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Growth and population structure of the European perch, *Perca fluviatilis* Linnaeus, 1758 (Osteichthyes: Percidae) in the Anzali Wetland south-west Caspian Sea

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ABSTRACT

Population parameters of the European perch *Perca fluviatilis* in the Anzali Wetland, south-west Caspian Sea were estimated using samples collected between June 2008 and May 2009. The von Bertalanffy growth functions estimated were $L_t = 21\,(1- e^{-0.33\,(t-0.9)})$ for females and $L_t = 21.17\,(1- e^{-0.31\,(t-0.8)})$ for males. The length-weight relationship is $W = 0.011{*}L_t^{3.1}$ (males) and $W = 0.024{*}L_t^{2.8}$ (females) suggesting positive and negative allometry in males and females, respectively ($p<0.05$). There was no difference in sex ratio throughout the year, while deviation from equal proportion was observed in selected months ($p<0.05$). This study revealed differences in the population parameters of perch in the Anzali Wetland as compared to perch in other geographical regions.

Keywords: Anzali Wetland, Growth, *Perca fluviatilis*, von Bertalanffy growth curve

Introduction

The Anzali Wetland, which is located in south-west of Iranian coastal waters of the Caspian Sea, is known as a humid area with mild winters and hot summers. The average low and high temperatures of Anzali Wetland were in the range 21.6 - 28.4°C and 5.3- 11.4 °C in summer and winter respectively. The range of humidity and the annual mean humidity were 24-100% and 84% respectively.

Mathematical models for fish growth using length-at-age data are useful for fisheries researchers and decision makers. The von Bertalanffy (1957) growth equation for size at age data is commonly used in fisheries science for estimation of population parameters that are responsible for shaping the population structure. The magnitude of differences in population parameters may have important implications for fisheries management strategies based on population responses to both environmental conditions and fishing mortality impact.

Perca fluviatilis is a percoid species widely distributed in Europe and Asia between 40° and 70° N lat. (Weatherly, 1963) and therefore the species is an appropriate candidate for comparing population parameters in different geographical areas. In Iran, the largest populations of perch are now concentrated in the wetlands (*e.g.,* Anzali) and rivers that are linked to the south Caspian Sea (Sattari, 2002). This study reveals the life history parameters of *P. fluviatilis,* in comparison with previous studies in different geographical habitats of the species. This highlights the variability in population structure of the species, in order to understand more about population responses to causative mechanism(s) such as fishing activity and the degradation of environmental conditions.

Materials and methods

Perca fluviatilis were sampled from the Anzali Wetland located in the south-west Caspian Sea (Fig. 1). Monthly water temperature and day length were measured (Fig. 2). A total of 286 specimens of *P. fluviatilis,* were caught monthly from the Anzali Wetland between June 2008 and May 2009, using gillnets (mesh size 18-20 mm). All fish were sexed, weighted to the nearest 0.01 g and the total length measured to the nearest 0.1cm.

Processing of opercular bones

The opercula were cleaned in boiling water to separate soft tissues, and then dried by placing on filter

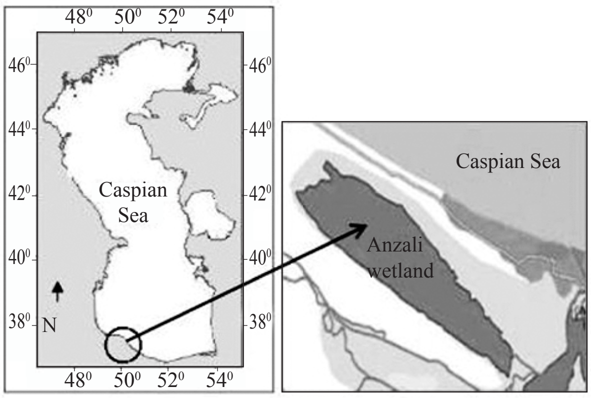

Fig. 1. Map showing *Perca fluviatilis* sampling location

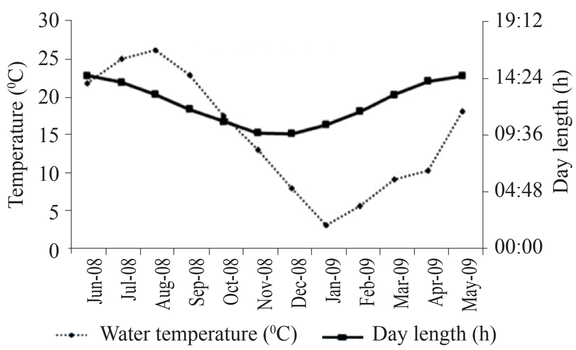

Fig. 2. Monthly changes in mean temperature and day length between June 2008 and May 2009 in the Anzali Wetland.

papers. The annual rings were assessed under transmitted light using microscope (Le Cren, 1947).

