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Largemouth bass, *Micropterus salmoides*, growth and reproduction in Primera de Palos' lake (Huelva, Spain)

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Abstract. Some aspects of the biology of *Micropterus salmoides* such as growth, population structure and reproduction, were studied in the Primera de Palos' lake. A total of 200 specimens were captured (98 females, 86 males and 16 juveniles) and distributed into seven different age-classes (from 0+ to 6+). Specimens 6+ were exclusively females. The mean values of male length and weight were slightly higher than females ones but the differences were not significant between sexes. The parameters of the von Bertalanffy growth's curve were $L\infty$=503.6 mm, k=0.19, t_0=-1.04 for males and $L\infty$=512.6, k=0.18, t_0=-1.05 for females. The final values of the Gompertz growth's curve for weight were: W_0=36.35, G=10.61, g=0.06 for males and W_0=31.81, G=6.93, g=0.11 for females. Reproduction took place in spring. Females mature older than males, in age-class 2+. The results clearly indicate that the largemouth bass population has acclimatised well to the Primera de Palos' lake, having found environmental and trophic conditions that are favourable to its development.

Key words: biology, black-bass, exotic fish

Introduction

The largemouth bass (*Micropterus salmoides*) is a native fish species in North America, where it inhabits both rivers and still waters (Wheeler & Allen 2003). Largemouth bass is considered the main piscivorous fish of North American freshwater and one of the most important freshwater game fish (Heidinger 1975, Carlander 1977, Doadrio 2001, Waters et al. 2005). It has been introduced into many countries worldwide (García-Berthou 2002). The largemouth bass was first brought in the Iberian Peninsula for fishing purposes in 1955 (Elvira 1995, Godinho & Ferreira 1996, Copp et al. 2004). The current distribution in Spain includes most of the larger river basins (Doadrio et al. 1991, Nicola et al. 1996) and it is considered as a serious threat to native Spanish fish (Elvira 1995).

Primera de Palos is a freshwater small lake of approximately 16 ha, located in the south west of Spain. The small lake is predominantly between 2 and 2.5 m deep and its water level suffer considerable fluctuations. Water temperatures ranges are from 15 to 25ºC. The lake has recently been environmentally restored and is included in the network of protected areas of Andalusia as a "Natural Place" (Paraje Natural).

The main objective of the present study is to research some aspects of largemouth bass biology in the Primera de Palos' lake, such as its growth, population structure and reproduction.

Material and Methods

The samples were collected monthly from September 2002 to August 2003. Fishes were collected by boat or from Primera de Palos' lake shores, using a fishing rod with different

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sizes of artificial lures. Captured specimens were frozen, and for each specimen, total length (TL), total weight (W) and eviscerated weight (W_e) were determined (S o r i g u e r et al. 2000).

From each specimen, eight to ten scales were collected from the body section between the lateral line and the dorsal fin (G o d i n h o & F e r r e i r a 1993, D e v r i e s & F r i e 1996). Scales were cleaned under running water and immersed in NaOH (4%) to remove mucus and to clean structures. We did not take damaged scales or scales with doubtful annuli (S c h u l z & L e a l 2005). Growth was analysed by scale reading and length frequency distribution (W e a t h e r l e y & G i l l 1987).

Total or eviscerated weight is assumed to indicate condition, fatness, or well-being of animals, based on the assumption that the heaviest specimens of a given length are in better conditions than other ones (B a g e n a l & T e s h 1978). The variation in the condition of the specimens through the different seasons was studied using an analysis of covariance (ANCOVA) of the total weight, with the variable length being the covariate.

The instantaneous rates of growth in length (Li) and the instantaneous rates of growth in weight (Gi) from mean lengths and weights computed for males and females, were separately calculated using the expressions:

$$L_i = \ln L_{t+1} - \ln L_t$$
$$G_i = \ln W_{t+1} - \ln W_t$$

Where L_{t+1} and W_{t+1} are mean length and mean weight respectively, of the age-class t+1, and L_t and W_t, mean length and weight of the previous age-class (S o r i g u e r et al. 2000).

