Key Words: *Cyprinus carpio*, age, growth
Palabras Clave: Cyprinus carpio, *edad, crecimiento*

Age and growth of the common carp *Cyprinus carpio* (L.) in the irrigation system of the Colorado River Valley, Buenos Aires Province, Argentina

Andrea López Cazorla & Guillermo Pizarro

Departamento de Biología, Bioquímica y Farmacia - UNS
San Juan 670 - 8000 Bahía Blanca (Bs. As.)
Argentina.
e-mail: acazorla@criba.edu.ar

ABSTRACT

The common carp (*Cyprinus carpio*), was introduced into Argentina at the beginning of the 20th century and recently invaded the irrigation system of the Colorado River Valley, Buenos Aires Province. We report the age range and growth of common carp in this system. Age was determined from scale reading and the estimation of growth parameters using the von Bertalanffy's equation. Eleven classes of age groups, from 0+ to 10+, were distinguished. The growth parameters for the total population, females and males respectively were $L\infty$: 54.23 cm, 52.96 cm and 57.07 cm; K values were 0.53, 0.53 and 0.38 and t_0 were -0.67, -0.84, and -1.18.

RESUMEN

Edad y crecimiento de la carpa común Cyprinus carpio (L.) *en el sistema de riego del valle del río Colorado, provincia de Buenos Aires, Argentina.*

La carpa común (Cyprinus carpio) *fue introducida en la Argentina al inicio del 1900 y recientemente dentro del sistema de riego del valle bonaerense del río Colorado. El presente trabajo tiene como objetivo determinar la edad que alcanza la carpa común que habita en el sistema de riego, y estimar los parámetros que permiten evaluar el ritmo de crecimiento que presenta esta especie en la región. La edad fue determinada mediante la lectura de escamas y la estimación de los parámetros de crecimiento por la ecuación de von Bertalanffy. Se diferenciaron 11 clases de edad, desde 0+ a 10+. El $L\infty$ estimado fue 54,23 cm para el total de la población, 52,96 cm para las hembras y 57,07 cm para los machos; los valores de K fueron 0,53, 0,53 y 0,38, respectivamente y los correspondientes a t_0 fueron -0,67, -0,84, y -1,18.*

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INTRODUCTION

The common carp *Cyprinus carpio* (Linné, 1758) originated in Asia (Gunther, 1868 in Alikunhi, 1966). Today it is distributed extensively in Europe (Sarig, 1966), North America and several South American countries, where it was introduced through private or official initiatives, almost one hundred years ago (Ringuelet *et al.*, 1967). It was introduced into the Buenos Aires Province in Argentina at the beginning of the twentieth century. Later it was taken to the Province of San Luis for commercial reasons (MacDonagh, 1948), and then to the Province of Córdoba for sports fishing (Ringuelet *et al.*, 1967). Cazzaniga (1981), in a study of the fauna in the drainage channels of the Colorado River Valley - Buenos Aires Province, did not mention the common carp. It is estimated that the species arrived in the Colorado River when the Desaguadero (Salado River) overflowed into the Colorado basin during the floods in 1983, 1984 and 1985 (Colorado River Interjurisdictional Commitee-COIRCO, pers. com., Fernández *et al.*, 1998).

The Colorado River irrigation system, administrated

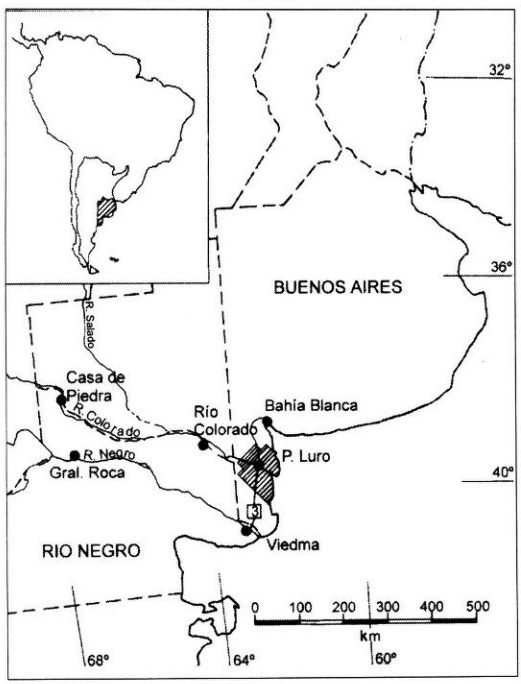

Figure 1

Location of the Colorado River Irrigation System, Buenos Aires Province, Argentina.

