GLOBAL JOURNAL OF BIOLOGY, AGRICULTURE & HEALTH SCIENCES
(**Published By**: Global Institute for Research & Education)
www.gifre.org

A FISH INDEX OF BIOTIC INTEGRITY FOR EVALUATION OF FISH ASSEMBLAGE ENVIRONMENT IN RESTORED CHYBAISH MARSH, IRAQ

Abdul-Razak M. Mohamed
Department of Fisheries and Marine Resources, College of Agriculture, University of Basrah, Iraq

Abstract

A multimetric fish Index of Biotic Integrity (IBI) was depended to assess the status of the fish assemblage of Chybaish marsh, Iraq from October 2005 to September 2006. IBI scores were calculated from 14 separate assemblage metrics based on the species richness, species composition and trophic groups. After more than two years of restoration activities, the state of the fish community in Chybaish marsh was fair (IBI= 45.6%), and was worse than the Huwazah Marsh, but slightly better than the Hammar marsh. The results revealed that no substantial improvements have been recorded during the late years of restoration, reflect that the environment is still fragile and need time to be recovering.

Key words: *Index of Biotic Integrity (IBI), fish assemblage, Chybaish marsh, Iraq.*

1. Introduction

Historically, the marshes of southern Iraq constituted the largest wetland ecosystem in southwest Asia and Europe, covered densely with tall reed beds, interspersed with several large open-water bodies. The marshes are important for economic, social, and biodiversity values characterized by frequency of water flows, accumulation of nutrients and organic matter, production of commercially important vegetation and fish, and are an important stopover along the inter-continental flyway of migratory birds, support endangered species, and sustain freshwater and marine fish (Maltby, 1994 and USAID, 2004). The Chybaish marsh (Central marshes) is at the heart of the Mesopotamian wetland ecosystem, located immediately above the confluence of the two Mesopotamian Rivers. The Tigris River bound them to the east and the Euphrates River in the south, the area is roughly delimited by a triangle between Al-Nasiriyah, Al-Amarah and Al-Basrah cities. The Chybaish marsh cover an area of about 3,000 km², this may extend to well over 4,000 km² during flood periods. The Chybayish marshes historically received water influx mainly from Tigris distributaries branching southward from Al-Amarah (Partow, 2001).

The Chybaish marsh was completed dried through the construction of the Glory and Prosperity Rivers in 1993, which stopped water inflow from the Tigris River and diverted water flow from the marshlands and into the Euphrates River, consequently the aquatic habitats were destroyed (Richardson and Hussain, 2006). After the war of 2003, actions were taken by the Iraqi Ministry of Water Resource and the dwellers to breach several embankments that were preventing water from the Euphrates River from flowing into the marshes. As of summer 2004, the middle core of the Central marshes remains dry. The periphery of the Central marshes has been re-flooded, including the northwestern corner (Al-Awdeh marsh); the southwestern portion (Abu Zirig Marsh) and the southern portion (Chybayish marsh).

Karr and Dudley (1981) stated that the Index of Biotic Integrity (IBI) provided a tool for monitor the ecological integrity of ecosystem health as a result of habitat degradation or flow alteration, in addition to chronically poor chemical water quality. Karr *et al.* (1987) defined IBI as the ability to support and maintain a balanced, integrated, adaptive community of organisms having species composition, diversity, and functional organization comparable to that of natural habitat of the region. The original IBI is a multimetric index that uses a combination of 12 attributes, called metrics, of local fish assemblages to assess biotic integrity directly (Karr, 1981). As the IBI became more widely used, different versions were developed for different regions and different ecosystems included lakes and wetlands (Minns *et al.*, 1994; Simon, 1998; Belpaire *et al.*, 2000; Simon *et al.*, 2000; Bozzetti and Schulz, 2004; Uzarski1 *et al.*, 2005; Bhagat *et al.*, 2007; Brousseau and Randall, 2008; Krause *et al.*, 2012).

Since inundation in 2003, several studies have been focused on describe the fish assemblages in the southern marshes (ARID, 2006; Hussain *et al.*, 2009; Mohamed *et al.*, 2008, 2009, 2012; Youns *et al.*, 2011). Some works have been carried out attempting to evaluate water quality change as result of environmental alteration in the marshes by using Water Quality Index (WQI) or water characteristics (Al-Saboonchi *et al.*, 2011; Al-Kenzawi *et al.*, 2011) or fish structure changes in the marshes by applying the Index of Biotic Integrity, IBI (Al-Shamary, 2008; Abd, 2010; Mohamed and Hussain, 2012a).

