Iran. J. Ichthyol. (2023) 10(4): 225-235
P-ISSN: 2383-1561; E-ISSN: 2383-0964

ORIGINAL ARTICLE

Forecasting the catch of the stocks of Persian sturgeon (*Acipenser persicus*, Borodin 1897) in the southern shores of the Caspian Sea using DB-SRA and dynamic model

Elham MIRRASOULI[1*], Rasoul GHORBANI[1], Saeed GORGIN[1], Ali Jalali[2], Seyed Mostafa AGHILINEJHAD[3]

[1]Department of Aquatic Production and Exploitation, Faculty of Fisheries and Environment, Gorgan University of Agricultural Sciences and Natural Resources, Gorgan, Iran.
[2]Coastal Research Institute, University of Agricultural Sciences, Melbourne, Australia.
[3]Management of sturgeon affairs in Golestan province, Gorgan, Iran.

Correspondence
elhammirrasooli@gmail.com

Article history:
Accepted 27 December 2023

Abstract
This study aims to analyze the fishing trend and predict the future catch of Persian sturgeon (*Acipenser persicus*) stocks by DB-SRA and dynamic models in the southern shores of the Caspian Sea. The results showed that, according to the size of the initial population in 2018, equal to 153 spicemens (mean weigth 30kg); assuming a constant rate of catch from the population equivalent to 0.2 per year (half of the current catch); until the next 30 years (2050), the amount of catching of Persian sturgeon will increase until the stocks of this species have the ability to fully restore themselves. While assuming the current catch rate, there has been a sharp decrease in the catch of fish in the southern shores of the Caspian Sea; it is estimated that the stocks of this type of sturgeon fish will be extinct by 2050.

Keywords: Catch, DB-SRA, Dynamic model, Persian sturgeon, South Caspian Sea.

INTRODUCTION

The Caspian Sea is considered as the largest of the brackish water lake in the world (Kamza et al. 2023). The Caspian Sea is the habitat of valuable commercial fish such as sturgeon, so that six species of fish (beluga, Persian, Russian, starry, ship and sterlet sturgeons) live in Caspian Sea and its catchment area that the major part of the world's sturgeon (90-92%) is caught from it (Ermolin & Svolkinas 2016). Persian sturgeon, *Acipenser persicus* (Brodin, 1897) is found in the southern shores of the Caspian Sea and it is rarely seen in its northern parts (Farhani 2015).In fact, this kind of fish is considered native to Iran and has a special status in the composition and quantity of sturgeon fish (60% of it) in Iran (Raisi et al. 2018).

Sturgeons are extremely valuable species due to increasing demand for their Caviar and boneless meat (Hatef et al. 2011). However, they were severely affected by long-term anthropogenic activities that have resulted in a significant decline in the population of Sturgeons especially *A. persicus* species in the Southern Caspian Sea (Pourkazemi 2006; Nazeri et al. 2019; Haghshenas et al. 2021) and are listed as threatened species in the International Union for Conservation of Nature (IUCN) (Iranian Fishery Statistics Yearbook (IFSY) 2008).

Today, unlike the previous extinctions, where natural factors were the main cause of the mass death of organisms, today the rapid decline of animal species, especially sturgeon fish, due to the pressure caused by human activities, especially the loss of habitats, hydrocarbon pollution caused by the exploitation of oil in the sea and pollution chemicals of rivers; excessive and illegal exploitation of water ecosystems (Ceballos et al. 2015).

Unfortunately, the instability in exploiting the valuable sturgeon fish, and the non-compliance with fishing laws have caused serious concerns about the sustainable exploitation of sturgeon (Sumaila et al. 2016). At the beginning of the 20th century, the catch of sturgeon was around 40,000 tons (Sumaila et al. 2016) and 80-90% of the world's caviar was produced in the Caspian Sea (Pourkazemi 2006). However, in recent years, the amount of catch and stocks of sturgeon fish in the Caspian Sea has had a very sharp downward trend; so that their catch has decreased from 28,500 tons in 1985 to less than 861 tons in 2009 (Iranian Fishery Statistics Yearbook (IFSY) 2008) and 6/97 tons in 2020 has decreased (National Fisheries Science Research Institute 2021). The sharp decrease

Journal homepage: ijichthyol.org/ DOI: https://doi.org/10.22034/iji.v10i4.990

in the commercial catch of Persian sturgeon fish in the southern coast of the Caspian Sea depends on several factors, overfishing especially illegal fishermen is considered as the main factor (Mirrasooli et al. 2019). Ecological and geographical factors can play a decisive role in the decision-making of fishermen about targeting suitable fishing areas. These factors are particularly important in the case of the activities of illegal fishermen due to their ambiguous behavior that they often try to target specific areas to avoid the risk of detection and also to take advantage of the opportunity to reduce costs and maximize profits (Jalali et al. 2015). Considering the importance of Persian sturgeon and the excessive reduction of their stocks in recent years, which has caused this valuable species to be at risk of extinction (IUCN 2015).

Several previous studies have been conducted on the stocks of Persian sturgeon (*Acipenser persicus*). Most of them assessed the Sturgeon wild stock has been dramatically decreased due to overfishing, poaching and environmental degradation and since 1990s, interest in aquaculture-based protection programs has been increased (Ceballos et al. 2015; Mirrasooli et al. 2019; Meng et al. 2022) and have investigated the amount of sturgeon stocks at present and less attention has been paid to the amount of sturgeon harvest in the coming years.

