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[Research]

Relationship between Biological Egg Characteristics and Female Brood Fish in Stellate Sturgeon, *Acipenser stellatus* Pallas, 1771 (Pisces: Acipenseridae) in the Southeast Caspian Sea, Iran

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ABSTRACT

Fecundity is one of the important indicators of reproduction biology in fishes especially in rearing and restocking management of endangered species such as sturgeon. The fecundity of stellate Sturgeon (*Acipenser stellatus* Pallas, 1771) was studied in 50 specimens captured by gill net (mesh size= 100 mm) and seine net in different fishing areas along the southeastern part of the Caspian Sea from October 2004 through June 2005.Some biological characteristics of eggs (including diameter, surface-to-volume ratio of egg) and of fish (including age, fork length, weight, fecundity and gonadosomatic indices) were determined, and the relationship between them was defined. The results obtained showed that eggs were in stage F5 of development, and mean fork length, weight, age, fecundity and gonadosomatic indices were 125.26±8.01 (cm), 10.3±1.97 (kg), 12±1.34 (years), 170730±43211.11 and 20.88±3.19 (%), respectively. Also, the average egg diameter and surface-to-volume ratio were 2.92±1.44 (mm) and 2.06±0.12 (mm^{-1}), respectively. Positive correlation was detected between egg diameter and surface, and volume, while negative correlation was found between egg diameter and surface-to-volume ratio. Weight, length and age have linear relationships with absolute fecundity and age was the best predicator of fecundity (r^2= 0.848, F=27.962 and P value=0.003).

Keywords: *Acipenser stellatus*, Biological characters, Caspian Sea, Egg, Fecundity

INTRODUCTION

Stellate sturgeon, *Acipenser stellatus* Pallas, 1771, is an anadromous species distributed in the Caspian, Black and Azov Seas, and migrates into tributaries and rivers for reproduction (Anon, 2000b, unpublished data; Bemis & Kynard, 1997; Pikitch *et al*., 2005). Anthropogenic activities such as construction of dams on the rivers (causing loss of spawning ground), overfishing, illegal catch and other environmental pollution have decreased its populations (Pourkazemi, 1997). Wild sturgeon populations have declined dramatically over the recent decades (Pourkazemi, 2006), as the latest IUCN Red List Assessment, published in March 2010, classified all four species under review as critically endangered and reported that 85% of sturgeon are at risk of extinction (IUCN, 2010).

The future of Caspian sturgeon stocks has become highly dependent on the effectiveness of recruitment activities, management and control of poaching for illegal trade (Pourkazemi, 2006). Iran is one of the countries that has participated in restocking programs since 1990s (De Meulenaer & Raymakers, 1996) and has produced sturgeon fingerlings by artificial propagation and released them into the rivers to support their recruitment and prevent them from extinction (Hallajian *et al*., 2008).

Reproduction biology of fishes plays an important role in artificial propagation; because evaluation of hatched eggs and survival rates in nature is impossible, understanding and determining fecundity can provide an estimation of generation and population dynamics (Pitcher & Hart, 1996; Bruch *et al*., 2006). Knowledge of generation and production capacity of fishes can help in the management and predication of hatchery equipment, live food and etc.

Data are available on fecundity and its relation with eggs and female characters of other sturgeon (Bruch *et al*., 2006; Imanpoor & Alavi, 2009; Yousefian, 2011) and other species (Tedesco *et al*., 2008; Froese & Luna, 2004; Rahbar *et al*., 2009; Azari Takami & Rajabinejad, 2002), but limited information is reported on reproduction biology of *A. stellatus* specially on fecundity and its relations with biological features.

The aims of this study are to quantify the fecundity and gonadosomatic indices of female *A. stellatus* in stage F5 of egg development and relations between fecundity and some biological aspects of fish including length, weight and age.

MATERIALS AND METHODS

A total 50 *A. stellatus* were captured by gill net (with a mesh size 100 mm) and seine net in different fishing areas along the south-eastern shores of the Caspian Sea from October 2004 through June 2005 (Fig.1).

