

Status of Diadromous Fish Species in the Restored East Hammar Marsh in Southern Iraq

ABDUL-RAZAK M. MOHAMED*

*Department of Fisheries and Marine Resources, College of Agriculture
Basrah University, Basrah, Iraq*

NAJAH A. HUSSAIN AND SAJED S. AL-NOOR

Department of Biology, College of Science, Basrah University, Basrah, Iraq

BRIAN W. COAD

Canadian Museum of Nature, Box 3443, Station D, Ottawa, Ontario K1P 6P4, Canada

FALAH M. MUTLAK

Marine Science Centre, Basrah University, Basrah, Iraq

Abstract.—A total of 31 fish species belonging to 14 families were collected from the restored East Hammar marsh from October 2005 to September 2006 using seine net, electrofishing gear, fixed gill net, and dip net. Eleven marine diadromous species were caught, representing 35.5% of the total number of species, which is similar to the fish assemblage of the Shatt Al-Arab River during the 1970s and 1980s. Marine diadromous species in the East Hammar marsh were divided into a resident group, including only one species (greenback mullet *Liza subviridis*), a seasonal group represented by three species (hilsa *Tenualosa ilisha*, moustached thryssa *Thryssa mystax*, and dusky frillgoby *Bathygobius fuscus*), and an occasional group consisting of seven species (yellowfin seabream *Acanthopagrus latus*, spotted scat *Scatophagus argus*, sobaity seabream *Sparidentex hasta*, Klunzinger's mullet *L. klunzingeri*, mud skipper *Boleophthalmus dussumieri*, long billed half beak *Rhynchorhamphus georgii*, and ocellated sole *Brachirus orientalis*). These species were all derived from the Arabian Gulf. Marine fish comprised 15.8% of the total catch of which hilsa was the most abundant comprising 10.1%, followed by moustached thryssa (3.8%) and greenback mullet (1.6%), of the total catch. Water temperature showed positive correlations with both number and total catch of marine species. The marine assemblage in the East Hammar marsh consisted of small-sized (juvenile) individuals. Hilsa fed mostly on alga and diatoms; greenback mullet on diatoms, higher plants, and organic materials; Klunzinger's mullet on diatoms and organic materials; moustached thryssa on insects, shrimps, and fish; dusky frillgoby on shrimps and fish; and yellowfin seabream on shrimps and insects. The presence of marine fish species has major effects on the seasonality and levels of ecological indices (richness, diversity, and evenness) of the fish assemblages in the East Hammar marsh. The restored East Hammar marsh has regained its original biological role as a nursery as well as a forage ground for marine diadromous fishes.

Introduction

The Tigris and Euphrates rivers and their tributaries are the main sources of inland freshwater in

Iraq. The inland freshwater bodies cover between 600,000 and 700,000 ha, made up of natural lakes (39%), dams and reservoirs (13.3%), rivers and their branches (3.7%), and marshes (44%), in addition to coastline of approximately 50 km along the northwestern Arabian Gulf (FAO 1999). There are

* Corresponding author: abdul19532001@yahoo.com

more than 58 freshwater fish species in Iraqi inland waters, about a further 53 marine species penetrating estuarine and freshwater (Coad 1991; www.briancoad.com), and 125 fish species and five species of shrimps in the Iraqi marine waters (Mohamed et al. 2001).

In the 1950s and 1960s, the main elements of the marshlands economy in southern Iraq were based on their biological diversity: agriculture, livestock raising, birding, mat making, and fishing. Fishing was practiced widely in the marshes, and fish were a major food item for people inhabiting marshes. The estimated annual catch of fish in the Mesopotamian marshes in the early 1960s was 30,000 metric tons, of which 70% were Cyprinid species.

In 1990, the Food and Agriculture Organization of the United Nations estimated that the total inland catch of fish in Iraq was 23,600 metric tons, with more than 60% of this coming from the Mesopotamian marshes (Partow 2001). The marshlands also once served as a natural filter for waste and other pollutants transported by the Tigris and Euphrates rivers, thus protecting the Arabian Gulf, which has now become noticeably degraded along the coast of Kuwait (Al-Ghadban et al. 1999; Saeed et al. 1999). They were the permanent habitat for millions of birds and a flyway for millions more migrating between Siberia and Africa (Maltby 1994; Evans 2002). Several marine fish species of great economic importance in the Arabian Gulf are dependent on the estuarine systems and marshes for spawning, such as Clupeidae (Hussain et al. 1994), or for feeding, such as Mugilidae and Sparidae (Hussain et al. 1987; Hussain and Ahmed 1995). The penaeid shrimp, jinga shrimp *Metapenaeus affinis*, undertakes seasonal migrations between spawning grounds in the gulf and nursery and feeding grounds in the East Hammar (Mathews et al. 1986).

Concomitant factors, including the Iran–Iraq War in the 1980s; new hydrological projects in Turkey, Syria, and Iran; the constructions of drainage systems by diversions of major rivers surrounding the marsh areas; and drainage processes in the 1990s drained the southern marshlands and led to substantial loss of native aquatic flora and fauna well known for a long period as marsh biota of southern Iraq. In 2002, 85% of permanent marshes defined in 1973 had been environmentally destroyed. Only 3% of the central marshes and 14.5% of the East Hammar marshes remained, along with the largest

natural expanse of marsh, the Hawizah, near the Iranian border (Richardson and Hussain 2006).

Since 2003, great efforts have been made to restore the marshes and revive the fishing industry, but major dams across the border in Turkey have reduced the river discharge significantly. As of August 2005, the marshes had recovered almost 40% of their former levels, according to the United Nations Environment Programme. Satellite imagery shows the southern marshlands now occupy about 3,500 km² after having dwindled to just 760 km².

