

Age, growth and diet of the Iberian loach, *Cobitis paludica* in two different environments

Ramona SÁNCHEZ-CARMONA*, Lourdes ENCINA, Amadora RODRÍGUEZ-RUÍZ and Victoria RODRIGUEZ- SÁNCHEZ

Department of Plant Biology and Ecology, Faculty of Biology, University of Seville, Apdo. 1095, 41080 Seville, Spain; *e-mail: ramoni@us.es

Received 24 April 2007; Accepted 10 June 2008

A b s t r a c t. Several aspects of growth and feeding of *C. paludica* have been assessed in two different environments: a lenitic and a lotic hydrosystem, Portil lagoon and Rivera de Cala river respectively. Growth patterns showed some differences with Iberian loach growing slower in the lagoon than in the river. Because of this, although individuals of both populations reach sexual maturity in their second year (year-class 1+), specimens of lagoon population mature at smaller sizes. The *C. paludica* population in the river showed a better somatic condition than in the lagoon. In both hydrosystems, their diet was mainly chironomid larvae and ostracods, although the Portil lagoon Iberian loach population showed a clear trophic segregation between young of the year (year-class 0+) and sexually matures individuals (year-class $\geq 1+$).

Key words: *Cobitis paludica*, lenitic hydrosystem, feeding strategies, biological parameters

Introduction

The Iberian loach, *Cobitis paludica* (De Buen, 1930), is an endemic Iberian species which belongs to *Cobitidae* family. The range of this species covers central and southern rivers of the Iberian Peninsula, and has also been found in several places of Duero basin (D o a d r i o et al. 1988, V e l a s c o et al. 1992). The Iberian loach is currently undergoing a pronounced decline and has become extinct from several water courses basins in the last decade. Introduction of exotic predators has had negative effects on the survival of Iberian loach populations, since they have very restricted swimming abilities. Destruction of its habitats by gravel extraction and water diversion to agriculture and habitat alteration through pollution, canalisation and dam construction have also contributed to the decline of this species. As a result of this, nowadays the Iberian loach is catalogued as “vulnerable” in Spain and in the European Community (D o a d r i o 2001).

C. paludica normally lives in the middle to lower reaches of rivers, with low current and it is restricted to zones with sandy or gravel substrate with aquatic vegetation and shallow water. However, some populations have settled in lenitic environments, such as the Portil lagoon. This species is well established in this lagoon where co-exists with eel (*Anguilla anguilla*) and mullet (*Mugil capito*) populations (E n c i n a et al. 2001), indicating good adaptation of its life history to the environment.

On the biology of this species there is little knowledge. As quoted in O l i v a - P a t e r n a et al. 2002, there are some recent papers on its taxonomy, karyology, genetic variability and feeding in the genus *Cobitis* (M a d e i r a et al. 1992, V a s i l e v a et al. 1992, P e r d i c e s et al. 1995, V a l l a d o l i d & P r z y b y l s k i 1996, P e r d i c e s & D o a d r i o 1997) although few papers treat *C. paludica* exclusively and only some of them describe some

* Corresponding author

aspects of its life history (Lobón-Cerviá & Zabala 1984, Przybylski & Valladolid 2000, Soriguer et al. 2000 and Oliva-Paterna et al. 2002, Valladolid & Przybylski 2003). This dearth of information must be added to the lack of updating existing data, since the last study in the Iberian Peninsula was performed by Soriguer et al. in 1990 and 1991 on the population established in Palancar stream, a tributary of the Guadalquivir River (Soriguer et al. 2000). Moreover, the few studies about Iberian loach in Iberian Peninsula have been largely confined to river populations (Jarama and Lozoya rivers; Palancar and Mascatomiza streams). Therefore this is an unprecedented study, as it is the first time that life history of a *C. paludica* population established in a lenitic environment in Iberian Peninsula has been assessed.

The biological parameters of given species are closely related to the habitat in which they live. In general, fish have a great phenotypic plasticity (Wootton 1990). When a species is able to inhabit two very different habitats, such as a lenitic and lotic environment, it is possible that some of the life history parameters could have been altered. To check this we have studied the biological parameters of *C. paludica* in two different environments. This study is relevant on three main aspects: first, it is important within the need to increase the knowledge about the characteristics of the livelihood strategies of fish that are under threat, as a tool for the implementation of operations and maintenance programs conservation (Wootton et al. 2000). Second, we have studied the biological parameters of *C. paludica* in two different environments to assess if these biological parameters are altered by the environment and third, it presents some innovative data concerning the growth and feeding strategies of a *C. paludica* population established in a lenitic environment, unusual habitat for this species.

Materials and Methods

Study area

The study was conducted in a lenitic and a lotic hydrosystems, the Portil lagoon and the Rivera de Cala river, respectively, both located in the southwestern of Spain (Fig. 1). The nature reserve of Portil lagoon is situated in the east coastal area of the region of Huelva (southwest Spain), comprising an extension of 15.5 hectares. This lagoon is one of the few coastal marsh ecosystems in the Gulf of Cádiz which maintains a considerable volume of water throughout the year. This area has a Mediterranean subhumid climate with oceanic influences, characterized by a hot summer period, with absence of precipitation and a winter period with mild temperatures and irregular rainfall.

The irrigation channel of Rivera de Cala river determines the frontier between two protected areas: the natural park of the Aracena mountain range (Huelva) and Aroche peaks (Sevilla). This river has a hydro regime that is characteristic of mediterranean regions. These rivers are subject to a characteristic climatic regime, seasonal droughts (summer to the beginning of autumn) and inflows (from the end of autumn through winter), which are predictable but highly variable between years (Gait & Resh 1999).

Samples were collected every two weeks from March to July in 2002. Different methods were used for capturing specimens depending on the hydrosystem. Four points were selected in the lagoon in which there were three conical fishing baskets of three depths and three millimetres mesh, applying the same fishing effort in each sampling. In Rivera de Cala river the specimens were captured by electro-fishing, applying a power of 500 volts during an hour and a half, remaining fishing effort in each sampling.

