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On the Growth and Reproductive Biology of asp, *Aspius vorax*, Population from the Middle Reaches of Euphrates River

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Abstract

Endemic asp, *Aspius vorax*, from the middle section of the Euphrates River flowing through eastern Syria were studied to determine the main characteristics of their population structure, morphological parameters and reproductive biology. Samples ranged between 0+ and 4+ years of age and were dominated by 2+ years old group. Total length (TL) ranged between 19 and 70 cm corresponding with 46 to 2824.5 g weight, respectively. Fish growth has isometric pattern and the overall sex ratio was unbiased. Seasonal changes in the condition factor were related with the water temperature as well as the spawning season. Annual cycle of gonadosomatic index (GSI) readings indicated that spawning season occur around March when fish longer than 36 cm can mate. Average pre-spawning GSI was greater in individuals older than 2 years. Meanwhile, female fecundity was highly related to TL and weight. These findings did not always concur with previous observations from other asp populations, mainly in southern and northern Mesopotamia. Our results highlighted basic biological aspects of the local population and indicated differences between populations which can assist in fisheries management, conservation and commercial culture of the investigated species.

Keywords: *Aspius vorax*, growth, reproduction, Euphrates-Tigris Rivers, Syria.

Introduction

The Euphrates-Tigris Basin, known as Mesopotamia, is primarily shared by Turkey, Syria and Iraq, with tributaries originating in Iran which make it the largest river system in southwest Asia (Altinbilek, 2004; Isaev and Mikhailova, 2009). Human activities have affected the fluvial system and hydrological regime remarkably presenting a great threat to the native aquatic life. Endemic ichthyofauna in Mesopotamia is endangered by overfishing, water abstraction, eutrophication, exotic species introduction and habitat destruction (Jawad, 2003; Richardson *et al.*, 2005), which urge the need to study these species and their habitats for future conservation, restocking and even commercial culture.

Some 106 freshwater and euryhaline species fish have now been recorded in the non-marine waters of this basin, of which *Cyprinidae* is the major endemic freshwater family (Coad, 2010). Among native cyprinids, endemic asp, *Aspius vorax*, is the only representative of their genus with a geographical distribution limited to the Euphrates-Tigris Basin (Beckman, 1962; Coad, 1996, 2010). Due to their economical and ecological importance, growth and reproductive biology of the carnivorous asp has been the focus of few studies in the lower section throughout Iraq (Shafi and Jasim, 1982; Epler, *et al.*, 2001; Szypuła *et al.*, 2001) and the upper section, flows through Turkey (Oymak *et al.*, 2011) of the Euphrates-Tigris Rivers. However, less is known on the biology of endemic asp populations from the middle section of this Basin. At present, no specific management and conservation arrangements exist for endemic asp neither valid assessment of the population status in the middle reaches of the Euphrates River flowing for about 700 km through eastern Syria.

Without understanding of geographical variation in growth and reproduction cycles, it is difficult to effectively manage, and subsequently conserve, endemic fish populations. Therefore, we investigated main aspects of the population structure, growth and reproductive biology of asp from the middle reaches of the Euphrates River. We also compared key biological characteristics of asp populations in the studied area with those from northern and southern

sections of the same Rivers Basin.

Materials and Methods

Monthly samples of asp (13-20 fish) were collected over a year by experimental electrofishing (GPP Electrofishers, Vanguard v-twin generator). Sampling sites covered around 200 km to the north and to the south of Deir ez Zor city (35°20′N, 40°9′E) by the Euphrates River (Figure 1). For each obtained specimen, total length (L, to nearest 0.1 cm) and weight (W, to nearest g) were recorded and age estimated by examining the relatively proportional-shape scales as validated for other *Asp* species (Martyniak and Heese, 1994; Krpo-Ćetković, *et al.*, 2010). Weight-length relationship for males, females and both sexes were computed separately. Regressions of L on W were described following Ricker (1975) by the power function:

$W = aL^b$

whose parameters were fitted to a regression line by the least square method. Student's *t*-test determined the significance level ($P<0.05$) of differences between isometric growth (b =3) and calculated b value in the equation.

