AMAZONIANA	VII	4	445 – 464	Kiel, Januar 1983

Age determination by scale analysis in juvenile Matrinchã (*Brycon* cf. *melanopterus* Müller & Troschel, Teleostei: Characoidei) a tropical characin from the Central Amazon*

by

Ulrich Werder

Institut für Hydrobiologie und Fischereiwissenschaft, Hamburg

1. Introduction

Age determination by scale-reading in fish from temperate climate zones is based on the fact that wider- or narrower-spaced sclerites (circuli) are formed on the scale's surface during different seasons (HOFFBAUER 1899).

Sclerite-patterns reflect changes in water temperature and fish growth, allowing the recognition of classical "year marks", which most authors believe to be formed at the beginning of a new growth season.

In tropical areas the lack of seasonal temperature fluctuations prevents the formation of such year-marks, and age determination by the classical method becomes impossible (McLARNEY 1973).

An interpretation of irregularities in sclerite patterns is quite difficult when basic ecological informations (spawning period, rainy season, water level, food availability etc.) are missing, and the life-history of the fish is not well known.

PANNELLA (1971) elaborated a method for age determination by counting daily rings on otoliths which most teleostean fishes produce (BROTHERS et al. 1976), at least during their juvenile stages. Their formation occurs rhythmically and is independent of the fish-length and the diameter of the otolith (TAUBERT and COBLE 1977).

However, this method requires more sophisticated equipment than the scale-method, and it often leads to reduced market-values of the dissected fish.

Earlier investigators (WINGE 1915; CUTLER 1918) obtained itentical results from scales and otoliths regarding growth bands. This may lead to the assumption that both structures underlie similar rhythmic growth.

---

* This publication is part of a PhD-thesis conducted at the University of Hamburg, FBR Biologie

WINGE (1915), TAYLOR (1916), and GRAHAM (1929) deduced the existence of a rhythmic scale-growth from regular sclerite-widths, which they attributed to identical time-intervals between the formation of subsequent sclerites, and OTTAWAY (1978) found both a diurnal and a seasonal rhythm of Glycin (^{14}C) incorporation in isolated scales of *Rutilus rutilus.*

Matrinchã *(Brycon* sp.), a fast growing characin from the Central Amazon (WERDER 1982), has many fine and closely packed sclerites on its scales.

Even underyearlings, either from ponds or from the wild show 100 sclerites or more, which means that only little time is required for the formation of any single sclerite.

The object of the present investigation was to examine the relationship between time and the number of sclerites formed, in order to elaborate a simple method for age-determination. Another aspect was to test the reliability of local fishermen's knowledge in regard to the importance of ecologic factors (rain, water-level) for the onset of spawning.

2. Material and Methods

The Matrinchã is a characid fish, belonging to the *melanopterus* complex of the genus *Brycon.* The classification on the species level (WERDER in prep.) is still somewhat doubtful.

Juvenile Matrinchã were collected with seine-nets in the surrounding waters of Manaus. Alevins were caught in the Rio Solimões, about 5 km above its junction with the Rio Negro in flooded areas of the Ilha de Marchantaria, while larger juvenile fish were caught during their upstream migration in the Rio Negro, a few kilometers upstream Manaus.

After the determination of length and weight, the specimen were fixed in formalin (5 %), and transferred into 70 % ethanol after watering.

Standard scales were taken from the 6^{th} to 10^{th} row between lateral line and dorsal fin, previously selected after the method recommended by DANNEVIG and HØST (1931).

The main criteria were constancy in shape (HOFFBAUER 1899, WALTER 1901), maximum number of sclerites (PERLMUTTER and CLARKE 1949), and the presence of the first sclerites.

Normally 4 to 10 scales were taken from the left body side (THOMSON 1904, CASSIE 1956). When the number of normal scales was not sufficient, also scales from the opposit side had to be considered.

After cleaning the scales in 70 %-ethanol, they were mounted under glass-cover in "Kaisers Glyceringelantine" (Fa. Merck, Art. 9242).

The number of sclerites and the orad diameter were determined microscopically (1 : 33).

For testing the influence of time on sclerite formation, fingerlings of 7.9 $\pm$1.1 cm length (N = 50) were kept in a groundwater-pond at a density of 1 ind./m^2 for 213 days. Additional feeding with dry pellets guaranteed sufficient food which would result in growth increment similar to those under natural conditions (WERDER 1981).

At the end of the experiment, 14 fish were taken at random for scale examination.

The original values for number of sclerites and scale radius were determined by means of growth stop marks (FRASER 1917; THOMPSON 1926; MOREAU 1977), which were caused by temporary physiological disturbances due to transport and lack of food before the beginning of the experiment.

All data were analyzed on a Sharp Personal Computer m 2 - 80 k.

2.1. Description of the scale

The exposed part of Matrinchã's cycloid scale contains a number of radii. The outer ones run out almost parallel with the axis of the fish, while the ones closer to the center may slightly overlap onionlike and end still on the scale's surface. In this region no sclerites are present and the total area may amount to between ca. 20 % and 40 % of the total surface.

The cranial part of the scale is characterized by a large number of very closely packed sclerites, which are not arranged concentrically, but run out dorsally and ventrically.

Very typical are their high density and the constant distances in between them (ca. $22,6 \times 10^{-3}$ mm).

On scales of certain older individuals, bands of wider or narrower spaced sclerites can be found, probably reflecting different periods of growth.

Sometimes, irregular sclerite patterns can be observed, mainly on the dorsal and ventral side, but in many cases they include the whole scale (WERDER 1982), especially in older fish. Such "bands" or "lines" may be the result of reabsorption-processes during gonadal maturation (LEE 1912; GARROD and NEWELL 1958; GODOY 1959; FLEMING et al. 1964; CORDIVIOLA 1971; MUGIYA and WATANABE 1977), or growth stagnation (FRASER 1917; HELLAWELL 1974; LINFIELD 1974), and sometimes both factors interfere (DANNEVIG 1928; HESS et al. 1928; SEGERSTRÅLE 1932; BAILEY 1957; WALLIN 1957; BERG and GRIMALDI 1967; HOLČIK 1967; BAYLEY 1973; PROKEŠ et al. 1977; BLAKE and BLAKE 1978; LIBOSVÁRSKÝ and BARUS 1978).

In juvenile fish, growth stop marks (MOREAU 1977) often can be found in several individuals of the same population, probably being the result of their migratory behaviour combined with periods of limited food availability.

For pond experiments these growth stop marks were provoked through transport and food shortage (FRASER 1917), and were then used as biological tags.

3. Results

3.1. Pond experiments

The results of the pond experiments are listed in table 1.

