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KARYOTYPES OF 10 SPECIES OF NEOTROPICAL CICHLIDS (PISCES, PERCIFORMES)

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SUMMARY — Ten neotropical species of family Cichlidae (Pisces: Perciformes) were analyzed cytogenetically. The results obtained also support the indications that the chromosomal evolution of this group was more conservative than divergent from the numerical point of view. All species showed a chromosome number of $2n=48$, although differences in chromosome morphology were observed. The species *Chaetobranchopsis australe* exhibited a karyotype consisting of 48 subtelo-acrocentric chromosomes, which is possibly of a more primitive type in relation to the karyotypes of the remaining species investigated. No chromosome differences were detected between males and females, indicating the absence of morphologically differentiated sex chromosomes.

INTRODUCTION

Among the various fish groups, family Cichlidae occupies fourth place in number of species, comprising about 85 genera and 700 species thus far described. The greatest diversity is encountered in Africa, with South America following in second place (DARLINGTON 1957; NELSON 1976).

In general, these fish are appropriate for both intensive and extensive pisciculture because of their habits, i.e. absence of long migrations, reproduction in lentic environments, and care for their progeny, and also because they are well accepted as food (FERREIRA 1981). Several investigators consider these fish to be highly specialized and to have an extremely rapid speciation rate (LOWE-McCONNELL 1969; KORNFIELD 1978; THOMPSON 1981).

Until 1979, chromosomal studies had been made only in about 11 of 200 or more known species of neotropical cichlids (POST 1965; OHNO and ATKIN 1966; HINEGARDNER and ROSEN 1972; NISHIKAWA *et al.* 1973; OYHENART-

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PERERA *et al.* 1975; MICHELE and TAKAHASHI 1977). THOMPSON (1979) analyzed the karyotypes of 41 neotropical species in a highly interesting cytotaxonomic study of the group. Of these species, 31 had $2n$ equal to 48 chromosomes.

THOMPSON (1979) suggested that the most common scheme of karyotype evolution for these cichlids may have been from a karyotype consisting of 48 subtelo-telocentric chromosomes, which is considered to be of the more primitive type, with pericentric inversions mainly involved.

The objective of the present study was to complement existing cytogenetic studies in this family by supplying further data contributing to the knowledge of their chromosome evolution.

MATERIAL AND METHODS

Ten species of Cichlidae collected at different sites in Brazil were investigated (Table 1).

Kidney cells were used for the study of mitotic chromosomes by the air-drying technique of EGOZCUE (1971), modified by BERTOLLO *et al.* (1978). Meiotic chromosomes were studied by the method of KLIGERMAN and BLOOM (1977), slightly modified.

Chromosome analysis and counts were carried out using the best preparations, and the $2n$ and n number for males and $2n$ for females was established. The chromosomes were arranged in pairs in decreasing order of size and separated into morphological categories. Chromosome measurements were carried out to determine the chromosome types and sizes and the fundamental number (FN) for each karyotype. The arm ratio (AR) was calculated according to the limits proposed by LEVAN *et al.* (1964).

In view of the difficulties involved in the precise identification of several

TABLE 1 - Collecting places and specimens number of each analysed species. M = male, F = female, T = total.

Species	Collecting places	Number of analysed specimens		
		M	F	T
<i>Crenicichla lacustris</i>	Registro-SP	3	0	3
<i>Crenicichla lepidota</i>	Miranda-MS	1	0	1
<i>Crenicichla vittata</i>	Miranda-MS	2	0	2
<i>Batrachops semifasciatus</i>	Miranda-MS	12	1	13
<i>Geophagus brasiliensis</i>	Brotas-SP	6	0	
	São Carlos-SP	14	10	
	Pirassununga-SP	4	0	
	Registro-SP	3	1	38
<i>Geophagus surinamensis</i>	Manaus-AM	6	3	9
<i>Gymnogeophagus balzanii</i>	Miranda-MS	3	1	4
<i>Astronotus ocellatus</i>	Miranda-MS	9	7	
	Manaus-AM	2	2	20
<i>Cichlasoma facetum</i>	Registro-SP	6	1	
	Rio Claro-SP	17	7	31
<i>Chaetobranchopsis australe</i>	Miranda-MS	2	4	6

chromosomes, they were divided into two general groups: M-SM (meta-submetacentrics) and ST-A (subtelo-acrocentrics). To determine the fundamental number, M-SM chromosomes were considered to have two arms, and ST-A chromosomes, a single arm.

