Egyptian Journal of Aquatic Biology & Fisheries
Zoology Department, Faculty of Science,
Ain Shams University, Cairo, Egypt.
ISSN 1110 – 6131
Vol. 25(2): 253 – 265 (2021)
www.ejabf.journals.ekb.eg

Reproductive dynamics of the redbelly tilapia (*Tilapia zillii* Gervais, 1848) in Ayata lake as a Ramsar site in south-eastern Algeria

Guezie Rabie[1*], Matallah Ahlem[1], Sahar F. Mehanna[2]
[1]Laboratory Saharan Bio-Resources, Univ. of Kasdi Merbah Ouargla, 30000 Ouargla, Algeria.
[2]Fisheries Division, National Institute of Oceanography & Fisheries, Egypt.
[*]Corresponding Author: guezi.rabie@gmail.com

ARTICLE INFO
Article History:
Received: March 20, 2021
Accepted: April 9, 2021
Online: April 14, 2021

Keywords:
Tilapia zillii,
Spawning season,
Length at first maturity,
Ramsar site,
Ayata lake,
Algeria.

ABSTRACT

Understanding the reproductive dynamics of a fish species is a fundamental aspect to provide sound scientific advice for fisheries management. So, the aim of this study is to afford some aspects of the reproductive dynamics of *Tilapia zillii* for the first time in a Ramsar site (Ayata Lake), south-eastern Algeria. A total of 470 individuals of *T. zillii* (224 males, 231 females, and 15 undetermined) ranging in size from 3.53 to 23.8 cm TL, were sampled in a Ramsar site (Ayata lake) between November 2018 and November 2019. The overall sex ratio was 0.97:1 males to females which were not significantly different from 1:1. Seasonal sex distribution was in favor of females during autumn, winter, and spring. Macroscopic examination of gonads and monthly follow-up of gonado-somatic index indicated that spawning occurred once a year between March and August with peak activity in June. The length at first maturity (L_{m50}) was estimated at 9.7 cm for females and 8.5 cm for males. The condition factor k indicated a good condition of the individuals that is reflected by an accumulation of reserves.

INTRODUCTION

To understand fish population dynamics, reproductive information, such as the spawning season, the maturation of oocytes, the size at first sexual maturity, gonado-somatic index (GSI), sex ratio, fecundity and recruitment, is crucial. Understanding the reproductive biology of a species is the central aspect of providing sound scientific advice for fisheries management such as minimum legal lengths, closed season and closed area. Reproductive biology also plays an important role in determining productivity and therefore a population's resiliency to exploitation by fisheries or to perturbation caused by other human activities (Mehanna *et al.*, 2012; Al-Kiyuni *et al.*, 2014; Mehanna, 2014; Mehanna *et al.*, 2019). In Algeria, despite the recent updating attempts of freshwater fish species inventory (Bacha and amara, 2007; Kara, 2012; Guezi and Kara, 2015; Guezi *et al*, 2017), efforts are still needed in some geographical areas to construct a database about the fishery status, biology, ecology and dynamics of fish species because most of these data are generally unknown.

Tilapia is the common name of more than 70 fish species belonging to family Cichlidae which undergo under three genera (*Sarotherodon, Oreochromis* and *Tilapia*)

(Meyer, 2002). It is known that family Cichlidae have a high economic significance in tropical inland waters in Africa, and they play important role in the ecology of freshwater bodies (Ikomi & Jessa 2003). *Tilapia zillii* (Gervais, 1848) along with the other tilapias have been the object of considerable research because of its suitability for aquaculture. It can tolerate a wide range of temperature and salinity and can utilize aquatic vegetation. This species has established successfully in the Ayata lake and forming a considerable part of the catch.

Many data are available on the growth, biology and physiology of *Tilapia zilli* in the African countries (El-Zarka, 1956; El-Zarka *et al.*, 1970; Polat, 1998; Dikel *et al*, 2002; Yildirim *et al.*, 2009; Mahmoud *et al.*, 2011; Yildirim and Guro, 2015), but there are very scarce researches on its ecology and biology in Algeria (Zouakh *et al.*, 2005 & 2016; Belarouci, 2005; Chaibi *et al.*, 2012). Despite the importance of *T. zillii* and its widespread occurrence, little information about its reproductive biology and dynamics is available. So, this study was undertaken to provide the basic data on some aspects of the reproduction such as the spawning period, the size at first maturity, gonado-somatic index (GSI), sex ratio and condition factor of *Tilapia zilli* in a Ramsar site (Ayata lake), south-eastern Algeria for the first time.

MATERIALS AND METHODS

1. Study area

Ayata lake, which lies on Oued Righ valley, extends over 155 ha near the National Highway n° 3 to about 6 km after Djamaa direction towards the city of Touggourt. The site is located 150 km West of El Oued city. It has an average altitude of 31 m, delimited by the following geographic coordinates: 33° 29′17″an d 33° 29′48″N-05° 59′10″and 05° 59′37″E (Fig.1). The region has a typical climate of Sahara where the dry season extends throughout the year with annual average temperatures exceeding 25 °C. Rainfall (~2–3 months in winter) is characterized by great irregularity inter-annually and inter-monthly. The coldest month is January (11 °C) and the warmest one is July where temperatures often exceed 47 °C. Sirocco blows frequently in the area and it often creates sandstorms (Guezi et al., 2017). Water temperature is between15.8 and 31 °C and salinity between 8 and 11.5 g/l (Gouasmia *et al.*, 2016).