That is why the investigation of Forecasting the of catch of the stocks of Persian sturgeon (*Acipenser persicus*) in the southern shores of the Caspian Sea in the coming years, based on the current fishing situation and the amount of stocks harvested from them an important step towards an improved management and conservation of Persian sturgeon populations in the Southern Caspian Sea.

Several methods exist for assessing stock status for data-deficient populations. These methods are based on trends in commercial catches whereby the scale of depletion is assumed based on knowledge of the relationship between current population sizes relative to the unknown historic size which one of them is DB-SRA. Depletion-Based Stock Reduction Analysis is a catch-based method for determining sustainable yields for data-poor fish stocks that we are able to use it to determine the sustainable yield for aquatic stocks that face a lack of data and stated that according to the natural mortality rate, maturity age and fishing history, the state of the stock to reach production Stable can be evaluated (Dick & MacCall 211). As, Owashi (2014) and Walters et al. (2006) presented an alternative using a stock reduction analysis (SRA) where assumptions about fleet behavior are unnecessary. Instead, stock reduction draws on estimates of life history parameters (primarily intrinsic population growth rate r, the carrying capacity K, and the natural mortality rate M) and predicts what the historical abundance would have been in order to sustain the observed fishery catches without reaching extinction (Walters et al. 2006; Owashi 2014).

As a result, the aim of this research is prediction of the catch status of Persian sturgen stocks in the southern shores of the Caspian Sea using the Depletion Based Stock Reduction Analysis (DB-SRA) model and the dynamic model.

MATERIAL AND METHODS

Study area: The area studied in this research; the southern shores of the Caspian Sea, about 800km long, were determined in special fishing areas for sturgeon fishing (Fig. 1).

Data collection: Modeling the prediction of the catch of Persian sturgeon based on the DB-SRA model: Based on DB-SRA modeling R 4.1.1, taking into account the average age of fish catched in accordance with Lm50, the equivalent of 14 years and a minimum of 5 to a maximum of 15,000 tons of total biomass of fish was formulated (Table.1).

Dynamic model: To study the dynamics of the population of Persian sturgeon based on the exponential growth rate and the effect of environmental parameters, a dynamic model is used using Stella 8 software (McCarthy 1996).

$$\text{Exponential growth rate} = \text{Ln}\left(\frac{Nt}{Nt+1}\right)$$

In order to obtain the exponential growth of the population of this fish (population production), the catch information of previous years has been used. It

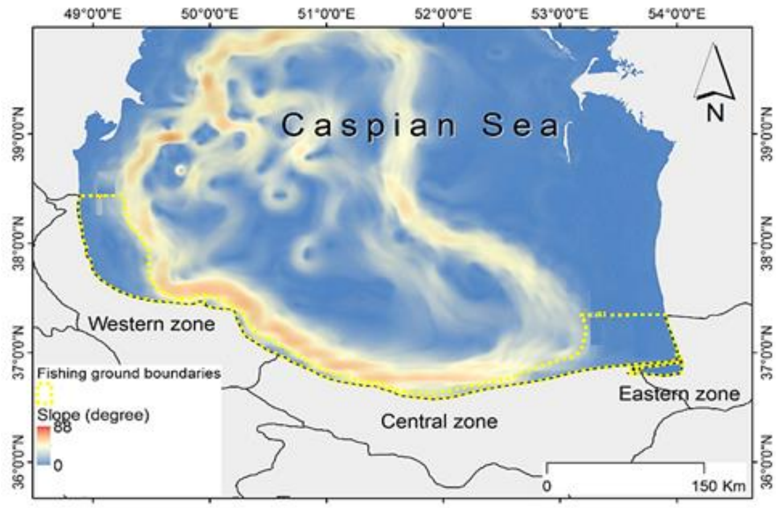

Fig.1. Legal and illegal catch ranges of sturgeon (range of yellow lines) based on data obtained from fishermen in the southern region of the Caspian Sea. A map of the bed slope is also shown.

is necessary to mention that in the population of a migrant species, the annual population density fluctuates greatly and the migration factor cannot be ignored. In these conditions, an equation with a high standard error and the absence of a linear relationship with the parameters (due to R^2 being less than 0.5) may be obtained, which has low credibility for modeling. The statistics of climatic parameters were obtained from the offices of Meteorology centers (the located in the south of the Caspian Sea) for the years 2014 to 2018.

The required parameters in the proposed model are NYP (size of the catchable population in the next year), TYP (size of the population in the current year), REF (population mortality), H (catch from the population), HR (catch rate) and PP (production of population). To calculate population growth, the effect of climatic parameters on the exponential growth of sturgeon has been studied in the form of a multiple regression equation. The parameters studied in this equation are Nt (population size in each year), Nt+1 (population size in the next year) and environmental parameters including of; water temperature (°C), relative humidity (percent) in the morning, noon and evening, the amount rainfall (mm), evaporation rate (mm), wind speed (m/s) and wind direction (degrees) are in the morning, noon and evening. Using the mentioned information and the resulting equation, a population dynamics model was created with Stella 8 software, in which the dynamics of the population of this type of fish was simulated in a state where it is catched to a certain ration. Also, the effect of different catch rates on its population was tested. The reduction of the population of Persian sturgeon was considered at a constant rate. If the amount of catch is a fixed proportion of the population every year, considering the climatic parameters as a constant, different rates from zero to one are considered. In this way, it can be shown which of these rates causes the maximum amount of catch from the annual population of Persian sturgeon. As a result, in the verification chart, catch rates from 0.2 to 0.6 are considered in 5 classes, and the amount of population is calculated based on the expected exploitation rate and available data, and then the best scenario is selected and for the simulation will be considered to 2050 (Pereverzoff & Ackerman 1998).

