Int Aquat Res (2022) 14:71-79
https://doi.org/10.22034/IAR.2022.1949666.1229

SHORT COMMUNICATION

Feeding and reproduction ecological patterns of *Coptodon zillii* in Shadegan wetland: An aggressive potential species for local aquaculture

Shima Bavali . Mahsa Haghi . Mohammad Zakeri . Preeta Kochanian

Received: 17 January 2022 / Accepted: 18 March 2022 / Published online: 27 March 2022

Abstract The knowledge of feeding and reproduction ecology of *Coptodon zillii*, as an aggressive species for endemic fisheries stocks and aquaculture activity, is very important. Sampling was performed monthly for one year in the northern area of Shadegan Wetland. The relationship between length and weight showed negative allometric growth. According to the *gut* contents; macrophytes, fish scale, fish eggs, cladocerans, copepods, and periphyton were preferred food. The feeding type of this species was identified as vegetarian with low animal source origin. The condition index showed that the species condition was good in terms of being fat. The highest hepatosomatic (HSI) and gonadosomatic indices (GSI) indices were recorded in February and May, respectively. The highest relative fecundity index was 1315.26 ± 379- July, and the lowest was 78.86 ± 28 eggs per gram of female somatic weight. Therefore, based on food and reproduction conditions, it can be said that *C. zillii* had successfully resided in Shadegan Wetland and had relatively good ecological conditions. It could be harmful risk for practical aquaculturists because of the aggressive potential of this species in interaction with endemic and farmed fishes, and should be managed with fisheries decision-makers.

Keywords Food items . Reproduction . *Coptodon zillii* . Invasive species . Shadegan Wetland

Introduction

The wetlands are important ecosystems for wild commercial and farmed fish in the points of shelter, fish eggs, nursery grounds, maturity, and fisheries (Abbasi et al. 2009). Shadegan Wetland is the largest wetland in Iran, the 34th wetland of 1201 wetlands registered in Ramsar Convention List, and is the largest Persian Gulf Coastal wetland. This wetland is located in the Khuzestan plain and the delta of Jarahi River, and is the bridge between the Jarahi River in the north and the Persian Gulf in the south. Some important and sensitive endemic species lives in this wetland such as *Mesopotamichthys sharpeyi*. This wetland is one of the most important ecosystems for the restoration of the native fish stocks by the practical aquaculturists and affected the local climate. The livelihood of many locals depends on its aquatic and terrestrial resources.

The invasive species become stable species without human intervention in an area outside the native habitat. Invasive species thrive in freshwater due to their high tolerance to environmental conditions, reproduction, and feeding methods (Keller and Lodge 2009). The effects of invasive species on inland water depend on invasive species, invasion, aggressiveness, and ecosystem vulnerability. The invasive species reduce the native species abundance and alteration the structure and processes of the ecosystem (Clarke et al. 2020). Therefore, recognizing ecological feeding and reproduction patterns as two principle

Shima Bavali . Mahsa Haghi (✉) . Mohammad Zakeri . Preeta Kochanian
Department of Fisheries, Faculty of Marine Natural Resources, Khorramshahr University of Marine Science and Technology, Khuzestan Province, Iran.
e-mail: haghi.mahsa@gmail.com

and vital factors of aggressive species is one of the most important ways to conserve aquacultural endemic species. This knowledge can be helpful for further success in breeding native species and increasing local aquaculture production.

Coptodon zillii (Gervais 1848) is a potamodromous fish and is native to brackish and freshwater in West Africa (Akel and Moharram 2007). *C. zillii* feeds on the substrate and serves as an opportunistic feeder with a wide range of nutrients includes plants, larvae, zooplankton, small crustaceans, and Mollusca (Agbabiaka 2012). It feeds mainly on large plants and aquatic macrophytes; when it gets older, it feeds on plants with ground origin (Negassa and Prabu 2008). This species was introduced in many countries worldwide as a fish with economic and environmental uses in aquaculture, commercial aquariums, weed control, and recreational fishing (Dadebo et al. 2014).

Various studies have focused on the reproduction and food biology of *C. zillii,* in different places of the world. In recent decade, aggressive *C. zillii* has entered the inland waters of Iran. Roozbehfar et al. (2014) reported the *C. zillii* in Iranian inland waters, specifically in the Dez River in Khuzestan Province. In the same year, Khaefi et al. (2014) reported the *C. zillii* in Shadegan Wetland fresh water and Bahmanshir River. Similarly, Ghofleh Maramazi et al. (2014) confirmed the presence of this invasive species in the sources of Khuzestan inland water and even in the farms. Simultaneously, this species has been reported in neighboring countries with shared water resources. For the first time, AL-Zaidy (2013) observed the *C. zillii* in the Al-Delmj Watershed. Al-Faisal and Mutlak (2014) also reported *Oreochromis niloticus* in the Arvandrud river of Southern Iraq. Accordingly, the present study was aimed to investigate the type of food, the main food items, the recognition of the sexual periods, and the peak time of the reproduction of *C. zillii*, as an invasive species, in Shadegan Wetland.

