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Stock assessment and management of hilsa shad (*Tenualosa ilisha*) in Iraqi marine waters, northwest Arabian Gulf

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ABSTRACT
The stock assessment and management of Hilsa shad (Sbour), *Tenualosa ilisha* in Iraqi marine waters, northwest Arabian Gulf were assessed using FiSAT II software from November 2012 to October 2013. Fish total lengths ranged from 12.2 to 48.0 cm and the lengths of 26 to 44cm dominated the population comprising >93% of the total catch. Length-weight relationship was obtained as W= 0.0041 $L^{3.2683}$. The asymptotic growth (L∞) was 61.47 cm, growth rate (K) was 0.275. The annual instantaneous rate of total mortality (Z) was 1.66 and the natural mortality (M) was 0.55. Fishing mortality was 1.11 and the exploitation rate was 0.67. A bimodal recruitment pattern of unequal strength was observed. The maximum yield per recruitment could achieved at E_{max}= 0.72 and L_c= 27.8 cm. Result showed that *T. ilisha* is over exploited and some management policy should be taken to the stock in the areas of migration reproductive and nursery in inlands waters.

Keywords: Population Dynamic, Hilsa Shad, Mortality, Fishery Management, Iraq.

1. Introduction

The Hilsa shad, *Tenualosa ilisha,* belongs to the family Clupeidae, locally known as 'sbour' in Iraq and other Arabian Gulf countries. Its geographical distribution extends from Shatt Al-Arab River, along the coasts of Iran, Pakistan, India, Bangladesh, and Burma to South Vietnam [1]. The species is largely anadromous in nature, migrating up rivers during the breeding season and after spawning return to the original habitat where they remain until the next breeding season [2].
T. ilisha form an important part of the marine fishery production of Iraq, and are traditionally caught by artisanal fishermen and most of the catches are made by dhow boats and speedboats using drifting gillnets. The percentage of *T. ilisha* landings during 1965-1973 constituted 90.2% of total landings, and this decreased to 52.9% during 1991-1994, and to 41.8% and 30.7% during 1995-1999 and 2000-2006, respectively [3]. Similar findings have been recorded in declining *T. ilisha* fisheries and other species like Zobaidy (*Pampus argenteus*) in the waters of Kuwait and Iran which shares in the stocks and fisheries with Iraq [4-6].
Several studies have been done on the stock assessment of *T. ilisha* at different water bodies, especially in the Indian subcontinent by Rahaman *et al.* [7], Nurul Amin *et al.* [8-10], Halder and Nurul Amin [11], Ahmed *et al.* [12], Rahman and Cowx [13], Milton [14], Dutta *et al.* [15] and Panhwar and Liu [16], in Kuwait by Al-Baz and Grove [17] and in Iran by Hashemi *et al.* [18] and Roomian and Jamili [19]. Little work has been done on stock assessment of this species in Iraq by Jabir [20], Mohamed *et al.* [21] and Mutlak [22].
The decline in the catch of *T. ilisha* punctuated by fluctuating catch trends during recent years necessitated this study. The study deals with estimating the basic parameters required for assessing the status of *T. ilisha* in Iraqi marine water, northwest Arabian Gulf and make appropriate management recommendations.

2. Materials and Methods

Fish samples were collected monthly basis from Iraqi territorial water, northwest Arabian Gulf during November 2012 to October 2013 (Fig. 1). Fishing operations were carried out by steel fishing dhow "Zainab", 21.5 m length, 7 m width and 2.5 m draft with inboard engine of 240 hp.

Samples of fish were captured by drift gill nets (2800-3600 m long and 7 m height) with different mesh sizes (42x42, 48x48 and 57x57 mm). Additional random samples were collected from artisanal fishermen at fish landings site in Fao city. A total of 3523 fish were collected throughout the study period. Total length and weight of the specimens were measured in 'cm' and 'g', respectively. Samples taken to the laboratory were used for estimation of the length-weight relationship [23]: $W=aL^b$, where W is weight (g) and L total length (cm). The length frequency data were pooled into groups with 2cm length intervals. Then the data were analyzed using the FiSAT II (FAO-ICLARM Stock Assessment Tools) software as explained in detailed by Gayanilo *et al.* [24].