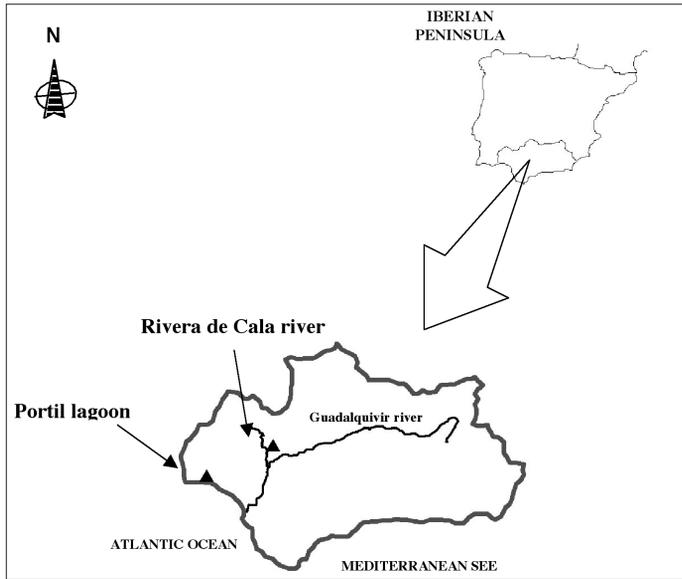


Fig. 1. Location of study areas.

Captured specimens were measured (total length, TL) and weighted (total weight, TW) in the field and released. The sex of the individuals captured was identified in the field being the males identified by the presence of a *lamina circularis*, a plate-like ossification on the base of the second pectoral fin ray (P e r d i c e s et al. 1995). Some captured specimens representing the complete range of sizes were selected and frozen for further diet analysis.

Age determination was carried out using two methods: based on scales and based on length-frequency distribution. Scales below the first radius of the dorsal fin and above the lateral line were removed from each captured sample. These were cleaned using 7 % NaOH, and placed between two slides for age determination. A clear pattern of growth in scales was detected, so it was not considered necessary to resort to extracting the otoliths. We were based on the length frequency distribution so the sizes distribution of the total catch showed modes that could be assimilated to average sizes of the different year class of the population, in this way, each mode corresponding to a year class (W e a t h e r l y & G i l l 1987). The year class assigned to each mode was determined from data obtained from the scales.

Weight-length relationship was tested by the linear relationship $\log W = \log a + b \log L$, where $\log a$ is the origin ordinate and b is the slope of straight line. This expression comes from the equation $W = a L^b$; where W is total weight measured in grams, L is total length measured in millimetres and a and b are constants (W o o t t o n 1990).

A covariate total weight with total length analysis (ANCOVA) and a analysis of variance (ANOVA) of the total length of captured specimens was studied in each sex separately in both populations, to observe differences in somatic status of individuals and the existence of sexual dimorfism. Length and total weight variance analysis, sample normality and homoscedasticity were verified by means of Kolmogorov-Smirnov and Levene analysis converting the variables to logarithms. Statistical package SPSS 11.0. was used to carry out all statistical analysis.

Intrinsic growth rates in length and weight were determined separately for males and females, using the following expressions:

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

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

where L_{t+1} and L_t are the mean length of the age-class $t+1$ and the previous age-class respectively and W_{t+1} and W_t are mean weight of age-class $t+1$ and t .

The digestive tracts of selected specimens from each sample were extracted to perform diet studies and preserved in 4% formaldehyde. Fats adhered to digestive tract walls were separated and the content extracted, visualized and analyzed. Feeding strategy was determined using the graphical method of Costello (1990) modified by Mundsen et al. (1996). We calculated the percentage frequency (%F_i) and the prey-specific abundance (%P_i) in percentage of each item prey. The equations employed were:

$$F_i = N_i / N \times 100$$

$$P_i = (\sum S_i / \sum S_{ii}) \times 100$$

where N_i is specimens with prey i in gastrointestinal contents, N is total specimens, S_i is the stomach content (number) composed by prey i and S_{ii} is the total stomach content (number) in only those predators with prey i in their stomach.

The Feeding Importance Index (FII) of Widel (1971) was used to characterize the diet. This index is described by following equation:

$$FII = \sqrt{F_i \times A_i}$$

where A_i is the percentage abundance of prey type i and can be described by the equations:

$$A_i = (\sum S_i / \sum S_j) \times 100$$

where S_j is the total stomach (number) content of all stomachs in the entire sample. This index was analyzed for all specimens analyzed and grouped by age.

The index of Levins was used as a measure of trophic niche width (Krebs 1998):

$$B = 1 / \sum p_i^2, i = 1 \dots n$$

where p_i is the fraction of prey i in the diet and n is the total number of items in the diet.

Finally, the comprehensive study of diet grouped by sex was performed using a canonical discriminate analysis.

Results

In total, 855 and 236 specimens were captured Portil lagoon and Rivera de Cala river respectively. The age structure of *C. paludica* was wider in the river than in the lagoon. In the river we found eight age-groups (0+ to 7+), whereas the lagoon population sample only had six (0+ to 5+). Maximum length captured was a 115 mm female from the river population (age-class 7+) (Table 1).

Table 2 shows the components of the equations for the length-weight relationship in both areas of study and for each sex separately. A higher value of b for females of both hydrosystems under study reveals a growing weight higher than for males to a certain length.

Table 1. Size range of age (minimum and maximum length), mean and standard deviation (S.D.) for the total length (mm) of *C.paludica* in Portal lagoon and Rivera de Cala river populations.

| Year class | Portil lagoon | | | | | Rivera de Cala river | | | | |
|------------|---------------|-----|-----|-----------|------|----------------------|-----|-----|-----------|------|
| | n | Min | Max | \bar{x} | S.D. | n | Min | Max | \bar{x} | S.D. |
| 0+ | 369 | 32 | 52 | 43,97 | 4,35 | 110 | 31 | 50 | 39,37 | 3,10 |
| 1+ | 149 | 50 | 61 | 56,58 | 2,67 | 13 | 53 | 70 | 62,85 | 4,61 |
| 2+ | 234 | 58 | 78 | 65,95 | 3,45 | 44 | 63 | 81 | 71,36 | 4,74 |
| 3+ | 97 | 76 | 88 | 79,00 | 3,71 | 44 | 70 | 87 | 78,52 | 5,38 |
| 4+ | 5 | 90 | 93 | 90,80 | 1,30 | 11 | 87 | 94 | 90,55 | 1,50 |
| 5+ | 1 | 102 | 102 | 102 | - | 8 | 95 | 98 | 95,63 | 1,06 |
| 6+ | - | - | - | - | - | 5 | 103 | 105 | 104,20 | 0,83 |
| 7+ | - | - | - | - | - | 1 | 115 | 115 | 115 | - |

