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Research Article

Assessment of the restoration trend of sturgeon stocks in Iranian waters of the Caspian Sea using SWOT model

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Abstract

Over the past three decades, sturgeon populations in the Caspian Sea have significantly declined due to overfishing and inadequate sustainable management practices. This research aims to assess assessment of the restoration trend of Sturgeon stock by using SWOT model. The data was collected through questionnaires, which provided both quantitative and qualitative insights into various aspects of the phenomena. The findings were then generalized to identify the strengths, weaknesses, opportunities, and threats related to the restoration process of sturgeon stocks in these waters. The reliability of the questionnaire was confirmed using the internal consistency method (Cronbach's alpha), In this research, the Cronbach's alpha coefficient was 0.94, as well as the reliability of each of the strengths (0.89), weaknesses (0.83), opportunities (0.92) and threats (0.88). Key reasons for the decline in sturgeon stocks and catches include lack of effective management and sustainable exploitation of fish stocks, insufficient revival and protection measures for stocks, socio-economic issues, particularly unemployment in coastal communities, inadequate policy-making and investment in the fisheries sector, habitat destruction and obstruction of migration routes for spawning due to dam construction on major rivers, changes in food resources in spawning areas, and industrial pollution, urban, and agricultural activities.

Introduction

One of the significant habitats for sturgeon fish is the Caspian Sea (Belyaeva *et al*., 1989). five sturgeon species are particularly important and valuable: *Huso huso, Acipenser gueldenstaedtii, Acipenser nudiventris, Acipenser persicus,* and *Acipenser stellatus* (Khodorevskaya *et al*., 1997). These species feed and grow in the sea, migrating to the freshwater rivers of the Caspian Sea basin for spawning once they reach maturity (Khodorevskaya *et al*., 1997; Billard and Lecointre, 2001; Nasrollshzadeh, 2003; Pourkazemi, 2006; Larijany *et al*., 2019). According to the Iranian Fisheries Organization, caviar exports from Iran have declined in both quantity and value from 2000 to 2020 (Vaezi and koochekian, 2023). Therefore, assessing the status of sturgeon production in the Caspian Sea over the past three decades and developing effective management solutions is crucial (Billard *et al*., 1981). This emphasizes the need for comprehensive research and knowledge management to restore sturgeon populations. Various studies have addressed the biology and stock assessments of sturgeon fish (Pourkazemi, 2006; Larijany *et al*., 2019; Vaezi and Koochekian, 2023).

Material and methods

This research is applied, and regarding the study type, it is a combination of exploratory methods (Creswell *et al*., 2003). The qualitative aspect involved targeted sampling of desirable cases, engaging 30 experts with extensive experience in sturgeon. Semi-structured interviews were conducted to identify strengths (S), weaknesses (W), opportunities (O), and threats (T). Initially, the SWOT analysis for the strategic management of the sturgeon stock restoration process was performed. This involved investigating the current situation and utilizing results from the semi-structured interviews to compile a comprehensive list of factors (Phadermrod *et al*., 2016). Subsequently, the Delphi technique was employed to develop a preliminary questionnaire, which was distributed to the experts. After analyzing their feedback, a refined list of internal and external factors was created and sent back to the respondents for prioritization (Creswell *et al*., 2003; Mukherjee *et al*., 2015). For the quantitative part of the research, a questionnaire derived from the interviews was utilized, aligned with the research objectives. This questionnaire, designed to assess the restoration process of sturgeon stocks, comprised 50 items rated on a five-point Likert scale (very high=5; high=4; moderate=3; low=2; very low=1). Following the collection of responses, the final questionnaire was compiled. To evaluate the reliability of the questionnaire, the internal consistency method (Cronbach's alpha) was employed. The overall Cronbach's alpha coefficient was 0.94, with reliability coefficients for each factor as follows: strengths (0.89), weaknesses (0.83), opportunities (0.92), and threats (0.88). After data collection, two statistical methods were applied for data description and analysis (Bonett and Wright, 2015).

Descriptive statistics

This method was used to collect and classify data, calculating statistical indicators such as frequency, relative frequency, mean, and standard deviation.

Inferential statistics

One-sample t-tests were conducted to assess the significance and desirability of the factors, while Friedman's test was utilized to rank each of the SWOT items.

Results

This section presents the research findings derived from the analysis of completed questionnaires. Initially, the significance of each item was assessed, followed by a detailed analysis of the items themselves. Table 1 displays the significant results of these items, while Tables 2 to 5 illustrate the analysis of the strengths, weaknesses, opportunities, and threats regarding the restoration process of sturgeon stocks in the Iranian waters of the Caspian Sea.

Table 1: The results of the Friedman analysis test in each of the SWOT lists.

statistical index Test item	Chi square	degrees of freedom	Significance level	The amount of test error	Test result
Strengths	36.48	8	0.001	0.05	significant difference between the subjects
Weaknesses	44.36	8	0.001	0.05	significant difference between the subjects
Opportunities	19.09	8	0.001	0.05	significant difference between the subjects
Threats	14.96	8	0.001	0.05	significant difference between the subjects

The results indicated several strengths in the restoration of sturgeon stocks in the Iranian waters of the Caspian Sea:

- Biological Values and Benefits: Presence of five indigenous species and the collection and production of fingerling fish.
- Social and Economic Values and Benefits: Value of caviar, marketability of sturgeon meat, and high nutritional value of both caviar and fish meat.
- Reproductive Opportunities: Availability of sturgeon breeders for reproduction and the presence of spawners in the sea and rivers.
- Technical Expertise: Comprehensive understanding of artificial reproduction techniques and sturgeon fingerling technology.
- Infrastructure: Existence of specialized complexes for reproduction and rearing of fingerling sturgeon, staffed by experienced experts.
- Stock Enhancement: Annual release of fingerling sturgeons into the sea.
- Surgical Expertise: Sufficient knowledge and experience regarding microsurgical cesarean sections.
- Collaborative Potential: Opportunities for cooperation with global and regional centers dedicated to sturgeon protection.
- Government Support: Investment from the government to restore sturgeon reserves.