RESULTS

The results obtained based on the modeling of the DB-SRA model of the catch of Persian, taking into account the average age of catch in accordance with Lm50, equivalent to 14 years and a minimum of 5 tons to a maximum of 15,000 tons of fish are given in Figure 2. The model can start with a population in K (environmental carrying capacity) or a number of K iterations. The final distributions of K are the intrinsic rate of population growth (r), then Bmsy and Umsy can be estimated from the distributions of the set of

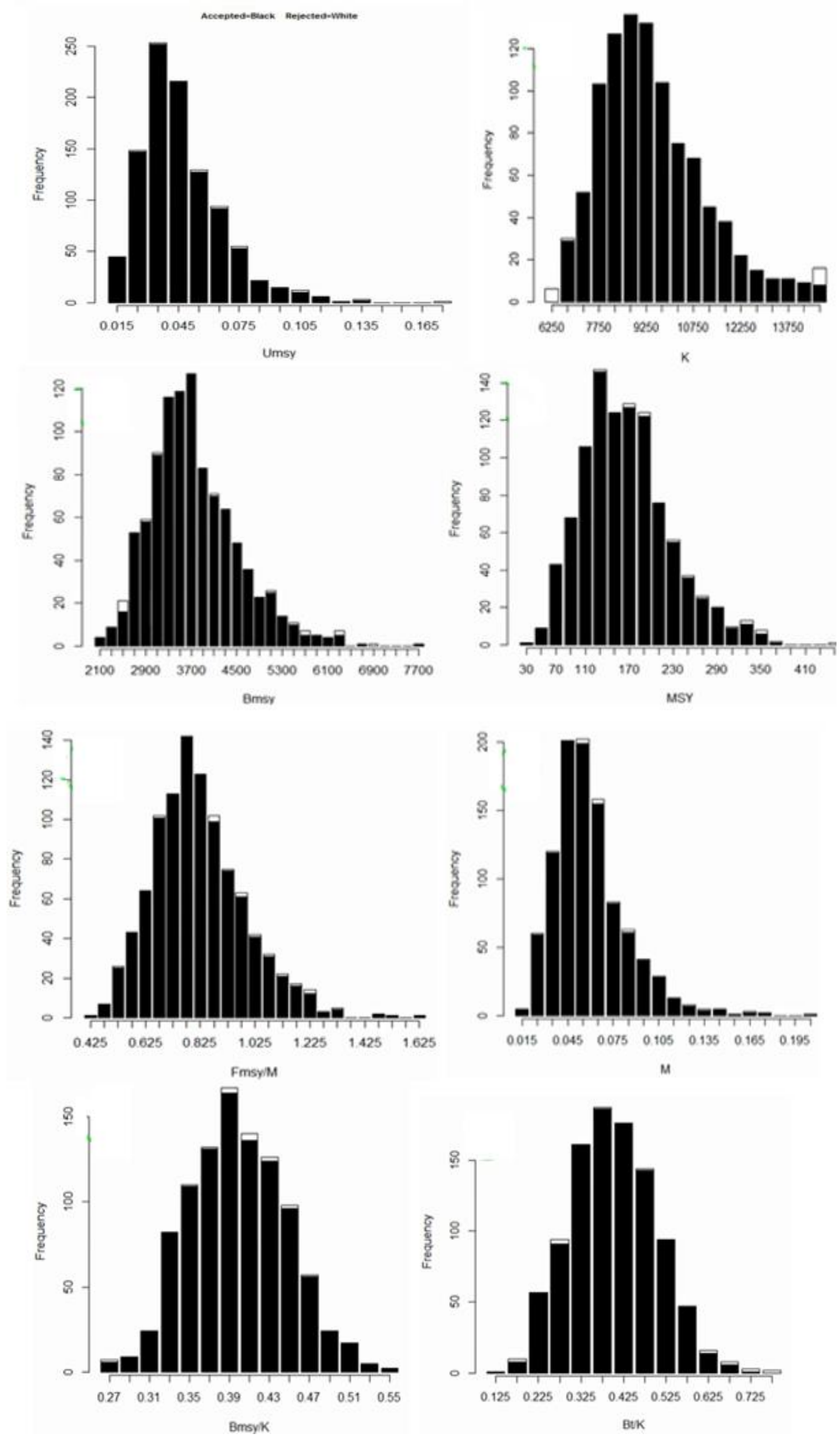

Fig.2. List of estimated parameters based on SRA model.

accepted parameters. According to the According to the figure 2, the amount of acceptable K is in the range of 650 to 13775 tons with the highest frequencies corresponding to 7750 to 10500 tons. The acceptable amount of Umsy is between 0.015 and 0.135 and the maximum acceptable frequency is 0.025 to 0.045. The acceptable amount of Bmsy is between 3100 and 3900 tons and the maximum acceptable amount is 3300 to 3700 tons. The acceptable amount of MSY is between 30 and 150 tons and the maximum acceptable frequency is 150 tons. The acceptable level of M is between 0.015 and 0.045 and the maximum acceptable frequency is 0.045. The acceptable amount of Fmsy is between 0.475 and 0.825 and the maximum

