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RESEARCH ARTICLE

Population dynamics and the risk of stock extinction of Persian sturgeon (*Acipenser persicus* Borodin) in the Caspian Sea

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Abstract. Persian sturgeon, *Acipenser persicus* Borodin, has been the most significant proportion of Iranian commercial sturgeon catches in the Caspian Sea over in the last three decades. This endemic species has suffered continuous population declines from the impact of anthropogenic factors. The present study filled in information gaps on underlying population biology parameters, evaluated the population status, and determined the vulnerability risk of the stock extinction of Persian sturgeon in the south Caspian basin of Iran. Growth parameters were L_∞ = 224.7 cm, K = 0.058 years^{-1}, t_0 = -3.4 years. Sexual maturity of 50% for males and females was FL = 127.2 cm and 137.5 cm, respectively. The long-term age composition data showed 35 age groups, and the ages of 14–18 years comprised 80% of the total catch. Natural mortality was 0.123 years^{-1}, and fishing mortality ranged between 0.104 and 0.331 years $^{-1}$. The total biomass trend decreased and collapsed from 6,071.3 tons in 1990–91 to 144.1 tons in 2014–15. Although >93% of the catch included maturing specimens, the Persian sturgeon stock is now critically endangered because of several anthropogenic factors.

Keywords: growth parameters, fishing indicators, biomass, stock extinction, Persian sturgeon, Caspian Sea

Introduction

Several researchers report that anthropogenic effects are impacting all components of the Caspian Sea (Ganjian et al. 2010, Roohi et al. 2010, Pourang et al. 2016). It is revealed that the ecosystem shifted to new conditions (Beyraghdar Kashkooli et al. 2017), and the stocks of the leading pelagic component of the ecosystem (two species of kilka) are now critically endangered (Fazli et al. 2020). These pelagic fish species are the main food items for sturgeons (Prikhod'ko 1979). Persian sturgeon, *Acipenser persicus* Borodin is a bottom inhabitant that prefers sandy bottoms and fees mainly on invertebrates and fish species (Berg 1934). It also inhabits mainly the Iranian part of the sea and the rivers entering into it (Khodorevskaya et al. 1997, Holčík 1989). It is also the highest proportion of the total catch of sturgeons

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Table 1
Annual changes in catch and sample size of Persian sturgeon (*A. persicus*) in Iranian waters of the Caspian Sea (1990–2015)

Year	Catch (tons)	n	Sample size (n)
1990-91	554.5	21042	6211
1991-92	704.8	27321	7923
1992-93	559.7	21923	6431
1993-94	415.0	15706	3425
1994-95	409.0	15549	3508
1995-96	386.5	15177	3174
1996-97	488.3	18891	3797
1997-98	448.3	17407	4302
1998-99	547.4	21609	3614
1999-00	439.9	17519	3098
1999-00	448.5	17881	3358
2000-01	564.7	22259	4921
2001-02	448.2	17612	4421
2002-03	349.0	13131	3956
2003-04	200.0	7328	4078
2004-05	108.0	4245	3708
2005-06	201.0	7527	2827
2006-07	91.8	3414	2035
2007-08	97.6	3767	1336
2008-09	78.2	3009	926
2009-10	51.0	2024	695
2010-11	39.7	1616	581
2012-13	39.6	1758	462
2013-14	29.5	1316	383
2014-15	21.5	946	336

in the last three decades (Moghim et al. 2006, Tavakoli et al. 2018).

