AGE-STRUCTURE, GROWTH AND REPRODUCTION OF THE INTRODUCED PUMPKINSEED *(Lepomis gibbosa,* L. 1758) IN A TRIBUTARY OF THE GUADALQUIVIR RIVER (SOUTHERN SPAIN).

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ABSTRACT

The age structure, growth and reproduction of *Lepomis gibbosa* (L. 1758) (= *L. gibbosus)* was studied from March 1993 to September 1994 in a tributary stream of the Guadalquivir River. The maximum age observed was 5+ years both in males and females. In the 0+ group, seasonal growth began in February and lasted 8 months. Males and females matured during their second year of life (1+). There were no significant differences in the overall sex-ratio, which was 1:1.1 (677 males to 745 females). Reproductive activity started in March/April and lasted until August/September. During this period, females spawned *2* batches of eggs. The relationship between fecundity (*F*) and fork length (&, mm) was: F=5.09 $L_F^{2.79}$ (1993) and F=85.81 $L_F^{\ 56}$ (1994). The maximum contribution to the fecundity of the population was observed in the 4+ female group. The reproductive effort was maximun in the 3+ group. Compared with the American pumpkinseed populations that have been studied, the life-history patterns of this stock are characterized by low annual growth, early maturity, reduced longevity and low fecundity.

Key words: introduced species, life history, age, growth, reproduction, sunfish.

RESUMEN

La estructura por edades, el crecimiento y la reproduccidn de Lepomis gibbosa *(L. 1758)* (= L. gibbosus) *fue estudiadu desde marzo de 1993 hasta septiembre de 1994 en un afluente del río Guadalquivir. La máxima edad observada tanto en machos como en hembras fue 5+. El grupo de edad 0+ comenzd su crecimiento en febrero y se extendid durante 8 meses. Tanto machos como hembrus muduraron durante su segundo año de vida (1+). No se encontruron diferencias significativas entre la cantidud de machos y hembrus capturudas, sexratio de 1: 1.1 (677 machos frente 745 hembras). La actividud reproductiva comenzd en marzo/abril y se extendid hasta agosto/septiembre. Durante este período reproductivo, las hembras deposituron dos grupos de huevos. La relación entrefecundidad (F) y longitudfurcal (LF, mm) fue: F=5.09* $L_F^{2\ 79}$ *(1993)y F=85.81* $L_F^{1\ 56}$ *(1994). La contribución máxima a la fecundidad fue observadu en el grupo de hembras de edad* **4+.** *El esfuerzo reproductivofue máximo en el grupo 3+. Comparado con el resto de pobluciones americanus de perca sol, el ciclo de vida de nuestra población se caracteriza por un crecimiento anual bujo, unu madurez temprana, una longevidad reduciduy una buju fecundidad.*

Palabrus clave: especies introducidas, ciclo de vida, edud, crecimiento, reproducidn, pez sol.

INTRODUCTION

Among vertebrates, the introduction of freshwater fish species have been among the most numerous. Their impact on native fish fauna and their ecosystems are, however, among the least documented. The consequences of such introductions are still highly controversial and have been the subject of fierce debate between fishery managers and conservationists (Holcik, 1991; Stewart, 1991; Crivelli 1992; Allan & Flecker, 1993; Frissel, 1993). One reason for this state of affairs is that the introduction of species, even when it is done intentionally, is rarely followed by a monitoring programme to determine the biology, behavior and impact on the host fish community and its ecosystem.

The pumpkinseed, *Lepomis gibbosa* (L. 1758) (= *L. gibbosus)*, a North-American fish species, was first introduced into Europe in 1880 (Vooren, 1972). Nowadays it is widespread from the United Kingdom to Italy (Vivier, 1951; Tandon, 1977a,b; Groot, 1985) including Spain (Sostoa *et al.*, 1987; Zapata & Granado-Lorencio, 1993; Gutierrez-Estrada, 1997). In Eastern Europe the species is found from the Black Sea to Greece (Crivelli & Mestre, 1988).

The pumpkinseed has been studied in its natural geographic range (Werner & Hall, 1979, Collins, 1989), but little is known about its biology outside its natural distribution. Papadopol & Ignat (1967), Tandon (1977a,b) and Crivelli & Mestre (1988) studied the age, growth and morphology of the pumpkinseed in the lower Danube, Hungary, Italy and Camargue respectively. In the Iberian Peninsula, Rodríguez-Jiménez (1989) and Godinho *et al.* (1997) examined stomach contents of populations of this species and Braband & Saltveit (1989) and Zapata & Granado-Lorencio (1993) studied several ecological aspects of reservoir populations.

