Oceanological and Hydrobiological Studies

International Journal of Oceanography and Hydrobiology

Volume 50, No. 3, September 2021
pages (325-332)

sciendo

ISSN 1730-413X
eISSN 1897-3191

Demographics of great sturgeon (*Huso huso*) in Iranian waters of the Caspian Sea (2008–2010)

by

Shima Bakhshalizadeh[1,*],
Ali Bani[1,2],
Shahram Abdolmalaki[3],
Jesus T. Ponce Palafox[4]

DOI: **10.2478/oandhs-2021-0027**
Category: **Original research paper**
Received: **December 21, 2020**
Accepted: **February 12, 2021**

[1]*Department of Marine Science, Caspian Sea Basin Research Center, University of Guilan, Rasht, Iran*

[2]*Department of Biology, Faculty of Science, University of Guilan, Rasht, Iran*

[3]*International Sturgeon Research Institute, Agricultural Research, Education and Extension Organization (AREEO), Rasht, Iran*

[4]*National School of Fisheries Engineering, Autonomous University of Nayarit, Nayarit, Mexico*

* Corresponding author: shima@phd.guilan.ac.ir

Abstract

Demographic data of the great sturgeon, *Huso huso*, from the Iranian coastal waters of the Caspian Sea were derived from measurements of individuals with a fork length ranging from 84 to 255 cm, obtained from commercial fisheries. The maximum age of fish caught in the south Caspian Sea was 30 years. The estimates of the asymptotic length L_∞ and the growth coefficient (K) were 265.255 cm and 0.062 per year for males and 275.78 cm and 0.08 per year for females, respectively. Total mortality rates obtained by Gulland's method were larger for males (0.64) than for females (0.46). Annual mortality rates were calculated as 47% for males and 37% for females. Data obtained in this study and their comparison with data from previous studies indicate that the great sturgeon stock is definitely exploited in an unsustainable manner.

Key words: age, growth, mortality, management, population dynamics

online at www.oandhs.ug.edu.pl

1. Introduction

The great sturgeon *Huso huso* is one of the most important sturgeon species in the world, occurring in the Caspian Sea, the Black Sea and the Sea of Azov (Ta'ati et al. 2011). It is the main species of sturgeons bred in Iran (Kazemi et al. 2014) and many other countries for meat and caviar production (Williot et al. 2000; Boscari et al. 2017). However, the combination of the species' life cycle characteristics (long-lived, late-maturing and anadromous fish) with environmental degradation of water basins, water-level fluctuations, water pollution, damming of their spawning rivers, overfishing (including extensive poaching), poor fisheries management, intensive and selective illegal and unreported fishing, failure to protect their nursery grounds, and lack of regulation during the past 50 years have resulted in a drastic reduction in catches (Karayev 2006; Graham & Murphy 2007; Tavakoli & Khoshghalb 2018; Mirrasooli et al. 2019), thereby negatively impacting the fishing industry of this species from fishermen to consumers.

This fish is common in commercial catches from the Iranian coastal waters of the Caspian Sea, accounting for less than 40% of the total sturgeon catch (WCMC 2010). Sturgeons tend to have a vulnerable and long life cycle, maturing at an advanced age (10 to 18 years) and spawning every 3 or 5 years with a generation duration of 20–25 years (Onara et al. 2014). Males spawn more intensively in a shorter time than females and reach sexual maturity 2–3 years before females (Holčík 1989). Males are caught more frequently in the inshore and estuarine waters because they spend more time reproducing in these habitats than females.

At present, there are many problems that affect the sustainable management of sturgeon populations from the Iranian coastal waters of the Caspian Sea. Therefore, different models of population dynamics are required to reflect the status of sturgeon populations, the consequences of overexploitation and aspects related to environmental pressure (Karayev 2006; Bakhshalizadeh et al. 2020). New approaches have emerged that combine aspects of ecosystem analysis and cognitive theory, such as those developed by Karayev (2006). The beluga fishery in the Caspian Sea is maintained through a stock enhancement program (Ustaoglu & Okumus 2004). In other areas (Danube River), beluga populations were found to continue to decline, showing long-term changes in their structure and size (Rosten 2012; Sandu et al. 2013). The Islamic Republic of Iran uses the catch per unit effort (CPUE) to asses the *H. huso* stock and determines total allowable catch limits based on these estimates (Ustaoglu & Okumus 2004; Mirrasooli et al. 2019). This method has been used to adjust the total allowable catches (TACs). However, more long-term data on population parameters along with analysis of behavior, age, growth and mortality of *H. huso* as well as their comparison with recent data are required. The objectives of this study were to estimate the age, to study the somatic growth, to determine the age structure and to estimate the mortality rate of great sturgeons collected between 2008 and 2010.

