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Maturity Stages, Gonado-Somatic Index (GSI) and Fecundity of Leaping Grey Mullet, *Liza saliens* (Risso, 1810) in the Western Part of Iranian Waters of the Caspian Sea (Guilan Province, Iran)

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Abstract

The paper focuses on some of the biological characteristics of leaping grey mullet, *Liza saliens* (Risso, 1810) in the western part of the Iranian waters of the Caspian Sea (off Guilan province). Samples of the mullet were taken monthly from commercial catch of beach seine fishing cooperatives (from October 2008 to April 2009). From May to September 2009 (a period not considered fishing season here), fish samples were obtained from local markets which caught them illegally. Fork length (FL), weight and sex were recorded for 302 fish. In addition, gonad weights were recorded for calculating Gonado-Somatic Index (GSI) and scales were removed for aging. The M:F (male/female) sex ratio of this species was 1:2.23 during the whole course of the study which deviate significantly from 1:1 common sex ratio ($\chi 2$=59.83, sig. level=0.000, df=1). During 2008-2009, the peak of the spawning time for leaping grey mullet occurred in July in Guilan shores. The highest GSI was found to occur during June-August and declined to its lowest level in September and remained relatively stable during October to April. The average absolute fecundity of leaping grey mullet was 207,050±134,630 (±SD) eggs with a range of 29,700 and 512,900 eggs. The length of females at 50% sexual maturity was estimated at 23 cm.

Introduction

In recent years the species composition of mullet fishes in the Caspian Sea has changed significantly and the contribution of leaping grey mullet declined from 24% 1995 (Fazli and Ghaninejad, 2004) to 1.5% in 2005 (Abdolmalaki et al. 2005). There was a reduction in catch from 450 tonnes to 38 tonnes during the years 1995 to 2005 (Abdolmalaki et al. 2005).

The leaping grey mullet occurs in the Mediterranean Sea, Black Sea, Atlantic Ocean, from Morocco up to the Biscay Bay. The mullet was introduced into the Caspian Sea (Kosarev and Yablonskaya, 1994) and lakes in Egypt (Katselis et al. 2002). Mullets are not native fish species of the Caspian Sea. In order to increase fish productivity of this water body, 3,000,000 individuals of *Liza aurata*, leaping grey mullet and *Mugil cephallus* caught from the Black Sea were introduced into the Caspian Sea during 1930-1934 (Konovalov, 1959; Oren, 1981; Kosarev and Yablonskaya, 1994; Belyaeva et al. 1989).

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In general, during the past 63 years, mullet fisheries in Iranian waters experienced fluctuations. Mullet fishery in this period amounts to a total of 125,000 tonnes (Abdolmalaki et al. 2005). Based on the report by Kuliev and Ragimov (2003) leaping grey mullet reach maturity at the age of 3-4 years. The spawning areas are situated throughout the south and middle Caspian Sea. Mass spawning takes place in June-July when surface water layer warms up to 25-29 °C. Yousefian et al. (2003) and Fazli (1999) studied the fecundity and sexual maturity of leaping grey mullet in the eastern part of the Iranian waters of the Caspian Sea. Population dynamics and biology of this species were also investigated by Ghadirnejad (1996). Sexual maturity of the species in the western part of the Iranian waters of the Caspian Sea (off Guilan province) was studied by Abdolmalaki et al. (1998). In addition, Patimar (2008) investigated the growth, fecundity and sexual maturation of leaping grey mullet in the Gorgan Bay in the southeast of the Caspian Sea. In view of the ecological changes which occurred in the Caspian Sea and the decrease in leaping grey mullet landings, this research was carried out to shed more light on the reproductive biology of the species.

Materials and Methods

The commercial catch of bony fishes including leaping grey mullet along the Iranian waters of the Caspian Sea is carried out with the use of beach seine by cooperatives in fishing regions (Fig. 1). Monthly samples of leaping grey mullet were collected from October 2008 to April 2009, from cooperatives in the western part of the Iranian waters of the Caspian Sea (off Guilan province, southwest of Caspian Sea). From May to September 2009, fish samples were obtained from local markets.

