Age, growth and reproduction in creole perch (*Percichthys trucha*) in the Negro River, Argentinean Patagonia

By A. Lopez Cazorla and N. Sidorkewicj

Departamento de Biología, Bioquímica y Farmacia, Universidad Nacional del Sur, Bahía Blanca, Argentina

Summary

Age, growth and reproductive characteristics of creole perch, *Percichthys trucha,* were investigated in the Negro River, southern Argentina from samples collected seasonally, December 1994–December 1995. Age was estimated via scale and whole otolith reading methods. Total length (n = 413) ranged from 103 to 432 mm, and weight from 12 to 1042 g. Significant differences between the length-weight relationships of males and females were detected (P < 0.05). Isometric growth was observed in juveniles and males, whereas total population and females exhibited positive allometric growth. The marking pattern in scales and otoliths followed an annual rhythm, with the formation of only one annulus in scales and only one hyaline band in otoliths during autumn-winter. The oldest males were 5 years old whereas maximum age in females was 12 years from scales and 15 years from otoliths. Because scales were found to underestimate age in individuals older than 4 years, otoliths were considered to be the best structures for creole perch age determination. Gompertz growth parameters based on otolith data were $L\infty$: 428.0 mm, $k = 0.46$ and $t_0 = 0.43$ for total population ($r = 0.90$), $L\infty$: 410.7 mm, $k = 0.42$ and $t_0 = 0.46$ for males ($r = 0.91$), and $L\infty$: 434.1 mm, and $k = 0.49$ and $t_0 = 0.43$ for females ($r = 0.91$). Lengths at first maturity (TL_{50}) were 260 and 241 mm in males and females, respectively, both of which corresponded to ages between 1 and 2 years. Macroscopic gonad inspection and the high percentage of juveniles captured during summer indicated that spawning begins at the end of spring.

Introduction

Creole perch, *Percichthys trucha*, a member of the south temperate perch family Percichthyidae, is endemic to southern South America. It lives in freshwater rivers and lakes in central and southern Chile and Argentinean Patagonia (Arratia, 1982, 2003). In Argentina, this species is distributed from 38° to 55°S (Arratia et al., 1983).

Percichthys shows a high morphological variability throughout its range to the extent that, to date, seven living species have been described. Studies conducted by López-Arbarello (2004) proposed that only five of the species are valid, namely, *P. trucha*, *P. colhuapiensis* and *P. laevis* in Argentina, and *P. chilensis* and *P. melanops* in Chile. On the other hand, and based on mtDNA and nuclear sequence analysis, Ruzzante et al. (2006) claimed that only two species of *Percichthys* are valid, namely the widely distributed *P. trucha* and a Chilean species with a more restricted distribution, *P. melanops*.

Creole perch has not been thoroughly investigated. The majority of studies on this species have focused on its distribution (Arratia, 1982, 2003; Baigún and Ferriz, 2003) and systematic aspects taking into account morphological (Campos and Gavilan, 1996; Cussac et al., 1998; López-Arbarello, 2004) as well as biomolecular (Ruzzante et al., 2006; Paterson et al., 2008) data. Biological knowledge of this species is scarce. Some authors have evaluated its trophic polymorphism, habitat, dietary aspects, relative abundances and ecological behaviour (Ruzzante et al., 1998, 2003; Macchi et al., 1999; Logan et al., 2000; Scasso and Campos, 2000; Lopez Cazorla and Tejera, 2003–2004; Buria et al., 2007; Aigo et al., 2008). However, little is known about other biological traits. Only a few studies, have, in fact, been carried out on age and growth taking into account scale (Guerrero, 1991) and otolith (Dománico and Guerrero, 1990) readings in some Patagonian freshwater systems. Still, no studies of this type have been carried out in the Negro River basin, Argentina.

The scarcity of data available on the ecology of *P. trucha* prompted an investigation regarding its life history including age validation, growth, and reproductive parameters. These ecological aspects were examined in an attempt to understand the life cycle strategy of this fish on the one hand, and to compare information with other species of percichthyids, on the other.

Materials and methods

Creole perch specimens were obtained from five sampling stations distributed along the Negro River, southern Argentina (39°–41°S; 63°–68°W; Fig. 1). A thorough description of the study area is available from Lopez Cazorla and Sidorkewicj (2008).

Surveys were conducted on a seasonal basis, covering an annual cycle: (i) spring (9-17 / XII / ′94); (ii) summer (6-19 / III / ′95); (iii) autumn (25 / V-9 / VI / ′95); (iv) winter (23 / VIII-7 / IX / ′95); and (v) spring (20 / XI-4 / XII / ′95). Fish were caught by using seven 30–105-mm mesh size gill nets. For all specimens collected (n = 413) total length (TL, mm) and weight (W, g) were recorded. Sex was determine by macroscopic observation of gonads (n = 401) and maturity stages of adults were classified as: I, immature; II, developing; III, spawning; and IV, resting.

Fish length-weight relationships were estimated by the model $W = aL^b$. Parameters *a* and *b* were calculated by least-squares on log-transformed data. The hypothesis of isometric growth was tested with *t*-test. Length at first sexual maturity (TL_{50}) was calculated by the method proposed by Hernández and Cordo (1986).