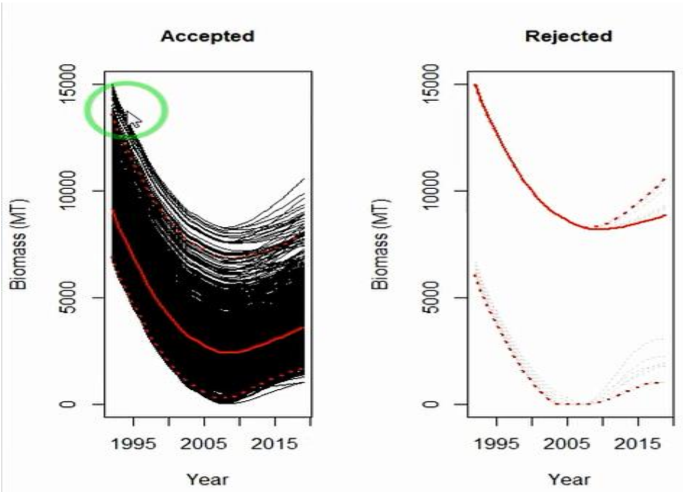

Fig.3. A set of parameters that results in the extinction or non-extinction of the biomass of Persian sturgeon.

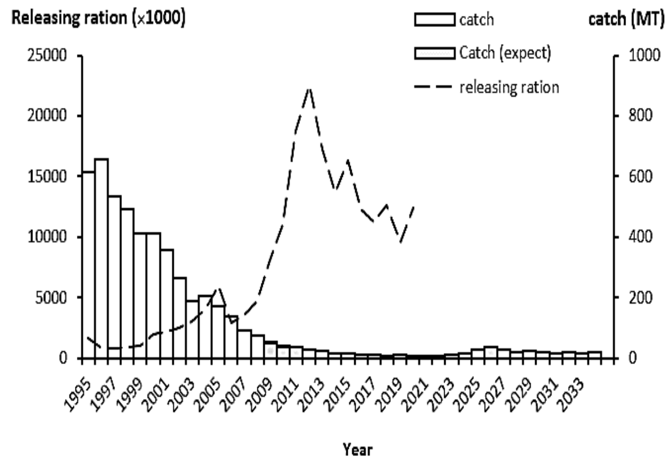

Fig.4. The relationship between release rate and catch of Persian sturgeon on the shores of the Caspian Sea.

acceptable frequency is 0.775. The acceptable amount of Bt/K is between 0.325 and 0.575 and the maximum acceptable frequency is 0.375. The acceptable amount of Bmsy/K is between 0.29 to 0.37 and 0.47 to 0.55 and the maximum acceptable frequency is 0.37 (Fig. 2).

In the best scenario, K by releasing about 22 million Persian sturgeon juveniles and observing the appropriate weight and optimal conditions of the river with a return of 0.002 and with an average weight of 30kg, the expected biomass is about 14000 tons of sturgeon biomass; Therefore, the sharp reduction of the catch reached the extinction limit in 2007 and 2008, which is due to the reduction of the release of juveniles, the conditions of releasing the juveniles into the river and the increase of illegal fishing. At this time, according to the arrangements of the Caspian basin countries, with the approval of the fishing law in 2010 for at least 5 years (and if necessary, its extension), especially the non-fishing in the rivers and determining the minimum capacity, the situation has improved. It seems that due to the increase in the quantity and quality of the release of juveniles into the rivers and the double control of illegal fishing, the amount of biomass has an increasing trend (Fig. 3).

The relationship between the rate of release of juveniles into the rivers, the reported catch ration and the expected return rate of the fishes was investigated considering the minimum capacity of natural reproduction due to the unsuitable conditions of the rivers for the reproduction of broodstocks in the southern part of the Caspian Sea. To verify the reported catch data with the data related to the release of fish and the fishery return of broodstocks fish (with an average age of 14 years and 30kg, the coefficients of fishery return from a maximum of 0.0015 in 1996 to 0.00005 was tested in 2004 onwards. It seems that the situation of the return coefficient of Persian sturgeon has been decreasing due to the unfavorable conditions of the weight of the released juveniles and also the inappropriate quality of the place where the juveniles are released (Fig. 4).

On the other hand, in the dynamic modeling of the prediction of the catch of Persian sturgeon, 27-year catch statistics (1992-2018), received from the Sturgeon Affairs Organization of Golestan Province, have been used to determine the effective and significant factors on the catch of it. The required parameters in the proposed model are NYP (population size in the next year), TYP (population size in the current year), REF (mortality), H (catch), HR (catch rate), PP (production), Wind speed at 18:00 (WF18) and wind direction at 12:00 noon (WD12).

$$PP = Exp(1.846 - .013WD12 + 0.322WF18 + 0.0001TYP) + TYP$$

$$R = 0.837,\ R^2 = 0.70$$

Therefore, the proposed model for predicting the

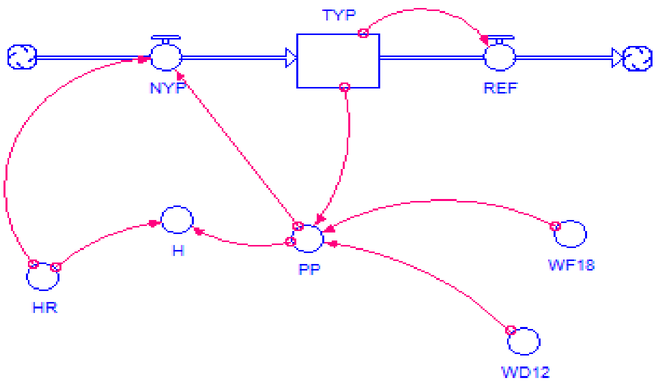

Fig.5. Proposed dynamic model for predicting the population of Persian sturgeon.

