Research Article

Reproductive biology of the Bloch's gizzard shad, *Nematalosa nasus* (Teleostei: Clupeiformes) in the coastal waters of the Persian Gulf

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Abstract: This study was conducted to determine the reproductive biology of *Nematalosa nasus* for a period of 18 months from September 2016 to April 2018 in the coastal waters of the Persian Gulf. In total, 618 specimens (331 males and 287 females) were collected as bycatch in the shrimp bottom trawl net. Fork length ranges from 95-160mm (mean 135±0.7mm) and 95 to 169mm (mean 139±0.8mm) in males and females, respectively. The overall sex ratio showed that the males were dominating (1.15:1). Also, the size-specific sex ratio showed that the number of males was more dominant in fork length classes less than 135mm, and females generally dominated at lengths greater than 150 mm. Monthly variations in the Gonad Somatic Index (GSI) and morphological maturity stages of ovary indicated that Bloch's gizzard shad had a long spawning season with two distinct peaks in autumn and winter (from September to February). The smallest females mature Bloch's gizzard shad were found in the size classes 120-124mm of fork length and the Lm50% was estimated at 150mm.

Keywords: Clupeidae, Sex ratio, Spawning season, LM50%, Indian Ocean.


Introduction

The clupeiform fishes (Herrings & allies) are ecological important marine fish, which exhibits shoaling behavior and a dominant pelagic group of fish landed in the south of Iranian waters. The family Clupeidae Cuvier, 1816 currently includes 191 valid species (Fricke et al. 2020). Most species of this family are known to be marine, some are permanently freshwater living while some species are anadromous (Fischer & Bianchi 1984; Nelson et al. 2016). In the Persian Gulf, 20 species of this family have been reported up to now which were caught with different gears including seines, lift nets, and shallow trawls (Carpenter et al. 1997; Eagderi et al. 2019). The genus *Nematalosa* Ragan, 1917 has some marine species with a medium size (Whitehead 1985). This genus has three representatives in the Persian Gulf. The Bloch's gizzard shad, *N. nasus* (Bloch 1795) is the common clupeids exploited (as bycatch) in the shrimp bottom trawl net in the Iranian coast.

The present study aimed to investigate some aspects of the reproductive biology of Bloch's gizzard shad, *N. nasus* in the northern Persian Gulf. These are the annual reproductive cycle (in terms of seasonal changes in the gonadosomatic index and maturity stages), the sex-ratio, and the size at first sexual maturity as the first experience time to be used for further resource management on this species.

Materials and Methods

Study area, sampling, and measurements:
Sampling was carried out by using the shrimp bottom trawling nets with a 20mm cod-end mesh size. Biological data were collected monthly for 18 months from September 2016 to April 2018 in the
coastal waters of Hormozgan province in the northern Persian Gulf, Iran (restricted in an area extending from 26°55 E, 56°52 N to 26°59 E, 56°05 N) (Fig. 1). At least 30 specimens were taken per month. Samples were measured, recorded for its sex, total and fork length, its body weight, and ovary maturity stages. The maturity stages of ovaries were sorted into five main classes following the procedure adopted by Biswas (1993). The Gonad-Somatic Index (GSI) was calculated after the following formula:

\[
\text{GSI} (%) = \frac{\text{Drained ovary weight}}{\text{Total live weight}} \times 100
\]

**Data Analysis:** Using size-frequency distribution of length, for male and female fishes were depicted in each month. To establish the length-weight relationship, the commonly used relationship \( W = a L^b \) was applied (Pauly 1983), Where: \( W \) is the weight (g), \( L \) is the fork length (cm), \( a \) is the intercept (condition factor) and \( b \) is the slope (growth coefficient).

A linear equation (\( \ln W = \ln a + b \ln FL \)) was fitted for log-transformed data. The Parameters \( a \) and \( b \) were estimated using power regression and the coefficient of determination (\( R^2 \)) to show the fork length-weight relationship. The parameter \( b \) is a shape parameter for the body form of the fish species. In theory, one might expect that the exponent \( b \) would have a value of roughly \( b = 3 \) because the volume of a 3-dimensional object is roughly proportional to the cube of length for a regularly shaped solid. Computing \( b \) value estimated with 3 was tested by using the t-test (Pauly 1983):

\[
t = \frac{s.d.(L)}{s.d.(w)} \times \frac{|b - 3|}{\sqrt{1 - r^2}} \times \sqrt{n - 2}
\]

Where: s.d. (L) is the standard deviation of the ln FL values, and s.d. (W) the standard deviation of the ln W values, \( n \) being the number of fish used in the computation. The value \( b \) is different from 3 if \( t \) is greater than the table value for \( t \) in \( n-2 \) df. (Pauly 1983).