Scales (n = 396) were removed from the area just above the lateral line, and the sagittal otoliths (n = 393) extracted.
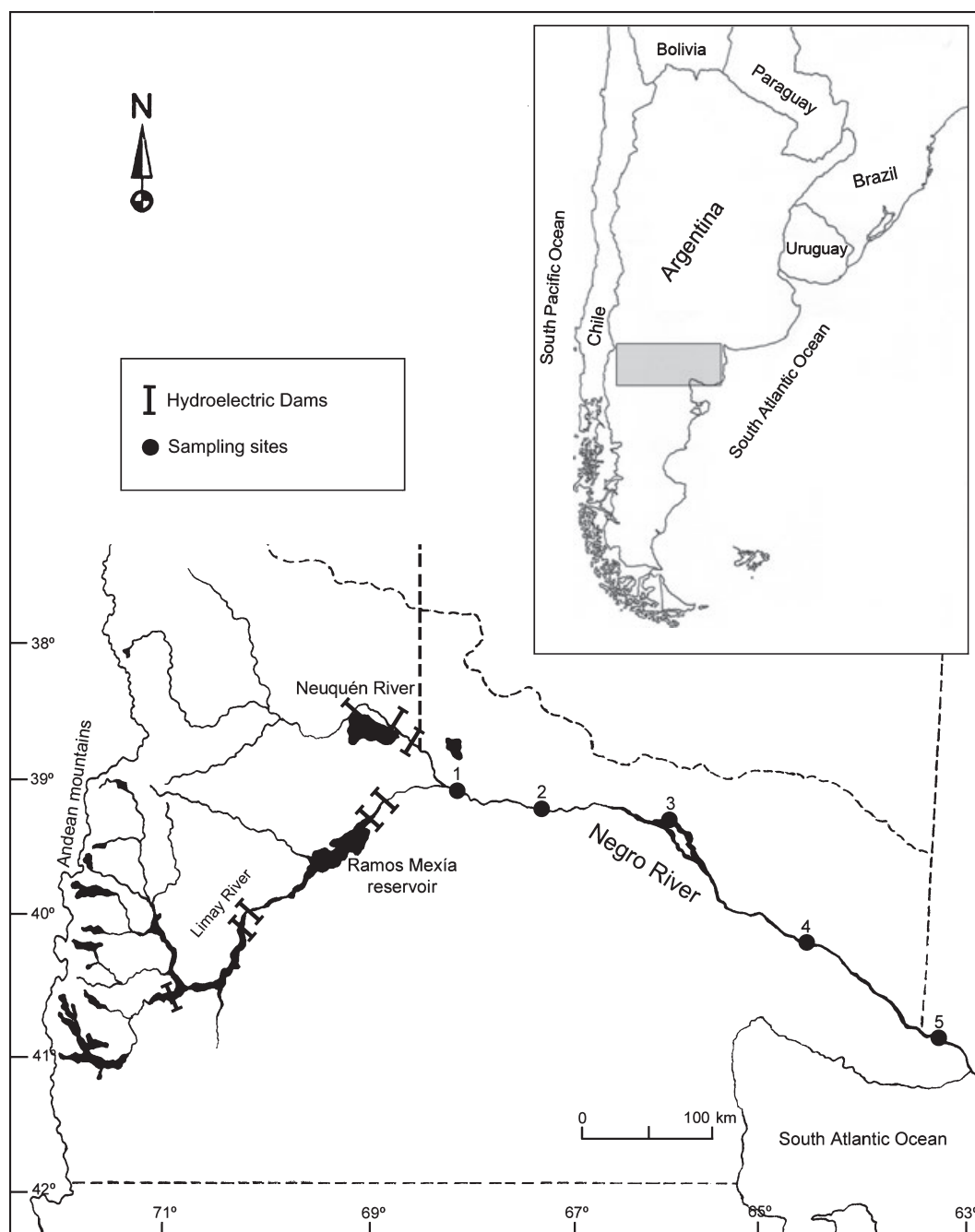
Fig. 1. Negro River study area sites (1–5) where *Percichthys trucha* samples were collected December 1994–December 1995

Both structures were preserved dry. Readings were carried out twice by independent readers without prior information on sex, length, or capture time. Scale reading was carried out at the anterior field using binocular lenses and a microfiche reader (22.5×). The zone where growth was interrupted was labelled as a presumed annual mark. Otoliths were placed in water and examined under a binocular microscope (10×) with reflected light against a dark background. The number of hyaline (translucent) bands was recorded over the rostral area.

Marking periodicity of scales was determined by analysing seasonally the edge type (scales with and without growth edge), whereas for otoliths changes in the proportion of opaque and hyaline edges were examined. Each specimen was assigned to a year class taking into account the number of marks counted,

date of capture, birth date, and edge type; 1 January was considered as the birth date to assign individual ages to age groups. The index of average percent error (IAPE, Beamish and Fournier, 1981) and the coefficient of variation (CV; Campana et al., 1995; Campana, 2001) were used to determine the level of precision of age interpretations. Systematic differences in estimated age (bias) within and between ageing structures were assessed by age bias plot.

Sizes-at-ages were used to fit the growth models of Gompertz (CurveExpert, version 1.3) and von Bertalanffy (Maximum Likelihood method). Age was expressed as a decimal number whose decimal part represents the proportion of the year from the birthday of the species to the date of capture of the specimen. The length-at-age data for juveniles were included in the curves of both sexes. To test the overall

growth performance, phi-prime index Φ' was calculated (Pauly and Munro, 1984): $\Phi' = \log_{10} k + 2 \log_{10} L\infty$.

Results

Even though *P. trucha* was captured during all samplings, different abundances were observed throughout the year. Juveniles were captured mostly in summer (39%) whereas adults were most abundant in spring 1995 (males: 63% of the total male capture; females: 58%). Fish ranged from 103 to 432 mm TL and from 12 to 1042 g, the highest values corresponded to females; maximums registered in males were 395 mm and 835 g.

Length-weight relationships were significant for total population, juveniles and sexes ($P < 0.01$ in all cases) (Fig. 2), with significant differences between males and females (ANCOVA, $P < 0.05$). Juveniles and males exhibited isometric growth, whereas total population and females were characterized by positive allometric growth, as expected from longer and heavier females than males.

Scales had clear alternating patterns of active growth, on which circuli were deposited, and growth interruption (annulus). One year of life was assigned to each of these marks. The high percentage of scales with growth edge during spring and summer, and the sharp declination in autumn-winter indicated that marking may occur during this period (Fig. 3a). Age ranged from 0 to 12 years, and a strong difference in the maximum age attained by sexes was observed (Tables 1 and 2). The age structure of the total population was found to be unimodal, with the highest abundance in age 2 (40%), and with the same tendency observed in the separate sexes.

Otoliths showed alternating narrow opaque and broad hyaline bands, which became progressively narrower and of similar width as the number of bands increased. A clear annual cycle in the seasonal evolution of the edge type was observed, with the highest percentage of opaque margins in spring and the lowest values in autumn (Fig. 3b). These data indicate that only one hyaline band is formed yearly mainly during this season, and that the opaque band is deposited during late spring-summer. The range of otolith-based ages was 0–15, and maximum ages registered for adults corroborated the sex differences observed with scales (males: 5 years; females: 15 years) (Tables 1 and 2). Age 2 was again the most important for the total population (41%), males (42%) and females (44%).

Age bias plots showed no systematic bias between the two readers for each ageing method (Fig. 4a,b). The low values of IAPE and CV from both types of structures indicated the good level of precision of our readings. However, the age bias plot for ages estimated from scales compared to those from otoliths revealed a notorious discrepancy between the two reading methods, scales tending to seriously underage fish older than 4 years (Fig. 4c).

A consistent pattern of increase in length with age was generally observed (Tables 1 and 2). The main increments of TL at age occurred up to age 3–4 years with a subsequent decrease. Notwithstanding the underageing of fish older than 4 years with scales, the Gompertz and von Bertalanffy growth models were applied to data from both reading methods. Best estimations were obtained with the Gompertz equation on otolith-derived data, as indicated by the highest values of the correlation coefficients and the lowest standard errors (Fig. 5). Growth performance index Φ' based on both reading methods was of similar magnitude for males, females and sexes combined, ranging from 4.85 to 4.97.