The aim of this work was to evaluate the restored environment of Chybaesh marsh by applying modified lBl metrics and to identify eventual recovery trends after two years of inundation, in comparison with other southern marshes of Iraq.

2. Materials and Methods

Fieldwork included monthly sampling of the fish fauna from two selected sites, Abu-Sobat (N 30^0 $57^{'}$ $92^{"}$, E 47^0 $02^{'}$ $23^{"}$) and Baghdadia (N 31^0 $07^{'}$ $58^{"}$, E 47^0 $03^{'}$ $07^{"}$) in Chybaish marsh (Fig. 1) from October 2005 to September 2006, using seine net, fixed gill nets and electro-fishing gear as explained by Mohamed *et al.* (2012). Each species was accounted and classified in respect to its geographic origin (native or alien), trophic guilds and environment degradation tolerance (Table 1) using several fisheries publications (Hussain and Ali, 2006; Hussain *et al.*, 2006; Mohamed *et al.*, 2008, 2012; Coad, 2010; Mohamed and Hussain, 2012a, b).

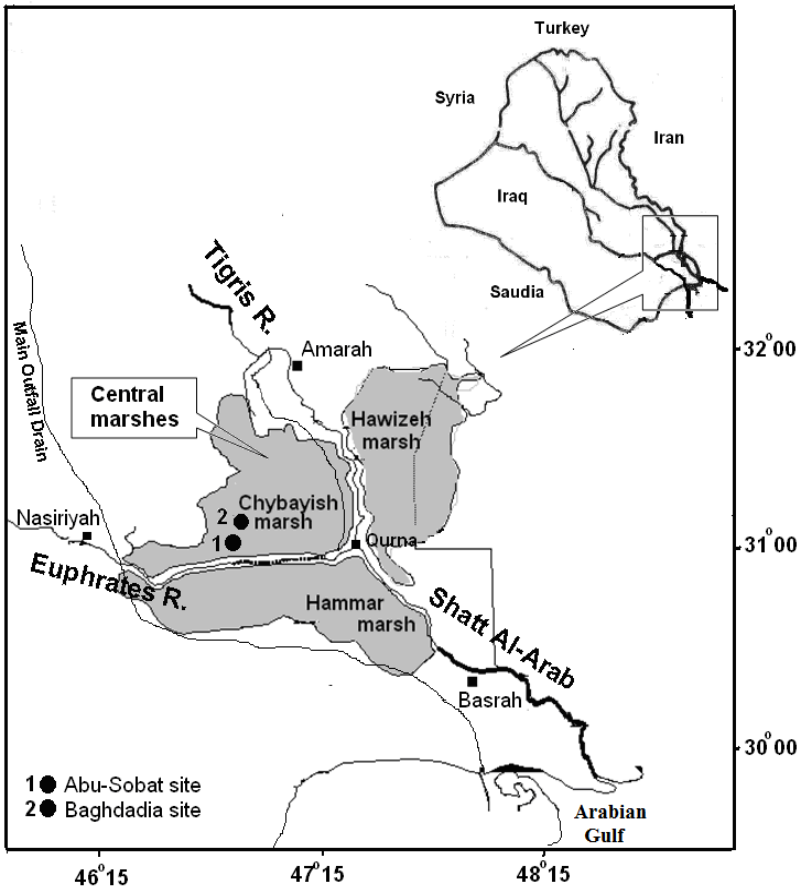

Fig. 1: Map of southern of Iraq, showing the location of Chybaish marsh

In this study, 14 metrics were used (see Table 2), most them already applied successfully in other studies (Karr, 1981; Minns *et al.*, 1994; Belpaire *et al.*, 2000; Simon *et al.*, 2000; Mohamed and Hussain, 2012a; Mohamed, 2013). The IBI methodology presently being used in the study was modified from Minns *et al.* (1994) to meet the regional conditions of the marsh, who scored metrics from 1 to 10. Scores for metrics that increase with environmental quality (numbers of native, common native fish species, proportion of sensitive native species, proportion of herbivore, proportion of carnivore and proportion of piscivore, and species richness) were standardized to a scale of 0 to 10. A value of 10 would be assigned to the highest value of each raw metrics, otherwise the standardized score was calculated as B x raw score, where B = 10/ highest value. Scores of metrics that increase with decreasing environmental quality (number and proportion of alien, and proportion of tolerance species, proportion of *Liza abu*, proportion of *Carassius auratus*, proportion of omnivore and proportion of detrivore fish) were standardized to a scale of 0 to 10. A value of 0 would be assigned to the highest value of each raw metrics, otherwise the standardized score was calculated as 1- B x raw score, where B = 10/ highest value. Standardized IBI metrics were summed to obtain an IBI score that varied continuously from 0 to 100 for the marsh and the month, for each metric. IBI scores are rated as very poor (0-20), poor (20-40), fair (40-60), good (60-80) and excellent (>80) (Minns *et al.* 1994). The species richness index (D) is defined by (Margalef, 1968): D= S-1 / loge N, where, S= number of species and N= number of individuals. Analysis of variance (ANOVA) was used to assess the monthly IBI scores differences ($p \leq 0.05$) among the southern marshes using SPSS software (version 11, 2001) statistical package.

3. Results

3.1 Species composition and richness metrics