The sex ratio analyses were carried out by monthly data sets of the total number of male and female fish. Chi-square (\( X^2 \)) statistical was performed to test the difference between ratios in both sexes. The spawning season of this species was forecast from the percentage of ovary stage 4 and the monthly GSI index trend.

The \( L_{50}\% \) was estimated by using the following formula (King 2007) and least square method (Solver Tools in Microsoft Excel ver. 2013):

\[
P = \frac{1}{1 + \exp \left( -\frac{cm}{Lm} - Lm50 \right)}
\]

Where: \( r_m \) is the slope of the curve, \( L_m \) is the mean fork length (cm) at sexual maturity, \( L \) is the mean fork length (cm) and \( P \) is the probability of the
Table 1. Fork length-weight relationships of *Nematalosa nasus* in the Persian Gulf.

<table>
<thead>
<tr>
<th>Sex</th>
<th>Length-weight Equation</th>
<th>R²</th>
<th>N</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>W = 0.0002 × FL^{2.58}</td>
<td>0.72</td>
<td>331</td>
<td>P&lt;0.05</td>
</tr>
<tr>
<td>Female</td>
<td>W = 0.0001 × FL^{2.70}</td>
<td>0.72</td>
<td>287</td>
<td>P&lt;0.05</td>
</tr>
<tr>
<td>Total</td>
<td>W = 0.0001 × FL^{2.68}</td>
<td>0.73</td>
<td>618</td>
<td>P&lt;0.05</td>
</tr>
</tbody>
</table>

**Fig. 2.** The changes in fork length (Mean±Se) for studied specimens of *Nematalosa nasus*.

**Results**

**Descriptive statistics and fork length-weight relationship:** The results showed that the fork length (FL) of males and females *N. nasus*, ranged from 9.5 to 16 cm and 9.5 to 16.9 cm, respectively. The mean (±SE) FL was 13.5±0.7 for males and 13.9±0.8 cm for females (Fig. 2).

The fork length-weight relationship (Table 1) of *N. nasus* had a high R² value and the exponent (b=2.68) was significantly different from 3 (P<0.05), indicating that growth in this species is negatively allometric.

**Sex ratio, Gonad Development, and Size at Sexual Maturity (LM₅₀%):** Overall, 331 (53.56%) out of the 618 individuals of *N. nasus* sexed were males, and 287 (46.44%) were females. The M:F ratio was

**Fig. 3.** The sex ratio of male and female individuals of *Nematalosa nasus* from the Persian Gulf, Iran.
1.15:1 and did not differ significantly ($P=0.08$) from unity. An inspection of the monthly sex ratio revealed that there was also a male bias in sex ratio in most months of the year (Fig. 3).

Also, the size-specific sex ratio showed that the number of males was higher for fork length classes less than 135mm, and females generally dominated at lengths greater than 150mm (Fig. 4).

The recorded result showed that the GSI index has a large monthly fluctuation in both sexes of *N. nasus* in the study period. The highest value was also estimated in October 2017 at 5.77±1.58 for both genders (Fig. 5). All five stages of ovarian development were observed throughout the year (Fig. 6). The abundance of mature fish (stages 3 to 5) had relatively high percentage and young fish (stages 1 and 2) showed the same trend, indicating these species have a long spawning season with two distinct peaks in autumn and winter (from September to February). The $L_{m50\%}$ was estimated at 150mm of
fork length in females. The smallest mature females were observed in the size classes 120-124 mm of fork length.

Discussion

Clupeiform are small fishes, many of them perform shoaling behavior that has great importance to the fisheries; yearly average catch of small pelagic fish in the Persian Gulf (1997-2008) was estimated at 24,000 t (FAO 2011). It is one of the major fisheries targets in the south of Iranian coastal waters. The present study, give new information on some aspects of the reproductive biology of *N. nasus* along the Bandar Abbas coast.