Table 2. Statistical (F), significance (p), regression coefficient (R²) and parameters estimated for the linear relationship weight-length of *C. paludica* from Portil lagoon and Rivera de Cala river.

| PORTIL LAGOON | | | | | Parameters estimated | |
|----------------------|----------|----------------|----------|--------|----------------------|-------|
| Sex | Ecuation | R ² | F | p | Log a | b |
| Males | Lineal | 0,746 | 578,977 | <0,001 | -4,525 | 2,623 |
| Females | Lineal | 0,950 | 2828,905 | <0,001 | -5,641 | 3,264 |
| Total | Lineal | 0,927 | 7108,619 | <0,001 | -5,304 | 3,070 |
| RIVERA DE CALA RIVER | | | | | Parameters estimated | |
| Sex | Ecuation | R ² | F | p | Log a | b |
| Males | Lineal | 0,826 | 160,943 | <0,001 | -4,660 | 2,747 |
| Females | Lineal | 0,883 | 571,831 | <0,001 | -5,179 | 3,034 |
| Total | Lineal | 0,966 | 3699,89 | <0,001 | -5,874 | 3,399 |

Table 3. Results analysis of covariance (ANCOVA) made on the total weight of specimens of *C. paludica* captured by age and zone (lagoon and river). Total length has been used as a covariate. Total length has been used as a covariate. The dependent variable and covariate were transformed by log₁₀. df: degrees of freedom.

| Factors | df | F | p |
|-------------|-------|----------|--------|
| Regression | 1,465 | 3760,546 | <0,001 |
| Sex | 1,465 | 45,237 | <0,001 |
| Zone | 1,465 | 6,512 | 0,011 |
| Interaction | 1,465 | 4,014 | 0,046 |

Table 4. Results of analysis of variance (ANOVA) made on the total length of the copies of *C. paludica* captured by age and zone (lagoon and river). Total length was transformed by log₁₀. df: degrees of freedom.

| Factors | df | F | p |
|-------------|-------|---------|--------|
| Sex | 1,465 | 107,409 | <0,001 |
| Zone | 1,465 | 68,346 | <0,001 |
| Interaction | 1,465 | 8,132 | 0,005 |

If we do not differentiate between sexes, we found that a smaller value of *b* for the loach from lagoon shows that, overall, growth in weight is lower for loach from lagoon than for loach from river to a certain size.

Analysis of covariate total weight with total length (ANCOVA) was carried out for each sex separately (Table 3), and both populations showed significant differences. The somatic condition of both sexes was different in both hydrosystems. Specimens from the river were in better somatic condition than from lagoon. On the other hand, females were in better somatic condition than males in both the river and the lagoon. Analysis of variance of the total length for both sexes and for populations (ANOVA) (Table 4) showed that these differences also remain in relation to the size of individuals, that is, specimens from river showed a higher size than those from lagoon, and females were longer than males. In both environments the Iberian loach revealed a clear dimorphism in length and weight.

The greatest differences in growth, both in length and weight were produced during early growth stages. In these years the Iberian loach from the river grew faster than the Iberian loach from the lagoon. For this reason, only younger individuals (year-class 1+ and 2+) showed significant differences between the two populations in analysis of variance (Total length: Year class 1+: $F_{1,162} = 61.165$, $p < 0.001$, Year class 2+: $F_{1,278} = 63.732$, $p < 0.001$) (Total weight: Year class 1+: $F_{1,162} = 70.267$, $p < 0.001$, Year class 2+: $F_{1,278} = 81,442$, $p < 0.001$), specimens were significantly longer and heavier in the river than in the lagoon. Similar results were observed when we studied the intrinsic length and weight growth rate (Fig. 2), which is greater in the river population than in lagoon in the early year class. However, growth rates tended to be similar in older year classes. These results confirmed that somatic growth was slower in the population from the lenitic environment during the early stages of life.

The 50 % of the specimens were sexually mature in their second year of life (year class 1+) in the two hydrosystems, although this happens at different sizes. In the lagoon population, males and females were mature when they reached 56 mm and 55 mm mean length, respectively, whereas in Rivera de Cala River, maturity was reached at 61 mm mean length in males and 65 mm mean length in females. These results agree with the intrinsic growth rate, which is greater in the river than in the lagoon population in the first years of life.

The proportion of males to females was different between the two environments. The lagoon population showed a better balanced sex-ratio (1.29) which is biased towards the females in the river (0.44). In the Portil lagoon population, the proportion of sexes varied depending on the year class. Males predominated in younger year classes, while females predominated from year class 3+ onwards, with only females reaching the oldest year classes. In Portil lagoon we found individuals who have matured sexually in their first year of life; thus proves that loach from Portil lagoon tend to mature earlier. However, the percentage of individuals mature at that age does not exceed 14 % and therefore could not be considered as age of maturity.

Sex ratio varied among different year classes in the river population also, although in this population females dominated in all the year classes with increasing extent (Fig. 3, A and C). In both hydrosystems, females live longer than males, being from year class 3+ all individuals' females. As for the temporal variation in sex ratio we reported, an important number of young specimens were captured both in the river and in the lagoon during June and July sampling, not caught earlier, that correspond to the *young of the year* (YOY) (Fig. 3, B and D).

The diets of 97 specimens from the Portil lagoon were analysed, although 68 specimens had no stomach contents. In the river, only three of the 24 specimens studied had stomach contents. We have commented only the results obtained for the lagoon population, due to the low number of valid specimens from river analyzed. The main food items were chironomids larvae and ostracods. Other macroinvertebrates, such as Plecoptera and Simuliidae nymphs were observed in lower quantities.