Gonad inspection revealed a similar tendency in both sexes throughout the year (Fig. 6). Immature males (stage I) were registered during all seasons except in summer whereas females
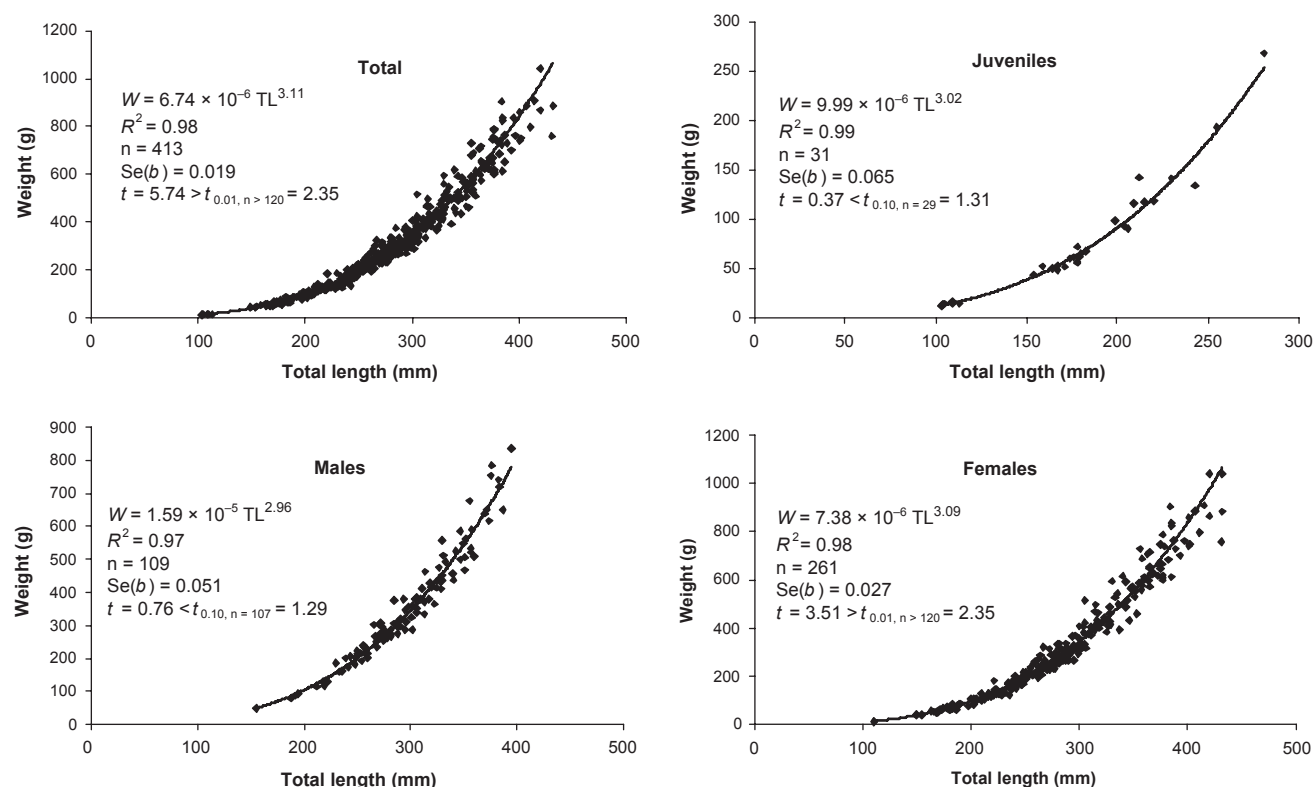

Fig. 2. Length-weight relationships for different groups of *Percichthys trucha*, including determination coefficient (R^2), number of individuals (n), standard error of the slope (Se(b)), and t-test results for hypothesis of isometric growth
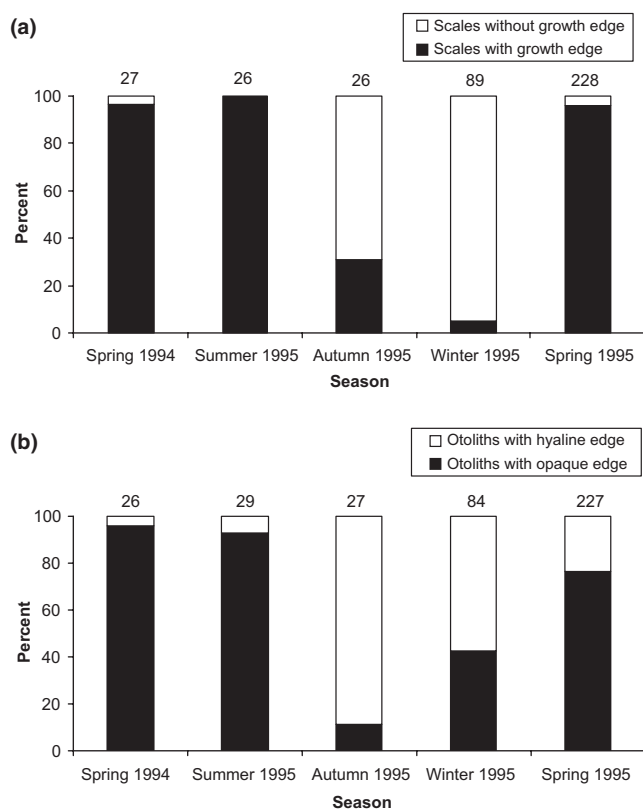
(a)

(b)

Fig. 3. Seasonal evolution of *Percichthys trucha* edge type (a) scales and (b) otoliths. Number of specimens examined per season indicated above each bar

Table 1
Number of specimens and mean length-at-age ($\pm$ standard deviation) corresponding to total population and juveniles of *Percichthys trucha* in the Negro River according to scale and otolith readings

	Scales		Otoliths	
Age	n	Mean TL ($\pm$ SD) (mm)	n	Mean TL ($\pm$ SD) (mm)
Total				
0	14	153.5 ($\pm$ 41.3)	13	134.0 ($\pm$ 30.7)
1	74	209.3 ($\pm$ 40.4)	76	203.2 ($\pm$ 29.1)
2	160	276.3 ($\pm$ 41.0)	163	265.7 ($\pm$ 32.6)
3	88	305.8 ($\pm$ 51.6)	59	314.0 ($\pm$ 30.4)
4	38	348.2 ($\pm$ 42.1)	57	352.7 ($\pm$ 22.9)
5	15	361.1 ($\pm$ 30.9)	16	381.6 ($\pm$ 23.2)
6	2	349.5 ($\pm$ 46.0)	4	366.7 ($\pm$ 51.1)
7	3	384.3 ($\pm$ 18.1)	2	394.0 ($\pm$ 9.9)
8				
9	1	432.0	1	420.0
10				
11				
12	1	431.0		
13			1	432.0
14				
15			1	431.0
Juveniles				
0	6	125.8 ($\pm$ 31.3)	8	121.6 ($\pm$ 27.6)
1	11	177.6 ($\pm$ 40.2)	15	192.9 ($\pm$ 27.2)
2	8	204.7 ($\pm$ 33.1)	6	187.0 ($\pm$ 12.4)
3	2	229.5 ($\pm$ 72.8)	1	281.0