Fourteen freshwater fish species (5,095 individuals) were collected from Chybaish marsh during the present study (Table 1). The monthly variations in the species composition and richness metrics used to calculate IBI of Chybaish marsh are presented in Table 2. The fish fauna was comprised of ten native species, constituted 71.4% of the total number of species, with the highest appearance of the species was 7 in October, March and July-August and the lowest was 4 in December. The highest number of common native species was 5 recorded in March and August and the lowest was two recorded in January. The alien species was four, formed 28.6% of the total number of species. The lowest number of alien species was one in November and the highest was four in April. The highest proportion of alien fish was 40.6% in November and the lowest (11.2%) in January. The detritovorus species, *Liza abu* and the alien species, *Carassius auratus* have been chosen as the most abundant species and wide range of water quality conditions in Iraq. The relative proportion of *L. abu* ranged from 40.7% in May to 77.2% in June, and C. *auratus* from 10.1% in January to 40.6% in November. Species that previously were very abundant but presently occur only occasionally because of environmental deterioration, were considered intolerant species. The relative proportion of intolerant species fluctuated from 5.5% in June to 29.9% in August, while the proportion of tolerant species ranged from 70.1% in August to 94.5% in June. The species richness of fish assemblage was varied between 0.8 in December to 1.7 in February.

3.2 Trophic groups metrics

Monthly fluctuations in the trophic groups metrics used to calculate IBI of Chybaish marsh are presented in Table 2. The trophic groups metrics, which is composed of percent of individuals that are considered as herbivorous, carnivorous, omnivorous, detrivorous and piscivorous species, which constituted 26.0, 8.1, 2.0, 56.1 and 7.8% of the total catch, respectively. The highest proportions of them were 43.0%, 18.3%, 5.7%, 77.2% and 19.0%, respectively.

3.3 Integrated Biological Index (IBI)

The monthly variations in IBI scores of different metrics of fish assemblage in the marsh during the study period are illustrated in Figure 2. IBI score of native fish species ranged from 5% in December to 10% in June, and the highest IBI score of alien fish species was 7.5% in November, whereas, the maximum IBI score of common native species was 10% in March and August (Fig. 2a). The IBI score of proportion alien species attained the highest value 40.6% in November and the IBI score of species richness ranged from 4.7% in December to 10% in February (Fig. 2b). The maximum IBI score of proportions of herbivorous, carnivorous and piscivorous were 10% in May, October and August, respectively, and for omnivorous and detrivorous species were 9.5% and 4.7% in March and May, respectively (Fig. 2d).

The monthly variations in the overall IBI score of fish assemblage in the marsh during the study period is shown in Figure 3. The lowest value of IBI was 38.1% in December and the highest value 62.9% in August. In general, the value of IBI was good during August, fair during October, January - March and May – July, and poor during November – December, April and September. The overall IBI value of Chybaish marsh during 2005-2006 was evaluated to be fair (45.6%).