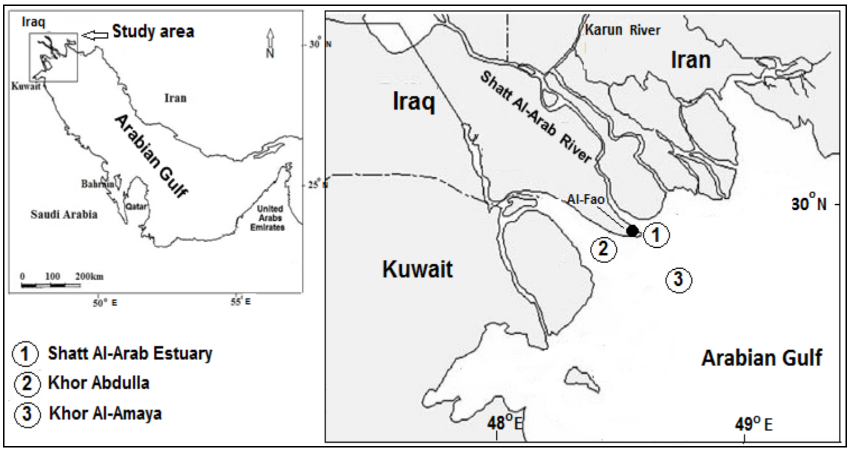

Fig 1: Study area in the Iraqi marine water, northwest Arabian Gulf

Bhattacharya's modal progression analysis was applied to identify different cohorts in the monthly length distributions and to estimate the mean length for each cohort. Means were then involved in the estimation of the growth parameters (L_∞ and K) using Fabens method integrated in FiSAT software package. The growth performance index (ø) was computed according to the formula of Pauly and Munro [25] as $ø = \text{Log } K + 2\text{Log}L_\infty$.

The total mortality rate (Z) was estimated using the length-converted catch curve [26]. Z was estimated from the slope b (with sign changed) of the descending right arm of the curve. Natural mortality rate (M) was estimated following Pauly's empirical formula [27]:

$$\log (M) = -0.0066 -0.279 \log (L\infty)+0.6543 \log (K) + 0.4634 \log (T)$$

Where T is mean annual environmental temperature which is 21 °C. Fishing mortality rate (F) was calculated from F=Z-M, and the exploitation rate (E) from E = F/Z [28].

The recruitment pattern was obtained by backward projection on the length axis of a set of length-frequency data as described in the FiSAT routine. The probability of capture was estimated for gill net selectivity and the mean size at first capture (L_c) was derived by plotting the cumulative probability of capture against mid-length. From the resultant curve, L_c was taken as corresponding to the cumulative probability at 50%.

Relative yield-per-recruit model of Beverton and Holt [29] as modified by Pauly and Soriano [30] and incorporated in the FiSAT software, was used to estimate the current state of the stock and the yield and biomass, using selective ogive procedure. The yield isopleth diagram was used to assess the impact on yield created by changes of exploitation rate E and the ratio of length at first capture to asymptotic length (L_c/L_∞) in relation to changes in mesh size to recommend adequate management regimes.

3. Results

3.1. Length frequency distribution

The monthly samples of 3523 fish were pooled to produce a single length frequency distribution (Fig. 2). No juveniles or young (<12 cm) were captured throughout the year. The smallest fish was 12.2 cm caught during January, whereas the largest one was 48.0 cm caught during June. The major peak was at length 30cm and formed 8.1% from the species population. Fish lengths from 26 to 44cm were dominated *T. ilisha* population in the region comprising >93% of the species catch.

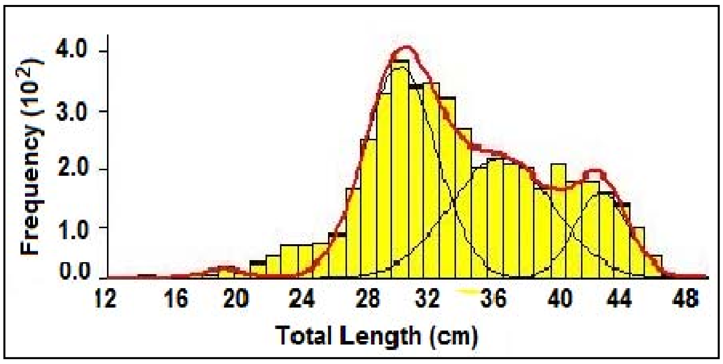

Fig 2: Length frequency distribution and Bhattacharya's method of separating the cohorts of *T. ilisha*

3.2. Growth

The length–weight relationship of *T. ilisha* was $W = 0.0041\ L^{3.2683}$, $r^2 = 0.9863$, TL= 12.2-47.0 cm. The b value is significantly differing from value 3 (t= 14.91, P<0.05), which indicates allometric growth.

