

ORIGINAL ARTICLE

Reproductive biology of the Caspian Shemaya, *Alburnus chalcoides* (Pisces, Cyprinidae), from the southern Caspian Sea basin

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Abstract

In the present investigation, some reproductive characteristics of *Alburnus chalcoides* were examined. Sampling of 195 specimens were carried out at monthly intervals from southern coasts of the Caspian Sea (Iran) through the year 2023. The sex ratio, fecundity, ova diameter, and gonadosomatic index (GSI) were studied. Sex ratio differed significantly from unity, in favor of females. The spawning took place from beginning of May to late July, when water temperature was 21-26°C. All stages of ovarian development were recorded macro- and microscopically. Spent fish were caught at five of twelve sampling times. The average egg diameter was 1.18mm. Average GSI value at the beginning of the reproduction period was 14.5% and ranged between 5% and 22% in ripe, mature females. The averages of absolute and relative fecundities were calculated 8064 and 135, respectively. The results of this study showed that the fish displays asynchronous oocyte development.

Keywords: Cyprinid Fish, Gonadosomatic index, Reproduction, Oocyte development, Caspian Sea

INTRODUCTION

Iran harbors approximately 300 freshwater fish species in 110 genera, 38 families, 23 orders, and 3 classes distributed throughout different basins (Sayyadzadeh & Esmaeili 2024). This ichthyofauna is dominated by the family Cyprinidae. Among the drainage systems, the Caspian Sea basin shows the greatest fish species diversity (Jouladeh-Roudbar et al. 2015; Keivany et al. 2016; Eagderi et al. 2022; Mousavi-Sabet et al. 2026).

The Caspian shemaya, *Alburnus chalcoides*, is widely distributed in the Black, Caspian, and Aral Seas, and the Caspian population differs from those of the Black and Aral Seas in morphological and life-history traits (Coad 2017). *A. chalcoides* is a commercial or semi-commercial species in Iran (Keivany et al. 2016). Several studies have examined different biological, morphological, and ecological aspects of *A. chalcoides* in the southern Caspian Sea basin (Bagherian & Rahmani, 2009; Shirvani & Jamili, 2009; Patimar et al. 2010; Mousavi-Sabet et al. 2014; Mouludi-Saleh et al. 2019; Abbasi et al. 2021).

Reproductive biology investigations of fish species are vital to assess the commercial potential of their stocks, culture practices, and fishery management (Soofiani et al. 2006; Dopeikar et al. 2015). It has three key components, including sexual maturity, reproductive period, and fecundity, which are

important demographic characteristics essential for understanding a species' life history (Cortes 2000). Age data are used to assess fish population dynamics, including growth, mortality, recruitment, and stock structure; they are also an essential component of age-structured population models (Bagenal 1967; Ghanbarzadeh et al. 2014). Estimating age at first maturity requires precise determination of gonadal maturation stages, regardless of the method used to estimate the spawning season (Bagenal 1967; Oso et al. 2013).

Fecundity is the number of ripening eggs in a female prior to the next spawning season. Ripe ovaries are appropriate for fecundity estimation. Gonadosomatic Index (GSI) expresses the weight of the gonad in relation to the body weight and is expressed as percentage (Oso et al. 2013; Mousavi-Sabet et al. 2011; Mousavi-Sabet et al. 2012; Mousavi-Sabet et al. 2012a,b). Reproductive potential, i.e., fecundity, is an important biological parameter for evaluating the commercial potential of fish stocks (Gómez-Márquez 2003; Jamali et al. 2016). The main objective of this study was to provide data on the reproductive biology of a cyprinid fish, including sex ratio, gonadosomatic index, fecundity, oocyte diameter, and spawning season, needed to conduct conservation and management programs for *A. chalcoides* sampled from the southern Caspian Sea