2. Sampling

Monthly samples of *T. zillii* were collected from the Ayata lake using beach seine of length = 10 m, height = 1 m, and mesh = 4 mm. A total of 470 individuals of *T. zilli* (224 males, 231 females, 15 undetermined) ranging in size from 3.5 to 23.8 cm TL, were sampled from Ayata lake between November 2018 and November 2019. For each specimen, the total length (TL) was measured to the nearest centimeter and both body weight (W) and gutted weight were recorded to the nearest 0.1 g. Sex of each individual fish was detected macroscopically after dissection of specimens. The gonads and liver were removed and weighed to the nearest 0.01 g.

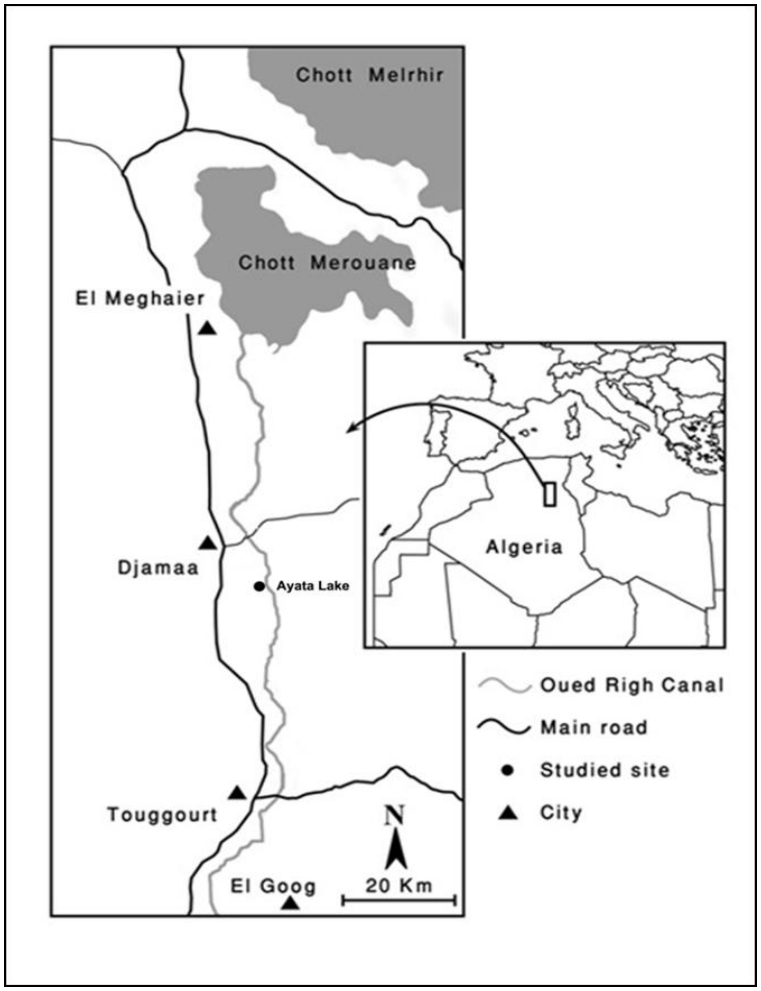


Fig. 1. A map of the Valley of Oued Righ showing the location of Ayata Lake (Guezi *et al*., 2017).

3. Methods

The different aspects of the reproductive dynamics of *T. zillii* were investigated by considering the sex distribution, the spawning season, and the length at first sexual maturity. Overall sex ratio (S/R) was calculated as: S/R = (number of males/number of females). The variations in sex ratio according to different seasons and length groups were analyzed and tested using the $\chi 2$ test (Scherrer 1984).

Gonads were staged after dissection macroscopically according to Orange (1961) and mentioned in Mehanna *et al.* (2019) as follows: Stage I (immature): gonads thread-like, sexes can't be visually determined. Stage II (mature): gonads enlarged, sexes can be easily determined, but ova not visible to naked eye. Stage III (ripe): gonads enlarged occupying about 10% of body cavity, ova visible to naked eye. Stage IV (running): gonads greatly enlarged, ova easily dislodged from follicles or loose in lumen of ovary. Stage V (spent): gonads small containing mature ova as remnants in various stages of resorption.

Gonado-somatic index (GSI) was determined for males and females as:

GSI = Wg*100/Wt, where Wg is the gonad weight in gram and Wt is the eviscerated body weight in gram (Bougis, 1952).

Monthly fluctuations of lipid reserves in the liver were evaluated by monitoring the variations of the hepatosomatic index (HSI) which calculated as: HSI = WL*100/Wt, where WL: liver weight (g) and Wt: gutted weight (g) (Bougis, 1952).

Condition factor K was calculated as K= Wt*100/TL3 (Wt: eviscerated body weight in g, TL: total length in cm) and its monthly variations were analyzed.

Length at maturity was modeled by using a 2-parameter logistic ogive of the form: $PL = 1/1+e^{-(L - L50\%)/\delta}$. Where PL is the percentage of fish mature at length L, L_{50} is the length at first sexual maturity and δ is the steepness of the ogive. The ogive was fitted by minimizing the negative log-likelihood.

