 93.96" N and 45˚ 22′ 38.15" E, and the other one located at 32˚ 13′ 38.32" N and 45˚ 50′ 14.11" E, at south-east from the previous site; which is the only place for drainage the water for this water body (Figure 1). Fish were collected by using different means of fishing gears, i.e. the seine net, whose length 120 m and the size of the openings at the sides was 10 × 10 mm and in the centre was 5 × 5 mm; the gill nets, whose length ranged between 50 to 100 m with 1 to 7 cm mesh size; cast nets were used, especially in places where the bottom was full of dense plant. The catch by using electricity is the most heavily traded method for research purposes, in all regions, for high-and medium-depth plant densities, by using a power generator (providing 300-400 V and 10 A). The samples harvested were stored in containers containing crushed ice until to the laboratory. The height and weight were measured to the nearest decimal grade of centimeters and grams, respectively. The length-frequency data were plotted into length groups (1 cm between each a length group and other). The length-weight relationships were calculated by the allometric equation proposed by Le Cren (1951): $W = a \times L^b$, where W = total weight, L = total length, a and b are the regression constants.

To study food items two methods were used based on the nature of the food points method (P%) and the frequency of occurrence method (F%). Each stomach was removed, washed with water. A degree of fullness was given according to the point method (Hynes, 1950) and its contents were flushed into a Petri dish and examined under a low power binocular microscope (zoom Force × 10 and × 40). The study neglected the food of seasonal and occasional species. Index of Relative Importance (IRI%) was calculated according to the following equation (Pinkas *et al.*, 1971):

$$IRI\% = [P\% \times F\% / \sum P\% \times F\%] \times 100$$

where

P% = percentage of each food component.

F% = percentage of frequency of each component.

Gonado-somatic index (GSI) for males and females was calculated according to the following equation (Webber & Giese 1969):

$$GSI = [\text{wet weight of gonads (g)} / \text{wet weight of fish (g)}] \times 100$$

Figure 1. Map of Hawr Ad Dalmaj marsh, with the two locations of the sampling sites (from Google Earth).

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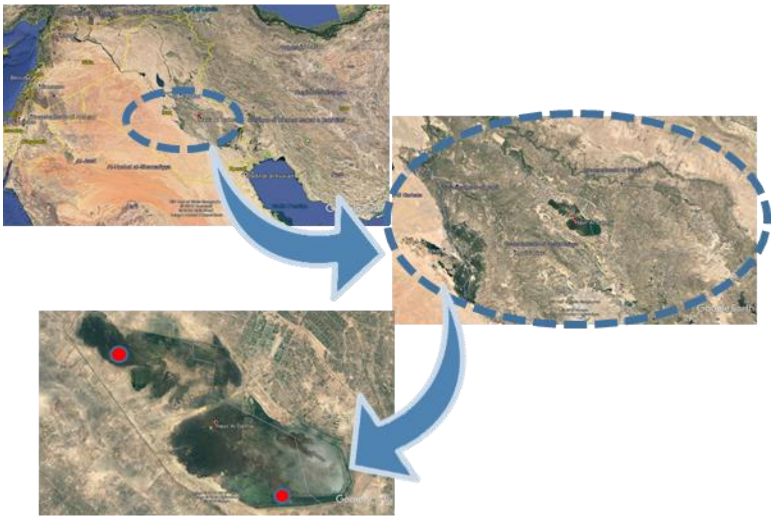
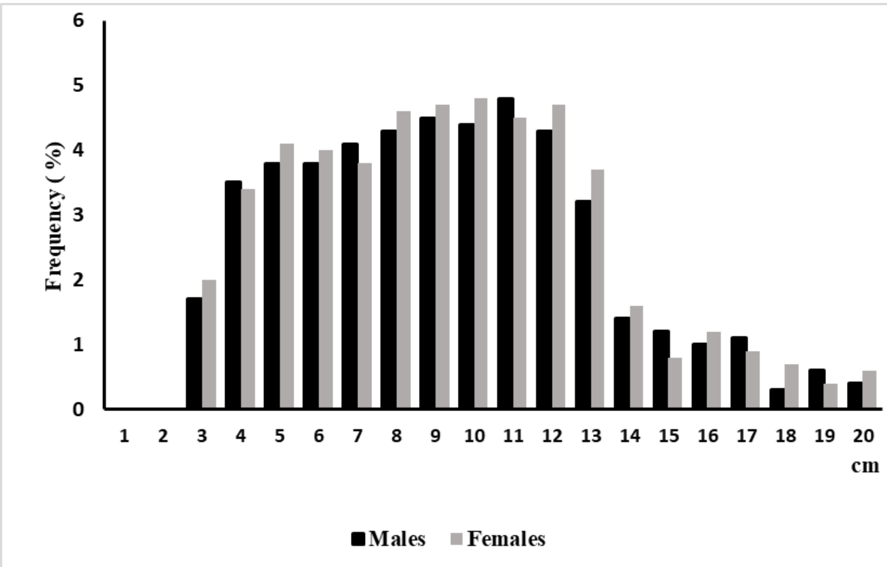


Results

A total of 15 fish species belonging to 7 families were caught from different areas from Hawr Ad Dalmaj marsh, all belonging to Osteichthyes. In addition to *P. abu*, specimens belonging to other 14 species were *Carassius auratus*, *Cyprinus carpio*, *Mesopotamichthys sharpeyi*, *Carasobarbus luteus*, *Leuciscus vorax*, *Arabibarbus grypus*, *Luciobarbus xanthopterus* (Cyprinidae Family), *Coptodon zillii* and *Oreochromis aureus* (Cichlidae Family), *Silurus triostegus* (Siluridae Family), *Mystus pelusius* (Bagridae Family), *Heteropneustes fossilis* (Heteropneustidae Family), and *Mastacembelus mastacembelus* (Mastacemblidae Family). *P. abu* was the most abundant species (n. 5853 specimens), representing the 35.99% of the total number of the fish collected from two sampling sites on Hawr Ad Dalmaj marsh through the study period from January to December 2017. The morphometric characteristics (total weight and length) of the abu mullet utilized for the analyses of gastro-intestinal content were examined in a subsample of the total specimens collected, represented by 515 individuals, The morphometric parameters of abu mullet were not affected by the site of sampling (31.79 and 32.08 g for weight and 10.89 and 11.16 cm for length in site 1 and in site 2, respectively). Figure 2 shows the frequency distribution of *P. abu* total length in the period considered. The specimens collected were distributed in 18 groups of length ranging from 3.7 to 20.9 cm. The length group in the range 8-13 cm resulted the dominant in number, representing the 54.13% of the numerical abundance. The length group in the range 14-18 cm was the 9.47% of the total length groups. The largest length group (corresponding to the range 19-20 cm) was limited to a low frequency (1.35%), while the group with the smallest length (3-7 cm) was found in all months of the year and represented the 35.05%, as shown in Figure 3.

Based on the data collected and analysed (Table 1), the weight of the fish increased with the increasing length according to the regressions represented in the Figures 4, 5 and 6. The statistical analysis also showed that there were not significant differences between the two the sexes during the study ($P > 0.05$). The value of the slope coefficient "b" for Combined Sex was 2.98, a value lightly lower than the ideal, thus indicating a tendency towards negative allometric growth. The correlation coefficient "r" of the three regression equations ranged between 0.97 and 0.98, then resulting statistically highly significant. The values of the slope coefficient "b" for males and females were 3.04 and 2.87, respectively.

Figure 2. Body total length frequency histogram showing male and female distributions of *P. abu* in Hawr Ad Dalmaji marsh from January to December 2017.



The food items found in the gastro-intestinal tract of *P. abu* specimens were very similar throughout the study period, with sand and mud grains found at rates ranging between 25 and 30% of the total contents, during the months of the study. However, they were excluded from the calculations of the real food items of these fish each of Diatoms and algae and organic crumbs, received the highest percentages of the Index of Relative Importance (IRI%). Diatoms was on the top of the overall importance of *P. abu* food items making 47.01%, followed by algae (34.68%), organic crumbs (13.01%), crustacean (2.15%), worms (2.06%), plant and seeds (0.82%), and Mollusca that were found in the lowest percentages (0.03%), as it is detailed in Table 2.