The total length at the end of the experiment varies only little, proving that growth conditions were equal for all individuals. The increase of the scale radius (Δr) also shows only slight deviations from the average value.

The distance between either two sclerites ($\Delta r/\Delta n$) is larger during the experiment than before, which could be attributed to better food conditions, however, similar observations were made in fish from natural habitats. Thus it seems to be a natural phenomena of allometric growth, rather than a nutritional effect. The standard deviation of the sclerite-numbers does not change during the experiment, and the numbers of sclerites formed during the experiment are almost identical with an average of 106 ± 3 sclerites produced in 213 days.

Therefore the time required for the formation of one sclerite was 2 ± 0.05 days.

Table 1: Scale parameters at the beginning and at the end of the 213 days' pond experiment

No	L (cm)	r_o (mm)	r_t (mm)	Δr (mm)	n_o	n_t	Δn	r_o/n_o (mm x 10^{-3})	$\Delta r/\Delta n$ (mm x 10^{-3})	$t/\Delta n$
1	23.2	0.60	3.00	2.40	34	140	106	17.6	22.6	2.00
2	25.8	0.60	3.00	2.34	34	141	107	19.4	21.8	1.99
3	27.7	0.45	3.06	2.61	26	130	104	17.3	25.1	2.05
4	25.6	0.45	3.30	2.85	27	137	110	16.7	25.9	1.94
5	26.7	0.60	2.94	2.34	35	137	102	17.1	22.9	2.09
6	24.3	0.24	2.82	2.53	19	126	105	12.6	24.6	2.03
7	25.0	0.60	3.00	2.40	31	139	108	19.4	22.2	1.97
8	25.5	0.36	3.00	2.64	26	133	107	13.8	24.6	1.99
9	25.8	0.30	2.88	2.58	21	131	110	14.3	23.5	1.94
10	26.1	0.33	2.85	2.52	21	125	104	15.7	24.2	2.05
11	25.7	0.57	3.09	2.52	28	134	106	20.4	23.8	2.01
12	26.4	0.33	3.03	2.70	19	129	110	17.4	24.5	1.94
13	24.0	0.42	2.76	2.34	21	125	104	20.0	22.5	2.05
14	27.0	0.75	3.27	2.52	38	145	107	19.7	23.6	1.99
$\bar{X}$	25.7	0.48	3.00	2.52	27	134	106	17.2	23.7	2.00
S	1.2	0.15	0.15	0.15	6	6	3	2.5	1.2	0.05

L = total fish-length at the end of the experiment; r_o = initial scale radius; r_t = final scale radius; $\Delta r = r_t - r_o$; n_o = initial number of sclerites; n_t = final number of sclerites; $\Delta n = n_t - n_o$; r_o/n_o = distance between sclerites before the experiment; $\Delta r/\Delta n$ = distance between sclerites during the experiment; t/dn = time of experiment (days)/number of sclerites formed

3.2. Back-calculation of the day of spawning

The chapter above clearly shows that fish during their growth from 7 cm to 30 cm length produced one new sclerite every other day. Presuming that the same rhythm applies to smaller fish than the investigated ones, it is possible to back-calculate the day (a) on which the first sclerite was formed:

$$a = n \cdot 2$$

Scales of teleost fishes generally first appear at the end of or right after the larval stage (SCHNAKENBECK 1955). This means that for calculating the actual "birthday" of any fish, the time-interval between fecundation and formation of the scale must additionally be considered.

In the case of *Tilapia macrocephala, T. nilotica,* and *T. tholloni* the average time needed amounts to 14 - 24 days (FISHELSON 1966). Two south-american characins, *Prochilodus* sp. (FONTENELLE et al. 1946) and *Colossoma* sp. (SILVA et al. 1977) require less than a week for the absorption of the yolk sac, and personal observations showed that postlarvae of Matrinchã of 3 cm length had already 6 to 8 sclerites, while one 1.8 cm long larva did not possess any scales yet.

Matrinchã schools often migrate together with *Semaprochilodus theraponura* and *Prochilodus* sp. into white water rivers as the Rio Solimões, where spawning takes place under identical conditions. Therefore it can be assumed that Matrinchã's embryonic and larval development will not substantially differ from those of the above pelagically spawning species. Their fry swim up and feed actively a few days after spawning (JUNK 1975). Supposing furthermore that about another week is needed until the first sclerite is formed, approximately 14 days have to be added for the calculation of the actual age (b) of Matrinchã.

$$b = n \, . \, 2 + 14$$

By subtracting the age (b) from the number of days (c) which have passed in a year until the day of capture, the exact day of spawning (d) can be calculated.

$$d = c - (n \, . \, 2 + 14)$$

d = day of bith (spawning)
c = number of days of a year at the day of capture
n = number of sclerites

As mentioned in the introduction, local fishermen have a special, inherited knowledge of the interaction of certain ecological parameters which, in their opinion, induce spawning-activities of fish. According to their statements Matrinchã only spawns when the rise of the water-level and heavy rains occur simultaniously (see also: GEISLER et al. 1971). This was confirmed by personal observations on several occasions. Moreover, the relative increase of the water-level per unit time is said to strongly influence the number of fish which spawn at the same time.

On the other hand, falling water-level and minute rainfalls are supposed to be disadvantageous for spawning.

In the following chapters, data derived from the above formula are brought in relation to these parameters.

3.2.1. Back-calculation of the spawning-date

3.2.1.1. Pond-fishes

The average number of sclerites of pondfishes (see 2.1.) was 134 ± 6 on 10.31.1980, the 305th day of the year. Thus, the calculated "birthday" of these fish is:

$$d = c - (n \cdot 2 + 14)$$
$$d = 305 - (134 \cdot 2 + 14)$$
$$d = 23$$
$$d = 01.23.1980$$

The parent-population of the investigated fish presumably spawned around the 23rd of January 1980.