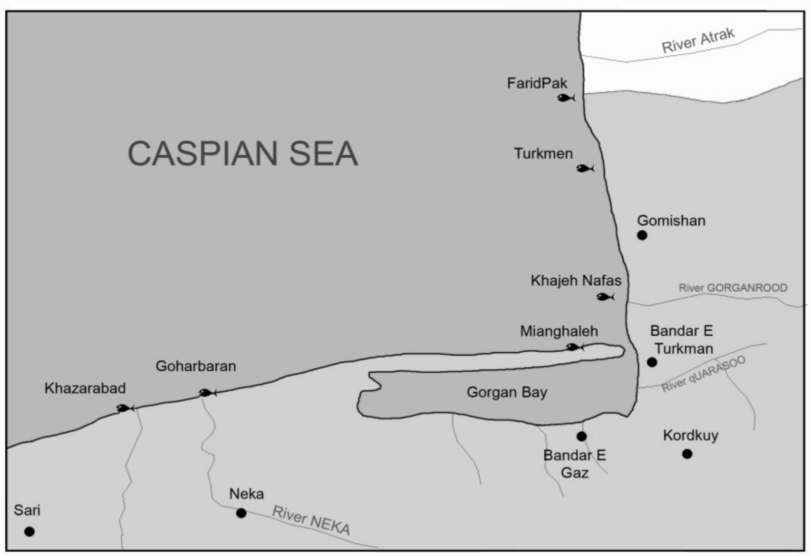

Fig.1: Map of the Iranian coastal waters of south eastern Caspian Sea. Stellate Sturgeon capturing locations are Khazarabad, Goharbaran, Mianghaleh, Khajeh Nafas, Turkmen and Faridpak

All fishes were measured for fork length (±0.1cm), body weight (±100g for adults) and gonadal weight (±1.0g). One pectoral fin ray was removed from each fish for age determination. Age was determined using the cross sections of dried portions of pectoral fin rays as described previously by Van Eenennaam *et al*. (1996). The gonad samples were fixed in Bouin's fluid and gonadal stage was determined by oocyte development and follicles (Van Eenennaam *et al*., 1998). Three sub-samples (1g) of fully grown ovarian follicles were also collected from mature females and weighed (±0.001g) for fecundity estimation.

Absolute fecundity was estimated by Gravimetry method as follows (Biswas, 1993):

$$AF = \frac{n\,G}{g}$$

Where: n = number of eggs in sub-sample, G and g are gonad weight (g) and weight of sub-sample (g), respectively.

Also, relative fecundity (eggs per kg) was estimated by the following equation (Biswas, 1993):

$$RF = \frac{\text{Absolute fecundity}}{\text{Total weigh (kg)}}$$

Gonadosomatic index was evaluated using the equation below (Biswas, 1993):

$$GSI - \frac{\text{gonad weight (g)}}{\text{body weight (g)}} \times 100$$

After measurement of the diameter of the largest (d_1) and smallest (d_2) of eggs, biological characteristics of 50 samples including diameter (d), radius (r), surface (S) and volume (V) were calculated by the following formulae. Also, the surface to volume ratio S/V was calculated (Bonislawska & Winnicki 2000).

$$d = {(d_1 + d_2)}/{2}\quad r = {d}/{2}\quad S = 4\pi r^2\quad V = 4/3\,\pi r^3$$

Relationships between absolute fecundity and weight, length and age were modeled by different functions (fitted and tested with *F*-test) and their intercept and slope were noted. To determine if fecundity changed non-linearly, the exponent of the power model we tested for significant departure from a value of 1.0 using a *t*-test. When *t*-test was not significant, it was concluded that there was a linear relationship (Bruch *et al.*, 2006). Differences in fecundity between ages were compared by One Way ANOVA (α=0.05).

RESULTS

Data on some biological characteristics of *A. stellatus* and its eggs are presented in Table 1.