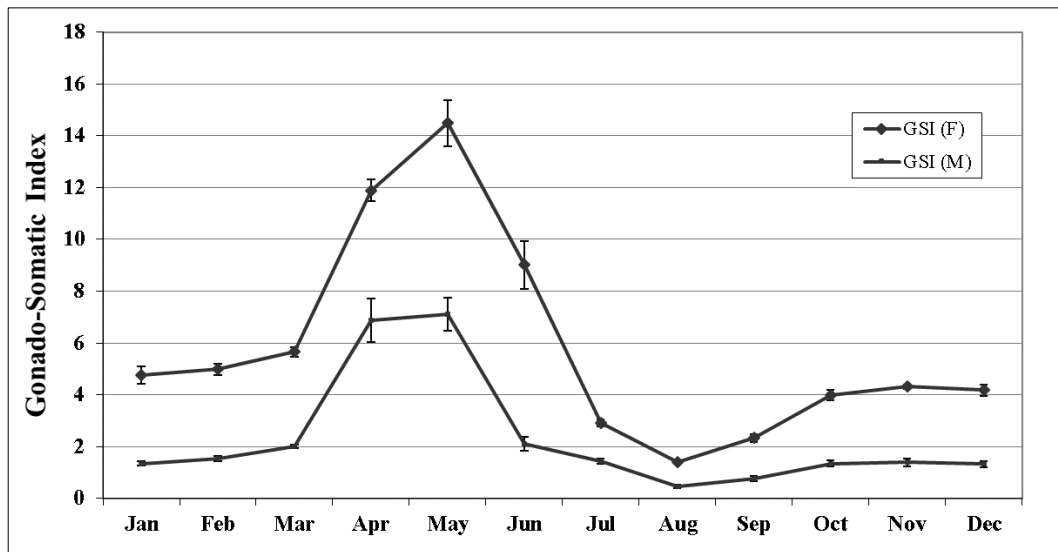


Fig.1. Variation of mean gonadosomatic index (GSI) of female (F) and male (M) specimens of *A. chalcoides* from the southern Caspian Sea basin in different months.

basin.

MATERIALS AND METHODS

Study area. The study was conducted along the southern coast of the Caspian Sea, at the estuary of the Babolrud River (lat 36°26'N, long 52°35'E), north of Iran. Fish were collected from the area monthly from January to December 2019 using a beach-seine net. The water temperature at the sampling site was measured simultaneously. Water analysis showed that water temperature at the sampling site ranged from 5 to 27°C, and salinity from 10 to 13 ppt, during the sampling period.

Biometry and data analysis. Fish were measured (total length = TL; standard length = SL) to the nearest 0.1 mm and weighed (body weight = Wb) to the nearest 1.0g. The gonads and liver were weighed (gonad weight = Wg; liver weight = Wl) to the nearest 0.1g. The gonadosomatic and hepatosomatic indices were calculated following the formulas: $GSI = (Wg \times Wb^{-1}) \times 100$, $HSI = (Wl \times Wb^{-1}) \times 100$ (Nikolsky 1963). Altogether, absolute fecundity (Fa) was estimated in 30 ovaries by counting oocytes with a diameter greater than 0.2mm (Bagenal 1967). To ensure accurate results, we used fish caught in early May and June 2009 and on 6 May 2010 (before spawning). The relative fecundity (Fr) was expressed as absolute fecundity (Fa) divided by fish body weight. The result was the number of eggs per 1 g of body weight (Bagenal 1967). To determine the oocyte diameter, the ovaries were preserved in 10% formalin

solution. The diameters of 60 ova from each female fish were measured using a Zeiss SV 6 dissecting microscope outfitted with an ocular micrometer. The sex was determined based on the examination of gonad morphology after dissection. The chi-square test was used to assess sex ratio deviation from a 50:50 ratio (Thulasitha 2013). Fish were aged using scales taken from the left side of the body, between the end of the pectoral fin and the beginning of the dorsal fin. To compare significant differences in the GSI index between samples taken in different months and across size classes, we applied analysis of variance (ANOVA I). Regression analysis was used to determine the relationship between absolute fecundity (Fa) and body length and weight, gonad weight, and female age. Data were analyzed using SPSS version 16.0 and Microsoft Excel 2010.