Figure 3. Total length frequency groups percentages of the individuals sampled in Hawr Ad Dalmaj marsh during the study period (from January to December 2017).

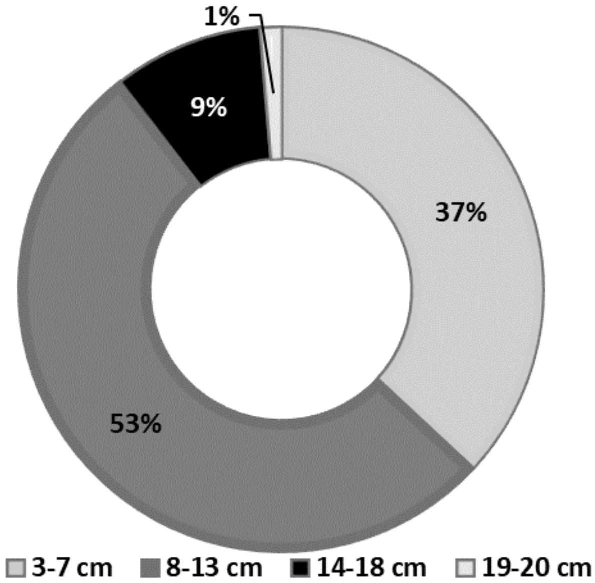


Table 1. Morphometric parameters of *P. abu* in Hawr Ad Dalmaj marsh during the study period (from January to December 2017).

Item	Sex		Combined Sex
	♀	♂	
No.	298	217	515
Length, range (cm)	3.7-20.8	3.8-20.5	3.7-20.8
Length, mean (cm)±SE	12.33±0.27	12.24±0.3	12.29±0.2
Weight, range (g)	5.01-91.47	5.33-90.33	5.01-91.47
Weight, mean (g)±SE	30.39±1.3	28.94±1.37	29.84±0.95
a	0.01	0.013	0.012
b	2.87	3.04	2.98
r	0.97	0.98	0.98

a = intercept on x-axis; b = slope;
r = Coefficient of Regression.

Figure 4: Length-Weight relationship of *P. abu* females in the Hawr Ad Dalmaj marsh during the January to December 2017 period.

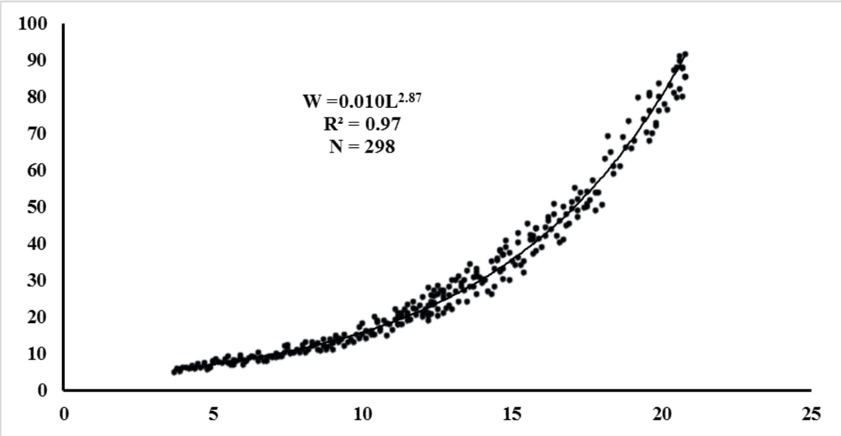
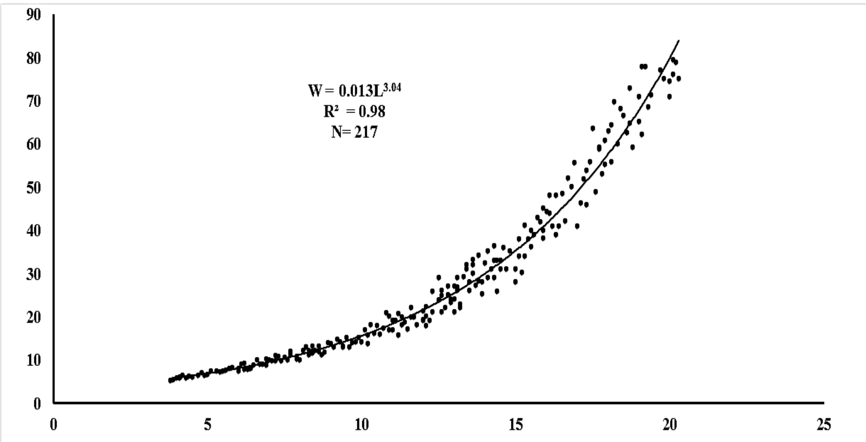


Figure 4. Length-Weight relationship of *P. abu* males in the Hawr Ad Dalmaj marsh during the January to December 2017 period.



A total of 435 specimens of P. *abu* was examined for the purpose of studying the intensity of feeding and the feeding activity. The highest rate of the feeding activity for males and females were recorded in August and July (100% and 94.74%, respectively), while this parameter reached its minimal value in April (75%) for males and in February for females (78%), as shown in Table 3.

The highest rate of the feeding intensity for females and males were recorded in August (15.27 and 15.45, respectively), while the minimal values were found in May (9.48) for females and in April (9.87) for males.

The present study showed that, based on GSI, *P. abu* has the spawning cycle extended during the year, even though during the summer months the values of this parameters were low. The highest values of GSI for both females and males were registered during January (12.81 and 10.3, respectively), while the lowest values for females and males were recorded in July (0.99 and 0.80, respectively), as shown in the Figure 6.

Figure 5. Length-Weight relationship of combined sexes of *P. abu* in the Hawr Ad Dalmaj marsh during the January to December 2017 period.

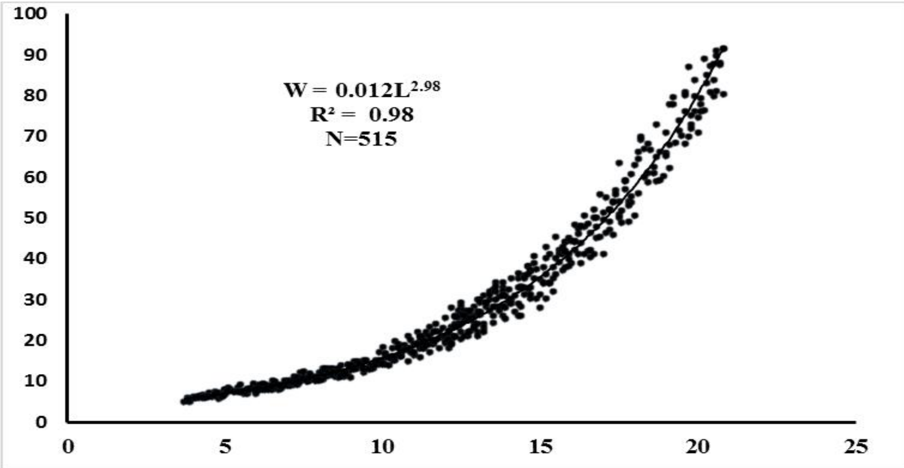


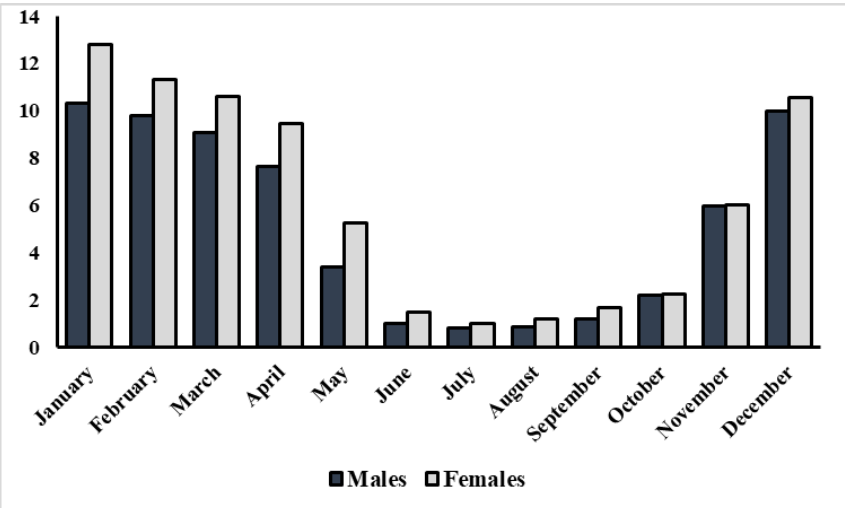
Table 2: Analysis of the gastro-intestinal content determined by two methods and Index of Relative Importance (IRI%) during the study period, from January to December 2017.