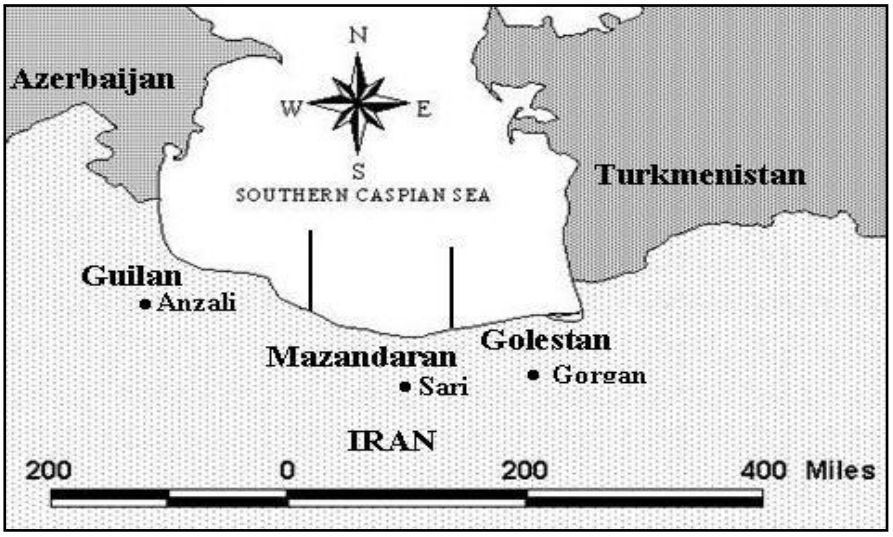

Fig.1. The location of Guilan province in the southwest of the Caspian Sea.

In this study, a total of 302 leaping grey mullet were examined. For each sample, the fork length (FL) was measured to the nearest 0.5 cm and the total weight (W) to the nearest 5 g. Age was determined by reading scale rings under a stereoscopic zoom microscope of 40x magnification. Ages were assigned on the basis of formed annular counts. From each specimen, scales were removed from the second row of scales just under the front edge of the first dorsal

fin of the left side of the body (Chugunova, 1959). The overall sex ratio of males to females was evaluated with $\chi 2$ - test (Sokal and Rohlf, 1995). Sexual maturation was determined via the six-stage maturation criteria (Nikolsky, 1963).

In order to determine fecundity, ovaries taken from 47 ripe females (stage 4 and 5 of maturity) were used, including the available size range of individuals collected during the study. Ovaries were weighed to the nearest 0.001 g. A small section of ovaries removed midway along the length of either the left or right ovarian lobe (chosen at random), was weighed (0.5-0.7 g) and then placed in a separate petri dish with 70% alcohol solution. The eggs in each sample were separated using scalpel and forceps and then were counted. The absolute fecundity was calculated using the gravimetric method (i.e. simple proportion; Hunter et al. 1985). The spawning season was determined through variation of the Gonado-Somatic Index (GSI) which was computed by the equation GSI (%) = (gonad weight/total body weight) * 100.

The length at 50% of maturity (macroscopic gonad stage 3 and above) was calculated through devising a logistic trajectory on the proportion of the matured female and the fork length which was computed through the following logistic equation (King, 2007):

$$P=1/1+\exp [-r (L-Lm)]$$

Where r, represents the slope of the trajectory and Lm represents the mean length in sexual maturity which is equal to 50% ratio under reproductive condition. SPSS and Excel software packages were used for data analysis.

