

KARYOTYPE STUDIES IN TWENTY-TWO SPECIES OF PARROTS (PSITTACIFORMES: AVES)

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ABSTRACT

The karyotypes of 12 species of Psittaciformes new to cytology are described: *Lorius hypoinochrous*, *L. lory* and *Phigys solitarius* of the Loriidae, and *Amazona autumnallis*, *Aratinga jandaya*, *Eclectus roratus*, *Pionus maximiliani*, *P. menstruus*, *P. senilis*, *P. seniloides*, *Poicephalus senegalus* and *Polytelis alexandrae* of the Psittacidae. The karyotypes of *Amazona ochrocephala*, *Ara ararauna*, *Ara macao*, *Psittacula krameri*, *Psittacus erithacus* and *Pyrrhura molinae* of the Psittacidae have been previously described. For reasons of comparison the karyotypes of *Aratinga aurea*, *Forpus xanthopterygius*, *Brotogeris sanctithomae* and *B. versicolorus* of the Psittacidae are also described. These karyotypes are compared to those in the literature and the karyological relationships in the Psittaciformes are briefly discussed. Microchromosome fusions and translocations and pericentric inversions probably are responsible for the heterogeneity of karyotypes in the Psittaciformes.

INTRODUCTION

Three hundred and thirty-two species of parrots are distributed mainly in the Southern Hemisphere and are most prevalent in tropical regions. Brazil has the largest number of species, 70 and in South America there are 138 species (Forshaw, 1977).

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The karyotypes of twenty-seven species of the order have been previously studied in some detail (De Boer, 1984; Aquino, 1987; Valentine, 1987). The family Loriidae still remains completely unstudied. The species so far analyzed exhibited a heterogeneous karyotypic morphology in contrast to several other avian orders in which very uniform karyotypes are found. However, since the number of species whose karyotype has been analyzed is very small, the aim of the present paper is to record the data of 22 species, 12 of which are new to cytology and three of which belong to the family Loriidae. On the basis of these data and previously described karyotypes, the karyological relationships of the Psittaciformes are discussed.

MATERIALS AND METHODS

Chromosome studies were carried out on the following birds from the family Loriidae: one male purple-bellied lory (*Lorius hypoinochrous*), one male black-capped lory (*L. lory*) and one male collared lory (*Phigys solitarius*). From family Psittacidae the species analysed were: one female red-lored amazon (*Amazona autumnalis*), one male yellow-headed parrot (*Amazona ochrocephala*), two male and two female blue and yellow macaws (*Ara ararauna*), one male scarlet macaw (*Ara macao*), one male jandaya conure (*Aratinga jandaya*), one male eclectus parrot (*Eclectus roratus*), one male scaly-headed parrot (*Pionus maximiliani*), one male blue-headed parrot (*Pionus menstruus*), one male white-capped parrot (*Pionus senilis*), one female white-headed parrot (*Pionus seniloides*), one male senegal parrot (*Poicephalus senegalus*), one male princess parrot (*Polytelis alexandrae*), one male rose-ringed parakeet (*Psittacula krameri*), two male grey parrots (*Psittacus erithacus*) and one male and two female green-checked conures (*Pyrrhura molinae*). These birds came from private collections.

Chromosome preparations were obtained from feather pulp cultured in NCTC 135 medium supplemented with 20% calf serum and Pen/Strep (100 μ g/ml).

The karyotypes of female peach-fronted conure (*Aratinga aurea*), female canary-winged parakeet (*Brotogeris sanctithomae*), male tui parakeet (*Brotogeris versicolorus*) and female blue-winged parrotlet (*Forpus xanthopterygius*) were described previously (Lucca and Marco, 1983; Lucca, 1984; Lucca, 1985), and for purposes of comparison they were added to this series. Chromosome preparations of these species were made from bone marrow according to Ford and Hamerton (1956) with slight modification.

Relative length and arm ratio were calculated according to Rothfels and Siminovitch (1958). The system of Levan *et al.* (1964) was followed for the nomenclature of the chromosomes.

RESULTS

In the karyotypes presented here the chromosome pairs are arranged in decreasing order of size and only the macrochromosomes were considered.

The diploid number of *L. hypoinchrous* (Figure 1) is approximately 72. Pair 1 consists of two large metacentric elements (arm ratio 1.3). Pair 2 consists of two large subtelocentric chromosomes (arm ratio 4.6). Pairs 3, 4 and 7 are made up of subtelocentrics (arm ratios 3.2, 5.0 and 5.0). Pairs 5, 6 and 8 are submetacentrics (arm ratios 1.7, 1.9 and 2.0). There are three pairs of small biarmed chromosomes: pairs 9, 10 and 11. The remaining chromosomes are small telocentrics or of uncertain centromeric position.