Food items	**Point method**		**Frequency of occurrence**		**IRI%**
	n.	**%**	**n.**	**%**	
Algae	1326	30.38	354	96.72	34.68
Plant and seeds	124	2.84	89	24.32	0.82
Diatoms	1748	40.04	364	99.45	47.01
Organic crumbs	650	14.89	271	74.04	13.01
Crustacean	223	5.11	131	35.79	2.15
Unidentified decomposition material	58	1.33	55	15.03	0.24
Mollusca	20	0.46	17	4.64	0.03
Worms	216	4.95	129	35.25	2.06
Total	*4365*	*100*	*1410*	-	*100*

Table 3. Feeding activity and Feeding intensity for males and females, by month, from January to December 2017.

Month	Sex	Stomachs Examined n.	Stomachs With food n.	Stomachs Empty n.	Feeding activity	Feeding Intensity
January	♀	19	16	3	84.21	11.81
	♂	14	12	2	85.71	12.08
February	♀	18	14	4	77.78	14.43
	♂	15	13	2	86.67	13.46
March	♀	22	18	4	81.82	11.28
	♂	17	13	4	76.47	10.85
April	♀	25	21	4	84.00	11.10
	♂	20	15	5	75.00	9.87
May	♀	25	21	4	84.00	9.48
	♂	20	17	3	85.00	10.06
Jun	♀	27	23	4	85.19	11.65
	♂	21	20	1	95.24	11.45
July	♀	19	18	1	94.74	11.83
	♂	16	13	3	81.25	10.77
August	♀	13	11	2	84.62	15.27
	♂	11	11	0	100.00	15.45
September	♀	19	16	3	84.21	14.56
	♂	14	11	3	78.57	14.27
October	♀	15	12	3	80.00	13.50
	♂	14	12	2	85.71	14.29
November	♀	21	18	3	84.21	12.47
	♂	17	14	3	82.35	12.57
December	♀	19	16	3	84.21	9.50
	♂	14	11	3	78.57	10.09
Total	♀	*242*	*204*	*38*	*84.08*	*12.24*
	♂	*193*	*162*	*31*	*84.21*	*12.10*

Figure 6: Gonado-Somatic Index (GSI) of males and females of *P. abu* in the Hawr Ad Dalmaj marsh, from January to December 2017.



Discussion

The maximum length of *P. abu* fish in this study was 20.8 cm. This result is almost similar to the maximum lengths registered for this species of fish in the Iraqi environment (Hussain *et al.*, 2006; Mutlak, 2012; Abdullah,2015). The results of the present study showed that the growth of *P. abu* specimens was convergent to isometry. The value of the slope coefficient (b) found in this research (equal to 2.98) resulted consistent with the value reported by Ciepielewski *et al*. (2001) and Doğu *et al.* (2013), whilst differed from that of Ünlü *et al*. (2000). These last Authors recorded for *P. abu* an asymmetric growth, with the increase in the weight more than the cubic of the length increase. This difference in the values of the coefficient b may be due to differences in sampling or due to differences in age, maturity and nutrition of the fish collected in the samplings, or it could be due to the difference in the temperatures of the sites examined, which may affect the value of b for the same species in the different environments (Weatherley & Gill, 1987). In this study, the values of b registered for males and females were 3.04 and 2.97, respectively. This disparity observed between males and females may be due to the variation in the weight of the gastro-intestinal apparatus and also to the difference in body organs incidence. Adams (2014) reported that fish growth usually slows down after sexual maturity because a large part of the food that has been digested goes to the formation of eggs or sperm, resulting in the emergence of differences in growth between the sexes. The results of the sex ratio of *P. abu* showed a tendency for a more favourable ratio for the females (1.37:1), a result that was consistent with that obtained in other studies (Na'ama,1982; Khalaf *et al*.,1986; Ünlü *et al*., 2000), while was different from the result of Yousif (1983), that noted that the sex ratio in *P. abu* tended to the male prevalence. This difference may be due to the difference in the mortality rate between the sexes, as result of the selectivity in the methods of fishing (Wijeyaratne & Costa, 1988). The highest values of the Gonado-Somatic Index (GSI) for the males and females were found in January (10.3 and 12.81, respectively). This result as well as the date of beginning of the spawning season for *P. abu* found in the current study coincide with those of other studies which were conducted in the Iraqi environment (Na'ama, 1982; Abbas & Al-Rudainy, 2006). Contrary, Chelemal *et al.* (2009) noted that the highest values for GSI for both sexes were in March. The differences in GSI values may be due to the differences in the environmental factors, as well as, to the types of items available in the specific environment (Nikolsky, 1963). The highest values of feeding activity and feeding intensity of this study were observed during the summer months, whilst a clear decline in those rates appeared during the winter, in line with many studies (Wahab, 1986; Abdul-Samad, 2001; Mohamed, 2014), as a consequence of the direct effect of temperature on the fish's appetite as well as of the direct effect of the temperatures on digestive enzymes. Sarker (1973) showed that food consumption increases by increasing the temperatures, until it reaches an ideal level. Based on the results of the analysis of the contents of the gastro-intestinal apparatus of specimens collected during the study period, the fish were detritivores, depending on vegetative sources. They were also benthonic in the nature of nutrition. Diatoms topped the Index of Relative Importance (IRI%) of the food ingredients. These results were consistent with those obtained by Na'ama (1982), Mohamed *et al.* (2008) and Hussain *et al*. (2008), whilst these results differed from those reached by Epler *et al*. (٢٠٠١), which found that organic crumbs are the main component in the food of *P. abu* in Al-Razazah Lake, Al- Tharthar Lake and Al- Habbaniyah Lake, located in the middle Iraq. Perhaps the reason for this difference is due to the nature of the food available in these environments. It appears that specimens of *P. abu* do not tend to feed on plants when other nutrients can be obtainable and are available. Pillay (1953) pointed out that differences in the food preference for the species are associated with the abundance and accessibility of food components in the different environments.

Conclusions

The study present clearly indicates that the relationship between length and weight, feeding activity, feeding intensity and reproductive cycle of *P. abu* fish in Hawr Ad Dalmaj were within the tolerance range. Also, it is concluded that Hawr Ad Dalmaj marsh could become a reliable source aquaculture species; which requires further studies on population status with a strong implementation of conservation laws to protect fish habitat.

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PAPER 4

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Classification of the Key Functional Diversity of the Marshes of Southern Iraq

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Abstract

The term "marshes" refers to the wetlands that are almost of shallow water with relatively dense plant cover, mainly of prominent plants (such as *Phragmytes* and *Typha*), or other submerged plants. The marshes of Southern Iraq (Ahwar) are of unique environmental and cultural features that rarely meet in similar habitats worldwide. They are the most distinctive wetlands in Southwest Asia and worldwide as well. In the past, these wetlands covered more than 15,000 km², however, now consists of less than this area. Functional diversity is fundamentally considered as a guide to comprehend the nature of ecosystem work. Despite the possession of the marshes of Southern Iraq for many major and minor functions, no study to determine the function diversity of this area has been conducted.

Keywords: *Iraq, Marsh, Functional Diversity, Cultural and Natural Heritage.*

Introduction

The marshes of Iraq are located in the southern part of the Mesopotamia (Fig. 1), on confluence of Tigris and Euphrates rivers. The marsh area has unique properties that rarely can be met worldwide, which make them one of the most important wetlands on the global level [1]. The Iraqi Marshes fall under class of wetlands; hence, the functional diversity of wetlands can be summarized in how wetlands can affect neighbouring environments [2]. It is defined by [3] a process or series of biological processes that take place within the wetlands. The functions of the wetlands vary from region to region; therefore, no wetland can perform all functions at a high level because many of these functions might act normally in opposite forms [4-6].