Catches of Persian sturgeon increased from 554.4 tons in 1990–91 to 704.8 tons in 1991–92 and then declined to 559.7 tons in 1992–93. The catch remained relatively stable from 1992–93 to 2002–03 when the trend decreased and collapsed to the lowest level in 2014–15 (21.5 tons, Table 1). Moghim et al. (2006) summarizes the history of Persian sturgeon catches. They mention that stocks and catches fluctuated strongly in the last century. In Iran, the catch declined from 51,800 individuals between 1900 and 1915 to 17,000 individuals in 1952–57, and according to Ralonde and Griffiths (1972), catches collapsed to 1,728 individuals in 1972 (Moghim et al. 2006). Finally, during 1990–2001, catches increased to 15,000–25,000 individuals per year. They also report that the catch rate increased from 0.324 kg in 1972 to more than 3.0 kg day ×100 gillnets^{-1} in 1990–2001, and the bottom trawl CPUE (catch per unit effort) increased from 0.88 to 0.49 specimens per trawl in 1989–91 to 5.08 in 2004 in the south and middle Caspian (Moghim et al. 2006). Whereas most Caspian Sea sturgeons stocks sharply declined, because of this increasing trend they conclude that after the collapse in the 1970s, the Persian sturgeon has stock increased slightly in the last 30 years and now seems to be reasonably stable.

Previous studies on the biology of the Persian sturgeon are limited to some biological characteristics (Bakhalizadeh et al. 2011, Tavakoli et al. 2018) and feeding habits (Haddadi Moghadam et al. 2009). Data on the population structure and stock status are also scarce. Moghim et al. (2006) analyzed the catch and CPUE of sturgeons in the Caspian Sea. According to Khodorevskaya et al. (2014), sturgeon species have suffered continuous population reductions caused by anthropogenic factors in the Caspian Sea. Despite the significant importance of the species in the Caspian ecosystem, little is known about population parameters or the status of stocks of this fish. On the other hand, a new invasive species (*Mnemiopsis leidyi*) is affecting all components of the ecosystem and especially stocks of bottom and pelagic fish species (Ivanov et al. 2000, Fazli et al. 2009, 2013, Pourang et al. 2016). Therefore, the main objectives of this study were to (1) fill in gaps in information on primary population parameters, (2) describe stock status and management, and (3) provide a quantitative method for assessing the extinction vulnerability of Persian sturgeon based on population parameters in the Caspian Sea.

Methods

Study area and sampling

Fish samples were collected from Iranian commercial fisheries (deploying gillnets and beach seines) in 1990–91 and 2014–15. A total of 79,506 Persian sturgeon individuals were sampled and analyzed (Table 1). Total catches of Persian sturgeon were collected and recorded by the Iranian Fisheries Organization (Table 1). During the sampling period, fork length (FL) and body weight (W) were measured to the nearest cm and the nearest 100 g, respectively. According to Brennan and Cailliet (1989), pectoral fin sections are the most practical aging structure in terms of ease of collection, processing, legibility, and precision of interpretation. Thanks to these advantages, pectoral fin sections are the most practical aging structure for sturgeons, and Stevenson and Secor (2000) recommend using fin spines rather than otoliths. Therefore, in the present study, fin ray sections (n = 52,925) were used to determine the age structure of Persian sturgeon. The fin ray sections were prepared by removing approximately 3 cm of the left pectoral fin ray at the point of articulation with a hacksaw. The fin rays were air-dried, and approximately 0.5 mm thick sections were cut with a two-bladed jeweler's saw. Then these sections mounted in glycerine and examined with a binocular microscope. Catch at age compositions were deduced from the length structure of fish and age-length key data. After visual sex determination, the maturity stages were distinguished according to the six-stage maturity scale by macroscopic examination as described by (Moghim et al. 2002).

Analysis

The fork length (FL) and bodyweight (W) relationship were obtained by $W = aFL^b$ (Ricker 1975), where a and b are parameters.

Growth in length with the age of Persian sturgeon was fitted to the growth equation (von Bertalanffy 1938):

$$L_t = L_\infty (1 - e^{-k(t-t_o)})$$

where L_t is the length at age t, K is the growth coefficient, L_∞ is the theoretical maximum length, and t_0 is the L_∞ hypothetical age when L_t = 0. The TropfishR package in R software was used to estimate the growth parameters (Mildenberger et al. 2017).