Table 1

Date of capture and number of specimens registered during the period from April'93 to December'94.

Date	Fishing data Number of *Cyprinus carpio* Total	Males	Females	Juveniles	Not determinded	Method
April/93	33	2	1	26	4	gill nets
May/93	98	3	2	93	0	gill nets
June/93	32	2	0	30	0	gill nets
July/93	143	20	20	103	0	gill nets
August/93	2	0	1	1	0	gill nets
September/93	0	0	0	0	0	gill nets
October/93	4	4	0	0	0	gill nets
November/93	0	0	0	0	0	gill nets
December/93	29	0	0	25	4	Electrofish
January/94	22	9	8	4	1	Electrofish
February/94	15	1	1	8	5	Electrofish
March/94	24	21	1	1	1	Electrofish
April/94	18	7	5	6	0	Electrofish
May/94	535	291	143	58	43	Electrofish
June/94	0	0	0	0	0	Electrofish
July/94	0	0	0	0	0	Electrofish
August/94	30	20	10	0	0	Electrofish
September/94	172	84	54	0	34	Electrofish
October/94	7	5	2	0	0	Electrofish
November/94	212	0	0	0	212	Electrofish
December/94	96	0	0	0	96	Electrofish
Total	1472	469	248	355	400	

by the Colorado River Economic Development Corporation (CORFO), is situated in the south of Buenos Aires Province, Argentina (62°37' W, 39° 23'S) (Fig.1). It covers approximately 8,000 km^2, with an extensive network of canals which irrigate 90,000 ha dedicated to agriculture and animal husbandry. It has a semi-arid temperate climate. The average water temperature varies between 5.5 and 25.6 °C according to the season, and the conductivity varies between 0.73 - 1.43 mS cm^{-1} in the irrigation channels and 2.04 - 10.54 mS cm^{-1} in the drainage channels. The depths of the latter are between 30 cm and 1 m.

The bibliographic references to the common carp in Argentina only cite its presence. Recent studies by Lopez Cazorla *et al.* (unpublished) show that the carp is widely distributed throughout the canal and is now the predominant species. The objectives of this study were to determine the age and growth parameters of the common carp (*C. carpio*) in the Colorado River irrigation system (CORFO).

MATERIAL Y METHODS

The material was obtained in the lower irrigation system of the Colorado River (CORFO) between April 1993 and December 1994. A total of 1472 individual fish were caught in 21 monthly samples (Table 1). Of these, the first eight were taken using gill nets 10 m long by 2.5 m deep, with meshes of 20, 40, 80, 120 and 150 mm (stretched) and the other thirteen by electro fishing using an Electrocatch WFC7 - 30/50

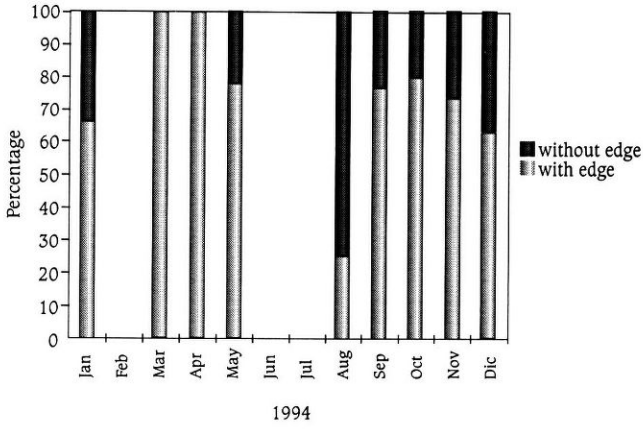

Figure 2

Monthly distribution of the *Cyprinus carpio* scale edge.

(220 V AC, 50 Hz). The nets were set for six hours during daylight. The electric fishing was carried out in 100 and 500 m sections of the canal that had been previously closed off with nets.

Scales were taken from the first 10 specimens of each 10 mm size-class, 891 specimens in total. Total length (TL), rounded down to the nearest mm and weight in grams were recorded. Sex was determined macroscopically.