Materials and methods

This study was conducted for one year in Shadegan Wetland in the lower part of Jarahi River and the geographical coordinates of 50° 30' to 00° 31' N and 20° 48’ to 20° 49' E. Sampling were performed monthly (except for January due to the lack of samples despite frequent netting). The 335 specimens of *C. zillii* samples were caught using a cast net with different mesh size (14, 15, 16, and 17 mm) for coverage all specimens size. Fish were immediately fixed in formalin 10% and then transferred to the laboratory (Alkahem et al. 2007). All samples were collected from local fisheries and, no ethical approval was necessary.

The samples biometrics, including total length, was performed using biometrics board and total-wet weight (PT600 scale, Germany) with an accuracy of 0.1 g. The length-weight relationship is used to determine the growth pattern ($W=aL^b$). W: total weight (g), L: total length (cm), a: refractive index of the curve or y-intercept, and b: curve slope (King 1997).

To distinct feeding ecology, viscera completely were removed from the body cavity and weighed using a digital scale with an accuracy of 0.01 g (BEL-ES202, Italy). After measuring the length and weight of the stomach and its contents, the contents of the stomach and gut were removed, weighed, and finally fixed in 95% ethanol to determine food habits (Hyslop 1980). Also, the sex was determined using the direct observation method of gonads. The liver and gonads weights were recorded to calculate hepatosomatic (HSI) and gonadosomatic indices (GSI) indices only for the female sample with an accuracy of 0.01 g (Biswas 1993).

The numerical method was used to survey periphytons (Venkatra and Ramanatham 1994). After volume determination (Pillay 1952), for each fish sample, five ml were separated three times and placed in counting chambers, food items were identified and counted using an inverted microscope (Wilovert30, Germany). Identification key Chihara and Murano 1997; was used for the identification.

The relative length of the gut (RLG) is an index that presented the type or nature of consumed food. There is a relationship between food habits and gut relative length index. The value of RLG is calculated using gut length to body length ratio (cm) (Biswas 1993). Gastro-somatic index (GI) is used to estimate the fish food intensity based on the ratio of viscera to body weight (Kumar et al. 2007). K represents the living conditions of the fish; the more it is, the better the existing conditions, and the more energy has just been spent on growth (Ayoade and Ikulala 2007). The following formula is used to measure the condition factor:

$$K = {}^{W}/_{L^3} \times 100$$

In this formula, K is the condition factor, W is the weight of the fish (g), and L is the fish length (cm). The index of fullness (IF) indicates the proportion of the food eaten by the fish. If the value of food intensity is between 400 and 900, it is an indicator of the good feeding condition of the fish (Alkahem et al. 2007). In this formula, IF is the food index, w is the gut content weight, and W is the fish body weight (g). CV calculates the fish feeding estimate (Oso et al. 2013).

$$CV = ({}^{ES}/_{TS}) \times 100$$

In this formula, CV is the empty gut index, ES is the number of empty guts, and TS is the number of the examined guts.

For absolute fecundity, the whole separated ovary was then weighed by a digital scale with an accuracy of 0.01 g and placed inside the Gleason solution. The ovary was kept in this solution in darkness and stirred every 2 or 3 days to release the ovum. Then, the resulting solution was filtered and, the ova were separated and dried on the filter paper. Then, by weighing the ova, their total dry-weight was obtained. Finally, 0.01 g of ova was counted and determined using the following formula (Biswas 1993).

$$F = \frac{nG}{g}$$

In this formula, F is absolute fecundity, n is the number of ova, G is total ovary weight (g), and g is the mean sample weight (g). Relative fecundity was also calculated using the ratio of the number of ova to the fish body weight (Relative fecundity was obtained by dividing absolute fecundity with total weight of fish) (Biswas 1993). The sex ratio was measured using the formula Oso et al. 2013 and checked by chi-square test. One-way ANOVA was used to checked significant differences in indices.

Results

According to fishermen reports and observations of pervious study (Valikhani et al. 2018), in recent decade, the highest part of their catch in Shadegan wetland belongs to tilapia species, especially *C. zillii*. Therefore, *C. zillii* seems to have affected the native populations and settled there successfully.

The study of the length of *C. zillii* in different months showed that the maximum and minimum length-mean were observed in February (16.38 ± 0.3 cm) and July (11.77 ± 0.42 cm) (Fig. 1). Also, the study of the bodyweight of this species in various months showed that the highest mean weight was for February samples with 94.86 ± 5.72 g, and the lowest mean was for July samples with 37.04±3.46g (Fig. 2). The regression equation between the length and weight of *C. zillii* is as follows $R^2 = 0.7563$ and $y = 0.072x^{2.5404}$ (Fig. 3). Based on the formula $W=aL^b$, the values of a and b are 0.07 and 2.54, respectively. Given that the value of b is significantly less than 3, *C. zillii* has negative allometric growth.