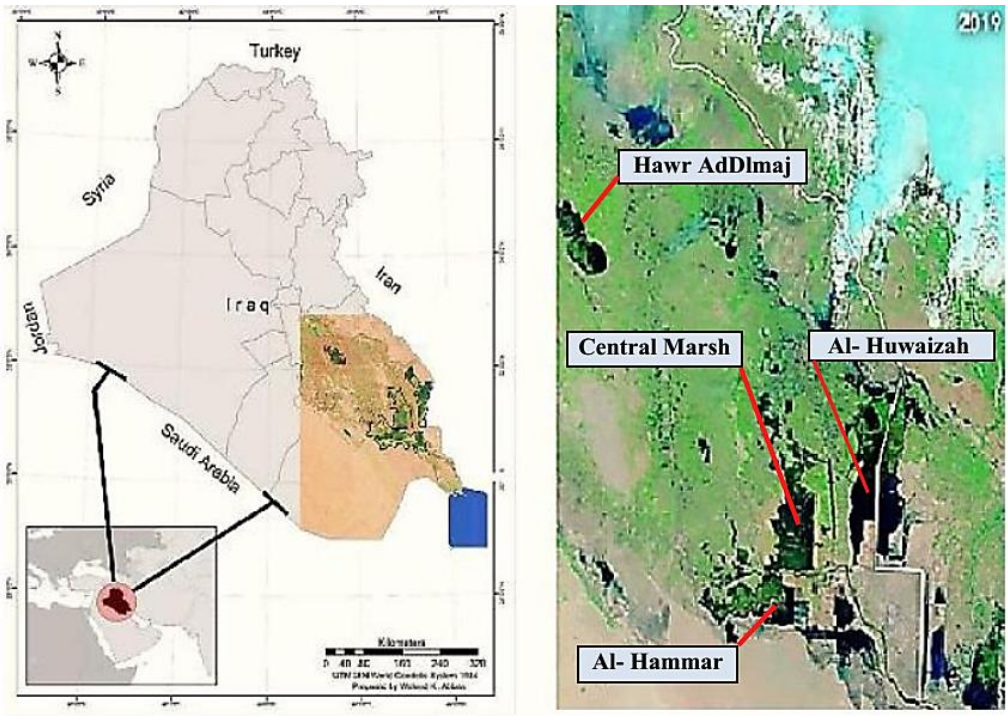

Figure 1. Two of the key Mesopotamian Marshlands in Southern of Iraq (the marshes of Southern Iraq complex and Hawr Ad Dalmaj marsh).

The topographical area and size of wetlands decide the nature of the functions they will perform [7]. Data on the environmental functional diversity help to give economic evaluation of wetland resources and services of which contribute to the country's total national production [8-9]. Due to their vast areas, the richness and diversity in flora and fauna of the marshes in Southern Iraq magnify their major and minor functions [10]. The physical, chemical and ecological properties of freshwater wetlands in general and of the Mesopotamian marshes in particular can be classified into four key levels of functional diversity: production function, regulation function, habitat and biodiversity function, information function [11-13].

The classification of the key functions

The classification of the key functions of the marshes in Southern Iraq are detailed below:

1. Production Function

The ecosystem of wetlands, with all its components, plays a crucial role by converting solar energy to other types of energy that result in producing useful materials for plants and animals [14]. Human social orders, since the beginning of mankind, have used renewable resources in nature; these resources have a value known as "existence value" [15]. The function of production is determined by the amount of the wetlands' natural resources. Accordingly, the production function in wetlands is divided into several levels, the most important of which are:

Raw Materials

Wetlands give a reasonable domain to creatures to graze, produce wood for fuel, as well as raw materials for industries, for example, warehouse equipment like mats, trays, baskets. In addition, the Iraqi marshlands is a source of essential to supply paper industries in Iraq by raw materials [16]. The most common plant species in the marshes of Southern Iraq marshlands are reed *Phragmites australis* and reed mace *Typha domengensis* and they are considered as economic plants. A report by United Nations Environment Program (UNEP, 2001) alludes to the utilization of these plants in structure houses by local individuals as an acquired Sumerian tradition. In addition, the plants of these marshes have been used as a primary material in local industries of paper production [17], as a consequence the Iraqi marshlands is an essential source of raw materials to supply paper industries, in Iraq.

Food Production Function

Wetlands are considered as the basic harbour of fish resources [16]. Fisheries of Iraqi bogs have an extraordinary significance since they are one of the primary financial establishments. According to a study by Jawad (2006) [18], there are 14 economic importance fish species in the Iraqi Marshes. Abd & Rubec (2009) [19] have distinguished 4 extra fish species of high economic significance. In 1990, the FAO has evaluated the fishing in Iraqi inland waters to reach 23,600 tons/yr, and over 60% of that amount was originated from marshlands [1]. The measure of the catch in Iraq amid the 1970s and 1980s was probably going to be greater than that of the 1990s [20].

2. Regulation Function

The marshes perform regulatory functions forms for the biological systems, through bio-geochemical cycles and other biosphere processes [14]. These procedures have direct advantages in keeping up biological balance and species productivity. These regulating functions of marshes are of two types: hydrological and biological [14].

Hydrological Functions

Maltby (2009) [20] affirmed that the hydrological characteristics of wetlands influence the soil and the idea of vegetation. Hydrological elements of wetlands are characterized by few levels: flood control, water supply, water storage, and erosion control [21].

Flood Control. A standout amongst the most widely recognized hydrological functions of wetlands is to reduce the risk of floods and torrents. Wetlands store the water through rainy periods, and the stored water is released again through the dry periods. Iraqi Marshlands are described by their dry desert atmosphere, where water levels decline in summer season because of absence of downpour and low water imports. The bog regions in Southern Iraq are fairly bigger in winter when water imports are accessible, and the water depth reaches 4 m in some areas of the marshes [13]. Nonetheless, it appears that the function of flood control in Iraqi Marshes is uncommon, particularly considering the ebb and flow water circumstance to Iraq, where does not anticipate the event of floods in this area, particularly with the expanding number of dams built on the two rivers Tigris and the Euphrates [22-23].

Water Supply. The majority of the Middle East countries are considered as arid or semi-arid, with an average annual rainfall of 166 mm [24-25]. About 75 billion m^3 of water flow to Iraq from Tigris and the Euphrates. The marshes play an important role through the function of water conservation and storage [12]. The marshes of Southern Iraq account for about 44% of the total inland waters of Iraq [26]. Thus, the marshlands in the Southern Iraq are potential strategic reservoirs of the water supply used in agricultural, human, and industrial purposes before being discharged into the Persian Gulf [22-23].

Water Storage. Water is generally invading into soil holes among soil grains, through little cavities called small micropores spaces, also through networks of cracks, roots and channels known as macropore or larger cavities known as soil pipes [27]. The theory of groundwater formation in each marsh of the Iraqi Marshlands is considered only one theory. Groundwater in the marshes of Southern Iraq area is of an air origin and is rarely of marine origin and that means that the Iraqi groundwater originates through the penetration of rainwater and floods into the ground [28]. The groundwater levels amidst the marshlands achieve shallow profundities that, in certain territories, don't surpass 1 m above sea level. The amount of water that can be released from the wells in the Mesopotamian marshes ranges between 400 and 900 m^3 s/day. However, groundwater is rarely used to fill the marshes due to their low quality which may cause monetary and natural harms [29].

Corrosion-reduction Function. Without the plant cover spread, the effect of erosion factors increases. Numerous countries, particularly those located in tropical territories, lose a lot of soil due to the erosion. In general, 11 million km^2 of land (i.e. an area identical to the area of the United States of America and Mexico joined) are influenced by the high erosion rates. Every year, around 75 billion tons of soil are affected as a result of corrosion in this planet, 13 to 40 times more than the normal required for soil creation [30]. Wetlands and their plant spread assume a noteworthy role in diminishing dust storms. Globally, the Mesopotamian marshlands are known for their dry climate and they are surrounded by arid and semi-desert areas; therefore, Iraqi Marshes assume an important role in shielding the soils from the erosion. This function of the marshes of Southern Iraq was clear when Saddam Hussein's regime committed the crime of depleting the marshes in the nineties of the last century; consequently, that, the dust storms expanded and rising dust has become more obvious in the light of losing major parts of the of marshes, in addition to regression of the vegetation in those regions [31].