Results

The fork length of leaping grey mullet ranged from 11.9 cm to 39 cm with the mean of 22.6±3.97 cm (±SD) and their weight varied from 17.1 g up to 600 g with the mean weight of 127±77.2 g. Age of the fish ranged from 2 to 11 years with mean age of 3.39 years. The age groups of 3, 4 and 5 years constituted 66% of the age composition. Fig. 5 shows the sex composition in different age groups. As seen in the figure, the female fish account for the bulk of the sex composition in younger age groups, and even they constitute the whole population of age group of 6-11 years old. In this study, the overall male:female sex ratio of the population was 1:2.23 showing that sex ratio deviated significantly from 1:1 ($\chi 2$=59.83, sig level=0.000, df=1). The highest value of GSI for females was observed in June-August, whereas it declined in September. It remained relatively stable during October till May (Fig. 2).

The mean absolute fecundity was 207,050±134,630 eggs with the range of 29,700 and 513,000 eggs as the minimum and maximum number respectively. The smallest spawner had a length and weight of 11.9 cm and 17.1 g respectively. The mean relative fecundity amounts to 1,179±604 eggs per gram of body with the range of 75 as minimum and 2,367 as maximum eggs per gram.

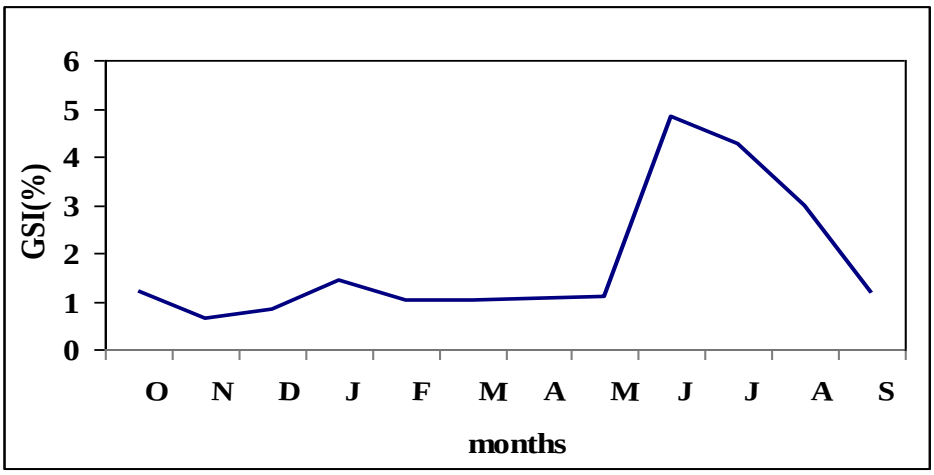

Fig. 2. The trend of monthly variations of GSI in female of leaping grey mullet in the western part of the Iranian waters of the Caspian Sea