Table 1: Geographic origin, tolerance and trophic group of fish captured from the Chybaish marsh during 2005-2006

Family/species	**Origin**	**Tolerance**	**Trophic Guild**
Cyprinidae			
Carassius auratus	Alien	Tolerance	Herbivore
Barbus luteus	Native	Sensitive	Herbivore
Acanthobrama marmid	Native	Tolerance	Carnivore
Alburnus mossulensis	Native	Tolerance	Carnivore
Cyprinus carpio	Alien	Tolerance	Omnivore
Aspius vorax	Native	Sensitive	Piscivore
Cyprinion microstmum	Native	Sensitive	Carnivore
Barbus sharpeyi	Native	Sensitive	Herbivore
Mugilidae			
Liza abu	Native	Tolerance	Detrivore
Siluridae			
Silurus triostegus	Native	Sensitive	Piscivore
Heteropneustidae			
Heteropneustus fossilis	Alien	Tolerance	Carnivore
Poecillidae			
Gambusia holbrooki	Alien	Tolerance	Carnivore
Mastacembelidae			
Matacembelus matacembelus	Native	Sensitive	Piscivore
Cyprinodontidae			
Aphinus dispar	Native	Tolerance	Omnivore

Table 2: Monthly variations in the fish assemblage metrics used to calculate IBI of Chybaish marsh during 2005-2006

IBI metrics	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**	**Sep**
No. of native species	7	6	4	5	7	7	6	5	8	7	7	5
No. of alien species	2	1	2	2	3	3	4	2	3	3	3	3
No. of common native species	3	3	4	2	4	5	3	4	3	4	5	3
Proportion of alien species	25.8	40.6	14.6	11.2	30.5	16.2	34.0	32.2	13.5	37.9	22.9	39.7
Proportion of *L. abu*	50.8	46.6	76.4	77.0	47.5	63.6	53.3	40.7	77.2	51.9	44.3	50.8
Proportion of *C. auratus*	23.8	40.6	12.7	10.1	26.9	10.3	16.6	29.4	13.1	26.6	20.7	23.8
Proportion of intolerant species	7.1	10.1	8.9	8.7	8.1	8.8	7.8	23.8	5.6	6.7	29.9	7.1
Proportion of tolerant species	92.9	90.0	91.0	91.3	91.9	91.2	92.1	76.3	94.5	93.2	70.1	92.9
Proportion of herbivores	25.0	42.3	14.7	10.1	28.7	14.1	21.7	43.0	17.3	29.0	31.7	34.5
Proportion of carnivores	18.3	2.8	0.0	3.1	15.7	17.6	16.5	3.4	3.9	11.7	3.9	0.6
Proportion of omnivores	0.0	0.0	1.9	1.1	1.8	0.3	5.7	2.8	0.3	3.3	1.2	5.2
Proportion of detrivores	50.8	46.6	76.4	77.0	47.5	63.6	53.3	40.7	77.2	51.9	44.3	44.3
Proportion of piscivores	6.0	8.3	6.9	8.7	6.3	4.4	2.7	10.2	1.4	4.1	19.0	15.5
Species richness	1.5	1.0	0.8	1.2	1.7	1.5	1.6	1.2	1.4	1.5	1.5	1.2