- Legal Framework: Presence of national and international laws aimed at protecting sturgeon stocks.
- Innovation Opportunities: Potential for establishing knowledge-based companies focused on sturgeon-related activities.
- Research Collaboration: Possibility of partnerships with research and academic institutions, particularly in the northern coastal provinces.

Additionally, the results presented in Table 2 reveal that biological values and benefits (presence of five native species and production of fingerling fish) received an average score of 6.5, while the annual release of fingerling sturgeons scored an average of 4.8, indicating these were the highest and lowest priorities, respectively, among the respondents. Friedman's test was employed to prioritize these items, yielding a significant chi-square value of 36.48 with 8 degrees of freedom (p<0.001). This analysis underscores the higher priority assigned to biological values and benefits, which received an average rating of 7.52, compared to the lower priority of the annual release of fingerlings, which averaged 4.4.

Table 2: Friedman's test results of the strengths of the restoration process of sturgeon stocks in the Iranian waters of the Caspian Sea.

Rank	Component	Average	Rank average	Sig
	Biological values and benefits			
1	(Existence of indigenous 5 species, collection, and production of fingerling fish)	6.5	7.52	0.000
	Social and economic values and benefits			
2	(The value of caviar, the marketability of meat, and the high nutritional value of caviar and fish meat)	6.4	7.47	0.000
3	The existence of specialized complexes for reproduction and rearing of fingerling sturgeons and the presence of experienced experts in the complexes	6.4	7.47	0.000
4	Complete understanding of artificial reproduction technique and the technology of reproduction and rearing of fingerling sturgeon fish	6.25	7.15	0.000
5	The possibility of creating and operating knowledge-based companies in the direction of activities related to the field of sturgeon fish	5.87	6.28	0.000
6	Government investment to restore reserves	5.87	6.28	0.000
7	Existence of national and international laws to protect sturgeon stocks	5.87	6.28	0.000
8	Having enough information and experience about microsurgical cesarean	5.71	6.23	0.000
9	The possibility of cooperation with global and regional centers for the protection of sturgeon fish	5.63	6.13	0.000
10	The possibility of cooperation with research and academic institutes and centers with emphasis on their number in the northern coastal provinces	5.63	6.13	0.000
11	Availability of the possibility of catching sturgeon breeders for reproduction	5.60	6.01	0.000
12	The presence of sturgeon breeders in the sea and rivers	5	5.98	0.000
13	Annual release of a number of fingerling sturgeons in the sea	4.8	5.68	0.000

Also, the results indicated several weaknesses in the restoration process of sturgeon stocks in the Iranian waters of the Caspian Sea:

- Illegal and indiscriminate fishing due to economic and social issues in coastal areas.
- Absence of comprehensive laws to deter illegal fishing and inconsistent enforcement against offenders.
- Insufficient reproduction of sturgeon in the Caspian border countries.
- Lack of coordinated management and effective actions among the five Caspian Sea border countries to combat illegal fishing and smuggling, and to restore and protect reserves.
- Underutilization of regional and international resources and capabilities.
- Absence of a long-term sustainable exploitation strategy and inadequate investment in the sturgeon sector.
- Environmental degradation from industrial, oil, urban, and agricultural pollutants affecting spawning habitats.
- Low public awareness and recognition of environmental issues, lead to community indifference.
- Changes in food sources for larvae and juvenile fish in rivers and estuaries were compounded by the influx of non-native fish species into the Caspian Sea, which negatively impacts sturgeon populations.
- Inaccurate identification of suitable release areas for sturgeon.
- Lack of scientific mechanisms to accurately estimate and report statistics on fish release and returns.
- Poor coordination among the Iran Fisheries Organization, the specialized agricultural services company, and the marine protection unit during fishing, reproduction, and stock restoration phases.

The results in Table 3 reveal that the most significant issue was the destruction of rivers and marine environments due to pollutants, with an average rating of 12.5. Conversely, the inadequacy of coordinated management received a lower priority rating of 9.19. Friedman's test confirmed the significance of these weaknesses, with a chi-square value of 44.36 and 8 degrees of freedom (p<0.001).

These findings highlight the critical need for focused efforts on environmental protection and improved management strategies to enhance sturgeon stock restoration in the Caspian Sea.

These results show the higher priority of the item the trend towards the destruction of rivers and the sea with the entry of industrial, oil, urban and agricultural pollutants into the spawning place and habitat of sturgeon fishes in coastal areas with an average rating of 15.21 and a lower priority. The inadequacy of coordinated management and practical and effective action on the common reserves among the five Caspian Sea border countries to fight against illegal fishing, smuggling, restoration and protection of the reserves with an average rating of 11.19.

Table 3: Friedman's test results of the weak points of the restoration process of sturgeon stocks in the Iranian waters of the Caspian Sea.