4. *Statistical analysis*

Comparison of GSI, HSI and K values between months were carried out by analysis of variance (ANOVA) completed by Newman-Keuls. The overall sex-ratio was tested monthly using chi-square test χ^2 (Dagnélie, 1975). Statistical analyses were performed with Xlstat_Pro_7.5 software.

RESULTS

1. Sex ratio

The overall sex-ratio is 0.97:1 males to females (231 females, 224 males) and is in favor of females. Females dominated significantly in April and May with a value of χ^2 (1.6; 0.92). Males were the most abundant in July with a value of χ^2 (0.15) (Table 1). Sex distribution by season (Table 2) reveals a clear dominance of males during summer (spawning period), with a maximum value (55%; χ^2 = 0.84) and presents a well-balanced sex during winter and spring.

Table 1. Number of males and females in monthly samples of Tilapia zillii in Ayata lake

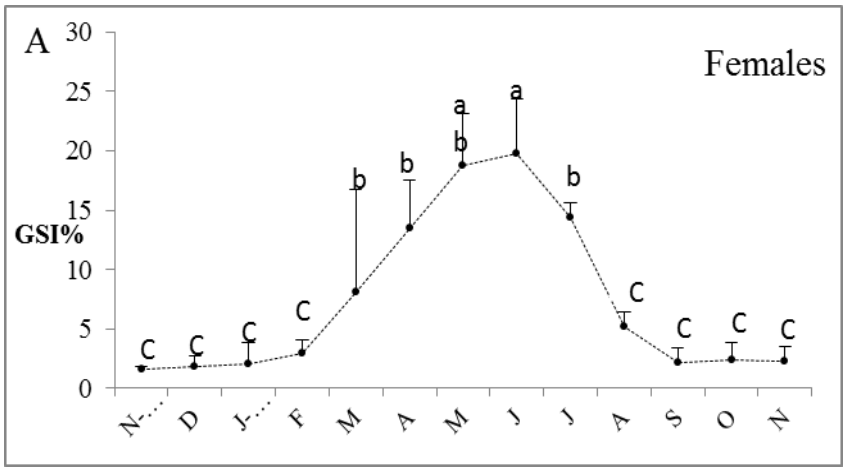
Month	Males	Females	Total No.	X^2 calculated
Nov. 2018	19	19	38	0
Dec. 2018	16	13	29	0.31
Jan. 2019	13	11	24	0.16
Feb.	13	10	23	0.39
Mar.	21	18	39	0.23
Apr.	16	24	40	1.6
May	23	30	53	0.92
Jun.	15	22	17	1.32
Jul.	31	28	59	0.15
Aug.	15	13	28	0.14
Sep.	14	17	23	0.29
Oct.	12	14	55	0.15
Nov.	16	12	27	0.57
Annual	224	231	455	0.1

Table 2. Seasonal sex distribution of *T. zillii* in Ayata lake.

Season	Males (%)	Females (%)	Total No.	X^2calculated
Summer	55.26	44.73	76	0.84
Autumn	45.45	54.54	132	1.09
Winter	49.19	50.8	124	0.03
Spring	49.59	50.4	123	0.008
Annual	49.23	50.76	455	0.1

2. Gonado-somatic index and Maturity stages

In females of *T. zillii*, the monthly variation in gonado-somatic index (GSI) revealed that GSI increased slowly from November to February with recorded values from 1.61 to 2.89. Then, it increases rapidly towards the maximum during June (19.74). After June the GSI sharply decreased to reach its minimum value during September (2.30), which reflected the period of spawning activity (Fig. 2). The evolution of the GSI in males was almost similar to that observed in females (Fig. 2). The maturation phase of gametes was between November and February. The maximum value of the GSI was observed in June; afterwards the values of the GSI began to decrease. The monthly evolution of GSI in the T. zillii populations from Ayata lake indicated a breeding season occurring between March and August, with a peak in June. This result was confirmed by analyzing the evolution of the maturity stages, the ripe gonads were noticed in high percentage during April to August with the highest during June. Females were in sexual rest stage from August to November while the gonad-somatic index remained almost constant (2.30).



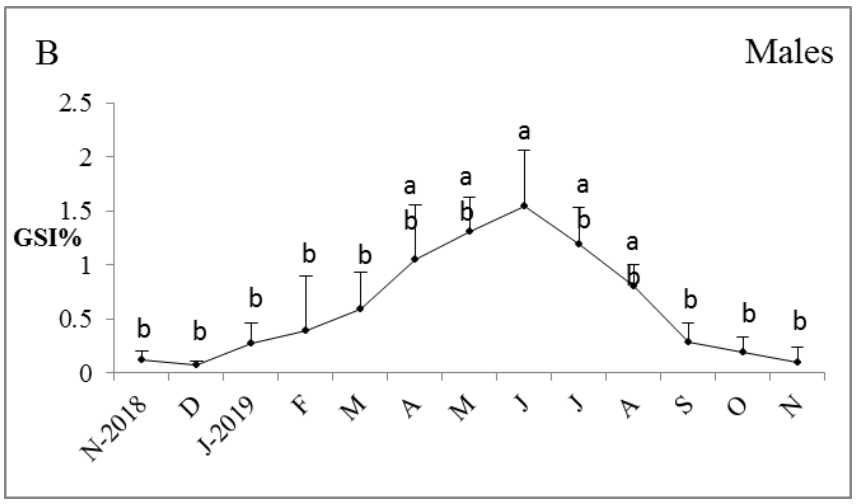


Fig. 2. Monthly variations in the gonado-somatic index (GSI) of *Tilapia zillii* (females and males) in Ayata lake, the different letters indicate significant differences between sampling points. Error bars correspond to standard deviations.