Table 2: Daily precipitation* in January 1980 at Lago Janauacá** and Reserva Ducke*** Water-level and daily fluctuations of the Rio Negro at Manaus****

Day	Janauacá (mm)	R. Ducke (mm)	Level (m)	Tendency (cm)
01	0.0	0.0	20.16	+ 8
02	0.0	11.2	24	+ 8
03	7.6	12.5	31	+ 7
04	0.0	0.1	38	+ 7
05	0.0	14.1	42	+ 4
06	22.3	0.0	46	+ 4
07	7.6	6.8	51	+ 5
08	7.6	4.8	57	+ 6
09	0.0	18.1	61	+ 4
10	15.3	0.0	62	+ 1
11	0.0	0.0	63	+ 1
12	0.0	0.0	62	- 1
13	0.0	0.0	62	0
14	0.0	0.0	62	0
15	0.0	0.0	62	0
16	63.5	0.6	62	0
17	0.0	0.4	67	+ 5
18	11.5	21.2	69	+ 2
19	0.0	9.4	72	+ 3
20	6.9	2.3	75	+ 3
21	0.0	0.3	77	+ 2
22	75.0	5.2	80	+ 3
23	17.3	3.2	84	+ 4
24	28.8	4.4	88	+ 4
25	0.0	1.5	93	+ 5
26	0.0	11.7	95	+ 2
27	0.0	0.0	97	+ 2
28	0.0	6.0	98	+ 1
29	0.0	3.8	98	0
30	0.0	0.0	97	- 1
31	28.8	0.0	20.96	- 1

* Source: Maria de Nazaré Góes Ribeiro, INPA

** ca. 30 km southwest of spawning site in the Rio Solimões

*** ca. 40 km north of spawning site on the "terra firme"

**** Source: Capitania dos Portos, Manaus

The precipitation data clearly show that heavy rains were registered between the 22nd and 24th of January. Before and after this period only little or no rain at all was observed.

At the same time the water-level of the Rio Negro, from where Matrinchã migrates to its spawning grounds, increased by 4 cm to 5 cm daily, while only small increase or even decrease of the level occured on other days. Both factors show highly favourable conditions for the spawning of Matrinchã.

In addition to this, the quantities of Matrinchã landed at the fish-market of Manaus in January were by 50 % higher than in December, and dropped to almost zero in February (ANNIBAL, pers. comm.).

Since Matrinchã forms larger schools only for the purpose of spawning at this time of the year, these data support the correctness of the calculated spawning date.

3.2.1.2. Comparison of sclae parameters of pond- and river-fishes

Having demonstrated the application of the formula for age determination using scales of pond-fishes, it is now necessary to prove if the same formula can also be applied to natural populations.

The main criteria for comparing scale parameters of pond-fishes and wild-fishes are listed in table 3.

Table 3: Scale parameters of pond- and river-fishes

No.	Fish-length (cm)	Scale radius (mm)	No. sclerites	Distance (x 10^{-3} mm)	N
I	25.7 ± 1.2	3.00 ± 0.15	134 ± 6	22.5 ± 0.9	14
II	23.6 ± 2.0	2.87 ± 0.33	127 ± 13	22.6 ± 1.7	14
III	44.1 ± 4.1	5.40 ± 0.84	239 ± 37	22.7 ± 1.4	13

I – Pond-fish
II – Wild-fish of August 1979
III – Wild-fish of January 1980

The average length of the pond-fishes (I) is slightly greater than the length of the sample II. The same holds for scale-radius and number of sclerites. Although sample II shows a higher deviation than the more evenly distributed pond-fishes, the average distance between subsequent sclerites can be considered identical.

Since all scale parameters of the wild-fish match with those of the pond-fish of approximately the same size, both fish- and scale-growth under natural conditions are consistend with the data derived from the pond experiments.

Consequently, the formula for age determination can also be applied to fish from natural environments.

Additionally, the scale parameters of adult wild fish (III) of about twice the size of the other two groups are presented in table 3. They indicate that the distance between sclerites does not substacially change with increasing age.

Summarizing these results it can be concluded:

a) Independent of fish-lenght, the distances between sclerites are identical in juvenile and adult fish from natural biotops.

b) Sclerite-distances which reflect fish growth are the same in pond-fish and fish from the wild.

c) The formula for age determination derived from pond experiments regarding scale growth, sclerite density, and time dependency, can also be applied on natural populations.

3.2.1.3. Back-calculation from scales of fingerlings

The following gives an example for the back-calculation of "birthdays" of three different samples of fingerlings from natural environments (Table 4).

Table 4: Fish-length and number of sclerites of three different samples of fingerlings, and their calculated "birthdays"

Sampling day	Length (cm)	No. sclerites	Age (days)	"Birthday"	N
01.23.79	3.9 ± 0.8	9.7 ± 3.0	33	12.21.78	9
02.12.79	6.5 ± 1.3	17.7 ± 3.1	49	12.24.78	10
03.03.80	7.2 ± 0.9	22.2 ± 4.2	58	01.06.80	17

The exactness of the formula for age determination when applied to fingerlings from natural biotops, receives strong support from the fact that stimulating ecological factors coincide at the back-calculated time of spawning.

The calculated "birthdays" of both '79 samples correspond with rising water-levels and heavy rains, the latter being concentrated in the period between 12.21.1978 and 12.25.1978 (Table 6). High precipitations were recorded from 01.02.1980 to 01.10.1980, when the water-level of the Rio Negro simultaniously rose by several centimeters per day.

Another striking phenomenon is the fact that in all cases mentioned, the water-level of the Rio Negro had reached at least the 20 m-mark.

3.2.1.4. Back-calculation from scales of underyearlings

The investigated fish were caught on 08.16.1979 – the 228th day of the year – during their upstream migration in the Rio Negro. The individual lenghts and sclerite numbers are listed in table 5.

Table 5: Fish length and sclerite number of 16 Matrinchã, collected on the 08.16.1979

No.	Length (cm)	Number of sclerites
01	22.9	118
02	24.8	130
03	21.8	121
04	23.6	150
05	18.8	97
06	24.0	140
07	22.8	112
08	21.7	122
09	25.5	120
10	24.1	134
11	28.2	143
12	23.7	144
13	23.6	152
14	23.5	132
15	23.4	121
16	23.0	124
$\bar{x}$ =	23.5 $\pm$ 2.0	129 $\pm$ 14.8

The calculated age is 272 days, which means that spawning occurred on the 11.18.1978 (228 - 272 = -44).

Table 6 presents water-level conditions and precipitations for the last three months of 1978.

At the calculated day of spawning, both water-level and precipitation are disfavourable for spawning. Local fishermen would not even leave their ports under these conditions, since no spawning schools are expected to be formed.

A more careful analysis of the sample reveals, that, though in regard to length, a normal distribution exists on the 5 % level, but not in regard to the number of sclerites.

It is a well-known phenomenon in fish from temperate zones that fish congregate in groups of equal size, rather than of the same age (CASSIE 1956), and obviously this is also true for the Matrinchã-sample of 08.16.1978.

Applying Fisher's discrimination analysis (1954), the sample can be divided into two subsamples (Table 7, 8).

Both subsamples only slightly overlap in regard to their length distributions, but are statistically seperated, as the number of sclerite concerns ($p < 0.05$).