RESULTS

Figures 1, 2, 3, 4 and 5 show the karyotypes and meiotic chromosomes of the species investigated. Except for *Gymnogeophagus balzanii* (FELDBERG and BERTOLLO 1984), all species showed the expected agreement between the observed diploid and haploid numbers, i.e., 48 chromosomes in somatic and spermatogonial cells, 24 bivalents at metaphase I, and 24 chromosomes at metaphase II. The karyotypic characteristics of the various species are summarized in Table 2.

DISCUSSION

Of the 10 species studied, 5 had been previously submitted to cytogenetic studies (*Astronotus ocellatus*, *Cichlasoma facetum*, *Crenicichla lepidota*, *Geophagus brasiliensis* and *Geophagus surinamensis*) for determination of the $2n$ number in at least one of the sexes, or to conventional karyotype analysis (OYHENART-PERERA *et al.* 1975; MICHELE and TAKAHASHI 1977; THOMPSON 1979; MOREIRA-FILHO *et al.* 1980), with constant agreement to the diploid number detected, which was equal to 48 chromosomes. However, when we studied the chromosome types, we found coincidence in only two species (*Crenicichla lepidota* and *Geophagus surinamensis*). The differences in the remaining results could be attributed to technical difficulties concerning the determination of the exact position of the centromere, more precise measurements of the short arm in many chromosome pairs, as well as the relative condensation occasionally shown by the chromosomes. In some cases, the arm ratio value was very close to 3.0, which is the borderline value between the M-SM and ST-A groups, with the consequent need to opt for one of the groups considered. Obviously this criterion may lead to errors in chromosome classification, a fact that has also been pointed out by THOMPSON (1979).

A clearly visible characteristic that was observed in all species analyzed was the presence of a chromosome pair exhibiting secondary constrictions that in general were considerably pronounced, so much so that in some cases they could even characterize satellites.

The genera *Batrachops* and *Crenicichla* are similar under many aspects (GOLDSTEIN 1973). From the karyotypic point of view, *Batrachops semifasciatus* (Fig. 1-D) and the three *Crenicichla* species analyzed: *C. lacustris*, *C. lepidota* and *C. vittata* (Fig. 1-A, B and C, respectively) were also quite similar, with no