2. Materials and methods

2.1. Study sites and sampling

The great sturgeon, *Huso huso*, was collected from commercial fisheries carried out in the Iranian coastal waters of the Caspian Sea (Fig. 1) between October 2008 and June 2010. A total of 194 individuals were collected with anchored gillnets and 140 with a beach seine. The gillnets were 18 m long (64 meshes) and 0.8 m deep (8 meshes), with a mesh size (knot to knot) of 280 mm. The length of the beach seine was 1500 m,

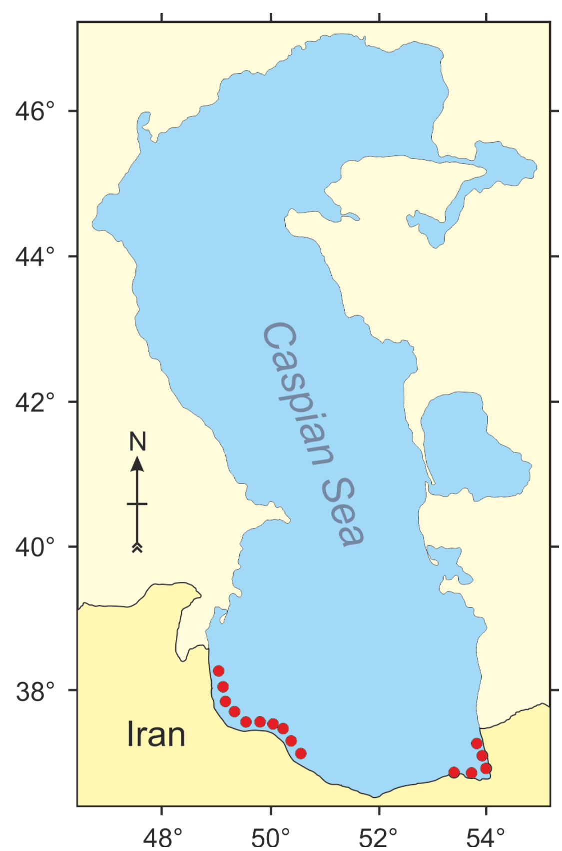

Figure 1

Sampling locations (red closed circles) of sturgeon in the Iranian coastal waters of the Caspian Sea the mesh size at the code end was 33 mm, and the height was 10–15 m. The height of the beach seine net was 10–15 m and the wings of the net were tapered to reduce the overall mass of the net. The net was deployed in a U-shaped line using a boat at a distance of 2000–5000 m from the shore and almost parallel to the shoreline. The net was hauled to the shore using a tractor.

After all samples were sacrificed, gutted weight (W) in kg and fork length (FL) in cm were measured for each fish. The sex and the development stage were determined by the examination of gonads. Right pectoral fin spines were removed for the purpose of age analysis (Rien & Beamesderfer 1994).

2.2. Preparation and interpretation of pectoral fin spines

Preparation and interpretation of fin spine sections were carried out according to the procedure used for sturgeons by Bakhshalizadeh et al. (2011). Images were used to estimate ring counts in the end spine sections. The age of all samples (194) was estimated by direct reading and estimates from the images. The variability of within-reader age estimates was calculated using the absolute percentage error (APE) between ring counts according to Beamish & Fournier (1981). To determine differences and precision of the estimated age, we used the T test and the coefficient of variation (CV), respectively, as indices of precision (Chang 1982). Differences in frequencies in the age distribution were determined by the Chi-square test of independence.

2.3. Growth estimates and curves

The length–weight relationship was analyzed by the function $W = a\ FL^b$ (Ricker 1975): where *W* is the gutted weight, "*a*" and "*b*" are regression constants and *FL* is the fork length. The condition factor (*CF*) was estimated as $CF = W/FL^b$, and the comparison of *CF* between the sexes was achieved using the ANOVA test (Saberowski & Buchholz 1990). The length and weight of the great sturgeon were compared with the results from the previous study (Taghavi-Motlagh 2001) carried out in the south Caspian Sea, using Student's one sample t-test. Finally, the von Bertalanffy growth function was fitted to the observed size-at-age data using the Fishparm program based on a nonlinear model with the least-square estimation (Saila et al. 1988). It has been determined that the population of great sturgeon in the study area is very homogeneous (Dudu et al. 2014), therefore data from different locations in the south Caspian Sea were pooled in this study.