The analysis of the contents of the stomach and gut of this species revealed the presence of macrophytes, fish scale, fish eggs, the zooplankton of Cladocera and Copepoda, and periphyton species. Furthermore, the analysis of *C. zillii* gut contents showed that the branches of Cyanophyta, Ochrophyta, Charophyta, Euglenophyta, Bacillariophyta, Miozoa, and Chlorophyta were 4.79, 6.37, 0.0, 28.84, 1.72, 0.51, and 13.21% of periphytons contained in the gut and stomach contents of this species. Among the identified periphytons, the genus *Achnanthes* had the highest frequency (19.58%), and the genus *Ceratium* had the lowest frequency (0.02%). Cladocera with 0.07%, Copepoda with 1.36%, and fish eggs with 1.56%, and fish scale with 1.98%, respectively, were the remaining gut and stomach contents.

The RLG study of *C. zillii* showed that its changes over the entire study period were more than 1 (Fig. 4), which indicates a vegetarian diet. The highest GI index of *C. zillii* was 0.13 ± 0.002 in November, and the lowest value was 0.092 ± 0.007 in September (Fig. 5). The condition factor for *C. zillii* in different months was always more than 2, which indicates the suitable condition of the species. The highest value for state *C. zillii* was 2.19 ± 0.04 in June, and the lowest value was 2.02±0.02 in October (Fig. 5). The values for RLG, GI, and K indices showed no significant difference during the study period and in different months ($P \leq 0.05$).

The study of the gut vacuity index of *C. zillii* showed that it was in the range of and was highly-fed in this