The karyotype of *L. lory* (Figure 2) shows many similarities to that of *L. hypoinchrous*. The diploid chromosome number of this species is 72. In this species pair 7 is submetacentric and pair 8 is subtelocentric. All the remaining chromosome pairs show the same morphology as in *L. hypoinchrous*.

The karyotype of *P. solitarius* (Figure 3) is quite similar to that of *L. hypoinchrous*. The diploid chromosome number of this species is 70. Pair 1 consists of two large subtelocentrics and pair 2 consists of two large metacentric elements. Only two pairs of small biarmed chromosomes are present: pairs 9 and 10. Most of the microchromosomes are telocentric. This species is the only representative from the genus *Phigys*.

The diploid number of *A. autumnalis* is about 72 (Figure 4). Pairs 1, 2 and 4 are subtelocentric (arm ratio 4.0, 4.2 and 4.1). Pair 3 consists of two large telocentrics. Pairs 5, 6 and 7 are telocentrics of medium size. Pair 8 are the only small metacentric elements in the karyotype (arm ratio 1.0). The remaining autosomes are of small to minute size. Many of them are telocentric but some are biarmed in as far as their centromeric position can be determined. The Z-chromosome is metacentric (arm ratio 1.1) and about the size of pair 4. The W-chromosome is metacentric as well (arm ratio 1.1) and somewhat larger than the chromosomes of pair 8.

The diploid chromosome number of *A. ochrocephala* is estimated to be 70. There is no clear boundary between macro- and microchromosomes. Pair 1 consists of two large telocentrics (arm ratio 8.0). Pairs 2, 3 and 4 are subtelocentric (arm ratios 4.0, 4.5 and 5.0). Pairs 5, 6 and 7 are telocentric (arm ratio 7.0, 8.5 and 15.0). Pair 8 consists of two small metacentrics (arm ratio 1.0). The remaining chromosomes are small telocentrics in as far as their centromeric position can be determined. According to Van Dongen and De Boer (1984) the Z-chromosome is metacentric (arm ratio 1.1) and about the size of pair 4. Since we analysed only one male, the Z and W chromosomes could not be identified.

