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Research Article

Reproductive Biology in a Native European Catfish, *Silurus glanis* L., 1758, Population in Menzelet Reservoir

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Abstract: The reproductive activities of *Silurus glanis* were investigated over 12 months in Menzelet Reservoir, in the East Mediterranean region of Turkey. Total length of the examined 245 *S. glanis* varied from 33.4 cm (220 g) to 195.0 cm (48,000 g), and age distribution ranged between 1 and 14.

Observations on the seasonal distribution of the maturity stages and variations in the gonadosomatic index (GSI) confirmed that *Silurus glanis* has a prolonged spawning period extending from the beginning of June to August. The males mature earlier than the females, at a minimum size of 78.82 cm in total length and at age 3, while the females mature at a minimum size of 87.05 cm in total length and at age 4. It was determined that a fishing ban should be applied from the end of May to the beginning of August and fish smaller than 90 cm in length should not be caught.

Fecundity estimates based on 49 mature females ranged from 9033 to 340,461 eggs/fish and correlated positively with total length (ln F = 5.4034 x ln L – 14.126; r = 0.8987), body weight (ln F = 1.7171 x ln W – 4.440; r = 0.9062) and ovary weight (F = 115.36 x OW +30105 r = 0.8721). Relative fecundity ± $CI_{(95\%)}$ for each kilogram of female fish was 8434 ± 1114 eggs and each gram of ovaria consists of 195 eggs prior to the spawning season.

Egg size varied monthly and egg diameters ranged from 1.00 mm to 3.63 mm in May. Egg size correlated negatively with the number of eggs in the ovaria.

Key Words: Reproduction, fecundity, egg size, European catfish, *Silurus glanis*.

Menzelet Baraj Gölündeki Doğal Yayın, *Silurus glanis* L., 1758, Populasyonunda Üreme Biyolojisi

Özet: Türkiye'nin Doğu Akdeniz Bölgesi'nde bulunan Menzelet Baraj Gölü'ndeki *Silurus glanis*'in üreme aktiviteleri 12 aylık bir periyotta incelenmiştir. İncelenen 245 adet *S. glanis* bireylerinde total boylar 33,4 cm (220 g) ile 195,0 cm (48.000 g) arasında ve yaş kompozisyonu ise 1-14 arasında dağılım göstermiştir.

Aylık Gonadosomatik Index (GSI) ve olgunluk safhalarının incelenmesiyle *Silurus glanis*'in yumurta dökme periyodunun Haziranda başlayıp Ağustos'a kadar sürdüğü tesbit edilmiştir. Erkekler 3 yaşında ve 78,82 cm total boyda, dişişler ise 87,05 cm total boy ve 4. yaşta eşeysel olgunluğa gelmiş ve erkeklerin daha erken olgunlaştığı görülmüştür. Av yasağının Mayıs ayı sonunda başlayıp Ağustos ayı başına kadar sürmesi gerektiği ve yaklaşık 90 cm'den küçük bireylerin avlanmaması gerektiği kanaatine varılmıştır.

Toplam 49 dişi bireyde incelenen yumurta sayıları 9033 ile 340.461 yumurta/balık arasında değişmiş ve fekondite ile total boy (ln F = 5,4034 x ln L – 14,126; r = 0,8987), vücut ağırlığı (ln F = 1,7171 x ln W – 4,440; r = 0.9062) ve ovaryum ağırlığı F = 115,36x OW + 30.105; r = 0,8721) arasında pozitif bir korelasyon bulunmuştur. Kısmi fekondite ± $CI_{(\%95)}$, 8434 ± 1114 yumurta/kg balık olarak bulunmuş ve üreme dönemi öncesi bir gram ovaryum parçasında 195 adet yumurta tesbit edilmiştir.

Yumurta büyüklüğünde aylık farklılıklar gözlenmiş ve Mayıs ayında yumurta çapları 1,00 mm ile 3,63 mm arasında değişmiştir. Yumurta büyüklüğü ile ovaryumdaki yumurta sayısı arasında negatif bir korelasyon vardır.

Anahtar Sözcükler: Üreme, fekondite, yumurta büyüklüğü, yayın, *Silurus glanis*.