Biological Functions

Primary Productivity. The primary productivity is a natural process carried out by the plant, depending on changing the solar energy to chemical energy. Primary productivity plays a significant role in the dynamics in ecosystems, and thus can be deemed as a specific factor to many serves of the ecosystem. All in all, freshwater marshes connected with rivers, usually are highly productive ecosystems [32], and the marshes in Southern Iraq do not contrast from this hypothesis. The expansion in the primary productivity inside nature of the Iraqi Marshlands is because to weak water flows, prompting the expansion and the development of aquatic plants [13]. The Iraqi Marshland Restoration Program (IMRP) has advertised that the initial productivity of phytoplankton in the marshes of southern Iraq is between 1.1-12.5 $g/m^3/h$ at surface and 9.37-37.5 $g/m^3/h$ [33]. Emergent plants in the marshes of Southern Iraq are natural surroundings for many organisms. On the other hand, disintegrating these plants lead to organic pathways, which are at the basis of the energy cycle in these places. The plants assume an essential role in lessening the speed of water flows, in this way, encouraging the deposition of suspended particles in the water. Then, and in an integrative role, submerged plants in the water absorb nutrients and particulate which are deposited, to complete the process of photosynthesis. *Phragmites australis* is known as one of the most widespread aquatic plant in the Iraqi Marshes; followed by the *Schoenoplectus litoralis* and, thirdly, by *Typha domingensis* [34].

The Function of Carbon Sequestration. Ecosystems of the marshes manage carbon sequestration from the air, which helps in diminishing the harm brought about by global warming. Plants absorbs CO_2 through their growth process and then store it underground after the death of the plants. Quantitative assessment of the micro-organisms has influences of very important on the biogeochemical procedures of wetlands, which is reflected on the cycle of carbon and of the other nutrient [35]. In the normal cases, carbon dioxide emissions are coming about because of plant breath and soil activities, while methane emissions are produced only from the vital role of the soil, notwithstanding, the total CO_2 and CH_4 outflows improve ecosystems in the nature, assuming that the balance in the ratios of these gases influence the process of global warming. Carbon emissions and greenhouse gases production leaked to the ozone layer in wetlands are affected by water salinity [36]. There seems to be a general agreement in the scientific circles that there is a decrease in methane emissions with an increase in the salinity of the water for the wetland. This diminishing is because of the presence of large quantities of sulphate which prevent methane formation, and lead to bring down methane emission for the upper layers. Al- Hammar Marsh (one of the Southern marshes' components) is the saltiest among Iraqi Marshes, and the carbon cycle dominates the cycles of different components [13]. Abed et al. (2017) have demonstrated the direct and subsequent effects of some of the climate change factors on the marshes of Southern Iraq, and the results have shown that are of considerable subsequences on the short and long terms.

Improving the Water Quality. Wetlands are utilized as characteristic channels to improve water quality by decreasing the suspended material [14]. Jin et. al. (2006) have expressed that the utilization of aquatic plants improves of the water quality, re-establishes water bodies, and controls pollution. Some plants possess the ability to expel dissolvable inorganic nutrients (ammonium, nitrite, nitrate and phosphate) and heavy metal by absorption or direct introduction for these materials from the water column through the stems of these plants, while their micro-roots expel these materials inside the soil. Algae, floating and submerged plants, differ in their treatment of heavy elements, and they remove pollutants directly from water column. The marshlands of Southern Iraq are considered as a natural refinery to free Tigris and the Euphrates from waste and contaminants, while Hawr Ad Dalmaj marsh do the same function for the Main Outfall Drain, which passes through of this region. This property of the marshes is due to the slow motion of water through the thick plants as the reed (*P. australist*) and reedmace (*T. domingensis*). These plants work on filtering the water of some pollutions, and purifying water flowing in the Arabian Gulf [20]. Few numbers of studies have discussed the treatment of water by aquatic plants in the Iraqi Marshlands. Aziza et al. (2006) consider the reed and reedmace as good vital evidence of the environmental treatments because of their ability to accumulate trace elements such as copper, lead and zinc. Awad & Abdulsahib (2007) recorded the presence of mercury concentrations in Al-Huwizeh and Qurna marshes and Shatt Al-Arab in 13 species of aquatic plants, water column and precipitation. The most elevated concentration was found in *Potamogeton pectinatus* in Al-Huwizeh marshes in Al-Amara, mercury concentrations were also higher in the aquatic plants than in precipitation and water. Sooknah (2000) showed that the decrease of organic substances by bio-oxidation process of the microbes are found on the vessels of biofilms, and which are on the stems and roots of aquatic plants.

Food Chains. "Food web is a map that describes which kinds of organisms in a community eat other kinds". Nutrition studies in the waterbodies are often driven by the desire to know the nature of the overlap of nutrients in determining and supporting fisheries production. Batzer et al. (2004) affirmed that the networks in the marshes, in general, depend on aquatic plants and organic detritus, hence, fauna (except predators) does not experience the ill effects of deficiency of items food because of the abundance of these foods in wetlands. Aquatic plants, macrobenthic algae, and phytoplankton are the major base in the marshes of Southern Iraq as primary producers within the food chain [44]. Aquatic plants, macrobenthic algae, and phytoplankton are consumed by a very large numbers of herbivores fauna, and the first-class of the herbivorous fish (primary consumers) naturally is not excluded from that division. In the marshes of Iraq prevails the detritivores fish on the other groups of fish [32]. Algae, diatoms and aquatic plants have extraordinary significance in these waterbodies, where 9 fish species in these regions feed on algae, diatoms and aquatic plants while 6 species of fish feed on diatoms only [45]. Al-Zaidy et al. (2019) depicted the idea of the nourishment web of fish in Hawr Ad Dalmaj wetland in Iraq at 2017 as shown in Fig. 2.