Rank	Component	Average	Rank average	Sig
1	The trend towards the destruction of rivers and the sea with the entry of industrial, oil, urban and agricultural developments into the spawning place and habitat of sturgeon fish	12.5	15.21	0.000
2	The pressure of illegal and indiscriminate fishing due to the economic and social problems of the coastal areas	12.20	15.11	0.000
3	Absence of a long-term sustainable exploitation strategy and sufficient investment in the sturgeon sub-sector	12	14.95	0.000
4	The lack of proper recognition and low public awareness of environmental issues and the indifference of local communities to it	11.96	14.77	0.000
5	Lack of scientific mechanisms to estimate and announce the correct statistics of release and return of fisheries	11.96	14.77	0.000
6	Failure to use regional and international capabilities and capacities	11.86	14.62	0.000
7	Lack of accurate location of suitable areas for release	11.83	14.62	0.000
8	Lack of proper and sufficient reproduction of sturgeon in the Caspian border countries	11.54	14.41	0.000
9	The reduction and change of food sources in spawning and feeding places of larvae and juvenile fish in rivers and estuaries and the influx of humpbacks into the Caspian Sea and their role in the reduction of stocks and the downward trend in the volume of live mass of sturgeon fish.	11.54	14.41	0.000
10	Lack of coordination between the specialized parent company of agricultural services, the Iranian Fisheries Organization and the Marine Protection Unit in the stages of fishing, reproduction and restoration of stocks.	10.25	12.51	0.000
11	The absence of comprehensive and deterrent laws to prevent illegal fishing and to deal with the perpetrators of illegal fishing in a selective and multiple manner.	10.11	12.21	0.000
12	The inadequacy of coordinated management and practical and efficient action on the common reserves among the five Caspian Sea border countries to fight against illegal fishing, smuggling, restoration and protection of reserves	9.19	11.19	0.000

The findings from the interviews, along with the analysis of reports and statistics, indicate several opportunities for restoring sturgeon stocks in the Iranian waters of the Caspian Sea:

- Global market: A robust global market exists for caviar and sturgeon meat.
- Research centers: Fisheries research centers in the region are available to conduct studies and applied research.
- Government support: There is financial and technical backing from the government and international organizations, such as CITES & JICA, to facilitate reproduction and breeding activities in rivers, aimed at preserving genetic resources and establishing a gene bank.
- Strategic planning: A strategic plan for sturgeon fish in the Iranian waters of the Caspian Sea is in place, leveraging existing expertise and facilities.
- Protection units: The active and continuous presence of aquatic resource protection units from the Fisheries Organization (general fisheries departments of the northern provinces) is noted in the Iranian waters of the Caspian Sea.

- Community engagement: There is a focus on cultivating knowledge, raising awareness, and empowering local organizations (NGOs) in collaboration with communities along the Caspian Sea to protect sturgeon populations.
- Private sector involvement: Utilizing the facilities and equipment from private breeding and rearing units is encouraged, creating an environment for local communities and knowledge-based companies to participate in sturgeon breeding and rearing.
- Monitoring programs: The potential for designing and implementing intelligent monitoring and registration programs for sturgeon reproduction and restoration is recognized, tracking the process from broodstock supply to juvenile release through computer systems.
- Standardization efforts: Standardizing the size of cooperative fishing fins is proposed to prevent the capture of released sturgeon fingerlings.
- Sustainable employment: Creating sustainable employment opportunities for local communities is essential to deter sturgeon fishing.
- Collaborative efforts: Active participation from various organizations and institutions, such as the Environmental Protection Organization, municipalities, and various ministries, is crucial for controlling pollution in the southern Caspian Basin.
- Policy coordination: Coordinating and integrating policies, management, and executive programs related to sturgeon reproduction, breeding, and fishing is vital.

Additionally, the results from Table 4 indicate that the existence of a global market for caviar and its meat" received the highest importance rating of 8.33, while "the existence of a strategic plan for sturgeon fish in the Iranian waters of the Caspian Sea received the lowest rating of 6.19. Friedman's test was applied to prioritize these items, revealing significant opportunities for sturgeon stock restoration in the Iranian waters of the Caspian Sea, with a Chi-square value of 19.09 and 8 degrees of freedom (p>0.001). The findings emphasize the higher priority of the global market for caviar and its meat, with an average rating of 10.63, compared to the lower priority of the strategic plan, which had an average rank of 16.8.

The results of the interviews and the review of reports and statistics indicate several imminent threats to the restoration of sturgeon stocks in the Iranian waters of the Caspian Sea:

- Overfishing: A significant number of cooperatives and gillnets are contributing to the decline of sturgeon populations.
- Illegal fishing: There is ongoing illegal fishing using gillnets and various other tools in both the sea and rivers.
- Environmental pollution: Increased pollution in marine and river environments is leading to the degradation of natural breeding habitats and a lack of river water during the release of fingerling fish.

Table 4: Friedman's test results of the upcoming opportunities for the restoration of sturgeon stocks in the Iranian waters of the Caspian Sea.