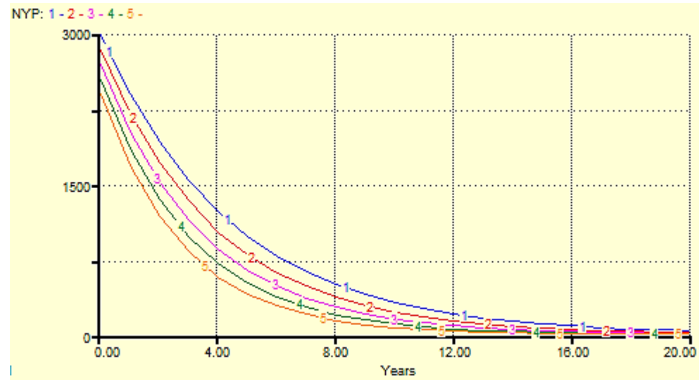

Fig.6. Predictable scenario of Persian sturgeon catching based on catch rate (1=0.2, 2=0.3, 3=0.4, 4=0.5, 5=0.6).

Table 1. Population size forecast in the next 20 years (NYP).

Year/catch ratio	0.2	0.3	0.4	0.5	0.6
2008	3000.9	2851.3	2700.6	2550.8	2401.4
2009	2401.4	2210.1	2025.9	1849.8	1681.5
2010	1921.7	1713.3	1519.8	1341.7	1177.5
2011	1537.6	1328.3	1140.4	972.9	824.7
2012	1230.6	1030.1	855.9	706	577.7
2013	984.9	798.7	642.3	512.2	404.6
2014	788.5	619.3	482.3	371.6	283.6
2015	631.3	480.4	362.1	269.8	198.9
2016	505.4	372.7	272	195.9	139.6
2017	404.6	289.1	204.5	142.5	98.1
2018	323.8	224.4	153.7	103.7	69.1

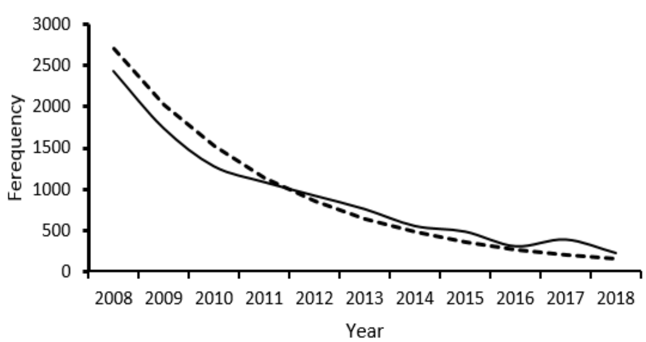

Fig.7. Validation of Iranian fish catch statistics with fisheries catch statistics Solid line: Catch data, dashed line: predicted data with a catch rate of 0.4.

Persian sturgeon population was drawn as follows (Fig. 5). Also, the designed mathematical model was formulated as follows.

```
TYP(t) = TYP(t - dt) + (NYP - REF) * dt
INIT TYP = 6000
INFLOWS:
  NYP = PP*(1-HR)
OUTFLOWS:
  REF = TYP*.7
H = HR*PP
HR = 0.5-0.9
PP = EXP(1.846-.013*WD12+0.322*WF18+0.0001*TYP)+TYP
WD12 = NORMAL(212.2,14.3)
WF18 = NORMAL(3.22,0.25)
```

If the amount of catching is a fixed proportion of the population every year, taking into account the climatic parameters in normal conditions, different rates from zero to one are taken into account. For this purpose, the reduction of the population of the fish is in the range of HR values from 0.2 to 0.6 were considered. In this way, it can be shown which of these rates will get the maximum catch from the annual population of Persian sturgeon. First, to validate the model as well as the environmental parameters, the catches made in the last 10 years were used to predict the decrease trend. In the dynamic model (IUCN 2015), the population size in the current year (TYP) equivalent to about 2500 pieces of fish in 2008 was considered as the initial population (the entire catch of the southern part of the Caspian Sea) (Fig. 6).