3. Hepatosomatic index HSI

The HSI reached its maximum in July in females (4.50%) and males (3.54%) and attained its minimum in November for both sexes (1.87; 0.46) (Fig. 3).

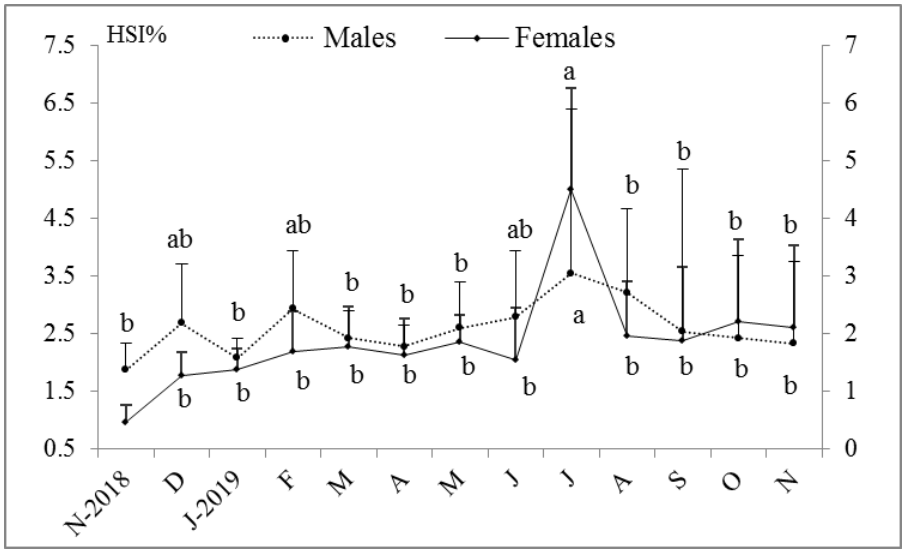


Fig. 3. Monthly variations in the hepatosomatic index (HSI) of *Tilapia zillii* in Ayata Lake (the different letters indicate significant differences between sampling points. Error bars correspond to standard deviations).

4. Condition factor

Monthly variations in the condition coefficient (K) were not perceptible in males (around 1. 75) (Fig. 4). In females, a significant increase occurs between October (2.87) and November (3.04).

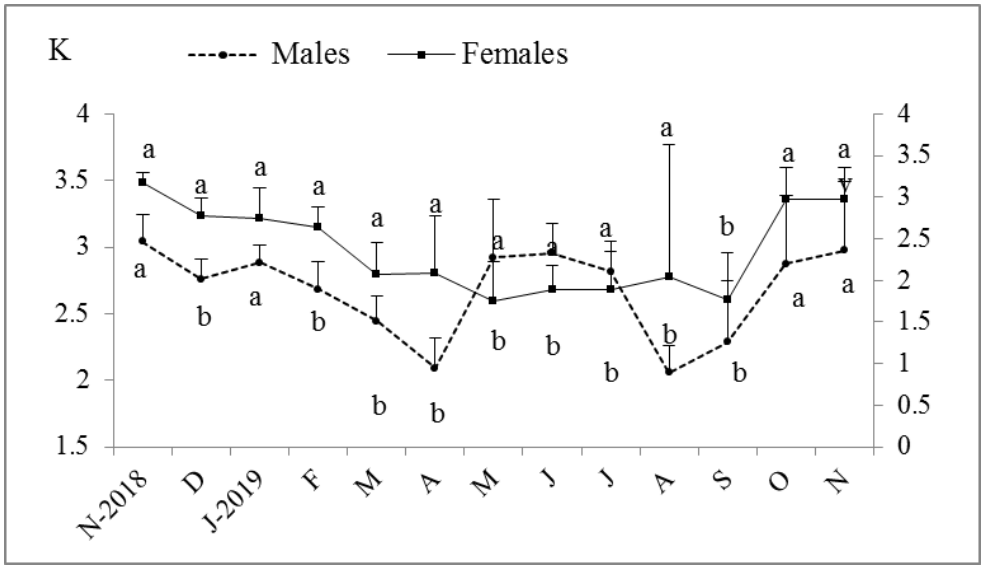
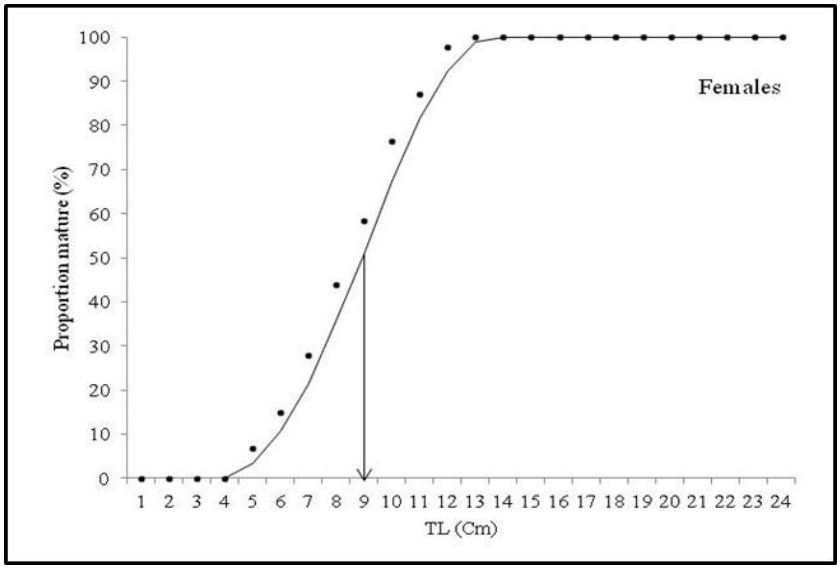


Fig. 4. Monthly variations in the condition factor (K) of *Tilapia zillii* in Ayata Lake (The different letters indicate significant differences between sampling points. Error bars correspond to standard deviations).