2.4. Mortality

The following formula was used (Gulland 1983) to estimate the annual instantaneous total mortality coefficient (*Z*):

$$Z = \frac{K\left(L_\infty - \bar{L}\right)}{\left(\bar{L} - L'\right)}$$

where *Z* is the instantaneous total mortality coefficient, *K* is the shape parameter from the von Bertalanffy growth equation, $L\infty$ is the length at infinity from the von Bertalanffy growth equation, $\bar{L}$ is the mean fork length at capture and *L´* is the length at which all fish of this length and longer are fully exploited. Following the calculation of *Z*, annual mortality was calculated using the following formula:

$$A\,(\%) = 100\,(1 - e^{-z}),$$

where A is the annual mortality and e is the base of natural logarithms. Thus, the survival rate using the formula according to Ricker (1975) is as follows:

$$S(\%) = 100 - A \qquad \text{(King 2013)}$$

where *S* = survival.

2.5. Statistical analysis

Statistical analyses and plotting of the data were performed using the STATISTICA (Version 5.5), Sigma plot (Version 2000) and Excel (Version 2016) software packages.

3. Results

A total of 194 individuals were sampled, including 111 males and 83 females. The sex ratio of 1:0.75 was significantly different from the 1:1 ratio (χ^2 = 1.5, n = 105). The mean *FL* of males was 194.17 ± 8.10 cm (mean ± SE) with a range of 84 to 255 cm, while the mean *FL* of females was 224.17 ± 7.06 with a range of 84.0 to 305 cm (Table 1). The mean *FL* of males was not significantly different from that of females (Mann–Whitney U test, n = 105, *p* = 0.08). The mean total weight was 69.77 ± 6.72 for males with a range of 4 to 141 g, while the mean W of females was 111.26 ± 10.70 g with a range of 4 to 287 g. The mean W was significantly different between the two sexes (Mann–Whitney U test, n = 105, *p* = 0.03).

Table 1

Descriptive length and weight composition of male and female great sturgeon from the Iranian waters of the Caspian Sea in 2008–2010

Size	Sex	Number	Mean	Standard error of the mean	Minimum	Maximum
Fork Length (cm)	Female	33	214.17	7.06	84	305
	Male	24	194.17	8.10	84	255
Weight (kg)	Female	33	111.26	10.70	4	287
	Male	24	69.77	6.72	4	141

The relationship between length and weight was expressed for each sex using a power regression (Fig. 2). The data revealed that only females were characterized by positive allometric growth. The effect of sex on the length–weight relationships was significant (ANCOVA, n = 105, $p < 0.05$). The condition factor (*CF*), expressing feeding activity during the year, was significantly different between the two sexes ($p < 0.001$).

To compare the age of the great sturgeon, the results obtained by direct reading and imaging were compared, finding no significant differences between the two techniques and the APE was 0.95%. During the study period, a mean of 21 and 20 years was determined with an interval of 5 to 30 years and 5 to 25 years for females and males, respectively (Fig. 3). There were no significant differences ($X^2 = 1.445$, df 2, $p = 0.18$) in the age–frequency distributions for males and females. A higher proportion of females than males was found in the 18- and 19-year-old classes. It was determined that 73% and 71% of the fish caught were less than 25 years old for females and males, respectively, and the proportion of fish under 8 years old was low (Fig. 3). The age range for the fish caught was 5 to 30 years and the age classes of 17 to 25 years had the highest proportion, with 70% and 83% for females and males, respectively.

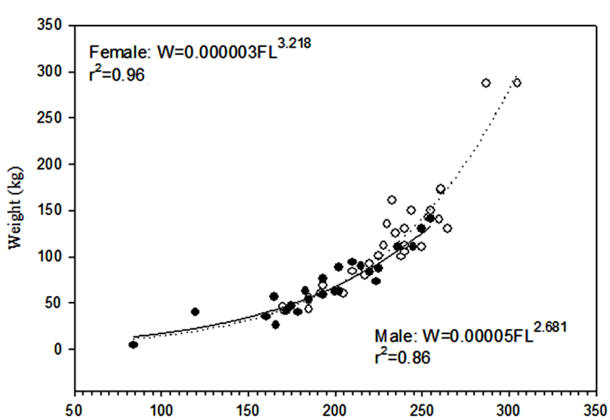

Figure 2

Length–weight relationship for female (open circles and dotted line) and male (closed circles and solid line) great sturgeon in the Iranian coastal waters of the Caspian Sea; *W* = gutted weight (kg); *FL* = fork length (cm)

