Int Aquat Res (2010) 2: 97-104
ISSN 2008-4935
Available online at www.intelaquares.com

International
Aquatic Research

Life cycle and feeding habits of the threespined stickleback *Gasterosteus aculeatus* (Linnaeus, 1758): an alien species in the southeast Caspian Sea

Hamid Niksirat[1*], Azadeh Hatef [2], Asghar Abdoli[1]

[1]Department of Biodiversity and Ecosystem Management, Environmental Sciences Research Institute, Shahid Beheshti University, G.,C, 1983963113, Tehran, Iran
[2]Research Institute of Fish Culture and Hydrobiology,University of South Bohemia, 389 25, Vodnany, Czech Republic

Received: 19 April 2010; Accepted: 26 July 2010

Abstract

The feeding habits and life cycle of a population of the alien threespined stickleback *Gasterosteus aculeatus,* were studied in the southeast Caspian Sea from December 2000 to November 2001 to evaluate its potential impact on the indigenous commercial species. The abundance (A%) and occurrence (O%) of prey items in *G. aculeatus* stomach content were calculated for Gammarids, *Nereis* sp., Chironomidae, fishes, Oligochaeta, fish eggs, and Hirudinea. The potential effects of the alien threespined sticklebacks on juvenile Persian and Russian sturgeons were discussed. The gonadosomatic index of female sticklebacks showed that breeding season began at March and lasted five months in the southeast Caspian Sea. The condition factor, somatic condition factor, and hepatosomatic index increased at the beginning of the spawning season and decreased with its progress. A significant negative correlation between gonadosomatic index and somatic condition factor in females indicates priority of reproduction over somatic growth; this can help the alien species to rapidly increase population size, thus enhancing its negative impacts on indigenous fauna. The similar or even higher mean weight and length of the alien sticklebacks in the study area in comparison with other native populations of sticklebacks might imply suitable conditions of the Caspian Sea for the establishment of alien populations of this species.

Keywords: Feeding habits, Gasterosteus aculeatus, Caspian Sea, Alien species, Life cycle components

Introduction

Alien species are an increasing problem in aquatic systems (Streftaris et al. 2005; Kalogirou et al. 2007). They compete for food, space and spawning sites or may be aggressive and limit the success of indigenous fishes (Coad and Abdoli 1993). Established populations of alien fishes can also alter the energy flow in an ecosystem either by filling vacant ecological niches or competing with indigenous fishes. They may also have significant impacts on the conservation and restoration of native biodiversity (Scott et al. 2003). A variety of alien fish species have become established in the Caspian Sea (Coad and Abdoli 1993). The Caspian Sea is one-third salty (12-13‰); however

[*] Corresponding author. Email: h_niksirat@yahoo.com. Tel: +98-911-3951015, Fax: +98-21-22431971.

typical fresh water species can be found, e.g. *Cyprinus carpio*. The Caspian Sea is an important commercial fishing region because most of the world's sturgeon catch (90-92%) originates from here (Dettlaff et al. 1993).

The threespine stickleback, *Gasterosteus aculeatus,* was reported from the northern part of Iran at the south of the Caspian Sea. The first specimen of this alien fish was collected in 1992. The origin of this species is unknown but it can be due to an accidental introduction along with food fish (Coad and Abdoli 1993). Now, large numbers of *G. aculeatus* occur in all river estuaries, lagoons and across the costal zone of the Iranian part of the Caspian Sea (Abdoli 2000). Although the feeding habits of this species is documented for localities of its native range of distribution (e.g. Maksimenkov and Tokranov 1995; Sanchez-Gonzales et al. 2001), no information is available for life cycle and feeding habits of this fish outside of its natural range. The potential impacts on indigenous and commercially important species such as sturgeons are still unknown.Therefore, the potential impact of an introduced species should be studied via monitoring of the life cycle of its established populations. In addition, an understanding of its feeding strategies would facilitate conservation management for the indigenous fishes (Coad and Abdoli 1993; Jang et al. 2006). Parameters such as Condition factor (CF), Somatic Condition factor (SCF), Hepatosomatic index (HSI), and Gonadosomatic index (GSI) can be used as good indicators of the physiological state of the fish, related to its welfare and feeding conditions (Wootton 1973a,b; Lizama et al. 2002), thus reflecting the adaptation ability of an alien species to a new habitat.