Natural mortality (M) was calculated with two empirical methods. The first was the Pauly method (Pauly 1980) with growth parameters:

$$L_n(M) = a_1 + b_1 \ln(L_\infty) + b_2 \ln(k) + b_3 \ln(T)$$

where a_1, b_1, b_2 and b_3 are constants (-0.0152, -0.279, 0.6543 and 0.463, respectively), and T is the average of habitat temperature, T=16.5°C (Nasrollahzadeh 2013). The second was the Alagaraja model (Alagaraja 1984):

$$M = \frac{4.6}{t_m}$$

where t_m is the maximum age.

Length at 50% maturity (L_m) was estimated for individuals collected during March-April that were classified as maturity stage IV. The parameters were estimated using the non-linear regression by Saila et al. (1988):

$$P = \frac{1}{1 + e^{(-r(L - L_m))}}$$

where P is the proportion of mature individuals in each length group, r is a parameter, and L_m $L_m = a/r$ is an intercept.

The catch curve method (Ricker 1975) was applied to calculate the survival rate (S) by using the age compositions in catches from 2010–11 to 2014–15. The total mortality (Z) and terminal fishing mortalities (F_T) were calculated:

$$Z = -\ln S$$

$$F_T = Z - M$$

The age at first capture (t_c, the age at which 50% of the fish at that age are vulnerable to capture) was calculated using a length-converted catch curve corresponding to age with the growth equation (Pauly 1984).

Zhang and Sullivan's (1988) cohort analysis model was applied to calculate biomass and fishing mortality. The biomass of the last year and the last age-class (B_t) was estimated:

$$B_t = \frac{C_t (F_t + M - G_t)}{F_t (1 - e^{-(F_t + M - G_t)})}$$

and for other cases:

$$B_{ij} = B_{i+1\,j+1} e^{(M - Gj)} + C_{ij} e^{(M - G_j)/2}$$

Fishing mortality was calculated:

$$F_{ij} = \ln(\frac{B_{ij}}{B_{i+1\,j+1}}) - M + G_j$$

where C_t is the catch (in weight) at the last age-class and last year, G_j is the coefficient of growth at age j, B_{i+1j+1} is the biomass at age j+1 in year i+1, and C_{ij}, B_{ij} and F_{ij} are the catch in weight, biomass, and fishing mortality at age j in year i, respectively. G_j was estimated:

$$G_j = \ln(\frac{W_{j+1}}{W_j})$$

where W_j is the weight of fish at age j, and W_{j+1} is the weight at j+1.

The exploitation ratio (E) was calculated as F/Z and the annual fishing and total mortality, respectively (Ricker 1975).

The stock status was assessed using three indicators based on the length of fish in the catches (Froese 2004): (I) percentage of mature individuals (>$L_{m50\%}$); (II) frequency of fish at ± 10% optimum length (L_{opt}), (III) frequency of fish with lengths greater than L_{opt} plus 10% were designated as mega-spawners. L_{opt} was calculated using the growth parameters (using L_∞, M, and K) (Beverton 1992):

$$L_{opt} = \frac{3L_\infty}{(3 + \frac{M}{K})}$$

Nine IUCN Red List categories and criteria were used to consider the extinction risk of the sturgeon. The criteria related to population reduction (criteria A) were applied to categorize the risk of extinction (IUCN 2017). Generally, reproductive potential is closely related to body size in many marine fish species. Since biomass is an index of abundance (IUCN 2017), the biomass of mature individuals of Persian sturgeon was used when applying criterion A, and intricate pattern decline was used to explain stock reductions. The proportional rate of population mature biomass declines (Reduction = R) was calculated:

$$R = 1 - (\frac{B_2}{B_1})$$

where $B2$ is the biomass of mature individuals for the last year (2014–15), and $B1$ is the biomass of mature individuals before overexploitation. We assumed that the decline of the population before overexploitation was zero. An exponential regression was applied to explain the reduction of the population of Persian sturgeon. The generation length (G, the average age of parents) was calculated (IUCN 2017):

$$G = \frac{1}{AM} + AFC$$

where *AM* is adult mortality = *M*, and *AFC* is the age at first reproduction.