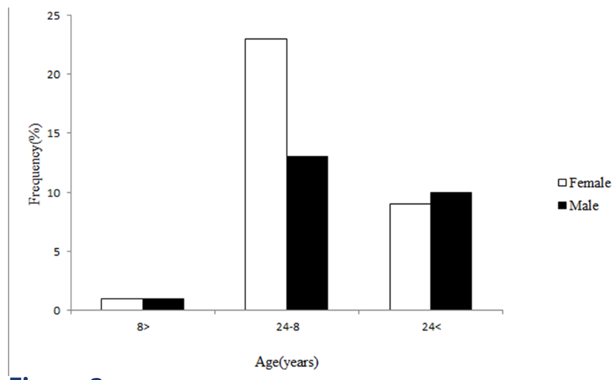

Figure 3

Age composition for female and male great sturgeon between 2008 and 2010 in the Iranian coastal waters of the Caspian Sea (n = 105). Arrows indicate the direction in which the observed frequencies differed from those expected under the assumption that the age class was uncorrelated with sex.

The von Bertalanffy growth parameters were determined for female (L_∞ = 275.784 cm; K = 0.082 per year; t_0 = –0.809 year) and male (L_∞ = 265.255 cm; K = 0.062 per year; t_0 = –2.208 year) great sturgeon (Fig. 4). The growth of females in relation to age was significantly higher (F = 16.67, df 3, 50, $p < 0.001$) compared to that of males (Fig. 4). Males were characterized by higher mortality rates Z (0.64) than females (0.46) and lower survival rates (53%) compared to females (63%), with annual mortality of 37%, which for females was 47%.

4. Discussion

The population and growth parameters of great sturgeon show a large variation due to intrinsic and

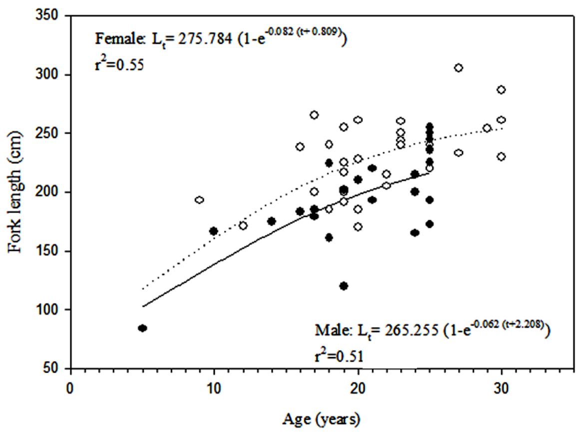

Figure 4

The von Bertalanffy growth function fit to size-at-age relationships for female (open circles and dotted line) and male (closed circles and solid line) great sturgeon in the Iranian coastal waters of the Caspian Sea; L_t = fork length (cm)

extrinsic factors. The species is characterized by slow growth, larger size and late gonadal maturity. Growth and population data were obtained from samples collected during several annual cycles (2008–2010). The sampled fish represented the southern populations from the Caspian Sea. The maximum age determined for this species in 1940 ranged from 107 to 118 years (Babushkin & Borzenko 1952). It was later estimated at 50 to 63 years (Kosarev & Yablonskaya 1994; Fazli et al. 2020) but our study indicated that the maximum age is 25 to 30 years. The presence of females in older classes (Pirogoviskiy & Fadeyeva 1982) may represent a life strategy that gives them a longer life expectancy (Roff 1984). The precision of age estimation based on pectoral fin spines for great sturgeon is acceptable compared to tarpon (*Megalops atlanticus*) (Cyr 1991) and white sturgeon (*Acipenser transmontanus*) (Rien & Beamesderfer 1994), which are also long-lived species. It was also found that the use of sectioned spines of pectoral fins as a non-lethal method of age determination is useful and precise, particularly for endangered species, such as great sturgeon, or when sacrifice of samples is undesirable (Glass et al. 2011). The APE was low (0.95%) and there were no differences in the profiles of pectoral fin spines and their images. The APE below 5% was consistent with the interpretation of age (Morison et al. 1998). Only the oldest fish showed multiple vascular channels and compressed or abnormal bands in the margin of the anterior fin spine, which made fin cross sections.

The mean fork length of both sexes revealed a decrease in size compared to data for great sturgeon from 1990–1994 (Taghavi-Motlagh 2001) and from 1990–2011 (Fazli et al. 2020), and also the mean fork length of both females and males was lower than that reported by Ruban & Khodorevskaya (2011) for great sturgeon from the Volga. These differences may be related to the capture of predominantly mature migrating fish in this area, while the catches in the southern part contained both mature and immature fish (Taghavi-Motlagh 2001; Ghadirnejad et al. 2010).