The present study aimed to describe the feeding habits and the parameters such as CF, SCF, HSI and GSI of the alien sticklebacks in the southeast Caspian Sea during one year. The feeding habit was also used to evaluate the potential impacts of the alien sticklebacks on the indigenous commercial species, such as juvenile sturgeons.

Materials and methods

The study area and sampling method

The Caspian Sea is the largest lake of the world. It has a surface area of 371,000 km^2 and a volume of 78,200 km^3. It is an endorheic body of water (it has no outflows) and lies between the southern area of the Russian Federation and the northern Iran. It has a maximum depth of about 1025 m and a salinity of approximately 12 ‰.

One sampling per month was carried out for 12 months from December 2000 to November 2001. No sample was captured in August and September. Samplings were conducted using a beach seine (5 mm mesh size, 1.5 m depth, 20 m length) within at least 1.5 km of the study area. In the laboratory, the total length of specimens was measured to the nearest mm, and the total weight, gonad weight, liver weight and carcass weight were determined using a digital balance to an accuracy of 0.01 g. Table 1 shows the number and the sex ratio of fishes for each month.

Table 1. The number and sex ratio of the alien stickleback in the southeast Caspian Sea at different months

Month	Male	Female	Total
Dec	21	32	53
Jan	22	28	50
Feb	21	33	54
Mar	22	27	49
Apr	22	38	60
May	22	29	51
Jun	19	31	50
Jul	21	34	55
Oct	20	39	59
Nov	21	28	49
Total	211	319	530

Feeding habit

The stomach contents of all samples were examined in the laboratory under a binocular microscope at 10 × and prey items were identified to the lowest recognizable taxon. In the prey count, each head was considered as one individual.

Percent occurrence (O%) was defined as the number of stomachs with a prey taxon divided by the number of all the analyzed stomachs (except empty stomachs). Percent abundance (A%) was defined as the number of a specific prey taxon divided by the number of all prey items in all predators (Castello 1990).

Life cycle components

The Condition factor (CF), Somatic Condition factor (SCF), Hepatosomatic index (HSI) and Gonadosomatic index (GSI) were calculated according to following the equations:

$CF = (W/L^3) \times 100$

where W is the wet weight in g and L is total length in cm.

$SCF = (CW/L^3) \times 100.$

where CW is carcass wet weight in g and L is total length in cm.

HSI= (wet weight of liver / total wet weight) ×100.

GSI= (wet weight of ovary/ total wet weight of female) ×100.

Statistical analysis for life cycle components

The data tested for normality (Kolmogorov–Smirnov test) and homogeneity of variances (Leven's test) prior to analysis using a one-way ANOVA with subsequent Tukey's test for comparison of mean values. A significance level of $P < 0.05$ was used. Data values were expressed as mean ± SE. A Pearson's correlation was used to test whether a relationship existed between life cycle components. Also, independent two samples t-test was applied to investigate significant differences between different sexes in case of life cycle components.

The length- weight relationship

The relation of weight to length was calculated applying the exponential regression equation $W=aL^b$, where W is the total weight, L the total length, and 'a' and 'b' the parameters to be estimated (Ricker 1975).

Results

Feeding habits

Seven major prey taxa were identified in the stomach contents of sticklebacks. Overall, the total abundance (A %) and occurrence (O %) of the prey items of the alien threespined stickleback, *G. aculeatus*, in the southeast Caspian Sea were as follows: Gammarids: 55.23%, 57.2%; *Nereis* sp.: 17%, 35.7%; Chironomidae: 17.2%, 8.4%; fishes: 5.7%, 18.2%; Oligochaeta: 1.05%, 1.6%; fish eggs: 3.6%, 0.91%, and Hirudinea: 0.22%, 0.91%.

November and December showed the highest diversity of the major prey taxa. The Gammarids were dominant in December and January. The Gammarids were gradually replaced by *Nereis* sp. in February. The *Nereis* sp. continued its dominance as prey item until the end of June. In July, sticklebacks preyed mainly on Chironomidae and shifted their preference to fishes in October. In November, the Gammarids again were the dominant prey. In November and March, fish eggs were found as prey items in the stomachs (Table 2).

Annual changes in body length and weight

Females (61.6 ± 0.4 mm) showed significantly ($P < 0.05$) higher mean length in comparison with males (60.5 ± 0.3 mm). There was no significant difference between mean total weight of males (2.76 ± 0.06 g) and females (2.92 ± 0.08 g) ($P > 0.05$). The minimum and maximum individual length and weight for females and males were: 47-82 mm and 43-74 mm, and 1-9.43 g and 0.74- 4.96 g, respectively (Fig. 1a-b).