Rank	Component	Average	Rank average	Sig
1	The existence of a global market for caviar and its meat	8.33	10.63	0.000
2	Coordinating and integrating the policies, management and executive programs of sturgeon reproduction, breeding and fishing	8.25	10.56	0.000
3	Creating sustainable employment for local communities to prevent sturgeon fishing	8.17	10.45	0.000
4	Active and responsible participation and playing the role of other organizations and institutions such as environmental Protection Organization, municipalities, Ministry of Health, Ministry of Energy, Ministry of Industries, etc. in order to control pollution in the southern Caspian Basin.	7.87	10.12	0.000
5	Standardizing the size of the springs of cooperative fishing fins in order to prevent the catching of released sturgeon fingerling.	7.68	10.01	0.000
6	Cultivation, promotion of knowledge and awareness and empowerment of people's organizations (NGOs) with the cooperation of local communities on the edge of the Caspian Sea in the protection of sturgeon breeders	7.51	9.85	0.000
7	Using the facilities and equipment of the breeding and rearing units of the private sector and creating an environment for the participation of local communities and knowledge-based companies by making them participate in the breeding and rearing of sturgeon fish	7.24	9.69	0.000
8	The possibility of designing and implementing intelligent monitoring and registration programs for the reproduction and restoration of sturgeon stocks from the time of supplying the broodstock to the release of the fingerling by computer systems.	7.03	9.35	0.000
9	The existence of fisheries research centers in the region to conduct studies and applied research	6.92	8.99	0.000
10	The active and continuous presence of the aquatic resource's protection units of the Fisheries Organization (general fisheries departments of the northern provinces of the country) in the Iranian waters of the Caspian Sea.	6.79	8.89	0.000
11	Financial and technical support from the government and international organizations such as CITES and JICA to carry out reproduction and breeding activities in rivers with the aim of preserving genetic resources and forming a gene bank.	6.54	8.36	0.000
12	The existence of a strategic plan for sturgeon fish in the Iranian waters of the Caspian Sea according to the existing expertise and facilities	6.19	8.16	0.000

- Communication gaps: There is insufficient organized communication among the specialized agricultural services company, sturgeon breeding centers, and reduced expert monitoring of fingerling fish releases.
- Lack of reproductive planning: There is an absence of strategic planning for reproduction, taking into account

available facilities, challenges, and human resources.

- Genetic bank degradation: The destruction of the genetic bank and the emergence of undesirable changes and abnormalities in sturgeon due to long-term artificial reproduction pose significant risks.
- Species imbalance: The overabundance of Persian sturgeon (*Acipenser persicus*) has resulted in a disproportionate release of this species compared to others.
- Economic pressures: Limited employment opportunities in the region have led to increased illegal fishing activities targeting sturgeon.
- Resource protection shortcomings: A lack of facilities and adequate manpower in the resource protection unit, coupled with legal loopholes, hampers the fight against illegal fishing.
- Management inefficiencies: Reduced management efficiency in maintaining and rearing fingerling fish in ponds is attributed to dwindling human and financial resources.
- Incentive deficiencies: There is a failure to create material and motivational incentives for personnel involved in breeding and rearing centers for sturgeon fingerlings.
- Community engagement: There is insufficient cultural engagement and participation from local communities in efforts to maintain and restore sturgeon stocks.
- NGO involvement: Non-governmental organizations and knowledge-based companies are not actively participating in the conservation and restoration of sturgeon stocks.

Additionally, the findings in Table 5 reveal that increasing pollution and habitat destruction" received the highest average score of 11.55, while genetic bank destruction and adverse changes due to artificial breeding" had the lowest at 8.29. Friedman's test confirmed the significance of these threats with a chi-square of 14.96 and 8 degrees of freedom (p<0.001). This analysis underscores the urgent need to prioritize efforts addressing pollution and habitat loss, which received an average rating of 13.63, compared to the lower priority assigned to genetic bank destruction, rated at 10.16.

To assess the strategic position of the sturgeon stock restoration process in the Iranian waters of the Caspian Sea, a SWOT analysis was conducted using an evaluation matrix for internal and external factors. After identifying the internal factors (strengths and weaknesses), these priority factors were organized into a matrix column and scored with specific coefficients and ranks. This process aimed to determine whether future strategic plans by the relevant departments would leverage more strengths or encounter more weaknesses. The evaluation matrix of internal factors is presented in Table 6.

To evaluate external factors, the evaluation matrix of external factors presented in Table 7 was utilized. This matrix also incorporated the methodology used for the internal factor’s matrix. A final score exceeding 2.5 in this matrix indicates that the identified opportunities surpass the threats, according to the predictions.

Table 5: Friedman's test results of the upcoming threats of the restoration process of sturgeon stocks in the Iranian waters of the Caspian Sea.

Rank	Component	Rank average	Average	Sig
1	The increase in sea and river pollution and the destruction of natural breeding places and the lack of river water at the time of releasing the fingerling fish.	13.63	11.55	0.000
2	Existence of illegal fishing with gillnet and other fishing tools in the sea and rivers	13.41	11.35	0.000
3	The lack of employment opportunities in the region and the increase in illegal fishing of sturgeon	13.16	11.20	0.000
4	Non-participation of non-governmental organizations and knowledge-based companies in preserving and restoring sturgeon stocks	13.13	11.16	0.000
5	The lack of organized communication between the specialized mother company of agricultural services, the sturgeon breeding and breeding centers of the Iranian Fisheries Organization and the reduction of expert monitoring on the performance of juvenile fish release.	12.87	10.98	0.000
6	Lack of planning for reproduction, considering the facilities, problems and human resources	12.67	10.75	0.000
7	Lack of culture and participation of local communities in preserving and restoring sturgeon stocks	12.16	10.25	0.000
8	Failure to create material and spiritual incentives in human resources active in breeding centers for fingerling sturgeon fish	11.74	9.89	0.000
9	The lack of facilities and sufficient manpower in the resource protection unit and the existence of legal loopholes to fight against illegal fishing.	11.12	9.58	0.000
10	Reducing the management efficiency of keeping and rearing fingerling fish in ponds due to the reduction of human resources and financial resources	10.97	8.86	0.000
11	The destruction of the genetic bank and the emergence of undesirable changes and abnormalities in sturgeon due to artificial reproduction in the long term.	10.85	8.74	0.000
12	A large number of cooperatives and their springs	10.62	8.59	
13	Due to the abundance of the Persian sturgeon *(Acipenser persicus*), the release of juveniles of this species is more than other species (single species).	10.16	8.29	0.000