Several taxonomic studies were previously published about freshwater and marine fishes of Iraq (Khalaf 1961; Mahdi 1962; Al-Nasiri and Shamsul-Houda 1975; Banister 1980; Al-Daham 1982; Coad 1991), and these refer to the marshes in passing. Other studies have focused on water quality, plankton and plant communities in the marshes before desiccation (Maulood et al. 1979; Pankow et al. 1979; Al-Saadi et al. 1981; Al-Saboonchi et al. 1982, 1986; Al-Zubaidy 1985; Mohamed and Barak 1988a), or on biological aspects of some of the freshwater fishes in the marshes (Al-Mukhtar 1982; Barak and Mohamed 1982, 1983; Naama 1982; Dawood 1986; Al-Sayab 1988; Jasim 1988; Mohamed and Barak 1988b; Al-Kanaani 1989; Al-Rudainy 1989; Mohamed and Ali 1994). A number of studies of the biological characteristics of some of the diadromous fish species in the Shatt Al-Arab River, Shatt Al-Basrah, and Iraqi marine waters have been undertaken (Hussain and Ali 1987; Hussain et al. 1987, 1989, 1999, 2001; Jabir and Faris 1989; Al-Daham et al. 1993; Younis 1995; Al-Noor 1998; Mohamed et al. 1998, 2000). Nevertheless, there is no published information on the species composition, fish ecology, and fisheries of the marshes before their draining, nor on its ecological role for marine fish species.

The specific objective of this research was to describe the composition, occurrence, abundance, and food habits of marine diadromous fish species in East Hammar marsh after restoration.

Study Site

The East Hammar marsh is situated south of the Euphrates, extending from near Nasiriyah in the west to the outskirts of Basrah on the Shatt al-Arab in the east (Figure 1). The marsh area historically consisted of 2,800 km² of permanent marsh and

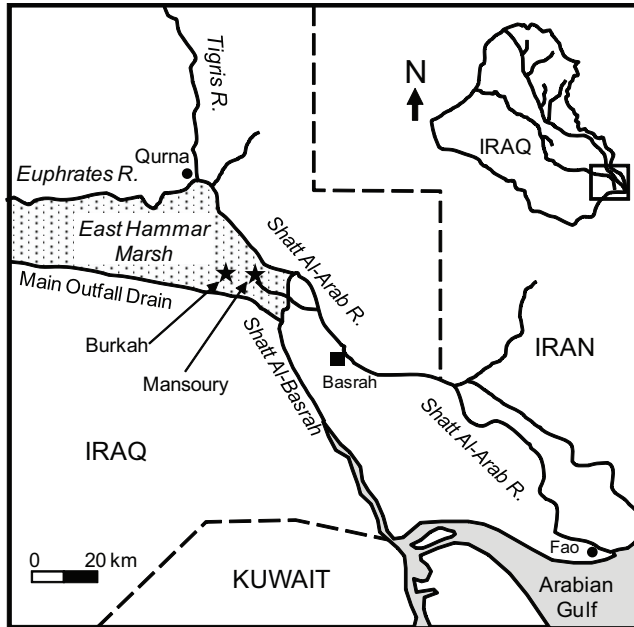


Figure 1.—Location of study area in the East Hammar marsh, south Iraq.

lake, expanding to more than 4,500 km² during periods of seasonal and temporary inundation. Hammar Lake (some authors used the term lake instead of marsh for Hammar), which used to dominate the marsh, is the largest water body on the lower Euphrates. In the late 1980s, it was approximately 120 km long and 25 km wide. Maximum water depth in the lake ranged from 1.8 to 3 m (Partow 2001).

During the 1990s, the East Hammar marsh completely dried out as a result of local drainage structures. These structures included two dams on the Euphrates, one at Nasiriyah and one at Medina to reduce water flow into the marsh area; sluice gates and dams placed on distributaries of the Euphrates to restrict water flow; and two canals and a pipeline that diverted water from the Euphrates and agricultural drainage water away from the marshlands.

In 2003 and 2004, the local Marsh Dwellers and Iraq's Ministry of Water Resources began to divert water back into the marshlands through opening sluice gates, breaching embankments, and other actions along the southern side (Garmat Ali marsh). Water from the Euphrates is returning from the western and northern sides of Hammar and from Shatt al-Arab through Garmat Ali marsh to the southeast (Figure 1).

Methods

The fishes were collected monthly from two selected sites (Mansoury: N 30° 40' 32", E 47° 37' 21"; and Burkah: N 30° 40' 22", E 47° 33' 03") in the East Hammar (Figure 1) as part of a larger study to investigate the composition of the fish community in the three restored southern Iraqi marshes during the period from October 2005 to September 2006. The Mansoury site consisted of previously drained tidal channel habitat, while the Burkah site was previously drained tidal open-water habitat.

Sampling was carried out using seine net (20 m long with a 2.5 cm mesh), electrofishing gear, fixed gill nets (50–100 m long with 2.5–10 cm mesh size), and dip nets. Specimens were immediately transported to the laboratory on crushed ice. Water temperature and salinity were measured to determine the relationships of these two factors with the number of species and total catch of marine species. Fishes were identified to species by using Khalaf (1961), Mahdi (1962), and Beckman (1962). The total length (mm) and weight (g) of all fish captured were recorded. Three analytical methods were used to analyze stomach contents (i.e. numerical, volumetric, and frequency of occurrence; Windell

1971). The importance of food item was determined by using the index of relative importance of (Pinkas et al. 1971). The similarity among fish species based on their diet was calculated according to Jaccard similarity coefficient, using SPSS software (version 11, 2001) statistical package.

The analysis of the nature of the fish communities in the East Hammar marsh was carried out by the following methods and indices: relative abundance (Odum 1970), the diversity index (Shannon and Weaver 1949), the evenness index (Pielou 1977), and the richness index (Margalef 1968). Fish species were divided into three categories according to their occurrence in the monthly samples following Tyler (1971).