Age was determined from the scales. These were extracted from the region above the central line on the left flank, between the dorsal fin and the area behind the operculum, and preserved dry. The scales were read through binocular lenses and using a microfiche reader which magnified 22.5 times. The anterior fields of the scale were measured on the microfiche screen using a millimetre scale.

The zone where growth was interrupted was considered to be a mark. Presumed annual marks were identified by standard criteria (Bagenal & Tesch, 1978). The periodicity of the marking was determined by studying scales taken in different months and dividing them into individuals with and without plus growth, expressing the results as percentages (Fig. 2).

The mark itself was validated by measuring the distance from the centre of the scale to each of the first four marks. Mean lengths of these distances were calculated together with their 95% confidence limits. The frequency of the distances from the centre to the first mark was also analysed (Fig. 3).

The relation between fish length and scale radius was estimated by means of a linear regression ($y = a+b.x$), based on 157 pairs of data, which covered sizes ranging from 120 to 450 mm total length (TL).

The length when the first and second marks were formed was back-calculated over 31 scales with two or more marks. This length was calculated using the formula $Ln = (((TL - a)/Rt)xRn)+a$, where Ln corresponds to the length of the fish when the n mark was formed; Rn, the length of the radius - centre point to n; Rt, the length from the centre point to the edge of the scale; "a" is the intercept on the length axis of the linear regression of fish length against scale radius, and TL, the length of the fish at the moment of capture. These results were compared with the mean length observed in animals captured in May, which was the nearest to the mark formation period.

The weight - length relationship was estimated using the model: $w=axL^b$. The parameters a and b were calculated by least-squares on natural logarithm transformed data. The comparison of the estimated gradients for males and females was carried out through the analysis of covariance (ANCOVA).

Growth was assumed to follow von Bertalanffy's model, as expressed by his equation: $Lt=L\infty(1-e^{K(t-t0)})$ where: Lt = mean length at age t; $L\infty$ = maximum mean length if the fish were to grow indefinitely; K = proportionality coefficient with which the fish reached $L\infty$; t_o = length of fish at age zero.

The parameters of von Bertalanffy's growth equation were calculated using the method proposed by Allen (1966) for the total population, and by sex.

RESULTS

Aging interpretation was validated by analysing the edge of the scale throughout the year. Thus, a wide growth border was observed on all of the scales of fish caught during March and April (end of summer), 75% showed a mark of growth interruption, indicating there would be no growth during August (Fig. 2). Yearly verifications, showing that *C. carpio* had only one growth period per year, followed by an interruption, allowed the allotment of the equivalent of one year to each ring.

The frequency distribution of the distance between the centre and the first mark was unimodal (mean: 2.92 mm ± 1.549 SD) (Fig. 3). The first mark, on some specimens, was found to be very close to the centre; 80% of the measured scales had their first mark between 1.5 - 3.5 mm from it, thus allowing them to be considered as true rings.

The mark validation carried out on the first four rings showed no overlap of their mean values, nor of the 95% confidence limits, thus allowing them to be designated as annual rings (Table 2).

The relation between the radius of the scale and the size of the fish turned out to be linear ($y=\pm1.03+0.027\times x$), within the range of sizes between 120 and 450 mm (Fig. 4). The mean back-calculated lengths were 194 mm at the time of the formation of the first annulus and 339 mm for the second. The observed mean lengths of fish captured close to the mark period were 200 and 302 mm TL (Table 3).

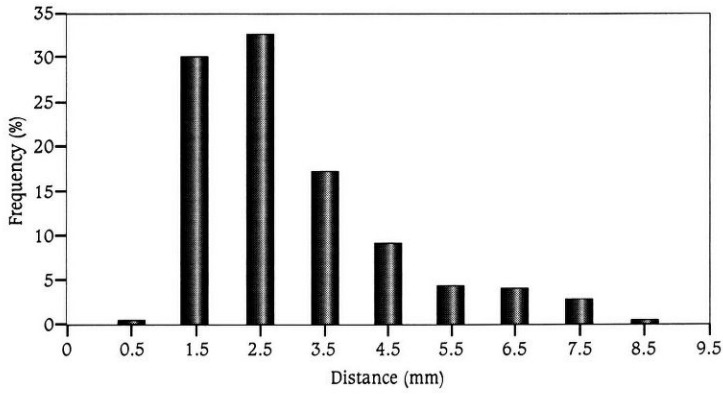

Figure 3
Frequency distribution of the distances from the centre to the first mark of growth on the scales of *Cyprinus carpio* (N:334).