The mean lengths obtained by Bhattacharya's method (Fig. 2) in FiSAT program were linked using modal progression method and used to estimate the growth parameters. The asymptotic growth (L_∞) was 61.47cm and the growth rate (K) was 0.275. Length of the species at the end of age 1, 2, 3, 4 and 5 was found to be 16.3, 27.1, 35.5, 41.3 and 46.1cm, respectively (Fig. 3). The growth performance index (ø) of *T. ilisha* was computed as 3.02.

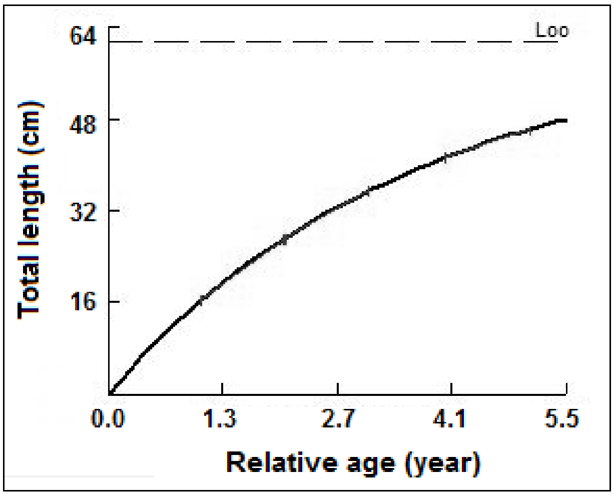

Fig 3: Growth curve of *T. ilisha* by Fabens method.

3.3. Mortality

The annual instantaneous rate of total mortality derived from the length converted catch curve (Fig. 4) was 1.66 and the natural and fishing mortality were 0.55 and 1.11, respectively. Exploitation rate (E) was calculated as 0.67.

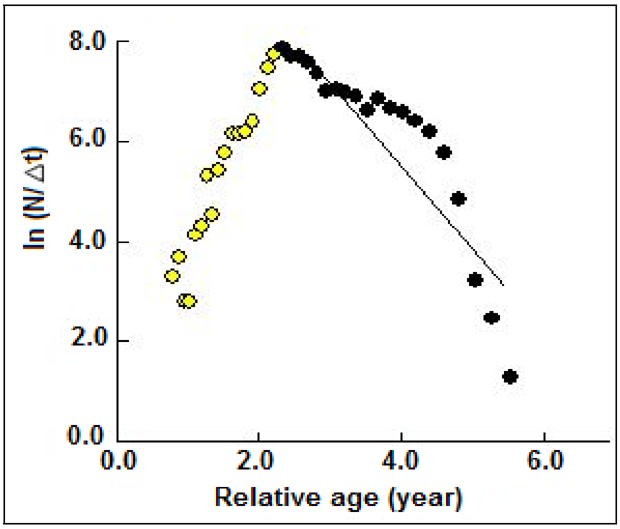

Fig 4: Length converted catch curve of *T. ilisha*

3.4. Probability of Capture

The selection length of L_{25} (25%) was 26.9 cm, L_{50} (50%) was 27.8 cm and L_{75} (75%) was 28.8 cm (Fig. 5). Therefore, the length at first capture was 33.74cm (L_c) was 27.8 cm.

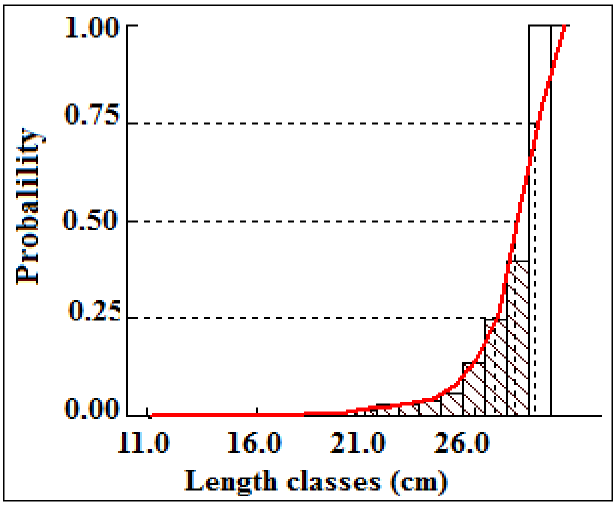

Fig 5: The selection curve for probability of capture of *T. ilisha.*

3.5. Recruitment pattern

The recruitment pattern (Fig. 6) shows double annual peak recruitment per year, the first peak in April (10.74%) is probably due to peak recruitment in migrant breeding stock while the July peak (16.61%) may be associated with the recruitment of juveniles bred the previous year into the adult stock.