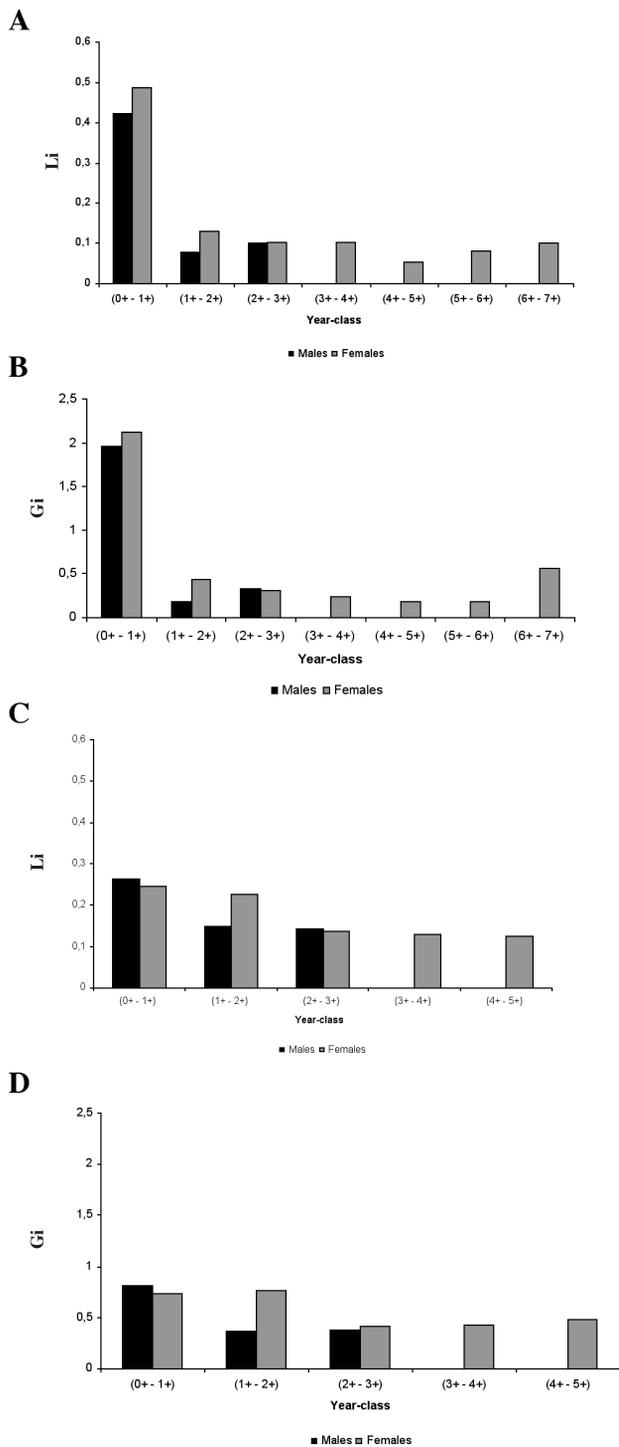
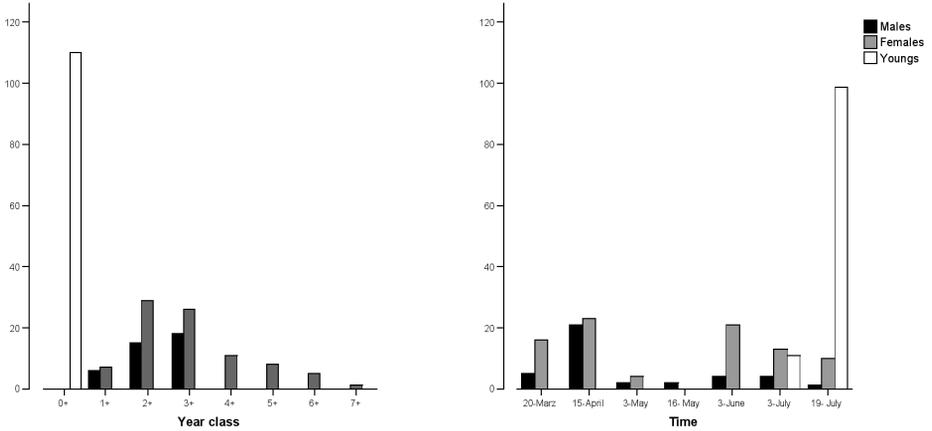


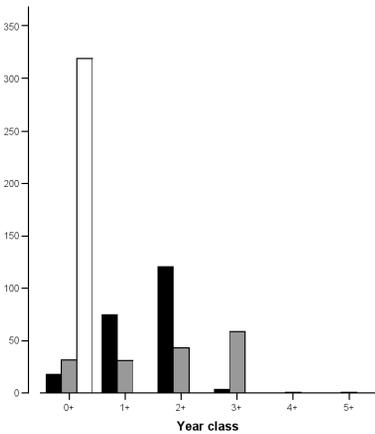
Fig. 2. Instantaneous growth rate in length (L_i) and in weight (G_i) for the specimens of *C. paludica* captured in Rivera de Cala river (A and B) and in Portil lagoon (C and D).

RIVERA DE CALA RIVER



PORTIL LAGOON

C



D

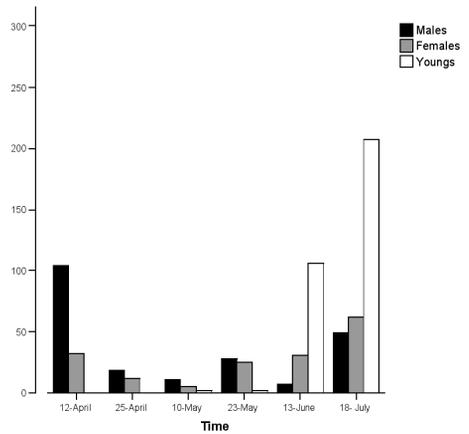


Fig. 3. Sex ratio for year class (A and C) and during study period (B and D) populations Iberian loach in Portil Lagoon and the Rivera de Cala River.

When analyzing the preys found in the digestive tracts of loach from the lagoon, we found that they have a different importance in the diet, in such a way that chironomid larvae are the most important prey in the diet of *C. paludica* in the lagoon, followed by ostracods and cladocerans (i.e. *Chydorus* sp.) (Fig. 4). By grouping specimens by year class shows that the importance of the different items in the diet varies depending on the age of the individual. These differences are mainly among individuals in year class 0+ and the other specimens. Thus, individuals young of the year (YOY) showed a different diet from the rest of the population, being the most important prey the nematodes, followed by rotifers (Fig. 5).