Eleven age groups, between 0+ and 10+, were determined. Age group 0+ corresponded to fish whose scales had no ring and age 10+ to those with 10 rings. Table 4 represents the range of sizes by age, with their corresponding mean value and the 95% confidence limits for the whole population of samples, and by sex, for the first seven age groups. The other four groups are grouped together, due to the low number observed. The size range of females was from 120 to 610 mm, their age groups being 0+ to 9+. The males presented the same size range as females, but with ages 0+ to 10+.

The estimated values of the relation between length and weight by sex were $w=1.84\times10^{-5}\times L^{2.967}$, (n:330, R:0.99) for males and $w= 1.16\times10^{-5}\times L^{3.044}$, (n:201, R:0.98) for females. Although the b coefficient estimated for females was not significantly different from 3, it was for males ($p<0.05$) (Fig. 6). For the combined groups the 95% confidence limits were very

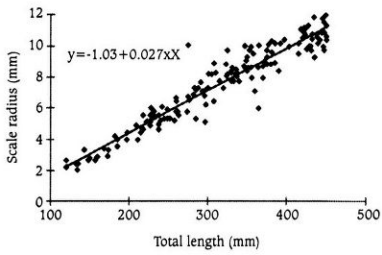

Figure 4

Relationship between the radius of the scale and the total length of the fish (R:0.92; N:157).

Table 2

Mean distances from the centre of the scales of the first four annual marks, standard deviations and 95% confidence limits.

	Distance to			
	First mark	Second mark	Third mark	Forth mark
Mean (mm)	2.917	7.052	9.203	10.209
Standard deviation	1.506	1.923	1.740	1.536
Confidence limits 95%	0.154	0.260	0.355	0.482
Range (mm)	0.66-9.02	3.11-12.44	5.87-12.89	6.62-12.93
N	334	209	92	39

Table 3

The total length (TL) back calculated to the moment at which the first and second growth interruption marks were produced.

	Mean TL observed (mm)	N	TL calculated (mm)	N
First mark	200±54	93	194±56	31
Second mark	302±56	155	339±58	31

Table 4

Mean lengths at each age, standard deviations, 95% confidence intervals, length ranges for total individuals and for males and females.

Total

Age	Mean TL mm	SD (Mm)	95 % CI	Range (Mm)	N
0+	155.6	62.2	8.1	40-320	224
1+	313.6	62.3	7.8	150-490	248
2+	406.4	58.3	8.5	250-570	180
3+	458.8	48.8	9.3	320-560	108
4+	492.9	45.8	14.3	410-590	42
5+	509.3	47.3	14.6	380-670	43
6+	519.7	51.1	18.7	450-690	31
≥7+	537.3	34.9	19.2	480-610	15
Total					891

Males

Age	Mean TL mm	SD (Mm)	95 % CI	Range (Mm)	N
0+	200.4	52.2	12.3	120-320	70
1+	320.7	53.4	8.3	170-440	161
2+	384.9	51.0	11.6	290-520	78
3+	457.9	42.5	12.5	340-530	47
4+	497.3	49.7	33.1	430-570	11
5+	512.4	41.9	21.5	440-610	17
6+	512.2	38.7	29.2	450-570	9
≥7+	545.7	42.0	37.5	480-610	7
Total					400

Females

Age	Mean TL mm	SD (Mm)	95 % CI	Range (Mm)	N
0+	185.0	34.8	19.9	160-260	14
1+	323.7	71.5	22.9	170-480	40
2+	414.8	46.6	10.6	340-550	77
3+	447.4	44.5	14.6	360-530	38
4+	478.3	44.0	21.8	410-560	18
5+	508.8	41.2	33.6	460-570	8
6+	503.8	29.3	23.9	450-540	8
≥7+	540.0	34.6	31.0	500-610	7
Total					210