The results showed that the fork length for males and females *N. nasus* ranged from 9.5 to 16 cm (mean 13.5±0.7 cm) and 9.5 to 16.9 cm (mean 13.9±0.8 cm), respectively. Dizaj et al. (2020) noted the fork length of *N. nasus* varied between 13.32-18.20 cm in the coastal waters of Iran. The total length of this species has been reported at a range of 6.7-22.3 cm in the Khor Al-Zubair estuary, Iraq (Hussain et al. 1998). The fork length ranges for another species of this genus, *Nematalosa come* (Richardson 1846) has been reported between 8.5 and 19.3 cm in the south of Taiwan (Chen & Hsiao 1996).

The b values were estimated as b=2.58, 2.70, and 2.68 for males, females, and total fishes, respectively derived from the length-weight relationship of *N. nasus* in which was significantly different from 3, implying these species have negative allometric growth. Similar results were recorded for other species of this family by Dizaj et al. (2020) so that they stated that the length-weight relationships of *N. nasus* were highly correlated (R²=0.83) from southern Iran, they also estimated a and b values at 0.0154 and 3.01, respectively for this species. Also, the positive allometric growth (with b=3.28) was reported for this species in the Khor Al-Zubair estuary, Iraq (Hussain et al. 1998). A similar result was recorded for *Grammoplites suppositus* (Troschel, 1840) in coastal waters of the Persian Gulf (Izadifar et al. 2019). While a different growth pattern (isometric) has been reported for other species (*N. come*) in the south of Taiwan (Chen & Hsiao 1996).

The length-weight relationship of the fish can be used to determine whether their growth is isometric or allometric (Ricker 1975). The positive allometric growth implies the fish becomes relatively stouter or deeper-bodied as it increases in length while negative allometric growth indicates the fish becomes slenderer as its increase in weight (Riedel et al. 2007).

There are sometimes significant differences in estimated b value between different populations of the same species, or between the same populations in different years, presumably associated with their nutritional condition. Also, Variation in estimated b value from cube law reported by other authors may
be due to differences in the number and range of size classes of samples used for t-test and the environmental conditions of the study area. (Ricker 1975).

The overall sex ratio M:F = 1.15:1 was not significantly different from the expected 1:1; and male bias in sex ratio in fork length classes of less than 135 mm and females generally dominated at lengths greater than 150 mm, indicating the sex ratios were dependent on fish size. A similar result in sex ratios was reported for *N. come* in the south of Taiwan (Chen & Hsiao 1996). While Izadifar et al. (2019) in their study on the reproductive biology of *G. suppositus* in the Persian Gulf stated the overall sex ratio M:F was significantly different from the expected 1:1, and female bias in sex ratio in most months of the year. The predominately of females in the largest size-classes was reported for *N. erebi* in South Australia (Puckridge & Walker 1990). In contrast, Ramya et al. (2016) stated that the males and females *N. nasus* was no significant difference in size groups and exhibited an equal sex ratio (M: F) in the Mangalore coast of Karnataka, India. The difference in the growth and mortality rates, as well as different longevity, could among the reasons for differences in sex ratios observed in different studies (Vicentini & Araujo 2003; Zhang et al. 2009).

The results of this study suggest that the spawning season of *N. nasus* in the Persian Gulf has extended from September to February. Also, the Lm50% was estimated at 150 mm of fork length for females. Ramya et al. (2016) reported that the *N. nasus* have spawning season from September to April in the Mangalore coast of India, and peak spawning activity occurred in October and November. Puckridge & Walker (1990) founded that the GSI of female's *N. erebi* has shown a distinct seasonal cycle with a peak in November at water temperatures of 18-20°C in South Australia. They also reported that the size at 50% maturity in female *N. erebi* occurred at 199 mm in total length. The maximum value in both sexes for *N. come* was reported in March and a peak spawning occurred from February to April in the south of Taiwan (Chen & Hsiao 1996).

Given the GSI trend and ovary maturity stages, the results of the present study indicated that Bloch's gizzard shad, *N. nasus* has two peaks of spawning season in the area, so that the exploitation of this resource should be properly managed accordingly.