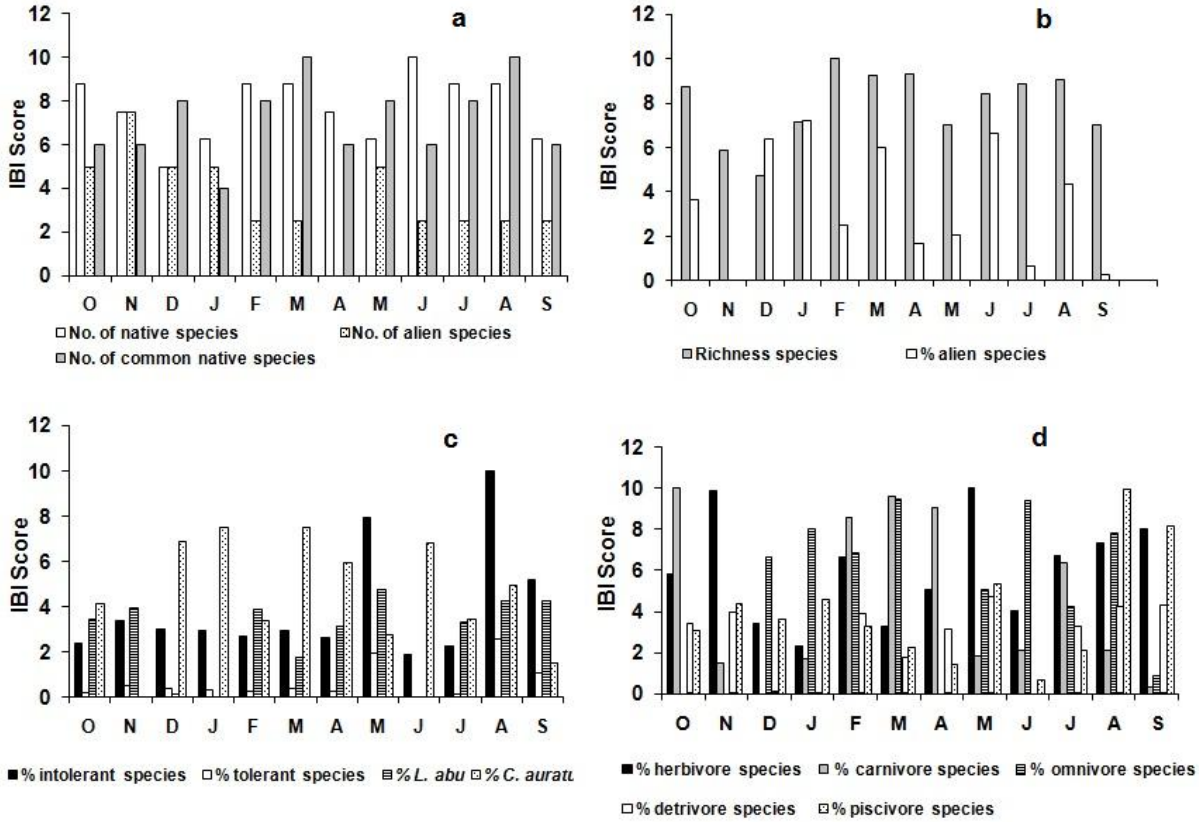

Fig. 2: Monthly variations in IBI scores metrics in Chybaish marsh (2005-2006)

4. Discussion

The IBI concept, which is based on qualifying the integrity of a fish community by evaluating a variety of essential ecological features (species composition, community structure, biological processes (e.g. trophic relationships) and individual health), has a high plasticity and can be used on a variety of aquatic habitats in quite different zoo-geographical regions all over the world (Belpaire, *et al.*, 2000).

The Chybaish marsh was suffered from intensive desiccation for more than a decade during the nineties of the last century, in addition, no historical information existing about fish assemblage in this marsh, therefore, a comparison was made with the status of study marsh with the adjacent marshes during the same period and sampling efforts (Mohamed, *et al.*, 2008, 2012; Hussain, *et al.*, 2009; Mohamed and Hussain, 2012a) as shows in Table 3 and with the same study marsh after eight years of inundation (Abd, 2010).

Table 3: Comparison of IBI scores metrics between Chybaish and other marshes

IBI metrics	**Chybaish[1]**	**Hammar[2]**	**Huwazah[3]**
No. of species	14	31	15
No. of native species	10	14	11
% of native species	71.4	45.2	73
% of native individuals	76.7	59.8	81.2
No. of alien species	4	6	4
% of alien species	28.6	19.4	27
% of alien individuals	23.3	29.4	18.8
No. of migratory species	0	11	0
% of migratory species	0	35.5	0
% of migratory individuals	0	10.8	0
% of *L. abu*	56.1	37.5	32.8
% of *C. auratus*	19.7	25.4	11.5
% of sensitive species	11.7	3.9	45.4
% of tolerant species	88.2	87.5	53.3
% of herbivores	23.5	27	47.7
% of carnivores	6.8	21.8	8.2
% of omnivores	1.5	11.5	1.3
% of detrivores	61.9	39.3	32.8
% of piscivores	6.4	2.3	8.6
Species richness	0.8-1.7	0.7-2.8	0.7-2.4

[1] Present study, [2] Mohamed and Hussain (2012), [3] Mohamed (2014)

Significant difference was found in the monthly IBI scores between Chybaish, Huwazah and Hammar marshes (ANOVA, F= 4.35, P= <0.05). The status of the fish community in Chybaish marsh was fair (IBI= 45.6%) after more than two years of restoration activities and recurrence water, and was better slightly than Hammar marsh, IBI= 42.6% (Mohamed and Hussain, 2012a), but was worse than Huwazah marsh (IBI= 53.2 %) during the same period (Mohamed, 2013). However, the values of IBI of Chybaish marsh after five years of its restoration were estimated to be 26 to 55.8% (Abd, 2010). Chybaish marsh represented the harshly degraded of the other southern marshes due to heavy desiccation, only 3% of the Central marshes, 14.5% of the Hammar marshes and 35% of the Huwazah marshes were remained in 2002 (Partow, 2001 and Richardson and Hussain, 2006). Therefore, the higher scores recorded in the Huwazah marsh than the rest of the southern marshes.