Results

Species Composition and Occurrence

The fish assemblage of East Hammar marsh consists of 31 species belonging to 14 families and is dominated by four species (Abu mullet *Liza abu*, crucian carp *Carassius carassius*, *Acanthobrama marmid*, and hilsa *Tenualosa ilisha*) that account for 80.4% of the total catch. The fish fauna was composed of 14 native, 6 alien, and 11 marine species. The marine species belonged to eight families, namely Mugilidae (greenback mullet *L. subviridis* and Klunzinger's mullet *L. klunzingeri*), Sparidae (yellowfin seabream *Acanthopagrus latus* and sobaity seabream *Sparidentex hasta*), Gobiidae (dusky frillgoby *Bathygobius fuscus* and mud skipper *Boleophthalmus dussumieri*), Clupeidae (hilsa), Engraulidae (moustached thryssa *Thryssa mystax*), Scatophagidae (spotted scat *Scatophagus argus*), Hemiramphidae (long billed half beak *Rhynchorhamphus georgii*) and Soleidae (ocellated sole *Brachirus orientalis*). The marine species comprised 35.5% of the total number of species. All marine species were collected from the Mansoury site and only four species, namely moustached thryssa, greenback mullet, dusky frillgoby, and yellowfin seabream, from Burkah site. The highest number of marine species (seven) was caught in July and the lowest (one) in November and December (Table 1). One marine species (greenback mullet) was considered as a resident species, three (hilsa, moustached thryssa, and dusky frillgoby) as seasonal species, and seven (yellowfin seabream, spotted scat, sobaity seabream, Klunzinger's mullet, mud skipper, long

billed half beak, and ocellated sole) were occasional species.

Relative Abundance

Of the total catch of 16,199 fish of East Hammar marsh, 2,560 were marine fish (Table 1). The majority of marine fish (2,502 fish, 97.7%) were caught from the Mansoury site. The relative abundance of the marine fish fluctuated from 0.2% (two fish) in November to 55.1% (1,610 fish) in September (Table 1), with an overall value of 15.8% of the total catch. Hilsa was the most abundant marine species, comprising 10.1%, followed by moustached thryssa (3.8%) and greenback mullet (1.6%) of the total catch.

The water temperature fell to a minimum of 12.5°C in February and rose to a maximum of 29°C in July. Salinity changed from 1.2‰ in August to 2.0‰ in May and July (Figure 2). Water temperature showed positive correlations (0.713 and 0.407), with both the number and the total catch of marine species, respectively, while salinity exhibited weak negative and positive correlations (−0.107 and 0.195), with both the number and the total catch of marine species, respectively.

Ecological Indices

The monthly variations in ecological indices relevant to fish species composition in the East Hammar marsh during October 2005–September 2006 are given in Table 1. The diversity index (*H*) fluctuated from 1.07 in November to 2.01 in July, with an overall value of 1.53. The richness index (*D*) varied from 0.74 in December to 2.83 in July, with an overall value 1.76. The evenness index (*J*) ranged from 0.49 in November to 0.84 in December, with an overall value 0.60.

Length-Frequency Distributions

The overall length-frequency distributions of the most abundant marine fish species in the East Hammar marsh are illustrated in Figure 3. Hilsa was the most abundant marine species in the marshes and appeared in the catches. The lengths of Hilsa ranged from 3 to 13 cm, and a length of 6 cm dominated the catch. The second most abundant marine species was moustached thryssa, which was found in the catch from March to October. Lengths from

Table 1.—Monthly variations in relative abundance (%) of marine fish species caught in the Hammar marshes (October 2005–September 2006).

Fish species	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Total
Hilsa	18.7	—	—	—	—	—	0.06	0.1	—	15.7	1.4	38.6	10.1
Moustrached thryssa	3.2	—	—	—	—	—	0.12	0.7	0.4	1.9	8.7	14.9	3.8
Greenback mullet	3.7	0.2	6.3	2.2	1.6	1.6	1.4	0.2	0.9	0.6	0.49	1.6	1.6
Dusky frillgoby	0.08	—	—	0.2	—	—	0.94	0.4	0.1	0.06	—	—	0.17
Yellowfin seabream	—	—	—	—	—	—	0.06	—	—	1.1	—	—	0.12
Klunzinger's mullet	—	—	—	—	—	—	—	—	—	0.18	—	—	0.02
Spotted cat	0.08	—	—	—	—	—	—	—	—	—	—	—	0.006
Sobaity seabream	—	—	—	—	—	—	—	—	—	—	0.1	—	0.006
Long billed half beak	—	—	—	—	—	—	0.06	—	—	—	—	—	0.006
Ocellated sole	—	—	—	—	—	—	—	—	—	0.06	—	—	0.006
Mudskipper	0.08	—	—	—	—	—	—	—	—	—	—	—	0.006
% of marine species	25.8	0.2	6.3	2.4	1.6	2.8	2.6	1.4	1.4	19.5	10.6	55.1	15.8
% of other species	74.2	99.8	93.7	97.6	98.4	98.4	97.4	98.6	98.6	80.5	89.4	44.9	84.2
No. of marine species	6	1	1	2	1	3	6	4	3	7	4	3	—
Catch of marine fish	307	2	50	23	14	37	44	17	21	326	109	1,610	2,560
Total catch	1,188	1,126	800	942	882	1,315	1,695	1,217	1,419	1,670	1,025	2,920	16,199
Diversity index	1.55	1.07	1.50	1.34	1.36	1.87	1.51	1.78	1.43	2.01	1.35	1.63	1.53
Richness index	2.12	1.14	0.74	1.61	1.33	2.23	2.15	1.83	1.65	2.83	1.73	1.76	1.76
Evenness index	0.56	0.49	0.84	0.538	0.59	0.66	0.53	0.67	0.56	0.65	0.53	0.60	0.60

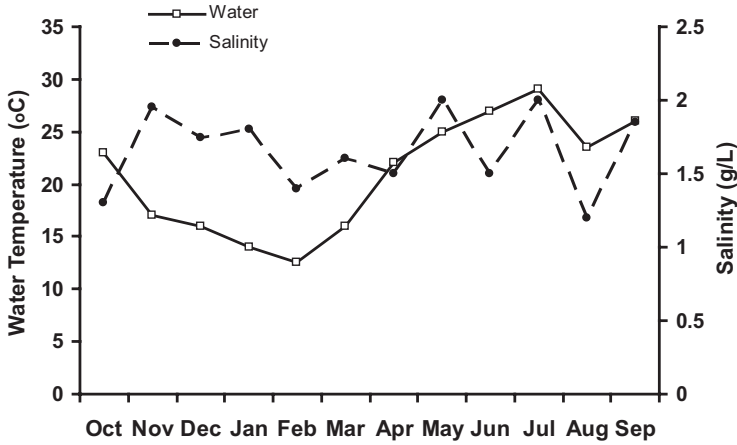


Figure 2.—Monthly variations in the water temperature and salinity in the East Hammar marsh.