To describe the growth pattern we followed the von Berfalanffy and Gompertz models (R i c k e r 1975, D i c k i e 1978). The equation of von Bertalanffy growth function was:

$$L_t = L_\infty (1-\exp^{-k\,(t-to)})$$

Where L_t is mean standard length at *t* age (mm), *t* is age (years), L_∞ is the asymptotic standard length (mm), t_0 is the origin of the growth curve and *k* is sometimes considered a stress factor (M o u r e a u 1987).

The Gompertz growth equation was:

$$W_t = W_o \,.\, \exp^{\{G\,(1-\exp[-gt])\}}$$

Where W_t is mean weight at *t* age (g), *t* is age (years), W_o is weight at the conventional time $t_{0.}$ *G* is the instantaneous rate at time t_0 and *g* describes the rate of decrease of *G* (P r z y b y l s k i & G a r c í a - B e r t h o u 2004). The product *Gg* is the specific instantaneous size at time t_0 (P r a g e r et al. 1994).

V a u g h a n & K a n c i r u k (1983) recommended the use of non-linear-techniques to fit the von Bertalanffy growth function. For this reason, to fit both models a non-linear least-squares regression with Marquardt´s algorithm was used (M a r q u a r d t 1963) as implemented in the Program FISHPARM of the Fisheries Science Applications System package (S a i l a et al. 1988). Models have been estimated for each sex using the mean length and weight values from all the age groups with a sufficient representation in the sample (G a r c í a - B e r t h o u & M o r e n o - A m i c h 1993).

Sex determination was done by direct gonad observation. The specimens were sexed on capture into three categories: males, females and juveniles. Gonads were weighed (W_g) with an accuracy of 0.0001g. Ovaries were preserved whole in Gilson's fluid after weighing (Bagenal & Braum 1978).

Age at maturity was calculated by the percentage of mature females in each age-class using the formula of Weatherley & Gill 1987. The number of oocytes present in each gonad was counted using a system of subsampling by area (Granado-Lorencio 1996). Their diameters were measured in mm using a screened ruler. Potential fecundity was estimated by the number of oocytes present in the ovary and absolute fecundity was estimated by the number of mature eggs present in the ovary, being mature eggs those hydrated eggs with diameters between 0.7–1.3 mm.

The spawning season was assessed by studying the variation of the gonadal weight through the different studied seasons, using an analysis of covariance (ANCOVA) of the gonadal weight, with the variable length being the covariate. No analysis was applied on winter data because very few specimens were caught. To avoid the use of negative values, all variables were previously multiplied by 10^6 (García-Berthou & Moreno-Amich 1993).

All data were analysed with the statistical package SPSS 13.0 (2004). Morphometric data were log-transformed and statistical significance were determinated as $p<0.005$ (Meador & Kelso 1990).

Results

A total of 200 specimens were caught (98 females, 86 males and 16 juveniles) and distributed into seven different age-classes (from 0+ to 6+) (Table 1). The maximum age-class observed was 6+.

The most important values for males length and weight were slightly higher (TL: 269 mm, W: 260 g) than for female ones (TL: 265 mm, W: 250 g) but the differences were not significant between sexes in all the studied age-classes (TL: $F_{1.176}=2.107$, $p>0.05$; W: $F_{1,174}=3.653$, $p>0.05$). The most important specimen quantities of the *Micropterus salmoides* population in Primera de Palos' lake were younger than five years old. Specimens 6+ were exclusively feminine.

Table 1. Number of specimens (n), mean total length (TL) at age, standard deviation (SD) and mean total weight (W) for the studied population of *M. salmoides* in Primera de Palos' lake.