However, as noted below, there were differences in a few individual metrics between the marshes, both positive and negative. The proportion of native individuals in Chybaish marsh was lower (73.4%) than that at Huwazah marsh (84.5%) and slightly higher than that at Hammar marsh (70.6%). The relative proportion of intolerant species in Chybaish marsh was 11.7%, whereas, 45.4% and 3.9% in Huwazah and Hammar marshes, respectively. Also, the proportions of the herbivores, carnivores and piscivores individuals were 41.9, 65 and 51% in Chybaish, Huwazah and Hammar marshes, respectively. Moreover, the proportions of *L. abu* and *C. auratus* individuals, as scores of metrics that increase with decreasing environmental quality formed 78.2% of the fish population in Chybaish marsh, while constituted 44.4 and 61.3% in Huwazah and Hammar marshes, respectively.

Several authors reported that the water quality, water level fluctuation and macrophyte coverage were among the most influential factors affecting fish IBI in wetland ecosystems (Minns *et al*., 1994; Brazner and Beals, 1997; Uzarski *et al*., 2005; Bhagat, *et al*., 2007). Before desiccation water influx coming from Tigris at the north of Chybaish marsh with natural circulation, after inundation in 2003 water resource coming from Euphrates at the south, against the slop which led to stagnation, lower water quality and low water level. Tigris River water contains less dissolved minerals than Euphrates River (Hamdan *et al.* 2010). Deterioration of water quality of the marshes led to substantially decreased in the abundance of several cyprinid species, especially *Barbus xanthopetrus, B. grypus, B. sharpeyi* and *B. luteus*. Several factors behind the shift in the species composition and disappeared of many cyprinid species from the restored marshes, the construction of more than thirty large dams in the headwater region of Turkey, eliminated the flood pulses that sustained wetland ecosystems in the lower Tigris-Euphrates basin, the marked degradation of water quality in the main rivers and the drainage processes of southern marshlands in the 1990s (Partow, 2001). Salinity of the Chybaish marshes increased from 0.4-0.6‰ in seventies of the past century (Pankow *et al*. 1979 and Al-Saadi *et al.* 1981) to 6.3‰ during 2008/2009 (Abed, 2010) which hindered the growth of vegetation in Chybaish marsh (Hamdan *et el*. 2010). The restoration percentage of the aquatic macrophyte species in Chybaesh marsh during 2006 was 61.4%, whereas, 97.2 and 63.2% in Huwazah and Hammar marshes, respectively (Al-Abbawy and AI-Mayah, 2010). Brazner and Beals (1997) stated that increased fish species richness and abundance were often correlated with increased macrophyte species richness and density.

5. Conclusions

The overall study reveals that the fish-based IBI integrated biological index is positively correlated with the species richness, species composition and trophic characteristics of the fish community in the marshes and decreases as the disturbance increase. The index may also present a more accurate assessment of system function than individual measures such as species richness, for example, East-Hammar marsh has more species than at any other marshes, while its overall IBI was low. Moreover, it is found very useful for continuation, permanence, persistence, continuously monitoring of the marshes with respect to the fish community and its integrity with ecosystem.

Acknowledgment

The data on which this paper is based were collected under the Canadian International Development Agency (CIDA)-funded project. My thanks and gratitude goes to my colleague's team of biologists in the project.

References

Abd, I.M. (2010). *Ecological assessment of Chybaish marsh using water quality index and index of biological integrity of fish and phytoplankton assemblages* (Unpublished Ph D. thesis). Basrah University, Iraq.

Al-Abbawy, D.A.H. & AI-Mayah, A.A. (2010). Ecological Survey of Aquatic Macrophytes in Restored Marshes of Southern Iraq during 2006 and 2007. *Marsh Bulletin*, 5, pp. 177-196.