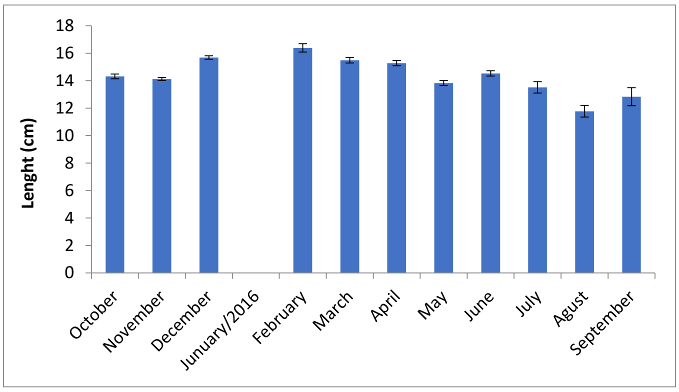

Fig. 1 Length Mean ±SE of *Coptodon zillii* in different months of study

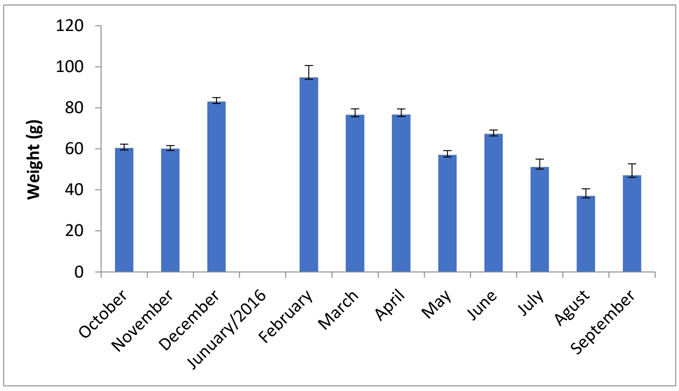

Fig. 2 Weight Mean ±SE of *Coptodon zillii* in different months of study

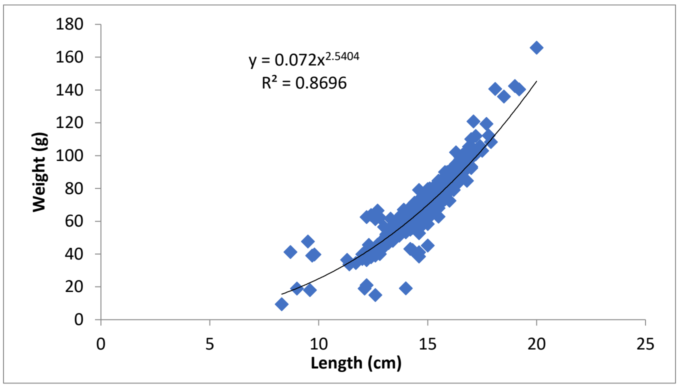

Fig. 3 Weight- Length regression for *Coptodon zillii* during study period

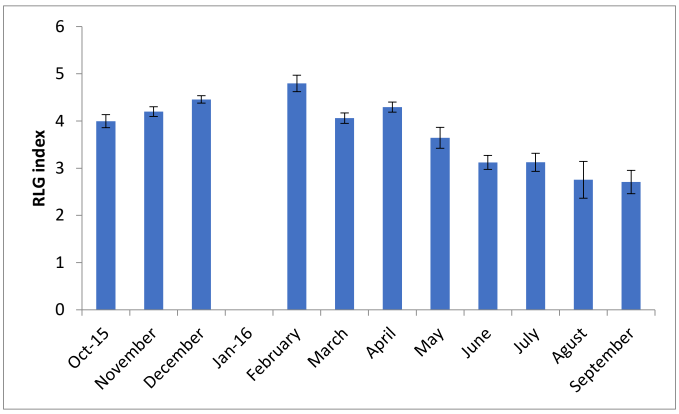

Fig. 4 RLG Mean ± SE index of *Coptodon zillii* in Shadegan wetland

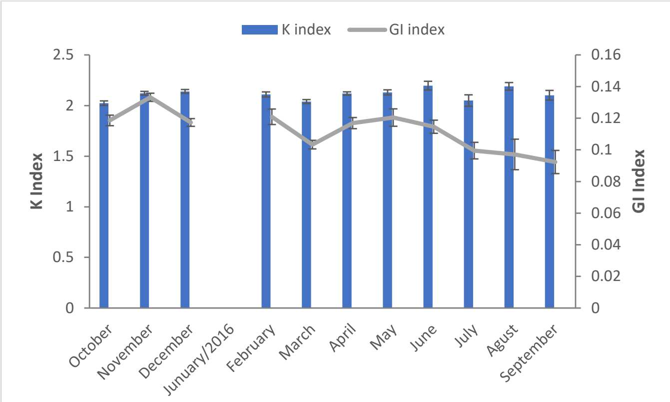

Fig. 5 GI and K Mean±SE indices of *Coptodon zillii* in Shadegan wetland

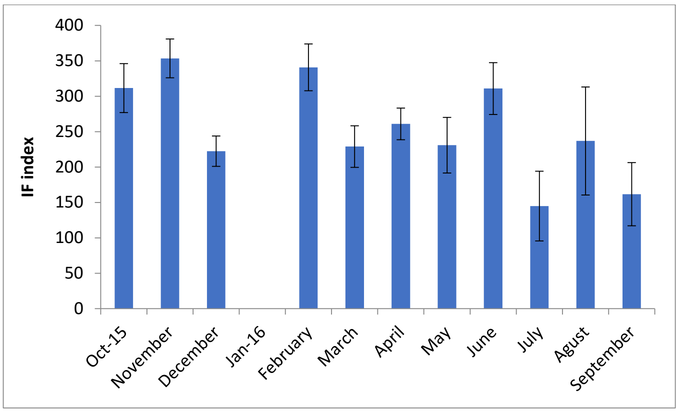

Fig. 6 IF Mean±SE index of *Coptodon zillii* in Shadegan wetland

region. Also, the highest food intensity index was 353.40 ± 27.39 in November, and the lowest was 144.83 ± 49.21 in July (Fig. 6). Its value in different months of the study was, on average, less than 400. This index during the year and months showed no significant difference ($P \leq 0.05$).

The results of calculating HSI index showed that the highest HSI index was 2.37 ± 0.26 in February and the lowest was 1.27±0.12 in June. Moreover, the highest GSI index for the female *C. zillii* was 3.64±0.50 in March, and the lowest was 0.33±0.07 in November. The highest absolute fecundity index for *C. zillii* was 80993.42±28528 eggs in June, and the lowest value of this index was 4849.99±1710 eggs in September. Also, the highest relative fecundity index was 1315.26±379 in July, and the lowest was 78.86±28 eggs per gram of female somatic weight (Table 1). Regarding the sex ratio, the study results showed that among 355 specimens, 115 fish were female, and 220 fish were male. The sex ratio of females to males in the one-year study period was generally 1:2. In most of the year, the number of males in this species was more than females except in May.

Discussion

The biologic and ecologic knowledge of ecosystems forms the essential core of fishery and aquaculture management (Lampert and Sommer 2007). *C. zillii* is, known as an aggressive and invasive species, has destructive impacts on aquatic ecosystems and native aquacultural species, and because of its high adaptation to the environmental conditions, it usually prevails in competition with the native species (Nico et al. 2020). Therefore, the information obtained about the ecology of this species, including its reproduction, food, environmental conditions, and growth, can be used to recognize and manage the presence of this species and help us find solutions to reduce or control the ecological and aquacultural damages caused by it and many other species.

During the study period, there were no significant fluctuations in the length and weight of the samples,

Table1 Mean ± SE of HSI index, GSI index, Absolute fecundity and Relative fecundity of *Coptodon zillii* in Shadegan wetland during study period.