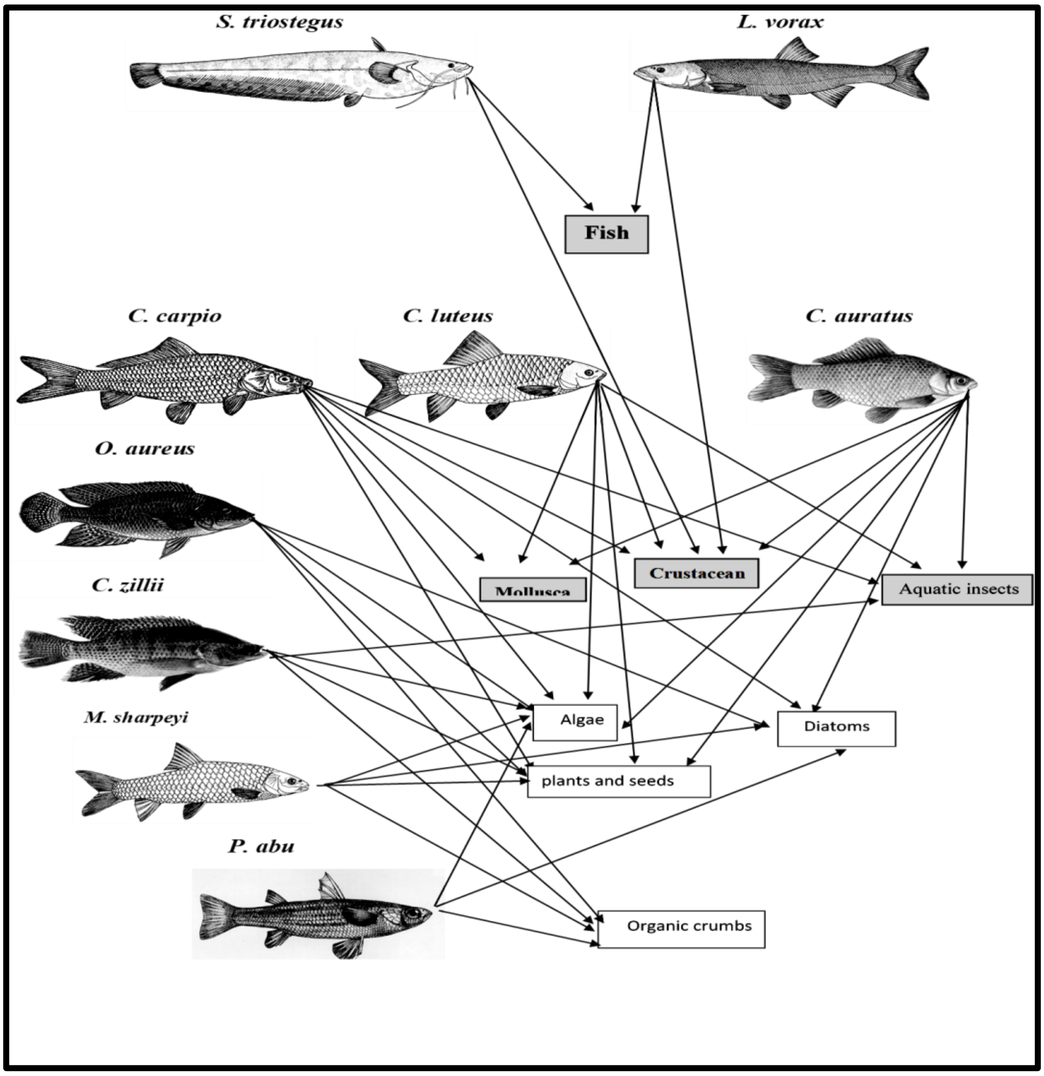

Figure 2. The relationship of the food chain between five levels of foods of the common fish species in fish in Hawr Ad Dalmaj wetland in Southern Iraq from January to December 2017 (Al-Zaidy et al. 2019).

3. Habitat Function and Biodiversity

Parker (1989) refers to the habitat as "part of the physical environment in which plants and animals live". Intuitively, living creatures require environments in which they find adequate sustenance, water, shelter, to breed and escape from potential predators. The vital services provided by wetlands keep up the general wellbeing of the biological system as it has become clearer over in the course of the recent decades. They provide big living environments for different species of flora, fauna, and improve the biodiversity. Several definitions of the term 'biodiversity' have prompted huge perplexity in the concept. Biodiversity can clearly be defined as the "number of taxa within a defined geographic range". It is concurred that each creature diverges in its interaction with other creatures inside the ecosystem, regardless of whether they are predominant in the network or not. The loss of any of these organisms will determine an unsettling ecological influence, so that its effects cannot be easily predicted [47].

The marshes in Southern Iraq have an outstanding biological diversity. The marshes are among the 200 global ecoregions and they have been identified as an endemic birds' area [48]; in addition, it includes a Ramsar site. Salim and Porter (2015) have described the global, regional and local importance of these marshes for the birds with details. The environmental functions of these wetlands are very important for the interactive relationships among the organisms and with the marsh dwellers as well. The surrounding areas and wetlands around the key marshes of Southern Iraq are also of considerable importance [10]. The four components of the marshes of Southern Iraq (Al-Huweiza, Central Marshes, East Al-Hammar, and West Al- Hammar) are inscribed as the natural components of ‘Ahwar’ World Heritage property [49]. Hawr Ad Dalmaj marsh is also of high environmental importance for harbouring considerable number of threatened *taxa* in addition to its being wintering and stop-over site for quite large numbers of birds, mainly water birds [37, 50-54].

4. Information Function

Antique human being regularly has utilized waterways and lakes as living spaces. Wetlands give drinking water and sustenance (for example, fish and birds as food), as well as, pastures and transport [55]. Wetlands have seen the developments in human societies since the dawn of history, including the mythology, arts and religion [56]. Accordingly, wetlands are a basic wellspring of data and the information function realized by these areas can be classified into many, as detailed below.

Cultural Heritage

The expression of Mesopotamia initially derives by a Greek word which alludes to the land between two waterways [57]. Additionally, it alludes to the social legacy of the marshlands, that are referenced in the Holy Scriptures by the name “Garden of Eden”. Also, the Mesopotamian marshes in Iraq are the land that witnessed the arose Abraham, and before that they are a sanctuary for Sumerians 5000 years' prior [58]. The Sumerians are the primary human beings who grew up the urban human progress. Moreover, they are the first to designed composition [59-61]. For their outstanding universal values (including cultural and natural), the marshes of Southern Iraq and three of the surrounding cultural sites (Uruk, Ur, and Erido) have been inscribed on the World Heritage list in the year 2016 [49]. The general population which lives in the Iraqi bogs are known by the name of Marsh Arabs or Ma'dan, that are descendants of the Sumerians [62]. The well-known reed guesthouse (*Mudheef*) one of the most prominent traditions inherited from the old Sumerians to the present marsh's inhabitants. It is a spot for gathering individuals of the clan and it is also used to receive guests or foreign travellers passing through the area; it is utilized as a spot to hold gatherings and compromise. All individuals from the tribe participate in its construction, in a way similar to the old Sumerian style enduring 5000 years (Fig. 3).

Scientific Research

Wetlands are a wellspring of data about oceanic life forms, bird species, living spaces, environment capacities, and common natural procedures and connections among them [63]. The marshes of Southern Iraq, along with Hawr Ad Dalmaj marsh, have been fertile ground for various study aspects: cultural, historical, on water, biological, and still much new facts are being discovered, such as the recording of new species [54,64]. The taxonomic studies of the *biota* in the Mesopotamia region involved microorganisms [65-66], plants [67-68], fishes [69], birds [70,71-73], mammals [74-75] and reptiles [76- 78]. These papers have provided better deepening on the current knowledge of these wetlands.

On the other hand, it is also worthy to mention that, about the current scientific knowledge of the marshes of Southern Iraq, among the recent researches, a scientific paper has been published which includes unreal results on the endangered Basra reed warbler (*Acrocephalus griseldis*), a species that finds in these wetlands the key breeding habitat for on the global level; therefore, a group of key scientists and international experts have reacted to the wrong information in this research paper in relation to the methodology that the researcher has not use in the field [79]. The authors of this paper [80] have replied for their defence, however, the argument is very weak and has only added more confusion to their work. In addition, there are some research papers published on these wetlands which are not been carried out by specialized experts; for this reason, it would be crucial to select those papers which are based on true, yet solid, methodologies applied in the researches performed on the marshes of Southern Iraq.

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Figure 3. Left: Al-Mmudheef in Southern Iraq 2015 (photo taken by the author). Right: Al-Mudheef, 3,000 year ago (UNEP, 2001).

Entertainment and Aesthetic Features

Wetlands are novel scenes that do not exist in different situations and offer open doors for recreational exercises, for example, outdoors, angling and winged animal watching [14]. Scott and Evans (1994) have introduced a general primary list of the components of the landscape which forms the marsh scene, i.e. freshwater lakes with thick development of submerged aquatic plants and narrow lanes within the large promontory plants of reed and papyrus and the inclining mud banks. Many sources, which are taken from books and reports that have considered numerous Iraqi Marshlands, give details about their magnificence and uniqueness [81-82] and there is likewise a reference to the Mesopotamian bogs in Sumerian writing [83]. Thesiger (1954) has depicted his first experience of visiting the bogs during the 1950s as follows:

"Memories of that first visit to the Marshes have never left me: firelight on a half-turned face, the crying of geese, duck flighting in to feed, a boy's voice singing somewhere in the dark, canoes moving in procession down a waterway, the setting sun seen crimson through the smoke of burning reed beds, narrow waterways that wound deeper into the Marshes…. Stars reflected in dark water, the croaking of frogs, canoes coming home at evening, peace and continuity, the stillness of a world that never knew an engine. Once again, I experienced the longing to share this with life, and to be more than a mere spectator." [84]

Conclusion

To the best of our knowledge, this is the first study about the functional diversity of the Mesopotamian marshes. The marsh in Southern Iraq area has unique properties that are rarely found in any other spot worldwide which make it one of the most important wetlands on the global level. The functional diversity of the Mesopotamian marshes is classified into four major levels: production function, regulation function, habitat function and biodiversity and information function. The need to conduct further studies, as well as showing of the size of the changes that have occurred on these functions in the light of climate change and establish reliable, yet updated, database capable of providing the required advice for the concerned authorities to ensure effective protection and development for these areas.