Table 2
Number of specimens and mean length-at-age ($\pm$ standard deviation) of male and female *Percichthys trucha* based on scale and otolith readings

	Scales		Otoliths	
Age	n	Mean TL ($\pm$ SD) (mm)	n	Mean TL ($\pm$ SD) (mm)
Males				
0	2	171.5 ($\pm$ 23.3)	1	155.0
1	10	241.1 ($\pm$ 45.0)	12	224.5 ($\pm$ 26.0)
2	53	284.0 ($\pm$ 33.1)	46	277.3 ($\pm$ 23.5)
3	21	312.6 ($\pm$ 37.9)	22	311.6 ($\pm$ 27.0)
4	17	341.6 ($\pm$ 34.5)	23	345.8 ($\pm$ 26.0)
5	6	347.7 ($\pm$ 15.6)	5	369.6 ($\pm$ 18.8)
Females				
0	6	175.2 ($\pm$ 41.6)	4	153.5 ($\pm$ 30.7)
1	53	210.0 ($\pm$ 35.0)	49	201.2 ($\pm$ 28.2)
2	99	278.0 ($\pm$ 40.2)	111	265.1 ($\pm$ 30.6)
3	65	306.0 ($\pm$ 53.7)	36	316.4 ($\pm$ 32.5)
4	21	353.5 ($\pm$ 47.5)	34	357.3 ($\pm$ 19.6)
5	9	370.0 ($\pm$ 35.9)	11	387.0 ($\pm$ 23.7)
6	2	349.5 ($\pm$ 46.0)	4	366.7 ($\pm$ 51.1)
7	3	384.3 ($\pm$ 18.1)	2	394.0 ($\pm$ 9.9)
8				
9	1	432.0	1	420.0
10				
11				
12	1	431.0		
13			1	432.0
14				
15			1	431.0

and winter with similar frequencies in both seasons (approximately 30% for males; 10% for females), whereas stage IV (resting) were present mostly in summer. These results, summed to the high percentage of juveniles captured during summer samplings, indicate that the spawning season seems to occur at the end of spring.

Length at first maturity was not significantly different in males ($TL_{50} = 259.64$ mm TL, $r = 0.78$) and females ($TL_{50} = 241.42$ mm TL; $r = 0.90$) ($P = 0.07$) and occurred at ages between 1 and 2 years. Total sexual maturation is also attained at the same time in both sexes, at 3–4 years (320 and 340 mm TL for males and females, respectively).

Discussion

Findings from our study extends the previously estimated life span of *P. trucha* from 9 to 10 years (Dománico and Guerrero, 1990; Guerrero, 1991) to 15 years in the base of otolith reading (the most accurate method for ageing creole perch, as explained below), and may allow the conclusion that it could be considered a relatively long-lived species. The notorious differences in longevity found between sexes (females: 15 years; males: 5 years) were not reported in the previous work of the above mentioned authors, and could reflect an effective ability of older males to avoid our sampling nets, some sex-specific life history trait, or simply the absence of older age classes in our study area.

To our knowledge, there is a general scarcity of studies about maximum ages attained by percichthyids in South America. Habit and Belk (2007) and Aedo et al. (2009) reported a maximum age of 4 years for the Chilean species *Percilia irwini* in the Andalién River and Biobío River basins. In Argentina, work performed on the largemouth perch *Percichthys colhuapiensis* in the Negro River, demonstrated a

of this stage were observed all year. Developing stages (II) increased from autumn to spring, completely disappearing in summer. Mature individuals (III) appeared only in autumn
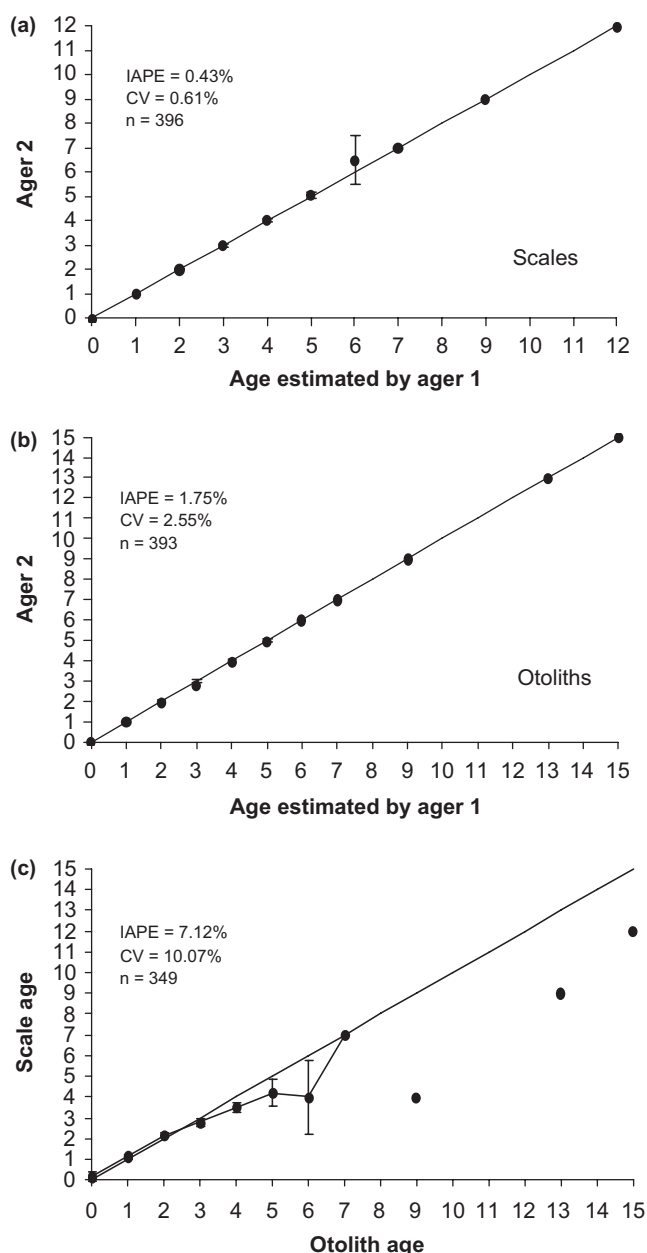
Fig. 4. Age bias plots of (a) scale age and (b) otolith age to evaluate agreement between readers; (c) scale age vs whole otolith age to evaluate agreement between aging structures. Solid line = 1 : 1 equivalence. Each error bar = 95% confidence intervals. Index of average percent error (IAPE) and coefficient of variation (CV) also indicated. n = number of individuals aged by two independent readers using (a) scales or (b) otoloths; (c) n indicates number of individuals aged using both structures

longevity of 11 years for this fish (Lopez Cazorla and Sidorkewicj, 2008), which extended the maximum age of 8 years previously reported for the species in other Patagonian environments, the Ramos Mexía dam (Guerrero, 1989) and the Limay River and Neuquén River basins (Guerrero, 1984). It has been largely discussed if *P. colhuapiensis*, commonly found co-occurring with creole perch, is a different species (López-Arbarello, 2004) or a sympatric morph of *P. trucha* (Ruzzante et al., 2003, 2006). Ruzzante et al. (2006), based on molecular evidence, claimed that 'morphological variability has not been able to unambiguously resolve species issues for *Percichthys*' and that in Argentina there exists only one perch species,