Age-class	Juveniles									
	n	TL (mm)	SD	W (g)	SD					
0+	16	89	30	12	7					
	Males					Females				
	n	TL (mm)	SD	W (g)	SD	n	TL (mm)	SD	W (g)	SD
1+	5	182	17	82	20	10	174	22	68	21
2+	13	211	14	131	23	19	212	14	132	28
3+	60	282	14	285	37	47	278	16	270	47
4+	7	318	16	362	59	20	314	10	336	71
5+	1	380	-	691	-	-	-	-	-	-
6+						2	420	28	934	221

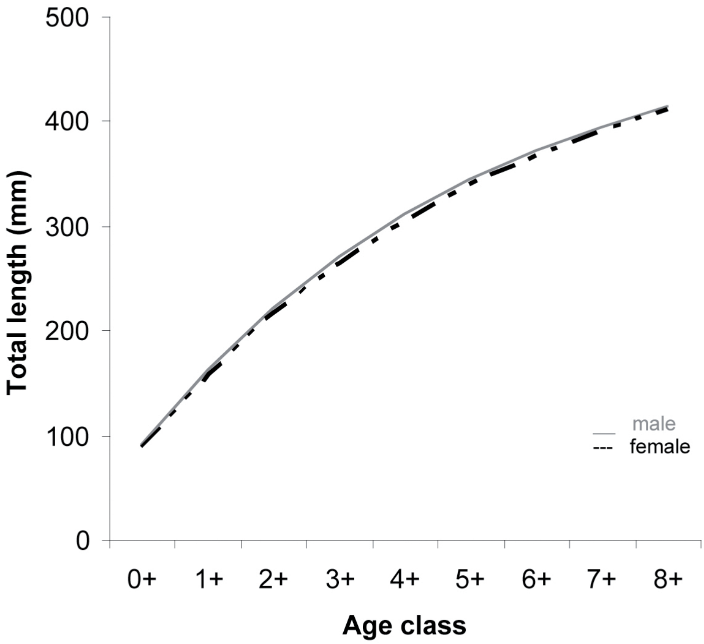

Fig. 1. Von Bertalanffy's length growth function calculated for both, male and female specimens of largemouth bass population in Primera de Palos' lake.

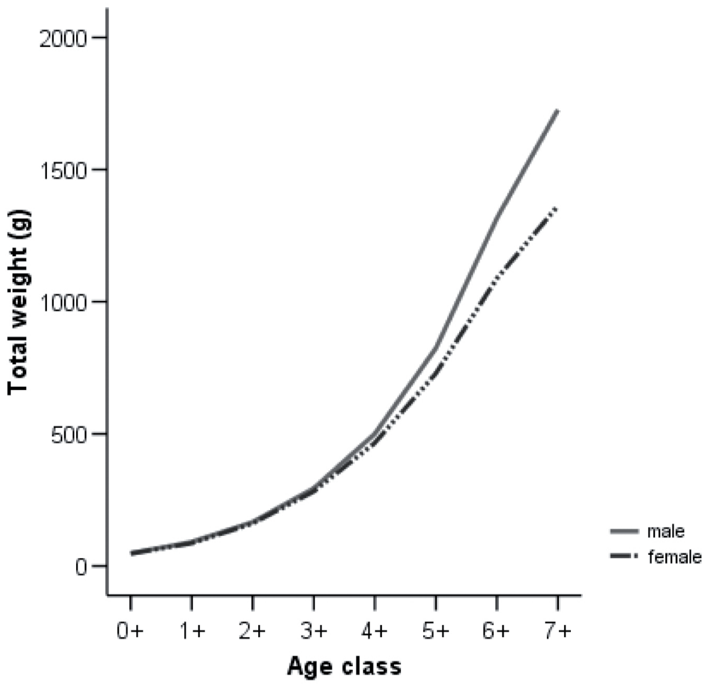

Fig. 2. Gompertz's weight growth function calculated for both male and female specimens of largemouth bass population in Primera de Palos' lake.