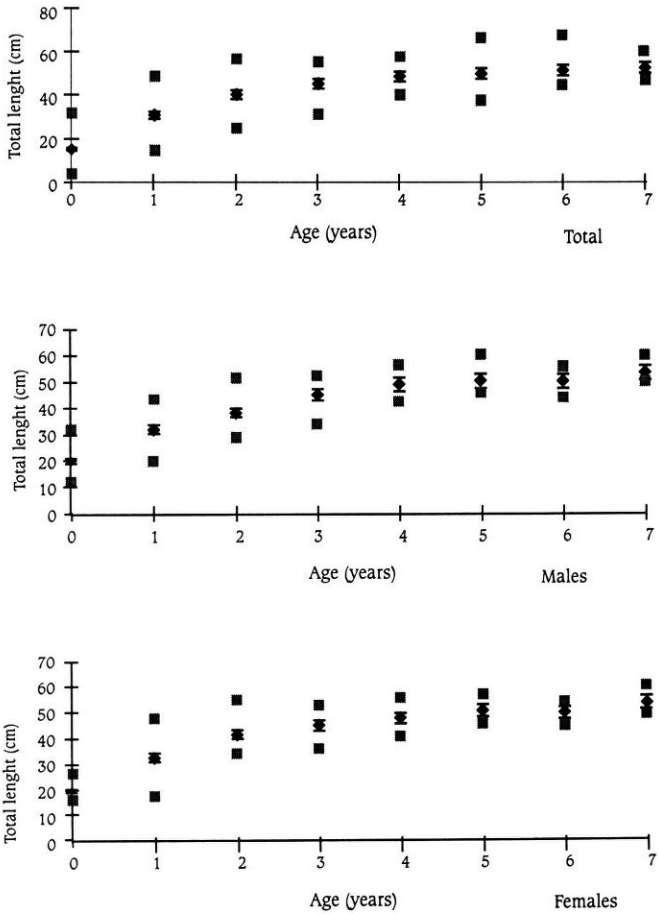

Figure 5

Mean size, 95% confidence interval (I), and range per age, as observed in the total population and in males and females of *Cyprinus carpio*.

Table 5

Growth size parameters of *Cyprinus carpio* for the total population and by sex.

	L_∞ (cm)	K	t_0	N
Total	54.23±1.51	0.53±0.049	-0.67±0.07	891
Female	52.96±2.53	0.53±0.106	-0.84±0.24	210
Male	57.07±3.23	0.38±0.07	-1.18±0.20	400

Table 6

Growth parameters estimated by other authors in other regions of the world.

Author	Location	L_∞(cm)	K	t_0
Ramos *et al* 1985	Portugal	49.20	0.27	0.308
Pinilla *et al.* 1992	Colombia	55.63	0.403	0.09320
Ritter-Ortiz *et al.* 1992	Mexico	61.25	0.1972	0.0052

close to 3. The statistical comparison between the estimated straight-line slopes for females and males indicated significant differences ($p<0.05$).

The estimated values for the parameters $L\infty$, K and t_0 of von Bertalanffy's equation, for the whole population and by sex, are presented in Table 5. Differences between the growth parameters were observed between sexes, with the result that the theoretical maximum length for males was greater than that for females. The constant K or proportionality factor with which the fish reaches $L\infty$ was greater for females than for males.

DISCUSSION

The common carp, which has recently been introduced into the irrigation system of the Colorado River in Buenos Aires Province (Fernández *et al.*, 1998), is characterised by its rapid adaptation to different environments and habitats in contrast to other freshwater fish. This species has been extensively studied due to its wide geographical distribution (Alikunhi, 1966; Sarig, 1966).

The interpretation of age, carried out by reading the scales, permitted the identification of 11 age groups (0+ to 10+ years). The majority of the samples taken corresponded to groups of up to 6+ years. The rest, 7+ to 10+, were sparsely represented, probably due to their recent introduction into the irrigation system and fishing-pressure. Local inhabitants capture the carp principally in the drainage canals, which are more accessible due to their shallowness and water flow rate.

A notable agreement was observed with the results obtained by other authors (Sarig, 1966; Crivelli, 1981; Ritter - Ortiz *et al.* 1992) in the longevity and in the estimated mean size for each of the age groups.

The annual ring mark is produced once a year during winter - early spring (July - September) in coincidence with the period of low temperatures. This agrees with the observations of Ramos *et al.* (1985) and Pinilla *et al.* (1992).