P. trucha. However, solely with the base of morphological differentiation of both perch, the strong differences we have encountered between them in the maximum ages observed, i.e. 11 years for *P. colhuapiensis* (Lopez Cazorla and Sidorkewicj, 2008) and 15 years for *P. trucha* (present study), could provide new evidence for the possible solution of the problematic issue in the systematics of the genera.

A key problem in ageing studies is to select the most suitable and accurate structure to determine the age of fish. Although scales have been widely used for ageing because of the ease of collection, little time involved in their processing and reading, and the advantage of performing non-destructive monitoring studies, their use has been disputed mainly because the ages of older fish are frequently underestimated (Beamish and McFarlane, 1987; Carlander, 1987). Otoliths have been considered to render more accurate age determinations than scales because the former have a higher priority in the utilization of calcium (Carlander, 1987) and, unlike scales, they continue to grow as the fish ages (Beamish and McFarlane, 1987; Casselman, 1990). From the results of the present study, it was evident that for specimens shorter than 300 mm TL (approximately age 3), both scales and otoliths could be used for ageing *P. trucha*. Nonetheless, owing to the clear advantages of scale over otolith reading, scales could then be the preferable structure to age small fish. On the contrary, for larger sizes the sole use of otoliths is recommended for this species because scales have been found to seriously underage individuals, leading to an underestimation of fish longevity (12 vs 15 years). These results were opposite to those reported for *P. colhuapiensis* in the same riverine system, with use of scales as the most suitable structures (Lopez Cazorla and Sidorkewicj, 2008).

The largest *P. trucha* sizes captured in the Negro River during the present work were similar to those reported by Dománico and Guerrero (1990) in the Ramos Mexía dam (430 mm), indicating that creole perch could attain similar sizes in lentic and lotic systems. In the present study, length-weight relationships revealed significant differences between sexes; these differences were evident also in the allometric coefficient *b*. The allometric growth pattern of females resulting in a heavier body weight and, hence, a higher *b* value, seem to indicate that they were in a better condition with respect to males, as is common among teleosts.

Although all growth functions applied in the present study provided accurate descriptions of somatic growth for creole perch, the Gompertz model based on otolith-age data was the best. The growth rates obtained were higher than those reported for the species in other Patagonian freshwater bodies, however the Φ' values were very much alike (Table 3). This confirms the accuracy of our growth estimations, since the overall growth performance has minimum variance within the same species because it is independent of growth rates. On the other hand, the high variability in the values of $L\infty$ summarised in Table 3 seems either to indicate different trophic status of the waterbodies, as stated by Guerrero (1991), or owe to the method involved in growth estimations. In fact, the authors cited in Table 3 obtained growth parameters from mean retrocalculated sizes at ages, a method commonly used in growth studies but that renders less precise estimates.

Males and females of *P. trucha* become part of the reproductive stock early in their lives, at 1–2 years old, with the entire population completely mature at ages 3–4 years. The time at which creole perch reaches maturity coincides with the reduction in growth rate, indicating that once maturity is attained, much of the available energy is used for reproduction
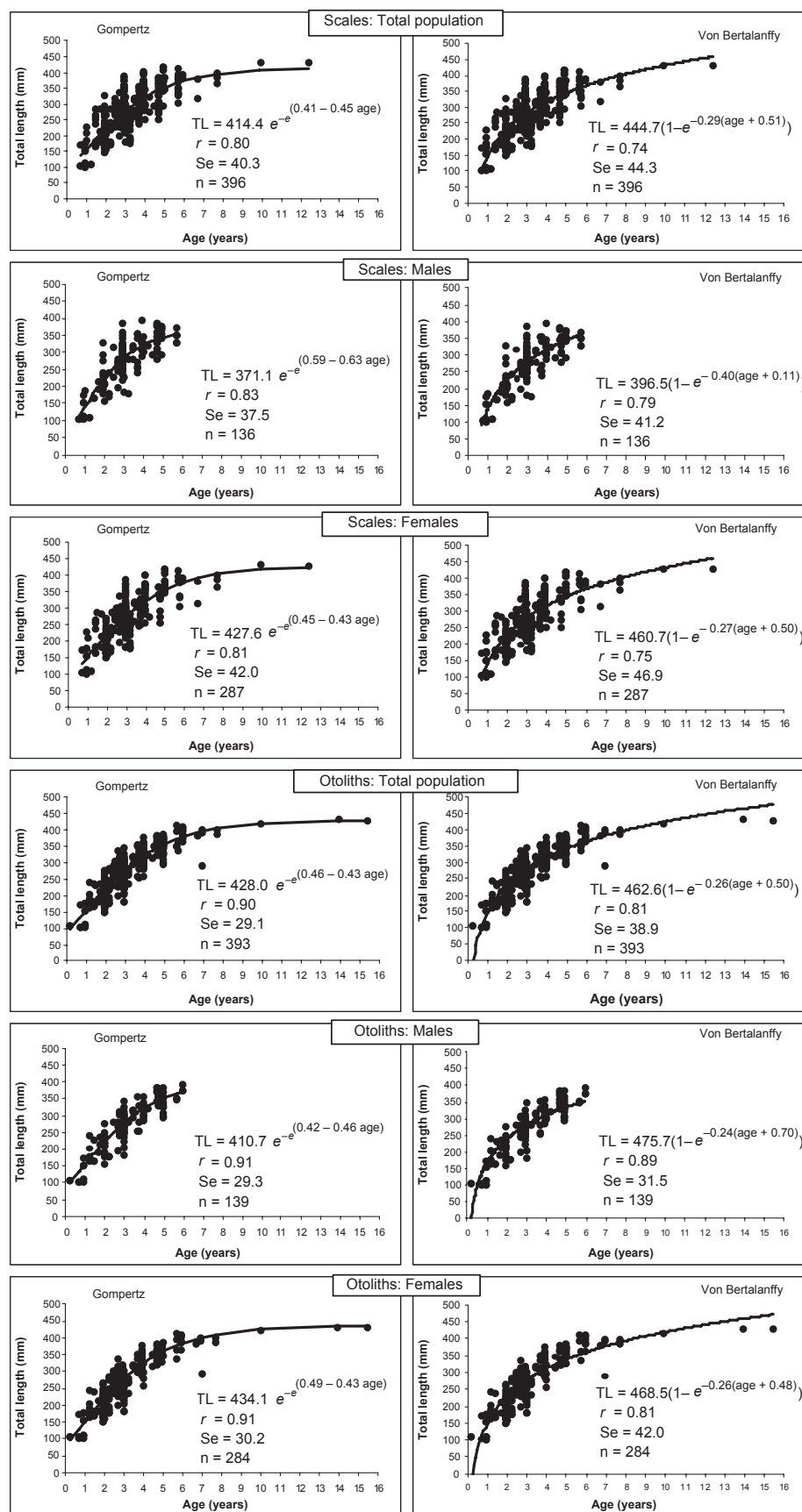
Fig. 5. Gompertz and von Bertalanffy fits to total length (TL)-age data for total population and sexes of *Percichthys trucha* based on scale and otolith readings. *r*: correlation coefficient; Se: standard error; n: pairs of data