The newly calculated "birthdays" of the two groups are:

Subsample A

$d = 228 - (117 \,.\, 2 + 14)$

$d = - 20$

$\underline{d}_A = 12.11.1978$

Subsample B

$d = 228 - (141 \,.\, 2 + 14)$

$d = - 68$

$\underline{d}_B = 10.25.1978$

Table 6 shows that both spawning dates coincide with periods of water-level and heavy rainfalls.

For better illustration the changes of the water-level and precipitation data are demonstrated in Figure 1.

Table 6: Water-level and daily fluctuations of the Rio Negro and daily precipitations between October and December of the year 1978

Oct. 1978	Janauacá (mm)	R. Ducke (mm)	level (m)	tendency (cm)	Nov. 1978	Janauacá (mm)	R. Ducke (mm)	level (m)	tendency (cm)	Dec. 1978	Janauacá (mm)	R. Ducke (mm)	level (m)	tendency (cm)
01	–	0.1	20.98	-10	01	–	0.0	20.66	0	01	36.5	1.0	20.14	- 3
02	–	0.0	85	-13	02	–	30.8	65	-1	02	0.0	3.6	14	0
03	–	0.0	75	-10	03	–	3.3	64	-1	03	0.0	3.9	14	0
04	–	0.5	65	-10	04	–	8.2	63	-1	04	19.2	0.3	14	0
05	–	0.0	55	-10	05	–	0.0	61	-2	05	0.0	0.8	12	- 2
06	–	4.9	50	- 5	06	–	0.0	59	-2	06	21.5	0.7	12	0
07	–	0.3	46	- 4	07	–	0.6	58	-1	07	1.5	1.4	12	0
08	–	2.0	42	- 4	08	–	0.0	55	-3	08	–	19.0	13	+ 1
09	–	0.0	38	- 4	09	–	0.9	53	-2	09	–	0.3	14	+ 1
10	–	–	35	- 3	10	–	0.3	50	-3	10	–	7.1	15	+ 1
11	–	0.0	33	- 2	11	10.0	0.0	46	-4	11	–	6.7	16	+ 1
12	–	0.0	32	- 1	12	0.0	7.4	42	-4	12	–	46.1	18	+ 2
13	–	0.0	32	0	13	73.0	0.0	39	-3	13	71.5	6.8	23	+ 5
14	–	0.1	34	+ 2	14	0.0	0.0	35	-4	14	0.0	0.2	34	+11
15	–	0.0	37	+ 3	15	0.0	0.1	32	-3	15	0.0	0.0	44	+10
16	–	0.0	40	+ 3	16	0.0	3.8	29	-3	16	0.0	6.9	54	+10
17	–	0.0	43	+ 3	17	0.0	1.8	26	-3	17	0.0	0.0	64	+10
18	–	7.5	44	+ 1	18	1.5	0.0	24	-2	18	0.0	0.0	73	+ 9
19	–	0.0	49	+ 5	19	0.0	9.5	22	-2	19	0.0	0.0	81	+ 8
20	–	0.0	52	+ 3	20	0.0	0.9	20	-2	20	0.0	0.0	90	+ 9
21	–	0.0	55	+ 3	21	15.7	0.0	20	0	21	0.0	20.5	21.01	+11
22	–	66.5	59	+ 4	22	0.0	0.0	20	0	22	–	0.4	12	+11
23	–	0.0	63	+ 4	23	0.0	0.0	20	0	23	15.3	0.0	23	+11
24	–	0.1	65	+ 2	24	0.0	0.0	20	0	24	73.0	10.5	34	+11
25	–	4.1	66	+ 1	25	0.0	0.0	20	0	25	17.3	0.6	45	+11
26	–	0.0	67	+ 1	26	0.0	0.0	19	-1	26	–	0.0	57	+12
27	–	0.0	69	+ 2	27	0.0	0.0	18	-1	27	–	2.8	68	+11
28	–	0.0	69	0	28	0.0	0.0	18	0	28	–	0.0	77	+ 9
29	–	0.0	69	0	29	0.0	0.0	18	0	29	30.7	0.5	85	+ 9
30	–	0.0	68	- 1	30	13.8	3.0	20.17	-1	30	–	10.5	94	+ 9
31	–	0.0	20.66	- 2						31	–	4.8	22.03	+ 9

Table 7: Subsample A

No.	Length (cm)	Number of sclerites
01	22.9	118
02	21.8	121
03	18.8	97
04	22.8	112
05	21.7	122
06	25.5	120
07	23.4	121
08	23.0	124
x	22.5 ± 1.9	117 ± 8.8

Table 8: Subsample B

No.	Length (cm)	Number of sclerites
01	24.8	130
02	23.6	150
03	24.0	140
04	24.1	134
05	28.7	143
06	23.7	144
07	23.6	152
08	23.5	132
x	24.5 ± 1.8	141 ± 8.2

The changes of the water-level as the sums of two days respectively, are transformed into a polynomial regression of the 5th degree:

$y = 33.31 + 8.50x - 0.61x^2 - 0.01x^3 - 0.25 \cdot 10^{-6}x^4 - 0.18 \cdot 10^{-5}x^5$

($r = 0.9060$; $n = 46$).

The regression curve demonstrates the relative changes of the water-level better than the original data (Table 6). Two separate peaks (periods of rising water-level) can clearly be distinguished which in combination with precipitation data show that favourable conditions for the spawning of Matrinchã existed both in October and December 1978. The very early spawning event of October 1978 receives proof from fry samples which were collected during this period (BAYLEY, pers. comm.).

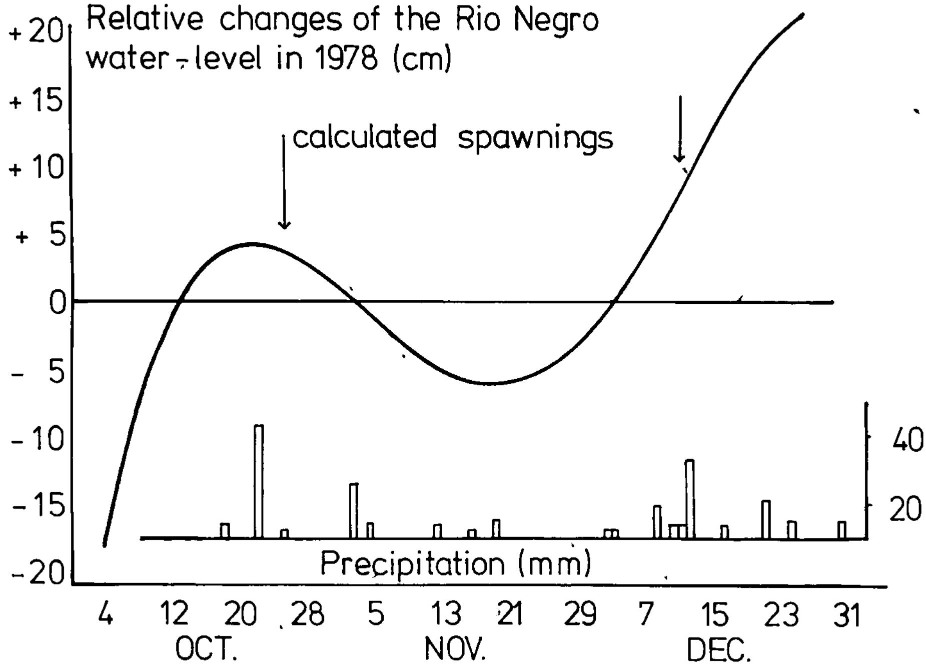

Fig. 1:
Relative water-level changes of the Rió Negro and precipitation at the Reserva Ducke between October 1978 and December 1978