6 to 19 cm were represented in the samples, and the dominant length-group was 10 cm. Greenback mullet was very common and regularly found in the catch throughout the year, except January. The length range of this species includes sizes from 7 to 22 cm, with fish of 11 cm dominating the catch.

Food Composition

The diet composition of some diadromous fish in the East Hammar marsh are given in Figure 4.

Hilsa fed primarily on algae (40%) and diatoms (34%); other food items were detritus (8%), Copepoda (7%), Cladocera (5%), Rotifera (4%), and Ostracoda (2%). The food items of greenback mullet consisted of diatoms (39%), higher plants (37%), Copepoda (3%), and detritus (37%). Diatoms formed (37%) of the total food items of Klunzinger’s mullet, followed by detritus (34%), higher plants (15%), algae (9%), Copepoda (3%), and Ostracoda (2%). Moustached thryssa preyed

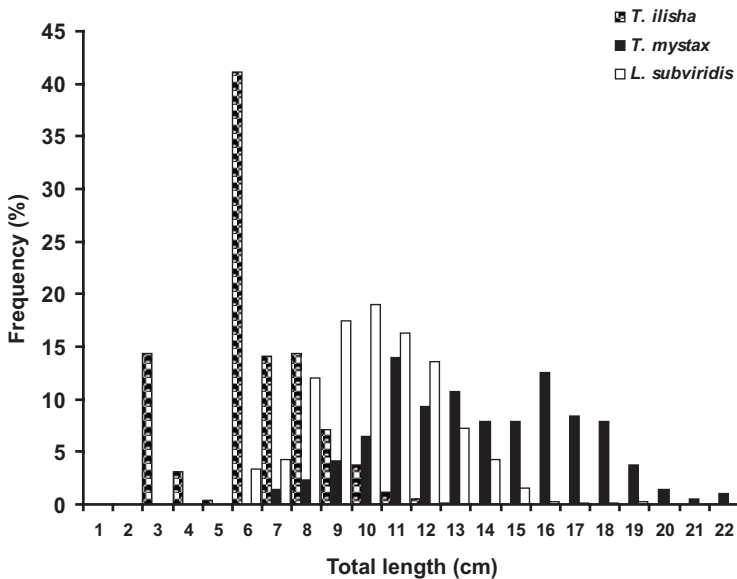


Figure 3.—The length frequencies of dominant diadromous fish in the East Hammar marshes.

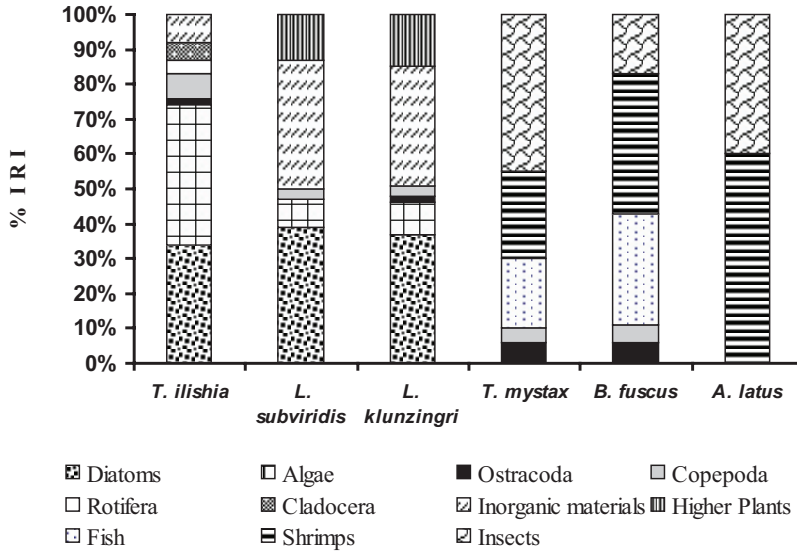


Figure 4.—Diet composition of some diadromous fish in the East Hammar marsh.

on insects (45%), shrimps (25%), fish (20%), Copepoda (6%), and Ostracoda (4%). Shrimps comprised 40% of the total food items of Dusky frillgoby, followed by fish (32%), insects (17%), Copepoda (6%), and Ostracoda (5%). Yellowfin seabream preyed mainly on shrimps (60%) and insects (40%).

Similarity dendrogram among fish species based on their diet is presented in Figure 5. Two main groups could be distinguished. Group I, consists of two subgroups: the first includes moustached thryssa and dusky frillgoby, which preyed mostly on shrimp, insects, and fish; and the second includes yellowfin seabream, which preyed on

shrimp and insects. Group II, also consists of two subgroups: the first includes greenback mullet and Klunzinger’s mullet, which fed mainly on diatoms, higher plants, and detritus; and the second included hilsa, whose diet consisted mostly of diatoms and algae.