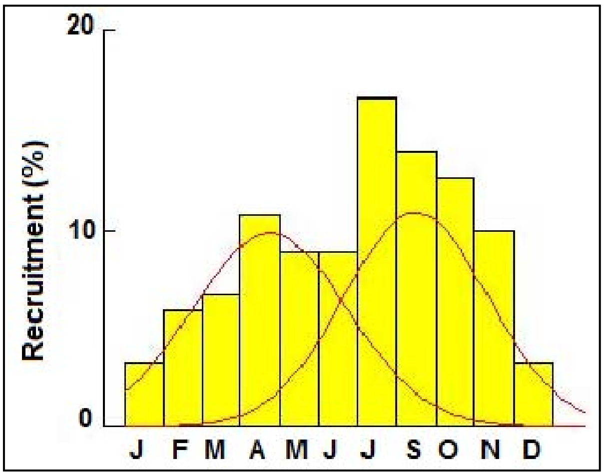

Fig 6: Recruitment pattern of *T. ilisha* in Iraqi marine water.

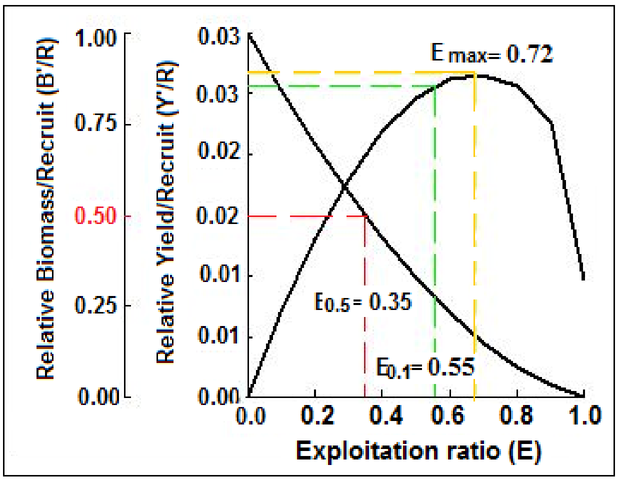

Fig 7: Relative yield per recruit and biomass per recruit curves.

3.6. Yield-per-recruit and biomass-per-recruit
The Beverton-Holt relative yield per recruit (Y'/R) and relative biomass per recruit (B'/R) estimated using selective ogive procedure are given in Fig. 7, the maximum catch (E_{max}) can be obtained when exploitation ratio is 0.72, whereas the current exploitation ratio is 0.67. The exploitation level which will result in a reduction of the unexploited biomass by 50% ($E_{0.5}$), was equaled 0.35. The yield isopleths are shown in Fig. 8, the yield contours predict the response of relative yield-per-recruit of the fish to changes in L_c and E; Lc/L∞ = 0.50 and E= 0.72.