5. Size at first sexual maturity

The size at 50% sexual maturity was estimated graphically where the maturation curve is constructed and length at maturity was estimated as the point on abscissa corresponding to the 50% point on the ordinate (Fig. 5). From the maturation curve, the length at first sexual maturity of T. zillii from Ayata Lake was 8.5 and 9.7 cm TL for males and females, respectively.



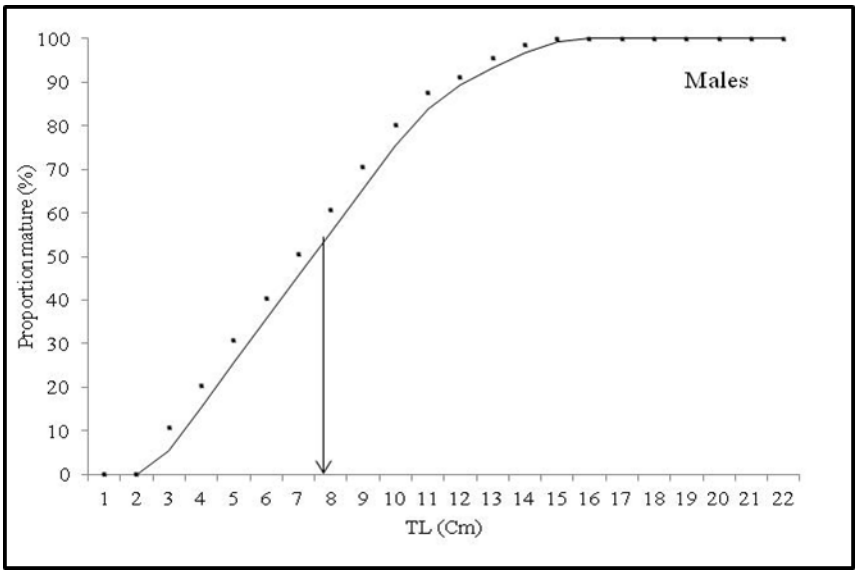


Fig. 5. Proportion of mature individuals (%) by total length for females and males of *Tilapia zillii* in Ayata Lake.

DISCUSSION

The present study has established key reproductive dynamical characteristics of one of the commercial species of family cichlidae, *T. zillii* in Ayata lake as a Ramsar site in south-eastern Algeria.

1. Sex ratio

Sex ratio constitutes basic information indispensable for the assessment of the potential of fish reproduction and stock size estimation in fish population (Vicentini & Araujo, 2003; Adebiye, 2013). The changes in the percentage of females to males of T. zillii in Ayata lake were most probably due to spawning and feeding behavior. The sex ratio of 0.97 M: 1 F observed in this study is statistically close to the theoretical sex ratio (1:1). However, it is biologically in favor of females during Autumn, winter and spring as well as in the spawning months. This result is more or less similar to the previous ones: El-Shazly (1993) gave M/F ratio as 1:0.91 in lake Mariut, Egypt, Phillips (1994) estimated M/F in lake Edku as 1 : 0.91 and as 1:0.97 by El-Sawy (2006) while in Abu Qir it was 1:1.05 (Akel and Moharram, 2007). These differences could be explained either by the number of individuals considered, which have a direct impact on the value (Phillip and ruwet, 1982; Negassa and Getahun, 2003; Negassa and Prabu, 2008; Mahmoud et al., 2011) or by the environmental conditions in the study area, such as water temperature (27°C seasonal average) and water salinity that varies between 7.8 and 10.2 psu (practical salinity unit) (Zouakh *et al.*, 2016).

2. Spawning season

Knowing the time of spawning is essential to protect both of the ripe females and the new recruits and to predict the recruitment variability. To determine the reproduction period of *T. zillii* in Ayata lake, monthly variations in both of maturity stages and gonado-somatic index values were analysed. Gonado-somatic index is one of the important parameter of fish biology, which gives the detail idea regarding fish reproduction and reproductive status of the species and help in ascertaining breeding period of fish (Gupta

& Srivastava, 2001; Shankar & Kulkarni, 2005; El-Kashef *et al.*, 2013). Monthly pattern of gonadal activity and the monthly variations in GSI of *T. zillii* population in Ayata lake showed that spawning occurred once a year and runs from March to August. This coincide with the finding of Maclaren (1981) who mentioned that cichlids exhibited prolonged spawning season in Lake Manzalah extended from April to September. Negassa and Getahun (2003) declared that *T. zillii* in lake Zwai (Ethiopia) breeds allover the year with peak activities between April and September. In Abu Qir Bay, *T. zillii* breeds with maximum activity during June and July (Akel and Moharram, 2007). A different pattern has been found in *T. zillii* in Lake Victoria (Welcomme, 1967) and in Naivasha lake, Kenya (Siddiqui, 1979), in Nigeria (Welman, 1948) and Zake (Grosse, 1963), where the climatic conditions are different from that of Algeria's Sahara (Zouakh *et al.*, 2016).