Annual changes in condition factor (CF)

For both sexes, condition factor increased at the beginning of the spawning season and decreased with its progress ($P < 0.05$). The minimum and maximum individual CF for females and males were 0.55-1.88 and 0.7-1.83, respectively (Fig.1c). Males (1.21 ± 0.01) were in a better CF than females (1.16 ± 0.01, $P < 0.05$).

Annual changes in somatic condition factor (SCF)

Similar to CF, for both sexes, somatic condition factor increased at the beginning of the spawning season and decreased with its progress ($P < 0.05$). The minimum and maximum individual SCF for females and males were 0.37-1.02 and 0.55-1.35, respectively (Fig. 1d). A significant negative correlation between gonadosomatic index and somatic condition factor (r=-0.278, $P < 0.0001$) in females indicated priority of reproduction over somatic growth. Males (0.88 ± 0.008) were in a better SCF than females (0.74 ± 0.007, $P < 0.05$).

Table 2. The feeding habits of the alien Stickleback in the southeast Caspian Sea at different months (Occurrence%, Abundance%)

Month		Fish	*Nereis* sp.	Gammaridae	Oligochaeta	Fish egg	Hirudinea	Chironomidae
Dec	A%	1.25	0.75	97	0	0	0.75	0.25
	O%	6.76	4.05	94.6	0	0	4.05	1.35
Jan	A%	4.2	7.7	88.1	0	0	0.25	0
	O%	13.16	19.73	89.47	0	0	13.15	0
Feb	A%	3.06	46.9	50	0	0	0	0
	O%	5.45	63.63	49.1	0	0	0	0
Mar	A%	0	20	4.3	0	74.3	0	1.43
	O%	0	81.81	27.27	0	27.3	0	9.1
Apr	A%	0	55.5	27.7	0	0	0	16.7
	O%	0	84.84	33.3	0	0	0	9.1
May	A%	0	60.5	14.2	3.2	0	0	10.1
	O%	0	82.2	20.1	5	0	0	7.5
Jun	A%	0	72.6	13.2	8.1	0	0	6
	O%	0	95.3	21.87	10.94	0	0	7.81
Jul	A%	0	1.1	1.6	0	0	0	97.3
	O%	0	20	20	0	0	0	90
Oct	A%	45.1	0	10.4	0	0	0	44.4
	O%	88.13	0	16.94	0	0	0	8.47
Nov	A%	5	0.5	69.2	0	6.6	0	18.7
	O%	17.54	1.75	80.7	0	1.75	0	22.8