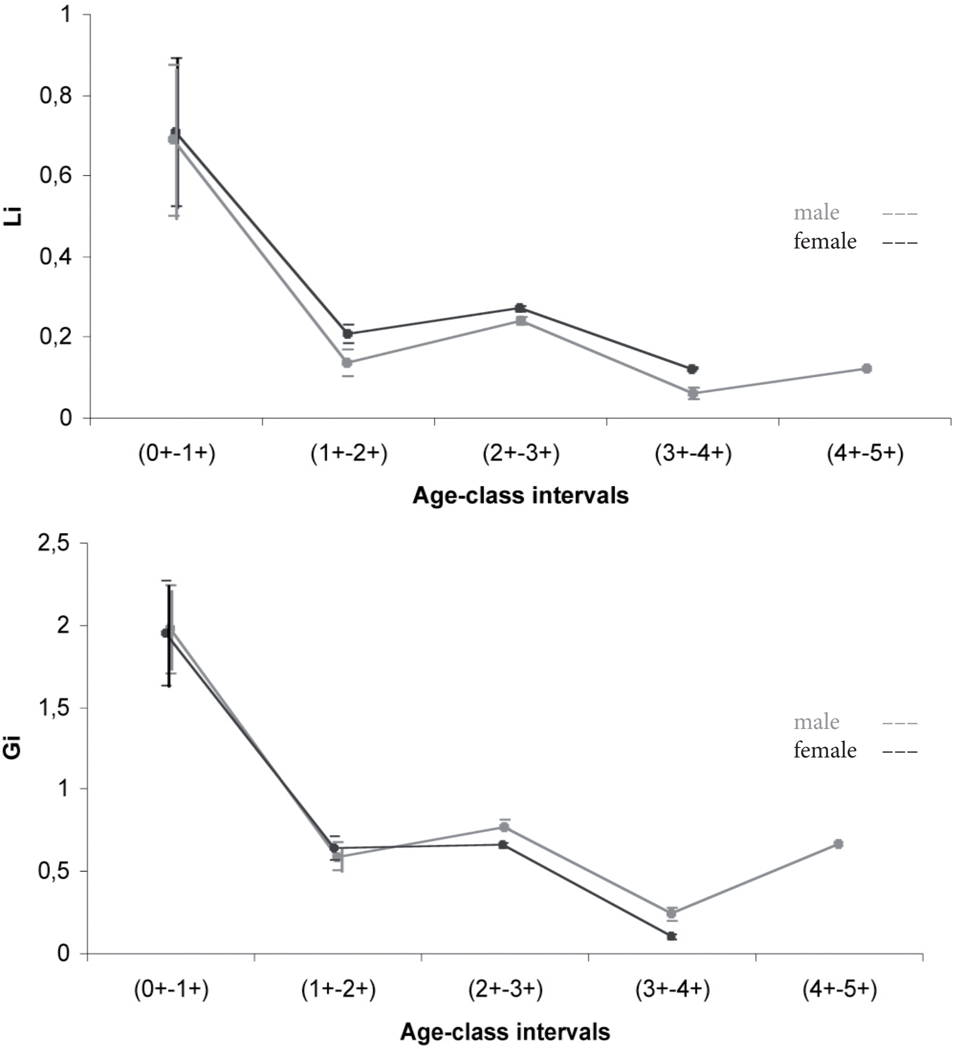

Fig. 3. Evolution of the instantaneous growth rate in length (A) and weight (B) and confidence limits calculated for male and female specimens of largemouth bass population in Primera de Palos' lake.

Length-at-age was adequately described by the von Bertalanffy model. The parameters of the von Bertalanffy growth's curve were: $L\infty$=503.6 mm, k=0.19, t_0= -1.04 (R^2=0.989) for males and $L\infty$=512.6, k=0.18, t_0= -1.05 (R^2=0.991) for females (Fig. 1). Both sexes showed a similar growth in length and the light differences in growth between sexes were not significant ($F_{1.128}$=2.579, p>0.05).