The condition factor (K) was calculated for each sex and for mixed sexes following Fulton's (1904) formula:

$K = 100 \times (W/L^3)$

Monthly K values were calculated for each sex and plotted as an indicator for seasonal changes (Le Cren, 1951; Froese, 2006).

Gonads were removed and weighed (0.1 g) to estimate gonadosomatic index (GSI):

GSI = [gonad weight / total body weight] × 100

after macroscopic examination to recognize sample's sex, then preserved in formalin (8%). Sex ratios were compared to an expected 1:1 (male:female) distribution ratio using a χ^2 test for goodness of fit (Quinn and Keough, 2002). Spawning season was determined by identifying monthly changes in the GSI values and observing high proportions of the final maturity stages in examined gonads. Proportion of fish identified as mature in each 5 cm length class between 25 and 56 cm TL was quantified in percent of total samples then L_{50} and L_{100} were calculated when 50 and 100% of fish were detected as mature. In order to measure developed oocytes diameters, mature preserved ovaries were sectioned from anterior, middle and posterior portions of each ovarian lobe and the diameter of 20 oocytes from each section were examined under stereoscope fitted with micrometer eyepiece. Absolute fecundity (F, n = 6), which is the number of mature oocytes per unit of ovary mass was calculated and related to samples weight and total length.

Results

Age classes ranging from 0+ to 4+ years were defined by scale readings. Modal age was 2+ year (47.5%) followed by 1+ year (33.4%) and the least dominating were 4+ and 3+ years (1.4 and 6.4%, respectively) (Figure 2). The total length of 222 sampled fish ranged from 19 to 70 cm and their weight ranged from 46 to 2824.5 g. The weight-length relationship for all fish was calculated as:

$W = 0.0049 \times L^{3.1304}$ (r^2=0.97).

Sampled asp showed that they have isometric growth patterns. Regression lines slope inferred from the weight-length relationships for males or females were not significantly different, while coefficient of determination (r^2) was very high for each sex group and for pooled samples of fish as well (Table 1).

The condition factor for males was 0.70 ±0.01 and for females was 0.71 ±0.01. For both sexes, K was calculated as 0.71 ±0.01 without any significant differences in K value between males and females. Monthly changes in K are shown in Figure 3 and reflected the temporal changes in this factor. The highest values of K were around the warmest months of the year while decreased to the lowest level in the coldest months.

The overall sex ratio in collected samples did not

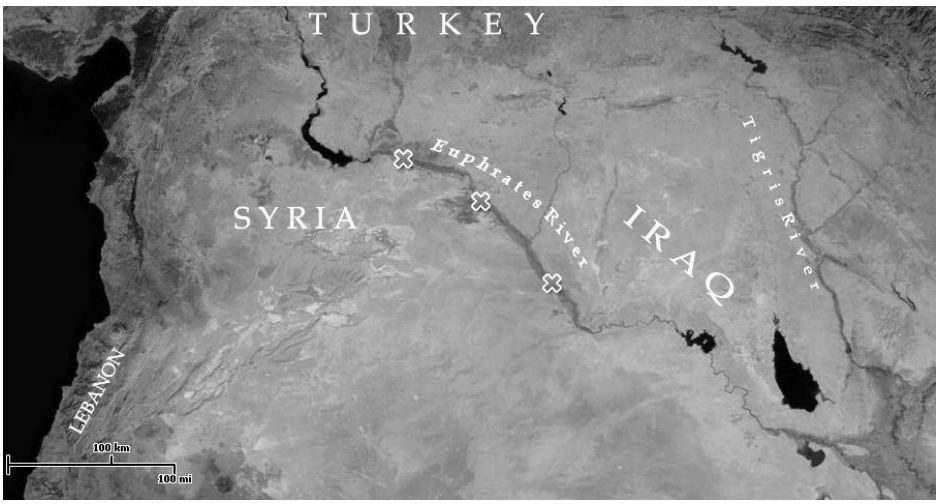

Figure 1. Sampling sites indicated by × across the middle reaches of the Euphrates River.