Excel 2013 software was used to calculate fishing mortality, biomass, generation length, and stock reduction.

Results

Length and age structure

The results showed that the *FL* and W of Persian sturgeon varied from 92 to 231 cm and 4.5 to 96 kg and averaged (± SD) 150.3 (± 15.6) cm and 25.85 (± 8.41) kg, respectively (Table 2). The *FL-W* relationship was: $W = 0.0067FL^{3.0205}$ ($R^2 = 0.79$, b = 0.0066, a = 2.2^{-4} and n = 52928). The slopes of the *FL-W* regression were not significantly different from 3 ($P > 0.05$). Fin ray section analysis showed that the ages ranged from 6 to 40 years (Table 1), the earliest growth occurred during the first 6 years of life, then increased slowly up to 20 years (Fig. 1). The growth parameters L_∞, K, and t_0 were 224.7 cm ± 3.14 (SE), 0.058 years^{-1} ± 0.003, and -3.4 years ± 0.45, respectively. In the catch compositions, ages 15-16 were the highest age groups in the years from 1990 to 2014 (except 2014-15) and accounted for 14.2-23.6% of catches (Fig. 2). In 2014-15, the age of 14 comprised 15.3%. In general, age groups 14-18 years comprised about 80% of the total catch. Based on the maturity give of females and males, 50% of individuals were sexually mature at *FL* of 137.0 and 127.2, respectively (Fig. 3). Also, mature gonads were present in 5, 82, and 100% of females and 33%, 86%, and 99% at ages 10, 15, and 20 for males, respectively (Table 2).

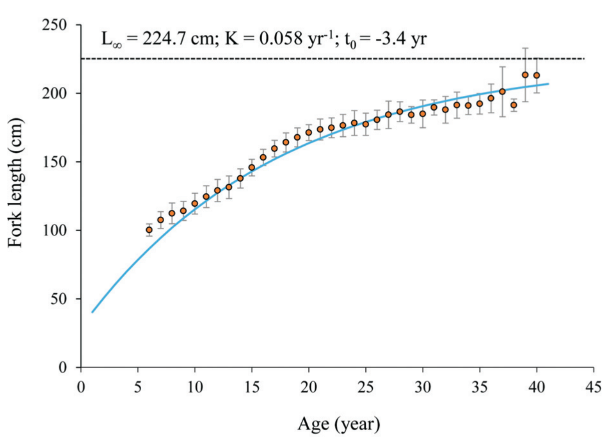

Figure 1. Theoretical growth curve for fork length of Persian sturgeon (A. *persicus*) in the Caspian Sea.

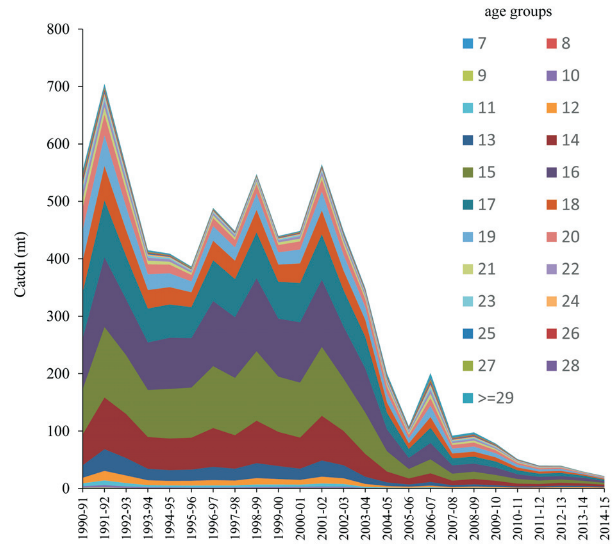

Figure 2. Catch at age of Persian sturgeon (*A. persicus*) in Iranian commercial catches in 1990–2015.