RESULTS

During this study, 195 specimens of *A. chalcoides* were caught, ranging 130-240mm FL, and 29 to 128g Wb. Females were longer, heavier, and reached maturity later (at age 2⁺) than males. The studied population had a narrow age range (1⁺ to 5⁺ years). Body length increased proportionally with age. Of the 195 fish specimens caught, 116 were females, and 79 were males, giving an overall sex ratio of 1:1.47; the difference between females and males was significant ($\chi^2 = 3.5103$; $P < 0.05$). To determine the spawning season, we calculated mean GSI (Fig. 1) and HSI (Fig. 2) monthly. The results showed that GSI and HSI

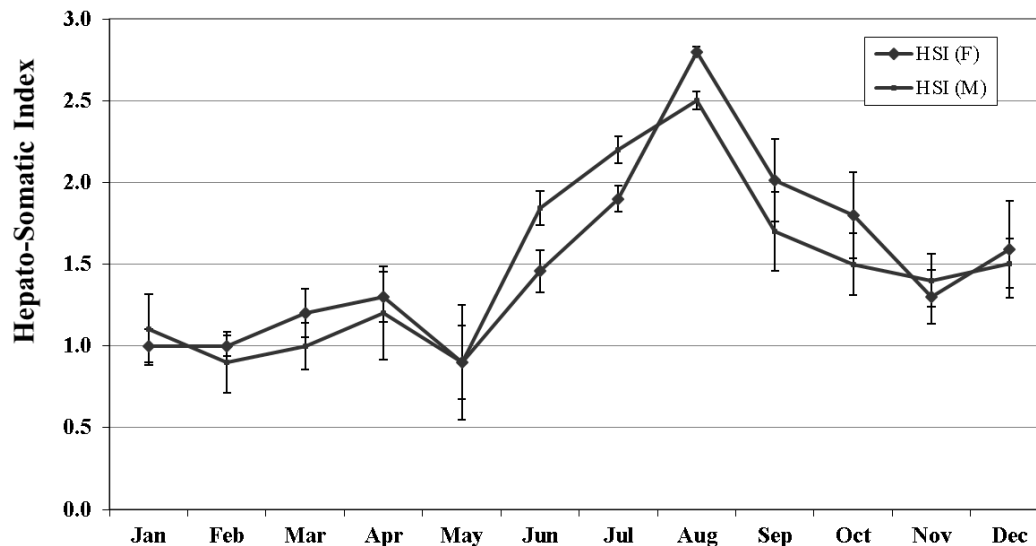


Fig.2. Variation of mean hepatosomatic index (HSI) of female (F) and male (M) specimens of *A. chalcoides* from the southern Caspian Sea basin in different months.

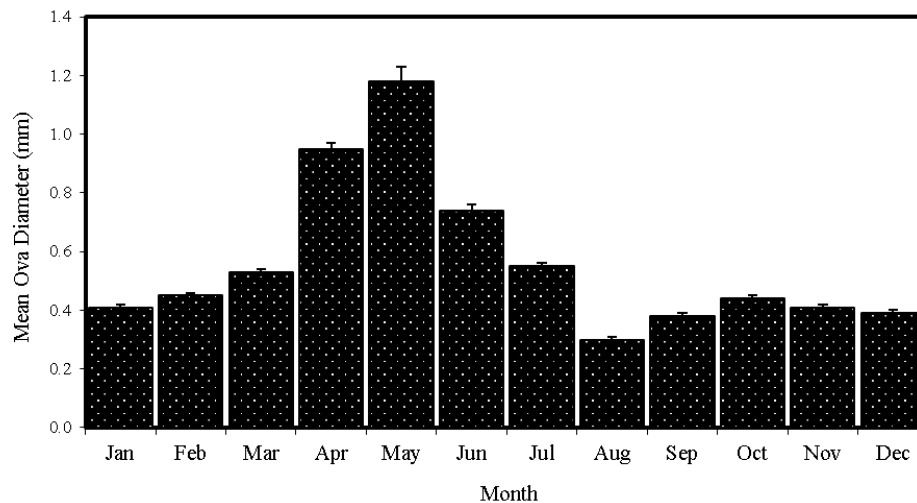


Fig.3. Variation of mean ova diameter (mm) in female *A. chalcoides* from the southern Caspian Sea basin in different months.