The final values of the Gompertz growth's curve for weight were: W_0=15.76, G=3.66, g=0.49 (R^2=0.98) for males and W_0=10.66, G=3.84, g=0.58 (R^2=0.99) for females (Fig. 2). Both sexes showed a similar growth in weight. From the age-class 3+ and older, male fish get its maximum weight earlier than females. However, those differences were not significant ($F_{1.128}$=0.022, p>0.05).

Table 2. Results of ANCOVA and analysis of the simple effects carried out on *Micropterus salmoides* gonadal weight data. Bonferroni contrast (α=0,05) corresponds to the different studied seasons: μ_1 is the mean gonadal weight of specimens captured during autumn, μ_3 is the mean gonadal weight of specimens captured during spring and μ_4 is the mean gonadal weight of specimens captured during summer. μ_{female} corresponds to the mean gonadal weight of female fish and μ_{male} is the mean gonadal weight of male fish. Total length is the covariate. All variables (dependent and covariate) were log-transformed. df: degrees of freedom.

	df	F	p
Regression	1.147	336.851	<0.001
Sex	1.147	221.565	<0.001
Time	2.147	72.196	<0.001
Interaction	2.147	1.054	0.351
		$\mu_{female} > \mu_{male}$	
		Males: $\mu_1 = \mu_3 > \mu_4$	
		Females: $\mu_1 = \mu_3 > \mu_4$	

* Juveniles were excluded from the analysis. 5+ and 6+ individuals were eliminated because representative of both sexes were not available. Analyses were not applied on winter data because very few specimens were caught.

Table 3. Potential fecundity (PF) and absolute fecundity (AF), mean, maximum and standard deviation for females of *Micropterus salmoides*.

Autumn		Spring		Summer	
PF	AF	PF	AF	PF	AF
19		36		32	
31194.64	0.87	9981.81	690.82	8253.35	-
51246.00	84.00	69258.00	16580.00	35603.00	-
21084.43	8.53	15456.11	2145.70	11010.47	-

The development of the instantaneous growth rate in length and weight (Fig. 3) was similar in males and females. The highest value was obtained in the first year of life, and then, the instantaneous growth rate suffered a sudden descent and remained low, with small fluctuations throughout the life cycle of the population.

On average, males matured one year earlier than females in the age-class 1+. Females presented ovaries with mature eggs from the age-class 2+. The results of ANCOVA and analysis of the simple effects carried out on largemouth bass gonadal weight data (Table 2) showed no significant interaction season*sex ($F_{2.147}$=1.054, p>0.05). The effect of sex was significant on gonadal weight, after leaving out the covariate effect. Throughout the whole reproductive period, females invested more energy in gonadal development than males. Variables with significant seasonal variation could be accurately described by a Bonferroni contrast. Thus, for mature fish in both sexes, the maximum value of gonadal weight was got during the spring season.

The oocyte diameters were significantly different throughout the annual cycle. The smallest oocytes, belonging to class 1 and 2 (with diameters between 0.1–0.3 mm and 0.4–0.6 mm, respectively) varied significantly throughout the seasons (K-W: χ^2=54.155, p<0.05 for class 1 and K-W: χ^2=44.080, p<0.05 for class 2) (Fig. 4). Similarly, classes 3 and 4 (with diameters between 0.7–0.9 mm and 1–1,3 mm, respectively) presented significant differences throughout the annual cycle (K-W: χ^2=59.199, p<0.05 for class 3 and K-W: χ^2=59.199, p<0.05 for class 4).