The aim of this article is to provide first information on the annual cycles of growth, reproduction and age-structure of a population of *L. gibbosa* introduced into a stream in southern Iberian Peninsula. The results form part of a more extensive study of this species (Gutíerrez-Estrada, 1997).

MATERIAL AND METHODS

The study area was a small tributary (126.9 km long) of the Guadalquivir River (37" 55' N 5º 0' W). Its flow is regulated by three dams: Sierra Boyera, Puente Nuevo and La Breña. The study area covered a section 20 km in length located between Puente Nuevo and the Breña Reservoir (Fig. 1). Here, pumpkinseed coexist with three autochthonous species: *Barbus sclateri*, *Chondrostoma polylepis willkommi*, *Cobitis paludica*, and four introduced species: *Cyprinus carpio*, *Gambusia holbrooki*, *Micropterus salmoides* and *Oncorhynchus mykiss*.

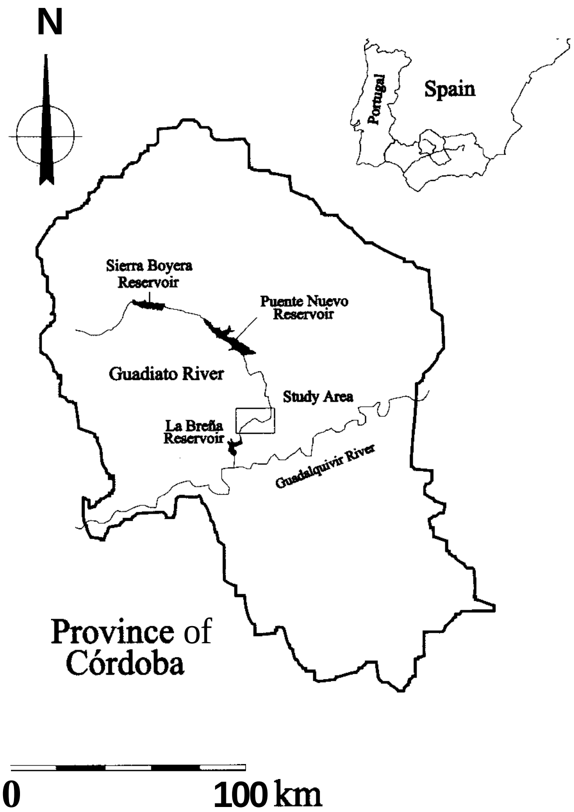

Figure 1. Map of the study area, showing the location of the sample site. *Mapa del área de estudio con indicación del lugar muestreado.*

During the study period (March 1993 to September 1994) the hydrological flow of the tributary reached its maximum between October and March. From June/July until September/ October flow ceased and the river was reduced to a series of isolated pools.

Specimens were electrofished weekly during the reproductive period (March-September) or monthly during the rest of the year. The fishes were immediately transported to the laboratory where their fork length (L_F, mm) and sex (males, female or immature) were recorded. Six to eight scales from the left side of the body, between the

Table 1. Mean backcalculated and observed fork lengths (mm) for *L. gibbosa* males and females (sexes combined). *Longitudes furcales (mm) medias retrocalculadas y observadas para machos y hembras de* L. gibbosa *(sexos combinudos).*

BACKCALCULATED LENGTHS (years)

Age at capture	**n**	**I**	**II**	**III**	**IV**
1+	10	32			
2+	8	42	*71*		
3+	3	38	94	103	
4+	1	25	95	104	109
Mean		33	82	104	109
±95 % CL		± 1.8	± 3.0	±1.8	
Annual growth			49	22	*5*
Instantaneous growth rate			0.91	0.24	0.05

OBSERVED LENGTHS (years)

	I	**II**	**III**	**IV**
Mean	29	88	95	112
f95 *% CL*	± 1.86	± 4.68	± 6.14	± 1.59
Annual growth		59	7	17

lateral line and dorsal fin, were removed and dry mounted between two slides for ageing study using a microfilm reader. Back-calculations were made as descibed by Le Cren (1947). Von Bertalanffy growth parameters were calculated using a linear regression method (Stamatopoulos & Caddy, 1989).