	HSI index	GSI index	Absolute fecundity	Relative fecundity
October 2015	1.30±0.07	0.52±0.15	48608.31±8294.4	802.13±141
November	1.53±0.06	0.34±0.07	46384.9±7544.5	809.98±100.2
December	1.53±0.09	0.35±0.03	43004.85±7455.3	537.32±81.32
January 2016	-	-	-	-
February	2.37±0.27	1.31±0.7	11814.75±2473.6	144.7±33.73
March	1.35±0.16	0.52±0.07	42502.02±18834	860.51±286.8
April	1.76±0.09	2.31±0.52	27940.2±4404.1	406.22±102.63
May	1.55±0.09	3.64±0.50	43302.79±6364	816.51±111.68
June	1.27±0.12	2.43±0.55	80933.42±28528	1079.46±366.72
July	1.4±0.12	1.7±0.67	64565.67±2155	1315.26±379.72
August	1.4±0.18	0.96±0.42	31018±14776	707.81±370.44
September	1.86±0.07	1.5±0.7	4900±1710.6	78.87±28.86

which is probably due to the use of a steady streamer cast net or because of the fast-growing pattern of *C. zillii*. The relationship between the length and weight of a species has a significant role in assessing fisheries. In this species, the value of parameter b is significantly smaller than 3, so it had negative allometric growth. When a species exhibited a negative allometric growth it's tended to be thinner. This means that, fish become slimmer with increasing length. The analysis of the relationship between the length and weight of *C. zillii* in natural environments has resulted in different reports based on several conditions in various ecosystems over several years. Nehemia et al. (2012) investigated the relationship between the length and weight in *C. zillii* specimens in salty and freshwater. Similar to present study, they concluded that *C. zillii* had negative allometric growth in fresh water and positive allometric growth in saltwater. Nevertheless, Mahomoud et al. (2011) reported the relationship between the length and weight of *C. zillii* as isometric. This difference reported in the different studies is related to seasonal fluctuations, changes in the environmental parameters such as temperature and salinity, the physiological conditions of fish during sampling, gender, food conditions, and fish reproduction stages (Biswas 1993). The study of *C. zillii's* gut and the analysis of its contents showed that in its stomach and, gut there were some species such as macrophytes, fish scale, and fish eggs, zooplankton of Cladocera and Copepoda, and mainly periphytons. This species stomach was so small due to the vegetarian diet and mostly empty, but the gut was longer than the body length and, if filled, was full of macrophytes and plant fiber.

According to results, *Coptodon zillii* was mostly benthic-feeder. This fish fed on macrophytes, vegetation, and periphytons in the substrate of Shadegan Wetland. Khalfeh Nilsaz et al. (2013) identified the genus of epipleon algae in Shadegan Wetland. The genera identified in Khalfah's study covered the genera identified in the gut of *C. zillii* in the present study.

Moreover, the RLG index showed a vegetarian species. However, the fish scale and eggs, Copepoda and Cladocera were continuously observed in all the monthly samples as secondary food, seems, *C. zillii* fed on a vegetarian diet and, to a lesser extent, on some animal sources.

In the study on *C. zillii* food habits in Ethiopian Ziway Lake, Dadebo et al. (2014) observed that phytoplankton, detritus, and insects were important fish food items for young. While macrophytes, detritus, and phytoplankton were important food items for adults. The importance of phytoplankton, detritus, and insects reduced with the size of tilapia. But the importance of macrophytes and nematodes increased with the fish size. Based on the analysis of the contents of the stomach and gut, it was concluded that the food of the vegetarian species was mainly macrophyte, detritus, and phytoplankton, and the share of animal-derived food was low. In a study on *C. zillii* food habits in the Otamiri River of Nigeria, Agbabiaka (2012) reported this species as omnivorous species with a dietary priority for algae, plant, detritus, and larvae of Chaeoborus and *Chironomus albidus* when matured and young. Also, in another study in Zwai Lake, the diet of *C. zillii* consisted of macrophytes and phytoplankton when it was mature and phytoplankton, detritus, and *Chironomus albidus* larvae when it was young (Gonzalez Acosta et al. 2004).

The *gastro-somatic* index indicates fish food intensity. The trend of changes in the *gastro-somatic* index during the study period had three peaks observed in November, February, and April during the reproduction months, which is consistent with the reproduction peaks of this species. Also, the highest condition index for *C. zillii* was in May, and the lowest was in October. The value of this index was always more than 0.5%. And the condition of this species was good in terms of being fat. Because this species tended to be vegetarian and the wetland was rich in food intensity. Moreover, this invasive species had the right tools to win a food competition with the native species (Tabasian et al. 2021). Nehemia et al. (2012) reported that the condition index for *C. zillii* was 0.74 in saline waters and 2.07 in freshwater. Dadzie and Wangila (1980) obtained the condition index for *C. zillii* and reported it to be 1.01. In general, some factors affect the changes in the status of this species. These factors are including the environmental conditions and fluctuations, fish physiological conditions at the time of sampling, age, sex, stomach fullness, the maturity of the fish, and its food status (Negassa and Prabu 2008). The condition index is used to compare the quality of fish in terms of being fat or fit and, in general, to determine the population's health status.