Bias and precision analyses

All sections were read twice and 20% of the samples were randomly chosen for a second reading by a different person to determine the percentage agreement (PA). All sections were read blind without reference to fish size (Brennan and Cailliet, 1989). To assess the precision of ring counts of opercula, the average percent error (APE) between the ring counts were calculated using the following formula (Beamish and Fournier, 1981):

$$APE = \frac{100}{N} \sum_{j=1}^{N} \left[\frac{I}{R} \sum_{i=1}^{R} \frac{|Xij - Xj|}{Xj} \right]$$

where, *N* is the number of fish aged in the subsample, *R* is the number of times the age of the fish was estimated, *Xij* is the i^{th} determination for the j^{th} fish, and *Xj* is the average estimated age of the j^{th} fish.

Growth parameters

Growth was characterised using the von Bertalanffy growth function, fitted to size-at-age data using standard nonlinear optimisation methods. The von Bertalanffy growth function is explained as (von Bertalanffy, 1957):

$$L_t = L_\infty (1- e^{-K (t-to)})$$

where, L_t is length at age t, L_∞ is the asymptotic length, K is the growth coefficient and t_0 is the hypothetical age at which length is zero. Additionally, length of few numbers of perch in fingerling size was measured. Initial growth rate was calculated as: $G_{init} = K \times L_\infty$ (Mooij *et al.,* 1999).

The length-weight relationship was calculated separately for two sexes by fitting the power function to length and weight data: $W_t = a (L_t)^b$, where W_t is the somatic weight, 'a' is a constant and 'b' is an allometric coefficient and L_t is the total length, 'b value' varies between 2 and 4 (Tesch, 1971), when b = 3, L and W_t are increasing at the same rate (isometry); when b>3, W is increasing faster than L (positive allometry); when b<3, W is increasing slower than L (negative allometry) (Viette *et al.,* 1997). The relationship was compared between the two sexes by applying the ANOVA test.

Results

Bias and precision analyses

The average percent error (APE) was very low (0.95%), suggesting no difference between the profiles of opercula between two readers. An APE of less than 5% (in this study 2.4%) (Fig. 3) is indicative of consistent interpretation of age (Morison *et al.,* 1998). A paired sample *t*-test indicated that there was no difference between the ages estimated by two readers (t = 0.63, df = 68, p = 0.53).

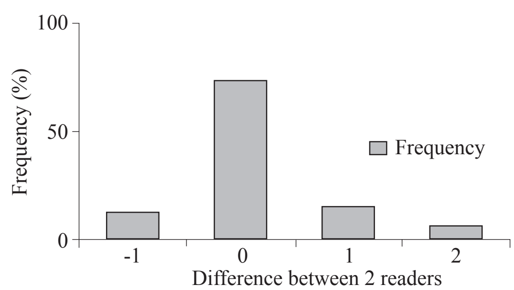

Fig. 3. Percent agreement of band pair counts between two readers for *P. fluviatilis* (n= 35)

The ANOVA test did not show difference in the mean total length between sexes while there was evidence of differences in the mean total weight between two genders ($p < 0.05$) (Table 1).

Age composition

The estimated age for both sexes caught in 2008-2009 ranged from 2 to 7 years with a median age

Table 1. Total length and weight composition in male and female *P. fluviatilis* in the Anzali Wetland, south-west Caspian Sea (2008-2009)

Parameter	Sex	N	Mean	S.D. of mean	Minimum	Maximum
L_t (cm)	Female	139	19.96	1.8	16	26
	Male	147	19.61	1.62	15	23.6
W(g)	Female	139	118.56	35.8	50	258
	Male	147	108.7	37.2	55	205

of 4.6 for female and 4.8 for male (Fig. 4). Males and females had similar age-frequency distributions in the Anzali Wetland (χ^2=5.8, df=5, p>0.05). Seven year-old individuals were the only age class in which the numbers of females were significantly (p>0.05) more than males (Fig. 4).