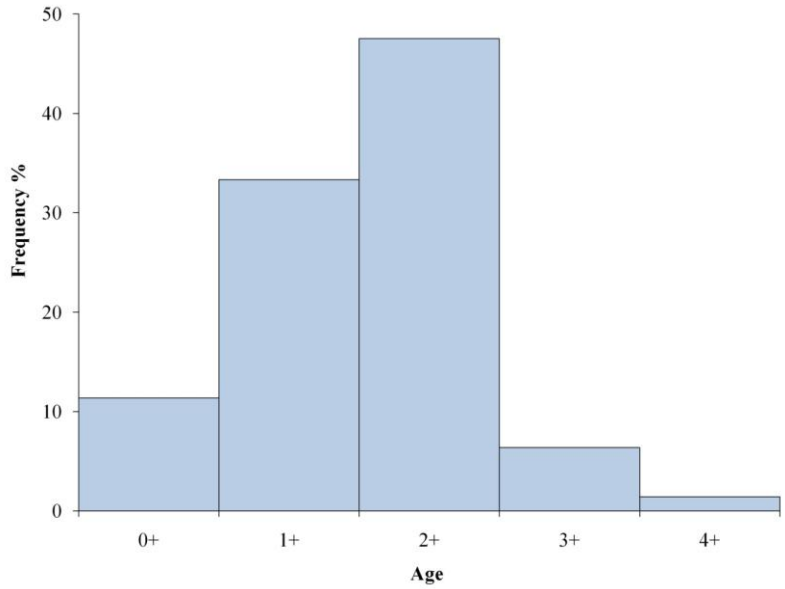

Figure 2. Age class distribution of asp sampled from the middle reaches of the Euphrates River.

Table 1. Measurements and parameters of weight-length relationships for asp males, females and combined samples from the middle reaches of Euphrates River

		Measurments		$W = aL^b$ parameters				
Sex	*n*	L_{min}- L_{max}	W_{min}-W_{max}	*a*	*b*	CI	r^2	t_{slope}
Males	126	18.7-55.2	46-1316	0.0049	3.1035	0.042	0.977	ns
Females	96	21.3-70.0	62-1915	0.0049	3.1024	0.050	0.975	ns
Combined	222	18.7-70.0	46-1915	0.0049	3.1044	0.032	0.976	ns

n, number of specimens; *L*, total length (cm); *W*, weight (g); *a*, intercept of the relationship; *b*, slope of the relationship; CI, confidence interval of *b* at ±95%; r^2, coefficient of determination, t_{slope}, *t*-test for the regression line slope with H_0=3.

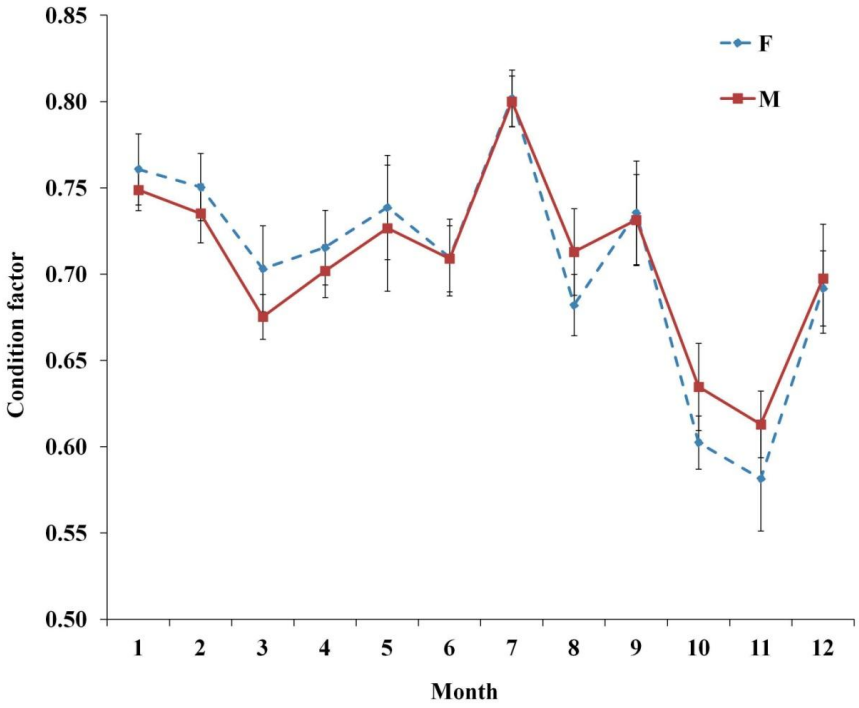

Figure 3. Monthly changes in the condition factor of female (F) and male (M) asp sampled from the middle reaches of the Euphrates River.