Conversely, a score below 2.5 suggests that threats outweigh opportunities (Hanger and Willen, 2010). In the context of restoring sturgeon stocks in the Iranian waters of the Caspian Sea, the calculated final score of 2.06 indicates that the threats present are greater than the opportunities available. The evaluation matrix of the internal factors concerning the restoration of sturgeon fish stocks in the Iranian waters of the Caspian Sea, as presented in Table 6, indicates a total score that reflects significant weaknesses in the restoration process. Similarly, the evaluation matrix for external factors, shown in Table 7, yields a total score of 2.06, suggesting that the restoration efforts are currently under threat.

Table 6: Evaluation matrix of the internal factors of the restoration management process of sturgeon stocks in the Iranian waters of the Caspian Sea.

	Row	Objects	Weight	Rank	Final score
Strength	S1	native species, ۵biological values and benefits (presence of collection and production of fingerling fish)	0.050	4	0.136
	S2	Social and economic values and benefits (value of caviar, marketability of meat and high nutritional value of caviar and fish meat)	0.049	3.8	0.126
	S3	Existence of specialized complexes for reproduction and rearing of fingerling sturgeon and the presence of experienced experts in the complexes	0.049	3.8	0.126
	S4	Complete understanding of artificial reproduction technique and breeding technology of sturgeon fingerling	0.047	3.76	0.115
	S5	The possibility of creating and operating knowledge-based companies in the direction of activities related to the field of sturgeon fish	0.044	3.68	0.108
	S6	Government investment to restore reserves	0.044	3.68	0.108
	S7	Existence of national and international laws to protect sturgeon stocks	0.044	3.68	0.108
	S8	The existence of sufficient information and experience regarding microsurgical cesarean section	0.042	3.52	0.095
	S9	The possibility of cooperation with global and regional centers for the protection of sturgeon fishes	0.040	3.45	0.090
	S10	The possibility of cooperation with research and academic institutes and centers, emphasizing their multiplicity in the northern coastal provinces	0.040	3.45	0.090
	S11	Availability of the possibility of catching sturgeon breeders for reproduction	0.038	3.22	0.086
	S12	The presence of sturgeon spawners in the sea and rivers	0.038	3.22	0.084
	S13	Annual release of a number of fingerling sturgeons in the sea	0.035	3	0.080
Weakness	W1	The trend towards the destruction of rivers and the sea with the entry of industrial, oil, urban and agricultural developments into the spawning place and habitat of sturgeon fishes	0.048	2	0.089
	W2	Illegal and indiscriminate fishing pressure due to economic and social problems in coastal areas	0.045	1.95	0.080
	W3	Absence of long-term sustainable exploitation strategy and sufficient investment in sturgeon sub-sector	0.044	1.9	0.078
	W4	lack of proper recognition and low public awareness of environmental issues and the indifference of local communities to it	0.042	1.82	0.075
	W5	Absence of scientific mechanisms to estimate and announce the correct statistics of release and return of fisheries	0.042	1.82	0.070
	W6	Failure to use regional and international capabilities and capacities	0.040	1.75	0.066
	W7	Lack of accurate location of suitable areas for release	0.040	1.75	0.065

Table 6 (continued):

Row	Objects	Weight	Rank	Final score
W8	Lack of proper and sufficient reproduction of sturgeon fish in Caspian border countries	0.035	1.58	0.056
W9	Reduction and change of food sources in spawning and feeding places of larvae and juvenile fishes in rivers and estuaries and the influx of humpbacks into the Caspian Sea and their role in reducing reserves and the downward trend in the volume of livestock of sturgeon	0.030	1.42	0.055
W10	lack of coordination between the parent specialized company of agricultural services, the Iranian Fisheries Organization and the Marine Protection Unit in the stages of fishing, reproduction and restoration of stocks	0.028	1.36	0.054
W11	lack of comprehensive and deterrent laws to prevent illegal fishing and collisions tasteful and multiple with the perpetrators of illegal fishing	0.024	1.30	0.053
W12	Inadequacy of coordinated management and practical and efficient action on common reserves among the five Caspian Sea border countries to fight against illegal fishing, smuggling, restoration and protection of reserves	0.022	1	0.051
	The sum of coefficients of interna l factors	**1**		**2.05**

Table 7: External evaluation matrix of the final management score of the restoration process of sturgeon fish stocks in the Iranian waters of the Caspian Sea.

	Row	Objects	Weight	Rank	Final score
Opportunity	O1	The existence of a global market for caviar and its meat	0.049	4	0.136
	O2	Coordinating and integrating the policies, management and executive programs of sturgeon reproduction, breeding and fishing	0.048	3.8	0.126
	O3	Creating sustainable employment for local communities to prevent sturgeon fishing	0.048	3.8	0.126
	O4	Active and responsible participation and playing the role of other organizations and institutions such as: Environmental Protection Organization, municipalities, Ministry of Health, Ministry of Energy, Ministry of Industries, etc. in order to control pollution in the southern Caspian Basin.	0.046	3.76	0.115
	O5	Standardizing the size of the springs of cooperative fishing fins in order to prevent the catch of released sturgeon fingerling	0.044	3.68	0.108
	O6	Cultivation, promotion of knowledge and awareness and empowerment of people's organizations (NGOs) with the cooperation of local communities on the edge of the Caspian Sea in the protection of sturgeon breeders.	0.044	3.68	0.108
	O7	Using the facilities and equipment of the breeding and rearing units of the private sector and creating an environment for the participation of local communities and knowledge-based companies by making them participate in the breeding and rearing of sturgeon fish.	0.044	3.68	0.108