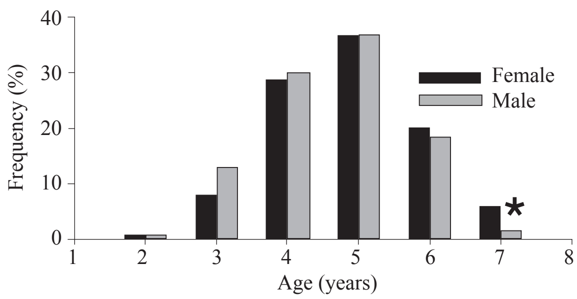

Fig. 4. Age frequency distribution for female and male *P. fluviatilis* in the Anzali Wetland (n = 286)

Estimation of growth parameters and asymptotic length

Growth trajectories were almost similar between the sexes for perch. The predicted length at age for both sexes had almost similar value. The von Bertalanffy growth parameters estimated for females and males were similar. The estimates of asymptotic length (L_∞) and the growth coefficient (K) for females were 21 cm and 0.33 per year, respectively. Males had an asymptotic length of 21.17 cm and a growth coefficient of 0.31 per year (Fig. 5).

The von Bertalanffy growth functions estimated are as follows: $L_t = 21\,(1 - e^{-0.33\,(t-0.9)})$ for females and $L_t = 21.17\,(1 - e^{-0.31\,(t-0.8)})$ for males (Fig. 6). From the estimates of

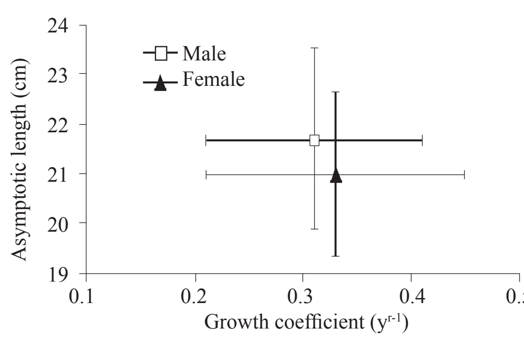

Fig. 5. Confidence regions (95%) of mean for growth parameter estimates (K and L_∞) for males and females of *P. fluviatilis* caught during June 2008 to May 2009 in the Anzali Wetland.

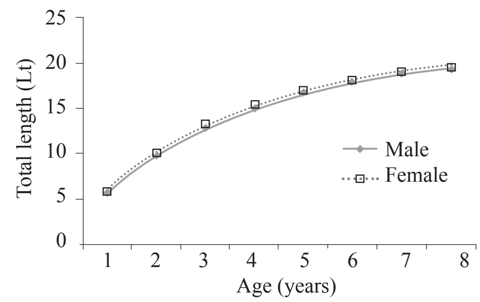

Fig. 6. The von Bertalanffy growth curve for female and male *P. fluviatilis* in the Anzali Wetland.

asymptotic length (L_∞) and the growth coefficient (K), it is possible to determine the amount of initial growth for male and female which were estimated as 6.6 and 6.9, respectively.

Length-weight relationship

The length-weight relationships were W_t=0.02*$(L_t)^{2.8}$ for females (r^2 = 0.79) and W_t = 0.01$(L_t)^{3.1}$ for males (r^2 = 0.75) (Fig. 7). The b value in males (b>3) was larger than in females (b<3), indicating positive and negative allometric growth for males and females, respectively. Significant differences in growth were found between females and males (F = 1.21, df = 1, p<0.05).

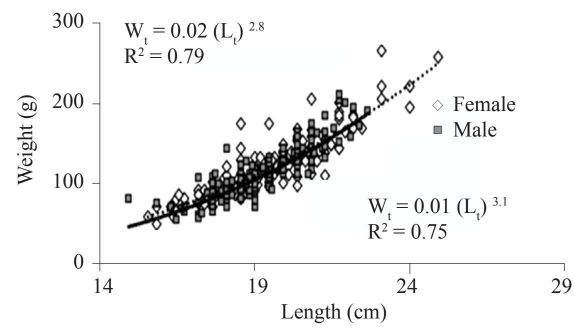

Fig. 7. Length-weight relationship for female and male *P. fluviatilis* in the Anzali Wetland.

Sex ratio

Chi square test did not show significant difference in proportion of female to male throughout the year (χ^2 = 0.01, df = 1, p>0.05), however, deviation from equal proportion was observed in selected months (p<0.05) (Fig. 8).

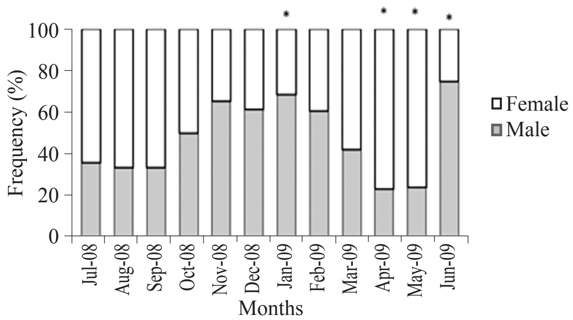

Fig. 8. The sex ratio of female to male in *P. fluviatilis* in different months (Asterisks above the bars represent months that deviate from equal proportion)

Discussion

Samples of *P. fluviatilis* for the study were collected throughout the year and hence it is assumed that the size and associated age structure was representative of the study populations. As previously mentioned, perch growth depends on complex interactions with water temperature (Le Cren, 1958; Coble, 1966), population density (Rask, 1983), and food density as well as availability (Rask, 1983).