The mean, maximum and standard deviation of potential and absolute fecundity in female specimens, during the different studied seasons, are in Table 3. In spring, absolute

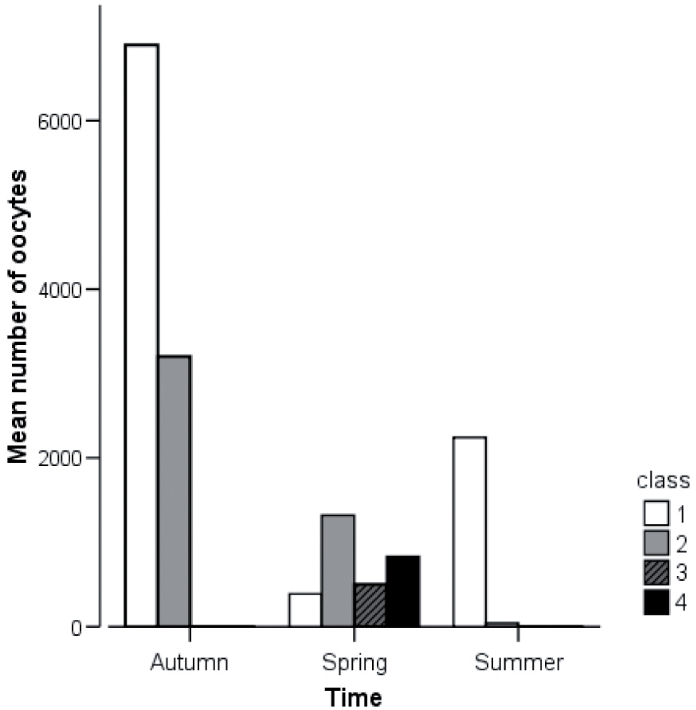

Fig. 4. Oocyte size histogram calculated for female of largemouth bass in Primera de Palos' lake. (Class 1: oocyte diameter between: 0.1 and 0.3 mm; Class 2: 0.4–0.6 mm; Class 3: 0.7–0.9 mm; Class 4: 1.0–1.3 mm).

fecundity values were bigger than those in autumn. During the summer period we did not find any mature eggs.

Class 1 was predominant in late summer and early autumn. Classes 3 and 4 were more numerous in spring. The maximum gonadal development took place during spring, with 15.10% of class 3 oocytes and 33.45% of class 4 oocytes. The highest absolute fecundity value was registered in a female specimen captured in March presenting a total length of 440 mm and a total weight of 1 090 g, with a gonadal weight of 41.60 g and a total of 16 580 mature eggs (belonging to class 3 and 4).

Results from gonadal development and egg size frequency distribution showed that spawning took place in spring when water temperature were warmer than in other seasons. In late spring and early summer, gonadal development came in a quiescent phase. Egg formation began in late summer, with predominance of oocytes with diameters between 0.1 and 0.3 mm (class 1).

Discussion

The fish community of Primera de Palos' lake integrates populations of largemouth bass (*Micropterus salmoides),* common carp (*Cyprinus carpio*), eel (*Anguilla anguilla*), mosquito fish (*Gambusia holbrooki*) and iberian loach (*Cobitis paludica*), but largemouth bass population dominates the community (95% of the sample) (L. E n c i n a , pers. comm.).

In this small lake, the largemouth bass population is ageing well, without fragmentation and with individuals in all the age-classes. The size-frequency distribution of largemouth bass presents an amplitude of age-classes intermediate to those found in other studied systems. Comparing to other European systems, the analysed population presents more age-classes than those registered in several populations of Portugal (G o d i n h o & F e r r e i r a 2000) and is similar to those found in Lake Trasimeno in Italy (L o r e n z o n i et al. 1996, 2002). Outside the European continent, studied population shows less age-classes than those known in lake Manyame, Zimbabwe (B e a m i s h et al. 2005). On the other hand, there were certain similarities with the observed structures of the largemouth bass populations of Tadenae lake, Canada (M a r a l d o & M a c C r i m m o n 1979).