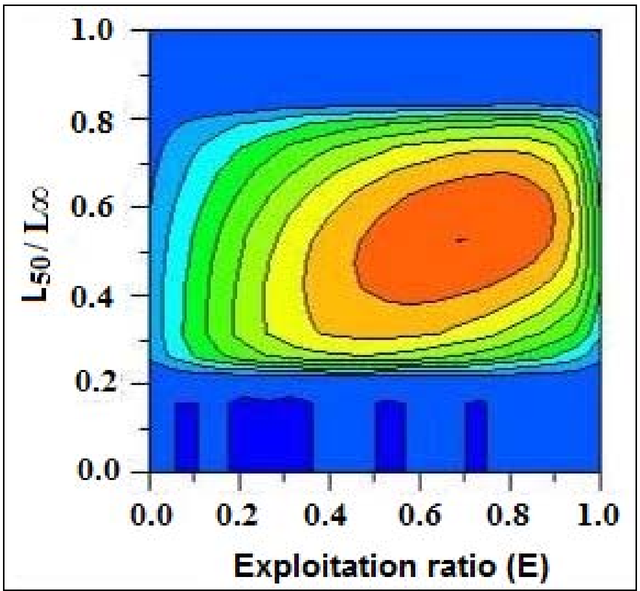

Fig 8: Yield isopleth diagram of *T. ilisha.*

4. Discussion
The population structure of *T. ilisha* in Iraqi marine waters indicates that over 93% of the catch was between 26 and 44cm of length, these fish are in the way to breeding grounds or back to the sea after spawning with their progenies. The spawning migrations of the species to Shatt Al-Arab River, east Hammar marsh and other rivers in south Iran have been documented by several authors viz. Hussein *et al.* [31, 32], Jabir [20], Al-Noor [33], Al-Hassan [34] and Roomiani and Jamili [19]. Al-Noor [33] stated that only mature individuals of *T. ilisha* ascend Shatt Al-Arab River during spawning season, and larvae and juveniles of the species were available along Shatt Al-Arab River. Also, Mohamed *et al.* [35] collected larvae of the species from the northern part of Shatt Al-Arab River (Al-Sindibad Island) from March to September. Mutlak [22] mentioned that the increasing of salinity in Shatt Al-Arab River during the last years pushing adult individuals of *T. ilisha* to enter east Hammar marsh for spawning, after it has been exploited by the species for nursery and feeding activities during 2005-2006 [36].

For comparison the published results of estimated growth and mortality parameters of *T. ilisha* derived from length frequency studies, are summarized in Table 1. It can be seen that estimated L_∞ obtained in this study is comparable to those in other waters, although is lower than the value recorded for females in Bangladesh waters by Haldar and Nurul Amin [11] and the value reported by Al-Sabbagh and Dashti [37]. The growth performance index (ø) was observed to be within the values mentioned by Al-Baz and Grove [17], Mohamed *et al.* [21] and Mutlak [22], and lower than those reported by other authors. The natural mortality rate (M) of the species is quite higher than the value mentioned by Al-Baz and Grove [17], and lower than those reported in other waters. The level of the fishing mortality rate (F) was considerably higher than those stated by Al-Baz and Grove [17], Mohamed *et al.* [21], Mutlak [22] and Dutta *et al.* [15], but lower than the values reported in other waters. Clearly, the exploitation rate (E) estimated in the present study agrees well with the values reported by Al-Baz and Grove [17] and Haldar and Nurul Amin [11] and higher than those recorded by Mohamed *et al.* [21], Ahmed *et al.* [12], Mutlak [22] and Dutta *et al.* [15]. However, it is slightly lower than the values estimated by Hashemi *et al.* [18] and Roomiani and Jamili [19]. The ecological differences, physiological conditions of fish, feeding variability, fishing pressure and data resources may be the reasons for the variation in these values in different regions [38].

The bimodal recruitment pattern observed for *T. ilisha* was also found for the same species in Shatt Al-Arab River by Jabir [20] and in northwest Arabian Gulf by Mohamed *et al.* [21]. So it is clear that the fishing mortality rate of *T. ilisha* was more than twice the natural mortality, which indicates that this species is now under intense fishing pressure. If the natural mortality and fishing mortality are equal, then the stock is supposed to be in a healthy state and an optimally exploited stock [28, 39]. This statement is also supported with the obtained relative yield-per-recruit (Y'/R) and relative biomass-per-recruit (B'/R) values. Both estimates indicated that the present level of exploitation rate (E=0.67) lower slightly than the maximum allowable limit based on the yield-per-recruit calculation (E_{max}), which was calculated to be 0.72. These findings suggest that the exploitation of this stock has approached from the maximum fishing level and thereby the present level of fishing mortality should be a great concern for the stock.

For management purposes, *T. ilisha* stock (s) in the north Arabian Gulf is certainly shared among Iraq, Iran and Kuwait [5]. Therefore, any actions on this stock by any country fleet may affect the landings in other countries [40]. *T. ilisha* stock from all countries is being exploited at a higher level than the optimum. Information about status of *the species* in Iranian waters indicated that the stock is overexploited, as E= 0.72 [19, 18]. Also, the stock in Kuwaiti water suffer from heavy exploitation, E= 0.67 [17]. Therefore, the regional co-ordination and co-operation in fisheries management is essential between these countries.

The present assessment shows that the marine *T. ilisha* stock is already heavily exploited and the current exploitation rate is very close to optimal exploitation that gives maximum yield per recruit and that increases in fishing effort and changes in size at entry were unlikely to increase the yield. Thus, either fishing effort should be reduced or size at first capture (L_c) should be increased, because L_c is already higher than size at first maturity (L_m). Morgan [41] indicated that the sheim (*Acanthopagrus latus*) fishery in Kuwait waters is producing the maximum yield per recruit at the current size at first capture and fishing mortality, and any changes in the existing situation will most likely result in a reduction in yield per recruit.