There was no evidence of differences in the mean total length of *P. fluviatilis* between genders in the Anzali Wetland. However, the mean total length of both females and males was lower than that reported in the Tjeukemeer Lake (13.5 - 41.5 cm) (Mooij, 1999); Lake Ijssel (29.40 cm) in the Netherlands (52° N) (Machiels and Wijsman, 1996) and Lake Trasimeno (26.67 cm), in Italy (Lorenzoni *et al*., 1993). This could be attributed to the fact that maximum size achieved would be greater at high-latitude localities where temperatures experienced during development would be lower (Gilligan, 1991; Atkinson, 1994). Comparison of the present study with other research investigations confirms the positive effect of high-latitude and larger size.

In our investigation, length of perch in the Anzali Wetland with 80 - 380 day degree (monthly average temperature multiplied by day-length) at a latitude of 37° N is similar to the samples from Widermer Lake at 52° N lat. with 150 - 450 day degree (Craig and Kipling, 1983). However, length of *P. fluviatilis* in the Tjenkemere Lake at 52° N lat. have larger size than those collected from the Anzali Wetland which can be attributed to higher day degree (350-635) (Mooij, 1999). It appears that equal day degree can declare similarity in length of perch in different geographical areas.

The length–weight relationship is affected by a number of factors including season, habitat, gonad maturity, sex, diet, stomach fullness, health and preservation techniques (Tesch, 1971). In this study b value of males is the same as in previous reports (Ceccuzzi *et al.,* 2011) showing positive allometry, but our observation showed negative allometry in females ($b<3$), that could be the result of increasing energy allocation of females to reproduction and lack of availability of appropriate food.

Majority of the ectotherms studied showed decreasing individual growth rates with decreasing temperature (Atkinson,1994; Atkinson and Sibly, 1997). In the present study, growth coefficient of perch in the Anzali Wetland (0.33 for females and 0.31 for males) is higher than in Lake Tjeukemeer (0.28) (Mooij *et al.,* 1999); Lake Varesea (0.2) (Ceccuzzi, 2007); Lake Trehorningen, Sweden (0.27) and Lake Stocksjon, Sweden (0.24) (Heibo and Magnhagen, 2005), which confirms larger length of perch in higher latitude compared to perch of Anzali Wetland. Lower value for growth coefficient of perch in Anzali (0.33 for females and 0.31 for males) compared to perch in Widermer Lake (0.5) indicates that fishing pressure in higher latitude (54° N) can weaken the hypothesis of effect of increased fishing pressure on the large component of perch population in the Azali Wetland.

In the present study, an equal sex ratio was observed throughout the year. Equal growth rate in both sexes can confirm equal sex ratio in the population studied. When fish have the same growth rate, they grow in the same speed; therefore availability of food and vulnerability of both genders to predators are similar that explain the same equal sex ratio for perch population. However, many previous studies confirmed larger size of female to male (Mooij *et al.,* 1999; Negri, 1999; Ceccuzzi *et al.,* 2011). Although growth rate and length of males and females were almost equal in our study, partial difference between initial growth rates in sexes can explain that female would have capability to achieve larger size if there are appropriate environmental and nutritional states. High abundance of males in some months (*e.g.,* January) could be attributed to the spawning time of perch in the Anzali Wetland (Saemi *et al.,* 2014). In many species like *P. fluviatilis,* more number of males is present in the spawning areas mainly due to spawning behaviour and sperm competition (Birkhead and Møller, 1998; Birkhead *et al.,* 2009). Additionally, more number of females in April, May, and June probably coincided with post-spawning behaviour of female perch (Saemi *et al.,* 2014). Previous studies showed that high abundance of individuals has been associated with the feeding activity, in particular by females, shortly after spawning (Fordham *et al.,* 1999). Therefore, more number of female perch has been caught in post-spawning period.

In spite of optimal growth performance of perch seen in this study, some differences in perch population of Anzali Wetland in comparison to previous studies can be attributed to inappropriate environmental conditions such as pollution and eutrophication process of the Anzali Wetland (Mirzajani, 2010). Such processes can have effect on nutritional state and finally on the population structure. For a better understanding of the mechanisms of the processes affecting population parameters, future studies on other species like roach in the Anzali Wetland is warranted.

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