The mean weight of the great sturgeon determined in this study was lower compared to that found in the periods from 1990 to 1994 (Taghavi-Motlagh 2001) and from 1990 to 2011 (Fazli et al. 2020), and with larger mature individuals which enter the Volga River (Ruban & Khodorevskaya 2011). In general, it was found that females had a greater fork length and body weight compared to males.

The length–weight relationship for the population of female great sturgeon from the Iranian coastal waters of the Caspian Sea (slope = 3.22) is similar to that for the populations of the sturgeon species that are distributed within the geographical range, which differs very little from 3.3 (Craig et al. 2005). This relationship shows that despite the conditions to which great sturgeon populations are exposed in the Iranian coastal waters of the Caspian Sea, the populations are relatively healthy (mean slope = 2.94, both sexes), with a better condition of females.

The length and weight-at-age relationships were asymptotic, with a rapid growth rate in the younger stage, decreasing at older stages. This growth behavior was determined in other sturgeon species from the same region (Brennan & Cailliet 1989). At the age of sexual maturity, the growth rate decreased and a physiological change from somatic growth to reproductive development was observed (Bruch & Binkowski 2002).

The growth parameters estimated in this study were within the range recorded for this species by Froese & Pauly (2019) and were lower than those obtained in 1990–1994 by Taghavi-Motlagh (2001). The length determined by age was generally greater for females than for males (Fig. 4). This may be due to the faster growth of females in a brood compared with that of the brood that underwent sexual maturation (Stamps 1993) and higher age at maturity of females (Scarnecchia et al. 2007). Estimates of the asymptotic length for females in 1990–1994 were greater than those for fish in 2008–2010, which indicates a reduction in size.

Estimates of the asymptotic length for females in 1990–1994 were much lower than for individuals in 2008–2010, and a decrease in size was observed (Fig. 5). Harvesting pressure could show slower growth and

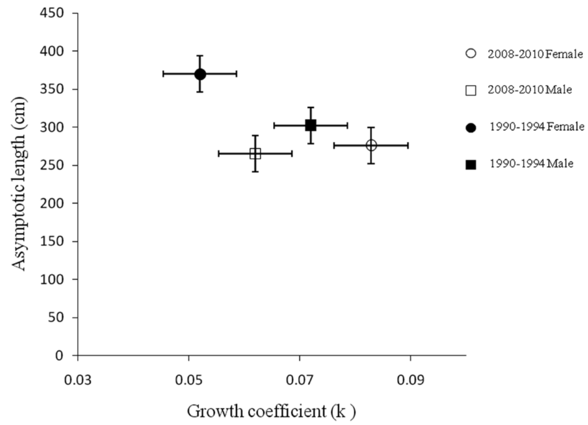

Figure 5

Confidence regions (95%) of mean estimates for the growth parameters (K and L_∞) for males and females of great sturgeon in1990–1994 and in 2008–2010 in the Iranian coastal waters of the Caspian Sea

smaller size, which is in agreement with data reported for i.a. *Pleuronectes platessa* L. (Rijnsdorp, 1989), *Gadus morhua* (Olsen et al. 2005) and *Micropterus dolomieu* (Dunlop et al. 2005). The mortality coefficient of female great sturgeon in 1990–1994 (Taghavi-Motlagh 2001) and 1990–2011 (Fazli et al. 2020) was lower than that obtained in this study for females and males. This indicates that intensive commercial fishing may be a causative factor in the sharp decline of the great sturgeon stock, the increase in the annual mortality rate and the decrease in the survival rate.

Overfishing and several environmental factors, such as pollution and modification of hydrological conditions, may have contributed to severe depletion of the great sturgeon stock (Pourkazemi 2006). The current fishing pressure on the great sturgeon is high. Fish stock analysis by continuous sampling is necessary to assess the status of the stock of this species in order to obtain technical data that will serve in the state regulation of the fishery of this species in the Iranian coastal waters of the Caspian Sea.

5. Conclusions

The age range of the fish caught was 5 to 30 years, with the highest proportion of age classes being 17 to 25 years – 70% and 83% for females and males, respectively. The annual mortality rates were calculated at 47% for males and 37% for females. The data obtained in this study and their comparison with previous studies indicate that the great sturgeon stock is exploited in an unsustainable manner. Overfishing and several environmental disturbances, such as pollution and modification of hydrological conditions, may have led to the severe depletion of the great sturgeon stock.