differ significantly from unity (χ^2= 4.05, P > 0.05). Median GSI, calculated as the average of observed pre-spawning season, increased slowly in the first two years of the asp lifecycle in both males and females then dramatically increased in the third year. Females had higher GSI in their 3+ and 4+ years of age (Figure 4). Observed annual changes of GSI peaked throughout February and March reaching 5.3 at mid-March then dropped dramatically since April for both males and females (Figure 5). Matured oocytes within observed spawning season ranged between 1.56 and 2.01 cm (Table 2).

The estimated length at maturity (L_{50} and L_{100}) for males and females was closely related (Figure 6). Both males and females began maturing at approximately 36 cm TL with most individuals mature when their TL was 45 cm and above. Absolute fecundity in female asp during their spawning season ranged between 41250 eggs at 41 cm of total length and 512 g up to 239765 eggs at 70 cm of total length and 2824 g of weight. Observed values of absolute fecundity were significantly correlated with female weight and total length (Figure 7). Observed values of r^2 indicated that trends of absolute fecundity are

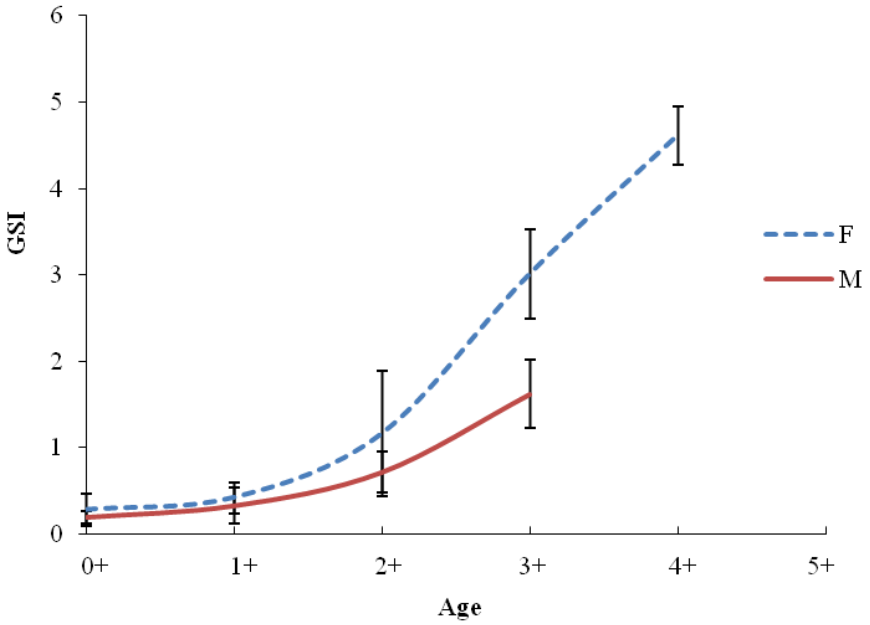

Figure 4. Gonadosomatic index (GSI) per age group of asp males (n = 126) and females (n = 96).

