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Research Article

The reproductive biology of the invasive redbelly tilapia, *Coptodon zillii*, case study: Shadegan wetland, Iran

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Abstract

Reproductive aspects and length-weight relationship were measured for the redbelly tilapia, *Coptodon zillii* in the Shadegan International Wetland, southwest of Iran. A total of 1161 specimens (520 males and 641 females) were collected from the wetland during the period from September 2015 to August 2016. Results showed that the fish's mean length ranged from 5.2- 24cm while the mean weight ranged from 11-265g. The species indicated a positive isometric growth pattern with a 'b' value of 2.90 and 2.95 for the males and females, respectively. The overall sex ratio (M/F) was 1:0.81. Adult females had an average of 180.5 eggs per cm of length. The result of the gonadosomatic index analysis showed that the period from April to September may be representing the spawning period of *C. zillii*. Finally, the long period of spawning shows an effective factor in the reproduction of *C. zillii* in the wetland, causing a high abundance of the species.

Keywords: Fecundity, Exotic fish, gonadosomatic index, Biological invasions

Introduction

Tilapia is the common name for nearly a hundred species of Cichlids which have been widely introduced worldwide. The species is a substrate spawner fish of the Tilapiine cichlid tribe, native to Africa and the Jordan system. It is currently reported in more than 56 countries either as native or introduced fish. Tilapia inhabits a variety of freshwater habitats including shallow streams, ponds, rivers, and lakes. Historically they have been of major importance in artisan fishing in Africa and are of increasing importance in aquaculture (Anene and Okorie 2008). Among the species, the redbelly tilapia, *Coptodon zillii* (Gervais, 1848) and blue tilapia, *Oreochromis aureus* (Steindachner, 1864) have been introduced to the natural water bodies of Khuzestan Province, southwest Iran (Khaefi et al. 2014, Roozbhfar et al. 2014, Valikhani et al. 2016). The species have likely been introduced accidentally to the Iranian water bodies via water connections with Iraq and *C. zillii* has a high abundance in one of the aquatic ecosystems that have international importance, the Shadegan Wetland (Valikhani et al. 2018), however, the species had not been reported from the wetland in previous years (Hashemi et al. 2015).

Unfortunately, there is limited information on different biological aspects of *C. zillii* such as reproductive characteristics in Iran. Understanding the population dynamics and life cycle of the target species is the foundation for successful invasive species management (Pasko and Goldberg 2014). As the success of *C. zillii* is remarkable because of its reproductive characteristics (Crutchfield et al. 1992), the reproductive ability of the species was studied in the Shadegan Wetland, which is the largest wetland of Iran and the 34th wetland registered in the Ramsar List and has ecological values, the importance of cultural exchange and high capability in attracting tourists (Kholfenilsaz et al. 2009). The paper aims at generating some information on the fecundity of *Tilapia zilli* to come
up with the management approach of the species in the reservoir.

Materials and methods

Study Area

The sampling was carried out by using gillnets with 1.8-4.2cm mesh size in the Shadegan Wetland from September 2015 to August 2016. The wetland is located at 30°20'N and 48°20'E, in the southwestern part of Iran in Khuzestan province, surrounded by cities such as Shadegan, Abadan, and Mahshahr (Fig. 1).