Indeed, the maturation of genital products begins in winter and is completed in spring. The first issuances of gametes take place in late spring. The gonads are then emptied of their gametes in summer and these results are similar to the other ones (Table 3).

Table 3. Spawning period of *Tilapia zillii* in different regions according to literature data

Authors	Study area	Spawning period
Zaoukh *et al*. (2016)	Oued Righ wetland (Algeria)	April-July
Mahmoud *et al*. (2011)	Timsah Lake (Egypt)	April-August
Negassa and Getahun (2003)	Zwai Lake (Ethiopia)	April-September
Maclaren (1981)	Lake Manzalah (Egypt)	April - September
Present study	Ayata lake (Algeria)	March-August

3. Hepatosomatic index HSI

Variations of HSI values indicate in both sexes of *T. zillii* that lipid reserves in the liver just after the breeding season (August). A reversion of trophic activity following this period of eventual fast may explain this situation. Indeed, fishes, which decrease their food intake during gonadal maturation, use nutrients originating from endogenous reserves in muscle, adipose tissue and liver (Lal and Singh, 1987; Nassour and Léger, 1989; Martin *et al.*, 1993).

According to Zaoukh *et al.* (2016), the minimum values are noticed at the end of the spawning period. Due to the significant variations in the HSI, this species would draw its energy from lipid reserves of the liver and, thus, could belong to the category of fish called 'lean' that store their lipid reserves in the liver. However, these remains to be confirmed by the study of the mesenteric reserve index (MRI) and the extra-visceral reserve index (EVRI) to check if the liver plays a more important role than the mesenteric fat and muscle in the phenomenon of genital product maturation.

4. Condition factor K

The relatively high value of K during November in both sexes of *T. zillii* could be explained by favorable trophic conditions during this period. Indeed, values of condition

coefficient have been used to measure various ecological and biological factors such as degree of fatness, gonad development and the suitability of the environment with regard to the feeding condition (MacGregoer, 1959).

5. Length (L_{m50}) at first sexual maturity

The length at first sexual maturity is important for determining the optimum length at first capture and consequently the optimum mesh size. It is accepted that the optimum size for the first maturation depends upon many factors, including the relative allocation of food energy between somatic and gonad growth (Mazzoni and Caramaschi, 1995). In our study, the length at first sexual maturity (L_{m50}) of males and females of T. zillii in Ayata lake was estimated as 8.5 and 9.7 cm TL, respectively. These values indicated that males reach their length at first maturity before females and this disagree with those of El– Shalloof (1991) who estimated the Lm as 8.6 cm (females) and 10.1 cm (males) in Lake Manzalah, El–Haweet (1991) for both sexes reached first sexual maturity at the same length 7 cm in Lake Borollus, Akel and Moharram (2007) gave Lm equal 8.7 cm (females) and 9.7 cm (males) in Abu Qir Bay. On the other hand, males reached first sexual maturity at smaller lengths than females in lake Edku (9 cm TL for females and 8 cm TL for males) (Phillips,1994). These differences in length at first sexual maturity may be attributed to differences in genetics and environmental conditions such as food availability, population structure and changes in temperature and salinity.

CONCLUSION

In conclusion, this paper highlights the basic data on the reproductive biology of *Tilapia zillii* in arid environment (Ramsar site, Ayata lake) for the first time. Results revealed two important facts which should be considered through the management of *T. zillii* in Ayata lake. Firstly, the timing of spawning (from March to August) and secondly, the size at first sexual maturity. Results are still to be debated with further incoming data on feeding habits, ecology and population genetics that may explain the patchy geographic repartition of such sensitive fish. So, it is recommended to make a detailed study concerned gear selectivity and type to find the proper mesh size which guarantees the contribution of a considerable part of the stock of *T. zillii* during the spawning season. Also, the recommended study should cover all the biological and dynamical aspects as well as the catch and effort data to be make sure that this species is exploited rationally.

REFERENCES

Adebiye, F. A. (2013). The sex ratio, gonadosomatic index, stages of gonadal development and fecundity of Sompatgrunt. *Pomadasys jubelini* (Cuvier, 1830), Pakistan J. Zool. 45(1): 41-46.

Akel, E. H. and Moharram S. G. (2007). Reproductive Biology of *Tilapia zillii* (Gerv, 1848) from Abu Qir Bay, Egypt. Egyptian Journal of Aquatic Research, 33(1): 379-394

Al-Kiyumi. F.; Mehanna, S. F. and Al-Siyabi, B. (2014). Reproductive dynamics as a management tool for the spotted grunter *Pomadasys commersonnii* (Lacepède, 1801) from the Arabian Sea off Oman. International Congress on "Estuaries & Coastal Protected Areas, "ECPA 2014, 04 - 06 November 2014, Izmir – Turkey.

Bacha, M. and Amara, R. (2007). Les poissons des eaux continentales d'algérie. Étude de l'ichtyofaune de la Soummam. Cybium., 31: 351-358.