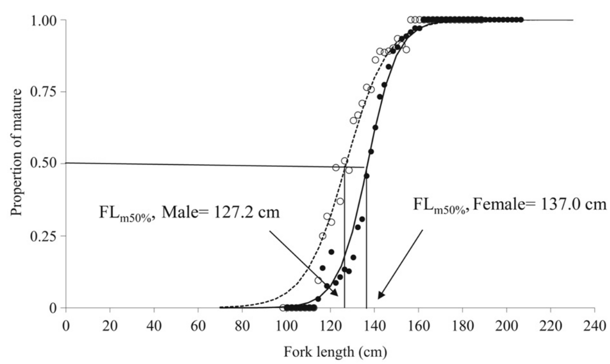

Figure 3. Persian sturgeon (*A. persicus*) female and male maturity ogive by length in the Caspian Sea.

Mortality and stock assessment

The annual survival rate (*S*) and total annual mortality (*Z*) were 0.708 and 0.346 years^{-1}, respectively. The natural mortality rates (*M*) obtained from the Pauly and Alagaraja methods were 0.123 and 0.115 years^{-1}, respectively. The M = 0.123 years^{-1}

Table 2
Average fork length, weight, and maturity at age of Persian sturgeon (*A. persicus*) in Iranian waters of the Caspian Sea (1990–2015)

		Fork length (cm)		Weight (g)		Maturity (%)	
Age	N	Mean	SD	Mean	SD	Female	Male
6	8	100.3	4.4	6.63	1.81	0	7
7	17	107.5	6.2	7.54	2.36	1	12
8	41	112.4	7.6	8.54	2.37	2	19
9	144	114.2	6.9	9.36	2.09	3	21
10	425	119.5	7.6	11.61	2.88	5	33
11	856	124.6	7.9	13.25	3.47	11	44
12	1702	129.1	8.1	14.83	3.61	18	57
13	3814	131.4	8.2	16.46	3.78	27	63
14	8937	137.9	7.0	19.57	3.76	56	75
15	11652	145.8	6.0	23.65	4.02	82	86
16	10209	153.2	5.9	27.65	4.21	93	93
17	6374	159.6	6.1	31.03	4.33	97	95
18	3155	164.1	6.9	33.51	4.90	98	96
19	2418	167.8	6.9	35.03	5.05	99	97
20	1446	171.3	5.8	37.62	4.93	100	99
21	476	173.6	7.7	39.53	5.00	100	100
22	398	174.8	7.2	40.41	4.89		
23	245	176.4	8.2	41.80	6.02		
24	149	178.3	9.1	42.69	5.62		
25	126	177.4	8.1	42.62	6.48		
26	97	180.6	7.0	44.34	6.62		
27	83	184.3	10.0	48.20	10.46		
28	42	186.6	7.2	49.95	8.42		
29	19	184.3	6.0	49.95	10.55		
30	26	185.0	10.1	46.55	8.02		
31	6	189.7	5.5	53.98	8.42		
32	12	188.0	9.7	49.76	8.15		
33	14	191.4	9.5	50.57	9.97		
34	4	191.0	6.5	51.35	7.07		
35	3	192.3	7.5	61.67	15.95		
36	10	196.3	10.5	60.24	12.24		
37	7	201.1	18.2	64.94	17.82		
38	3	191.3	4.5	59.90	10.34		
39	5	213.4	19.6	71.50	21.18		
40	2	213.0	12.7	61.70	19.37		
Total	52925	150.3	15.6	25.60	8.10	-	-

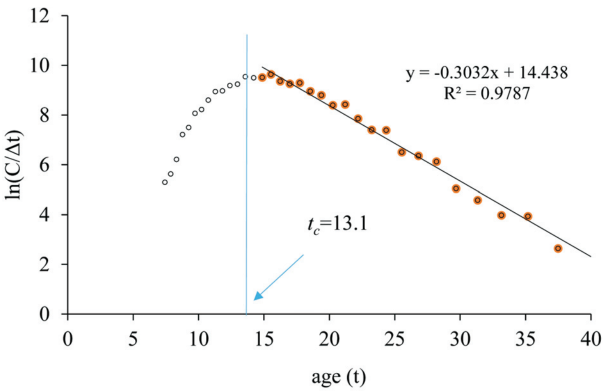

Figure 4. Estimated selection ogive of Persian sturgeon (*A. persicus*) from length converted catch curve analysis using the Pauly (1984) method.