The testis were dried to constant weight (0.1 mg) (24 h) at 80 "C. Ovaries were used to determine absolute fecundity and ovary development, and were then dried in the same way as the testis and weighed. After removal of gonads, specimens were eviscerated and dried at 80 °C for 24 h.

In order *to* compare our results with those of others authors, the linear regression between fork length (L_F, mm), length at the end of the scaled body (L_S, mm), and total length with closed caudal lobes (L_T, mm) was calculated for 41 specimens captured in winter.

Seasonal growth was studied using mean lengths of the 1993 to 1994 cohorts caught throughout the period of study.

Somatic condition (K) was estimated for males and females using the formula:

$$K = W/ L_F^{\ 3}$$

where W is the dry weight of the eviscerated fish (0.1 mg).

Gonad development was assessed using the gonadosomatic index (I_G):

$$I_G = 100\ (W_G/W)$$

where W_G is the gonad dry weight (0.1 mg).

Fecundity was estimated gravimetrically (Bagenal & Braum, 1978). There were no significant differences (t-test, P>0.05) in either egg diameter and number of eggs in relation to their position in the gonad, or between the two ovaries. Therefore, all eggs present in **a** subsample from the mid-portion of each preserved ovary were counted together measured under a stereomicroscope with an ocular micrometer.

The reproductive effort (E,) was determined as the relative annual investment in somatic growth and reproduction by age-group:

$$E_R = W_G / (W_G + W_I)$$

where W_G = ovary dry weight (0.1 mg) and W_I – somatic weight increment (dry weight, 0.1 mg) in the last year of life (Mills & Eloranta, 1985)

RESULTS

Age and growth

Male and female specimens caught in winter comprised six age-groups (0+ to 5+). The maximum fork length observed for males, 132 mm, was observed in July 1994 (age *5+)* while that of females was 135 mm (age 5+), observed in August 1994. The relationships between fork length (L,) and total length (L,) or standard length (L_F)follow the equations below:

$L_S = 0.7724 L_F^{1.013}$ r^2=99.72% n=41 P<0.05

$L_T = 1.0389 L_F^{1.002}$ r^2=99.95% n=41 P<0.05

$L_S = 0.7432 L_T^{1.011}$ r^2=99.80% n=41 P<0.05

A new annulus on the edge of scale were observed in some specimens at the end of winter but were most evident during the spring and by 1 April it were present in 100% of specimens. Therefore, 1 April was considered to be the hatching date.

The best fit between fork length and the oral scale redius [r, micrometer units (m.u., 1 mm = 62 m.u.)] was:

$L_F = 2.0468\, r^{0.6884}$ (r^2=96.42% n=50 P<0.05)

There were no significant differences (*Mann-Whitney* test; P>0.05) between the mean back-calculated length between years or sexes, therefore all the data was pooled (Table 1). There were no significant differences *(Mann-Whitney* test; P>0.05) between the mean observed and back-calculated lengths in any group (see Table 1), therefore Von Bertalanffy's growth parameters were calculated using mean observed lengths for both sexes. The equation was:

$L_P = 117.8\,[1-e^{(-0.869(t-0.622))}]$

L_∞ = 117.8 ± 0.29 (95% Confidence Limit - CL-) mm and t_0 = 0.622 ± 0.004 (CL) years.

The longest growth period was the 0+ group, which grew for 8 months (February to September).

The somatic condition of both sexes increased from April/May to August/September and decreased after September (*Tukey* test, P<0.05) (Fig. 2). Thereafter, their condition increased and reached their highest values in April/May (males and females). The minimun index value was observed during autumn/winter.

Reproduction

Both sexes matured in their second year of life (1+), reaching lengths of 41 mm (L,) in males and 62 mm (L,) in females.

There were no significant differences *(binomial test with normal approximation,* P>0.05) in the overall sex ratio of the 677 males to the 745 females.

The general cycle began with a quiescent period of about 8 months (August to March), after which the growth of gonads was rapid and the I_G reached its maximum in April/May 1993 (males and females). From this maximum, I_G progessively decreased, with some oscilations, until the end of the reproductive period in July/August, marking the next quiescent period. In March (males) and April (females) 1994, the I_G increased rapidly, reaching its maximum in April (males and females). This variable then decreased progessively, reaching minimum values in June.