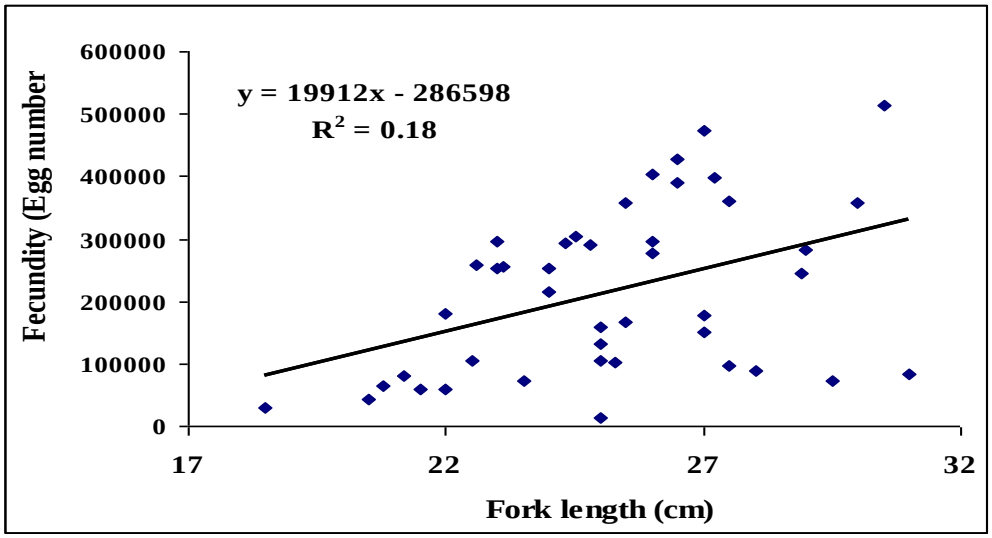

Fig. 3. Relationship between absolute fecundity and fork length (FL) for leaping grey mullet in the Giulan waters of the Caspian Sea

The relationship between fork length and fecundity was F=19,912 FL-286,598; (Fig. 3; R^2=0.18, n=47). As illustrated in the figure, the absolute fecundity has positive correlation with fork length.

Fitting the logistic equation for the female maturity ogive gave an estimate of Lm50=23 cm for leaping grey mullet in the Guilan province (Fig. 4). The relationship between body weight and absolute fecundity of the leaping grey mullet was as follows: F=1104.6 w + 11769 (R^2=0.2605, n=47). There also appears to be a positive relationship between fecundity and body weight in such a way that the fecundity increases as body weight rises.

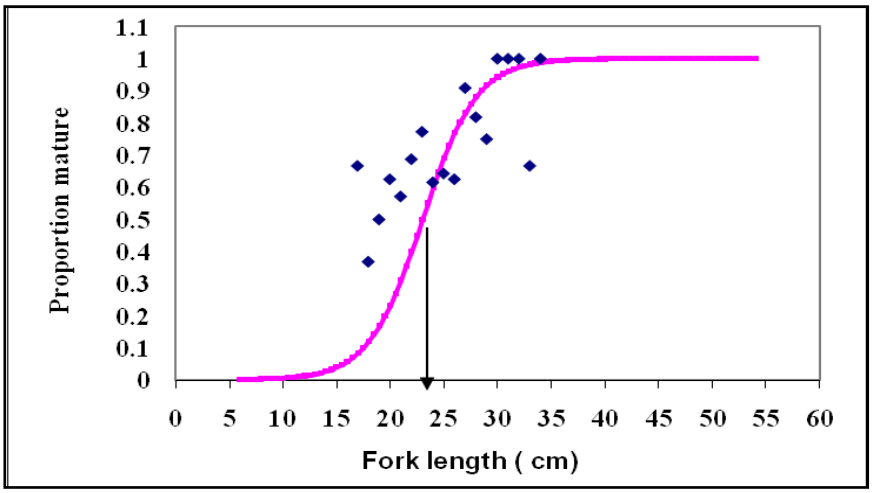

Fig. 4. Female leaping grey mullet fork length at 50% maturity (Lm50%) in the Guilan waters of the Caspian Sea

Discussion

In this study, sex ratio differs significantly from overall 1:1 sex ratio. Fazli (1999) also proposed the dominance of females (male:female ratio of 1:3.14 in the southeastern coastal sea areas of Caspian Sea). While Patimar (2008) reported that females were dominant only in older age groups in the Gorgan Bay in the southeastern of the Caspian Sea. In the Messolonghi Etoliko lagoon (western Greece) the overall sex ratio of males to females was 1:0.8 and X^2 analysis (P>0.05) revealed this to be not significantly different from the expected 1:1 ratio (Katselis et al. 2002). There is not a homogenous sex composition among the mullet catch within species and age groups (Fig. 5).