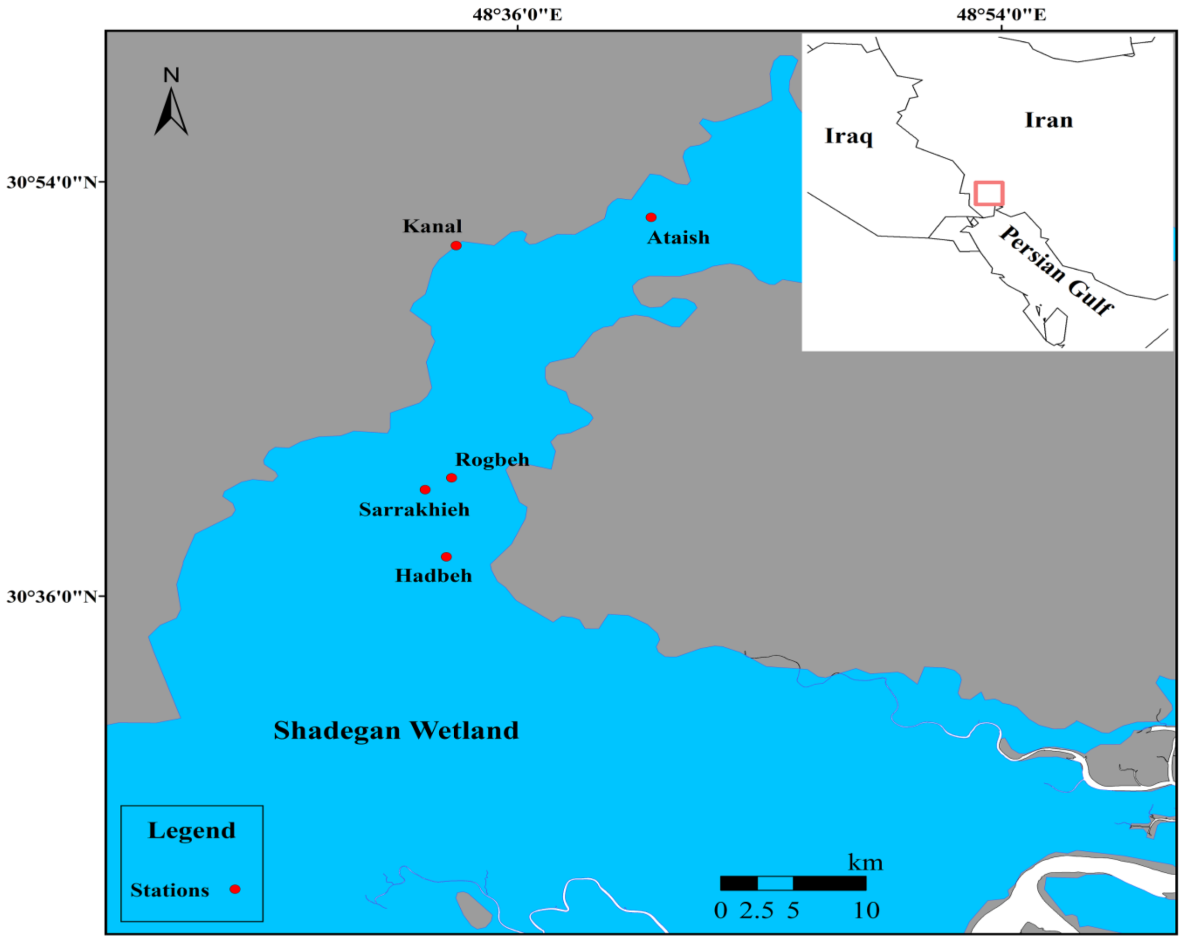

Fig.1. The coordinates of the sampling areas in the Shadegan Wetland, southwest Iran.

Length-Weight Relationship

The specimens were preserved in dried ice and were transferred to the laboratory in the South of Iran aquaculture fishery research center in Ahwaz. The total length (TL) and standard length (SL) collected specimens were measured with an accuracy of 0.1 mm using a measuring. The total wet body and gonad weight was also measured with an accuracy of 0.01g using an electronic balance scale. The length-weight relationship of the specimens was determined by using the formula:

$W=a\ L^b$ (Thomas et al. 2003)

Where:

W=weight of each fish specimen (g), L=total length of each fish, a=regression intercept, b=regression coefficient

The relationship was transformed into logarithmic form as:

LogW=loga±b (logL) (Anene and Okorie 2008).

Reproductive measurements

In the laboratory, each specimen was dissected and the gonads were removed and weighed immediately. Male and female sexes were identified based on the gonad morphologies. The gonad was expressed as a percentage of the Gonadosomatic Index (GSI). The GSI indicates the maturation of genital products in fish and shows the period
and annual spawning cycle (Khalaf and Authman,2010).