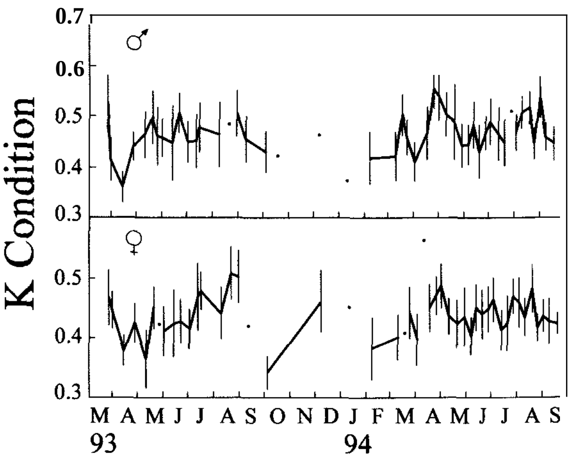

Figure 2. Seasonal changes in somatic condition **(k)** for *L. gibbosa* males and females of. Mean and 95% CL for samples of **5** or more fishes. *Cambios estacionales en la condicidn somatica (k) en machos y hembras de* L. gibbosa. *Media y límites de confianza al 95% para muestras con 5 o más individuos.*

Following, a second period of gonad activity was observed in both sexes, with a second peak in July. The variable I_G then decreased until the next quiescent period. The second period of gonad activity was less important than the first one (Fig. 3).

Maximum I_G values (mean ± CL) for females (1993: I_G = 15.41 ± 2.6; 1994: I_G = 15.69 ± 2.1) were as much as 10 or 11 times larger than those of males (1993: I_G = 1.19 ± 0.10; 1994: I_G = 0.89 ± 0.19)

Not all ovaries coincided in their stage of development, but the frequency distribution of egg diameters shown by eight females of similar lengths showed a representative sequence of events (Fig. 4a-h). During the quiescent period, ovaries displayed one mode of transparent immature eggs (0~0.25 mm) (Fig. 4a). In April/May, ovary activity started and the distribution veered towards the right (Fig. 4b-c). In mid-April, a bimodal distribution appeared, one made up of transparent eggs which always measured less than 0.25 mm and the other of opaque eggs (Fig. 4d). At the end of May the mode with opaque eggs divided, to give both opaque oocytes and yolky eggs (0.85 ± 0.15 mm; mean ± CL) (Fig. 4d). From this moment on the opaque egg mode reached sizes of 0.90 ± 0.20 mm (Fig. 4e). Spawning then occurred (Fig. 4f). In a second reproductive event, the rest of opaque eggs grew to a size of 1.09 ± 0.06 mm (Fig. 4g). In some gonads there was reabsorption of eggs (F) during this second mode, observed in September (Fig. 4h).

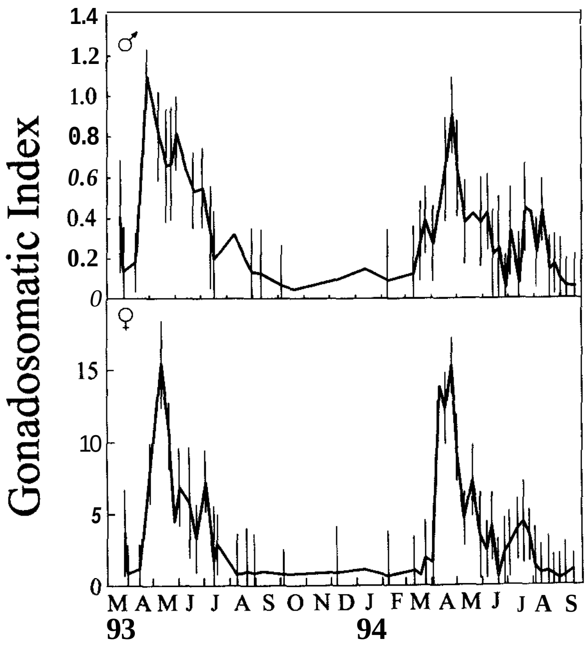

Figure 3. Seasonal changes in gonadosomatic index (GSI) for males and females of *L. gibbosa*. Mean and 95% CL for samples of 5 or more fishes. *Camhios estacionales en el índice gonadosomatico (IGS) en machos y hembras de* L. gibbosa. *Media y límites de confianza al 95% para muestras con 5 o más individuos.*