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General Conclusions & Recommendations

GENERAL CONCLUSIONS

1-This study was done to investigate the taxonomic level, biology and life history, and the effects of some ecological factors that approach the keystone species in the Hawr Ad Dalmaj marsh. This marsh was investigated for the first time in this study.

2- All species of the fish community belong to the freshwater fish, and there was no recorded any species of marine fish, that led to a decrease in the total number of fish species.

3- The study showed clearly the dominance of small-sized species of alien and native species.

4- A clear increase in fish stock of *M. sharpei* was found similarly to the studies that were carried out in the Iraqi water bodies after drying of the marshes.

5- The structure of fish community suffered for the competition due the high proportion of alien species recorded in this study, and interspecific competition does not lead to the fish community steadiness and development.

6- The human control over the quality and quantity of water entering the Hawr Ad Dalmaj marsh led to the creation of additional suffering in composition of the fish community.

RECOMMENDATIONS

1- The need to conduct further studies for showing the size of the changes in water quality, the measures related to biomanipulation, composition of the fish community and stocking of hatchery-reared fish.

2- Ban on fishing activities at the hatchery season and prohibit the employ of fishing gear illegal.

3- Stakeholders authorities should prevent discharging all kinds of pollutants into rivers without previous adequate treatment, to improve water quality, thus maintain fish species and other natural biological communities.

4- Activation of international agreements on the subject of water aimed to show environmental and biological risks at the regional level in the case of non-compliance with its clauses.

APPENDIXES

APPENDIX 1: Characterization of some of water quality standards recorded in the Iraqi marshes before drying (1978-1985) and after restoration (2004-2008) (Al-Maarof, 2015).

	WCD	LP	pH	DO	TSS	Salinity	Ca^{2+}	Mg^{2+}	SO_4^{2-}	Cl^-	NO_3^-	SRP	TDS	BOD
Central Marshes (Al-Baghdadia 1978-1979)														
No. of observations	5.0	5.0	5.0	3.0		5.0			1.0	1.0	5.0	5.0	5.0	
Minimum	2.0	0.2	7.1	4.5		0.2			39.0	24.0	3.0	1.0	0.3	
Maximum	3.5	3.5	8.2	5.3		0.7			39.0	24.0	81.0	26.0	1.9	
Mean	2.6	1.7	7.7	4.9		0.4			39.0	24.0	38.2	13.4	1.0	
Standard deviation (n)	0.6	1.2	0.4	0.3		0.2			0.0	0.0	25.7	8.0	0.7	
(Al-Baghdadia 1983-1984)														
No. of observations			9.0	9.0		9.0	9.0	9.0			8.0	8.0		
Minimum			7.4	3.1		0.6	11.0	32.0			0.4	0.1		
Maximum			8.0	8.5		2.2	97.0	88.0			1.2	1.4		
Mean			7.8	5.7		1.0	37.7	56.8			0.9	0.6		
Standard deviation (n)			0.2	1.6		0.4	31.2	21.8			0.3	0.4		
(Al-Baghdadia 2005 – 2007)														
No. of observations	29.0	2.0	112.0	122.0	124.0	112.0	49.0	49.0	49.0	48.0	70.0	93.0	32.0	35.0
Minimum	0.2	0.8	6.5	1.0	1.0	0.7	2.4	1.1	2.0	12.5	0.4	0.1	0.8	0.2
Maximum	2.5	1.2	8.9	15.1	78.4	5.6	521.0	388.0	1278.0	1595.3	372.2	78.3	3.4	22.8
Mean	1.3	1.0	8.0	5.8	7.6	1.5	100.0	96.6	494.0	432.6	22.6	8.3	2.2	4.4
Standard deviation (n)	0.5	0.2	0.6	3.0	9.4	0.7	91.6	77.5	310.7	357.4	53.4	11.5	0.7	6.0
(Abu Zarag 2004-2006)														
No. of observations	74.0	72.0	85.0	84.0	71.0	83.0					76.0	92.0		
Minimum	0.2	0.2	7.2	0.3	0.4	0.2					0.2	0.1		
Maximum	5.0	3.0	9.5	18.4	64.0	7.6					26.7	122.4		
Mean	1.9	0.9	8.1	6.2	13.1	1.0					2.5	15.9		
Standard deviation (n)	0.9	0.6	0.4	4.0	12.6	1.1					4.3	22.0		
Al-Hammar Marshes (Al-Burka 1985)														
No. of observations	14.0	36.0	35.0	36.0		36.0	36.0	36.0			36.0	36.0		
Minimum	0.3	0.3	7.6	1.0		1.3	16.0	11.0			0.3	0.1		
Maximum	8.0	1.2	8.6	12.0		4.3	311.0	251.0			9.2	0.9		
Mean	1.2	0.7	8.1	6.9		2.5	157.4	109.4			1.7	0.4		
Standard deviation (n)	1.9	0.2	0.3	2.6		0.7	85.1	64.0			1.7	0.2		
(Al-Burka 2005-2008)														
No. of observations	6.0		53.0	58.0	65.0	56.0	27.0	28.0	28.0	28.0	25.0	46.0	22.0	25.0
Minimum	1.2		7.2	1.0	0.8	1.2	12.2	8.2	12.0	46.9	0.9	1.5	0.6	0.4
Maximum	1.8		8.8	11.9	73.7	3.3	276.6	238.1	1538.8	1737.5	196.0	44.2	3.0	14.6
Mean	1.6		8.1	6.2	12.5	2.0	92.4	94.6	523.0	516.9	18.9	6.0	2.2	4.4
Standard deviation (n)	0.3		0.5	3.4	13.0	0.6	73.2	64.0	319.5	408.3	38.6	7.3	0.5	3.4
(Al-Kirmashia 2004-2008)														
No. of observations	32.0	29.0	45.0	45.0	37.0	40.0	2.0	2.0	5.0	5.0	36.0	43.0	1.0	2.0
Minimum	0.2	0.2	7.2	0.3	1.8	1.0	139.0	33.5	362.0	8.4	0.3	0.1	2.2	1.0
Maximum	5.0	3.0	8.9	8.6	69.2	5.7	228.5	151.6	1131.5	1524.4	4.8	62.3	2.2	1.8
Mean	1.6	0.7	7.9	4.7	23.9	1.8	183.7	92.6	623.9	333.9	1.2	14.4	2.2	1.4
Standard deviation (n)	1.1	0.7	0.4	2.1	18.5	1.0	44.7	59.1	282.6	595.8	1.2	11.5	0.0	0.4
(Al-Naggara 2006-2007)														
No. of observations	23.0		45.0	47.0	48.0	46.0	20.0	20.0	20.0	20.0	34.0	36.0		10.0
Minimum	0.7		6.9	1.4	1.0	1.1	12.2	7.5	5.0	62.7	0.4	0.1		0.8
Maximum	4.0		8.9	12.4	46.8	3.2	184.4	196.2	967.6	1169.9	367.9	25.1		8.0
Mean	1.9		7.9	7.3	16.3	2.0	80.9	84.5	443.9	564.3	29.2	5.8		4.1
Standard deviation (n)	0.8		0.5	2.2	12.0	0.6	62.7	51.5	321.8	341.1	82.9	6.5		2.3
Al-Hawizeh Marshes (Majnoon 1983-1984)														
No. of observations			9.0	9.0		5.0	9.0	9.0			8.0	8.0		
Minimum			8.0	1.1		3.4	28.0	23.0			0.4	0.2		
Maximum			9.2	8.9		6.5	249.0	3265.0			3.4	1.9		
Mean			8.5	5.7		5.5	134.8	602.2			1.6	0.7		
Standard deviation (n)			0.3	2.8		1.3	67.3	956.6			1.1	0.5		
(Majnoon 2006-2008)														
No. of observations	16.0	14.0	21.0	21.0	11.0	19.0	2.0	2.0	2.0	2.0	11.0	11.0	7.0	7.0
Minimum	1.0	0.3	6.7	1.3	5.0	0.9	8.3	14.9	42.1	367.8	0.4	2.1	1.0	0.8
Maximum	2.5	0.8	8.8	11.7	43.4	1.3	124.2	81.6	551.8	372.2	51.6	7.2	3.8	4.7
Mean	1.5	0.5	8.3	7.6	23.0	1.1	66.3	48.3	296.9	370.0	14.5	4.7	2.3	2.2
Standard deviation (n)	0.3	0.2	0.4	2.0	10.9	0.2	58.0	33.3	254.8	2.2	19.2	1.4	1.0	1.2
(Al-Udhaim 2006-2008)														
No. of observations	68.0	59.0	90.0	90.0	42.0	88.0	2.0	2.0	2.0	2.0	12.0	11.0	74.0	2.0
Minimum	1.6	1.6	6.8	1.2	0.7	0.4	46.3	35.7	222.4	265.9	0.5	0.6	0.8	3.0
Maximum	2.7	2.5	8.8	12.8	6.0	1.0	128.3	87.5	469.3	273.9	48.4	12.0	2.0	3.5

APPENDIX 1 (*continue*): Characterization of some of water quality standards recorded in the Iraqi marshes before drying (1978-1985) and after restoration (2004-2008) (Al-Maarof, 2015).