rather than for somatic growth. A similar growth pattern was verified for *P. colhuapiensis* in the Negro River (Lopez Cazorla and Sidorkewicj, 2008). For creole perch, the small size at maturity with respect to adult size, as well as the long growth phase found, is concomitant with the life history strategy of the order Perciformes (Rochet, 2000). Although other important
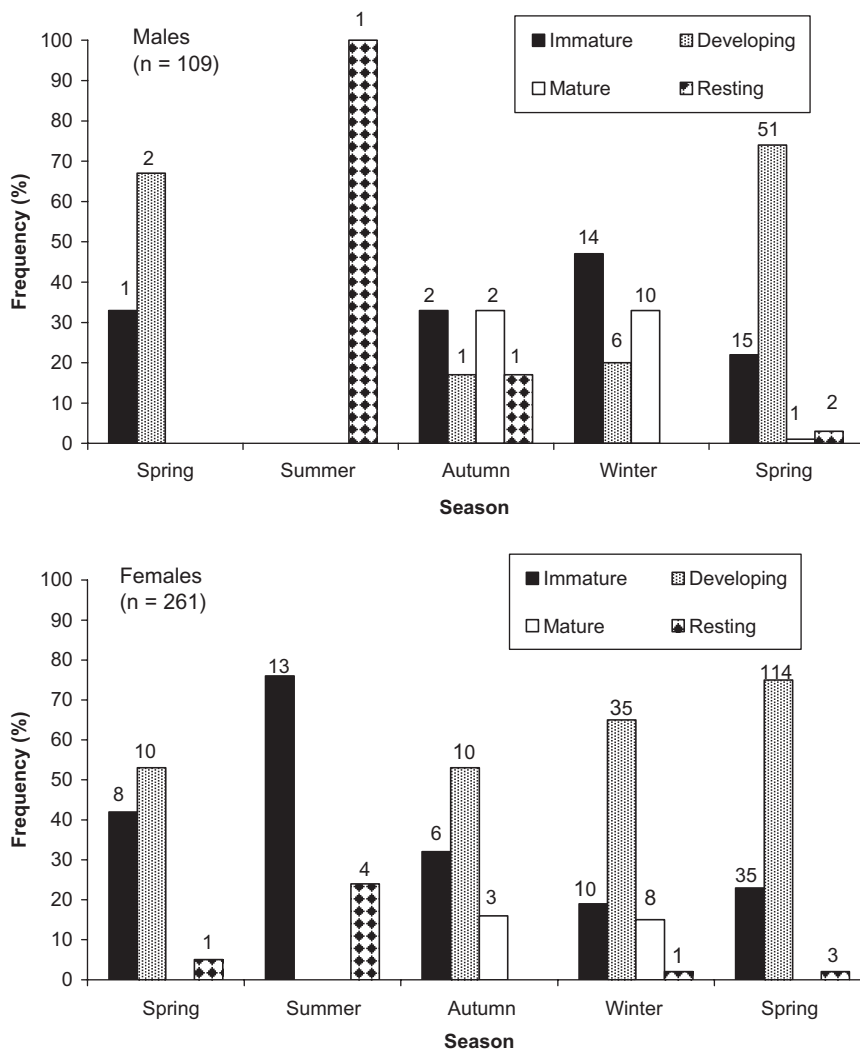
Fig. 6. Seasonal percentage of maturity stages for male and female *Percichthys trucha* (immature: stage I; developing: stage II; spawning: stage III; resting: stage IV). Number of individuals of each stage per season given above each bar; total number of individuals examined (n) indicated at top of each figure

Table 3
Growth parameters ($L\infty$, k, t_0), growth performance index (Φ') and age range of *Percichthys trucha* from different study areas of southern Argentina. Ageing structure (S, scales; WO, whole otoliths; SO, sectioned otoliths), sex (TP, total population; M, males; F, females) and sample size (n) included

Area	Ageing structure	Sex	n	$L\infty$	k	t_0	Φ'	Age range (years)	Author
Negro River	S	TP	396	414.4	0.41	0.45	4.85	0–12	Present study
Negro River	S	M	136	371.1	0.59	0.63	4.91	0–5	Present study
Negro River	S	F	287	427.6	0.45	0.43	4.92	0–12	Present study
Negro River	WO	TP	393	428.0	0.46	0.43	4.93	0–15	Present study
Negro River	WO	M	139	410.7	0.42	0.46	4.85	0–5	Present study
Negro River	WO	F	284	434.1	0.49	0.43	4.97	0–15	Present study
Muster Lake	S	TP	413	721.4	0.137	−0.070	4.85[a]	1–9	Guerrero (1991)
Colhué Huapi Lake	S	TP	351	580.2	0.155	−0.378	4.72[a]	1–9	Guerrero (1991)
Florentino Ameghino dam	S	TP	155	370.2	0.249	−0.480	4.53[a]	1–6	Guerrero (1991)
Esquel Lagoon	S	TP	311	414.9	0.325	−0.370	4.75[a]	1–8	Guerrero (1991)
Ramos Mexía dam	SO	TP	123	1155.9	0.03	−0.55	4.66[a]	1–10	Dománico and Guerrero (1990)

[a]Calculated in base of parameters provided by the corresponding author.

issues, such as fecundity and mortality, must be analysed to further learn about the whole life strategy of this species, it could be assumed that a long growth phase requires early maturity (before the growth period ends) to produce enough offspring.