The relationship is calculated using this formula:

$$GSI = GW / TW \times 100$$

Where:

GSI = Gonado-Somatic Index, GW = Gonad weight (g), TW = Fish weight (g)
(Worthington & Richardo, 1930)

45 full mature and ripe ovaries in the whole period of the present study were collected and fixed in 5% formalin (Aydın.2011). Determination of maturity stages was followed by Nikolsky (1963). Absolute fecundity (F) was calculated as the number of mature eggs per fish before the spawning season. However, *C. zillii* is a multiple-spawning species (Rana 1988), thus, it may have been over-estimated fecundity due to the use of ovarian counts of maturing oocytes rather than direct counts of the number of eggs oviposited (Rana 1988, Coward and Bromage 1999). Therefore, It is better to use the batch fecundity in multiple spawning fishes.

To obtain representative samples of the whole gonads, small portions were taken from the posterior, middle, and anterior regions of the ovary. These samples were weighed and the number of mature eggs was determined. The total number of mature eggs in the ovary was estimated by multiplying the number of mature eggs in the sample by the ratio of the ovary weight to the sample weight (El-Kasheif et al. 2013).

$$F = \frac{\text{No. of mature eggs in a sample} \times \text{weight of ovary}}{\text{weight of sample}}$$

In the present study relative fecundity was calculated as the average number of eggs per female fish length. Also, relative fecundity estimates as the following formula:

$$R = F/TW$$

Where R=relative fecundity F=absolute fecundity TW=total length (cm)

Statistical Analysis

Data obtained were subjected to the Analysis of Variance (ANOVA) test and the means from the various treatments were compared for significant differences ($P<0.05$). The data was analyzed using SPSS (version 23) and the graphs were plotted with MS-Excel 2010. The image file and fish location coordinates were imported into ArcMap 10.2 for mapping the study area.

Results

Length-Weight Relationship

A total of 1161 *C. zillii* individuals (520 males and 641 females) were surveyed during the study period. The range of total length (TL), and body weight (W) of females and males are shown in Table 1. The total length and weight of the specimens ranged from 5.2-24cm and 11-265g, respectively (Table 1).

Table 1. Biometric parameters in males and females of *Coptodon zillii* in the Shadegan Wetland from September 2015 to August 2016.

Sex	Parameters	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
M	Mean (W) ±Sd (g)	108±13.48	78.05±16.53	78.13±16.05	111±23.08	111.41±17.92	93.31±14.72	74.19±19	72.88±18.45	74.36±26.6	100±14.5	83±18.33	86±19
	Mean (TL) ±Sd (cm)	17.42±2.90	15.47±2.25	15±2.16	18±1.57	17.91±2.73	16.1±2	14.9±2.23	15.5±1.88	15.3±1.24	16.7±1.37	16.8±1.07	15.7±2.23
F	Mean (W) ±Sd (g)	67.17±14.53	68.47±18.81	78.81±21.14	60.27±1.67	52.12±18.45	68.47±14.23	58.95±18.5	65.79±18.5	61±19.01	74.36±15.16	67.97±18.53	64.35±18.6
	Mean (TL) ±Sd (cm)	14.91±2.82	15.01±2.21	14.8±2.35	14.3±22.11	13.5±2.32	14.8±1.52	13.9±1.87	14.7±1.56	14.3±1.43	15.02±2.20	14.5±1.85	13.7±2.05

The regression analysis of weight on length gave the following equations:

$W=0/002\ L^{2.90}$ (r=0.84, P<0.05, n=641) and $W=0/002\ L^{2.95}$ (r=0.95, P<0.05, n=520) for the females and of *C. zillii*, respectively (Fig. 2 and 3).