	WCD	LP	pH	DO	TSS	Salinity	Ca^{2+}	Mg^{2+}	SO_4^{2-}	Cl^-	NO_3^-	SRP	TDS	BOD
Mean	2.1	2.0	7.9	6.9	2.3	0.7	87.3	61.6	345.8	269.9	12.8	4.9	1.7	3.3
Standard deviation (n)	0.2	0.2	0.4	3.3	1.2	0.1	41.0	25.9	123.5	4.0	14.9	2.8	0.3	0.3
(Um Al-Niaaj 2006-2008)														
No. of observations	79.0	63.0	146.0	150.0	102.0	146.0	32.0	33.0	33.0	33.0	56.0	66.0	74.0	47.0
Minimum	1.8	1.3	6.9	1.0	0.5	0.3	1.3	4.4	17.9	16.4	1.5	0.1	0.7	0.6
Maximum	3.0	2.7	9.5	14.4	34.0	1.3	136.3	165.2	952.0	673.6	364.0	179.2	2.4	8.0
Mean	2.4	2.3	8.1	7.3	4.6	0.6	56.8	55.8	333.7	273.8	88.5	26.6	1.5	2.7
Standard deviation (n)	0.2	0.2	0.4	3.3	5.8	0.2	39.8	42.6	215.0	156.9	93.0	28.9	0.4	2.1
(Lissan Ijerda 2006-2008)														
No. of observations	23.0	14.0	30.0	30.0	18.0	28.0	2.0	2.0	2.0	2.0	18.0	18.0	9.0	6.0
Minimum	0.2	0.5	7.5	1.0	1.4	0.8	17.3	11.5	66.4	281.7	0.1	0.1	1.4	0.5
Maximum	2.1	1.8	8.5	12.5	97.8	7.8	131.2	121.5	412.8	779.9	51.9	65.4	2.8	6.5
Mean	1.2	1.5	8.2	7.3	14.8	1.5	74.3	66.5	239.6	530.8	10.2	8.1	2.1	2.8
Standard deviation (n)	0.7	0.3	0.3	2.6	24.4	1.2	56.9	55.0	173.2	249.1	16.6	14.1	0.4	2.1
(Um Al-Warid 2006-2008)														
No. of observations	22.0	15.0	73.0	77.0	71.0	74.0	32.0	32.0	32.0	32.0	52.0	62.0	37.0	32.0
Minimum	1.5	0.5	6.8	1.0	1.0	0.2	2.4	1.7	12.2	7.9	1.3	1.8	0.6	0.8
Maximum	2.7	2.5	9.0	13.5	78.6	0.8	132.3	155.5	1142.0	691.3	552.2	87.6	2.0	12.4
Mean	2.3	1.5	8.1	7.3	20.0	0.5	51.1	55.7	259.4	256.1	125.8	36.1	1.3	4.2
Standard deviation (n)	0.3	0.8	0.4	3.3	21.0	0.2	39.4	27.0	203.1	163.6	136.3	23.2	0.4	3.0
(Al-Souda north 2006-2008)														
No. of observations	15.0	13.0	24.0	24.0	12.0	22.0	2.0	2.0	2.0	2.0	12.0	12.0	16.0	6.0
Minimum	2.2	2.0	7.2	1.5	1.1	0.5	74.8	48.1	216.1	31.3	0.6	0.2	0.8	0.8
Maximum	3.1	3.1	8.5	12.8	3.2	1.0	128.3	65.6	484.8	32.9	35.4	7.6	2.6	4.0
Mean	2.7	2.6	7.8	7.6	2.1	0.7	101.5	56.9	350.4	32.1	9.6	4.5	1.7	2.1
Standard deviation (n)	0.3	0.4	0.3	2.3	0.6	0.1	26.8	8.8	134.3	0.8	11.7	1.9	0.5	1.1
(Al-Baydha 2006-2008)														
No. of observations	17.0	15.0	24.0	24.0	12.0	22.0	2.0	2.0	2.0	2.0	12.0	12.0	13.0	6.0
Minimum	1.3	1.3	7.5	1.0	0.9	0.6	14.2	7.5	73.5	222.5	1.3	2.6	1.2	1.2
Maximum	3.4	3.4	8.9	9.1	3.9	1.1	61.1	48.7	485.4	248.2	51.9	8.0	2.8	4.8
Mean	2.5	2.3	7.9	6.9	2.1	0.8	37.7	28.1	279.4	235.3	16.1	4.6	1.7	2.8
Standard deviation (n)	0.6	0.5	0.4	1.6	0.9	0.2	23.5	20.6	205.9	12.8	17.5	1.7	0.4	1.1
(Al-Souda south 2006-2008)														
No. of observations	17.0	15.0	24.0	24.0	12.0	22.0	2.0	2.0	2.0	2.0	12.0	12.0	16.0	6.0
Minimum	1.9	1.9	6.5	0.2	1.4	0.6	79.9	56.3	313.7	271.9	1.4	1.5	1.4	1.1
Maximum	3.0	3.0	8.3	8.0	3.9	1.3	144.3	63.2	481.6	283.8	54.0	6.6	2.0	24.0
Mean	2.4	2.3	7.4	1.9	2.2	0.8	112.1	59.8	397.6	277.8	13.2	4.0	1.7	7.9
Standard deviation (n)	0.3	0.3	0.4	1.8	0.6	0.2	32.2	3.4	83.9	6.0	18.5	1.5	0.2	8.3

WCD: Water Discharge;
WQP: water quality parameters including water temperature (WT), salinity, dissolved oxygen (DO), and pH;
TSS: total suspended solids;
DN: Dissolved Nutrients include Soluble Reactive Phosphate (SRP), nitrate (NO_3), nitrite (NO_2), and silicate (SiO_2);
MJ: Major Ions include calcium (Ca), magnesium (Mg), chloride (Cl), and sulphate (SO_4).

From: Al-Maarof Sama Sameer (2015). Ecological Assessment of Re-flooded Mesopotamian Marshes (Iraq). Doctoral dissertation, thesis, University of Waterloo in fulfilment, Canada. 189 pp.

APPENDIX 2: Preferred means for fishing some species in the Mesopotamian Marsh.

Species	Fishing methods							
	Seine net	Trammel Net	Fixed net	Drift gill net	Trawl net	Cast net	Hook and line	Electric catch
P. abu	■		■					■
C. auratus	■							■
T. whiteheadi	■							
A. mossulensis	■							
A. marmid	■							
T. hamiltonii	■							
P. latipinna	■							■
T. ilisha	■			■				
L. vorax	■		■					
H. limbatus	■							
L. subviridis			■					
C. luteus			■					
L. klunzingeri			■					■
A. dispar	■							■
H. leucisculus	■							
A. latus			■					
S. triostegus		■	■					
B. fuscus	■							
N. nasus			■					
G. holbrooki								
I. compressa .			■					
C. carpio			■					
S. hasta			■					
T malabarica								
S. sihama								
B. dussumieri								
A. mento	■							
A. bilineatus								
L. bindus								
B. orientalis								
L. xanthopterus	■							
A. grypus								
M. pelusius								
M. sharpeyi								
C. kais								
B. kersin								
S. arabica								
H. fossilis	■							
H. molitrix								
A. berda								
C. idella								
J. belangerii								
S. argus								
G. rufa								
M. mastacembelus								
S. albella								
O. carinata	■		■					
C. zilli	■		■					

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