peaked in May and August, respectively. Significant differences were observed between female and male GSI and MGSI ($P < 0.05$). No significant difference was observed between GSI and MGSI/DI ($P > 0.05$). The female GSI increased gradually in March and reached the maximum value in May (at a water temperature of 21-26°C) and decreased gradually from May to August (Fig. 1). This trend of the gonad indices and ova diameter showed that this species spawns in May (Figs. 1 and 3). The oocyte diameter ranged from 0.28 to 1.18 mm. Oocyte diameter was highest in May and lowest in August. The fish used to estimate fecundity were 3+, 4+, or 5+ years old. Individual absolute fecundity ranged from 1569 to

17921 eggs, with a mean of 8064 ($SD \pm 3417.50$). Relative fecundity ranged from 41 to 719, with a mean of 134.8 ($SD \pm 73.12$) per gram body weight (Fig. 3).

DISCUSSION

In this study, the most abundant age group in the catches was 3+ with average lengths of 130-210 mm and 140-240 mm for females and males, respectively. Jawad (2004) used eye lens diameter to age young (up to age 3) of this species from the marshes north of Basra. Ergene (1993) studied growth in the Karasu of Turkey, identified 4 age groups, and mentions 5 age groups in another Turkish study. Ergene (1993) reported average fork lengths of 118.2, 131.0, 145.2,

and 163.3mm for 4 age groups, respectively. Türkmen & Akyurt (2000) also worked on this species in the Karasu River and reported age groups of 1 to 6. According to them, age group 3 was the most abundant group. Length and age at first maturity have been reported to be 1.26 years and 9.24cm for males and 1.81 years and 9.65cm for females in the Karasu River, Turkey, with the oldest age group of 7 years (Yıldırım et al. 2007). In many species, the HSI is an appropriate index for predicting gonadosomatic condition and the amount of energy allocated to reproductive activity (Yagarina & Marshall 2000; Siami et al. 2017). Typically, in many fish species, GSI peaks at the peak of spawning, and HSI increases (Galloway & Munkittrick 2006; Mousavi et al. 2017). Based on the results from different months, HSI in *A. chalcoides* was lowest at the beginning of May and highest in August. Variation in HSI may be influenced by vitellogenesis in the liver. Vitellogenin is present in very low concentrations in the plasma of immature or male organisms. During vitellogenesis, the liver of females is stimulated to produce vitellogenin, which is then incorporated into the yolk of developing oocytes. Vitellogenesis induction generally increases liver metabolism, leading to liver enlargement and, consequently, increased HSI (Christensen et al. 1999). To respond to energy shortages, organisms manage their energy reserves (Wootton 1999). So, in the cold months (winter), fish may enter a reproductive cycle: at the beginning of the reproductive period, they face a cold period. On the other hand, the fish experienced poor environmental conditions, such as low food availability. Therefore, in order to increase survival, they save more energy in the summer when environmental conditions are favorable. This strategy (saving energy in summer to overwinter) has also been reported in other species (Love 1970; Dopeikar et al. 2015; Mousavi et al. 2017; Siami et al. 2017). The monthly changes in GSI showed that the reproductive period of *A. chalcoides* began in March and ended in August. According to gonadosomatic examination results, GSI values increased in March and reached their highest value in May, then decreased gradually from May to August. After that, ovarian development increased again from August to November, when some of the studied fish were ready to spawn. The average absolute fecundity of female *A. chalcoides*