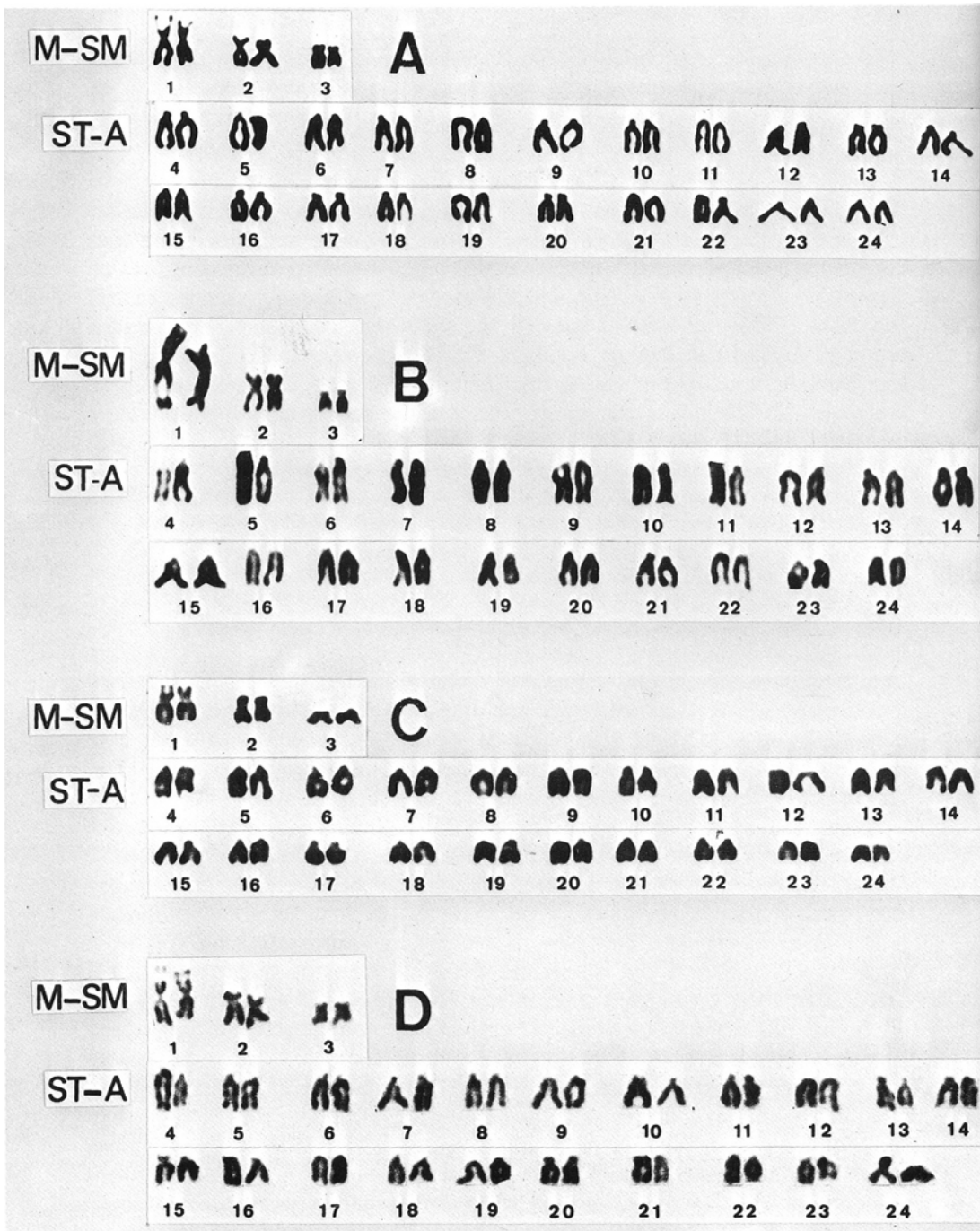


Fig. 1. — Karyotypes (48 chromosomes) of (A) *Crenicichla lacustris*, (B) *C. lepidota*, (C) *C. vittata* and (D) *Batrachops semifasciatus*.