Table 7 (continued):

	Row	Objects	Weight	Rank	Final score
	O8	The possibility of designing and implementing intelligent monitoring and registration programs for the reproduction and restoration of sturgeon stocks from the time of supplying the breeders to the release of the fingerling by computer systems.	0.043	3.52	0.095
	O9	The existence of fisheries research centers in the region to conduct studies and applied research	0.041	3.45	0.090
	O10	The active and continuous presence of the aquatic resources' protection units of the Fisheries Organization (general fisheries departments of the northern provinces of the country) in the Iranian waters of the Caspian Sea.	0.041	3.45	0.090
	O11	Financial and technical support of the government and international organizations such as CITES and JICA to carry out reproduction and breeding activities in rivers with the aim of preserving genetic resources and forming a gene bank.	0.037	3.22	0.086
	O12	The existence of a strategic plan for sturgeon fish in the Iranian waters of the Caspian Sea according to the existing expertise and facilities	0.037	3.22	0.084
	T1	The increase in the amount of sea and river pollution and the destruction of natural breeding places and the lack of water in the rivers at the time of releasing the fingerling fish.	0.046	2	0.092
	T2	Existence of illegal fishing with ear traps and other fishing tools in the sea and rivers	0.046	1.95	0.089
	T3	The lack of employment opportunities in the region and the increase in illegal fishing of sturgeonی	0.045	1.9	0.080
	T4	Non-participation of non-governmental organizations and knowledge-based companies in preserving and restoring sturgeon stocks	0.044	1.82	0.078
Threat	T5	Lack of organized communication between specialized mother company of agricultural services, sturgeon reproduction and breeding centers of Iran Fisheries Organization and reduction of expert monitoring on the performance of juvenile fish release.	0.043	1.82	0.075
	T6	Lack of planning for reproduction, considering the facilities, problems and human resources	0.040	1.75	0.070
	T7	Lack of culture and participation of local communities in preserving and restoring sturgeon stocks	0.040	1.75	0.066
	T8	Failure to create material and spiritual incentives in human resources active in breeding and rearing centers of fingerling sturgeons	0.035	1.85	0.065
	T9	The lack of facilities and sufficient manpower in the resource protection unit and the existence of legal loopholes to fight against illegal fishing.	0.030	1.42	0.056

Table 7 (continued):

Row	Objects	Weight	Rank	Final score
T10	Reducing the management efficiency of keeping and rearing fingerling fish in ponds due to the reduction of human resources and financial resources	0.029	1.36	0.055
T11	The destruction of the genetic bank and the occurrence of undesirable changes and abnormalities in sturgeon due to artificial reproduction in the long term.	0.028	1.30	0.054
T12	A large number of cooperatives and their springs	0.025	1.25	0.053
T13	Due to the abundance of the Persian sturgeon species, the release of juveniles of this species is more than other species (single species).	0.024	1	0.051
	The sum of coefficients of internal factors	$\sum = 1$		**2.06**

Consequently, the combined results from the internal and external matrices, illustrated in Figure 1, position the restoration process of sturgeon stocks in the WT (Weakness-Threat) quadrant of the strategic framework. This indicates that, due to the predominance of weaknesses over strengths and the inability to capitalize on opportunities or mitigate threats, a defensive and conservative strategy is necessary to achieve the restoration goals.

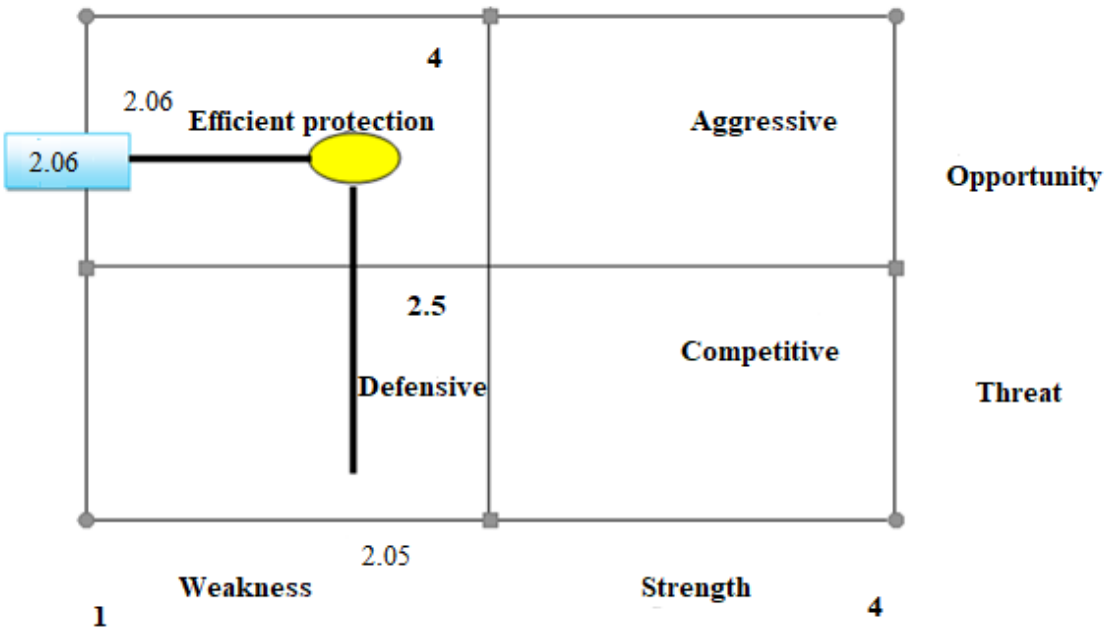

Figure 1: Final score of the evaluation matrix of internal and external factors IEF-EEF and determining the type of strategy.