was 8064 eggs (± 3417.50), ranging from 1569 to 17921 eggs. Berg (1949) reported mature eggs in a female measuring 155mm long. Yıldırım et al. (2007) examined this species in the Karasu River of Turkey and found a male: female sex ratio of 1:1.08, not significantly different from 1:1, a fecundity range of 3012 to 11427 eggs, significant correlations between fecundity and fork length, total weight, age, and gonad weight, and a spawning season from June to August when water temperature attained 15°C. Our results showed that the spawning season occurs from May to August in the southern Caspian Sea basin, which signifies the latitude effect of temperature on reproductive activity. Temperature (which has major effects on gonad maturation and spawning season) is important in the onset of spawning and has a modifying role, particularly in cueing the precise timing of gamete maturation and spawning, providing the capacity for reproductive cycles to be locally tuned (Wootton 1999; Wright & Trippel 2009; Pankhurst & King 2010). Different environmental factors affect fecundity, which varies among fish species (Wootton 1999). Several factors, such as female size and age (Thrope et al. 1984), life history strategy (Morita & Takashima 1998), and food supply and water temperature (Fleming & Gross 1990), affect fecundity. Ayoade (2011) suggested that variation in fecundity may result from differences in food abundance. According to Jonsson (1999), fecundity increases with body size because the energy available for egg production and the body cavity that accommodates the eggs increase with fish size. Length seems to be a better indicator of oocyte production capacity than weight because fish do not decrease significantly in size, whereas weight may vary throughout the year (Bagenal 1967). Usually, the relative fecundity is higher in small females than in large ones (Lobon-Cervia et al. 1997). Bagenal (1967) asserted that fish species exhibit wide fluctuation in fecundity among fish of the same species, size, and age.

The present study, on some aspects of reproductive biology of *A. chalcoides* has revealed the followings: the mature males and females were longer than 130 and 140mm, respectively in fork length (age 1+); the breeding season was from April to June with a peak in May; the mean absolute and relative fecundity were

8064 eggs (± 3417.50) and $134.8(\pm 73.12)$ per gram body weight, respectively, and mean ovum diameter range of 0.28-1.18mm.

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مقاله کامل

زیست‌شناسی تولیدمثل شاه‌کولی کاسپین *Alburnus chalcoides* در حوضه جنوبی دریای کاسپین

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چکیده: در پژوهش حاضر، برخی از ویژگی‌های تولیدمثلی شاه‌کولی کاسپین *Alburnus chalcoides* مورد بررسی قرار گرفت. نمونه‌برداری از ۱۹۵ قطعه ماهی در فواصل ماهانه از سواحل جنوبی دریای کاسپین (ایران) در طول سال ۲۰۲۳ انجام شد. در این مطالعه، نسبت جنسی، میزان هم‌آوری، قطر تخمک و شاخص گنادوسوماتیک (GSI) مورد ارزیابی قرار گرفتند. نسبت جنسی تفاوت معنی‌داری با نسبت یک‌به‌یک داشت و به نفع جنس ماده بود. تخم‌ریزی از اواسط اردیبهشت ماه تا اواخر تیر ماه، یعنی زمانی که دمای آب بین ۲۱ تا ۲۶ درجه سانتی‌گراد بود، صورت گرفت. تمامی مراحل رشد تخمدان به روش‌های ماکروسکوپی و میکروسکوپی ثبت شد. ماهیان تخلیه‌شده (پس از تخم‌ریزی) در پنج نوبت از دوازده نوبت نمونه‌برداری صید شدند. میانگین قطر تخمک ۱/۱۸ میلی‌متر بود. میانگین شاخص GSI در آغاز دوره تولیدمثل ۱۴/۵ درصد بود و در ماهیان ماده بالغ و رسیده، دامنه‌ای بین ۵ تا ۲۲ درصد را نشان می‌داد. میانگین هم‌آوری مطلق و نسبی به ترتیب ۸۰۶۴ و ۱۳۵ محاسبه شد. نتایج این مطالعه نشان داد که این ماهی دارای الگوی رشد ناهمگام تخمک است.

کلمات کلیدی: کپور ماهیان، شاخص گنادی بدنی، تولید مثل، توسعه تخمک، دریای کاسپین