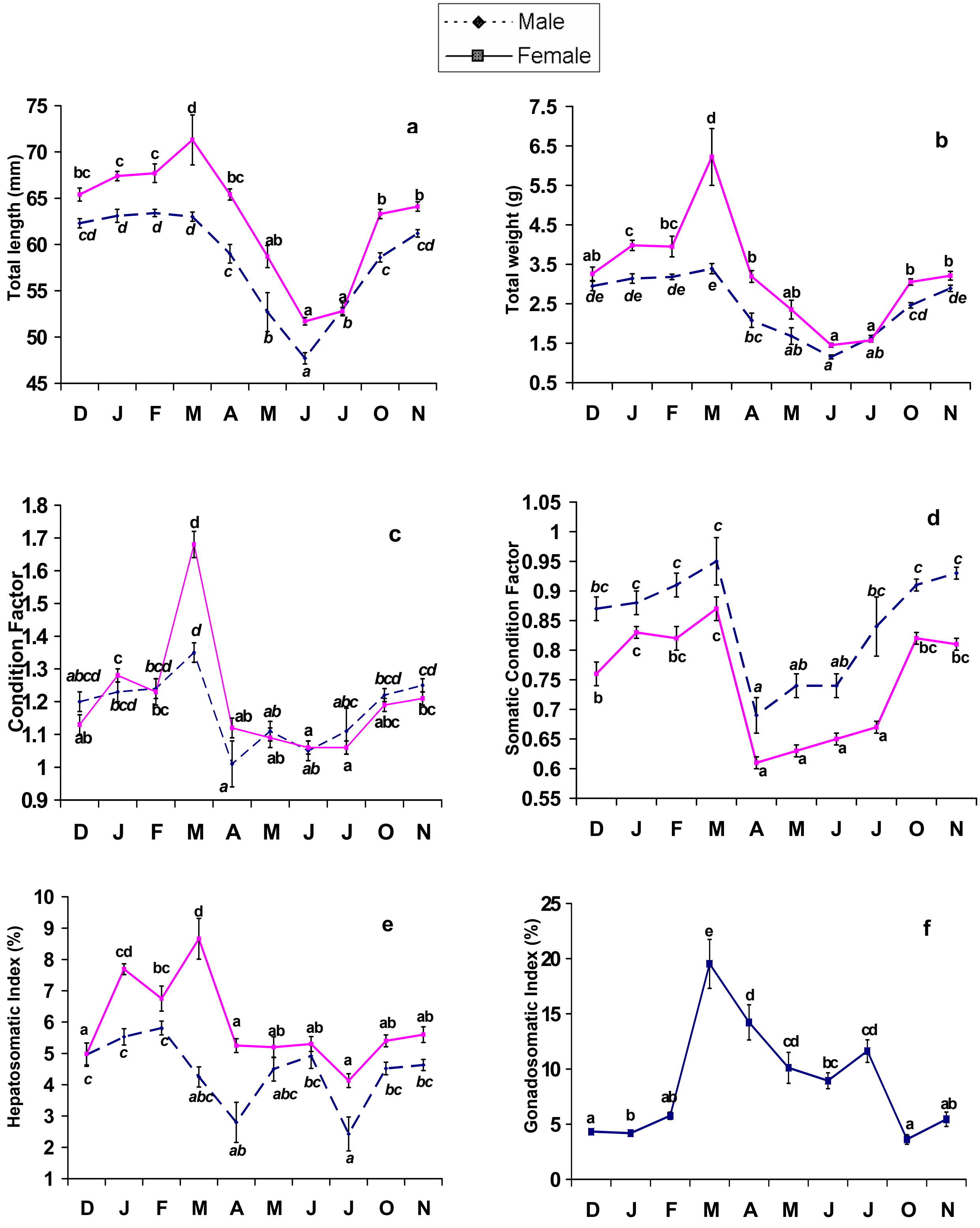

Fig. 1. Life cycle parameters of the alien threespined stickleback in the southeast Caspian Sea: a. Total length, b. Total weight, c. Condition factor, d. Somatic condition factor, e. Hepatosomatic index, f. Gonadosomatic index (females only). Letters over bars denote the hierarchy among months after Tukey's test. Figure reports mean (±SE).

Annual changes in hepatosomatic index (HSI)

This index increased at the beginning of the spawning season and decreased with its progress ($P < 0.05$). The minimum and maximum individual HSI for females and males were 0.81%-10.71% and 1.14%-9.07%, respectively (Fig. 1e). Females (5.6 % ± 0.11) had a higher HSI than males (4.95% ± 0.12, $P < 0.05$).

Annual changes in gonadosomatic index for females (GSI)

A period of slow increase over the autumn and winter months was followed by a period of very rapid increase in the GSI with a peak in March ($P < 0.05$), the first month of the spawning season. In the study area, the breeding season lasted for five months. Moreover, a female ready for spawning was caught at the beginning of autumn. The minimum and maximum individual GSI were 1.64%-34.4%, respectively (Fig. 1f). A significant correlation (r=0.53, $P < 0.0001$) was found between gonad weight and total weight of females.

The length- weight relationship

The results for the length-weight relationships were shown in Table 3.

Table 3. The length-weight relationship in alien threespined stickleback,Gasterosteus aculeatus, in the southeast Caspian Sea, Total Weight=a (Total Length)^b, R^2 is the correlation coefficient

Sex	n	a	b	R^2
Females	319	0.002	3.921	0.980
Males	211	0.007	3.274	0.983
Total	530	0.003	3.703	0.980

Discussion

The results of present study showed the abundance and occurrence of prey items in alien *G. aculeatus* stomach content including: Gammarids, *Nereis* sp., Chironomidae, fishes, Oligochaeta, fish eggs, and Hirudinea. Also, life cycle components of alien sticklebacks in Caspian Sea were revealed for both sexes. In the study area, the breeding season lasted for five months. In addition, significant differences were found between sexes and months in case of different components.

Feeding habits of alien threespined stickleback and potential impacts on indigenous species

The alien threespined sticklebacks in the southeast Caspian Sea mainly feed on seven items. In the Bol'shaya river estuary (west of Kamchatka), the threespined sticklebacks is a nectobenthophage and feeds primarily on the abundant bottom and near-bottom organisms such as mysidaceans, amphipods, shrimp, and cumaceans. Other prey items, such as Chironomidae and fishes, were also found in the diet of threespined sticklebacks (Maksimenkov and Tokranov 1995).