Following the first period of rising water (repiquete), spawning conditions become disfavourable, and rising water-level and high precipitation simultaneously occur again only in December. The period of disfavourable conditions coincides with the interval of 48 days between the two calculated spawnings, and thus confirms the exactness of the elaborated formula for age determination.

3.2.2. Dependency between water-level and spawning period

All calculated spawning events fell into periods of rising water and high precipitation.

The time-interval of favourable conditions amounts to more than two months, and the question arises whether beside those ecological factors so far considered, the absolute level of the river (in m above sea level) also might function as "Zeitgeber" for the onset of spawning. This is of special importance in the area concerned since the river-level of the Rio Negro may fluctuate up to 17 m between extreme maxima and minima (GEISLER et al. 1971).

4. Discussion

The finding of a two-day rhythm of sclerite formation in juvenile Matrinchã confirms the suppositions of earlier authors (WINGE 1915, TAYLOR 1916) about the existence of an endogenous rhythm in fish-scale growth.

During the 213 days' pond experiment, food conditions were the same for all individuals, and no clear evidence was found for the formation of additional sclerites in faster growing fish, as this was described by CUTLER (1918) for *Pleuronectes platessa* and *P. flesus.* From the data gathered, it seems more likely that instead of forming extra sclerites, growth differences are compensated by varying the distance between subsequent sclerites within certain limits (Table 2). This would correspond with TAUBERT and COBLE'S (1977) results, which prove that only time and not the growth-rate of *Lepomis cyanellus* is responsible for the formation of rings in otoliths.

No causal explanation can be given for the two-day rhythm of sclerite formation, but the fact that sclerite-patterns of pond and river-fishes are identical, underlines the existence of an inherent rhythm for scale-growth in juvenile Matrinchã, similar to the diurnal rhythm of Glycin (^{14}C) incorporation in *Rutilus rutilus* (OTTAWAY 1978).

The use of biological tags ("growth stop marks", MOREAU 1977) which can be provoked by a short period of starvation (BILTON 1974) allow an exact determination of the number of sclerites formed during the experiment. The slight differences in total number of sclerites formed can partly be explained from the fact that neither at the beginning nor at the end of the experiment, the developmental stages of the last sclerites were known. The exactness of the elaborated method for age determination is comparable to PANNELLA'S (1971) otolith-method, and it leads to more precise results than the Peterson-method of length frequency analysis, preferred by a number of authors (GODOY 1959; BAYLEY 1973; McLARNEY 1973). This underlines MONASTUIRSKY'S (1926) requirement for critical analysis of various criteria before applying any given method for age determination to new fish species.

A careful examination of the sample of 08.16.1979 reveals that, if deduced from length only, the two age groups would be considered as one. It is a well-known phenomenon in fish from temperate waters that individuals congregate in groups rather of equal size than of the same age (MOLANDER 1918; CASSIE 1956), which is also true for Matrinchã, especially for populations of older fish (WERDER, in prep). As demonstated above, the number of sclerites must be considered a more reliable criteria for age determination in Matrinchã than the actual length of any given fish.

The important roll of rainfall and changes of the water-level for the spawning of many fish species in connection with water chemical properties have been pointed out by a large number of authors (GODOY 1959; IHINGRAN 1959; SIOLI 1965; KAMAL 1969; BAYLEY 1973; JUNK 1975; WELCOMME 1975; HANUMANTHARAO 1976; RAO 1976; etc.), and some have been able to successfully induce spawning by varying these factors artificially (LAKE 1967; KIRSCHBAUM 1979).

In the case of Matrinchã all back-calculated spawning dates coincide with periods of rising water-level and substantial rainfalls.

Table 9: Calculated spawning-events and water-level of the Rio Negro at Manaus

Spawning date	Water-level	Tendency
10.25.1978	21.01	+ 1
12.11.1978	20.16	+ 1
12.21.1978	21.01	+ 11
12.24.1978	21.34	+ 11
01.06.1980	20.46	+ 4

In all cases the water-level of the Rio Negro had already reached the 20 m-mark, showing rising tendency. Although the lowest levels in 1978 and 1979 differ by ca. 2 m, no spawning events were either calculated or recorded below 20 m (Fig. 2).

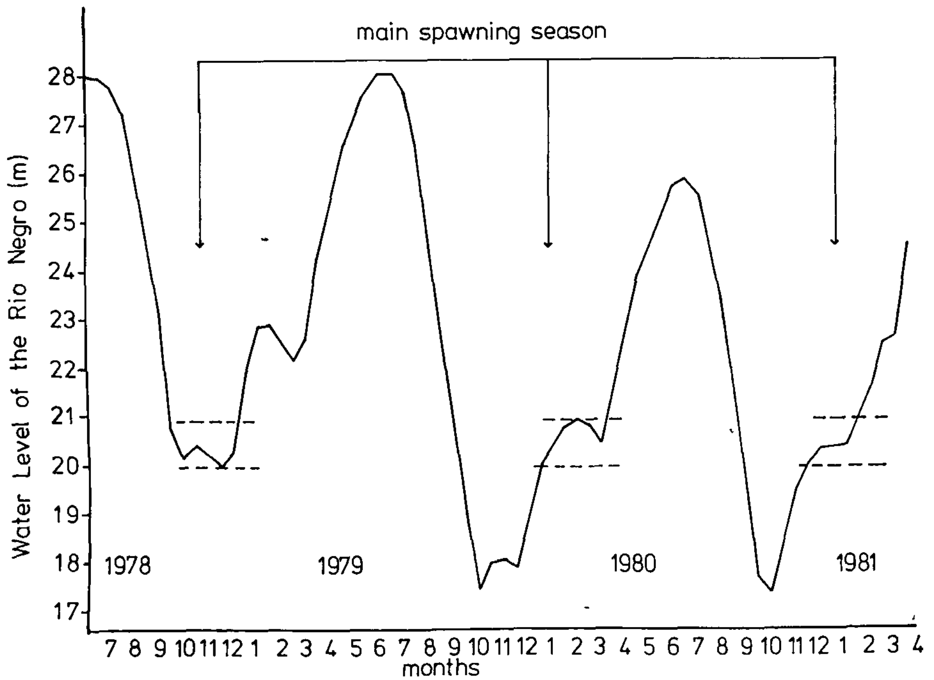

Fig. 2:
Water-level of the Rio Negro at Manaus from the year 1978 to 1981

In spite of substantial differences regarding low water-levels, the critical point for the onset of spawning seems to be at or above the 20 m-line. This becomes extremely evident in the case of the two spawning seasons in 1978, which were interrupted by a low level-period of below 20 m. Further support for the existence of a critical point around a level of 20 m is received from the fact, that also in January 1981 ripe Matrinchã were caught when the water-level was ca. 20.5 m.