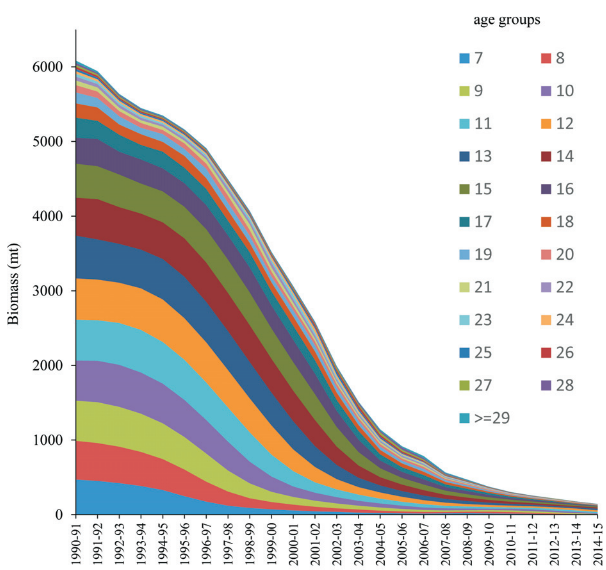

Figure 5. Biomass at age of Persian sturgeon (*A. persicus*) in Iranian waters of the Caspian Sea in 1990–2015.

from the Pauly method was chosen since it uses more information. The age at first capture (t_c) was calculated as 13.1 years (Fig. 4). Persian sturgeon biomass indicated a decreasing trend in the 1990–2015 period (Fig. 5). The total biomass decreased from 6071.3 tons in 1990–91 to 4903.7 tons in 1996–97, and then it collapsed to 564.5 tons in 2007–08. Finally, in 2014–15 it collapsed to the lowest level of 144.1 tons. In this period, the mean biomass of ages 14 and 12 depicted the highest proportion of total biomass at 10.29 and 12.28%, respectively. Annual fishing mortality (*F*) ranged between 0.104 and 0.331 years^{-1}, with a high *C.V.* of 0.32 (Table 3). The

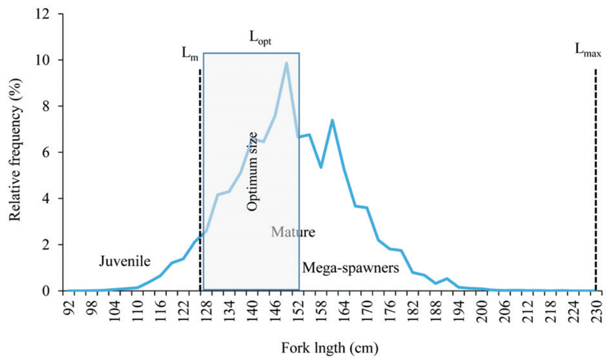

Figure 6. Length–frequency of Persian sturgeon (*A. persicus*) caught between 1990 and 2015 in Iranian waters of the Caspian Sea. L_m indicates length at first maturity, L_{opt} indicates the length range where optimum yield could be obtained, and L_{max} is the maximum recorded size.

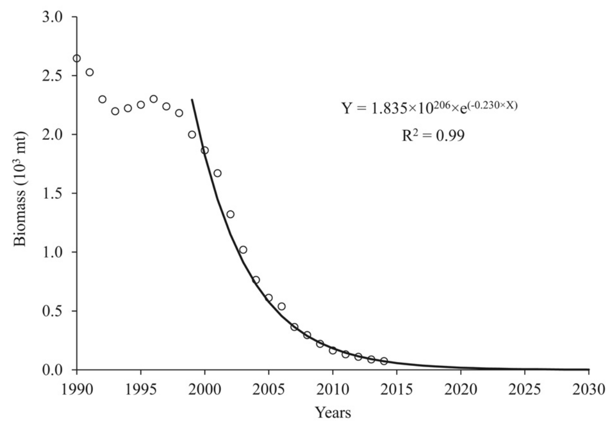

Figure 7. Population, mature biomass, and exponential reduction of Persian sturgeon (*A. persicus*) in Iranian waters of the Caspian Sea in 1990–2015.

exploitation ratios of Persian sturgeon were calculated with the estimates of *Z* and *F* and ranged between 0.46 and 0.73 (Table 3).