According to the distribution of food items in the Costello's graphic method modified by Amundsen (Fig. 6) the *C. paludica* population of the Portil lagoon has a generalist feeding strategy. The vertical axis represents the feeding strategy of the predator in terms

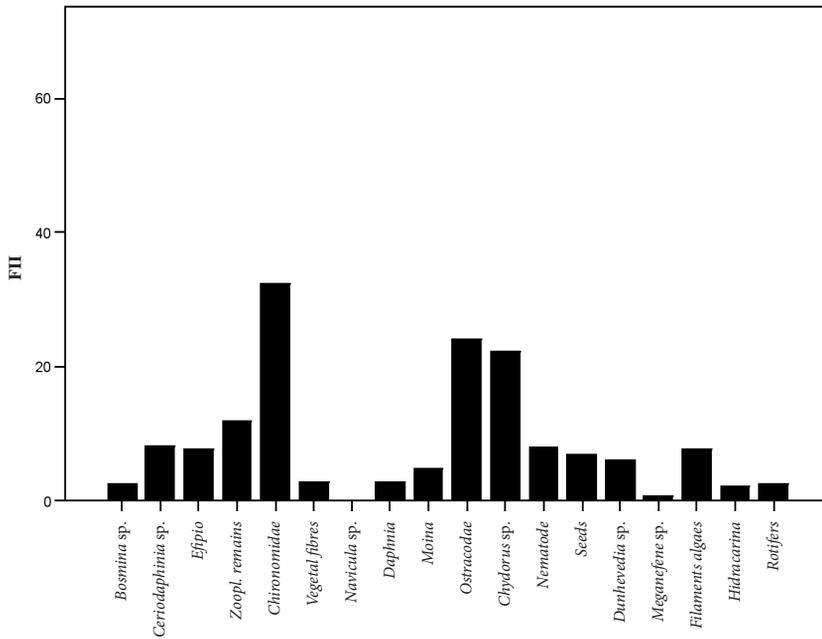


Fig. 4. Importance of preys, measure as Feeding Importance Index (FII) (%) for all individuals from Portal lagoon analyzed.

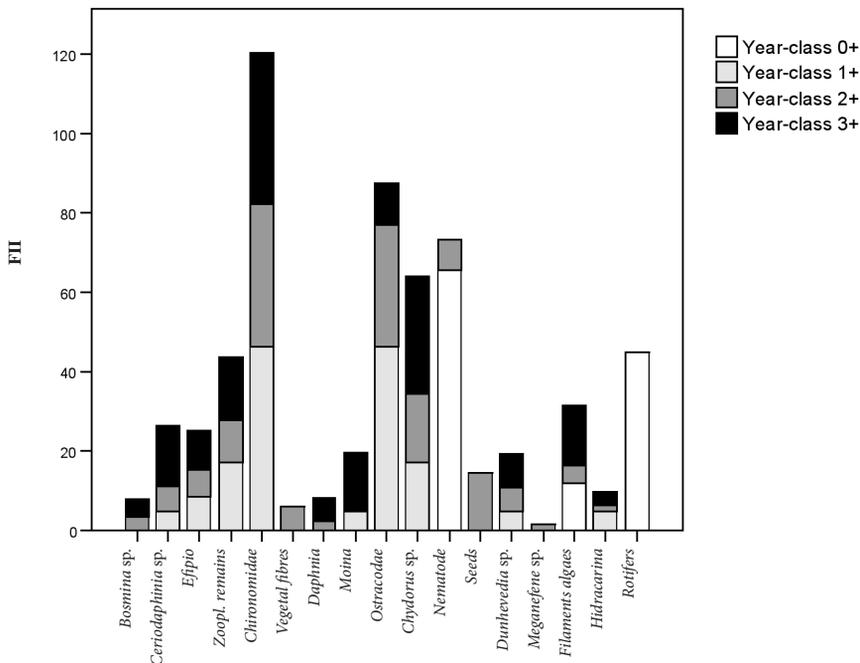


Fig. 5. Importance of preys, measure as Feeding Importance Index (FII) (%) presented in a stacked, grouping analyzed specimens in year class.

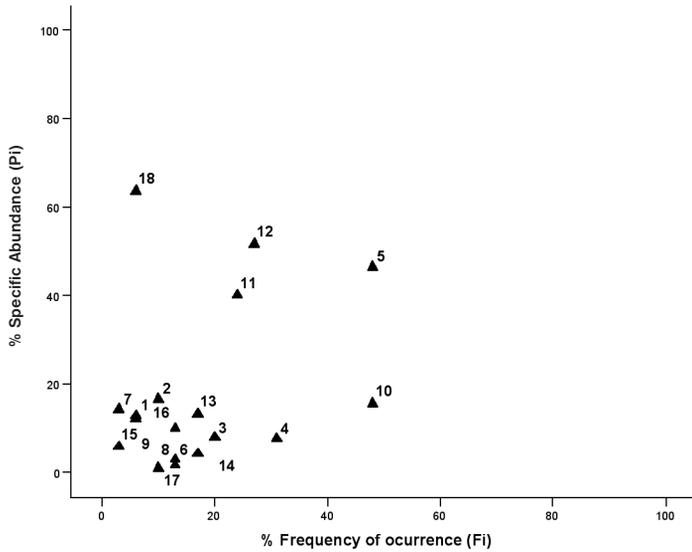


Fig. 6. Costello's graphic method modified by Amundsen (1996) for all preys presents in diet of *C. paludica* population in Portil lagoon. (1 = *Bosmina* sp., 2 = *Ceriodaphnia* sp., 3 = Efhipio, 4 = Zooplankton remains, 5 = Chironomidae larvae, 6 = Vegetal fibres, 7 = *Navicula* sp., 8 = *Daphnia* sp., 9 = *Moina* sp., 10 = Ostracodae, 11 = *Chydorus* sp., 12 = Nematodes, 13 = Seeds, 14 = *Dunhevedia* sp., 15 = *Meganefene* sp., 16 = Filaments algae, 17 = Hidracarina and 18 = Rotifers).