Table 1. Biological characteristics of *A. stellatus* and its egg

Characters	Mean ± S.D	Min – Max
Fork length (cm)	125.26±8.01	110-144
weight (kg)	10.3±1.97	7.1-14.4
Age (year)	12±1.34	9-15
Gonad weight (g)	2144.3±505.75	1235-3186
GSI (%)	20.88±3.19	15.26-26.45
Absolute fecundity	170730±43211.11	104040-261038
Relative fecundity (egg per kg)	16632.41±3022.24	10483.88-24860.76
Number of egg (per 1g)	80±8	67-95
Egg diameter (mm)	2.92±1.46	2.6-3.15
Egg surface (mm^2)	26.91±2.99	21.23-31.16
Egg Volume (mm^3)	13.18±2.17	9.2-16.35
S/V ratio (mm^{-1})	2.06±0.12	1.91-2.31

Fork Length, weight, gonadal weight and absolute fecundity increased by when increasing the age while the gonadosomatic index and numbers of eggs per 1 gram of gonad did not have much variation in different age groups of *A. stellatus* (Table 2).

Table 2. Fork length, weight, gonadal weight, GSI and number of egg per g in *A. stellatus* in different age groups.

Parameter/age	9	10	11	12	13	14	15
Fork length (cm)	111.4±1.53	116±1.63	121.5±6.13	124.83±7.55	128.5±6.17	133.75±7.58	138±7.07
Weight (kg)	7.37±1.22	8.2±0.42	9.6±1.64	10.1±1.6	11.21±1.8	12.4±1.93	13±1.2
Gonad weight (g)	1633.75±184.5	2036±241.8	2096.4±600.9	2062±426.8	2314±563	2403±317.5	2885.4±77
GSI (%)	21.51±1.75	19.93±2.05	21.59±3.75	20.83±3.12	20.56±3.29	19.90±5.02	22.45±0.23
Absolute fecundity	129345.75 ± 9580	150664 ± 17895	167623.9 ± 47895	163061.5 ± 43849.2	183735.4 ± 35031.7	201754.25 ± 38220.08	231058 ± 22488.82
Number of egg	74±5	79±6	81±9	78±8	81±9	84±9	80±6

Assessing relationships between some biological aspects (weight, length and age) and absolute fecundity showed that the linear model is the best model for describing their relationships. Results of model fitness comparison are presented in Table 3.

Table 3. Model fit parameters of age, weight and length relationships with fecundity of *A. stellatus*.

Model /parameter		Slope	Intercept	r^2	F	Sig	t
Age	Linear	14361	2987.3	0.848	27.962	0.003*	---
	Power	0.932	17253	0.801	20.168	0.006*	0.327 n.s
	Logarithmic	164909.7	-23216.6	0.807	20.967	0.006*	45.789*
	Cubic	66.314	228190	0.819	22.623	0.007*	1.834 n.s
Weight	Linear	15082	15451	0.473	43.089	0.000*	---
	Power	0.913	20012	0.485	45.251	0.000*	0.418 n.s
	Logarithmic	154564.8	-186886	0.474	43.238	0.000*	6.575 n.s
	Cubic	-18.997	21527.6	0.474	21.338	0.000*	0.479 n.s
Length	Linear	3833.3	-310339	0.649	94.369	0.000*	---
	Power	2.849	0.1755	0.638	89.823	0.000*	6.142*
	Logarithmic	489201.4	-2192208	0.642	95.639	0.000*	9.779*
	Cubic	-0.109	-765819	0.645	47.454	0.000*	7.487*

*significant at ($P<0.05$)

According to Table 3, age-fecundity relationship are the best predictor models ($r^2=0.848$, $F=27.962$ and $P<0.05$), because of the highest regression coefficient. Comparison exponent of the power model for significant departure from a value of 1.0 showed significant differences in age-fecundity logarithmic, length-fecundity power, logarithmic and cubic models, because correlation coefficient of length-fecundity relationship in linear models was higher than its value in other models in these cases, so the linear model was chosen to describe their relations (Fig. 2). The statistical correlation between a number of fish and egg biological characteristics in *A. stellatus* are presented in Table 4.