The analysis of the stomach content of threespined stickleback in a population of northwestern Baja California showed a diet dominated by Cyclopoid and Chironomidae (Sanchez-Gonzales et al. 2001). A changing feeding strategy observed among different areas indicates a high degree of trophic adaptability in response to prey availability in the environment and might be one of the reasons that help sticklebacks to quickly establish permanent populations in the southeast Caspian Sea.

The alien threespined stickleback may compete with native species for food. For example, the prey composition of the juvenile Persian sturgeons (*Acipenser persicus*) in the Caspian Sea consists of Gammarids, *Nereis* sp., Chironomidae larvae, Oligochaeta, and some other items. Juvenile Russian sturgeons (*Acipenser gueldenstaedti*) in the Caspian Sea feed on crustaceans including gammarids, cumaceans and *Nereis* sp. (Holčík 1989). Ghorbani (2000) reported a similar diet composition in the juvenile Persian and Russian sturgeons in the southeast Caspian Sea.

The Persian and Russian Sturgeons are highly valuable commercial species. They are classified as vulnerable species in the south of the Caspian Sea in the Red List of IUCN (Kiabi et al. 1999). Therefore, the alien threespined sticklebacks may represent a new risk for the growth and survival of juvenile sturgeons in the Caspian Sea.

Pungitius platygaster (Gasterosteidae) is native to the Caspian Sea. Its disappearance from the southeast Caspian Sea, where it was once abundant, was observed in the recent years. This might be the result of similarity of life cycle and feeding habits with the alien threespined sticklebacks. The possible interaction between these two species needs further investigation.

A negative potential impact confirmed by the present study is that alien sticklebacks in the southeast Caspian Sea prey on the eggs of other species. Our results are in agreement with Mukhomediyarov (1966), who reported that, on the White Sea coast, adult sticklebacks consume eggs and fry of their own and other fishes.

Life cycle components of alien threespined sticklebacks in southeast Caspian Sea

Our results showed that sticklebacks in the Caspian Sea had the length, body and liver weight and egg production rate similar to or higher than native populations. Wootton (1978) reported 29.4-49.7 mm and 0.19-1.16 g as the mean length and weight for native populations, respectively and their spawning period lasted for 1-4 months. On the contrary, the alien population of the Caspian Sea reaches higher lengths and body weights and their spawning period lasts for at least five months.

This result can be explained by the extent of food availability in different areas. High food availability increases the weight and length at maturity, as well as the percentage of fishes that matured. Weight at maturity was positively correlated with the number of spawned eggs. Larger females produce more eggs per spawning and have longer spawning periods and shorter intervals between successive spawnings (Wootton 1973a, b). During the breeding season, if an adequate supply of food is available, a large stickleback female can produce two to three times its own weight of eggs and females may spawn 15 or 20 times (Baggerman 1957; Wootton 1973a, b).

A significant portion of the annual production of threespined stickleback consists of eggs and sperm. Wootton and Evans (1976) reported that on average, for 100 cal of food consumed, 26 cal of eggs, 3 cal of somatic growth and 11 cal of feces were produced. To carry out such an expensive reproduction, they may obtain their energy requirement via extra feeding, thus limiting food availability for native fishes. Wootton and Evans (1976) mentioned that in the intervals between successive spawning, a female may consume a biomass of Oligochaeta equal to her body weight that can be considered as an index of their high nutritional need to overcome expense of reproduction.

Townshend and Wootton (1984) showed that food supply can change fecundity and egg size of female fishes. Therefore, invasion of this species with such high rate of energy consumption for reproduction may decrease food availability and subsequently energy investment for reproduction of the indigenous species. It is also noteworthy that this high rate of egg production by the female sticklebacks is associated with complex parental care by male, such as guarding and tending the eggs laid in the nest, which suggests that reproduction in the stickleback is very efficient (Wootton 1973b). As a consequence, changes in the structure of native populations in aquatic communities are inevitable.

The Caspian Sea offers a suitable feeding condition for establishing of permanent population of alien threespined sticklebacks. The Caspian Sea needs careful conservation. Kiabi et al. (1999) reported 15 alien fish species in the southern Caspian Sea. More studies are needed to monitor the established populations of the threespined sticklebacks for their ecological effects on the indigenous fishes of Caspian Sea. There is also the need to develop plans to control the established alien species and to reduce or prohibit future invasions.