The growth of largemouth bass in Primera de Palos' lake registered the highest values during the first year, presenting higher lengths than the American mean length (B e a m e s d e r f e r & N o r t h 1995) and lower lengths than the Portuguesse mean length (G o d i n h o & F e r r e i r a 1993, 2000) and similar lengths to those found in southern states of the United States (B e a m e s d e r f e r & N o r t h 1995). Therefore, the growth is faster than in other freshwater fish species, with male and female specimens getting a 50% of their maximum length in their first three years of life, with fast growing of the larval fish into size classes less vulnerables to predation (W o o t t o n 1990, W i n f i e l d & N e l s o n 1991) and early stages characterized by high growth rates (J o b l i n g 1995). In addition, among other factors, the growth of largemouth bass depends on the water temperature, begins in temperatures over 10ºC and reaches maximum values with temperatures over 25ºC (C o u t a n t 1975). These temperatures happen in over ten month long periods in Spanish southern waters, and this extended growth period is probably the main reason for the high growth rates found. The largest fish recorded during this study was a female of 440 mm in length (age-class 6+) and 1 090 g in weight.

Although sexual dimorphism in the size of largemouth bass was already debated in the first studies published on this species (H e i d i n g e r 1976) and larger females were observed only occasionally (A l e s s i o 1981), in Primera de Palos' lake, the comparison between sexes did not show significant differences.

The $L\infty$ values of the von Bertalanffy growth's equation obtained for the population of largemouth bass studied were bigger than those found in Zimbabwe (B e a m i s h et al. 2005) or Japan (F r o e s e & P a u l i 1998) and were similar to the obtained values in Italy (L o r e n z o n i et al. 1996), in Lake Rebeca, USA (F r o e s e & P a u l i 1998) and those found in high latitude American populations (B e a m e s d e r f e r & N o r t h 1995). Nevertheless, k values were lower than those found in other European populations. In Primera de Palos' lake, the largemouth bass population grows slowly reaching a big size (weak k and high $L\infty$) like the populations studied in North America.

According to the results of B e a m i s h et al. (2005), sexual maturity is reached at 180 mm and 75 g in the case of males (age-class 1+) and at 230 mm and 125 g in the case of females (age-class 2+). In Primera de Palos' lake, like in other studied populations (B e a m i s h et al. 2005), females of largemouth bass invested more energy than male specimens in gonadal development. Sex-ratio changed throughout the life span of this population probably as a result of the different reproductive stress suffered by males and females (G r a n a d o - L o r e n c i o 2000).

In Primera of Palos' lake the water temperature is getting high from March to August, being the spring the most favourable period in the ecosystem for reproduction, when temperatures vary between 20–25 ºC. As reported in the literature, largemouth bass can initiate its reproductive period in temperate zones between late winter and early spring, due to this water temperature is a primary factor in reproduction of this species (K e r r & G r a n t 1999, L o r e n z o n i et al. 2002).

Potential fecundity mean values were similar to those described for this species in the Iberian Peninsula, with values ranging from 10 000 to 11 000 eggs (Doadrio 2001). The maximum absolute fecundity value in Primera de Palos' lake was 16 580 mature eggs found in a 440 mm long female, a high value in comparison with the mean value referenced. The maximum gonadal weight for females was recorded in spring just before spawn and the increase in testicular weight occurred at the same time that in ovaries. Spawning takes place in spring once a year, like in other European communities (Lorenzoni et al. 2002) when egg sizes are big, the water temperature is warmer than in other seasons and the nutritional resources in the small lake have increased considerably. The drop of gonadal weight in both sexes after spring suggests that reproduction takes place in a narrow period, this fact has also been described in other populations of largemouth bass (Wootton 1990, Rosemblum et al. 1994, Lorenzoni et al. 2002).

In the Primera de Palos' lake, largemouth bass population has been acclimatised well. The southern Spanish waters present excellent possibilities for largemouth bass growth, with favourable environmental and trophic conditions to its development. Unfortunately, the diversity of the native freshwater fish communities is threatened with the introduction of exotic species (Elvira 1995). The knowledge of the alteration caused by exotic species could be the base to prevent successive introductions and to decide methods to control them. On the other hand, to limit further ecological damage, recreational anglers are urged to stop additional introductions of *Micropterus salmoides*.

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