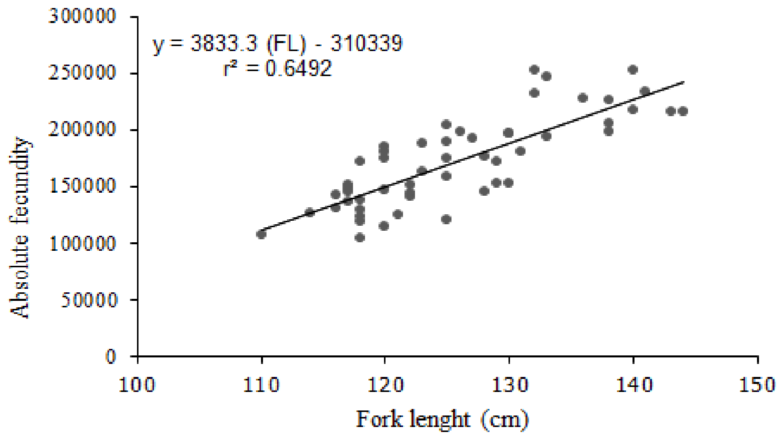

Fig. 2. Fecundity-length relationship in *A. stellatus*.

Table 4. Pearson's correlation between a number of fish and egg biological characteristics in A. stellatus. (FL: fork length; d: egg diameter; S: egg surface; V: egg volume; S/V: surface to volume ratio; AF and RF: absolute and r: relative fecundity).

Parameter	FL (cm)	*d* (mm)	S (mm^2)	V (mm^3)	S/V (m^{-1})	Age (year)	W (g)	AF
FL (cm)	1							
d (mm)	0.554**	1						
S (mm^2)	0.550**	1**	1					
V (mm^3)	0.545**	0.998**	1**	1				
S/V (m^{-1})	-0.561**	-0.998**	-0.996**	-0.993**	1			
Age (year)	0.603**	0.352	0.360	0.367	-0.336	1		
W (g)	0.952**	-0.009	-0.11	-0.014	0.002	0.542**	1	
AF	0.806**	-0.160	-0.168	-0.176	0.143	0.431**	0.552**	1

** $p< 0.01$, * $p< 0.05$

DISCUSSION

Stellate Sturgeon migrates to tributaries of Caspian Sea during spring and autumn, the intensity of spawning being high particularly after heavy rainfall (Pourkazemi, 2006). The age of its spawning ranged between 6-28 years, on average 11-16 years. The average weight of females is 11-12 kg (Levin, 1997). In present study, age and weight of females recorded 9-15 years and 7.1-14.4 kg, respectively. In spite of small number of sample, but it cover suitable length and weight distribution of matured females which lead to accuracy estimation. The average of fecundity of fishes varies between intra and inters-species and even year-to-year for specific population. It depends on genetics differences in species and even in sub-species, and environmental conditions such as food accessing, population density and temperature variation (Unlu & Balci, 1993). According to Yousefian (2011), mean absolute fecundity of *A. persicus* was 264000±73000. The mean fecundity of *A. fulvescens* is reported 323684±24294 (Bruch *et al*., 2006). In this study the mean absolute fecundity was 170730±43211.11. Since previous studies carried out based on same method we can conclude that beside the differences between species in these studies, ecological and environmental conditions (water quality, temperature and food availability) and age are the most resources of difference in the results. As the sample of *A. persicus* were cultured and collected from hatchery and length ranged 138-200 cm, *A. fulvescens* were caught from lake and age ranged 30-45, while *A. stellatus* of present study were sampled from sea, wild and have 9-15 years old.

Absolute fecundity increases with increasing of fish length (Nikolsky, 1963). Also, it increases with increasing of gonad weight because the gonad weight calculated by numbers of eggs which existed it. Results of model fitting show that linear model is the best model to describe relationship between biological features (age, weight and length) because in almost all of cases linear model is significant and has higher r^2 rather than other model. So it confirms this fact clearly. Many studies are reported similar relationship in different species (Bruch *et al*., 2006; Rahbar *et al*., 2009; Takami & Rjabinegad, 2002).