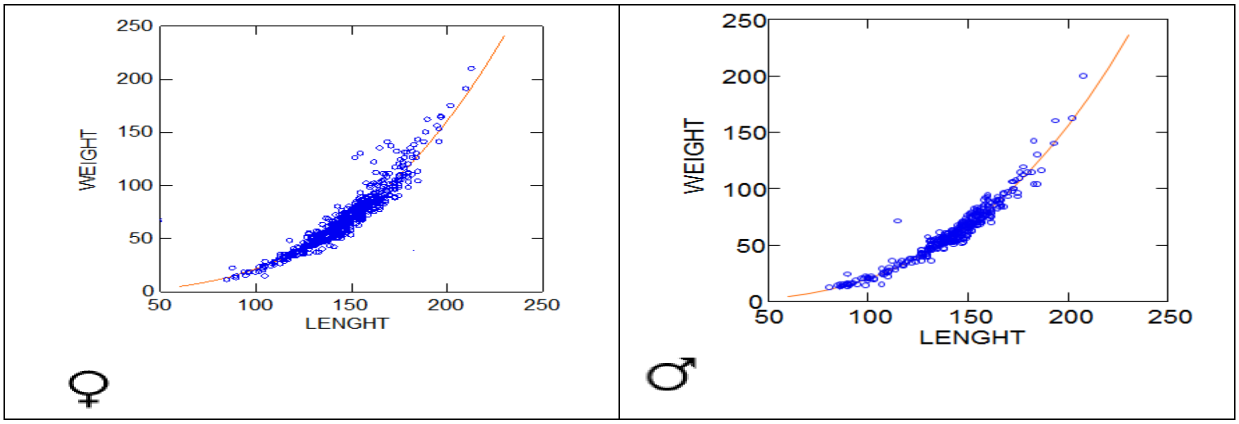

Figure 2. Length-Weight Relationship in *Coptodon zillii* in the Shadegan Wetland.

Sex ratio

The overall sex ratio of males to females was 1:0.81. The occurrence of females was relatively higher than males in autumn (57%), winter (58%), summer (52%), and spring (54%). also for females, the sex ratio was found to occur in higher percentages in winter (58%). The chi-square test (X^2) showed significant seasonal differences between both sexes (P< 0.05) (Table 2).

Table 2. Seasonal variation in the sex ratio for males and females of *Coptodon zillii* in the Shadegan Wetland.

Season	Males		Females		Chi-square	Sex-ratio M/F
	No.	%	No.	%		
Autumn	111	0.42	151	0.57	1.43	1:0.74
Winter	82	0.42	112	0.58	1.66	1:0.64
Spring	157	0.45	191	0.54	1.17	1:0.82
Summer	170	0.48	187	0.52	1.07	1:0.91
Total	520	0.44	641	0.55	0.85	1:0.81
X^2=0.85 P<0.05						

Length-fecundity relationship

The absolute and relative fecundity of *C. zillii* has been shown in Table 3. It was evident from the table that the calculated absolute fecundity for *C. zillii* ranged from 1252 to 4360 eggs with a mean of 2524±113 for the specimens of a size range of 11 to 16cm (TL). Also, it could be detected that the relative fecundity had the same trend of increase from 114 to 272 eggs per length unit with a mean of

180±57. The relationship between total length and fecundity (absolute and relative) was positive (Fig.4) and found to be curvilinear and represented by the following equation:

LogF=0.43+1.22logL (r=0.94, P=0<0.05)

Table 3. Absolute and relative fecundity of *Coptodon zillii* in the Shadegan Wetland

Total length (cm)	Number of fish	Absolute fecundity Mean±Sd	Relative fecundity Mean±Sd
11	3	1252 ±39.02	114±18.04
12	5	1611±25.54	134±12.1
13	9	2119±38.66	163±15.9
14	11	2571±31.96	184±13.65
15	8	3236±26.23	216±14.9
16	9	4358±36.4	272±12