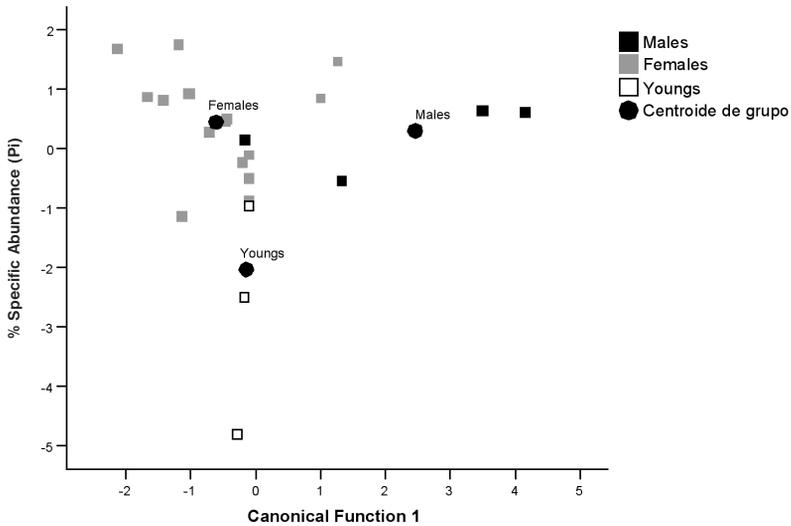


Fig. 7. Distribution of studies specimens grouped for sex in the defined space by functions 1 and 2 canonical discriminant analysis.

of specialization or generalization. The predators have specialized on prey types which positioned in the upper part of the graph, whereas prey positioned in the lower part have been eaten more occasionally (generalist). Most items appear in the lower left of the graphic, which indicates that almost all specimens were eating a few of all the prey that form the

Table 5. Summary of autovalues on canonical discriminate function of analysis for sex in the studied specimens in Portil lagoon.

| Function | Autovalues | % of variance | % accumulated | Canonical correlation |
|----------|------------|---------------|---------------|-----------------------|
| 1 | 1.438 | 59.9 | 59.9 | 0.768 |
| 2 | 0.963 | 40.1 | 100.0 | 0.700 |

Table 6. Summary of matrix values of structure of discriminate analysis for sex of studied specimens in Portil lagoon.

| Prey | Function | |
|----------------------------|----------|--------|
| | 1 | 2 |
| <i>Moina</i> sp. | -0.071 | 0.098 |
| <i>Chydorus</i> sp. | 0.045 | 0.144 |
| Filament algae | -0.067 | 0.115 |
| Ehipio | -0.145 | 0.162 |
| Zooplankton remains | 0.094 | 0.185 |
| <i>Ceriodaphnia</i> sp. | -0.110 | 0.138 |
| <i>Daphnia</i> sp. | 0.226 | 0.139 |
| Chironomidae | -0.255 | 0.285 |
| <i>Dunhevedia</i> sp. | 0.027 | 0.180 |
| <i>Megafene</i> sp. | 0.325 | 0.081 |
| Rotifers | -0.032 | -0.661 |
| Vegetal fibres | 0.047 | 0.186 |
| Seeds | 0.320 | 0.234 |
| Ostracodae | -0.227 | 0.309 |
| <i>Bosmina longirostri</i> | 0.289 | 0.107 |
| <i>Bosmina</i> sp. | -0.113 | 0.126 |
| Hidracaria | 0.118 | -0.012 |
| Nematode | -0.177 | -0.289 |

trophic niche of the population. The dominant preys in the diet, as we saw earlier, were the chironomid larvae. This breadth of trophic niche we found was confirmed by the Levins index, which reached a value of 11,3 ($B > 9$).

The results of the canonical discriminate analysis carried out on the diet depending on sex are reported in Fig. 7. Autovalues of the analysis and the matrix coefficients of the discriminate functions are shown in Tables 5 and 6. Sexually mature specimens, both males and females are placed in the upper zone of the graphic which is characterized by the great presence of chironomids larvae and ostracods. Young specimens (YOY) are located in the lower zone of the graph, where rotifers and nematodes have more importance. The results show again a clear ontogenic trophic segregation in the population.

Discussion

The age structure found in the population of the Rivera of Cala is different to that reported in the River Jarama (Lobón-Cerviá & Penczak 1984) and the Lozoya River (Przybylski & Valladolid 2000), both located in the Tajo River basin, at more northern latitude than this study. The age structure is also different from the Palancar River (Soriguer et al. 2000) and the Mascatomiza River populations (Oliva-Paterna et

al. 2002), both situated at a southern latitude. The Rivera of Cala river population had a wider age structure, with more age classes than populations in other rivers studied. However, the age structure observed in the Portil lagoon population is more similar to those of the other studies mentioned.

On average, females were older than males in both the lagoon and the river. Females of the *C. paludica* population studied in Palancar river were one year older than the males (Soriguer et al. 2000). In this study this difference was even greater with females two and four years older than males in the Portil lagoon and Rivera de Cala river populations, respectively. We found clear sexual dimorphism respect body length in the two populations. Both populations showed two traits in age structure, which are common to most of European populations of *Cobitis*: a low age class number and greater life expectancy in females (Oliva-Paterna et al. 2002).

Younger age classes are characterized by higher growth rates. The fast growth in early years is an adaptation to minimize the period when the young are vulnerable to predation (Winfield & Nelson 1991, Wootton 1990). The intrinsic growth rate of *C. paludica* was greater in the river than in the lagoon population. The slower growth in the lagoon than in the river population does not only occurs in the early years of life but is also observed in older year classes of the population. These results demonstrate how the same species can show different growth patterns in different environments (Wootton 1990). In addition, females grew faster than males in both ecosystems. According to Winfield & Nelson (1991), when females are sexually mature, natural selection favours them with a faster growth rate.

Specimens that inhabit the lotic system were in better physical condition than those in the lagoon. We suspect that, although *C. paludica* has adapted itself with success to lenitic environment conditions, the new environment could lead to some loss of its somatic condition in respect to its natural habitat in the river.

The sex ratio in the *C. paludica* population in the Potil lagoon fits with the results obtained in Jarama river (Lobón-Cervía & Zabalá 1984). It was close to parity with the *C. paludica* in Mascatomiza stream (Oliva-Paterna et al. 2002) and with the *C. taenia* population in Italy (Lodi 1967) and England (Robotham 1981). These studies show similar biased sex ratio but near to parity. Results obtained from the Rivera de Cala river population were more similar to values observed by Soriguer et al. (2000) in the Palancar river, and observed by Przybylski & Valladolid (2000) in the Lozoya river which has a sex-ratio biased towards females (Table 7). Sex ratio values are usually related to the environmental characteristics of where the fish population lives. In general, high values are found in situations where the population is at carrying capacity of the environment whereas the opposite situation usually occurs when the population is still expanding. Equal values indicate a well-balanced population (Granado-Lorenzo 1996). This is the case for the Iberian loach in the Portil lagoon, where a more stable environment keeps the sex ratio balanced, whereas the Rivera de Cala river population faces a continual fight for persistence in the environment and has a sex-ratio biased towards females. As we mentioned above, this imbalance leads to faster population growth. In this case, we could hypothesise that the imbalance is an adaptation, aimed to colonizing empty habitats quickly after environmental fluctuations, especially in flood.