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مقاله بروزه‌شی

زمینه نمادی؛ تولید مثل گواف، رشته‌دار (نامهای استخوانی عالی: شگ) Nematalosa nasus در آب‌های ساحلی خلیج فارس

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چکیده: این مطالعه با هدف بررسی زیست‌شناسی تولید مثل گواف، رشته‌دار Nematalosa nasus و به مدت 18 ماه از شهریور 1395 تا فروردین 1397 در آب‌های ساحلی خلیج فارس انجام شد. در مجموع 618 ماهی (شامل 331 ماهی نر و 287 ماهی ماده) به عنوان صید ضمنی می‌گو جمع‌آوری و مورد زیست‌سنجی قرار گرفتند. طول چنگالی ماهی‌های نر بین 95 تا 160 میلی‌متر (با میانگین ±135) و در ماهی‌های ماده بین 95 تا 169 میلی‌متر (با میانگین ±139) متغیر بود.

نتایج نسبت جنسی (نر: ماده) نشان داد که نرها غالبی‌تر از ماده‌ها بودند (15:1). همچنین نشان داد که طول چنگالی کمتر از 135 میلی‌متر و طول چنگالی بیش از 150 میلی‌متر، ماهی‌های ماده غالب بودند. تغییرات ماهی‌های نمادی و GSI که در ماهی‌های نرم‌نوازی، ماهی‌های نرم‌نوازی بالا بودند، تغییرات ماهی‌های نرم‌نوازی و GSI که در ماهی‌های نرم‌نوازی، ماهی‌های نرم‌نوازی بالا بودند، تغییرات ماهی‌های نرم‌نوازی و GSI که در ماهی‌های نرم‌نوازی، ماهی‌های نرم‌نوازی بالا بودند، تغییرات ماهی‌های نرم‌نوازی و GSI که در ماهی‌های نرم‌نوازی، ماهی‌های نرم‌نوازی بالا بودند، تغییرات ماهی‌های نرم‌نوازی و GSI که در ماهی‌های نرم‌نوازی، ماهی‌های نرم‌نوازی بالا بودند، تغییرات ماهی‌های نرم‌نوازی و GSI که در ماهی‌های نرم‌نوازی، ماهی‌های نرم‌نوازی بالا بودند، تغییرات ماهی‌های نرم‌نوازی و GSI که در ماهی‌های نرم‌نوازی، ماهی‌های نرم‌نوازی بالا بودند، تغییرات ماهی‌های نرم‌نوازی و GSI که در ماهی‌های نرم‌نوازی، ماهی‌های نرم‌نوازی بالا بودند، تغییرات ماهی‌های نرم‌نوازی و GSI که در ماهی‌های نرم‌نوازی، ماهی‌های نرم‌نوازی بالا بودند، تغییرات ماهی‌های نرم‌نوازی و GSI که در ماهی‌های نرم‌نوازی، ماهی‌های نرم‌نوازی بالا بودند، تغییرات ماهی‌های نرم‌نوازی و GSI که در ماهی‌های نرم‌نوازی، ماهی‌های نرم‌نوازی بالا بودند، تغییرات ماهی‌های نرم‌نوازی و GSI که در ماهی‌های نرم‌نوازی، ماهی‌های نرم‌نوازی بالا بودند، تغییرات ماهی‌های نرم‌نوازی و GSI که در ماهی‌های نرم‌نوازی، ماهی‌های نرم‌نوازی بالا بودند، تغییرات ماهی‌های نرم‌نوازی و GSI که در ماهی‌های نرم‌نوازی، ماهی‌های نرم‌نوازی بالا بودند، تغییرات ماهی‌های نرم‌نوازی و GSI که در ماهی‌های نرم‌نوازی، ماهی‌های نرم‌نوازی بالا بودند، تغییرات ماهی‌های نرم‌نوازی و GSI که در ماهی‌های نرم‌نوازی، ماهی‌های نرم‌نوازی بالا بودند، تغییرات ماهی‌های نرم‌نوازی و GSI که در ماهی‌های نرم‌نوازی، ماهی‌های نرم‌نوازی بالا بودند، تغییرات ماهی‌های نرم‌نوازی و GSI که در ماهی‌های نرم‌نوازی، ماهی‌های Nmatalosa nasus

کلمات کلیدی: شگ ماهی‌های نمادی، ۶۰۰٪ نمادی، نمادی‌شناسی، بلوغ جنسی، طول چنگالی

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