Introduction

Silurus glanis, known as the European catfish, wels and sheatfish, is the largest freshwater fish species and is characterized by its rapid growth and large body weight (1). Its natural distribution includes the tributaries of the Caspian, Black, Aral, Aegean and Eastern Mediterranean seas, and is also likely to include some Baltic Sea tributaries and the upper part of the River Rhine (2,3). Two Silurus species inhabit Turkish freshwaters: *Silurus glanis* has a wide distribution that includes the Sakarya, Manyas, Apolyont, İznik, Gölhisar, Samsun, Kura, Aras, Seyhan and Ceyhan rivers (4,5), and *Silurus triostegus* inhabits the Euphrates Basin (6).

Because of its economic importance, *S. glanis* has attracted interest as a potential species for fish culture, and so a number of studies have been carried out for artificial reproduction and aquacultural purposes (1,7-9). Its genetic and chromosomal structures have also been investigated (2,10-12). Studies related to the wild population of *S. glanis* are generally on growth and feeding behavior (13-16). There is insufficient research on the reproduction biology of wild populations of *S. glanis*. However, it is very important to identify the reproduction biology of the species for successful fishery management and aquacultural facilities.

Therefore, the aim of this study was to determine the maturity stages, gonadosomatic index, minimum size at first maturity, fecundity and egg size in a wild population of *S. glanis*.

The Study Area

Menzelet Dam Lake, constructed on the River Ceyhan in the East Mediterranean region of Turkey in 1989, has a surface area of 42 km^2 at 700 m altitude, and it is used for electrical energy production. The maximum depth is nearly 100 m and total water volume is about 12 x 10^9 m^3. The fish fauna of the reservoir consists of *Silurus glanis*, *Cyprinus carpio, Capoeta capoeta angorae, Capoeta barroisi, Barbus rajanorum* and *Alburnus orontis. C. carpio* was introduced into the reservoir after the construction of the dam lake but the others are original species of the River Ceyhan. *Anguilla anguilla* used to inhabit this area but it is now extinct, because 6 dam lakes, Aslantaş, Berke, Sır, Kartalkaya, Kılavuzlu and Menzelet, have been constructed on the River Ceyhan in succession and there is no fish passage or lifting systems on these dams.

Thirty fishermen belong to a fisheries cooperative fishing in Menzelet Reservoir and their annual total catch varied from 35 to 45 t, of which 15 t consisted of *S. glanis* (17). This species is caught by baited hook or long line nets in the region. Most of the catfish in the reservoir are caught in the rainy season (February and March), while in the summer months the amount of catfish is very low. Fishing for catfish is banned between April and August because of reproductive activities.

Materials and Methods

Samples of *S. glanis* were collected from December 2000 to November 2001, using baited hooks or obtained from commercial fishery catches. The total length (L cm) and body weight (W g) of each fish sampled were recorded upon arrival in the fishery cooperative building. All the fish were dissected, and their gonads were removed and weighed (mg). Using these data the gonadosomatic index (GSI) was determined by the equation: GSI = (Weight of gonad (g)/Total weight of fish (g) x 100). Age was determined from 3-5 vertebrae according to Polat and Gümüş (18) and Turner (19). The maturity stages were determined according to Shikhshabekov (20), Clay (21) and Yalçın et al. (22) and for estimation of the mean lengths at 50% maturity a logistic function was fitted to the proportion of the mature individuals by size class using non-linear regression (23). The function used was $P = 1/[1+\exp^{(-rx\ (L-Lm))}]$, where P is the proportion of mature fish in each size class, r (-b slope) is a parameter controlling the shape of the curve and Lm is the size at 50% maturity. Lm = a/b, where a is the intercept and r is the slope (b) (23). The frequencies of the various maturity stages and the monthly variations in the GSI were used to study the maturation pattern and the extent of the breeding season. Ovaries were fixed in Gilson's fluid for fecundity studies, and fecundity was estimated by the gravimetric method (24). For this purpose, three 0.5 g subsamples (front, middle and caudal sections) from each ovary were taken and the number of eggs was counted in each subsample and then the total fecundity (F) was estimated using the equation F = (Gonad weight x Egg number in the subsample/Subsample weight) (25). The diameters of 10 oocytes from each subsample were measured by a digital micrometer under a microprojector for determining egg size.