The results of the dietary analysis carried out on the Rivera de Cala river population agreed with results obtained by Soriguer et al. (2000) in the Palancar stream. The diets of *C. paludica* consisted mainly of chironomid larvae and ostracods, both small benthic

Table 7. Sex ratio in different European populations of *Cobitis*.

| SPECIE | LOCALITY | SEX-RATIO (M/F) | LITERATURE |
|--------------------|------------------------------|-----------------|--------------------------------|
| <i>C. paludica</i> | Portil lagoon (Spain) | 1,29 | This study |
| <i>C. paludica</i> | Rivera de Cala river (Spain) | 0,44 | This study |
| <i>C. paludica</i> | Mascatomiza stream (Spain) | 0,61 | Oliva-Paterna et al. (2002) |
| <i>C. paludica</i> | Palancar stream (Spain) | 0,50 | Soriguer et al. (2000) |
| <i>C. paludica</i> | Lozoya river (Spain) | 0,18–0,52 | Przybylski & Valladolid (2000) |
| <i>C. paludica</i> | Jarama river (Spain) | 0,97 | Lobón-Cerviá & Zabala (1984) |
| <i>C. taenia</i> | river (Italy) | 0,65 | Lodi (1967) |
| <i>C. taenia</i> | river (England) | 0,76 | Robotham (1981) |

preys. Chironomid larvae are one of the most important benthic resources in lotic system because they may live within sediments for several weeks or even months (Windfield & Nelson 1991). Presence of detritus in gastrointestinal contents was scarce.

The main food items in the diet of *C. paludica* from Portil lagoon were ostracods and chironomids with detritus featuring infrequently. This result contradicts those obtained by Valladolid (2002) and Rodríguez Jiménez (1987), where detritus was of higher importance. However, our results agree with those reported by Soriguer et al. (2000) related to a population from the south of the Iberian Peninsula. In their study ostracods and chironomids were favoured prey, complementing by small benthic prey and the eggs of macrobiotids, with little detritus found. The diet of *Cobitis taenia* reported by Spartaru (1970) is composed of macroinvertebrates and algae as the main food items in a Romanian population, while two other authors Maksunov (1969) and Skóra (1966) emphasized the importance of detritus in populations of Tadjikistan and Poland respectively. Robotham (1977) was the first to point out that detritus is a typical component of the diet in this species in the United Kingdom, although its importance changes depending on the season, and Moretti (1948) identified chironomids as the main prey in an Italian population.

In the Costello's graphic method modified by Amundsen, prey with high specific abundance and a low occurrence (upper left) will have been eaten by a few individuals displaying specialisation, whereas prey with a low specific abundance and a high occurrence (lower right) will have been eaten occasionally by most individuals. These differences in feeding strategy are related to the between- and within- phenotype contributions to the niche width. In a population with a high between-phenotype component, different individuals specialise on different resource types, whereas in populations with a high within- phenotype component, most of the individuals utilise many resource types simultaneously (Giller 1984, Pianka 1988, Wootton 1990). The Iberian loach population from the lagoon had a high between-phenotype component, which means that the individuals that make up the population do not contribute equally to the trophic niche width; only part of the population shows some specialization. In our study, these individuals were the young of the year which mainly fed on nematodes and rotifers.

C. paludica and all the other species of the *Cobitis* genus have usually been described from a trophic point of view as generalists. This description has always been based on population studies, and not on individual feeding strategies. It is obvious that a population with a narrow trophic niche is necessarily composed of individuals that have narrow and specialised trophic niches also. However, a population that shows a wide trophic niche can

be composed of individuals also with wide trophic niches or narrow but distinct niches, or a combination of both (Amundsen 1995). The latter case resembles the Iberian loach population in the Portil lagoon, which has a wide trophic niche (B>9), where part of population, specifically young of the year specimens, have a more specialised or narrow trophic niche, feeding mainly on nematodes and rotifers. A clear trophic segregation between young of the year (year-class 0+) and sexually mature individuals (year-class $\geq 1+$) have been shown. A similar trophic segregation was found by Sorriquer et al. (2000) for this species in the Palancar river.

The results of this study are the first reported for this species in a lenitic system. Iberian loach show an ability to adapt to this environments, which could be important to consider when developing management plans for the protection and recovery of this threatened species.

Acknowledgements

We wish to thank to Rafael Benjumea, Sergio Tirado and Irma Vela for their useful help with the fieldwork. We are also grateful to Dr Rubio, Odiel Marsh Natural Park director for permitting this study and R. Ponce, the forestry agent, for making our fieldwork easy.