Acknowledgements

The authors thank R. Nahrevar, R. Rastin, H. Dadari, A. Alinejad, M. Ataee, A. Qavidel, F. Shakori, A. Kor and G. Salehi for their technical assistance. Sampling authorization was given by the Madar Khaviari sector of the Iranian fisheries organization. We greatly appreciate the constructive comments and suggestions provided by G. Cailliet.

References

Babushkin, N.Y.A. & Borzenko, M.P. (1952). Sturgeon of the Caspian. *Pishchepromizdat Moscow*: 5–67. (In Russian).

Bakhshalizadeh, S., Zykov, L.A., Nasibulina, B.M., Kurochkina, T.F. & Fazio, F. (2020). Influence of growth on the biological and commercial productivity of Caspian great sturgeon *Huso huso*. *Aquaculture* 736139. DOI: 10.1016/j.aquaculture.2020.736139.

Bakhshalizadeh, S., Bani, A., Abdolmalaki, S., Nahrevar, R. & Rastin, R. (2011). Age, growth and mortality of the Persian Sturgeon, *Acipenser persicus*, in the Iranian waters of the Caspian Sea. *Caspian Journal of Environmental Sciences* 9(2): 159–167.

Beamish, R.J. & Fournier, D.A. (1981). A method for comparing the precision of a set of age determinations. *Canadian Journal of Fisheries and Aquatic Sciences* 38: 982–983. DOI: 10.1139/f81-132.

Boscari, E., Vitulo, N., Ludwig, A., Caruso, C., Mugue, N.S. et al. (2017). Fast genetic identification of the Beluga sturgeon and its sought-after caviar to stem illegal trade. *Food Control* 75: 145–152. DOI: 10.1016/j.foodcont.2016.11.039.

Brennan, J.S. & Cailliet, G.M. (1989). Comparative age-determination techniques for white sturgeon in California. *Transactions of the American Fisheries Society* 118: 296–310. DOI: 10.1577/1548-8659(1989)118<0296:CATFWS>2.3.CO;2.

Bruch, R.M. & Binkowski, F.P. (2002). Spawning behavior of lake sturgeon (*Acipenser fulvescens*). *Journal of Applied Ichthyology* 18(4–6): 570–579. DOI: 10.1046/j.1439-0426.2002.00421.x.

Campana, S.E. (2001). Accuracy, precision and quality control in age determination, including a review of the use and abuse of age validation methods. *Journal of Fish Biology* 59: 197–242. DOI: 10.1111/j.1095-8649.2001.tb00127.x.

Chang, W.Y.B. (1982). A statistical method for evaluating the reproducibility of age determination. *Canadian Journal* *of Fisheries and Aquatic Sciences* 39: 1208–1210. DOI: 10.1139/f82-158.

Craig, J.M., Thomas, M.V. & Nichols, S.J. (2005). Length–weight relationship and a relative condition factor equation for lake sturgeon (*Acipenser fulvescens*) from the St Clair River system (Michigan, USA). *Journal of Applied Ichthyology* 21: 81–85. DOI: 10.1111/j.1439-0426.2004.00635.x.

Cyr, E.C. (1991). *Aspect of the life history of the tarpon, Megalops atlanticus, from South* Unpublished doctoral dissertation. University South Carolina, Columbia, SC, USA.

Dudu, A., Georgescu, S.E. & Costache, M. (2014). Molecular analysis of phylogeographic subspecies in three Ponto-Caspian sturgeon species. *Genetics and Molecular Biology* 37(3): 587–597. DOI: 10.1590/S1415-47572014000400016.

Dunlop, E.S., Shuter, B.J. & Ridgway, M.S. (2005). Isolating the influence of growth rate on maturation patterns in the small mouth bass (*Micropterus dolomieu*). *Canadian Journal of Fisheries and Aquatic Sciences* 62: 844–853. DOI: 10.1139/F05-045.

Favro, L.D., Kuo, P.K. & Mcdonald, J.F. (1979). Population-genetic study of the effects of selective fishing on the growth rate of trout. *Journal of the Fisheries Research Board of Canada* 36: 552–561. DOI: 10.1139/f79-079.

Fazli, H., Tavakoli, M., Khoshghalb, M.R.B. & Moghim, M. (2020). Biological parameters and fisheries indices of beluga sturgeon *Huso huso* in the southern Caspian Sea. *Croatian Journal of Fisheries* 78: 1–10. DOI: 10.2478/cjf-2020-0001.

Froese, R. & Pauly, D. (2019). *FishBase. World Wide Web electronic publication*. Retrieved November 20, 2020, from http://www.fishbase.org/Summary/SpeciesSummary.php?ID=2067&AT=Beluga.