Al-Kenzawi, M.A.H., Al-Haidary, M.J.S Talib, A.H & Karomi, M. F. (2011). Environmental study of some water characteristics at Um-Al-Naaj marsh, south of Iraq. *Baghdad Science Journal*, 8(1), pp. 531-538.

Al-Saadi, H.A., Antoine, S.R. & Nurl Islam, A.K.M. (1981). Limnological investigation in Al-Hammar marsh area in Southern Iraq. *Nova Hedwiga,* 35, pp. 157-166.

Al-Saboonchi, A., Mohamed, AR. M., Alobaidy, A.H.M., Abid, H.S. & Maulood, B. K. (2011). On the current and restoration conditions of the southern Iraqi marshes: Application of the CCME WQI on East Hammar marsh. *Journal of Environmental Protection,* 2, pp. 316-322.

Al-Shamary, A.C. (2008). *Ecological assessment for South-East Al-Hammar marsh, north of Basrah*. (Unpublished M.Sc. thesis). Basrah University, Iraq.

ARDI. (2006). *Final report, marshlands monitoring team*. Development Alternative International.

Bhagat, Y., Ciborowski, J. J. H., Johnson, L.B., Uzarski, D.G., Burton, T.M., Timmermans, S.T.A. & Cooper, M.J. (2007). Testing a Fish Index of Biotic Integrity for Responses to Different Stressors in Great Lakes Coastal Wetlands. *J. Great Lakes Res*. 33, pp. 224-235.

Belpaire, C., Smolders, R., Auweele, I. V., Ercken, D., Breine1, J., Thuyne, G. V. & Ollevier, F. (2000). An Index of Biotic Integrity characterizing fish populations and the ecological quality of Flandrian water bodies**.** *Hydrobiologia,* 434, pp 17-33.

Bozzetti, M. & Schulz, U.H. (2004. An index of bioticintegrity based on fish assemblages for subtropical streams in southern Brazil. *Hydrobiologia,* 529, pp. 133-144.

Brazner, J.C. & Beals, E.W. (1997). Patterns in fish assemblages from coastal wetland and beach habitats in Green Bay, Lake Michigan: a multivariate analysis of abiotic and biotic forcing factors. *Can. J. Fish. Aquat. Sci.,* 54, pp. 1743-1761.

Brousseau, C.M. & Randall, R.G. (2008). Assessment of long-term trends in the littoral fish community of Hamilton Harbour using an Index of Biotic Integrity. *Can. Tech. Rep. Fish. Aquat. Sci.,* 2811, pp. ii + 85 p.

Coad, B.W. (2010). *Freshwater Fishes of Iraq*. Pensoft Publishers, Sofia, Bulgaria.

Hamdan M.A., Asada, T., Hassan, F.M., Warner, B.G., Douable, A., Al-Hilli, M.R. & Alwan, A.A. (2010). Vegetation response to re-flooding in the Mesopotamian wetlands, Southern Iraq. *Wetlands,* 30, pp. 177-188.

Hussain, N.A. & Ali T.S. (2006). Trophic nature and feeding relationships among Al Hammer marsh fishes, southern Iraq. *Marsh Bulletin*, 1, pp. 9-18.

Hussain, N.A., Mohamed, A.R.M., Al-Noor, S.S., Coad, B., Mutlak, F.M., Al-Sudani, I.M., Mojer, A.M., Toman, A.J. & Abdad, M.A. (2006). *Species composition, ecological indices, length frequencies and food habits of fish assemblages of the restored southern Iraqi marshes*. Annual Report, Basrah University, Iraq.

Hussain, N.A., Mohamed, A.R.M., Al-Noor, S.S., Mutlak, F.M. Abed, I.M. & Coad, B.W. (2009). Structure and ecological indices of fish assemblages in the recently restored Al-Hammar Marsh, southern Iraq. *BioRisk,* 3, pp. 173–186.

Karr, J.R. (1981). Assessment of biotic integrity using fish communities. *Fisheries,* 6, pp. 21-27.

Karr, J.R. & Dudley, D.R. (1981). Ecological perspective on water quality goals. *Environmental Management,* 11, pp. 249-256.

Karr, J.R., Philip, R.Y., Fausch, K.D. & Schlosser, I.J. (1987) Spatial and temporal variability of the Index Biotic Integrity in three Midwestern stream. *Transaction of the American Fisheries Society,* 116, pp. 1-11.