Fig. 5. Sex composition (%) of leaping grey mullet in each age group during the years 2008-9

According to Belyaeva et al. (1989), the females account for 86% of the mullet landings. But in recent years, the number of females decreased in the catch and closed to the typical 1:1 ratio. Abdolmalaki et al (1998) reported that female leaping grey mullet constituted 78% of the mullet landings in the western part of the Guilan coastal waters. In addition, Ghadirnejad (1996) reported that females constituted 75.6% of sex composition of the catch in the Iranian coastal waters of the Caspian Sea. Laevastu and Favorite (1988) reported that fish behavior in relation to the fishing gears, might vary according to their body size, age and physiological condition that may have some effects on sex composition. The sex ratio in the Gorgan Bay and Messolonghi Etoliko Lagoon did not deviate from the usual 1:1 sex ratio where two water bodies are coastal lagoons and samples were caught by gillnet of a variety of mesh size. In this survey leaping grey mullet was in stage 2 and 3 of maturity in May and was in stage 3 and 4 in June. Sexual maturation of female from stage 2 or 3 of maturity to stage 4 only lasted 1.5-2 months altogether which was very rapid. Belyaeva et al. (1989) reported that stage 4 of maturity has been observed in May-June. According to Askerov et al. (2003) mass spawning of the leaping grey mullet in the Caspian Sea takes place in June-July when the surface water layer warms up to 25-29 °C.

In this study, the spawning peak of leaping grey mullet in the Guilan waters was in July. GSI of females were highest in July-August, showing the peak of spawning in this species. It thereafter decreases slightly in September and approaches the low values similar to that of the rest of the year. The reproductive period for this species in this particular environment is thus from June through August when GSI is considerably higher (Fig. 2). It was also reported by Fazli (1999) that maximum values of GSI in leaping grey mullet was in July and the peak of spawning occurred in August in the Mazandaran coastal waters (the southern part of the Caspian Sea). According to Patimar (2008) reproduction phase is extended from May to July. Peaking occurs in mid June, with the highest average values of GSI of 1.996 for males and of 5.973 for females. It thereafter decreases sharply in August. The GSI of both sexes followed the same pattern, but during the reproductive period, the average values of males were significantly lower than those of females. The earlier spawning of this species in the Gorgan Bay could be attributed to the higher temperature of the water and shallower depth of the Bay in comparison to the western part of the Caspian Sea (the Guilan waters). Upon comparison of the sexual maturity pattern of leaping grey mullet during the past years and in different areas, it is reasonable to conclude that sexual maturity and the subsequent spawning by the species differ in space and time and depend on water temperature (Rankin et al. 1983).The increase in the surface water temperature to 25-29 °C along the Guilan province occurs relatively later than that of the Gorgan Bay (Poorgholam et al. 1996), which resulted in peak spawning taking place later in the Guilan waters in comparison to the Gorgan Bay. According to Cardona (1999) many of the papers reviewed by Brusle (1981) reported that spawning periods of this species lasts more than 3 months, but some other populations are known to show very limited spawning seasons, usually June and July or July and August. In a long term study on the recruitment of estuarine fish, Arias and Drake (1990), it was observed that leaping grey mullet did not have a constant recruiting pattern (Cardona, 1999). Mullet fishes have high reproductive capacity. In this study, the mean absolute fecundity was 207,050±134,630 eggs with a range of 29,700 and 512,900 eggs. Patimar (2008) reported that in the Gorgan Bay a maximum value of 389,800 eggs was recorded in a 7+ year old fish weighing 197.3g and a minimum value of 135,000 eggs was calculated for 2+ years

old fish weighing 66.6 g. The absolute fecundity of 25-39 cm long mullet is an average 450,000-600,000 eggs (Askerov et al. 2003). Kazancheyev (1981) reported that absolute fecundity of leaping grey mullet is about 530,000 to 2,150,000 eggs. The mean of absolute fecundity with mean length of 28 cm was found to be 684,300 eggs (Khoroshko, 1989).

However, Belyaeva et al (1989) reported a fecundity range of 500,000 to 3,000,000 eggs. Ghadirnejad (1996) reported that the minimum and maximum fecundity of this species were 345,600 eggs and 1,800,000 eggs respectively with mean number of 661,300 eggs (Table 1). According to our study, the absolute fecundity was found to be both positively and linearly related to fork length and body weight.