The estimated growth parameters for the population of the irrigation system (Table 6) were more similar to those obtained by Pinilla *et al.* (1992) in Colombia and less similar than those obtained by Ramos *et al.* (1985), and Ritter - Ortiz *et al.* (1992) in Portugal and Mexico who estimated smaller and greater growth parameters respectively than the estimated in the present study.

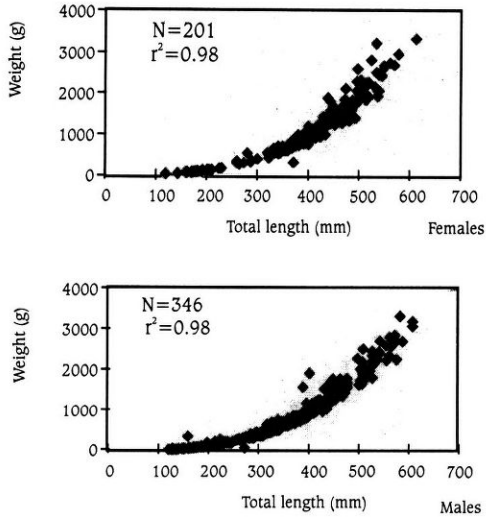

Figure 6

Relationship between the total length and the weight in and females ($w=1.16x10^{-5}L^{3.044}$) males ($w=1.84x10^{-5}L^{2.967}$) of *Cyprinus carpio*.

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REFERENCES

Alikunhi, K.H. 1966. Synopsis of biological data on common carp *Cyprinus carpio* (Linnaeus), 1758 (Asia and the Far East) *FAO Fish Synops.* (31.1): pag. var.

Allen, K.R. 1966. A method of fitting growth curves of the Bertalanffy type to observed data. *J. Fish. Res. Board Can., 23*(3):163-277.

Bagenal, T.B. and F.W. Tesch. 1978. Methods for Assessment of fish production in fresh waters. *3rd Edition. IBP Handbook no. 3. Blackwell Scientific Publications, Oxford*: 365 pp.

Cazzaniga, N. 1981. Sinopsis de la composición del complejo bafon-bentos en canales de drenaje del Valle Bonaerense del río Colorado. II Reunión sobre Malezas Subacuáticas en canales de desagüe de CORFO. *CIC*: 79-87.

Crivelli, A.J. 1981. The biology of common carp *Cyprinus carpio* L in the Camargue, Southern France. *J. Fish Biol.* (18): 271-290.

Fernández, O.A., K.J. Murphy, A. Lopez Cazorla, M.R. Sabbatini, M.A. Lazzari, J.C.J.

Domaniewski and J.H. Irigoyen. 1998. Interrelationships of fish and channel environmental conditions with aquatic macrophytes in an Argentine irrigation system. *Hydrobiologia* 380: 15-25.

Mac Donagh, E. 1948. Sobre la cría de carpas y pejerreyes en la provincia de San Luis. *Inst. Mus. Univ. Nac. La Plata. Secc. Zool.* (114): 315-325.

Pinilla G.A., G. Vargas y E. Patiño. 1992. Aspectos poblacionales de la Carpa *(Cyprinus carpio)* en la Laguna de Funquene (Departamento de Cundinamarca, Colombia). *Boletín Ecotrópica: Ecosistemas tropicales 25*: 28-41.

Ramos, M.A., G. Pestana y T.G. Pereira. 1985. Estudo biológico da carpa *Cyprinus carpio* L. no río Tejo. *Bol. Inst. Nac. Invest. Pescas. Lisboa* (13): 3-59.

Ringuelet, R.A., R.H. Arámburu y A. A. de Arámburu. 1967. Peces argentinos de agua dulce. *CIC:* 602 p.

Ritter-Ortiz, W., J. Suárez Sánchez y R. Rodríguez Maldonado. 1992. Crecimiento, sobrevivencia y optimización de la carpa *(Cyprinus carpio)* en la presa de Atlangatepec, Tlaxcala. *An. Inst. Cienc. del Mar y Limnol. Univ. Nal. Autón. México, 19*(1): 43-56.

Sarig, S. 1966. Synopsis of biological data on common carp *Cyprinus carpio* (Linnaeus), 1758 (Near East and Europe). *FAO Fish Synops.* (31.2) pag. var.

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