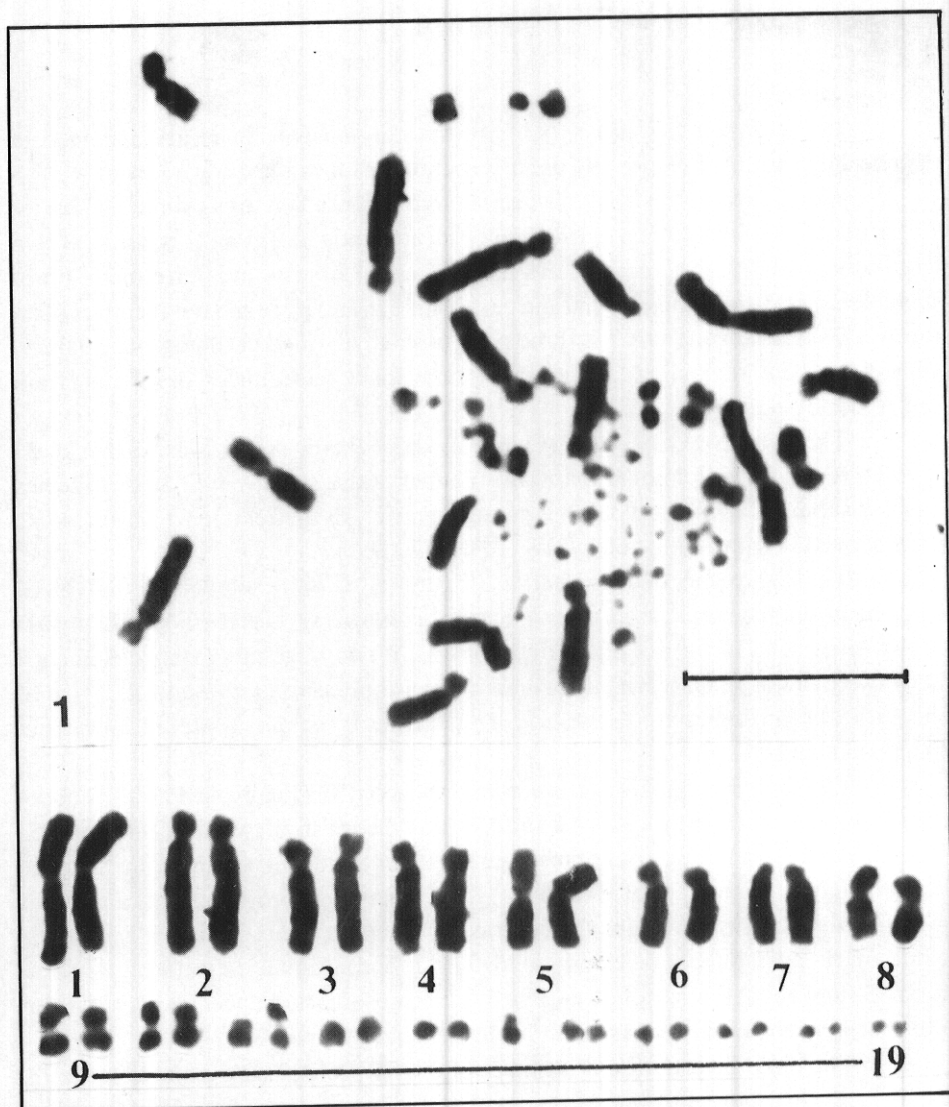


Figure 1 - Metaphase plate and karyogram (large chromosomes only) of a male *Lorius hypoinochrous*. Bar represents $10\mu\text{m}$.

As already reported by Van Dongen and De Boer (1984), the diploid chromosome number of *A. ararauna* is approximately 70 (Figure 5). Pair 1 consists of clearly distinguishable large metacentrics (arm ratio 1.2). Pair 2 is almost of same size as pair 1 but, like pairs 3 and 4, is subtelocentric (arm ratio 5.0, 3.8 and 3.9 respec-

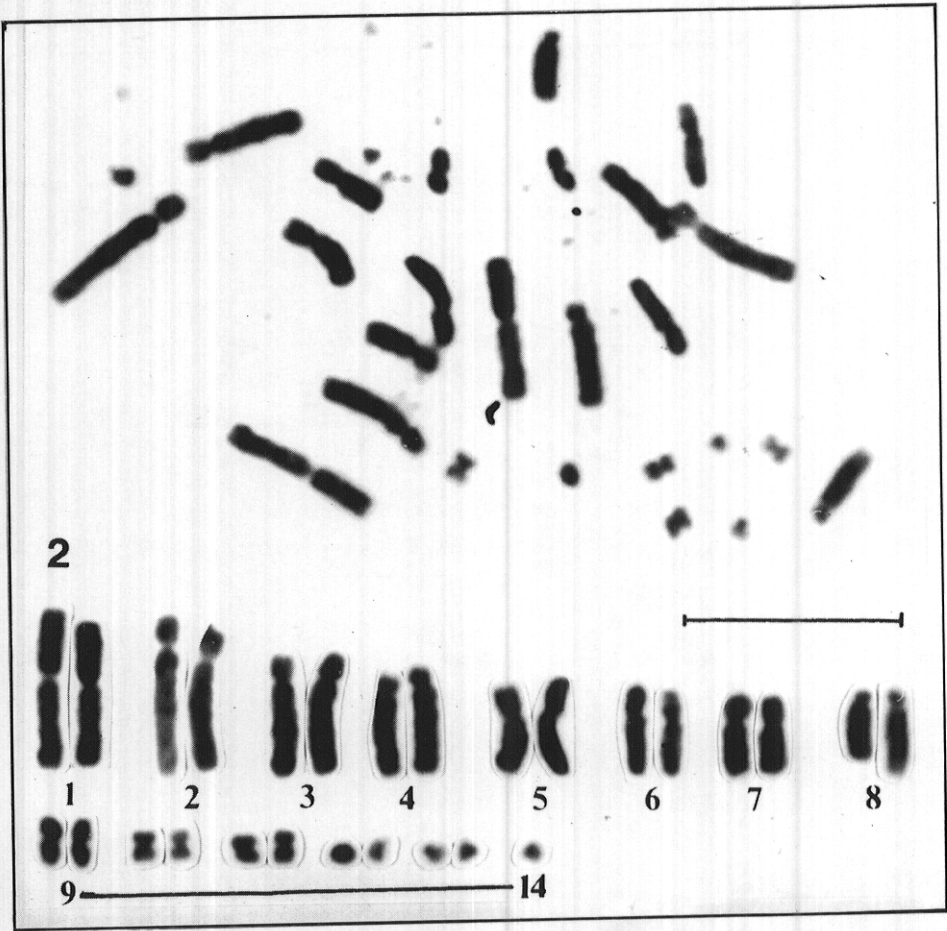


Figure 2 - Metaphase plate and karyogram (large chromosomes only) of a *Lorius lory*. Bar represents 10 μ m.