The gut vacuity index estimates the fish fullness. The highest value of the CV index for *C. zillii* was synchronized by the peak of reproduction activity. Lack of appropriate food, sudden changes in the environmental factors such as temperature, the instability of environmental factors, catching before intake, and high rates of intra-species competition could affect the CV index (King 2007).

The food intensity index indicates food intake by fish. In the present study, the value of the food intensity index in different months was always below 400, which presented a lack of optimum food in this period. However, the K and CV indicators confirmed the species' good condition, and many fish samples showed a value above 400. The food and vegetation values were also good. It can be assumed that the food condition of this period was not so bad.

Determination of GSI and HSI indices can lead to the accurate diagnosis of ovulation, vitellogenesis, and reproduction schedules, which play an important role in fishery decision-making (Bartulovic et al. 2004). GSI and HSI indices were calculated only for the female sample fish. The highest HSI index for *C. zillii* was observed in February, March, and August, respectively. The highest GSI index was observed in April, February, May, and September, respectively. The peak points in these two indices were almost identical, indicating three reproduction periods for this species. *C. zillii* can reach maturity over one to three months, with several reproduction periods throughout the year (AL-Zaidy 2013). The highest GSI and HSI values in February indicated intense vitellogenesis. The process of vitellogenesis needs lots of glycoproteins, and the food should be rich. The maximum length and weight for this species were observed in February, which confirms the high growth of this fish this month. Length and weight are two important growth indices. And, when these two parameters increasing synchronous, it is indicating an obvious increasing in growth. The high GSI index in May (with maximum temperature in study period) and its decrease in June indicates spawning time, because of releasing gametes into water, and gonads showed losing weight. generally, the most important factor affecting spawning is the temperature (Biswas 1993), so the spawning peak was observed in the warmest months of the year.

Oso et al. (2013) reported a significant gonadosomatic index, 0.19 to 2.08, for *C. zillii.* Negassa and Prabu (2008), due to the fluctuations of the GSI index over the study period, concluded that *C. zillii* had two peaks from March to May and May to October. Ishikawa and Tachihara (2008) reported *C. zillii* reproduction season from June to September, with a maximum in May and June, at a temperature of 22.5-31.5 °C. Minor differences in the spawning season can be related to the differences in habitat or weather conditions, the average temperature of the regions, or differences in the years.

In the present study, in general, the male-to-female sex ratio for *C. zillii* was 1:2 during the one-year study period. In all months, except May, the number of males was more than that of females, and in February, males and females were almost equal. Different male-to-female sex ratios have been reported for *C. zillii,* include 1: 3 (Bulut et al. 2012), 1: 1.05 (EL-Sayed and Moharram 2007), and 1: 0.97 (El-Sayed 2006). In February, May, and September, the GSI and HSI indices were also the highest during this study. Thus, these months can be considered as the reproduction season for this species in Shadegan Wetland. During the study period, the absolute and relative fecundity in October, February, and May was more than the previous and the following months, with a month delay of changes and the GSI peak points. Fecundity was recorded at 50-3178 eggs per body weight. El-Sayed and Moharram (2007) reported a mean fecundity of 2138 eggs per cm of body length and 2464 fish eggs per gram of body weight for the female fish. Dadzie and Wangila (1980) obtained a mean fecundity of 2359 for *C. zillii.* These differences can be related to climatic, geographical, and genetic differences and environmental factors such as population density, food, and changes in the temperature (Wootton 1992). Also, the mean fecundity achieved can be different from one year to another in a population. This is why stock assessment studies and dynamics of fishery populations should be done continuously. Changes in such indicators determine the health status of stocks and population size over time, and it is important to understand the trend of these changes in fisheries decisions.

To sum up, *C. zillii* has several reproduction cycles with high fecundity. For this reason, it has a high survival chance. Such species have a high feeding intake, so it acts as a potent food competitor to other species. *C. zillii* is mostly herbivore but feeds on a wide range of food items, includes animal and vegetable sources. All these characteristics allow this species to enter every water system, turn it into a favored species in the ecosystem, and potentially affect its survival rate. If there is no proper monitoring of the distribution and control of the population, what happened in Shadegan wetland will be repeated in other water systems in the region. It seems that *C. zillii has* successfully inhabited Shadegan Wetland. Due to the favorite food and reproduction conditions of this wetland and its relatively good ecological conditions. To decrease the consequence of the presence of this species, more management or control on this species populations must be considered by practical aquaculturists and decision-makers, before being a serious treat for invaluable fisheries ecosystems such as Shadegan wetland or aquaculture farms.