Discussion

The results indicate that the biological values and benefits, specifically the presence of five native species and the collection and production of juvenile fish, have an average importance rating of 6.5. In contrast, the annual release of sturgeon juveniles into the sea holds the least importance with an average rating of 4.8. To prioritize these items, Friedman's test

was employed, revealing significant strengths with a chi-square value of 36.48 and 8 degrees of freedom (p<0.001). This analysis highlights the higher priority of biological values and benefits, which received an average rating of 7.52, compared to the lower priority of the annual release of sturgeon fingerlings, rated at 4.4. The sturgeon species found in the Caspian Sea include *Huso huso*, *Acipenser gueldenstaedtii*, *Acipenser persicus*, *Acipenser stellatus*, and *Acipenser nudiventris*. Historically, the Caspian Sea accounted for 85-90% of global sturgeon and caviar production, with output reaching 29,000 tons in the early 20th century (Noei, 2011). There is an opportunity for collaboration among the countries bordering the Caspian Sea to rebuild sturgeon stocks, supported by past successful experiences (Bloesch *et al*., 2005). One effective strategy for preserving sturgeon species is through full-time breeding, aligning with research by Abdolhay and Karmi Rad (2017) that focuses on developing sturgeon breeding in Iran for meat and caviar production. Updating breeding and rearing protocols and employing modern technologies in hatching, larval feeding, and transportation methods can significantly enhance conservation efforts and restore sturgeon populations (Abdolmalaki *et al*., 2019). Weaknesses identified include the trend toward habitat destruction due to industrial, oil, urban, and agricultural pollutants entering spawning areas, which received an average rating of 15.21. Conversely, the lack of coordinated management among the five Caspian Sea border countries to combat illegal fishing and protect shared reserves was rated lower at 11.19. Other significant concerns include increased pollution and habitat destruction, rated at 11.55, and the long-term effects of artificial reproduction on genetic diversity, rated at 8.29. The ongoing human activities, including industrial and agricultural development, have disrupted ecological stability and water capacity (UNESCO, 2006; Chu and Karr, 2017; Pathak *et al*., 2022; Kalogiannidis *et al*., 2023). Pollution has become a critical issue for water resources, particularly in the southern Caspian Sea basin, where various sectors, including ecotourism and agriculture, interact with the environment (Nasrollahzadeh, 2003). The lack of effective scientific policies and management has exacerbated pollution, threatening both aquatic life and human health. The evaluation of opportunities reveals that the existence of a global market for caviar and sturgeon meat is rated highest at 8.33, while a strategic plan for sturgeon in Iranian waters is rated lower at 6.19. Friedman's test confirms the significance of these opportunities, with a chi-square of 19.09 and 8 degrees of freedom (p<0.001). The higher priority is placed on the global market for caviar, rated at 10.63, compared to the strategic plan, rated at 8.16. Caviar remains a key product in global trade, with significant consumption by specific demographics. Sturgeon breeding has expanded to approximately 35 countries, with production increasing significantly over the past decade. In 2018, China, Russia, and Armenia accounted for 88% of sturgeon meat exports, while China alone produced 84% of the global supply in 2020 (FAO,

2020). Threats to sturgeon restoration include pollution and habitat loss, with the highest concern being the lack of river water during fingerling releases, rated at 11.55. The long-term effects of artificial reproduction on genetic integrity were rated lower at 8.29. Friedman's test indicates significant threats to sturgeon restoration, with a chi-square of 14.96 and 8 degrees of freedom (p<0.001). The most pressing issues include pollution and habitat destruction, rated at 13.63, while genetic concerns were rated at 10.16. The Caspian Sea's closure and the influx of industrial effluents from major rivers, which supply 90% of its water, contribute to accumulating pollution (Modabberi *et al*., 2020; Kaleji, 2023). Effective management of pollution in the Caspian Sea necessitates collaborative efforts at national, regional, and international levels, as supported by similar findings from other researchers (Nejat *et al*., 2018). Pollution can be categorized into abiotic (oil, industrial, urban, and agricultural) and biological (marine environment degradation and invasive species like *Mnemiopsis leidyi*) (Afraei Bandpei *et al*., 2016; Mammadov *et al*., 2016; Mahmudov, 2023). The internal evaluation matrix of the sturgeon restoration process indicates significant weaknesses, while the external matrix suggests threats to the restoration efforts, placing the process in a defensive strategic position. This indicates a need for a conservative approach to achieve restoration goals.