tively). Pair 5 consists of two submetacentric elements (arm ratio 2.7) and pair 6 consists of two subtelocentric chromosomes (arm ratio 4.0). There are four pairs of small biarmed chromosomes: pair 7, 8, 9 and 10 (arm ratio 1.5, 1.2, 1.0 and 1.0 respectively). The remaining autosomes are of small to minute size and telocentric in as far as their centromere position can be determined. The Z-chromosome is almost the size of pair 4, metacentric (arm ratio 1.3) and easily identifiable. The W is a small metacentric (arm ratio 1.3) of the size of pair 8.

In as far as detectable the karyotype of *A. macao* is identical to that of *A. ararauna*. The chromosomes of *A. macao* were described by Van Dongen and De Boer (1984) and Aquino (1987).

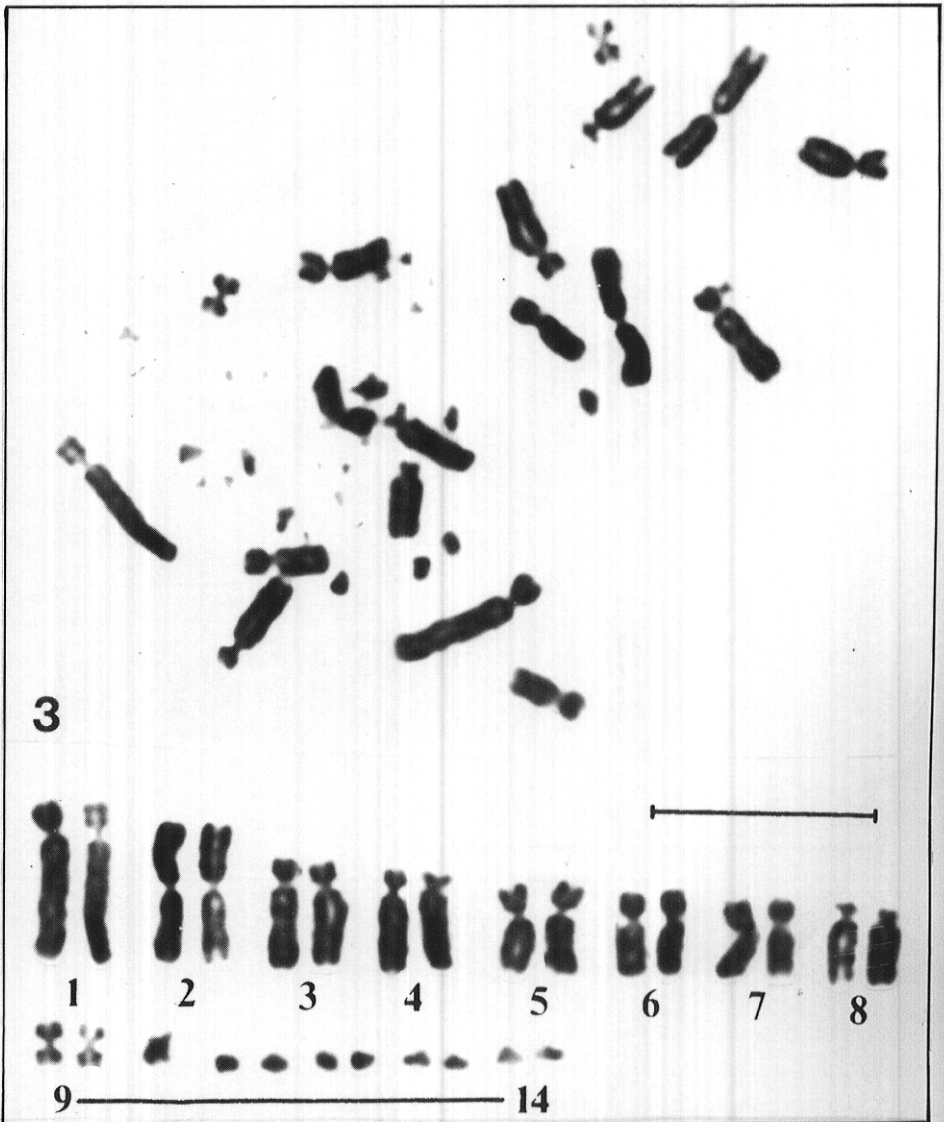


Figure 3 - Metaphase plate and karyogram (large chromosomes only) of a male *Phigys solitarius*. Bar represents $10\mu\text{m}$.