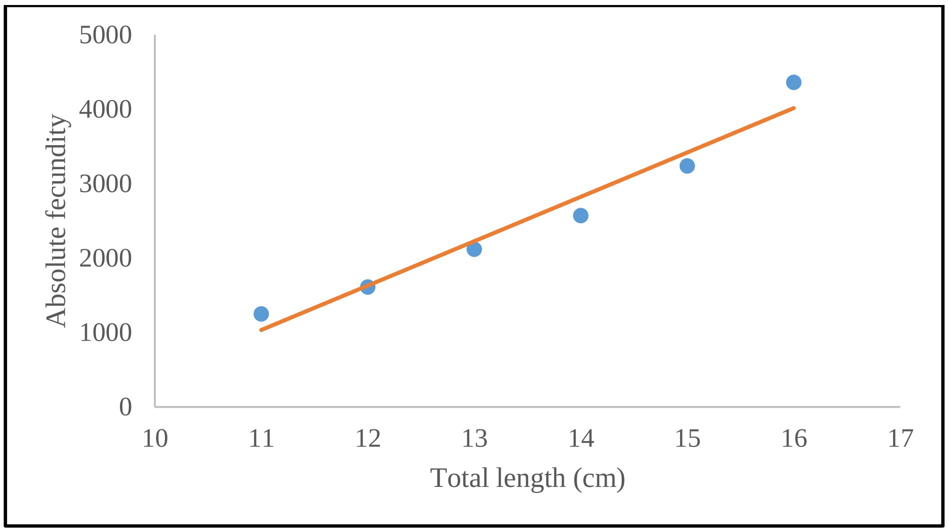

Figure 4. The length-fecundity relationship in *Coptodon zillii* in the Shadegan Wetland.

Gonadosomatic Index (GSI)

Monthly changes in the GSI revealed that both sexes followed nearly the same pattern. The GSI showed higher values during the spring and summer season with a peak in April, while the lower values occurred during the period from October to February (Table 4). So, the period from April-September may be representing the reproductive period of *C. zillii*. It should be noticed that the females acquired higher GSI values than the males (Fig. 5).

Table 4. Mean gonadosomatic index (GSI) for the males and females of *Coptodon zillii* in the Shadegan Wetland from September 2015 to August 2016.

Parameters	Mean Gonad weight	Mean GSI±SD	Mean Gonad weight	mean GSI±SD
Sex	F		M	
Oct	0.83	1.23±0.28	0.57	0.53±0.25
Nov	0.45	0.66±0.67	0.26	0.33±0.14
Dec	0.60	0.76±0.71	0.26	0.34±0.41
Jan	0.15	0.23±0.14	0.11	0.1±0.16
Feb	0.25	0.48±0.36	0.36	0.32±0.66
Mar	0.56	0.82±0.27	0.21	0.23±1.99
Apr	0.90	3.23±0.36	0.56	0.76±2.72
May	1.83	2.79±0.93	0.47	0.64±1.97
Jun	1.54	2.53±0.66	0.40	0.54±1.61
Jul	2.13	2.87±0.25	0.68	0.68±2.04
Aug	1.33	1.96±0.36	0.46	0.56±1.12
Sep	1.10	1.71±0.03	0.39	0.46±0.88

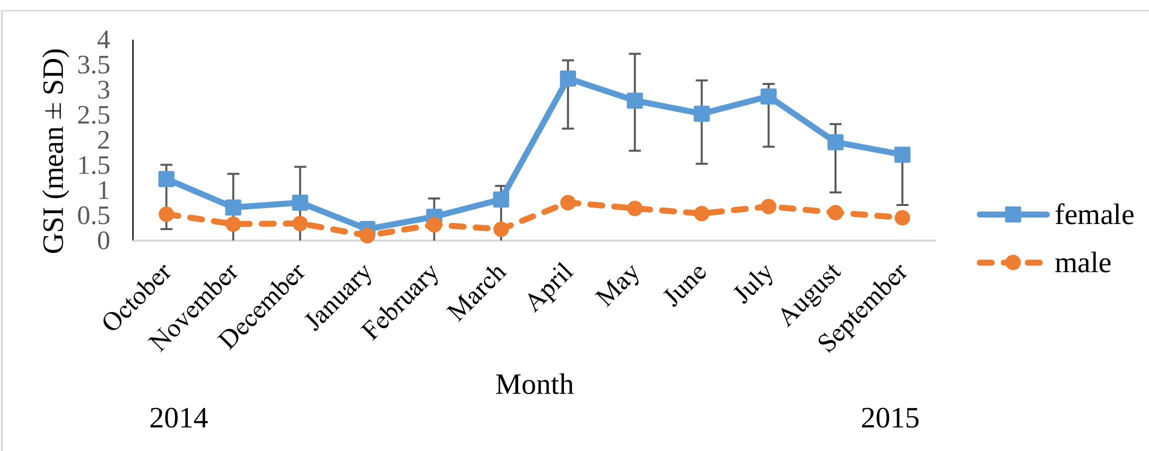

Figure 5. Monthly changes in the gonadosomatic index (GSI) for males and females of *Coptodon zillii* in the Shadegan Wetland from September 2015 to August 2016.