List of abbreviations RLG: relative length of the gut; GI: Gastro-somatic index; K: living conditions of the fish; CV: gut index; IF: index of fullness; FOI: frequency of the occurrence index; HSI: Hepatosomatic Index; GSI: Gonadosomatic index.

Conflict of interest The authors declare that they have no conflict of interest.

Acknowledgements The authors gratefully acknowledge the Khorramshahr University of Marine Science and Technology for their financial support for this research project.

References

Abbasi K, Noruzi H, Sayad Rahim M, Zahmatkesh Y, Sabzi M, Sedaghat Kish A, NiKseresht K, Rohani A, Sarpanah A, Ramezani R, Sadeghi Nejad A, Abdoli A, Komad B (2009) Final report of native fish of Hamedan province. Hamedan Province Fisheries Management Publication

Agbabiaka LA (2012) Food and feeding habits of *Tilapia zilli* (Pisces: Cichlidae) in river Otamiri South-eastern, Nigeria. Biosci Discovery 3:46-148

Akel EHKH, Moharram SG (2007) Reproductive biology of *Tilapia zillii* (Gerv, 1848) from Abu Qir bay, Egypt. Egypt J Aqua Res 33:379-394

Al-Faisal A, Mutlak F (2014) First record of the Nile tilapia *Oreochromis niloticus* (Linnaeus, 1758) from the Shatt Al-Arab River, Southern Iraq. Mesopotamian J Mar Sci 29:45 – 50

Alkahem HF, Al-Ghanim AA, Ahmad Z (2007) Studies on feeding ecology of sailfin molly *(Poecilia latipinnd)* dwelling in Wadi Haneefah Stream, Riyadh. Pak J Biol Sci 10:335-341. doi:10.3923/pjbs.2007.335.341

Al-Zaidy KJ (2013) First record of *Tilapia zilli* (GEWAIS, 1848) in AL-Delmj marsh weast AL-Diwania city middle of Iraq. Diyala Agricul Sci J 5:9–16

Ayoade AA, Ikulala AOO (2007) Length weight relationship, condition factor and stomach contents of *Hemichromis bimaculatus*, *Sarotherodon melanotheron* and *Chromidotilapia guentheri* (Perciformes: Cichlidae) in Eleiyele Lake, Southwestern Nigeria. Revista de Biología Tropical (Int J Trop Biol Conserv) 55:969-977

Bartulovic V, Glamuzina B, Conides A, Dulcic J, Lucic D, Njire J, Kozul V (2004) Age, growth, mortality and sex ratio of sand smelt, *Atherina boyeri* Risso, 1810 (Pisces, Atherinidae) in the estuary of the Mala Neretva River (middleeastern Adriatic, Croatia). J Appl Ichthyol 20:427-430. doi.org/10.1111/j.1439-0426.2004.00560.x

Biswas SP (1993) Manual of methods in fish biology. South Asian publishers VTLtd New Delhi

Bulut S, Mert R, Konuk M, Algan B, Alaş A, Solak K (2012) The variation of several biological characteristics of the chub, *Squalius cephalus* (L., 1758) in the Orenler Dam Lake, Northwest Anatolia, Turkey. Not Sci Biol 4:27-32. doi.org/10.15835/nsb437674

Chihara M, Murano M (1997) An illustrated guide to marine plankton in Japan. Tokai University Press, Tokyo, 1574 pp

Clarke SA, Vilizzi L, Lee L, Wood LE, Cowie WJ, Burt JA, Mamiit RJ, Ali H, Davison PI, Fenwick GV, Harmer R, Skóra M, Kozic S, Aislabie LR, Kennerley A, Le Quesne W, Copp GH, Stebbing PD (2020) Identifying potentially invasive non-native marine and brackish water species for the Arabian Gulf and Sea of Oman. Glob Chang Biol 26:2081-2092

Dadebo E, Kebtineh N, Sorsa S, Balkew K (2014) Food and feeding habits of the red-belly tilapia (*Tilapia zillii* Gervais, 1848) (Pisces: Cichlidae) in Lake Ziway, Ethiopia. Agricul For Fish:3:17-23. doi: 10.11648/j.aff.20140301.14

Dadzie S, Wangila BCC (1980) Reproductive biology, length-weight relationship and relative condition of pond raised *Tilapia zilli* (Gervais). J Fish Biol 17:243-253. doi.org/10.1111/j.1095-8649.1980. tb02758.x

El-Sayed A F M (2006) Tilapia culture. CABI Publishing, Wallingford OX 108. DE, UK. 273 pp

EL-Sayed H, Moharram SG (2007) Reproductive biology of *Tillapia zilli* (Gerv, 1848) from Abu Qir Bay, Egypt. Egypt J Aqua Res 33:379-394

Ghofleh Maramazi J, Mayahi Y, Kuchaknejad A (2014) Unwanted presence *Tillapia zilli* in water resource of Khuzestan province. The first Tilapia National Conference. Yazd- Bafgh

Gonzalez Acosta AF, De la Cruz G, De La Cruz Agüero J (2004) Length–weight relationships of fish species caught in a mangrove swamp in the Gulf of California (Mexico). J Appl Ichthyol 20:154 –155. doi.org/10.1046/*j*.1439-0426.2003.00518.x

Hyslop EJ (1980) Stomach content analysis — a review of methods and their application. J Fish Biol 17:411–429. doi:10.1111/j.