Krause, J., Bertrand, K., Kafle, A. & Troelstrup, N. (2012). *A Fish Index of Biotic Integrity for South Dakota's Northern Glaciated Plains Ecoregion.* 142nd Annual Meeting of the American Fisheries Society, Minneapolis-St Paul, MN, August 19-23, 2012.

Maltby, E. (1994). *An environmental and ecological study of the marshlands of Mesopotamia*. Draft Consultative Bulletin, Wetland Ecosystems Research Group. University of Exeter. AMAR Appeal Trus, London.

Margalef, R. (1968). *Perspectives in ecology*. University of Chicago Press.

Minns, C.K., Cairns, V.W., Randall, R.G. & Moore, J.E. (1994). An index of biotic integrity (IBI) for fish assemblages in the littoral-zone of Great-Lakes areas of concern. *Can. J. Fish. Aquat. Sci*., 51, pp. 1804-1822.

Mohamed, AR. M. (2013) *Evaluation of fish assemblage environment in Huwazah marsh, Iraq using Integrated Biological Index.* Paper presented at HydroEco2013, May 13-16, 2013, France.

Mohamed, A.R.M. & Hussain, N.A. (2012a). Evaluation of Fish assemblage environment in east Hammar using Integrated Biological Index. *Basrah Journal of Science*, 30(2), pp. 87-105.

Mohamed, A.R.M. & Hussain, N.A. (2012b). Trophic strains and diet shift of the fish assemblage in the recently restored Al-Hammar marsh, southern Iraq. *Journal of University of Duhok*, 15(1), pp. 119-127.

Mohamed, A.R.M., Hussain, N.A., Al-Noor, S.S., Mutlak, F.M., Al-Sudani, I.M., Mojer, A.M. & Toman, A.J. (2008). Fish assemblage of restored Al-Hawizeh marsh, Southern Iraq. *Ecohydrology & Hydrobiology*, 8(2-4), pp. 375-384.

Mohamed, A.R.M., Hussain, N.A., Al-Noor, S.S., Coad, B. & Mutlak. F.M. (2009). Status of diadromous fish species in the restored East Hammar marsh in southern Iraq. *American Fisheries Society Symposium*, 69, pp. 577-588.

Mohamed, A.R.M., Hussain, N.A., Al-Noor, S.S. & Mutlak. F.M (2012). Ecological and biological aspects of fish assemblage in the Chybaish marsh, Southern Iraq. *Ecohydrology & Hydrobiology*, 12, pp. 65-74.

Partow, H. (2001). *The Mesopotamian Marshlands: Demise of an ecosystem*. Nairobi (Kenya): Division of early warning and assessment, United Nation for Environmental Programs: UNEP publication UNEP/DEWA, 103p.

Pankow, H., Al-Saadi, H.A., Huq, M.F. & Hadi, R.A.M. (1979). On the algal flora of the marshes near Qurna (Southern Iraq). *Willdenowata.* 8, pp. 493-506.

Richardson, C.J. & Hussain, N.A. (2006). Restoring the Garden of Eden: An ecological assessment of the marshes of Iraq. *BioScience*, 56, pp. 477-489.

Simon, T.P. (1998). Modification of an index of biotic integrity and development of reference condition expectations of dunal, palustrine wetland fish communities along the southern shore of Lake Michigan. *Aquat. Ecosyst. Health Manage,* 1, pp. 49–62.

Simon, T.P., Jankowskib, R. & Morris, C. (2000). Modification of an index of biotic integrity for assessing vernal ponds and small palustrine wetlands using fish, crayfish, and amphibian assemblages along southern Lake Michigan. *Aquatic Ecosystem Health and Management* 3: 407-418.

United States Agency for International Development, USAID (2004). *The Iraq Marshlands Restoration Program*, Electronic document. Retrieved from http:// www.usaid.gov/iraq.

Uzarski, D.G., Burton, T.M., Cooper, M.J., Ingram, J.W. & Timmermans, S. (2005. Fish habitat use within and across wetland classes in coastal wetlands of the five Great Lakes: development of a fish-based index of biotic integrity. *J. Great Lakes Res.* 31: 171-187.

Youns, K.H., AL Mossawy, M.H. & Jabir, A.A. (2011). Composition structure of fish assemblage in Um Alnaaj, Al-Hawaizah marsh, Iraq. *Basrah Res. J*. (Scientific), 37(1): 49-59.