Results

Length frequency, age distribution and sex ratio

Total length of the sampled fish varied from 33.4 cm (220 g) to 195.0 cm (48,000 g) and males were bigger than females. Total length of the males varied from 35.0 cm to 195.0 cm, while the females ranged from 33.4 cm to 155.0 cm. The length frequency distribution of the sampled fish is given in Figure 1. The age distribution of the samples varied between 1 and 14 years old fish; 4, 5 and 6 year-old fish dominated the sample, accounting for over 68% of the total aged. Younger fish were poorly represented, and 4 specimens older than 10 years old were males. The oldest recorded female was 10 years old (Figure 2). Of the total fish examined 110 were males and 135 females. The ratio of males to females was 0.82:1.00 and this ratio was not different from the ratio of 1.00:1.000 ($X^2 = 1.276 < X^2_{1,0.05} = 3.84$).

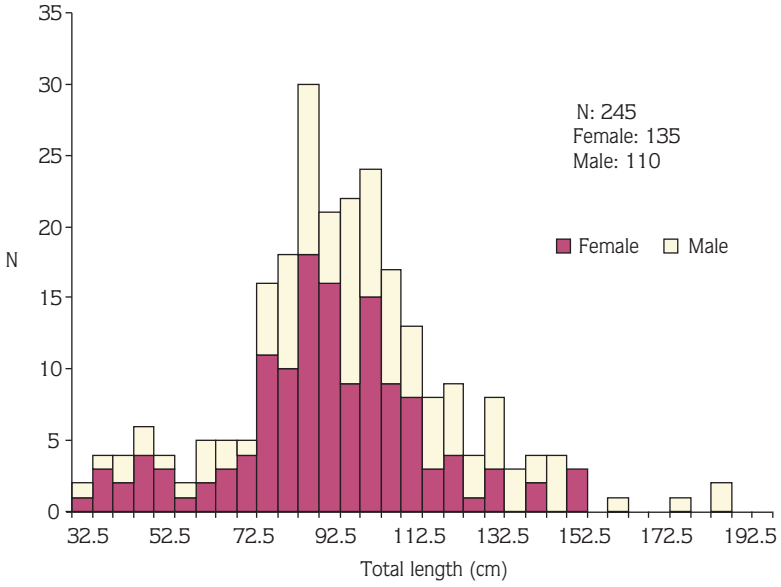

Figure 1. Length frequency distribution of *Silurus glanis* from Menzelet Reservoir.

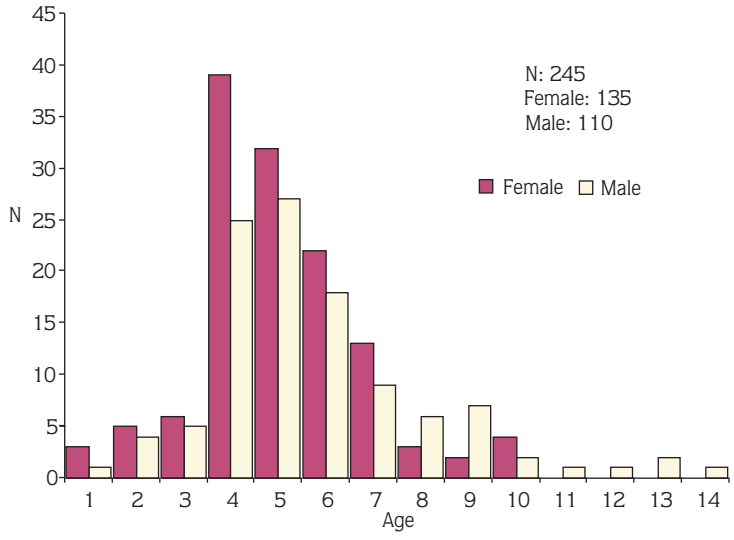

Figure 2. Age frequency distribution of *Silurus glanis* from Menzelet Reservoir.

Maturity stages of the gonads

Immature individuals (Stage I) were seen in nearly all months and the oocytes in this stage were not visible with the naked eye. Sex differentation for this stage was done by microscopic inspection. Granular structures of the ovaries were first seen in late November (Stage II). In December, January and February the genders were easily distinguished with the naked eye (Stage III). Females with maturing ovaries (Stage IV) appeared from March to May. At this stage ovaries and testes began to fill the abdomen but the ovary membrane was still thick. Mature ovaries (Stage V) appeared in May-July and the first occurrence of running (Stage VI) females was noted in June and continued until August. Seasonal distribution of the maturity stages is given in Table 1.

The monthly distribution of the maturity stages confirmed that *S. glanis* began to mature during the winter (December, January and February) and that its sexual development accelerated in spring (March, April and May), spawning mainly between June and August, after which there was a resting period during the autumn.