LITERATURE

- Amundsen P. A. 1995: Feeding strategy of Arctic charr (*Salvelinus alpinus*). General opportunist, but individual specialist. *Nordic J. Freshwat. Res.* 71: 150–156.
- Amundsen P.A., Gabler H.M. & Staldvik F.J. 1996: A new approach to graphical analysis of feeding strategy from stomach contents data – modification of the Costello (1990). *J. Fish Biol.* 48: 607–614.
- Costello M. J. 1990: Predator feeding strategy and prey importance: a new graphical analysis. *J. Fish Biol.* 36: 261–263.
- Doadrio I. 2001: Atlas y libro rojo de los peces continentales de España. *Ministerio de Medio Ambiente y Consejo Superior de Investigaciones Científicas, Madrid.*
- Doadrio I., Elvira B. & Garzón P. 1988: Revisión taxonómica y distribución de *Cobitis maroccana* Pellegrin, 1929 (Osteichthyes, Cobitidae). *Doñana Acta Vertebr.* 15 (1): 156–161.
- Encina L., Vela De Pablos I., Benjumea R., Tirado S., Rodríguez-Sánchez V. & Sánchez-Carmona R. 2001: Estudio cualitativo de la ictiofauna de las zonas húmedas de Huelva y análisis de las poblaciones. Informe técnico. *Confederación Hidrográfica del Guadiana.*
- Gasith A. & Resh V.H. 1999: Streams in Mediterranean climate regions: abiotic influence and biotic responses to predictable seasonal events. *Annual Review of Ecology and Systematics* 30: 51–81.
- Granado-Lorencio C. 1996: Ecología de Peces. *Publicaciones de la Universidad de Sevilla, Sevilla.*
- Giller P. S. 1984: Community structure and the niche. *Chapman and Hall, London.*
- Krebs C. J. 1998: Ecological Methodology. 2nd Ed. *New York, Benjamin/Cummings, New York.*
- Lobón-Cerviá J. & Penczak T. 1984: Fish production in Jarama River, Central Spain. *Holarctic Ecology* 7: 128–137.
- Lobón-Cerviá J. & Zabala A. 1984: Observations on the reproduction of *Cobitis paludicola* (De Buen, 1930) in the Jarama river. *Cybium* 8: 63–68.
- Lodi E. 1967: Sex reversal of *Cobitis taenia* L. (Osteichthyes, fam. Cobitidae). *Experientia* 23: 446–447.
- Madeira J. M., Collares Pereira M. J. & Elvira B. 1992: Cytotaxonomy of Iberian loaches with some remarks on the karyological evolution of both familias (Pises, Cobitidae, Homalopteridae). *Caryologia* 45: 273–282.
- Maksunov V. A. 1969: The Aral Loach (*Cobitis aurata aralensis* Kessl.) in the waters of Tadzhikistan. *Problemy Ichthyology* 9: 320–325.
- Moretti G. P. 1948: Il regime alimentare estivo del *Leuciscus aula* e del *C. taenia* nelle acque del F. esino [The summer diet of *Leuciscus aula* and *C. taenia* in the waters of F. esino]. *Natura Milano* 39: 1–8 (in Italian). *Natura Milano* 39: 1–8.

- Oliva-Paterna F. J., Torralva M.M. & Fernandez-Delgado C. 2002: Age, growth and reproduction of *Cobitis paludica* in a seasonal stream. *J. Fish Biol.* 60: 389–404.
- Perdices A. & Doadrio I. 1997: Threatened fishes of world: *Cobitis paludica*. (De Buen, 1930) (Cobitidae). *Environ. Biol. Fish* 49: 360–360.
- Perdices A., Marchodom A. & Doadrio I. 1995: Allozyme variation of African and Iberian populations of the genus *Cobitis*. *J. Fish Biol.* 47: 707–718.
- Pianka E. R. 1988: Evolutionary Ecology. 4th edn. *Harper Collins, New York*.
- Przybylski M. & Valladolid M. 2000: Age and growth of the Iberian loach, *Cobitis paludica* in the Lozoya River (Madrid, Central Spain), an intermittent stream. *Folia Zool.* 49: 163–169.
- Robotham P. W. J. 1981: Age, growth and reproduction of a population of spined loach, *Cobitis taenia* (L.). *Hydrobiologia* 85: 129–136.
- Robotham P. W. J. 1977: Feeding habits and diet in two populations of Spined loach, *Cobitis taenia* (L.). *Freshwat. Biol.* 7: 469–477.
- Rodríguez Jiménez A. J. 1987: Relaciones tróficas de una comunidad íctica, durante el estío Aljucén (Extremadura, España). *Miscellanea Zoologica* 11: 249–256.
- Skóra S. 1966: Koza (*Cobitis taenia* L.) z rzeki Wschodniej (Der Steinbeisser (*Cobitis taenia* L.) aus dem Wschodnia-Bach). *Acta Hydrobiol., Krakow (Suppl. 1)* 8: 425–435 (in Polish with German summary).
- Soriguer M. C., Vallespín C., Gómez-Cama C. & Hernando J. A. 2000: Age, diet, growth and reproduction of a population of *Cobitis paludicola* (De Buen 1930) in the Palancar stream (southwest of Europe, Spain) (Pises: Cobitidae). *Hydrobiologia* 436: 51–58.
- Spartaru P. 1970: Biologia nutritiei la zviruga, *Cobitis taenia taenia*, din complexul de balti crapinajjila [Biology of nutrition of spined loach (*C. taenia*) in the balti crapinajjila complex]. *Annales of the University of Bucarest, Series Stiint Naturii* 16: 163–168 (in Romanian).
- Valladolid-Martín M. 2002: Ecología trófica de la ictiofauna del Bajo Lozoya: uso de recursos, patrones en la dieta y ecomorfología. *Tesis Doctoral, Universidad Complutense de Madrid*.
- Valladolid T. M. & Przybylski M. 2003: Feeding ecology of *Cobitis paludica* and *Cobitis calderoni* in Central Spain. *Folia biologica* 51: 135–141.
- Valladolid T. M. & Przybylski M. 1996: Feeding relations among cyprinids in the Lozoya river (Madrid, Central Spain). *Polskie Archiwum Hydrobiologii* 43: 213–223.
- Vasil'eva E. D., Collares-Pereira M. J. & Madeira J. 1992: Variability, divergence and taxonomy of loach on the Iberian Peninsula. *J. Ichthyol.* 32: 69–84.
- Velasco J. C., Peris S. J., González Sánchez N. & Poll C. J. 1992: Presencia de *Cobitis maroccana* Pellegrin, 1929 (Osteichthyes, Cobitidae) en la cuenca del Duero. *Miscellanea Zoologica* 15: 237–239.
- Weatherley A. H. & Gill H. S. 1987: The biology of fish growth. *Academic Press, London*.
- Windel J. T. 1971: Food analyses and rate of digestion. In: Ricker W.E. (ed.), Methods for Assessment of Fish Production in Freshwater. *I.B.P. Handbook, N° 3, Blackwell, Oxford*: 125–183.
- Winfield I. J. & Nelson J. S. 1991: Cyprinid Fishes. Systematics, Biology and Exploitation. *Chapman & Hall, London*.
- Wootton R. J., Elvira B. & Baker J. A. 2000: Life-history evolution, biology and conservation of stream fish: introductory note. *Ecol. Freshwat. Fish* 9: 90–91.
- Wootton R.J. 1990: Ecology of Teleost Fishes. *Chapman & Hall, London*.