Discussion

One of the obvious differences between the three restored southern marshes is that they represent different environments that receive their water from three separate sources, the Tigris, Euphrates, and Shatt Al-Arab rivers, each with a distinct water qual-

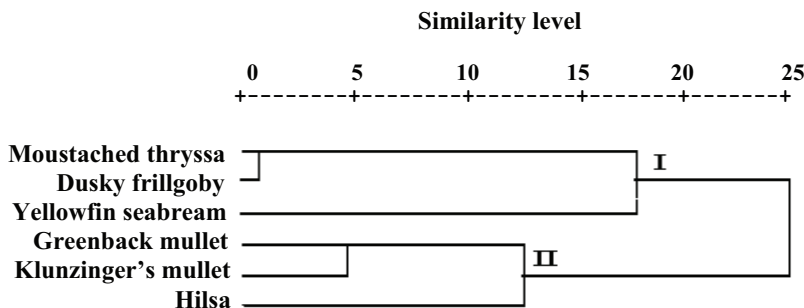


Figure 5.—Similarity dendrogram among some diadromous fish based on their diet in the East Hammar marsh.

ity (Rzóska et al. 1980; Richardson et al. 2005). The fish assemblage of East Hammar marsh, which receives water from both the Euphrates and the Shatt Al-Arab rivers, differs from other restored marshes by the occurrence of marine diadromous fish species, in addition to freshwater species both native and alien (Hussain et al. 2006). The dykes between the former East Hammar marsh and the Shatt Al-Arab River were demolished in late April 2003, and water has been flowing upstream due to the tidal action of Gulf waters forcing the waters of Shatt al-Arab back into the marsh. As a result, several diadromous species have returned to the Hammar marsh through the Shatt Al-Arab River for spawning, to nursery grounds, or for feeding (Richardson and Hussain 2006).

No species composition studies exist on this marsh before they were drained, but the occurrence of marine species in southern marshes was recorded by several authors (Al-Daham 1982, 1988; Al-Hassan and Naama 1986; Coad 1991). However, a few surveys were conducted in the upper reaches of the Shatt Al-Arab River, about 30 km from the marsh, before the draining of the marshes and indicated the presence of several marine species. Al-Nasiri and Shamsul-Hoda (1975) listed 12 marine species, forming 37.5% of the total species during 1973; Hussain et al. (1989) found 14 marine species, comprising 42.4% of the total species during 1982–1983; Hussain et al. (1997) collected seven marine species during 1992–1993; and Younis (2005) caught eight marine species during 2003. The present study indicated the presence of 11 marine species in East Hammar marsh. It can be seen that the proportion of marine species from the total species in the East Hammar was 35.5%, which is close to that of Shatt Al-Arab River during the 1970s and 1980s. Hussain and Taher (2007) suggested that during flood tide, a greater volume of water from Shatt Al-Arab River enters the Hammar marsh due to the semidiurnal tide, making the Hammar marsh mixed waters and not from the Euphrates River alone; consequently the environment of the Hammar is rather similar to Shatt Al-Arab to a certain degree.

The marine fish species recurring in the East Hammar marsh moved from the Shatt Al-Arab estuary via the Shatt Al-Arab River, a distance of 130 km, after the inundation of the marsh in April

2003 (Reiss and Farhan 2006). Moreover, Mohamed et al. (2006) reported that the Tigris fisheries at Qurna confluence, north of Basrah consisted of seven marine species during the spring and summer seasons of 2005, constituting 31.8% of the total number of species.

The marine species occurring in the East Hammar marsh were derived from the lower reaches of the Shatt Al-Arab estuary, northwest Arabian Gulf. However, the number of species invading the East Hammar marsh represents a small percentage of the total number of species in the fish assemblage of the Shatt Al-Arab estuary (Mohamed et al. 2001; Hussain et al. 2003). It seems that only the euryhaline species able to tolerate the low salinity of the marsh (1.2–2.0‰) have invaded. Al-Hassan and Hussain (1985) showed that hydrological parameters influenced the penetration of marine species from the gulf to the Shatt Al Arab River. Blaber et al. (1998) found that the juveniles of four species of *Ilisha* (Pristigasteridae) enter the upper reaches of Sarawak estuaries. These species were *Ilisha filigera*, *I. pristigastroides*, elongate ilisha *I. elongate*, and bigeye ilisha *I. megaloptera*. The last two were recorded from the Iraqi coastal water and Hammar marsh before desiccation during the 1990s. Utilization of salt marshes by marine fishes was reported in many Australian estuaries (Blaber and Blaber 1980; Blaber et al. 1985 and Morton et al. 1987).

It is also apparent that the relative abundance of marine diadromous species fluctuated temporarily. The low values coincided with low temperature (winter) and the high values with high temperature (summer), synchronizing with plankton blooms in the Hammar marsh (Reiss and Farhan 2006). Water temperature showed positive correlations with both the species number and total catch, indicating the environmental impact of this factor on migration and emigration of marine fish to the East Hammar marsh.

Only one marine species (greenback mullet) was considered a resident species and the other 10 species were considered seasonal or occasional species. These species enter into the East Hammar marsh in summer due to biological factors such as feeding, spawning, and protection from predators. The high abundance in late summer was due to an increase of Hilsa juveniles. Hilsa comprised 63.6% of the marine species and 10.1% of the total catch

in the East Hammar marsh. Such a high number of juveniles confirms the importance of the marsh as a protected area for rearing young of the year of several species.

Examination of the stomach contents of the investigated fishes has shown that while the diet varied among the fish species, most of them depend on two or three major food items. In general, the diets of examined species were similar to that previously reviewed by Al-Daham et al. (1993), Hussain and Ali (1987), Hussain et al. (1987, 1999, 2001), and Mohamed et al. (1998, 2000) with certain differences in the percentages, which could be related to the difference in environments. Thick aquatic plants (*Ceratophyllum demersum*, *Potamogeton crispus*, and *Vallisneria spiralis*) could play a major role in Hammar marsh, offering extensive shelter from piscivorous predators and availability of food (insect, isopod, and amphipod). The same was noted previously by Lenanton (1982), that aquatic plants played a role as source of food (amphipod) and shelter. Blaber and Blaber (1980) identified that Australian salt marshes serve as nursery grounds for juveniles due to the absence of big predators and plenty of food. Subrahmanyan and Drake (1975) observed that most marine species in two tidal marshes in Florida were represented by juveniles and found a seasonal succession in the recruitment of juveniles.