Seasonal fluctations in the GSI

The GSI values of male and female *S. glanis* were low between August and November. The GSI of both sexes increased month to month and reached a maximum in May, and then declined to a minimum in August. The GSI of females was higher than that of males in all months. The monthly fluctations in the GSI of females and males are given in Figure 3. The fluctations confirmed that *S. glanis* began to spawn in June and continued until August.

The minimum size at first maturity

Maturing ovaries and testes (Stage IV and above) were considered mature for determination of the minimum size at sexual maturity. The smallest males belonged to the 80.0-85.0 cm length class (the smallest male was 83.0 cm in total length and 3744 g in weight) and were 3 years old. The smallest mature female was 86.0 cm in total length and 4434 g in weight, belonging to the 85.0-90.0 cm length class at an age of 4 years. The percentages of mature fish at different length classes of *S. glanis* and the parameters of the sexual maturity ogive for males and females are given in Table 2. The maturity ogives for *S. glanis* showed that 50% of males $P = 1/[1 + \exp^{(-0.121 \times (L - 78.82))}]$ and females $P = 1/[1 + \exp^{(-0.130 \times (L - 87.05))}]$ were sexually mature at total lengths of 78.82 cm and 87.05 cm, respectively (Figure 4).

Fecundity

The total length of the female individuals used in the study of fecundity ranged from 86.0 cm to 151.0 cm (mean ± $CI_{(95\%)}$ is 106.39 ± 4.59 cm in total length) and their weight varied between 4434 g and 26,920 g (mean ± $CI_{(95\%)}$ is 9163.45 ± 1426.79 g in weight). Fecundity

Table 1. The monthly frequency of maturity stages in female and male *S. glanis* obtained from Menzelet Reservoir.

	Maturity stages of the females						Maturity stages of the males					
	I	II	III	IV	V	VI	I	II	III	IV	V	VI
December	1	14	4				1	3	13			
January		5	12						6			
February		5	13						17			
March	1		1	9			1		1	17		
April	8			21			2			19		
May	3			7	8					6	18	
June	1				2	1					1	
July	2				2	4	1					1
August						5						
September	4						1					
October	2											
November	2											

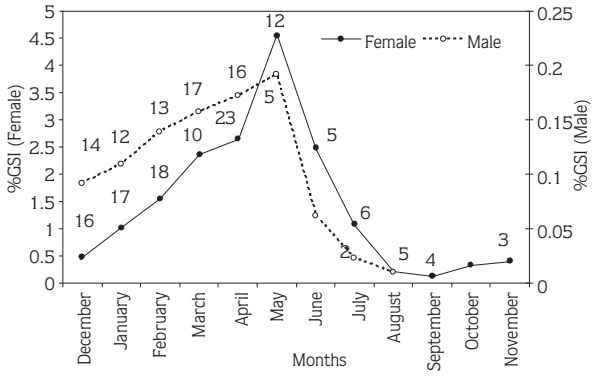

Figure 3. Seasonal fluctations in gonadosomatic index in female and male *Silurus glanis* in Menzelet Reservoir. (The numbers on the mean GSI values indicate fish numbers).

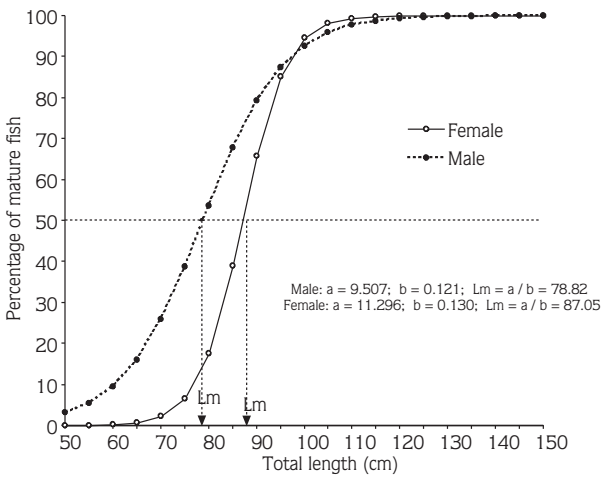

Figure 4. The first maturity ogive for males and females of *Silurus glanis* from Menzelet Reservoir. (Arrows indicate first maturity length for males and females).

estimates based on 49 mature females (Stages IV and V) varied from 9033 to 340,461 eggs/fish and the mean fecundity with 95% confidence limits was 87,108 ± 20,992 eggs/fish, and relative fecundity for each kilogram of female fish was 8443 ± 1114 eggs (Table 3). Furthermore, the mean number of eggs per gram of ovaria varied from month to month, ranging from 800 (in December) to 195 (in June). A negative correlation was found between the egg number in ovaria and egg size (Figure 5). Linear relationships were found between fecundity and (a) total length (Figure 6a), and (b) body

Table 2. The percentage of mature individuals of different length classes of *Silurus glanis* from Menzelet Reservoir.