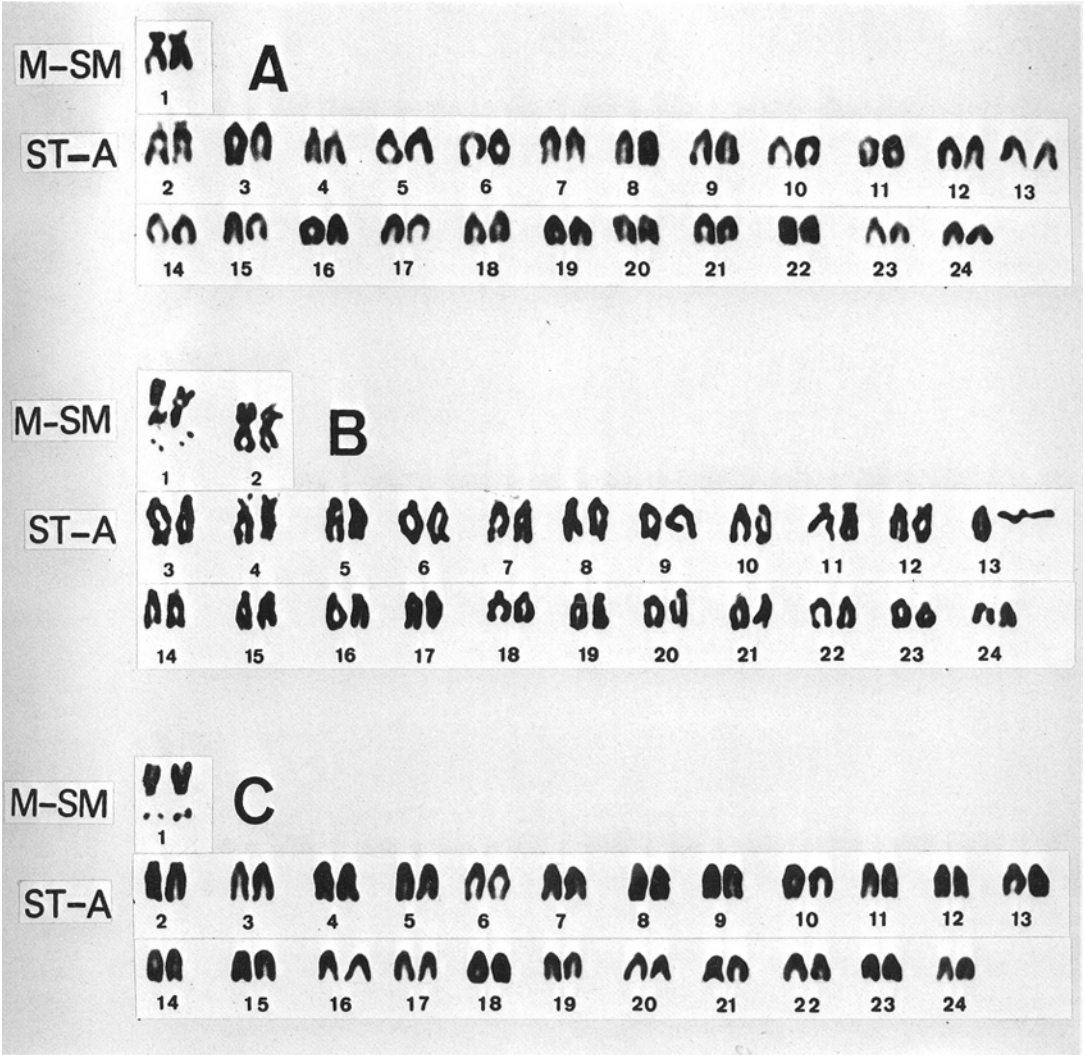


Fig. 2. — Karyotypes (48 chromosomes) of (A) *Geophagus brasiliensis*, (B) *G. surinamensis* and (C) *Gymnogeophagus balzanii*.

marked difference observed. *C. lepidota* was the only species showing a more obvious differentiation in that it exhibited the secondary constriction on the long arm of the first pair in the karyotype (M-SM), rather than on the short or upper arm of the same pair, as was the case for the three other species.

Geophagus is a genus in which we also had the opportunity to examine more than one species, *G. brasiliensis* and *G. surinamensis* (Fig. 2-A and B,