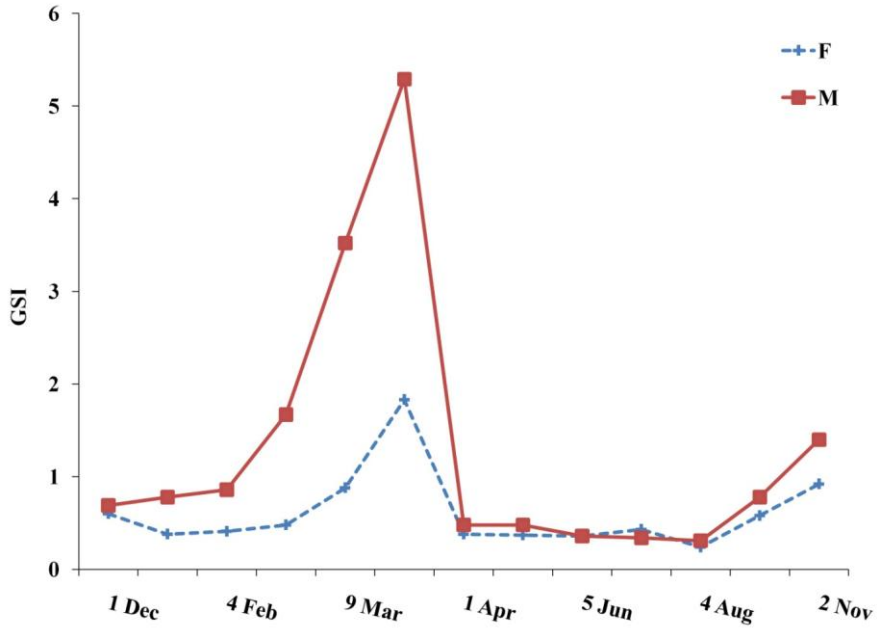

Figure 5. Annual cycle of gonadosomatic index (GSI) of asp males (n = 126) and females (n = 96) sampled from the middle reaches of the Euphrates River between December 2007 and November 2008.

related similarly to either weight or total length in female asp.

Discussion

The present study is the first report on population structure, morphological parameters and reproductive biology of the endemic asp in the Euphrates River from Syria. The number of man-made flow-altering constructions increased significantly in Mesopotamia since early 1970s fragmenting rivers ecosystems, isolating fish populations, manipulating trophic state and changing fluvial geomorphology in many locations (Al-Yamani *et al.*, 2007; Al-Hilli *et al.*, 2009; Sowers *et al.*, 2010). Endemic species, such as asp, *Barbus* sp. and others, are valuable fish for their ecological and commercial impact and their populations need to be studied to

Table 2. Ranges of relative content (oocyte/g) in mature ovaries, oocytes diameters (cm) and distribution in ovaries of females asp (n = 6, two lobes each) samples in mid-March from the middle reaches of Euphrates River

Ovary	Content		Oocyte diameter	
	Right lobe	Left lobe	Right lobe	Left lobe
Anterior	328-529	477-525	1.58-1.71	1.66-2.01
Central	341-620	340-613	1.56-1.92	1.57-1.95
Posterior	322-562	339-561	1.60-1.88	1.61-1.97

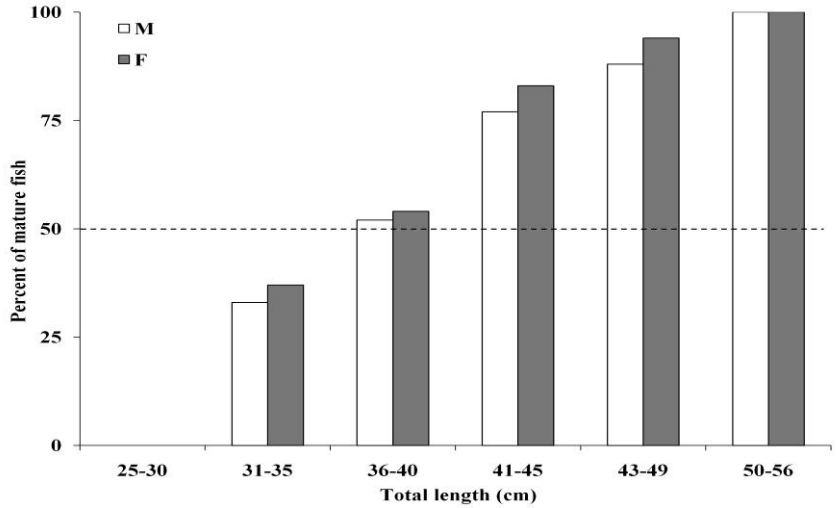

Figure 6. Percentage of mature male (M) and female (F) asp grouped in length.