Belarouci, M. E. (2005). Caractérisation morphologique et systématique du tilapia de l'oued Righ. Suivi d'un élevage intensif de l'Oreochromis niloticus dans la région d'Ouargla. Mémoire de magister en Agronomie saharienne. Université d'Ouargla. 74p.

Bougis, P. (1952). Recherches biométriques sur les Rougets (*Mullus barbatus* et *M. surmuletus*). Arch. Zoo. Exp. Gén., T (89): 57-174.

Chaibi, R. Si Bachir A.; Chenchouni, H.; Bouletreau, S.; Cereghino, R. and Santoul, F. (2012). Effect of large-scale environmental variables and human pressure on distribution patterns of exotic continental fish in east Algeria. Zool. Ecol., 22: 166-171.

Dagnelie, P. (1975). Théorie et méthodes statistiques. 2: les méthodes de l'inférence statistique. Les presses agronomiques de Gembloux. 451 pp.

Dikel, S.; Alev, M.V.; Kiriş, G. A. and Kumlu, M. (2002). Growth and yield of two tilapia species *Tilapia zillii* and *Tilapia rendalli* raised in floating cages in Seyhan Dam Lake. J. Fac. Agric., 17: 93-98.

El-Haweet, A. A. (1991). Biological studies of some Cichlid species in Lake Borollus. M.Sc., Fac. Sci. , Alex. Univ. Egypt.

El-Kasheif, M. A.; Shalloof, K. A. and Authman, M. M. N. (2013). Studies on some reproductive characters of *Tilapia* species in Damietta branch of the River Nile, Egypt. J. Fish. Aquat. Sci., 8: 323-339.

El-Sawy, W. M. (2006). Some biological aspects of dominant fish population in Lake Edku in relation to prevailing environmental conditions, M.Sc. Fac. Sci., Zagazig Univ., Egypt.

El-Shalloof, K. (1991). Biological studies on tilapia species in the middle region of Lake Manzalah. M.Sc. Fac. Sci., Mansura Univ. Egypt.

El–Shazly, A. (1993). Biological Studies On Four Cichlid Fishes (*Tilapia nilotica, Tilapia galilae, Tilapia zillii, Tilapia aurea*). Thesis M.Sc. Fac. Sci. Zagazig Univ. Egypt.

El-Zarka, S. (1956). Breeding behaviour of the Egyptian Cichlid Fish *Tilapia zillii*. Copia (1956).

El-Zarka, S. A.; Koura, R. and Shaheen, A. H. (1970). Selectivity of wire basket traps for tilapias (*T. nilotica, T. galilae* and *T. zillii*) J. Cons. Int. Explor. Mer., 282-291.

Gervais, P. (1848).Sur les animaux vertébrés de l'Algérie, envi-sagés sous le double rapport de la géographie zoologique et de la domestication. Ann. Sci. Nat. Zool., 3(10): 202-208.

Guezi, R. and Kara, M. H. (2015). Age, growth and reproduction of the endangered jewelfish *Hemichromis bimaculatus* (Cichlidae) in the valley of Oued Righ (South-eastern Algeria). Cybium., 39(4) :301-307.

Guezi, R.; Chaoui, L. and Kara, M. H. (2017). Life history of the Mediterranean killifish *Aphanius fasciatus* in brackish water habitat of Algerian low Sahara. Env. Biol.Fishes., 100(5): 481-491.

Gouasmia, G.; Amarouayache, M.; Frihi, H. and Hichem Kara, M. (2016). Caractérisation physico-chimique de trois lacs salés permanents de la vallée d'Oued

Righ (sahara septentrional, Algérie nord-est). Rev. Ecol. Terre et Vie., 71 (4): 330-341

Grosse, J. P. (1963). Le milieu aquatique et l'écologie des poissons dans la région de Yagambi. Ann. Mus. Roy Afr. Centr., 116: 115-271.

Gupta, J. P. and Rivastava, S.P. (2001). Maturity determination by gonadosomatic index during annual reproductive cycle in Passer domesticus. Environment and Ecology (Kalyani), 191: 216-218.

Ikomi, R. B. and Jessa, H. O. (2003). Studies on Aspects of the Biology of *Tilapia mariae* (Boulenger, 1899) (Osteichthyes Cichlidae) in Ethiope River, Niger Delta, Nigeria. African Zoology, 38 (2): 255–264.

Kara, M. H. (2012). Freshwater fish diversity in Algeria with emphasis on alien species. Eur. J. Wildlife. Res., 58: 243-253.

Lal, B. and Singh, T. (1987). Changes in tissue lipid levels in the freshwater catfish *Clarias batrachus* associated with the repro-ductive cycle. Fish. Physiol. Biochem., 3: 191-201.

Mac Gregoer, J. S. (1959). Relation between fish condition and population size in the sardine (Sardinops caerulea). US Government Printing Office.

Maclaren, J. F. (1981). Lake Manzalah Study Report to the A. R. E., Ministry of Development and New Communities and UNDP office for projects excusions. vol. 12.

Mahmoud, W. F.; Amin, A. M.; Elboray, K. F.; Ramadan, A. and El-Halfawy, M. (2011). Reproductive biology and some observation on the age, growth, and management of *Tilapia zillii* (Gervais, 1848) from lake Timsah, Egypt. Int. J. Fish. Aquac., 3: 16-26.