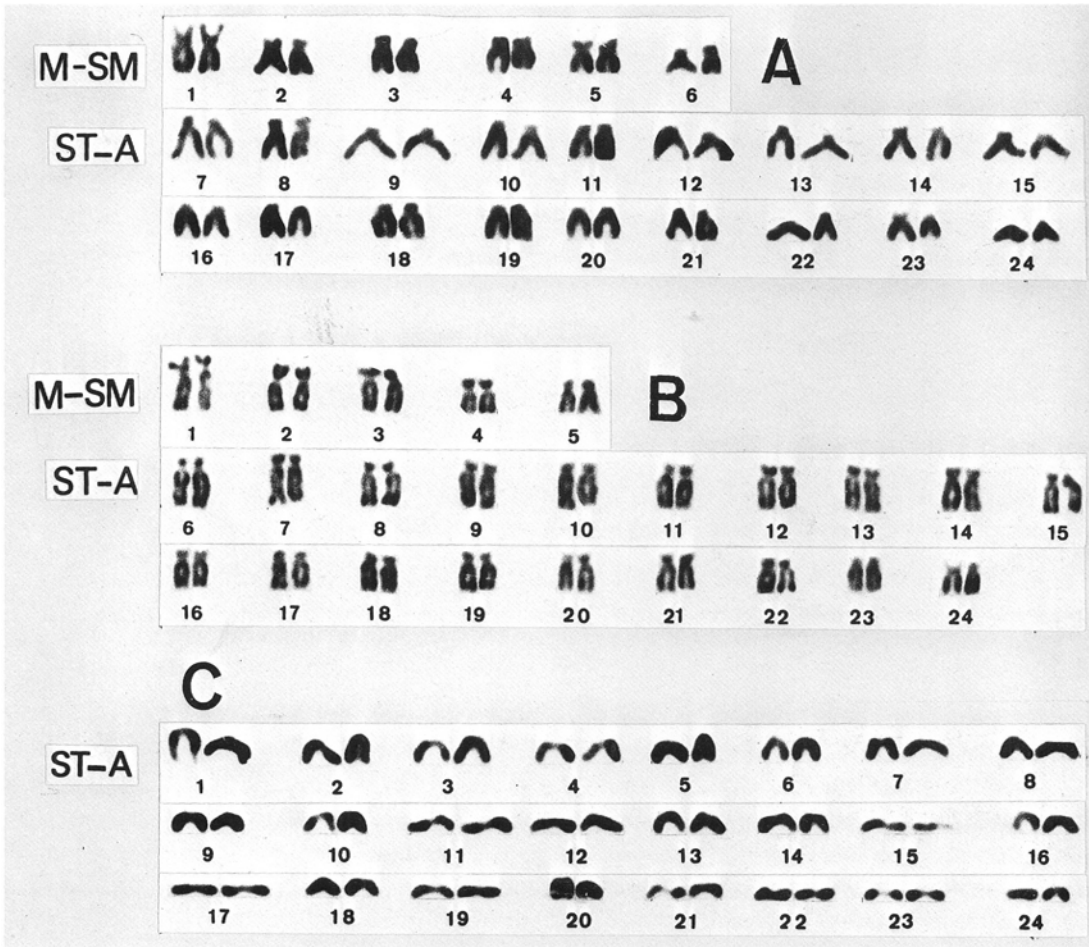


Fig. 3. — Karyotypes (48 chromosomes) of (A) *Astronotus ocellatus*, (B) *Cichlasoma facetum* and (C) *Chaetobranchopsis australe*.

respectively). Despite the numerical coincidence, the morphologic similarity of the chromosomes was not as marked as between *Crenicichla* and *B. semifasciatus*, with some differences already visible in the largest pairs in the karyotype. In addition, an interstitial secondary constriction was well visible in the first pair (M-SM) of *G. surinamensis*, an occurrence that was not detected in *G. brasiliensis*. In some metaphases of the latter species, a terminal secondary constriction was visualized in one pair of the ST-A group, which showed a weaker-staining end of the short arm.