Differences in size of eggs dimensions depend on the size of parental fish (Bonislawska *et al.*, 2000), brood protection (Tilney & Hecht, 1993; Marteinsdottir & Steinarsson 1998; Bonislawska *et al*,. 2001), absolute fecundity (Thorpe *et al*., 1984) and environmental parameters (George, 1999). Generally, it is reported that the eggs with larger size had more chance of being fertilized and took shorter time to develop during hatchery period. So, larger eggs protect more survival offspring (Yousefian, 2011). In the life process of an egg, surface of its membrane provides possibility of diffusing which let it to exchange gases like oxygen and uptake critical substances from surrounding environment (Imanpoor *et al.*, 2009).Thus, the size of egg and its characters (surface, volume and S/V) have important role in efficiency of fertilizing and surviving. In the present study the mean egg diameter was 2.92±1.46. Results show that there is a slight negative correlation between absolute fecundity and eggs characters except in the S/V. In the other hands, when the fecundity increases, its surface, volume and diameter decrease. Also, the egg surface and volume increase with increasing egg diameter, but the surface-to-volume ratio decrease. Generally, having bigger eggs provide higher efficiency of fertilizing and result in more survival rate. But we can't say it easily that increasing of fecundity and decreasing of egg's diameter is good or bad index. It depends on biological require of specie like where it lives (bottom, pelagic and etc.) and environment condition and require of embryo (because egg's surface is a layer to exchange gases and nutrients). Since *A. stellatus* is an endangered species it seems that producing more eggs even is a biological strategy for it to save their stock and increase their survival chance.

In the present study, age-fecundity linear model was the best predicator of absolute fecundity. Among the linear models (the best model for each biological character) length-fecundity was on the second place because of its r^2. Whereas taking length data is easer in field condition and also it has less damage for fishes, so suggests use it to predicate fecundity however, it has less precision rather than age model. Linear length-fecundity model express that fecundity has slight variation in low age and its increase highly in older fish. Imanpoor and Alavi (2009) determined significant correlation coefficients between fork length (0.772), total weight (0.856) and age (0.845) with fecundity of Iranian sturgeon. Our results are accordance with their result. Bruch *et al.* (2006) reported weight was the best predicator of fecundity as linear relation. This difference related to fish biology characters and they are influenced by the interaction between species and their environment (Berg *et al*., 1949; Rass, 1953; Bagenal, 1971).

Considering that number of *A. stellatus* has been declined thus it seems artificial propagation programs should focus on improving efficiency of propagation by recognizing all feature of its reproduction biology. According to the limited information on fecundity of *A. stellatus*, our results can provide basic information for use to improve the propagation efficiency.

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رابطه بین ویژگی‌های زیستی تخم و مولدین ماده ازون‌برون در جنوب شرقی دریای خزر، ایران (*Acipenser stellatus Pallas, 1771*)

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چکیده

مطالعه هماوری یکی از مهم‌ترین شاخص‌های زیست‌شناسی تولیدمثل در ماهیان بویژه در بازسازی و نگهداری از گونه‌های در معرض خطر نظیر ماهیان خاویاری است. هماوری ماهی اوزون‌برون *Acipenser stellatus* (Pallas, 1771) در 50 نمونه صید شده بوسیله تورگوشگیر (با اندازه چشمه تور 100 میلی‌متر) و پره مورد بررسی قرار گرفت. نمونه‌ها از مناطق مختلف صیادی در جنوب-شرقی دریای خزر در مدت زمان بین مهرماه 1383 تا خرداد 1385 جمع‌آوری شده بودند. برخی از ویژگی‌های زیستی تخم (شامل قطر و نسبت سطح به حجم) و ماهی (شامل سن، طول چنگالی، وزن، هماوری و شاخص گنادوسوماتیک) تعیین شدند. سپس رابطه بین آن‌ها مورد بررسی قرار گرفت. نتایج نشان داد تخم‌ها در مرحله رسیدگی F5 قرار داشتند و متوسط طول فورک، وزن، سن، هماوری و شاخص گنادوسوماتیک بترتیب برابر با 8/01±125/26سانتی‌متر، 1/97±10/3 کیلوگرم، 1/34±12سال، 43211/11±170730و 3/19 ± 20/88 درصد بود. همچنین متوسط قطر تخم و نسبت سطح به حجم 1/44±2/92 میلی‌متر و 0/12±2/06 در میلی‌متر بدست آمد. بین قطر و سطح تخم، قطر و حجم تخم همبستگی مثبت و بین قطر تخم و نسبت سطح به حجم همستگی منفی مشاهده شد. وزن، طول و سن با هماوری مطلق دارای ارتباط خطی بودند و سن بهترین ویژگی زیستی جهت تخمین میزان هماوری مشخص شد (F=27/962، r^2=0/848، P value =0/003).

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