Stock status

Persian sturgeon juveniles represented about 7%. Also, the L_{opt} range and mega-spawners comprised 46 and 47% of the total catch, respectively (Fig. 6). The generation length of Persian sturgeon was estimated at 20 years. Based on ICUN criterion A, during 1990–2015, the proportional rate of mature population biomass showed an exponential reduction that indicated that the population will be close to zero in the next few years (Fig. 7). Under criterion A, with

Table 3
Estimated instantaneous fishing mortality and exploitation ratio of Persian sturgeon (*A. persicus*) in Iranian waters of the Caspian Sea (1990–2015)

Year	F	E
1990-91	0.191	0.61
1991-92	0.222	0.64
1992-93	0.197	0.61
1993-94	0.142	0.53
1994-95	0.126	0.50
1995-96	0.104	0.46
1996-97	0.127	0.51
1997-98	0.115	0.48
1998-99	0.144	0.54
1999-00	0.123	0.50
2000-01	0.138	0.53
2001-02	0.204	0.62
2002-03	0.206	0.62
2003-04	0.208	0.63
2004-05	0.181	0.59
2005-06	0.119	0.49
2006-07	0.331	0.73
2007-08	0.198	0.62
2008-09	0.281	0.69
2009-10	0.298	0.71
2010-11	0.247	0.67
2011-12	0.231	0.65
2012-13	0.271	0.69
2013-14	0.233	0.65
2014-15	0.226	0.65
Min	0.104	0.46
Max	0.331	0.73
Mean	0.194	0.60

a reduction rate exceeding 97% this species can be classified as Critically Endangered.

Discussion

The present study showed that the biomass of Persian sturgeon declined from 6,071.3 tons in 1990–91 to 564.5 tons in 2007–08, and then it reached the lowest levels in 2014–15 (144.1 tons; Fig. 6). A similar reduction in CPUE was observed for Persian sturgeon from 1.43 in 2004 to less than 0.17 specimens per trawl in 2010 in the southern Caspian (Moghim et al. 2006, Tavakoli 2018).

Although this species widely distributed throughout the Caspian Sea, according to the CITES Secretariat (2002), *A. persicus* is endemic to the southern Caspian Sea basin and rarely migrates to the other parts of this sea. Moghim and Valinasab (2001) also report that this species is concentrated in Iranian waters, and no specimens have been recorded in the northern part of the sea. At the Volga and Ural rivers it comprised less than 4.0% of total sturgeon catches (Lagunova 2001). Therefore, the stocks estimated in this study include most of the population of this species in the Caspian Sea.

In the 1990–2015 period, the exploitation ratio of Persian sturgeon was more than 0.5 (except, in 1995–96, 1997–98, and 2005–06), which is higher than the maximum harvest rate of 0.5 (Gulland 1983). Based on these results, overfishing could be one of the reasons for the biomass reduction of this species. This species is slow-growing and long-lived. The maximum recorded age of Persian sturgeon varies significantly. In the Caspian Sea, the maximum recorded ages in the Volga (Babushkin and Borzenko 1951) and Kura rivers were 38 and 48 years, respectively (cited in Bakhshalizadeh et al. 2011). Age groups 13 to 24 for males and 19 to 30 for females from the Volga River and age groups 14 to 23 years old from the Kura River comprised 70%, 66%, and 82% of the catch composition. According to Bakhshalizadeh et al. (2011), the maximum recorded age was 39, while 70% of females and 86% of males were between 15 and 27 years old. In the present study based on more than 52,000 samples over an extended time period, the catch at age composition comprised 35 age groups (6–40 years) and 66–86% (averaged 80%) of individuals were 14 to 18 years old.