Comparing the yield isopleths diagram in this study with that of Pauly and Soriano [30] quadrants rule, the L_c/L_∞ of 0.50 and exploitation rate of 0.72 falls within quadrant D which implies that the smaller fish are caught at higher effort level.

Taxonomic studies confirmed that the *T. ilisha* in the marine waters and those enter Shatt Al-Arab River and its ramifications to breeding and nursery are one population [33, 42]. Therefore, the management policy must be taken in consideration the status of *T. ilisha* stock in Shatt Al-Arab River and to the upper stretches.
According to Jaber [20] who carried out a preliminary stock analysis for *T. ilisha* in Shatt Al-Arab River found heavy exploited for the species during their reproductive migration which was 0.8 and fishing mortality rates were 3.5 for males and 5.5 for females. Also, the stock was exposed to high exploitation rate, as 0.52 in their spawning and nursery grounds in east Hammar marsh [22]. He stated that illegal fishing methods employed include, use of explosives, poisons and small mesh sized nets. Added to this, small *T. ilisha* (Called Milat) are caught in large amount from north Shatt Al-Arab River and east Hammar marsh using small mesh nets during nursery period by artisanal fishers. These fish are sold cheaply on the local fish markets in Basrah Province together with large quantity of egg carrying females. Similarly, Nurul Amin *et al.* [10] mentioned that 19,000 t of small *T. ilisha* (Jatka) were captured in inland rivers in Bangladesh in early 2000s. The harvesting of these valuable resources at a stage when the individuals have reached only a small part of their growth potential seems to be a waste of biological resources, and probably will have a negative effect on the species population.

Table 1: Growth, mortality and population parameters of *T. ilisha* from different regions

Region	Fish length (cm	L∞ (cm)	K	ø	Z	F	M	E	Source
North Arabian Gulf, Kuwait	14.0 - 57.0	52.5	0.36	3.00	1.20	0.80	0.40	0.67	Al-Baz and Grove [17]
Northwest Arabian Gulf, Iraq	25.0 – 58.0	60.5	0.32	3.07	1.28	0.66	0.62	0.52	Mohamed *et al* [21]
Bangladesh waters ♂	20.0 - 46.0	51.5	0.53	3.14	3.08	2.07	1.01	0.67	Haldar and Nurul Amin [11] =
= ♀	20.0 - 52.0	65.6	0.51	3.34	2.87	1.95	0.92	0.68	
Bangladesh waters	-	58.5	0.71	3.28	2.61	1.39	1.22	0.53	Ahmed *et al.* [12]
North Arabian Gulf, Kuwait	-	63.0	0.40	3.20	2.16	1.44	0.72	0.67	Al-Sabbagh and Dashti [37]
Northwest Arabian Gulf, Iran	20.0-39.0	43.3	0.78	3.16	4.53	3.24	1.29	0.72	Hashemi, *et al.* [18]
Northwest Arabian Gulf, Iran	-	42.7	0.77	3.14	2.55	1.80	0.75	0.70	Roomiani and Jamili [19]
Bay of Bengal, India	15.5 - 41.5	47.8	1.90	3.64	1.98	0.73	1.25	0.37	Dutta *et al.* [15]
East Hammar marsh, Iraq	2.3 - 47.7	57.1	0.33	3.03	1.55	0.87	0.68	0.56	Mutlak [22]
Northwest Arabian Gulf, Iraq	12.2 – 48.0	61.5	0.275	3.02	1.66	1.11	0.55	0.67	Present study

Therefore, have to focus on the management of *T. ilisha* stock in the areas of migration reproductive as well as in nursery areas in the Shatt Al-Arab River, its branches and east Hammar marsh. We suggest the following administrative points to keep the species stock at least in Iraqi waters:

- Closed areas to protect spawning as well as recruitment of *T. ilisha*, these areas are Shatt Al-Arab River and East Hammar marsh during breeding by imposed a 30-day ban during May to protect spawning biomass.
- Small *T. ilisha* (Milat) (up to 23.0 cm size) catch, transportation, marketing, selling and possessing must be banned in the spawning and nursery areas.
- Pollution from domestic, industrial and agricultural sources continues to be a serious problem, and several water quality parameters were seasonally correlated with fish species catch.
- Regional co-operation in fisheries management is essential for Iraq, as well as for other countries in the region.

In conclusion, evidence abound that *T. ilisha* is over exploited in Iraqi waters, there is therefore urgent need to protect the stock through the concerted effort of fishers, communities and governmental agencies.

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