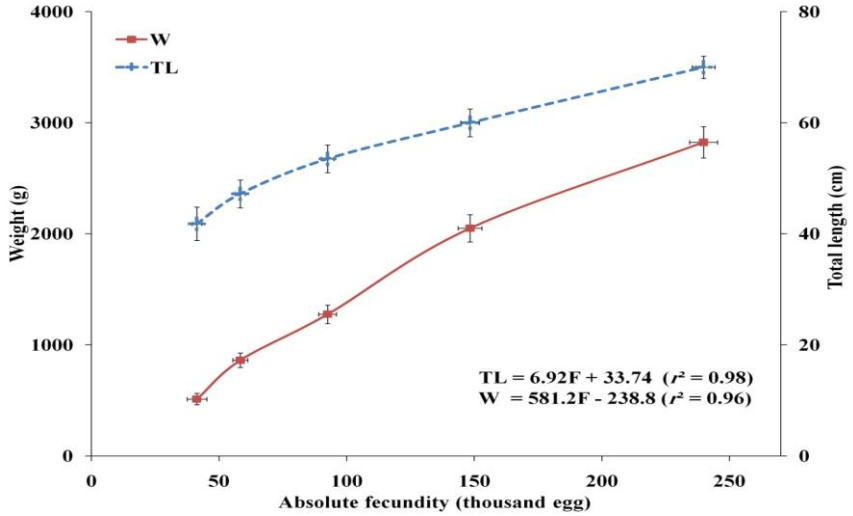

Figure 7. Absolute fecundity plotted against either weight (W) or total length (TL) in female asp (n = 21) sampled during their spawning season from the middle reaches of the Euphrates River.

facilitate fisheries management in this area (Al Hazzaa, 2005; Oymak, *et al.*, 2009).

Regardless of their sex, all asp samples in the studied area have isometric growth. This parameter was calculated as isometric to positively allometric in different locations in the southern section of same River (Al-Dabical and Al-Daham, 1995; Szypuła *et al.*, 2001). Meanwhile, only female asp had a negatively allometric *b* value in the northern part of Euphrates River (Oymak *et al.*, 2011). Changes in growth patterns, computed as the *b* values of the weight–length relationship, may be attributed either to differences in sampling methodology and location, stage of fish maturity, food availability and the influence of environment (Moutopoulos and Stergiou, 2002; Árnason, *et al.*, 2009). Most fish species change their shape as they grow and *b*-values may be different for larval, immature and mature fish. In most cases, growth in length dominates in early life stages while growth in weight becomes relatively more important as fish reach adulthood (Froese, 2006; Árnason, *et al.*, 2009). Previous works sampled older fish than the available in this study and reported that asp can grow up to 7+ years in natural habitats in the southern (Shafi and Jasim, 1982; Szypuła, *et al.*, 2001) and to 9+ years in northern (Oymak, *et al.*, 2011) sections of Euphrates. Meanwhile, observed sex ratio of sampled individuals was not significantly different from parity in our study but biased in favour of males in Atatürk Dam Lake in the same River (Oymak, *et al.*, 2011). Inability to cover all age groups and having biased sex ratio in fisheries stock assessment studies seems to depend mainly on the fishing area and sampling gear selectivity (Catalano and Allen, 2010; Gwinn, *et al.*, 2010). Growth rate and sexual maturity in poikilotherms, including most fish, is a function of temperature and the thermal integral, known as the growing degree-day (°C-day), is recognized to be a reliable predictor of growth and development (Neuheimer and Taggart, 2007). Spreading over latitudes from 30° to 39°N, differences in ranges of water temperature can have profound effect on fish populations in the Euphrates-Tigris Rivers as deduced by comparing our observations with reports from other regions of the same rivers system.

The condition factor ratio varies somewhat at different places and at certain times of the year (Fulton, 1904; Froese, 2006). The general pattern of condition factor temporal changes in adult fishes is well known: a decrease during times of low temperatures and/or low availability of food, an increase towards the spawning season, a sharp decline after spawning, especially in females, and a second increase after spawning (Le Cren, 1951; Froese, 2006). By overlaying seasonal changes of *K* with those of GSI, a shift in time can be noticed between these patterns in the investigated species. A decrease in the fish condition factor was recorded within the spawning season. However, the condition factor of the asp seems to be more related with the water temperature and, more likely, the nutritional condition and availability of food.