The genera *Gymnogeophagus* and *Biotodoma* are the closest to *Geophagus*

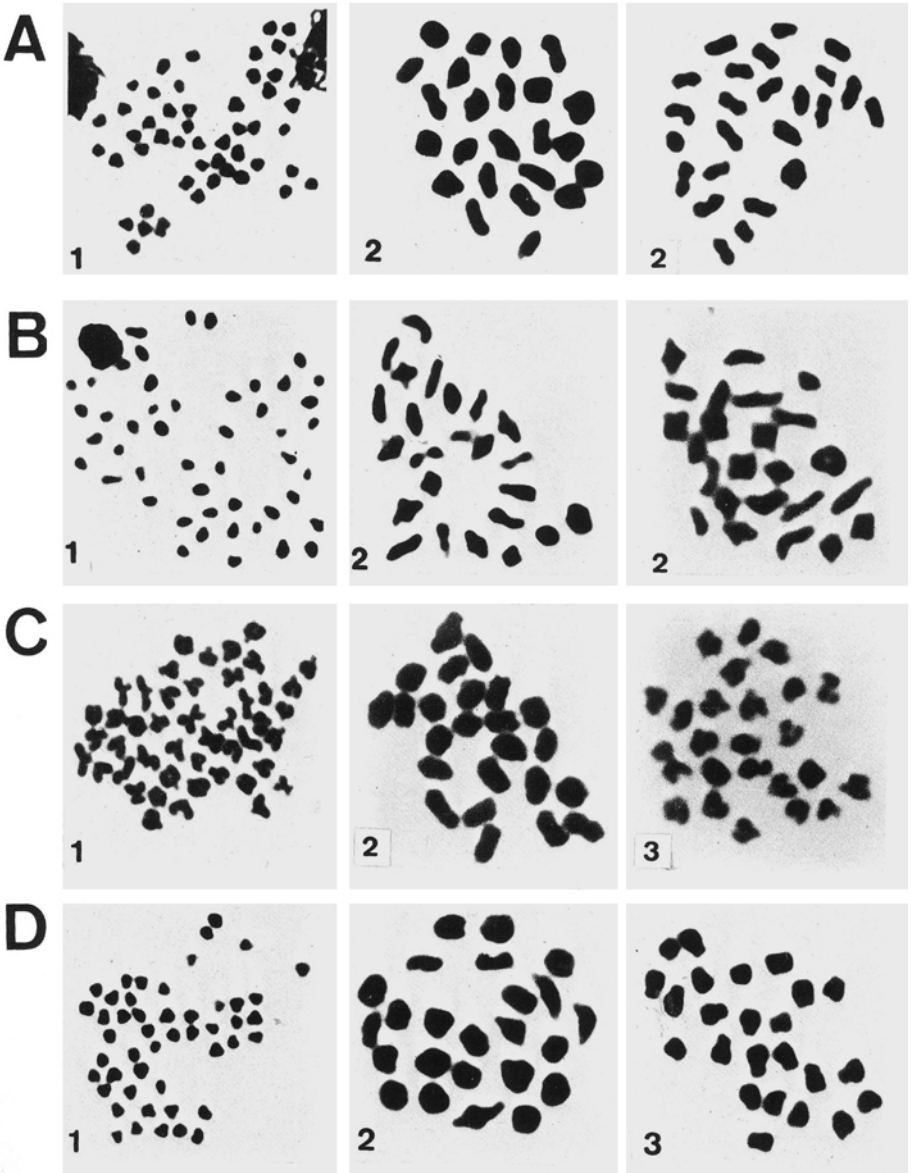


Fig. 4. — Meiotic chromosomes of (A) *Crenicichla lacustris*, (B) *C. vittata*, (C) *Batrachops semifasciatus* and (D) *Astronotus ocellatus*. (1) spermatogonial metaphase (48 chromosomes), (2) metaphase I (24 bivalents) and (3) metaphase II (24 chromosomes).