Length class (cm)	Mean length (cm)	Male		Female	
		% Nm	Ln [(1 – P)/P]	% Nm	Ln [(1 – P)/P]
50-55	52.5	0		0	
55-60	57.5	0		0	
60-65	62.5	0		0	
65-70	67.5	0		0	
70-75	72.5	0		0	
75-80	77.5	0		0	
80-85	82.5	66.67	-0.6933	0	
85-90	87.5	66.67	-0.6933	42.86	0.288
90-95	92.5	83.33	-1.6092	75.00	-1.099
95-100	97.5	91.67	-2.3983	83.33	-1.609
100-105	102.5	100.00		84.62	-1.705
105-110	107.5	100.00		100.00	
110-115	112.5	100.00		100.00	
115-120	117.5	100.00		100.00	
120-125	122.5	100.00		100.00	
125-130	127.5	100.00		100.00	
130-135	132.5	100.00		100.00	
135-140	137.5	100.00		100.00	
140-145	142.5	100.00		100.00	
145-150	147.5	100.00		100.00	
Regression analysis results for male and female *S. glanis*	a ± SD	9.507 ± 2.613		11.296 ± 3.923	
	b ± SD	0.121 ± 0.029		0.130 ±0.041	
	r^2	0.897		0.832	
	Lm (cm)	78.82		87.05	

Table 3. Fecundities and egg diameters in the age groups of *S. glanis* obtained from March to June in Menzelet Reservoir. (NF: The number of the fish; L: Total length; W: Body weight; F: Mean egg number; Range: Minimum and maximum values; F/W and F/L: Relative fecundities; NE: The number of eggs;)

Fish information				Fecundity information					Egg size information			
Age	NF	L (cm)	W (g)	F	Range	SD	F/ W	F/L	NE	Egg size (mm)	Range	SD
4	6	88.7	5188	21,365	9033-34,592	8805	4.07	241.69	143	1.842	1.00-2.67	0.448
5	11	97.9	6229	40,232	25,033-78,153	17,751	6.45	408.45	178	1.957	1.18-2.87	0.344
6	13	104.5	7986	80,929	40,260-137,775	31,978	10.12	772.39	298	2.179	1.03-3.63	0.469
7	12	115.1	11,233	138,639	70,396-251,477	49,422	12.30	1196.18	300	2.206	1.03-3.30	0.462
8	2	132.1	15,165	191,109	182,329-199,888	12,416	12.60	1446.24	27	1.884	1.52-2.29	0.194
9	2	136.5	19,560	189,761	166,794-212,728	32,480	9.69	1385.66	60	2.524	2.08-2.93	0.214
10	3	149.0	24,770	256,964	210,670-340,961	72,871	10.27	1720.99	90	2.323	1.45-3.73	0.559