Martin, N. B.; Houlihan, D. F. ; Talbot, C. and Palmer, R. M. (1993). Protein metabolism during sexual maturation in female Atlantic salmon (*Salmo salar*). Fish. Physiol. Biochem., 12: 131-141.

Mazzoni, R. and Caramaschi, E. (1995). Size structure, sex ratio and onset of sexual maturity of two species of *Hypostomus*. J. Fish Biol., 47: 841-849.

Mehanna, S. F. (2014). Reproductive dynamics of the common sole *Solea solea* (Linnaeus, 1758) from Bardawil lagoon, North Sinai, Egypt. Tropentag 2014: Bridging the gap between increasing knowledge and decreasing resources, September 17 - 19, 2014, Czech University of Life Sciences Prague, Czech Republic.

Mehanna, S. F. ; Al-Kiyumi, F. R. and Al-Kharusi, L. (2012). Reproductive dynamics of the goldlined seabream *Rhabdosargus sarba* (Forsskal, 1775) from the Arabian Sea coast of Oman. International J. AgriSci., 2(4): 365-373.

Mehanna, S.F.; El-Gammal, F.I.; Mahmoud, U.M.; and El-Mahdy, S.M. (2019). Reproductive cycle as a management tool of two-bar seabream, *Acanthopagrus bifasciatus* (forsskål, 1775) from the Red Sea, Egypt. Sci& Techn. Publishing (SCI & TECH), 3 (1): 128-132.

Meyer, D. E. (2002). Technology for successful small-scale tilapia culture (CRSP Research Report 02 - 179). CRSP (Aquaculture Collaborative Research Support Program). in: D. Meyer (Ed). 6th Simposioo Americano de Aquaculture Proceedings: Tilapia Sessions, 22-24 August 2001. Tegucigalpa, Honduras, 97-106.

Nassour, I. and Léger, C.L. (1989). Deposition and mobilisation of body fat during sexual maturation in female trout (*Salmo gairdneri* Richardson). Aquat. Living Resour., 2: 153-159.

Negassa, A. and Getahun, A. (2003). Breeding season, length-weight relationship and condition f introduced fish, *Tilapia zillii* Gerv.1848 (Pisces: Cichlidae) Lake Zwai, Ethiopia. SINET: Ethiopian Journal of Science, 26(2): 115 - 122.

Negassa, A. and Prabu, P. C. (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. Tech., 2: 345-360.

Orange, C. J. (1961). Spawning of yellowfin tuna and skipjack in the Eastern Tropical Pacific, as inferred from studies of gonad development. Inter-Am. Trop. Tuna Comm., Bull 5(6): 459-526.

Phillip, J. C. L. and Ruwet, J. C. L. (1982). Ecology and distribution of Tilapias ICLARM, Conf. Proc. Manila, Phillipines. 7: 15 - 59.

Phillips, A. E. (1994). Studies on the biology of two Tilapia species in Lake Edku. M.Sc. Thesis, Fac. Sci. Alex. Univ. Egypt.

Polat, A. (1998). The effects of methionine supplementation to soya bean meal (SBM)-based diets on the growth and whole body-carcass chemical composition of tilapia (*T. zillii*). Turk. J. Zool., 23: 173-178.

Scherrer, B. (1984). Biostatique. Morin G (ed) Boucherville,Montréal. 850 pp

Shankar, D.S. and Kulkarni, R.S. (2005). Somatic condition of the fish, *Notopterus notopterus* (pallas) during phases of the reproductive cycle. J. Environ. Biol. 2005, 26(1): 49-53.

Siddiqui, A. Q. (1979). Reproductive biology of *Tilapia zillii* (Gervais) in lake Naivasha, kenya. Environ. Biol. Fish., 4: 257-262.

Vicentini, R. and Araújo, F.G. (2003). Sex ratio and size structure of Micropogonias furnieri (Desmarest, 1823) (Perciformes, Sciaenidae) in Sepetiba Bay, Rio De Janeiro, BRAZIL. Braz. J. Biol., 63(4): 559-566.

Welcomme, R. L. (1967). Observations on the biology of the introduced species of *Tilapia* in Lake Victoria. Rev. Zool. Bot. Afr. 76: 249-279.

Welman, J. B. (1948). Preliminary survey of the freshwater fisheries of Nigeria. Government Printer, Lagos. 36 pp.

Yildirim, O.; Turker, A.; Ergün, S.; Yigit, M. and Gulsahin, A. (2009). Growth performance and feed utilization of *Tilapia zillii* (Gervais, 1848) fed partial or total replacement of fish meal with poultry by-product meal. Afr. J. Biotech., 8(13): 3092-3096.

Yildirim, O. and Guro,Y. D. (2015). Effects of dietary olive pomace meal levels on growth performance, feed utilization and bio-economic analysis of juvenile tilapia (*Tilapia zillii*). Rom. Biotech. Lett., 20: 10982-10987.

Zouakh, D. E.; Bouhadad, R.; Moulla, M. and Cherbi, M. (2005). Ichtyofaune, macrofaune benthique et peuplements zooplanctoniques du hoggar et du Tassili. Bull. Soc. Zool. Fr., 130 (1): 55-80.

Zouakh, D. E.; Chebel, F.; Bouaziz, A. and Kara, M. H. (2016). Reproduction, age and growth of *Tilapia zillii* (Cichlidae) in Oued Righ wetland (southeast Algeria). Cybium., 40(3), 235-243.