Mesopotamian asp reached sexual maturity at an age of 4+ for females with average fork length of 38.7 cm and 3+ for males at 30.2 cm fork length in the northern (Oymak, *et al.*, 2011) and southern (Epler, *et al.*, 2001) reaches of the Euphrates. Our current observation from the middle reaches of Euphrates showed comparable TL at maturity for the asp although female age at first maturity could be younger than those from other sections of the River. European asp reaches sexual maturity at 4+ years with an average total length of 42.5 cm in their native habitats (Teletchea *et al.*, 2009; Krpo-Ćetković, *et al.*, 2010). We also concluded significant correlations between fish length and weight with absolute fecundity for asp in the studied area which were not observed before in northern populations (Oymak, *et al.*, 2011). As reproduction is a major factor to slow growth down in fishes (Charnov *et al.*, 2001; Heino *et al.*, 2008), small females may benefit more from allocating more resources into growth, instead of producing many, large and nutritiously rich eggs (Braga Goncalves *et al.*, 2011). These facts can probably explain the weakening relation between fecundity and body weight in Mesopotamian asp females as they grow older. Our observations on egg size fell within recorded ranges of asp egg diameter from different populations in different sections of Euphrates River during spawning season (Shafi and Jasim, 1982; Oymak *et al.*, 2011) and for European asp as well (Teletchea *et al.*, 2009). It appears that egg diameter in Mesopotamian asp is less affected by populations differences of spawning season, condition factors and growth efficiencies. Egg size is important to offspring survival in many organisms, as offspring arising from larger eggs typically have better condition and greater resistance to starvation (Kamler, 2005, 2008). Hence, the relationships between female size, fecundity and egg size in animals have always attracted the interest of evolutionary ecologists (Parker and Begon, 1986; Hendry and Day, 2003; Kolm and Ahnesjö, 2005).

Asp started spawning as early as January until February in Iraqi water bodies, the southern section of Mesopotamia (Shafi and Jasim, 1982; Epler *et al.*, 2001). Meanwhile, spawning season of asp from Turkey, the northern section of Euphrates-Tigris Basin, start in April and last until May (Oymak *et al.*, 2011). European asp spawning season occurs within April-May when female can have an average absolute fecundity of 200 thousand eggs (Teletchea *et al.*, 2009; Krpo-Ćetković *et al.*, 2010). Our findings showed that the spawning season occurs within February-March in the study area which signifies the latitude effect in terms of temperature on poikilotherms. Temperature is important in the onset of spawning and has a modifying role, particularly in cueing the precise timing of gamete maturation and spawning, providing the capacity for reproductive

cycles to be locally tuned (Wright and Trippel, 2009; Pankhurst and King, 2010). Distinct spawning season can be considered as a characteristic aspect in the biology of asp populations in the middle reaches of the Euphrates.

Although it is not yet known whether the investigated asp are migratory fish, the closely related European asp, *Aspius aspius*, was shown as a rheophilic potamodromous species travelling through long ranges across rivers (Schiemer and Waidbacher, 1992; Fredrich, 2003). Dams and weirs have a strong impact on migration patterns and, ultimately, on population dynamics of these species. By comparing biological characteristics identified in the current study with others on the same species from the other physically-divided sections of the Euphrates-Tigris Rivers, it can be concluded that four decades of geographical isolation for asp populations has possibly created three distinct subgroups; in the northern, middle and southern sections of the Euphrates-Tigris Rivers Basin. Molecular markers of distinct populations need to be investigated and linked with any differences in morphological and biological traits.

Spawning of the European asp, *Aspius aspius*, has been successfully induced by hormonal treatment for commercial culture restocking (Targonska *et al.*, 2010) and their larval stages are managed under controlled conditions with high survival rates (Turkowski *et al.*, 2008). Spawning of few other endemic Mesopotamian fish have been also studied and successfully induced (Al Hazzaa and Hussein, 2003a, b; Şahinöz *et al*., 2007), their early life-stages are controlled (Şahinöz *et al*., 2006; Al Hazzaa and Hussein, 2007) and feeding commercial diets proved efficient (Gökçek *et al*., 2008; Gökçek and Tepe, 2009). It is possible, after understanding more details on the biology of Mesopotamian endemic asp, to apply advanced techniques for restocking this fish in natural habitats and to introduce it as a new species for aquaculture.

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