Another important finding is the fact that the spawning of larger schools obviously does not occur at river levels below 20 m above sea-level. This can be well understood as an ecological necessity, considering that only after a certain level has been surpassed, large areas of land become inundated in which the young fish find shelter and food (JUNK 1975; WELCOMME 1975).

A deliberate application of the formula even makes possible the separation of different spawning populations, provided that an interval of ca. two weeks lies between the two events. Result of similar exactness can only be achieved by the otolith method, but not all otoliths are readable, and the method itself requires considerably more technical efforts. The scale method presented here therefore offers itself as a simple and reliable method for collecting large numbers of samples in the field, for the analysis of which only little technical equipment is needed. This paper exclusively deals with juvenile populations of Matrinchã from the Manaus-area. Studies, actually in progress, will show whether the method for age determination – with some modifications – is applyable to older fish, and different populations, too.

5. Summary

– The experimental results prove the existence of a two-days' rhythm of sclerite formation in juvenile Matrinchã (*Brycon* sp.).

– Identical scale patterns of wild-fish and pond-fish permit the application of a formula for age determination derived from pond experiments, also to fish from natural environments.

– The exactness of the formula for age determination can only be met by the otolith method. since the latter requires considerably more technical effort, and includes the risk of dealing with unreadable otoliths, the scale method presents itself as quite feasable, also for field work.

– All back-calculated spawning events coincide with increasing water-level, and high precipitations, thus confirming the fishermens' knowledge about interactions between these two ecological factors and their importance for the onset of spawning.

– The back-calculated spawning events let assume, that no spawning takes place before a certain level of the river (ca. 20 m above sea-level) has been surpassed, which seems to be an ecological necessity. Large numbers of fry can only survive when sufficiently large areas of land have become inundated.

– Further research is necessary to confirm whether the method for age determination is applyable to other populations and age groups, too.

6. Zusammenfassung

– Die Untersuchungen lassen den Schluß über das Vorliegen einer 2-Tage Rhythmik bezüglich der Skleritenbildung bei juvenilen Matrinchã (*Brycon* sp.) zu.

– Übereinstimmende Skleritenbilder bei Wild- und Teichfischen erlauben die Anwendung der Formel zur Altersbestimmung, die aus Wachstumsuntersuchungen an Teichfischen erarbeitet wurde, auch auf Fische aus natürlichen Populationen.

– Die Genauigkeit der Altersbestimmung mit Hilfe der Skleritenzahl kann allein mit der Otolithenmethode erreicht werden, doch sind die Otolithen von Matrinchã nur schwer lesbar. Auch als Feldmethode empfiehlt sich die Schuppenanalyse, insbesondere aufgrund der Möglichkeit umfangreicher Probenahmen, sowie ihres geringen technischen Aufwandes.

– Die Tatsache, daß sämtliche an Hand der Formel rückberechneten Laichtermine der Elternpopulationen in Phasen steigenden Flußpegels und starker Niederschläge fallen, unterstützt die Richtigkeit des im Laufe von Generationen erworbenen Wissens der Berufsfischer um die Bedeutung des Zusammenwirkens bestimmter Ökofaktoren als Auslöser für den Laichakt.

– Aus den rückberechneten Laichterminen verschiedener Jahrgänge läßt sich ableiten, daß größere Laichschübe erst dann eintreten, wenn der Wasserstand des Rio Negro ca. 20 m (bei steigender Tendenz) erreicht oder überschritten hat. Nur unter dieser Voraussetzung kann das Überleben der Fischbrut in Überschwemmungsgebieten garantiert sein, die sowohl Nahrung, als auch Unterschlupf bieten.

– Weiterführende Untersuchungen sollten zeigen, ob die hier dargestellte Methode zur Altersbestimmung bei juvenilen Matrinchã aus dem mittleren Rio Negro auch auf andere Altersgruppen und verschiedene Populationen Anwendung finden könnte.

7. Resumo

– Os estudos indicam a existência de uma periodicidade de dois dias na formação de escleritos no matrinxã jovem (*Brycon* sp.).

– A formação igual de escleritos tanto em espécimens capturados nos rios, quanto em especimen criados em cativeiro permite a aplicação da formula para a determinação de idade, elaborada em peixes mantidos em cativeiro, tambem para peixes de populações naturais.

– A exatidão da determinação de idade atravéz do número de escleritos pode ser alcançada somente atravéz do método usando otólitos sendo porém os otólitos de matrinxã dificil de se analisar. A análise das escamas tem também vantagens como método de campo por causa da possibilidade de se obter um maior número de amostras, necessitando um tratamento menos sofisticado do que os otólitos.

– Todos os períodos de desova recalculados por meio da formula, coincidem com períodos de subida da água do rio e de fortes chuvados. Este fato é de acordo com o conhecimento dos pescadores obtido atravéz de muitos gerações sôbre a importância da interrelação de vários fatores ecológicos para e estimulação da desova.

– Os períodos de desova recalculados atravéz da fórmula indicam, que a desova prinicipal começa somente, quando o nível do Rio Negro perto de Manaus alcança ou ultrapassa a marca de 20 m acima do nível do mar com tendência a subir mais.
Acima deste nível, as áreas inundáveis existentes permitem a sôbrevivência dos alevinos oferecendo alimentação suficiente e proteção.

– Estudos adicionais são necessários para verificar a aplicabilidade do método referido para a determinação da idade de matrinxãs juvenís do baixo Rio Negro também para outras populações e classes de idade.

8. Acknowledgements

I wish to express my gratitude for every assistance given by INPA (Instituto Nacional de Pesquisas da Amazônia), especially towards the directors Prof. Dr. Warwick E. Kerr, Prof. Dr. Eneas Salati, and Prof. Dr. Henrique Bergamim, who supported my scientific work wherever possible during my research-activities at INPA.