Based on the period of gonad maturation (autumn-winter) and the maximum appearance of juveniles during summer, it seems evident that creole perch in the Negro River has a single annual spawning period at the end of spring. The latter is in agreement with observations from Buria et al. (2007) regarding this species in the Lake Moreno system, in the northern Argentine Patagonia. This timing also agrees with spawning periods observed for *P. colhuapiensis* in the Negro River (Lopez Cazorla and Sidorkewicj, 2008), for *Percilia irwini* in

South-Central Chile (Habit and Belk, 2007), and also for several Australian percichthyids (Ingram and Rimmer, 1993; Appleford et al., 1998; Rowland, 1998). The coincidence of spawning with increasing water temperatures and photoperiods that characterise temperate areas, indicates that such environmental factors may trigger gonadal development and breeding activities, as was noted for several freshwater fish (Lam, 1983). Buria et al. (2007) also found an association between the lunar cycle and behaviour during the spawning and prespawning periods of *P. trucha* in the Lake Moreno system, with important vertical and horizontal movements of fish along the lakes.

Gonad development seems to be one of the responsible factors of band formation on both otoliths and scales of adult creole perch. In effect, the banding pattern in this species follows an annual cycle, with the hyaline ring formation in otoliths and the annulus formation in scales during autumn-winter, at the same time of gonad maturation. Zone formation in otoliths has been recognized for a long time as linked to changes in calcium metabolism during periods of increased reproductive activity in many fish species (Simkiss, 1974; Beckman and Wilson, 1995). However, zone formation in hard parts of fish suggests a complex control by a combination of exogenous and endogenous factors, which vary at different ages and between sexes (Morales-Nin et al., 1998). Temperature, salinity, light, and food supply have been indicated among the most common environmental parameters involved in this mechanism (Simkiss, 1974; Morales-Nin, 2000). In *P. trucha*, the marking period coincided with lowest water and air temperatures and perhaps low food availability in the Negro River. Kalish (1989, 1991) reported that there is a strong relationship between Sr and other ions of the endolymph and otolith composition in fish. As the chemistry of the endolimph is likely to be determined by a fish's reproductive status, blood chemistry, seasonal temperature cycle and other factors, the changes in the Sr/Ca ratios in a fish's aquatic environment is difficult to interpret in spite of the apparently simple univariate correlations commonly reported.

The present study provides novel information about biological parameters of *P. trucha*, which are fairly consistent with previous knowledge of the species, and with the biology of other percichtyids. However, further research is necessary to extrapolate the results obtained along the geographical distribution range of this fish to elucidate if the relatively high degree of variability found in some of the biological parameters, such as the $L\infty$ values (Table 3), could represent either adaptations to local selective pressures or ecophenotypic variations.

Acknowledgements

References

Aedo, J. R.; Belk, M. C.; Habit, E. M., 2009: Geographic variation in age, growth and size structure of *Percilia irwini* from south-central Chile. J. Fish Biol. **74**, 278–284.

Aigo, J.; Cussac, V.; Peris, S.; Ortubay, S.; Gómez, S.; López, H.; Gross, M.; Barriga, J.; Battini, M., 2008: Distribution of introduced and native fish in Patagonia (Argentina): patterns and changes in fish assemblages. Rev. Fish Biol. Fish. **18**, 387–408.

Appleford, P.; Anderson, T. A.; Gooley, G. J., 1998: Reproductive cycle and gonadal development of Macquarie perch, *Macquaria australasica* Cuvier (Percichthyidae), in Lake Darmouth and tributaries of the Murray-Darling Basin, Victoria, Australia. Mar. Freshw. Res. **49**, 163–169.

Arratia, G., 1982: A review of freshwater percoids from South America (Pisces, Osteichthyes, Perciformes, Percichthyidae, and Perciliidae). Abh. Senckenb. Naturforsch. Ges. **540**, 1–52.

Arratia, G., 2003: Family Percichthyidae (temperate basses). In: Checklist of the freshwater fishes of South and Central America. R. Reis, C. Ferraris and S. Kullander (Eds). CLOFSA, Data Base of Neotropical Fishes, Porto Alegre (Edipucrs), pp. 596–598.

Arratia, G.; Peñafort, M. B.; Menu-Marque, S., 1983: Fishes of the southeastern region of Los Andes and their probable present biogeographic relationship. Deserta **7**, 48–107. [In Spanish].

Baigún, C.; Ferriz, R., 2003: Distribution patterns of native freshwater fishes in Patagonia (Argentina). Org. Divers. Evol. **3**, 151–159.

Beamish, R. J.; Fournier, D. A., 1981: A method for comparing the precision of a set of age determinations. Can. J. Fish. Aquat. Sci. **38**, 982–983.

Beamish, R. J.; McFarlane, G. A., 1987: Current trends in age determination methodology. In: Age and growth of fish. R. C. Summerfelt and G. E. Hall (Eds). The Iowa State University Press, Ames, Iowa, pp. 15–42.

Beckman, D. W.; Wilson, C. A., 1995: Seasonal timing of opaque zone formation in fishes otoliths. In: Recent developments in fish otolith research. D. H. Secor, J. M. Dean and S. E. Campana (Eds). University of South Carolina Press, Columbia, SC, pp. 27–43.

Buria, L.; Walde, S. J.; Battini, M.; Macchi, P. J.; Alonso, M.; Ruzzante, D. E.; Cussac, V. E., 2007: Movement of a South American perch *Percichthys trucha* in a mountain Patagonian lake during spawning and prespawning periods. J. Fish Biol. **70**, 215–230.

Campana, S. E., 2001: Accuracy, precision and quality control in age determination, including a review of the use and abuse of age validation methods. J. Fish Biol. **59**, 197–242.

Campana, S. E.; Annand, M. C.; McMilland, J. I., 1995: Graphical and statistical method of determining the consistency of age determinations. Trans. Am. Fish. Soc. **124**, 131–138.

Campos, H.; Gavilan, J. F., 1996: Morphological differentiation between *Percichthys trucha* and *Percichthys melanops*, between 36°S and 41°S (Chile and Argentina), with multivariate analisis. Gayana Zool. **60**, 99–120. [In Spanish].

Carlander, K. D., 1987: A history of scale age and growth studies of North American freshwater fish. In: Age and growth of fish. R. C. Summerfelt and G. E. Hall (Eds). The Iowa State University Press, Ames, Iowa, pp. 3–14.

Casselman, J. M., 1990: Growth and relative size of calcified structures of fish. Trans. Am. Fish. Soc. **119**, 673–688.

Cussac, V. E.; Ruzzante, D. E.; Walde, S. J.; Macchi, P. J.; Ojeda, V.; Alonso, M. F.; Denegri, M. A., 1998: Body-shape variation of three species of *Percichthys* in relation to their coexistence in the Limay River basin, in Northern Patagonia. Environ. Biol. Fish **53**, 143–153.