Considering the forbidden on sturgeon fishing in the Casian Sea accepted by the adjucent countries and taking into account the 0.2 to 0.6 catch scenario, it is possible to predict the persian sturgeon catch for the next 10 years (from 2008 to 2018). (Fig. 6 and Table

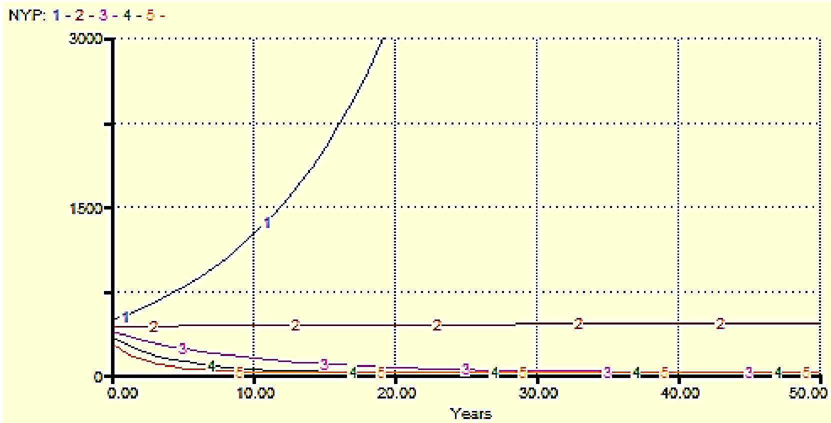

Fig.8. Predictable scenario of Persian sturgeon population based on catch rate for the next 30 years (NYP) (1=0.2, 2=0.3, 3=0.4, 4=0.5, 5=0.6).

Table 2. Predicted population size (frequency) in the next 30 years (NYP) (Withdrawal rate).

Year catch ratio	0.2	0.3	0.4	0.5	0.6
2018	529.5	421.3	325	241	168.5
2019	583.2	421.8	293.3	193	118.3
2020	642.1	422.4	264.3	154.9	83.18
2021	707.2	423.1	238.4	124.5	58.5
2022	778.7	423.7	214.8	100	41.23
2023	857.4	424.5	194.2	80.3	29.3
2024	943.6	425.1	175.4	64.6	20.8
2025	1038.9	425.4	158.2	52.1	15
2026	1143.7	425.8	143	41.9	10.9
2027	1258.6	426.4	129.3	34	8
2028	1385.2	427.1	116.7	27.4	5.9
2029	1524.7	427.7	105.6	22.6	4.5
2030	1677.7	428.3	95.5	18.6	3.4
2031	1846.3	428.9	86.3	15.3	2.7
2032	2032	429.6	78.3	12.7	2.2
2033	2235.7	430.4	71.2	10.2	2
2034	2706.7	431.5	58.4	7.5	1.5
2035	2978.3	432	53.2	6.7	1.4
2036	3277.1	432.9	48.3	5.5	1.5
2037	3277.1	432.9	48.3	5.5	1.5
2038	3605.7	433.4	44	4.8	1.3
2039	3967.2	434	40.2	4.1	1.2
2040	4365.4	434.6	36.7	3.6	1.3
2041	4803.1	435.2	33.3	3.2	1.1
2042	5285.4	436	30.6	3	1.3
2043	5814.4	436.4	28.2	2.9	1.1
2044	6397	436.7	25.9	2.9	1.1
2045	7038.2	437.3	23.6	2.7	1.1
2046	7744.1	437.7	21.9	2.75	1.25
2047	8519.9	438.2	20.1	2.5	0.96
2048	9374.4	438.9	18.6	2.6	0.99
2049	10315	439.4	17.1	2.4	0.99
2050	11349.7	439.8	15.8	2.5	1.1

2). However, the results of the random simulation show that this strategy can lead the fish population to a sharp decrease in the future years and it needs to be protected and supported. After drawing the graph of the reduction of the sturgeon fish population in the range of 0.4, the accuracy of the catch statistics was done with the fisheries catch statistics (Fig. 7). Based on the validation results, it can be stated that the proposed model for predicting the population of Persian sturgeon is consistent with the actual statistics and data of the catch in the southern shores of the Caspian Sea. This means that the proposed plan is suitable and can be used to predict the catch for the next 10 years. The predicted quantities in 2018 were approximately 154 Persian sturgeon with an average weight of 30 kg, which is equivalent to about 5 tons (Table 2). Then, taking ration in the scenario (catch rate 0.4), and the climatic parameters, the catch values were predicted for 2050. It should be noted that in recent years the average weight of fish caught is about 20kg (Fig. 8 and Table 3).

It seems that the continuation of the current fishing trend (based on the 0.4 catching rate scenario) shows that the amount of sturgeon fishing will be close to zero (Fig. 8 and Table.3). While compliance with even the catch rate of 0.3 can increase the current catch by 50%, but assuming a constant rate of catching from the population equal to 0.2 per year till the next 30 years, the catching rate of Persian sturgeon will greatly increase.

DISCUSSION

The obtained results in the current research indicated that according to the size of the initial population of Persian sturgeon on the southern shores of the Caspian Sea in 2018, it is only equal to 153 Spicemens. It seems that the continuation of the current fishing trend (based on the harvest rate scenario of 0.4) shows that even though the fishing prohibition law has been announced to all the countries basin the Caspian Sea, it is still due to illegal fishing and the fishing of immature fish due to unsiabale mesh size of nets, the process of destruction of sturgeon fish continues; it is estimated that the stocks of this type of sturgeon fish will be extinct by 2050. Whereas, according to the size of the initial population and assuming a constant rate of catch from the population equal to 0.2 per year (reducing the catch of sturgeon to half of the amount caught in the current conditions); until the next 30 years (2050), the amount catching of its stocks will increase until the stocks of this species have the ability to fully restore themselves.