The L_∞ and K of growth parameters were 224.7 cm, and 0.058 years^{-1}, which confirmed previous studies reporting on this species in the Caspian Sea. Previous studies showed that 50% of specimens were sexually mature at *FL* of 137.0 and 127.2 for females and males, respectively, and mature gonads at ages

10, 15, and 20 years old were noted in 5%, 82%, and 100% for females and for 33%, 86%, and 99% for males, respectively. The t_c of Persian sturgeon was estimated to be 13.1 years.

Furthermore, the Sefidrood, Tajan, and Gorganrood rivers are the main spawning grounds of this fish in the Iranian basin of the Caspian. According to Fadayee et al. (1999) and Lalouie (1996), few Persian sturgeon ascended these rivers, and these researchers never observed or reported juveniles from natural reproduction. Fadayee et al. (1999) also failed to find any signs of natural reproduction; this stemmed from poaching and spawning ground deterioration in the Sefidrood River. According to Moghim et al. (2006), the mean number of Persian sturgeon fingerlings from hatcheries released increased from 2.2 million in 1973–93 to more than 14 million specimens from 1994 to 2003. Therefore, they report that current catches of this sturgeon come mainly from stock enhancement programs and concluded that due to the recent sharp increase in the number of fish released, higher catches could be expected in the next decade, while, according to the present study, catches of Persian sturgeon collapsed to their lowest levels after 2010 (Fig. 3).

The second reason for this reduction is ecosystem change. *Mnemiopsis* leidyi, a new invasive species, influenced all components of the sea (Ganjian et al. 2010, Roohi et al. 2010, Pourang et al. 2016), but especially the zooplankton of two pelagic kilka species. According to Fazli et al. (2020), based on ICUN criteria, the stocks of *Clupeonella engrauliformis* (Borodin) and *Clupeonella grimmi* Kessler are critically endangered. These pelagic fish species are the main food for sturgeons and seals (Prikhod'ko 1979). Therefore, the other reason for this reduction could be habitat loss and decreased food resources.

The fork length distribution of the Persian sturgeon was assessed with three simple indicators. Based on indicator I, 100% of the fish caught should be mature individuals (Froese 2004). The results of the present analysis indicated that >93% and <7% of the catch included maturing specimens and juveniles, respectively, while, based on Indicator II, catches of individuals that were mature and optimum in length comprised 93%. Finally, 47% of the fish caught were mega-spawners. Froese (2004) reports that percentage of mega-spawners in catch, with 0% as target, and 30-40% as representative of reasonable stock structure if no upper size limit exists. Kiabi et al. (1999) classified 65 native fish species into IUCN Red List Categories based on data collected in the south Caspian Sea basin of Iran. They report that four anadromous taxa are critically endangered from overfishing, spawning ground deterioration, and restricted habitat. We found the Persian sturgeon to be critically endangered. A similar reduction in stocks is reported for the Russian sturgeon (Tavakoli et al. 2019), and Khodorevskay et al. (2014) hypothesize that all populations of sturgeon species are close to extinction because of anthropogenic factors. Moreover, most commercial endemic and native fish species such as *C, engrauliformis* and *C. grimmi* (Fazli et al. 2020) and five species of sturgeons (CITES and UNEP 2017) are vulnerable or critically endangered in the Caspian Sea.

In conclusion, Persian sturgeon is a slow-growing, long-lived species with a life expectancy of about 40 years. Male and female sexual maturity beings at age 6 and 7 years, but the bulk of fish (more than 80%) reach it at 15 years old. More than 93% and 47% of catches were of mature and mega-spawner individuals, respectively, which indicated that the population structure was healthy. If the fishery reopens, the minimum fork length limit should be about 130 cm. During the 1990–2015 period, overfishing and several anthropogenic factors affected Persian sturgeon stocks, which is why this species is critically endangered in the Caspian Sea.

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