The presence of marine fish species in the East Hammar marsh has also major effects on the seasonality and levels of ecological indices of the fish assemblages. There was a wide range in the richness index of the fish assemblages in the East Hammar marsh, leading to the conclusion that the marsh plays an important role as a nursery ground for several fish species. McErlean et al. (1973) considered a wide range of richness index as an indicator of the nursery function of an area. The marine diadromous fish species largely contributed to the high ecological indices obtained in the East Hammar marsh. These values were comparable to that of the Shatt Al-Arab River (Hussain et al. 1989), Shatt Al-Basrah (Al-Daham and Yousif 1990), and Khor Al-Zubair (Ali and Hussain 1990).

The aim of present study was to throw some light on the ecology of marine fishes in one of southern Iraq's marshes. However, the species composition within the Mesopotamian marshes requires detailed ongoing research.

Acknowledgments

We would like to express our thanks to the Canadian Iraqi Marsh Initiative (CIMI) and Iraq Nature for their support and help. Our thanks also go to the Canadian International Development Agency (CIDA) without whose financial support this work would never have been achieved.

References

- Al-Daham, N. K. 1982. The ichthyofauna of Iraq: a check-list. Basrah Natural History Museum, Publication No. 4, Basrah, Iraq.
- Al-Daham, N. K. 1988. Development of fisheries in the marshes, south of Iraq: obstacles and solutions. Arab Gulf Journal of Scientific Research 20(2):85-97.
- Al-Daham, N. K., A. R. M. Mohamed, and A. Y. Al-Dibakel. 1993. Estuarine life of yellow fin sea bream *Acanthopagrus latus* in southern Iraq. Marina Mesopotamica 8(1):137-152.
- Al-Daham, N. K., and A. Y. Yousif. 1990. Composition, seasonal and abundance of fishes in Shatt Al-Arab Canal, an estuary in southern Iraq. Estuarine Coastal and Shelf Science 31:411-421.
- Al-Ghadban, A. N., T. Saeed, A. M. Al-Dousari, H. Al-Shemmari, and M. Al-Mutair. 1999. Preliminary assessment of the impact of draining of Iraqi marshes on Kuwait's northern marine environment. Part 1. Physical manipulation. Water Science & Technology 40(7):75-87.
- Al-Hassan, A. J., and N. A. Hussain. 1985. Hydrological parameters influencing the penetration of Arabian Gulf fishes into the Shatt Al-Arab River, Iraq. Cybium 9(1):7-16.
- Al-Hassan, L. A. J., and A. K. Naama. 1986. New record for some Arab Gulf fishes in freshwater systems of Iraq. Bulletin of the Basrah Natural History Museum 6:35-44, Basrah, Iraq.
- Ali, T. S., and N. A. Hussain. 1990. Composition and seasonal fluctuations of intertidal fish assemblage in Khor Al-Zubair, northwest Arabian Gulf. Journal of Applied Ichthyology 6:24-36.
- Al-Kanaani, S. M. 1989. Diet overlap among the common carp *Cyprinus carpio* L. and three native species in Al-Hammar marshes, southern Iraq. Master's thesis. Basrah University, Basrah, Iraq. [In Arabic]
- Al-Mukhtar, M. A. 1982. Biological study for two freshwater fish, *Barbus luteus* (Heckel) and *Aspius vorax* (Heckel) in Hammar marsh, Basrah. Master's thesis. Basrah University, Basrah, Iraq. [In Arabic]
- Al-Nasiri, S. K., and N. I. Shamsul-Houda. 1975. Survey of fish fauna of Shatt Al-Arab (from Abu Al-Khasib