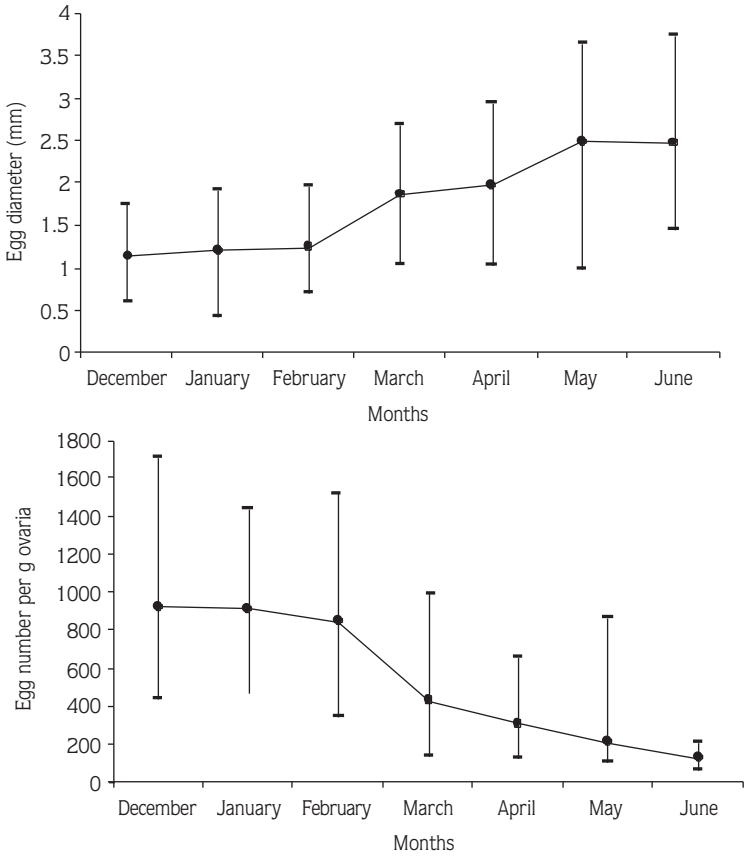

Figure 5. Seasonal fluctations in: (a) egg size and (b) egg number in each gram of ovaria in *Silurus glanis* obtained from Menzelet Reservoir. (Vertical lines show minimum and maximum values).

weight (Figure 6b) . Fecundity was also correlated with ovary weight (Figure 7a) and age of fish (Figure 7b). The r values higher than 0.8 indicated that these relationships were strong. These positive correlations may be expressed by the following equations:

$\ln F = 5.4034 \times \ln L - 14.126$; $r = 0.8987$; $n = 49$

$\ln F = 1.7171 \times \ln W - 4.4400$; $r = 0.9062$; $n = 49$

$F = 115.360 \times OW + 30105$; $r = 0.8721$ $n = 49$

$F = 289.60 \times Age^{3.0621}$; $r = 0.9021$ $n = 49$

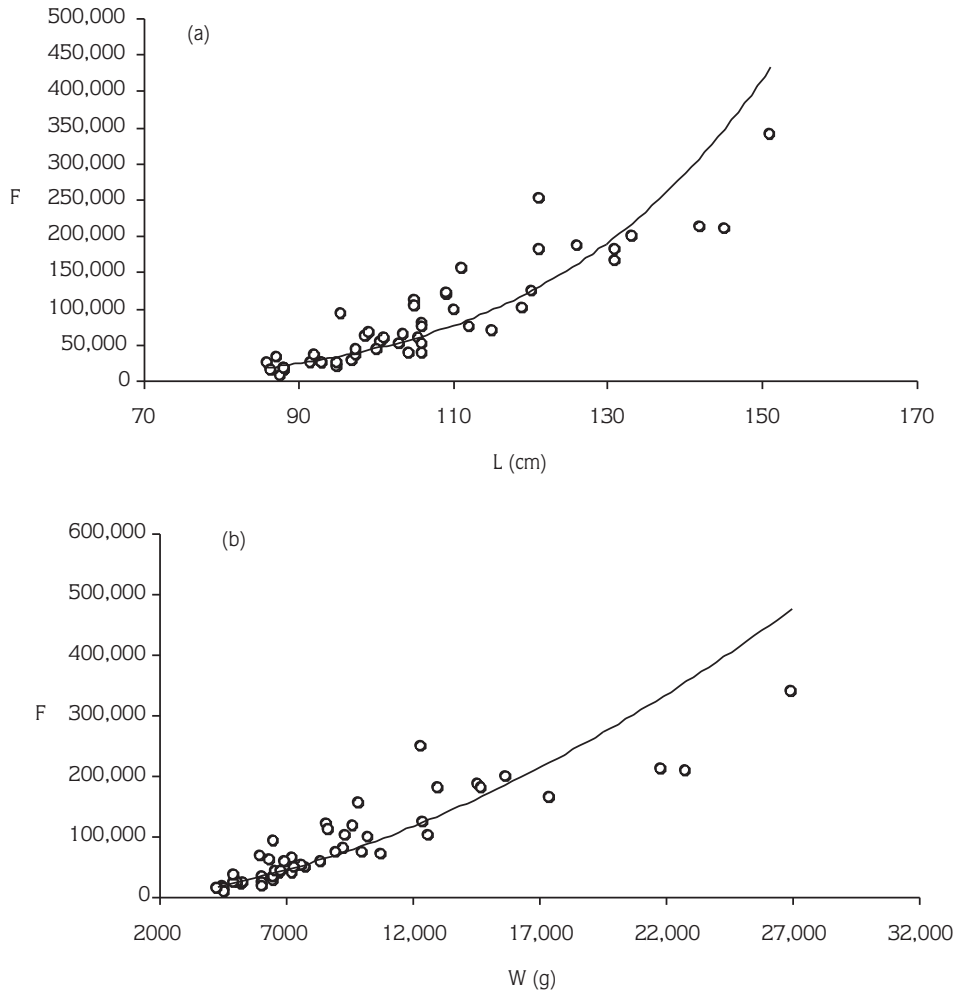

Figure 6. Relationships between fecundity and (a) total length (ln F = 5.403 x ln L – 14.126 , r = 0.899) and (b) body weight of *Silurus glanis*. (ln F = 1.717 x ln W – 4.440, r = 0.906) in Menzelet Reservoir.

Seasonal distributions of the egg size

Egg size did not increase much during winter months and the main increase in egg diameters occurred in March, April and May (Stage IV) (Figure 5a). Egg diameters varied from 0.630 mm to 3.730 mm from December to June, reaching a maximum in May and June. Egg size ranged from 1.45 mm to 3.73 mm in June, prior to spawning.

Egg size of fish obtained from March to June varied from 1.00 mm to 3.73 mm and egg size for the age groups is given in Table 3.

Discussion

The males of *S. glanis* had a greater weight and length than females. The age distribution of males ranged between 1 and 14 years, while the oldest female was 10 years old. These can be explained by the effect of sex on growth and life span. According to Phillips and Rix (26), the male *S. glanis* opens out a depression in the bottom and the eggs are laid in a large sticky pile by the female and guarded by the male until they hatch. Therefore in the exploited stock prior to spawning there will be fewer males fish than females because the males are guarding. Therefore we think that female individuals are probably