In line with the results obtained; Researchers such as Dick et al. in their studies in 2011 stated that the use of the DB-SRA model as a basic method to determine the sustainable performance of water resources that face a lack of information; According to natural mortality rate, maturity age and fishing history and stock status can be used to achieve sustainable production (Ye & Valbo-Jørgensen 2012). Also, Ye & Valbo-Jorgensen (2012) assessed the population dynamics of the starry sturgeon fish using the SRA model and showed that if the amount of illegal fishing continues at the current level, without restoration of stocks in the Caspian Sea, this species will become extinct in the coming decades (Sweka et al. 2018). On the other hand, the results of Sweka et al.'s studies in 2018, which used the DB-SRA model to simulate the population growth of Acipenser fulvescens from 1929 to 2018, showed that the final tolerable capacity was estimated to be 22,652 tons, and if the exploitation rate of the reserve is 37% was more than the required amount of harvest to reach the maximum sustainable production; The amount of reserves of this species will become extinct in the coming years (Alam et al. 2022). Likewise, Alam et al. (2022) showed that the two economically important shrimp species in Bangladesh are the tiger shrimp, Penaeus monodon, and the brown shrimp, Metapenaeus Monoceros. However, a continuous decline in the landing of these species from the industrial trawling made it critical to assess their stock biomass status to explore their response to the present degree of removal. Given the minimum data requirement and robustness, this study employed the depletion-based stock reduction analysis (DB-SRA) to assess these fisheries rigorously. For the industrial fishing zone (beyond the 40 m depth in the EEZ of Bangladesh), the estimated historic mean carrying capacity (K) was 5015 metric tons for the Penaeus monodon and 35,871 metric tons for Metapenaeus monoceros. The estimated overfishing limits (OFL), which were much smaller than the reported catches throughout the time series, indicate the overfishing status of these fisheries. As a result, the estimated biomass for the reference year (B2020) for both species was lower than BMSY, indicating that these fisheries are not producing MSY. Therefore, for the rebuilding and sustainable management of these stocks, this study recommended a catch limit of 100 metric tons for *P. monodon* and 750 metric tons for *M. monoceros* for the next ten years from biomass projections (Scheffer et al. 2021).

According to the obtained results from the proposed models in the present research, it can be showed that these models can be expanded in the future. It can also provide a better understanding of the current transformation processes. Although there are limitations in this research, such as the lack of accurate statistics and sufficient information on illegal fishing, as well as the lack of meteorological information to improve the model, it can be considered as a preliminary step and a model to show the need to protect this species. On the other hand, using common forecasting scenarios in order to define safe and fair boundaries may lead to ignoring the entire range of paths and interactions that lead the system to undesirable results. Especially for feedback-dependent systems such as fisheries, in which if any of the effective factors change slightly, it can bring disaster. However, models that are data or processor intensive (integrated evaluation models) and do not have computational resources are suitable for creating an acceptable path.

ACKNOWLEDGEMENTS

We thank the management staff of the International Sturgeon Research Institute, IRAN for their cooperation in data collection.

REFERENCES

Alam, M.S.; Liu, Q.; Schneider, P.; Mozumder, M M.H.; Uddin, M.M.; Monwar, M.M. & Barua, S. 2022. Stock assessment and rebuilding of two major shrimp fisheries (*Penaeus monodon* and *Metapenaeus Monoceros*) from the industrial fishing zone of Bangladesh. Journal of Marine Science and Engineering 10(2): 201.

Ceballos, G.; Ehrlich, P.R.; Barnosky, A.D.; García, A.; Pringle, R.M. & Palmer, T.M. 2015. Accelerated modern human–induced species losses: Entering the sixth mass extinction. Science Advances 1(5): e1400253.

Dick, E.J. & MacCall, A.D. 2011. Depletion-based stock reduction analysis: a catch-based method for determining sustainable yields for data-poor fish stocks. Fisheries Research 110(2): 331-341.

Ermolin, I. & Svolkinas, L. 2016. Who owns sturgeon in the Caspian? New theoretical model of social responses towards state conservation policy. Biodiversity and Conservation 25: 2929-2945.

Farhani, M. 2015. The effects of sturgeon breeding in pen culture on water quality and benthic communities in the Gorgan Bay. Ph.D. Thesis. Gorgan University of Agriculture and Natural Resources. 111 p.

Haghshenas, E.; Gholamalifard, M. & Mahmoudi, N. 2021. Ecosystem services trade-offs informing impacts of marine aquaculture development in the southern Caspian Sea. Marine Pollution Bulletin 171: 112792.

Hatef, A.; Alavi, S.M.H.; Noveiri, S.B.; Poorbagher, H.; Alipour, A.R.; Pourkazemi, M. & Linhart, O. 2011. Morphology and fine structure of *Acipenser persicus* (Acipenseridae, Chondrostei) spermatozoon: inter-species comparison in Acipenseriformes. Animal Reproduction Science 123(1-2), 81-88.

Iranian Fishery Statistics Yearbook (IFSY). 2008. Sturgeons fishing statistic insouthwest Caspian Sea. Statistic and Informatics office Iranian fishery. Tehran. Iran. pp. 1-60

IUCN. 2015. International Union for Conservation of Nature. https://www.iucn. Org/content/sturgeon-more-critically-endangered-any-other-group-species

Jalali, M.A.; Ierodiaconou, D.; Monk, J.; Gorfine, H. & Rattray, A. 2015. Predictive mapping of abalone fishing grounds using remotely-sensed LiDAR and commercial catch data. Fisheries Research 169: 26-36.