Dománico, A. A.; Guerrero, C., 1990: Otolith use for age and growth determination in *Percichthys trucha* (Valenciennes, 1850) (Osteichthyes: Percichthyidae). Medio Ambiente **11**, 42–52. [In Spanish].

Guerrero, C. A., 1984: Age and growth in the largemouth perch, *Percichthys colhuapiensis* Mac Donagh, 1955 (Osteichthyes, Percichthyidae). Rev. Mus. Arg. Cs. Nat. **4**, 95–108. [In Spanish].

Guerrero, C. A., 1989: Demography and dynamics of the population of the largemouth perch *Percichthys colhuapiensis* from the Ramos Mexía dam. PhD Thesis, Univ. Buenos Aires, Fac. Ciencias Exactas y Naturales, Argentina, pp. 201. [In Spanish].

Guerrero, C. A., 1991: Growth of the small mouth perch (*Percichthys trucha*) from four Patagonian lakes and ponds (Argentina). In: 2nd Internat. Workshop on ecology and management of fish in lakes and reservoirs. I. Vila (Ed.). Santiago, Chile, 28 September – 3 October 1987, COPESCAL Tech. Rep. 9, pp. 47–71. [In Spanish].

Habit, E.; Belk, M. C., 2007: Threatened fishes of the world: *Percilia irwini* (Eigenmann 1927) (Perciliidae). Environ. Biol. Fish **78**, 213–214.

Hernández, D. R.; Cordo, H. D., 1986: Methodology for the estimation of the length of first maturity in weakfish and king weakfish. Publicación Comisión Técnica Mixta Frente Marítimo **1**, 230–232. [In Spanish].

Ingram, B. A.; Rimmer, M. A., 1993: Induced breeding and larval rearing of the endangered Australian freshwater fish trout cod, *Maccullochella macquariensis* (Cuvier) (Percichthyidae). Aquac. Res. **24,** 7–17.

Kalish, J. M., 1989: Otolith microchemistry: validation of the effect of physiology, age and environment on otolith composition. J. Exp. Mar. Biol. Ecol. **132,** 151–178.

Kalish, J. M., 1991: Determinants of otolith chemistry: seasonal variation in the composition of blood plasma, endolymph and otoliths of bearded rock cod *Pseudophycis barbatus*. Mar. Ecol. Prog. Ser. **74,** 137–159.

Lam, T. J., 1983: Environmental influences on gonadal activity in fish. In: Fish physiology, Vol. IX, reproduction: behavior and fertility control. W. S. Hoar, D. J. Randall and E. M. Donaldson (Eds). Academic Press, NY. pp. 65–116.

Logan, M. S.; Iverson, S. J.; Ruzzante, D. E.; Walde, S. J.; Macchi, P. J.; Alonso, M. F.; Cussac, V. E., 2000: Long term diet differences between morphs in trophically polymorphic *Percichthys trucha* (Pises: Percichthyidae) populations from the southern Andes. Biol. J. Linn. Soc. **69,** 599–616.

Lopez Cazorla, A.; Sidorkewicj, N., 2008: Age and growth of the largemouth perch *Percichthys colhuapiensis* in the Negro River, Argentine Patagonia. Fish. Res. **92,** 169–179.

Lopez Cazorla, A.; Tejera, L., 2003–2004: Feeding habits of *Percichthys trucha* (Cuvier y Valenciennes, 1833) and *P. colhuapiensis* (Mac Donagh, 1955) (Osteichthyes: Percichthyidae) in the Negro River, Argentina. Natura Neotrop. **34-35,** 19–26. [In Spanish].

López-Arbarello, A., 2004: Taxonomy of the genus *Percichthys* (Perciformes: Percichthyidae). Ichthyol. Explor. Freshw. **15,** 331–350.

Macchi, P. J.; Cussac, V. E.; Alonso, M. F.; Denegri, M. A., 1999: Predation relationship between introduced salmonids and the native fish fauna in lakes and reservoirs in northern Patagonia. Ecol. Freshwat. Fish **8,** 227–236.

Morales-Nin, B., 2000: Review of the growth regulation processes of otolith daily increment formation. Fish. Res. **46,** 53–67.

Morales-Nin, B.; Torres, G. J.; Lombarte, A.; Recasens, L., 1998: Otolith growth and age estimation in the European hake. J. Fish Biol. **53,** 1155–1168.

Paterson, I. G.; Walde, S. J.; Cussac, V. E.; Habit, E.; Ruzzante, D. E., 2008: Isolation and characterization of 13 microsatellite loci for *Percichthys trucha* (Percichthyidae). Mol. Ecol. Res. **8,** 907–909.

Pauly, D.; Munro, J. L., 1984: Once more on the comparison of growth in fish and invertebrates. ICLARM Fishbyte **2,** 21.

Rochet, M. J., 2000: A comparative approach to life-history strategies and tactics among four orders of teleost fish. J. Mar. Sci. **57,** 228–239.

Rowland, S. J., 1998: Aspects of the reproductive biology of murray cod, *Maccullochella peelii peelii*. Proc. Linn. Soc. N. S. W. **1998,** 147–162.

Ruzzante, D. E.; Walde, S. J.; Cussac, V. E.; Macchi, P. J.; Alonso, M. F., 1998: Trophic polymorphism, habitat and diet segregation in *Percichthys trucha* (Pisces: Percichthyidae) in the Andes. Biol. J. Linn. Soc. **65,** 191–214.

Ruzzante, D. E.; Walde, S. J.; Cussac, V. E.; Macchi, P. J.; Alonso, M. F.; Battini, M., 2003: Resource polymorphism in a Patagonian fish *Percichthys trucha* (Percichthyidae): phenotypic evidence for interlake pattern variation. Biol. J. Linn. Soc. **78,** 497–515.

Ruzzante, D. E.; Walde, S. J.; Cussac, V. E.; Dalebout, M. L.; Seibert, J.; Ortubay, S.; Habit, E., 2006: Phylogeography of the Percichthyidae (Pisces) in Patagonia: roles of orogeny, glaciation, and volcanism. Mol. Ecol. **15,** 2949–2968.

Scasso, F.; Campos, H., 2000: Pelagic fish communities and eutrophication in lakes of an Andean basin of central Chile. J. Freshw. Ecol. **15,** 71–82.

Simkiss, K., 1974: Calcium metabolism of fish in relation to ageing. In: Ageing of fish. T. B. Bagenal (Ed.). Unwin Brothers, UK, pp. 1–12.

Author's address: Andrea Lopez Cazorla, Departamento de Biología, Bioquímica y Farmacia, Universidad Nacional del Sur, San Juan 670, 8000 Bahía Blanca, Argentina. E-mail: acazorla@criba.edu.ar