Acknowledgements

We are indebted to the research council of Shahid Beheshti University for financial support of project number 600/ 4793/ 727 and Gorgan University of Agricultural Science and Natural Resources for laboratory support. Also, the authors express their sincere appreciation to the Editor-in-chief and reviewers of *International Aquatic Research* for their useful comments on the manuscript.

References

Abdoli A. 2000. The inland water fishes of Iran. Iranian Museum of Nature and Wildlife,Tehran, 378 pp (In Farsi with English abstract).

Baggerman B, 1957. An experimental study on the timing of breeding and mirgration in Three-spined stickle back, *Gasterosteus aculeatus* (L.). Archs Neerl Zool 12: 105-318.

Castello MJ. 1990. Predator feeding strategy and prey importance: a new graphical analysis. J Fish Biol 36: 261-263.

Coad BW, Abdoli A. 1993. Exotic fish species in the Freshwaters of Iran. Zool Middle East 9: 65-80.

Dettlaff TA, Ginsburg AS, Schmalhausen OI. 1993. In: Sturgeon Fishes; Developmental Biology and Aquaculture, Berlin: Springer-Verlag.

Ghorbani R. 2000. The study of morphologic, age, growth, diet and parasites of juveniles *Acipenser persicus* and *A. gueldenstaedti* in southeast of Caspian Sea. MSc. Thesis, Gorgan university of Agricultural science and Natural resources, Faculty of Fisheries, Gorgan, Iran. 99 pp. (In Farsi with English abstract).

Holčík J. 1989. The Freshwater Fishes of Europe. Vol. 1, Part II. General introduction to fishes Acipenseriformes. AULA-Verlag Wiesbaden, 470 pp.

Jang MH, Joo GJ, Lucas MC. 2006. Diet of introduced largemouth bass in Korean rivers and potential interactions with native fishes. Ecol Freshwater Fish 15: 315-320.

Kalogirou S, Corsini M, Kondilatos G, Wennhage H. 2007. Diet of the invasive piscivorous fish *Fistularia commersonii* in a recently colonized area of the eastern Mediterranean. Biol Inv 9: 887-896.

Kiabi BH, Abdoli A, Naderi M. 1999. Status of fish fauna in the south Caspian basin of

Lizama M, De los AP, Ambrosio AM. 2002. Condition factor in nine species of fish of the Characidae family in the upper Parana´ river flood plain, Brazil. Braz J Biol 62(1): 113–124.

Maksimenkov VV, Tokranov AM. 1995. Feeding habits of threespined stickleback, *Gasterosteus aculeatus,* (Gasterosteidae), in the Bol' shaya river estuary (west Kamchatka). J Ichthol 35(6): 88-99.

Ricker WE. 1975. Computation and interpretation of biological statistic of fish populations. Department of the Environment, Fisheries, and Marine Service, Ottawa, pp. 382.

Sanchez-Gonzales S, Ruiz-Campos G, Contreras-Balderas S. 2001. Feeding ecology and habitat of the threespined stickleback, *Gasterosteus aculeatus microcephalus,* in a remnant population of northwestern Baja California, Mexico. Ecology of Freshwater Fish 10: 191-197.

Streftaris N, Zenetos A, Papathanassiou E. 2005. Globalisation in marine ecosystems: the story of nonindigenous marine species across European seas. Oceanogr. Mar Biol Annual Rev 43: 319–453.

Scott RJ, Noakes DLG, Beamish FWH, Carl LM. 2003. Chinook salmon impedes Atlantic salmon conservation in lake ontario. Ecol Freshwater Fish 12: 66-73.

Townshend TJ, Wootton RJ. 1984. Effect of food supply on the reproduction of the convict cichlid, *Cichlasoma nigrofasciatum.* J Fish Biol 24: 91-104.

Wootton RJ. 1973a. The effect of size of food ration on egg production in the female threespined stickleback, *Gasterosteus aculeatus*. J Fish Biol 5: 89-96.

Wootton RJ. 1973b. Fecundity of the female three-spined stickleback, *Gasterosteus aculeatus*. J Fish Biol 5: 689-688.

Wootton RJ, Evans GW. 1976. Cost of egg production in the three-spined stickleback, *Gasterosteus aculeatus.* J Fish Biol 8: 385-395.

Wootton RJ, Evans GW, Mills L. 1978. Annual cycle in female Three-spined sticklebacks (*Gasterosteus aculeatus* L.) from an upland and lowland population. J Fish Biol 12: 331-343.