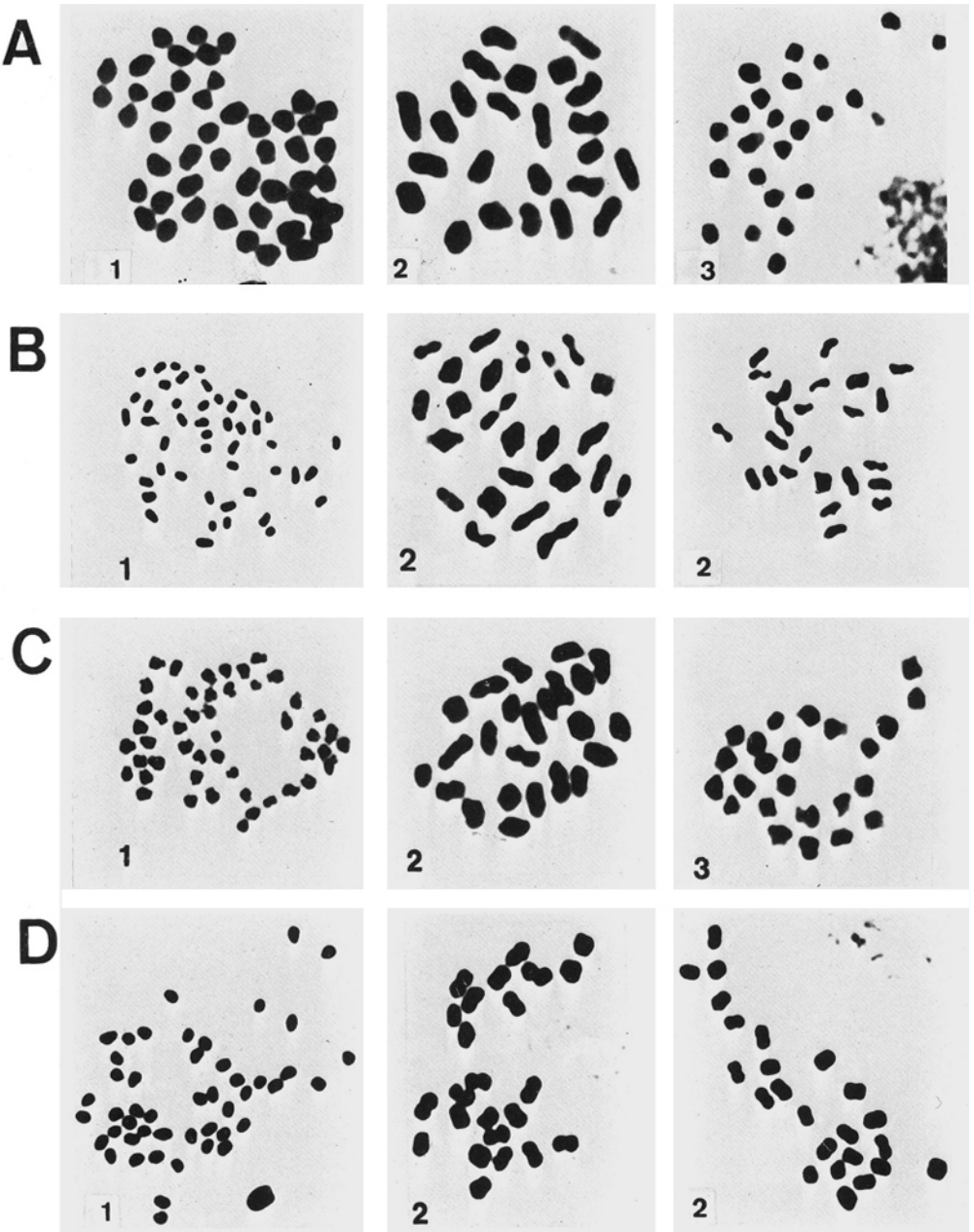


Fig. 5. — Meiotic chromosomes of (A) *Geophagus brasiliensis*, (B) *G. surinamensis*, (C) *Cichlasoma facetum* and (D) *Chaetobranchopsis australe*. (1) spermatogonial metaphase (48 chromosomes), (2) metaphase I (24 bivalents) and (3) metaphase II (24 chromosomes).

TABLE 2 - Karyotypic characteristics from analysed species. $2n$ = diploid number, n = haploid number, FN = fundamental number, M-SM = meta-submetacentric, ST-A = subtelo-acrocentric.

Species	$2n$	n	NF	Chromosomes Groups	
				M-SM	ST-A
<i>Crenicichla lacustris</i>	48	24	54	3 pairs	21 pairs
<i>Crenicichla lepidota</i>	48	—	54	3 pairs	21 pairs
<i>Crenicichla vittata</i>	48	24	54	3 pairs	21 pairs
<i>Batrachops semifasciatus</i>	48	24	54	3 pairs	21 pairs
<i>Geophagus brasiliensis</i>	48	24	50	1 pair	23 pairs
<i>Geophagus surinamensis</i>	48	24	52	2 pairs	22 pairs
<i>Gymnogeophagus balzanii</i>	48	24-26	50	1 pair	23 pairs
<i>Astronotus ocellatus</i>	48	24	60	6 pairs	18 pairs
<i>Cichlasoma facetum</i>	48	24	58	5 pairs	19 pairs
<i>Chaetobranchopsis australe</i>	48	24	43	—	24 pairs

(GOSSE 1975; REIS and MALABARBA 1983). Karyotypically, *Gymnogeophagus balzanii* (Fig. 2-C), *Geophagus brasiliensis* and *G. surinamensis* also have comparable features. Thus a single chromosome pair in the M-SM groups confers the same FN to *G. brasiliensis* and *G. balzanii*. In turn, the morphology of this chromosome as well as the localization of its secondary constriction confers, by this aspect, a greater similarity between the karyotypes of *G. balzanii* and *G. surinamensis*.

Astronotus ocellatus (Fig. 3-A), as was the case for most of the others species, showed the secondary constriction in the first pair (M-SM), but was characterized by a larger amount of chromosomes in the M-SM group, which was also the case for *Cichlasoma facetum* (Fig. 3-B). *C. facetum*, however, like *Geophagus brasiliensis*, did not show the secondary constriction in the first pair in the complement but on the short arm of one of the pairs in the ST-A group.