- to Karmat Ali). Bulletin of the Basrah Natural History Museum 2:36–46, Basrah, Iraq.
- Al-Noor, S. S. H. 1998. The reproductive biology of *Tenualosa ilisha* in Shatt Al-Arab and Iraqi marine waters. Doctoral thesis. Basrah University, Basrah, Iraq. [In Arabic]
- Al-Rudaini, A. A. J. 1989. Morphometric study of four cyprinid fish and their relation to food in Hammar marsh, south Iraq. Master's thesis. Basrah University, Basrah, Iraq. [In Arabic]
- Al-Saadi, H. A., S. R. Antoine, and A. K. M. Nurl Islam. 1981. Limnological investigation in Al-Hammar marsh area in southern Iraq. Nova Hedwigia 35:157–166 Stuttgart, Germany.
- Al-Saboonchi, A. A., N. A. Barak, and A. R. M. Mohamed. 1986. Zooplankton of Garma marshes, Iraq. Journal of Biological Sciences Research 17(1):33–39.
- Al-Saboonchi, A. A., A. R. M. Mohamed, and N. A. Barak. 1982. A study of phytoplankton in the Garma marshes, Iraq. Iraqi Journal of Marine Science 1:67–79, Basrah, Iraq.
- Al-Sayab, A. A. A. 1988. Ecology and bioggy of Asian catfish, *Silurus triostegus* Heckel, 1843 in Hammar marsh, South Iraq. Master's thesis. Basrah University, Basrah, Iraq. [In Arabic]
- Al-Zubaidy, A. J. M. 1985. Ecological study on the phytoplankton in some marshes near Qurna, South Iraq. Master's thesis. Master's thesis. Basrah University, Basrah, Iraq. [In Arabic]
- Banister, K. E. 1980. The fishes of the Tigris and Euphrates rivers. In J. Rzóska, editor. Euphrates and Tigris Mesopotamian ecology and destiny. Monographiae Biologicae 38.
- Barak, A. A., and A. R. M. Mohamed. 1982. Food habits of Cyprinid fish, *Barbus luteus* (Heckel). Iraqi Journal of Marine Science 1(1):59–67, Basrah, Iraq.
- Barak, N. A. A., and A. R. M. Mohamed. 1983. Biological study of the cyprinid fish, *Barbus luteus* (Heckel) in Garma marshes. Journal of Biological Research 14(2):53–70.
- Beckman, W. C. 1962. The fresh water fishes of Syria and their general biology and management. FAO Fisheries Biology Technical Paper 8.
- Blaber, S. J. M., and T. G. Blaber. 1980. Factors affecting the distribution of juvenile estuarine and inshore fish. Journal of Fish Biology 17:143–162.
- Blaber, S. J. M., J. Staunton-smith, D. A. Milton, G. Fry, T. Vanderelde, J. Pang, P. Wong, and O. Boon-Teck. 1998. The biology and life-history strategies of Ilisha (Teleostei: Pristigasteridae) in the coastal waters and estuaries of Sarawak. Estuarine and Coastal Shelf Science 47:499–511.
- Blaber, S. J. M., J. W. Young, and M. C. Dunning. 1985. Community structure and zoogeographic affinities of the coastal fishes of the Dampier region of northwestern Australia. Australian Journal of Marine and Freshwater Research 36:247–266.
- Coad, B. W. 1991. Fishes of the Tigris–Euphrates basin: a critical-list. Canadian Museum of Nature, Syllogeus No. 68, Ottawa.
- Dawood, A. H. 1986. Biology of common carp *Cyprinus carpio* L. in Al-Hammar Marsh, southern Iraq. Master's thesis. Basrah University, Basrah, Iraq. [In Arabic]
- Evans, M. I. 2002. The ecosystem. Pages 201–219 in E. Nicholson and P. Clark, editors. The Iraqi marshlands: a human and environmental study. Politico's, London.
- FAO (Food and Agriculture Organization of the United Nations). 1999. Fishery country profile. Food and Agriculture Organization of the United Nations, FID/CP/IRQ Rev. 2, Rome.
- Hussain, N. A., and S. M. Ahmed. 1995. Seasonal composition, abundance and spatial distribution of ichthyoplankton in an estuarine subtropical part of the north western Arabian Gulf. Marine Research 4(2):135–146.
- Hussain, N. A., and T. S. Ali. 1987. Some biological aspects of *Thryssa hamiltonii* and *Thryssa mystax* in Khor Al-Zubair, northwest Arab Gulf. Indian Journal of Fish of Fisheries 34(2):152–162.
- Hussain, N. A., T. S. Ali, and K. D. Saud. 1989. Seasonal fluctuations and composition of fish assemblage in the Shatt Al-Arab River at Basrah, Iraq. Journal of Biological Sciences Research 20(1):139–150.
- Hussain, N. A., H. A. Hamza, and K. D. Saud. 1987. Some biological aspect of the fresh water population of Shanag *Acanthopagrus latus* (Houttuynia) in Shatt Al-Arab River, Iraq. Marina Mesopotamica 2(1):29–40.
- Hussain, N. A., M. K. Jabir, and U. H. Yousif. 1994. On the biology of sbour *Tenualosa ilisha* (Hamilton) in the Shatt Al-Arab river, south of Iraq, with notes on their distribution in the Arab Gulf. Marina Mesopotamica 9(1):115–139.
- Hussain, N. A., A. R. M. Mohamed, S. S. Al-Noor, B. Coad, F. M. Mutlak, I. M. Al-Sudani, A. M. Mojer, A. J. Toman, and M. A. Abdad. 2006. Species composition, ecological indices, length frequencies and food habits of fish assemblages of the restored southern Iraqi marshes. Basrah University, Annual Report, Basrah, Iraq.
- Hussain, N. A., A. R. M. Mohamed, J. H. Saleh, and F. M. Mutlak. 2001. The biology of juvenile and immature of *Acanthopagrus latus* in tidal pools of Khor Al-Zubair lagoon, Iraq. Marina Mesopotamica 16(1):59–68.
- Hussain, N. A., A. R. M. Mohamed, U. H. Younis, and F. M. Mutlak. 1999. The biology of *Bathygobius fuscus* (Ruppell) at the intertidal mudflats of Khor