Discussion

The statistical test of the relationship between length and weight is significant, so it is an allometric growth, evidence that the fish becomes heavier for its length as it grows (Oniye et al. 2006). Isometric growth is associated with no change in body shape as an organism grows (Nehemia et al. 2012). Valikhani et al. (2020) reported an isometric growth for the juveniles of the species in the Shadegan Wetland.

The overall sex ratio of males to females was 1:0.81 in the Shadegan Wetland. The sex ratio is lower than the result of studies by El-Kasheif (2013) 1:0.97, Mahomoud et al. (2011) 1:0.9, Akel and Moharram (2007) 1:1.05, and El-Sawy (2006) 1: 0.97. However, Negassa and Getahum (2003) have reported a 1:0.78 ratio in Lake Zwai.

The highest rate of GSI was in spring and summer and the peak of the index was in April which is in agreement with what Negassa and Padanillay (2008) and Ishikawa and Tachihara (2008) reported. In April, the index for the males and females reaches 0.76 and 3.23 respectively, while the lower ones occur during the period from October to February. Therefore, the period from April to September may be representing the spawning period of *C. zillii*. The long period of spawning during a year has been effective in the success of the reproductive behavior of *C. zillii* in the Shadegan Wetland, causing a high abundance of the species. Fecundity was defined here as the number of mature oocytes in the ovaries during the spawning period, however, *C. zillii* is a multiple-spawning species (Rana, 1988), thus, it may have been a biased estimation of fecundity due to the use of ovarian counts of maturing oocytes rather than direct counts of the number of oviposited eggs (Rana, 1988; Coward & Bromage, 1999). Therefore, the results represent only a fraction of the reproductive potential of the species.

The evolution of parental care in tilapia is associated with an increase in egg size and a corresponding reduction in the number of eggs per clutch (Jegede and Fawole 2011). Mean absolute fecundity (2524±113) was less than the estimate of 3036±157 given for the fish in the Nile River (El-Kasheif 2013) and 3606±280 in laboratory conditions (Coward and Bromage 1999) and more than the Abu Qir Bay (2139±652), Lake Edku (2367±903) (Phillips 1994), and Lake Borollus (2451±782) (El-Haweet 1991). The highest value of fecundity was found in the Bhar Shbeen Canal (4514±2270) (Latif et al. 1986). Rogers (1989) and Wootton (1990) stated that the variation of fecundity within the wide limits of fish of the same length may be due to ecological conditions, genetic factors or the total amount of energy given to the ovary during gonad maturation.

The management of the population of *C. zillii*, as an invasive species, in the introduced waterbodies is problematic. Direct capture is one of the only practical methods of the control of *C. zillii* in much of the area; thus, the development of economic incentives for the catch of *C. zillii* might help the control of the species. The species-selective catch is very effective, especially in winter, before breeding season to minimize the impacts. However, for example, *C. zillii* has winter lethargy but the individuals can be attracted by releasing warm water sources (Ishikawa & Tachihara, 2008). As anglers prefer bigger sizes of *C. zillii*, this may increase the population abundance of the species by higher reproductive and survival rates for the remnants through biological overcompensation (Pasko & Goldberg, 2014). Therefore, it is necessary to also remove juveniles.

Conclusion

Overall, *C. zillii* has been able to reproduce successfully and abundantly in the wetland, so the species has been able to become the predominant fish in this water body within a few years. The species has also been the most abundant among fish caught in the Shadegan Wetland, in the local fish markets (Valikhani et al. 2018). In other areas, this rate has been observed to be fast enough to make it the fourth species abundantly found in North Carolina's reservoir in the third year after its introduction (Costache et al.2011). In recent years, the diversity of problems in the Shadegan International Wetland and their worsening as an aftermath of drought, as well as the presence and impact of invasive fish, such as *C. zillii*, are reaching an alarming level and threatening the integrity of the ecosystem, so, immediate rehabilitation actions are essential.

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