Ghadirnejad, H., Aghilinejad, M., Laloei, F., Asalollahi, M., Shabani, A. et al. (2010). *Global population structure of the great sturgeon (Huso huso) in the southern part of the Caspian Sea with emphasis on the Golestan Province*. Iranian Fisheries Science Research Institute, Tehran, Iran.

Glass, W.R., Corkum, L.D. & Mandrak, N.E. (2011). Pectoral fin ray aging: an evaluation of a non-lethal method for aging gars and its application to a population of the threatened Spotted Gar. *Environmental Biology of Fishes* 90: 235–242. DOI: 10.1007/s10641-010-9735-5.

Graham, L.J. & Murphy, B.R. (2007). The Decline of the Beluga Sturgeon: A Case Study about Fisheries Management. *Journal of Natural Resources and Life Sciences Education* 36: 66–75. DOI: 10.2134/jnrlse2007.36166x.

Gulland, J.A. (1983). *Fish stock assessment: a manual of basic methods*. FAO (United Nations Food and Agriculture Organization) New York: Wiley.

Holčík, J. (1989). *The freshwater fishes of Europe, Volume 1, Part 2: General introduction to fishes: Acipenseriformes.* AULA Verlag Wiesbaden, Germany.

Karayev, R.A. (2006). Modelling Caspian sturgeon population dynamics: a new paradigm and new technology. *ICES Journal of Marine Science* 63: 980–994. DOI: 10.1016/j.icesjms.2006.03.015.

Kazemi, R., Yousefi Jourdehi, A., Pourdehghani, M., Dejhandian, S., Hallajian, A. et al. (2014). Classification of sex and maturity stages of farmed great sturgeon (*Huso huso*) using blood plasma steroid hormone and calcium ion levels. *Iranian Journal of Fisheries Sciences* 13(3): 597–607.

Kosarev, A.N. & Yablonskaya, E.A. (1994). *The Caspian Sea*. The Hague: SPB Academic Publishing.

King, M. (2013). Fisheries biology, assessment and management. John Wiley & Sons, Australia.

Law, R. & Rowell, C.A. (1993). Cohort-structured populations, selection responses, & exploitation of the North Sea cod. In T.K. Stokes, J.M. McGlade & R. Law (Eds.), *The Exploitation of Evolving Resources* (pp. 73–155). Springer-Verlag: Berlin.

Mirrasooli, E., Ghorbani, R., Gorgin, S., Aghilinejhad, S.M. & Jalali, A. (2019). Factors associated with illegal fishing and fisher attitudes toward sturgeon conservation in the southern Caspian Sea. *Mar Policy* 100: 107–115. DOI: 10.1016/j.marpol.2018.11.028.

Morison, A.K., Robertson, S.G. & Smith, D.C. (1998). An integrated system for production fish aging: image analysis and quality assurance. *North American Journal of Fisheries Management* 18: 587–598. DOI: 10.1577/1548-8675(1998)018<0587:AISFPF>2.0.CO;2.

Olsen, E.M., Lilly, G.R., Heino, M., Morgan, M.J., Brattey, J. et al. (2005). Assessing changes in age & size at maturation in collapsing populations of Atlantic cod (*Gadus morhua*). *Canadian Journal of Fisheries and Aquatic Sciences* 62: 811–23. DOI: 10.1139/f05-065.

Onara, D., Holostenco, D., Paraschiv, M. & Suciu, R. (2014). Preliminary genetic variability of Lower Danube River young of the year (YOY) beluga sturgeon *Huso huso* (Linnaeus, 1758) using mtDNA markers. *Journal of Applied Ichthyology* 30: 1286–1289. DOI: 10.1111/jai.12596.

Pirogoviskiy, M.I. & Fadeyeva, T.A. (1982). The size-age composition of the Stellate Sturgeon, Acipenser stellatus, during the marine period of life. *Vopr Ichthyology* 5: 54–63.

Pourkazemi, M. (2006). Caspian Sea sturgeon Conservation and Fiseries: Past present and Future. *Journal of Applied Ichthyology* 22: 12–16. DOI: 10.1111/j.1439-0426.2007.00923.x.

Ricker, W.E. (1975). Computation and interpretation of biological statistics of fish population. *Bulletin of the Fisheries Research Board of Canada* 191: 1–382.

Rien, T.A. & Beamesderfer, R.C. (1994). Accuracy and precision of white sturgeon age estimates from pectoral fin rays. *Transactions of the American Fisheries Society* 123: 255–265. DOI: 10.1577/1548-8659(1994)123<0255:AAPOWS>2.3.CO;2.