The genus *Cichlasoma* is very rich in species; according to THOMPSON (1979), an interesting correlation seems to exist between the number of metacentric chromosomes present in the karyotype and the radiation center of the species. Thus, species originating from Central America do not exhibit obvious metacentric chromosomes (except for *Cichlasoma nigrofasciatum*), whereas species of south american origin exhibit an evolutionary tendency towards showing characteristic metacentrics in the karyotype (except for *Cichlasoma bimaculatum*).

Cichlasoma facetum is a typical south american species. According to THOMPSON (1979), the morphological similarity between this species and *Cichlasoma nigrofasciatum* was already pointed out by REGAN (1905) in a review of some genera of family Cichlidae. However, these two species differ in karyotypic terms because *C. facetum* shows no characteristic metacentric chromosome. In this respect, *C. facetum* represents one more example, side by side with *C.*

bimaculatum, of an autochthonous south american species having no characteristic metacentric chromosome in the complement.

Another interesting occurrence was detected in *Chaetobranchopsis australe* (Fig. 3-C), whose chromosomes were all of the ST-A type. The secondary constriction was located on a more terminal portion of the long arm also in the first chromosome pair. THOMPSON (1979) started from the assumption that the ancestral karyotype of neotropical cichlids may have consisted of 48 subtelo-telocentric chromosomes, in agreement with what is generally considered valid in terms of the chromosome evolution of teleostean fish. Thus, according to THOMPSON (1979) the case of *Cichla temensis*, which has $2n = 48$ chromosomes, all of them subtelo-telocentrics, seems to show a karyotype with few changes detectable from a primitive state. So, this same observation should apply to *Chaetobranchopsis australe*, whose karyotype constitution is similar to that of *Cichla temensis*.

It is interesting to point out, in a complement of the data of THOMPSON (1979), that of the 51 species of neotropical cichlids studied cytogenetically (POST 1965; OHNO and ATKIN 1966; HINERGARDNER and ROSEN 1972; NISHIKAWA *et al.* 1973; OYHENART-PERERA *et al.* 1975; MICHELE and TAKAHASHI 1977; THOMPSON 1979; MOREIRA *et al.* 1980; present paper) 41 had $2n = 48$, 7 had $2n$ lower than 48 and 3, $2n$ higher than 48. Curiously, the cichlids of the old world and of the ethiopian region generally have $2n$ lower than 48 chromosomes, as observed among the species studied of *Sarotherodon* ($2n = 44$), *Tilapia* ($2n = 40$ to 48), *Astatotilapia* ($2n = 40$), *Melanochromis* ($2n = 46$), *Tristramella* ($2n = 44$) and *Haplochromis* ($2n = 44$) (POST 1965; KORNFIELD *et al.* 1979; VERVOORT 1980; THOMPSON 1981).

Thus the data reported in the present study also support the hypothesis of THOMPSON (1979) that the karyotypic evolution of neotropical cichlids was more conservative than divergent, at least in respect to the chromosome number, and that pericentric inversions were probably the main events that led to the karyotypes more commonly found in this group, maintaining the diploid number 48 as the more frequent. On the basis of the fundamental numbers (FN) obtained (Table 2), at least 4 general groups could be considered among the specimens studied, possibly reflecting the occurrence of a progressive number of chromosome rearrangements: group 1, with FN = 48, represented by *Chaetobranchopsis australe*; group 2, with FN = 50-52, comprising *Geophagus brasiliensis*, *G. surinamensis* and *Gymnogeophagus balzanii*; group 3, with FN = 54, comprising the three *Crenicichla* species: *C. lacustris*, *C. lepidota* and *C. vittata*, in addition to *Batrachops semifasciatum*; group 4, with FN = 58-60, represented by *Astronotus ocellatus* and *Cichlasoma facetum*, i.e., the two species that showed the largest number of two-armed chromosomes. Thus, despite the constancy of chromosome number, a few peculiarities can be attributed to some species or group of species, such as the possible number of structural rearrangements (pericentric inversions) that occurred during their

karyotypic evolution. Future studies, including the analyses of the C-banding patterns, will be useful to obtain more conclusive data in respect to these considerations.

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