1095-8649.1980.tb02775.x
Ishikawa T, Tachihara K (2008) Age, growth and maturation of the redbelly tilapia *Tilapia zillii* introduced into the Haebaru Reservoiron Okinawa-jima Island. Fish Sci 74:527–532. doi:10.1111/j.1444-2906.2008.01555.x
Keller RP, Lodge DM (2009) Invasive species. University of Notre Dame, Notre Dame, IN, USA 2009 Elsevier Inc
Khaefi R, Esmaeili HR, Zareian H, Babaei S (2014) The first record of the redbelly tilapia, *Tilapia zillii* Gervais, 1848 in freshwaters of Iran. Turk J Zoo 38:96-98. doi.10.3906/zoo-1304-3
Khalfeh Nilsaz M, Khodadadi M, Dehghan Madiseh S, Mohammadi G (2013) Epipleon algae identification and study abundance of Shadegan wetland. Wetland Ecobio 5:41-52
King RP (1997) Fecundity of Tilapia marine in small tropical stream. Ph.D. Thesis. University of Port Harcourt, Port Harcourt, Rivers State, Nigeria
King M (2007) Fisheries biology, assessment and management (2ed ed.) Blackwell Scientific Publications, Oxford, 382 pp
Kumar R, Sharma BK, Sharma LL (2007) Food and feeding habits of *catla catla* (Hamilton- Buchanan) from daya reservoir, Udaipur, rajasthan. Indian J Anim Res 41:266-269
Lampert W, Sommer U (2007) Limnoecology (2ed ed.) Published in the United States by Oxford University Press Inc., New York, 324 pp
Mahomoud WFA, Amin AMM, Elboray KF, Ramadan AM, EL-Halfawy MMKO (2011) Reproductive biology and some observation on the age, growth, and management of *Tilapia zilli* (Gerv, 1848) from Lake Timsah, Egypt. Int J Fish Aquacul 3:16-26. doi. 10.1016/j.ecss.2016.03.007
Negassa A, Prabu PC (2008) Abundance, food habits, and breeding season of exotic *Tilapia zillii* and native *Oreochromis niloticus* L. fish species in Lake Zwai, Ethiopia. Maejo Int J Sci Technol 2:345-360
Nehemia A, Justin DM, Rumisha C (2012) Length-Weight relationship and condition factor of tilapia species grown in marine and fresh water ponds. Agric Biol J North America 3117-124. doi:10.5251/abjna.2012.3.3.117.124
Nico L, Neilson M, Loftus B (2020) *Tilapia zill*ii (Gervais, 1848) U.S. Geological Survey, Nonindigenous Aquatic Species Database, Gainesville, FL
Oso JA, Ogunleye OA, Idowu EO, Majolagbe FA (2013) Gonado-somatic index, sex ratio and fecundity of *Tilapia zilli* in a tropical reservoir, South West Nigeria. J Biol 2:42-45
Roozbehfar R, Dehestani-Esfandabadi M, Roozbehfar S (2014) First record of the redbelly tilapia, (*Tilapia zillii* Gervais, 1848) in Iran. J Appl Ichthyol 30:1-2. doi:10.1111/jai.12469
Tabasian H, Abdoli A, Valikhani H, Khosravi M, Dehghan Madiseh S (2021) An investigation into socio-economic impacts of invasive redbelly tilapia *Coptodon zillii* (Gervais, 1848) A case study from the Shadegan Wetland, Iran, Scientific Reports in Life Sciences 2:25-38. doi: http://dx.doi.org/10.22034/srls.2021.245823
Valikhani H, Abdoli A, HassanzadehKiabi B, Nejat F, Sadeghsaba M, Khosravi M (2018) A study on the status of invasive Tilapia species (*Coptodon zillii* Gervais, 1848 and Oreochromis aureus (Steindachner, 1864) in aquatic ecosystems of Khuzestan province, Iran. Envi Sci 15:29-44
Venkatra M, Ramanatham N (1994) Manual of fish biology. Published by raju primlani oxford. New Delhi, Bombay, 820 pp
Wootton RJ (1992) Fish ecology. Blackies and Sons Ltd. New York, 203 pp

Publisher's Note
IAU remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.