Rijnsdorp, A.D. (1989). Maturation of male & female North Sea plaice (*Pleuronectes platessa* L). *ICES Journal of Marine Science* 46: 35–51. DOI: 10.1093/icesjms/46.1.35.

Roff, D.A. (1984). The evolution of life histories parameters in teleosts. *Canadian Journal of Fisheries and Aquatic Sciences*

41: 989–1000. DOI: 10.1139/f84-114.

Rosten, C.M., Onara, D., Hawley, K. & Suciu, R. (2012). The status of Danube beluga sturgeon (*Huso huso*): Past, present and future. *VANN* 47(4): 523–534.

Ruban, G., Khodorevskaya, R. & Shatunovskii, M. (2019). Factors influencing the natural reproduction decline in the beluga (*Huso huso*, Linnaeus, 1758), Russian sturgeon (*Acipenser gueldenstaedtii*, Brandt & Ratzeburg, 1833), and stellate sturgeon (*A. stellatus*, Pallas, 1771) of the Volga–Caspian basin: A review. *Journal of Applied Ichthyology* 35: 387–395. DOI: 10.1111/jai.13885.

Ruban, G.I. & Khodorevskaya, R.P. (2011). Caspian Sea sturgeon fishery: a historic overview. *Journal of Applied Ichthyology* 27: 199–208. DOI: 10.1111/j.1439-0426.2011.01725.x.

Saborowski, R. & Buchholz, F. (1996). Annual changes in the nutritive state of North Sea. *Journal of Fish Biology* 49: 173–194. DOI: 10.1111/j.1095-8649.1996.tb00015.x.

Saila, G.B., Recksiek, C.W. & Prager, M.H. (1988). Basic fishery science programs. A compendium of microcomputer programs and manual of operation. *Developments in Aquaculture and Fisheries Science* 18: 1–203.

Sainsbury, K.J. (1980). Effect of individual variability on the von Bertalanffy growth equation. *Canadian Journal of Fisheries and Aquatic Sciences* 37: 241–247. DOI: 10.1139/f80-031.

Sandu, C., Reinartz, R. & Bloesch, J. (Eds.). (2013). *"Sturgeon 2020": A program for the protection and rehabilitation of Danube sturgeons*. Danube Sturgeon Task Force (DSTF) & EU Strategy for the Danube River (EUSDR) Priority Area (PA) 6 – Biodiversity. Bucharest, Romania.

Scarnecchia, D.L., Ryckman, L.F., Lim, Y., Schmitz, B.J. & Firehammer, J.A. (2007). Life history and the costs of reproduction in Northern Great Plains Paddlefish (*Polyodon spathula*) as a potential framework for other Acipenseriform fishes. *Reviews in Fisheries Science & Aquaculture* 15(3): 211–263. DOI: 10.1080/10641260701486981.

Stamps, J.A. (1993). Sexual size dimorphism in species with asymptotic growth after maturity. *Biological Journal of the Linnean Society* 50: 123–145. DOI: 10.1111/j.1095-8312.1993.tb00921.x.

Ta'ati, R., Soltani, M., Bahmani, M. & Zamini, A. (2011). Growth performance, carcass composition, and immunophysiological indices in juvenile great sturgeon (*Huso huso*) fed on commercial prebiotic. *Iranian Journal of Fisheries Sciences* 10(2): 324–335.

Taghavi-Motlagh, S.A. (2001). An estimation of growth parameters, mortality rates and yield-per-recruit for Beluga (*Huso huso*) living in Caspian Sea. *Iranian Journal of Fisheries Sciences* 3: 25–48.

Tavakoli, M. & Khoshghalb, M.R.B. (2018). Investigation on catch trend and caviar of (*Huso huso* Brandt, 1865) in the Iranian waters of the Caspian Sea during 2005-2015. *Journal of Wetland Ecobiology* 37: 5–12.

Ustaoğlu, S. & Okumuş, I. (2004). The Sturgeons: Fragile species need conservation. *Turkish Journal of Fisheries and Aquatic Sciences* 4: 49–57.

Williot, P., Sabeau, L., Gessner, J., Arlati, G., Bronzi, P. et al. (2001). Sturgeon farming in Western Europe: recent developments and perspectives. *Aquatic Living Resources* 14: 367–374.

World Conservation Monitoring Centre (WCMC). (2010). *Review of four sturgeon species from the Caspian Sea basin*. Retrieved December 21, 2020, from http://ec.europa.eu/environment/cites/pdf/reports/caspian_sea_sturgeon.pdf