The number of opaque plus yolky eggs was regressed against length (R_F). Data from the two spawning periods were not pooled as there were significant differences in the equations obtained for each year (ANCOVA, P<0.05). The regression equations for the 1993 and 1994 reproductive periods were:

$$F = 5.09\, L_F^{\,2.79} \quad (r^2=36.03\% \quad n=83 \quad P<0.05)$$

$$F = 85.81\, L_F^{\,1.56} \quad (r^2=35.11\% \quad n=109 \quad P<0.05)$$

The reproductive effort increased progressively with age (Table 2). Maximum values were found at age 5+, but in very few specimens. Thus, age-groups 3+ and 4+ showed the maximum reproductive effort.

DISCUSSION

Fish in this population show high annual growth in comparison with others European populations (Tandon, 1977a,b; Crivelli & Mestre, 1988). However, growth it was extremely low compared to similar data published for its native range (Parker, 1958; Carlender 1977; Crivelli & Mestre, 1988; Zapata & Granado-Lorencio, 1993). Variations in fish growth can be explained as an adaptative response to different environmental conditions (Nikolsky, 1963; Purdom, 1979; Wootton, 1990). The population studied is located in latitudes where temperature allows growth to occur for 6 months a year. In the Guadiato River, the pumpkinseed tolerates maxi-

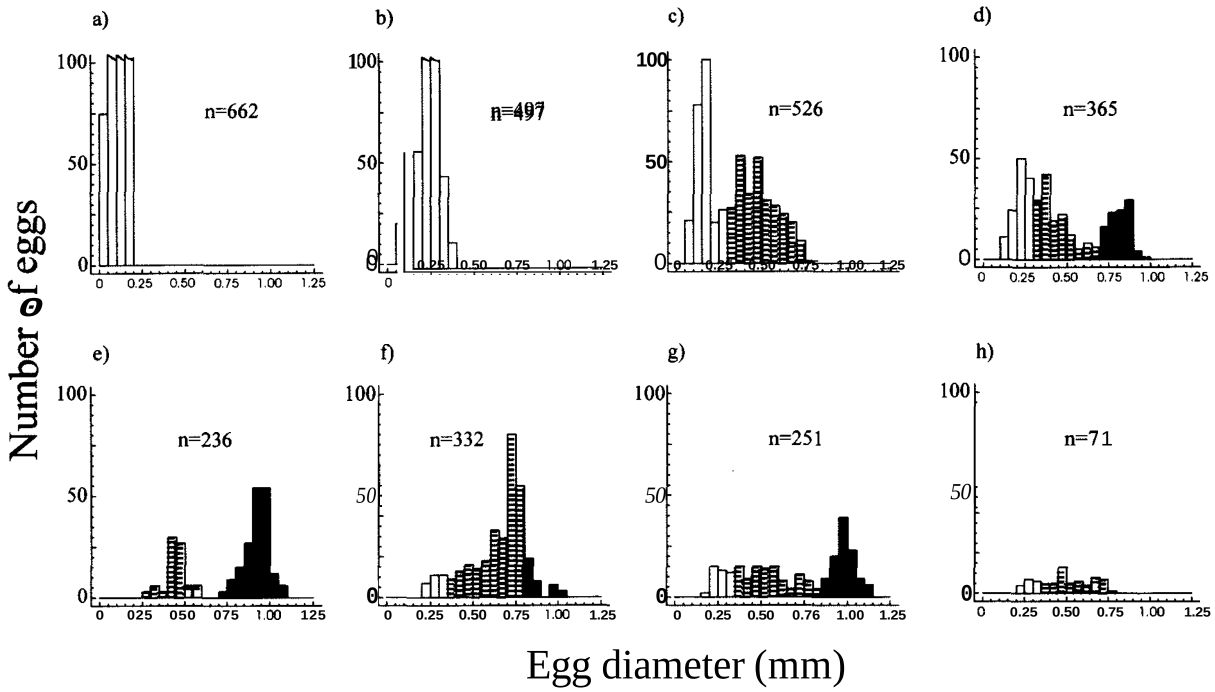

Figure 4. Size-frequency distribution of eggs from eight *L. gibbosa* females before, during and after the spawning period. White polygons represent immature oocytes; dotted polygons show maturing oocytes and black polygons mature oocytes. See text for further explanation. *Distribucidn de frecuencia del tamaño de los huevos de ocho hembras de* L. gibbosa *antes, durante y después del período de puesta. Los polígonos blancos representun los oocitos inmaduros; los poligonos rayados muestran los oocitos en proceso de maduracidn y los poligonos negros son oocitos maduros. Véase texto para una mayor explicación.*