Table 1. Fecundity of leaping grey mullet in different length groups.

	Length groups (cm)				
	15-20	20-25	25-30	30-35	35-40
			Khoroshko (1989)		
Minimum	-	357,900	447,100	637,000	-
Maximum	-	638,400	894,200	1,735,600	-
Mean	-	484,200	609,200	1,011,200	-
			Ghadirnejad (1996)		
Minimum	-	345,600	445,200	605,400	1,236,000
Maximum	-	610,300	800,000	1,699,000	,1805,200
Mean	-	486,000	619,200	834,200	1,615,000
			This study		
Minimum	29,700	43,900	88,900	71,700	-
Maximum	29,700	303,300	474,200	512,900	-
Mean	29,700	167,700	253,100	256,400	-

Khoroshko (1989) reported that the fecundity of leaping grey mullet like that of golden grey mullet increased considerably as the fork length increased, but the relative fecundity remained stable. It is evident that absolute fecundity increases with fish length, weight and age. Such a relation is quoted by Oren (1981) for other mugilidae species. The correlation of fecundity with weight in most fishes was higher than its correlation with the length (Nikolsky, 1969).

The result of this examination revealed that the fecundity of this species in the Guilan waters was lower than that of the Gorgan Bay. Patimar (2008) stressed that lower GSI values coupled with lower fecundity in the Gorgan Bay could be interpreted as lower energetic investment in reproduction. It seems that longer periods of growth, higher productivity and vast feeding area of the eastern regions (Poorgholam et al. 1996) could be the cause of higher fecundity of this species in the Mazandaran waters in comparison to the Guilan waters.

The mean relative fecundity of leaping grey mullet was observed in this study to be 1179±604 eggs per 1 gram of body weight with the range of 75 and 2,367 eggs per 1 gram of body weight as the minimum and maximum number. Patimar (2008) reported that the relative fecundity of this species in the Gorgan Bay fluctuated from 1,364 to 4,281 eggs per 1 gram, with a mean value of 2,225 ± 493 eggs per 1 gram. Fecundity is changed by many factors, such as the high feeding and growth (Wootton, 1990) temperature (King, 2007) length and age of the females fish (Oren, 1981) and life history strategy (Morita and Takashima, 1998). Results of this study show that the fork length (FL) at 50% sexual maturity of leaping grey mullet was 23 cm. Unfortunately there is no available report of the Lm50% concerning sexual maturity for this species in the Caspian Sea and in other areas. Alexsandrova (1964), Kazancheyev (1981), Kuliev and Ragimov (2003) reported that leaping grey mullet reaches sexual maturity at 3-4 years old in the Caspian and Black seas. The estimated Lm50% at maturity in this study is equal to 4 years old based on Von Bertalanffy (1938) growth equation of this species (unpublished data). Cardona (1999) reported that most of the leaping grey mullet in the 4+ age class were adults and were ripe in mid-summer in Minorca in the Balearic Islands. The differences which were observed in biological characteristics of this species in the region could be assigned to varieties of ecological conditions in the Iranian waters of the Caspian Sea. One of the most important changes is a considerable increase in stock of other mullet species, i.e. golden grey mullet. The biomass of golden grey mullet increased from 8,176 tonnes in 1993 (Ghadirnejad, 1996) to about 26,000 tonnes in 2006 (Fazli et al. 2008).

Conclusion

This study shows that in the Guilan waters the male:female sex ratio of leaping grey mullet was significantly different from 1:1, at the same time a comparison to the results of previous years shows that in sex composition the contribution of females has diminished. Sexual maturation of female only lasts 1.5-2 months altogether which is very rapid. The spawning peak which is in July is different compared to other places around the Caspian Sea and is influenced by temperature differences at different latitudes. The results of this examination reveal that the fecundity of this species has diminished in comparison to previous years. The changes in reproductive biological characteristics of leaping grey mullet are influenced by species composition, drastic changes in the amount of stocks and competition between species.

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