- Al-Zubair lagoon, northwest Arabian Gulf. *Marina Mesopotamica* 14(1):119–132.
- Hussain, N. A., F. M. Mutlak, and K. H. Younis. 2003. The small fish assemblages in the Shatt Al-Arab estuary, northwest Arabian Gulf. *Marina Mesopotamica* 18(2):179–188.
- Hussain, N. A. and M. A. Taher. 2007. Effect of daily variations, diurnal fluctuations and tidal stage on water parameters of East Hammar marshland, southern Iraq. *Marsh Bulletin* 2(1):32–42.
- Hussain, N. A., K. H. Younis, and U. H. Yousif. 1997. The composition of small fish assemblages in the river Shatt Al-Arab near Basrah, Iraq. *Acta Hydrobiol* 39:29–37.
- Jabir, M. K., and A. A. Faris. 1989. Fecundity of sbour *Tenuulosa ilisha* (Hamilton Buchana, 1822) in the Shatt Al-Arab rivers, Basrah. *Marina Mesopotamica* 4(2):281–296.
- Jasim, A. A. W. 1988. The reproductive biology of *Barbus sharpeyi* in Hammar marsh, Iraq. Master's thesis. Basrah University, Basrah, Iraq. [In Arabic]
- Khalaf, K. T. 1961. The marine and fresh water fishes of Iraq. Al-Rabitta Press, Baghdad, Iraq.
- Lenanton, R. C. J. 1982. Alternative non-estuaries nursery habitats for some commercial and recreational important fish species of south-western Australia. *Australian Journal of Marine and Freshwater Research* 33:881–900.
- Mahdi, N. 1962. Fishes of Iraq. Ministry of Education, Baghdad, Iraq.
- Maltby, E., editor. 1994. An environmental and ecological study of the marshlands of Mesopotamia. University of Exeter, Wetland Ecosystems Research Group, Draft Consultative Bulletin, UK. Published by The AMAR Appeal Trust, London.
- Margalef, R. 1968. Perspectives in ecology. University of Chicago Press, Chicago.
- Mathews, C. P., J. M. Bishop, and S. Salman. 1986. Stocks of *Metapenaeus affinis* in Kuwait and Iraq waters. Kuwait Institute for Scientific Research, Final Report KISR 2231, Safat.
- Maulood, B. K., G. C. F. Hinton, H. S. Kamees, F. A. K. Saleh, A. A. Shaban, and S. M. H. Al-Shahwani. 1979. An ecological survey of some aquatic ecosystems in southern Iraq. *Tropical Ecology* 20(1):27–40.
- McErlean, A. J., S. G. O'Connor, J. A. Mihurky, and C. I. Gibson. 1973. Abundance, diversity and seasonal patterns of estuarine fish populations. *Estuarine and Coastal Marine Science* 1:19–36.
- Mohamed, A. R. M., and T. S. Ali. 1994. The biological importance of Iraqi marshes in fish growth. Pages 205–215 in N. A. Hussain, editor. *Ahwar of Iraq: an environmental approach*. Basrah University, Marine Science Center Publication 18, Basrah, Iraq.
- Mohamed, A. R. M., S. S. Al-Noor, and R. A. K. Faris. 2006. Analytical study of the fisheries in the lower reaches of the Tigris River, North Qurna, Basrah, Iraq. *Iraqi Journal of Aquaculture* 1:57–73, Basrah.
- Mohamed, A. R. M., and N. A. Barak. 1988a. Growth and condition of a cyprinid fish, *Barbus sharpeyi* Gunther in Al-Hammar marsh, Basrah, Iraq. *Basrah Journal of Agricultural Science* 2:18–25, Basrah, Iraq.
- Mohamed, A. R. M., and N. A. Barak. 1988b. Seasonal variations in some limnological features of the Garma Marshes. *Basrah Journal of Agricultural Science* 1:56–63, Basrah, Iraq.
- Mohamed, A. R. M., N. A. Hussain, and T. S. Ali. 2001. Estuarine components of the ichthyofauna of the Arabian Gulf. *Marina Mesopotamica* 16(2):209–224.
- Mohamed, A. R. M., S. A. Hussein, and J. H. Saleh. 1998. The biology of green back grey mullet *Liza subviridis* in the northwest Arabian Gulf. *Marina Mesopotamica* 13(2):375–385.
- Mohamed, A. R. M., S. A. Hussein, and J. H. Saleh. 2000. Food habits of *Liza carinata* in the Iraqi marine waters. *Marina Mesopotamica* 15(1):275–284.
- Morton, R. M., B. R. Pollack, and J. P. Beumer. 1987. The occurrence and diet of fishes in a tidal inlet to a salt marsh in southern Moreton Bay, Queensland. *Australian Journal of Ecology* 12:217–237.
- Naama, A. K. 1982. Study of some biological aspects of *Mugil dussumieri* and *Liza abu* in Al Hammar marsh. Master's thesis. Basrah University, Basrah, Iraq. [In Arabic]
- Odum, W. A. 1970. Insidious alternation of the estuarine environment. *Transactions of the American Fisheries Society* 99:836–847.
- Pankow, H., H. A. Al-Saadi, M. F. Huq, and R. A. M. Hadi. 1979. On the algae flora of the marshes near Qurna (southern Iraq). *Willdenowata* 8:493–506.
- Partow, H. 2001. The Mesopotamian marshlands: demise of an ecosystem. United Nations Environment Programme, Early Warning and Assessment Technical Report, UNEP/DEWA/TR.01–3 Rev 1, Nairobi, Kenya.
- Pielou, E. C. 1977. *Mathematical ecology*. John Wiley, New York.
- Pinkas, L., M. S. Oliphant, and I. L. K. Iverson. 1971. Food habits of albacore, fin tuna and bonito in California waters. *California Department of Fish and Game Fish Bulletin* 152:1–105.
- Reiss, P., and A. Farhan, editors. 2006. Final report. Development Alternatives, Iraq Marshlands Restoration Program, Bethesda, Maryland.
- Richardson, C. J., and N. A. Hussain. 2006. Restoring the Garden of Eden: an ecological assessment of the marshes of Iraq. *BioScience* 56(6):477–489.
- Richardson, C. J., P. Reiss, N. A. Hussain, A. J. Alwash,

- and D. J. Pool 2005. The restoration potential of the Mesopotamian marshes of Iraq. *Science* 307:1307–1311.
- Rzóska, J., J. F. Talling, and K. E. Bannister. 1980. Euphrates and Tigris: Mesopotamian ecology and destiny. Dr. W. Junk, The Hague, Netherlands.
- Saeed, T., N. Al-Ghandban, H. Al-Shemmari, M. Al-Mutair, and H. Al-Hashash. 1999. Preliminary assessment of the impact of draining of Iraqi marshes on Kuwait's northern marine environment, part II: sediment associated pollutants. *Water Science and Technology* 40:89–98.
- Shannon, C. E., and W. Weaver. 1949. The mathematical theory of communication. University of Illinois Press, Urbane .
- Subrahmanyam, C. B., and S. H. Drake. 1975. Studies on animals communities in two north Florida salt marshes. *Bulletin of Marine Science* 25(4):445–465.
- Tyler, A. V. 1971. Periodic and resident component communities of the Atlantic fishes. *Journal of the Fisheries Research Board of Canada* 28(7):935–946.
- Windell, J. T. 1971. Food analysis and rate of digestion. Pages 215–226 *in* W. E. Ricker, editor. *Methods for assessment of fish production in fresh water*. Blackwell Scientific Publications, Oxford, UK.
- Younis, K. H. 1995. Occurrence and food habit of the juveniles of *Liza carinata* (valenciennes, 1836) in the Shatt Al-Arab river at Basrah, Iraq. *Marina Mesoptamica* 10(2):331–339.
- Younis, K. H. 2005. Biological assessment of fish assemblage environment in Shatt Al-Arab River, Karmat Ali, Basrah. Doctoral thesis. Basrah University, Basrah, Iraq. [In Arabic]