Table 2. Relative annual investment in somatic growth and reproduction of *L. gibbosa. Inversión relativa anual en crecimieizto somático y reproduccidn en* L. gibbosa.

	Age (years)	Number of specimens	Somatic weight (g)	Gonad a weight (g)	Somatic weight increment (g) b	a/a+b
1993	1+	13	2.2396	0.0847	2.2396	0.0364
	2+	7	4.22241	0.1603	1.9845	0.0747
	3+	11	6.1915	0.5134	1.9674	0.2069
	4+	4	9.2817	0.6912	3.0902	0.1828
1994	1+	10	2.6780	0.0928	2.6780	0.0335
	2+	6	4.6002	0.1432	1.9222	0.0693
	3+	19	7.1313	0.7783	2.5311	0.23.52
	4+	6	10.9258	0.843l	3.7945	0.1818
	5+	2	13.7267	0.9362	2.8009	0.2505

mum water temperatures of 36.6 ºC (July 1994). High water temperatures could lead to extended growth periods and to an increase in the relative growth rates of fish species. This could be the case of 0+ fishes, whose growth period is extended over seven months and could explain the differences in growth between the Iberian Peninsula populations and those in the rest of Europe. Nevertheless, the high temperatures and ecological conditions of our river could limit growth. Carlender (1977) mentions that *L. gibbosa* lives in cooler waters than other members of the genus. Scott & Crossmann (1973) state that pumpkinseed are distributed further north than other species of the genus, and that this species may do better in Canada than in the southern part of its range. The hydrological cycle of this small river is typical of the Mediterranean area. In the summer, ecological conditions may become critical for fish because flow ceases and the river consists of isolated pools. During this period, all fish species living in the river are forced to live in these small pools, hence, fish density increases, and competition for space and food is probably high. Moreover, pools receive plenty of sunshine (10-14 h), leading to high water temperatures and, consequently, to oxygen depletion, particularly at night.

Cyclical changes in the fish condition are the consequences of this seasonal cycle, patent during the summer, when the index reaches low values. This pattern is similar to that found by Herrera *et al.* (1988) and Kraiem (1980). This could explain the differences in growth between the Guadiato River pumpkinseed population and those of the North American range. Moreover, Crivelli & Mestre (1988) noted that pumpkinseed in Europe was imported for aquarium purposes, and selected for small ultimate size.

In this population, the highest values of somatic condition occur when reproduction has finished (at the end of August and September). This suggests that there is of trade-off between the energy invested in reproduction and that devoted to maintenance/growth.

Sexual maturity was reached at younger ages than in other pumpkinseed populations (Carlander, 1977; Scott & Crossman, 1973; Mahon & Balon, 1977; Tandon, 1977a,b). According to life history theory, females tend to invest in growth and delay maturity and this is later reflected in an increase in fecundity. However, if there is a restriction to growth, as is the case of this population, age and length at first maturity will be reduced to such an extent that the loss of reproductive value tends to be minimum (Steams & Crandall, 1984). The cost of early maturity is a reduction of life span (Roff, 1981). Thus in our population, we have detected a maximum of six age-groups, whereas Carlander (1977) found 10 age-groups.

During the reproductive period, females developed two batches of eggs starting from one mode of opaque eggs. Multiple spawnings have unboubtable advantages in fluctuating environments. The population, however, is not at **risk** when a catastrophic event destroy the whole spawning of a particular year. Moreover, increased individual fecundity occurs, which avoids the trade-off between body-cavity volume and fecundity (Nikolsky, 1963). Compared with other pumplunseed populations, the fishes in our population have lower fecundity

Reproductive effort shows that the largest and oldest females are more fertile and invest less energy than smaller ones. Compared with the American pumpkinseed populations that have been studied, the life-history patterns of this stock are characterized by low annual growth, early maturity, reduced longevity and low fecundity.

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