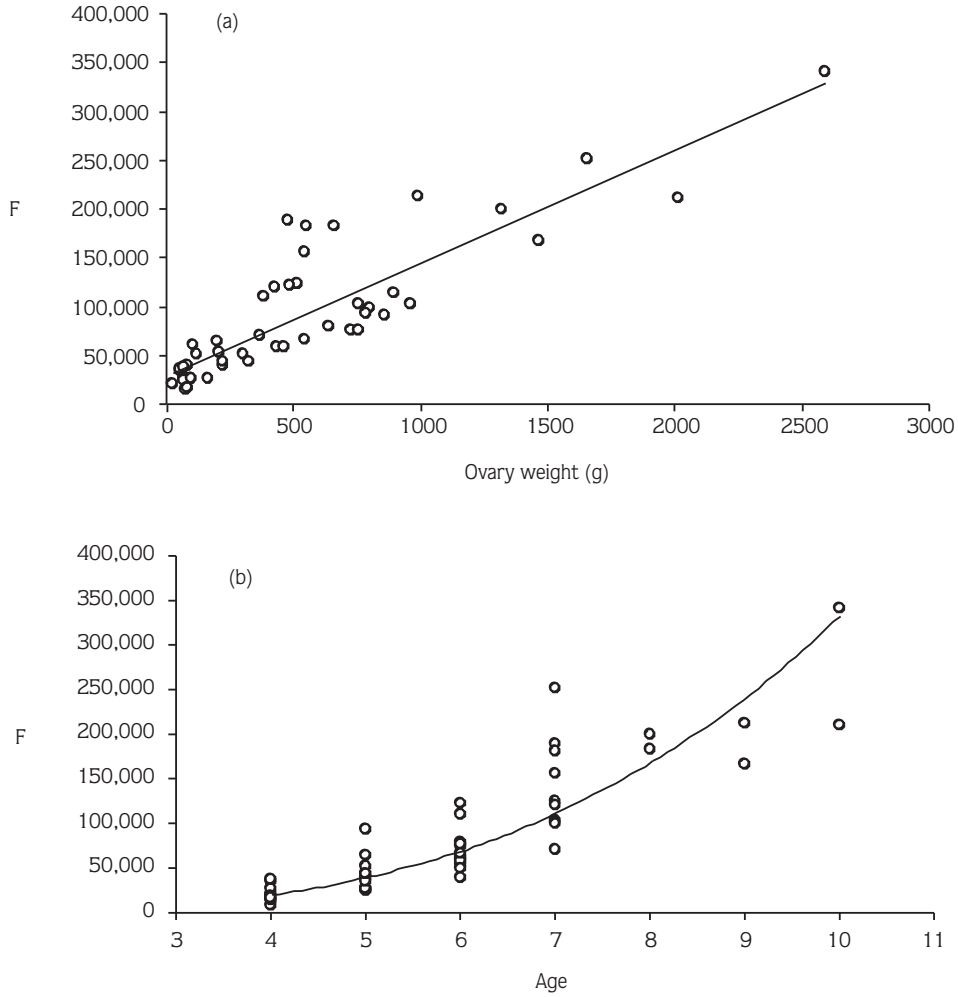

Figure 7. Relationships between fecundity and (a) ovary weight (F = 115.36 x OW + 30.105, r = 0.872) and (b) age (F = 289.6 x $Age^{3.0621}$, r = 0.902) of *Silurus glanis* from Menzelet Reservoir.

caught at an earlier age than males and females have a shorter life span than males. Haffray et al. (7) reported that males of *S. glanis* grew 2 to 15% faster than females. An important effect of sex on growth has been reported in other Silurids such as the channel catfish, *Ictalurus punctatus*, or the atipa, *Hoplesternum littorale* (27). In the channel catfish, males were 18 to 43% heavier than females (28,29).

The spawning of *S. glanis* and *S. triostegus* in Turkish waters was reported to occur mainly during May and June (30,31). Based on this general information, fishing for *S. glanis* was banned in the reservoir between 1 April and 1 August, because of the spawning season. In the present study, however, seasonal fluctations in maturity stages and the assumed GSI indicated that spawning took place from June to August, because the GSI value of the *S. glanis* caught on 27 May was higher than that of the other months. Therefore fishing for *S. glanis* in Menzelet Reservoir should be suspended during June and July and the fishing ban for this species should begin on 1 May instead of 1 April for good fisheries management and maximum sustainable yield.

In the present study, the male *S. glanis* started to reach first maturity at age 3, while the females attained it at age 4. The smallest mature male had a 83.0 cm total length and 3744 g body weight, while the smallest mature female had a 86.0 cm total length and 4434 g body weight. It is clear from this result that males

became sexually mature 1 year earlier and at a smaller size than females. The age at first maturity in several *S. glanis* populations shows a similar pattern, while the minimum size at first maturity shows remarkable variations. In the early information, the sexual maturity of *S. glanis* was reported as 2-3 (32) and 3-4 age (33) for the River Volga. Akyurt (30) reported that males attained sexual maturity at age 2-3, and females at age 3-4. Oymak et al. (31) reported similar results for *S. triostegus* inhabiting Atatürk Dam Lake, on the River Euphrates. Slastenenko (33) reported that the sexual maturity size of *S. glanis* in the River Volga was 60 cm in length, and Ladiges and Vogt (32) mentioned weight of 1-2 kg. Sexual maturity length and weight were also reported as 58 cm in standard length and 1430 g in body weight in Iğdır Karasu (30). Oymak et al. (31) mentioned that *S. triostegus* attained sexual maturity at 33.28 cm in length.

Fecundities in the present study varied from 9033 to 340,461 eggs/fish and mean fecundity was 87,108 ± 20,992 eggs/fish while relative fecundity for each kilogram of fish was 8443 ± 1114 eggs/kg fish. Fecundity for each kilogram of *S. glanis* in the Karasu River was reported to be 12,700 eggs/kg fish (30) and fecundity of *S. triostegus* in Atatürk Dam Lake varied from 6800 to 120,300 (31). The variation in fecundity between the populations may result largely from selectively different environmental factors such as water temperature, feeding and food abundancy and species differentiation.

It is clear from these results that *S. glanis* in Menzelet Reservoir attained sexual maturity at a larger size than other populations. This is probably the result of the feeding regime of the reservoir populations or physical factors such as the water temperature profile. Harka (14) reported that the growth rate of *S. glanis* inhabiting the River Tizsa in Hungary was slower than that in other regions, but, with the construction of dams and reservoirs on the River Tizsa, the environmental factors of this ecosystem would have changed to favor *S. glanis* growth mainly because of elevations in the temperature of certain surface waters of the reservoir. In accordance with this statement, all the studies above were carried out for river populations, and so their growth rates are slower than that in Menzelet Reservoir, and thus their minimum size at first maturity is smaller than that of Menzelet. Based on early information, fishing for *S. glanis* smaller than 70 cm in length was banned in Turkish waters because they are not mature. However, the present study indicated that this size limit should be ≈ 90 cm in total length in Menzelet Reservoir.

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