I am also especially obliged towards Dr. W. J. Junk, the program leader, for the excellent guidance and help, and towards Dr. U. Saint-Paul for our good collaboration.

Moreover, I would like to thank Mrs. Maria de Nazaré Góes Ribeiro, and Sérgio Roberto P. Annibal for allowing me to include precipitation data and market-statistics in this investigation.

I would also like to thank Maria Aparecida da Silva Gomes, and all members of staff who contributed in one way or the other to the completition of my studies.

The study was financed by INPA and additionally supported by DFG (Deutsche Forschungsgemeinschaft) and KFA (Kernforschungsanlage) Jülich.

9. References

BAGENAL, T. B. (ed.) (1974): The Ageing of Fish.- Unwin Brothers Ltd. The Gresham Press, Old Woking, Surrey, England.

BAILEY, R. E. (1957): The effect of estradiol on serum calcium phosphorus, and protein of goldfish.- J. exp. Zool. 136: 455 - 469.

BAYLEY, P. B. (1973): Studies on the migratory characin, *Prochilodus platensis* Holmberg 1889, (Pisces, Characoidei) in the River Pilcomayo, South America.- J. Fish. Biol. 5: 25 - 40.

BERG, A. and E. GRIMALDI (1967): A critical interpretation of the scale structures used for the determination of Annuli in fish growth studies.- Mem. Ist. Ital. Idrobiol. 21: 225 - 239.

BILTON, H. T. (1974): Effects of starvation and feeding on circulus formation on scales of young sockeye salmon of four racial origins, and of one race of young kokanee, coho and chinook salmon.- (In: Bagenal 1974: 40 - 70).

BLAKE, C. and B. F. BLAKE (1978): The use of opercular bones in the study of age and growth in *Labeo senegalensis* from Lake Kainji, Nigeria.- J. Fish Biol. 13 (2): 287 - 295.

BROTHERS, E. B., MATHEWS, C. P. and R. LASKER (1976): Daily growth increments in otoliths from larval and adult fishes.- Fish. Bull., U. S. 74: 1 - 8.

CASSIE, R. M. (1956): Age and Growth of the Snapper (*Chrysophrys auratus*) Forster, in the Hauraki Gulf.- Trans. Roy. Soc. N. Z. 84 (2): 329 - 339.

CORDIVIOLA DE YUAN, E. (1971): Crecimiento de peces del Paraná Medio. I. "Sábalo", *Prochilodus platensis* Holmberg.- Physis, B. Aires 30: 483 - 504.

CUTLER, D. W. (1918): A Preliminary account of the Production of Annual Rings in the Scales of Plaice and Flounders.- M. B. A. Journal. N. S. XI, 4: 470 - 496.

DANNEVIG, A. (1928): Om dannelsen av arringer i lakseungernes skjell.- Norsk Jæger & Fiskerforenings tidsskrift, Heft 5, Oslo.

DANNEVIG, A. and P. HØST (1931): Sources of Error in Computing 1_1 - 1_7 etc. from Scales taken from Different Parts of the Fish.- J. Conseil Copenhague 6: 64 - 93.

FISHELSON, L. VON (1966): Untersuchungen zur vergleichenden Entwicklungsgeschichte der Gattung Tilapia (Cichlidae, Teleostei).- Zool. Jb. Anat. 83: 571 - 656.

FISHER, R. A. (1954): Statistical methods for research workers.- 12. ed. Edinburgh.

FLEMING, W. R., STANLEY, J. G. and A. H. MEIER (1964): Seasonal effects of external calcium, estradiol and ACTH on the serum calcium and sodium levels of *Fundulus kansae*.- Gen. comp. Endocr. 4: 61 - 67.

FONTENELLE, O., CAMACHO, E. and R. MENEZES (1946): Obtencao de tres desovas anuais de Curimatá (*Prochilodus* sp.) (Pisces, Characidae, Prochilodinae), pelo método de hipofisacao.- Boletim do Museu Nacional de Zoologia N. 53.

FRASER, C. Mc. (1917): On the Scales of the Spring Salmon.- Cont. Canad. Biol., Ottawa: 1915 - 1916.

GARROD, D. and B. S. NEWELL (1958): Ring formation in *Tilapia esculentia*.- Nature, London 181: 1411 - 1412.

GEISLER, R., KNÖPPEL, H. A. and H. SIOLI (1971): Ökologie der Süßwasserfische Amazoniens. Stand und Zukunftsaufgaben der Forschung.- Naturwissenschaften 58: 303 - 311.

GODOY, M. P. DE (1959): Age, growth, sexual maturity, behaviour, migration, tagging and transplantation of the Curimbatá, *Prochilodus scrofa* Steindachner 1881, of the Mogi Guassu River, Sao Paulo State, Brasil.- Anais Acad. Bras. Cienc. 31: 447 - 477.