It highlights the higher priority of the issue concerning "the trend towards the destruction of rivers and the sea due to the influx of industrial, oil, urban, and agricultural pollutants into the spawning grounds and habitats of sturgeon fish in coastal areas," which received an average rating of 15.21. In contrast, the lower priority was assigned to "insufficient coordinated management and practical, effective actions regarding the common reserves among the five Caspian Sea border countries to combat illegal fishing, smuggling, and the restoration and protection of these reserves," which garnered an average rating of 11.19.Additionally, the findings indicate that "the increase in sea and river pollution, the destruction of natural spawning sites, and the lack of river water during the release of fingerling fish" received an average rating of 11.55, while "the destruction of the genetic bank and the occurrence of undesirable changes and abnormalities in sturgeon due to prolonged artificial reproduction" was rated lower at 8.29. These results reflect the varying levels of importance attributed to these issues. The investigation into water resources and ecosystems from both biological and non-biological perspectives reveals that the development of human activities across industrial, agricultural, urban, and domestic sectors—often lacking foundational development patterns—has disrupted the stable conditions of nature and adversely affected water capacity (UNESCO, 2006; Chu and Karr, 2017; Pathak *et al*., 2022; Kalogiannidis *et al*., 2023). Pollution has become a critical issue for water resources, particularly in the Caspian Sea and its significant fishing rivers, especially in the southern basin. Different conditions prevail along the northern coasts of our country, which are vital for sectors such as

ecotourism, agriculture, and industry (Nasrollahzadeh, 2003). Unfortunately, the absence of scientific policies and management capabilities to foster interaction, policy-making, planning, and effective information dissemination has led to a situation where the increase in pollution not only threatens the lives of valuable Caspian Sea fish reserves but also poses serious risks to human health. The closure of the Caspian Sea, combined with the influx of various industrial effluents into major rivers (like the Volga, Ural, and Kura, which supply 90% of the Caspian Sea's water) and their subsequent discharge into the sea, exacerbates this issue (Modabberi *et al*., 2020; Kaleji, 2023). Furthermore, the exploration, extraction, and transportation of oil and gas from the Caspian Sea contribute to the accumulation of pollution, particularly since the sea is landlocked with no outlet (Jafari, 2010). Factors such as the construction of water infrastructure, illegal and intensive fishing, river and sea pollution, and the loss of natural breeding habitats have led to the classification of four sturgeon species-giant sturgeon (*Huso huso*), thorn sturgeon (*Acipenser nudiventris*), stellate sturgeon (*Acipenser stellatus*), and Russian sturgeon (*Acipenser gueldenstaedtii*) to endangered fish species (IUCN, 2010).

The results also reveal that "the existence of a global market for caviar and its meat" received the highest average rating of 8.33, while "the existence of a strategic plan for sturgeon fish in the Iranian waters of the Caspian Sea, based on available expertise and resources," received the lowest at 6.19. Friedman's test was employed to prioritize these items, demonstrating that future opportunities for the restoration of sturgeon stocks in Iranian waters of the Caspian Sea are significant, with a chi-square value of 19.09 and 8 degrees of freedom. These findings underscore the higher priority of "the existence of a global market for caviar and its meat," rated at 10.63, compared to the lower priority of "the existence of a strategic plan for sturgeon fish in Iranian waters," which was rated at 8.16. Caviar is recognized as the most significant product derived from sturgeon fish in global trade (Tavakoli *et al*., 2018). As a luxury item, caviar is primarily consumed by a specific demographic both domestically and internationally. Historically, cultural and religious beliefs limited the consumption of caviar and sturgeon meat in the country. Currently, sturgeon farming occurs in approximately 35 countries, with production in 2016 increasing more than fivefold compared to 2006, reaching 340 tons. By 2018, China, Russia, and Armenia accounted for 88% of all sturgeon meat exports, while China represented 84% of global sturgeon production in 2020 (FAO, 2020).

The analysis also shows that the increase in sea and river pollution, the loss of natural breeding habitats, and the lack of river water during the release of fingerling fish received the highest average rating of 11.55, while the loss of the genetic bank and the occurrence of undesirable changes and abnormalities in sturgeon due to long-term artificial reproduction received the lowest rating of 8.29. Friedman's test was again employed to prioritize these threats, revealing that the upcoming threats to the restoration process of sturgeon stocks in the

Iranian waters of the Caspian Sea are significant, with a chi-square value of 14.96 and 8 degrees of freedom (p<0.001). The results indicate that the item "increasing sea and river pollution, destruction of natural breeding habitats, and lack of river water during the release of fingerling fish received a higher average rating of 13.63, while the destruction of the genetic bank and the emergence of undesirable and abnormal changes in sturgeon due to long-term artificial reproduction received a lower average rating of 10.16.

The closure of the Caspian Sea and the influx of various industrial effluents into the water flow of major rivers (such as the Volga, Ural, and Kura, which supply 90% of the Caspian Sea's water) exacerbate pollution levels. The exploration, extraction, and transfer of oil and gas from the Caspian Sea further contribute to the accumulation of pollution, as the sea is landlocked (Leroya *et al*., 2007). Consequently, managing pollution in the Caspian Sea necessitates national, regional, and international cooperation. Similar findings have been reported by other researchers (Nejat *et al*., 2018). Pollution in the Caspian Sea can be categorized into abiotic and biological pollution: abiotic pollution includes oil, industrial, urban, and agricultural contaminants, while biological pollution encompasses marine environment degradation and the invasion of jellyfish (*Mnemiopsis leidyi*) (Afraei Bandpei *et al*., 2016; Mammadov *et al*., 2016; Mahmudov, 2023).

Evaluation of restoration processes

The evaluation matrix of internal factors affecting the restoration process of sturgeon fish stocks in the Iranian waters of the Caspian Sea indicates a total score that reflects weaknesses in the restoration efforts. Additionally, the evaluation matrix of external factors shows a total score of 2.06, indicating that the restoration process is under threat. Therefore, the results of both matrices suggest that the restoration of sturgeon stocks in the Iranian waters of the Caspian Sea is in a weak strategic position. This implies that in spite of some activities for repelling possible threats, more efforts must be considered, and a defensive and conservative strategy should be adopted to achieve restoration goals.

Conflicts of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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