Kamza, A.T.; Kuznetsova, I.A. & Levin, E.L. 2023. Prediction of the flooding area of the northeastern Caspian Sea from satellite images. Geodesy and Geodynamics 14(2): 191-200.

McCarthy, M.A. 1996. Red kangaroo (*Macropus rufus*) dynamics: effects of rainfall, density dependence, harvesting and environmental stochasticity. Journal of Applied Ecology, 45-53.

Meng, D.; Leng, X.; Zhang, Y.; Luo, J.; Du, H.; Takagi, Y.; Zhiyuan, D. & Wei, Q. 2022. Comparation of the structural characteristics and biological activities of chondroitin sulfates extracted from notochord and backbone of Chinese sturgeon (*Acipenser sinensis*).

Carbohydrate Research 522: 108685.

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. Marine Policy 100: 107-115.

National Fisheries Science Research Institute. International Sturgeon Research Institute. 2021.

Nazeri, S.; Amiri, B.M.; Farahmand, H. & Raine, J.C. 2019. Triiodothyronine reduces toxic effects of diazinon in Persian sturgeon (*Acipenser persicus*) embryos. Comparative Biochemistry and Physiology Part C: Toxicology & Pharmacology 224: 108557.

Owashi, B.R. 2014. Evaluating the data-poor fishery stock assessment method, DB-SRA.

Pereverzoff, J. & Ackerman, J. 1998. A study of the Florida panthers (*Felis concolor coryi*) population using a dynamic modelling system.

Pourkazemi, M. 2006. Caspian Sea sturgeon Conservation and Fisheries: Past present and Future. Journal of Applied Ichthyology 22.

Raisi, H.; Moradinasab, A.A.; Patimar, R.; Kamrani, A.; Haqprast, S. 2018. Population dynamics of Persian sturgeon (*Acipenser persicus*) using Monte Carlo simulation model and bootstrap method in the southern Caspian Sea (case study: Gilan province). Applied Fisheries Research 7(3): 31-44.

Scheffer, M.; Carpenter, S.; Foley, J.A.; Folke, C. & Walker, B. 2001. Catastrophic shifts in ecosystems. Nature 413(6856): 591-596.

Sumaila, U.R.; Lam, V.; Le Manach, F.; Swartz, W. & Pauly, D. 2016. Global fisheries subsidies: An updated estimate. Marine Policy 69: 189-193.

Sweka, J.A.; Neuenhoff, R.; Withers, J. & Davis, L. 2018. Application of a depletion-based stock reduction analysis (DB-SRA) to Lake Sturgeon in Lake Erie. Journal of Great Lakes Research 44(2): 311-318.

Walters, C.J.; Martell, S.J. & Korman, J. 2006. A stochastic approach to stock reduction analysis. Canadian Journal of Fisheries and Aquatic Sciences 63(1): 212-223.

Ye, Y. & Valbo-Jørgensen, J. 2012. Effects of IUU fishing and stock enhancement on and restoration strategies for the stellate sturgeon fishery in the Caspian Sea. Fisheries Research 131: 21-29.

Iran. J. Ichthyol. (2023) 10(4): 225-235
P-ISSN: 2383-1561; E-ISSN: 2383-0964
http://www.ijichthyol.org

doi: 10.22034/iji.v10i4.990

مقاله کامل

پیش‌بینی صید ذخایر ماهیان خاویاری ایرانی (***Acipenser persicus*, Borodin 1897**) در سواحل جنوبی دریای خزر با استفاده از مدل DB-SRA و دینامیکی

الهام میررسولی*[1]، رسول قربانی[1]، سعید گرگین[1]، علی جلالی[4]، سیدمصطفی عقیلی نژاد[5]

[1]گروه تولید و بهره‌برداری آبزیان، دانشکده شیلات و محیط زیست، دانشگاه علوم کشاورزی و منابع طبیعی گرگان، گرگان، ایران.
[2]انستیتو تحقیقات سواحل، دانشگاه علوم کشاورزی، ملبورن، استرالیا.
[3]مدیریت امور ماهیان خاویاری استان گلستان، گرگان، ایران.

چکیده: این مطالعه با هدف تحلیل روند صید و پیش‌بینی صید آتی ذخایر ماهیان خاویاری ایرانی (*Acipenser persicus*) با استفاده از مدل DB-SRA و مدل دینامیکی در سواحل جنوبی دریای خزر انجام شد. نتایج نشان داد که با توجه به اندازه جمعیت اولیه در سال ۲۰۱۸ معادل ۱۵۳ قطعه ماهی (متوسط وزن ۳۰ کیلوگرم) است. با فرض نرخ ثابت صید از جمعیت برابر با ۰/۲ در سال (معادل نیمی از صید فعلی) تا ۳۰ سال آینده (۲۰۵۰)، میزان صید ماهیان خاویاری ایرانی تا زمانی که ذخایر این گونه توانایی احیای کامل خود را پیدا کنند، افزایش خواهد یافت. با فرض نرخ صید فعلی، کاهش شدید صید ماهی در سواحل جنوبی دریای خزر وجود داشته است؛ به‌طوری‌که برآورد می‌شود که ذخایر این نوع ماهیان خاویاری تا سال ۲۰۵۰ منقرض خواهد شد.

کلمات‌کلیدی: صید، DB-SRA، مدل دینامیک، ماهیان خاویاری ایرانی، دریای خزر جنوبی.