GRAHAM, M. (1929): Studies of age determination in fish. Part II, A survey of the Literature.- Fish. Invest. Lond., Ser. 2, II (3): 1 - 50.
HANUMANTHARAO, L. (1976): Studies on the biology of *Cirrhinus mrigala* (Hamilton) of the River Godavari.- Indian J. Fish. 21 (2): 303 - 322.
HELLAWELL, J. M. (1974): The problems of protracted check formation and the validity of the use of scales in age determination exemplified by two populations of dace (*Leuciscus leuciscus*) Linné.- (In: Bagenal 1974: 173 - 180).
HESS, A. F., BILLS, C. E., WEINSTOCK, M. and H. RIVKIN (1928): Difference in calcium level of the blood between the male and female cod.- Proc. Soc. exp. Biol. Med. 25: 349 - 350.
HOFFBAUER, C. (1899): Die Altersbestimmung des Karpfen an seiner Schuppe.- Jahresbericht des schlesischen Fischerei-Vereins, Breslau.
HOLCÍK, J. (1967): Some data on the biology of chub (*Leuciscus cephalus*) Linnaeus 1758, in the Klícava reservoir.- Acta Rerum Natur. Mus. Nat. Slov., Bratislava 13: 113 - 125.
IHINGRAN, V. G. (1959): Studies on the age and growth of *Cirrhina mrigala* (Ham.) from the river Ganga.- Proc. nat. Inst. Sci. India, (B) 25 (3): 107 - 137.
JUNK, W. J. (1975): The use of ecological guidelines for development in the American humid tropics.- Aquatic wildlife and fisheries, I.U.C.N., Session 2: 109 - 125.
KAMAL, M. Y. (1969): Studies on the age and growth of *Cirrhina mrigala* (Hamilton) from the river Yamuna at Allahabad.- Proc. nat. Inst. Sci. India. (B) 35 (1): 72 - 92.
KIRSCHBAUM, F. (1979): Reproduction of the weakly electric fish *Eigenmannia virescens* (Rhamphichtyidas, Teleostei) in captivity I. Control of gonadal recrudescence and regression be environmental factors.- Behav. Ecol. Sociobiol. 4: 331 - 355.
LAKE, J. S. (1967): Rearing experiments with five species of Australian freshwater fishes. I. Inducement to spawning.- Aust. J. mar. Freshwat. Res. 18: 137 - 153.
LEE, R. M. (1912): An Investigation into the methods of Growth determination in fishes.- Pub. de Circ. 63.
LIBOSVÁRSKÝ, J. and V. BARUS (1978): Computed growth and survival of chub (*Leuciscus cephalus*) from the Rokytná Stream.- Acta Sc. Nat. Brno, 12 (7): 1 - 45.
LINFIELD, R. S. J. (1974): The errors likely in ageing roach, *Rutilus rutilus* (L.), with special reference to stunted populations.- (In: Bagenal 1974: 167 - 172).
McLARNEY, W. O. (1973): Studies of the ecology of the Characid fish *Brycon guatemalensis* in the Rio Tirimbina, Heredia Province, Costa Rica with special reference to its suitability for culture as a food fish.- The Journal of the New Alchemists 1: 52 - 57.
MOLANDER, A. R. (1918): Studies in the Growth of the Herring, especially with regard to the Examination of the Scales for determining its Growth.- Ur Svenska Hydrogrfisk-biologiska Kommissiones Skrifter, VI, Stockholm.
MONASTUIRSKY, G. N. (1926): On the technique of Determining the Rate of Growth of Fish by Measurement of the Scales.- Siberian Ichthy. Lab. Krasnoyarsk.
MOREAU, J. (1977): Essai d'interprétation des annuli observés sur les écailles de *Tilapia nilotica* et *Tilapia rendalli* des laçs des hauts plateaux malgaches. III Observations sur *Tilapia nilotica* au lac Aloatra.- Ann. Hydrobiol. 8 (3): 363 - 373.
MUGIYA, Y. and N. WATABE (1977): Studies on fish scale formation and resorption – II. Effect of estradiol on calcium homeostasis and skeletal tissue resorption in the goldfish, *Carassius auratus*, and the killifish, *Fundulus heteroclitus*.- Comp. Biochem. Physiol. 57A: 197 - 202.
OTTAWAY, E. M. (1978): Rhythmic growth activity in fish scales.- J. Fish. Biol. 12: 615 - 623.
PANNELLA, G. (1971): Fish otoliths: Daily growth layers and periodical patterns.- Science N. Y. 173: 1124.
PERLMUTTER, A. and G. M. CLARKE (1949): Age and growth of immature rosefish (*Sebastes marinus*) in the gulf of Maine and off Western Nova Scotia.- Fishery Bulletin 45, Vol. 51: 207 - 228.
PROKES, M., LIBOSVÁRSKÝ, J. and V. BARUS (1977): Scale growth in juvenile chub, *Leuciscus cephalus*, from the Rokytná stream.- Folia Zool. Brno. 26: 277 - 288.

RAO, G. R. (1976): Observations on the age and growth, maturity and fecundity of *Labeo fimbriatus* (Bloch) of the River Godavari.- Indian J. Fish. 21 (2): 427 - 444.

SCHNAKENBECK, W. (1955): Handbuch der Zoologie (Hrsg. Helmcke, J.-G., Lengerken, H. v.), (6), Walter de Gruyter & Co., Berlin.

SEGERSTRALE, C. (1932): Über die jährlichen Zuwachszonen der Schuppen und Beziehungen zwischen Sommertemperatur und Zuwachs bei *Abramis brama*.- Arch. Zool. Fennica 13: 1 - 42.

SILVA, A. B. DA, SOBRINHO, A. C. and F. R. MELO (1977): Desova induzida de Tambaqui, *Colossoma macropomum* Cuvier, 1818, com o uso de hipófise de curimata comum, *Prochilodus cearensis* Steindachner.- Simposio de la Associación Latinoamericana de Aquicultura, Maracay, Venezuela.

SIOLI, H. (1965): Bemerkung zur Typologie amazonischer Flüsse.- Amazoniana I (1): 74 - 83.

STEINMETZ, B. (1974): Scale reading and back-calculation of bream *Abramis brama* (L.) and rudd *Scardinius erythrophthalmus* (L.).- (In: Bagenal 1974: 148 - 157).

TAUBERT, B. C. and D. W. COBLE (1977): Daily rings in otoliths of three species of *Lepomis* and *Tilapia mossambica*.- J. Fish Res. Board Can. 34: 332 - 340.

TAYLOR, N. F. (1916): The structure and growth of the scales of the Squeteague and the Pigfish as indicative of their life history.- U. S. Doc. 823.

THOMPSON, H. (1926): Haddock Biology III. Metabolism of Haddock and other Gadoid fish in the aquarium.- Fisheries, Scotland, Sci. Invest. (II), Edinburgh.

THOMSON, J. S. (1904): The periodic growth of scales in Gadidae as an Index of age.- M. B. A. Journal N. S. VII: 1 - 109.

WALLIN, O. (1957): On the growth structure and developmental physiology of the scale of fishes.- Rep. Inst. Freshwater Res., Drottningholm 38: 385 - 447.

WALTER, E. (1901): Die Altersbestimmung des Karpfens nach der Schuppe.- (In: Graham 1929: 19).

WELCOMME, R. L. (1975): The fisheries ecology of African floodplains.- CIFA/T 3, FAO, Rome.

WERDER, U. (1981): A new species for tropical fish culture: Matrinchã (*Brycon* sp.).- Aquaculture Ve 1981, Venezia Congressi s. n. c. (World Conference on Aquaculture and international trade show, contributed papers: 98 - 99.

WERDER, U. (1982): Remarks on age determination in a tropical fish (*Brycon* - Müller & Troschel 1844 - sp.) based on scale structures (Pisces Characidae), (Abstract).- Fourth Congress of European Ichthyologists 20. - 24.9.1982, Hamburg.

WINGE, Ö. (1915): On the value of the rings in the scales of the cod as a means of age-determination.- Illustrated by marking experiments. Meddelelser Komm. Havundersogelser. Fisk IV (8), Copenhagen.

Author's address:

Ulrich Werder
Institut für Hydrobiologie und
Fischereiwissenschaft
Olbersweg 24
D - 2000 Hamburg 50
West Germany

Accepted for publication in January 1983