The diploid chromosome number of *A. jandaya* is 70 (Figure 6). The first pair of autosomes consist of two large metacentric elements (arm ratio 1.1). Pair 2 is of almost the same size as pair 1 but, like pairs 3, 4, 5 and 6, is subtelocentric. There

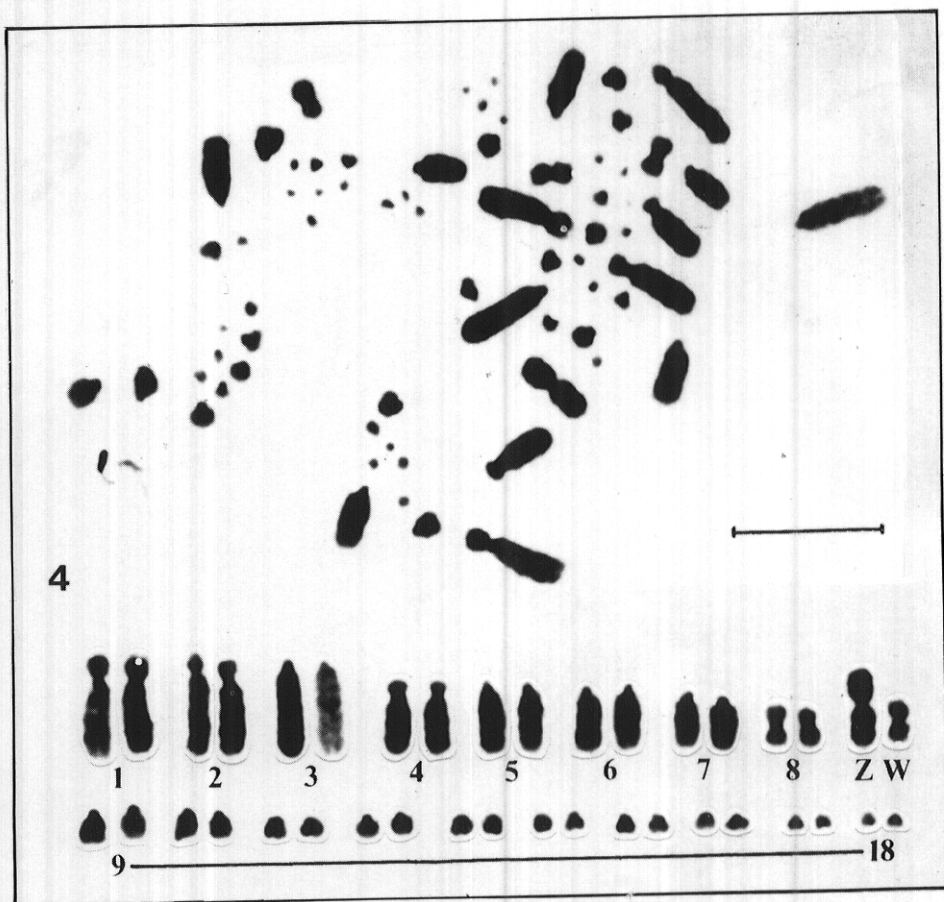


Figure 4 - Metaphase plate and karyogram of a female *Amazona autumnalis*.

are two pairs of medium-sized metacentrics: pairs 7 and 8 (arm ratio 1.5 and 1.1 respectively). Pair 9 consists of two small metacentric elements (arm ratio 1.5) and pair 10 consists of two small telocentric elements. Although no female specimens could be studied, in Figure 6 a pair of metacentric elements (arm ratio 1:2) is tentatively chosen as the Z-chromosome pair since all other *Aratinga* studied to date (Lucca, 1984) possess metacentric Z-chromosomes of comparable size (somewhat smaller than pair 4) and morphology. The remaining chromosomes are of small to minute size, telocentric or of uncertain centromere position.

The karyotype of *A. aurea* (Figure 7) is identical to that of *A. jandaya*.

The diploid chromosome number of *B. sanctithomae* (Figure 8) is estimated to be 72. Apart from the sex chromosomes the karyotype consists exclusively of

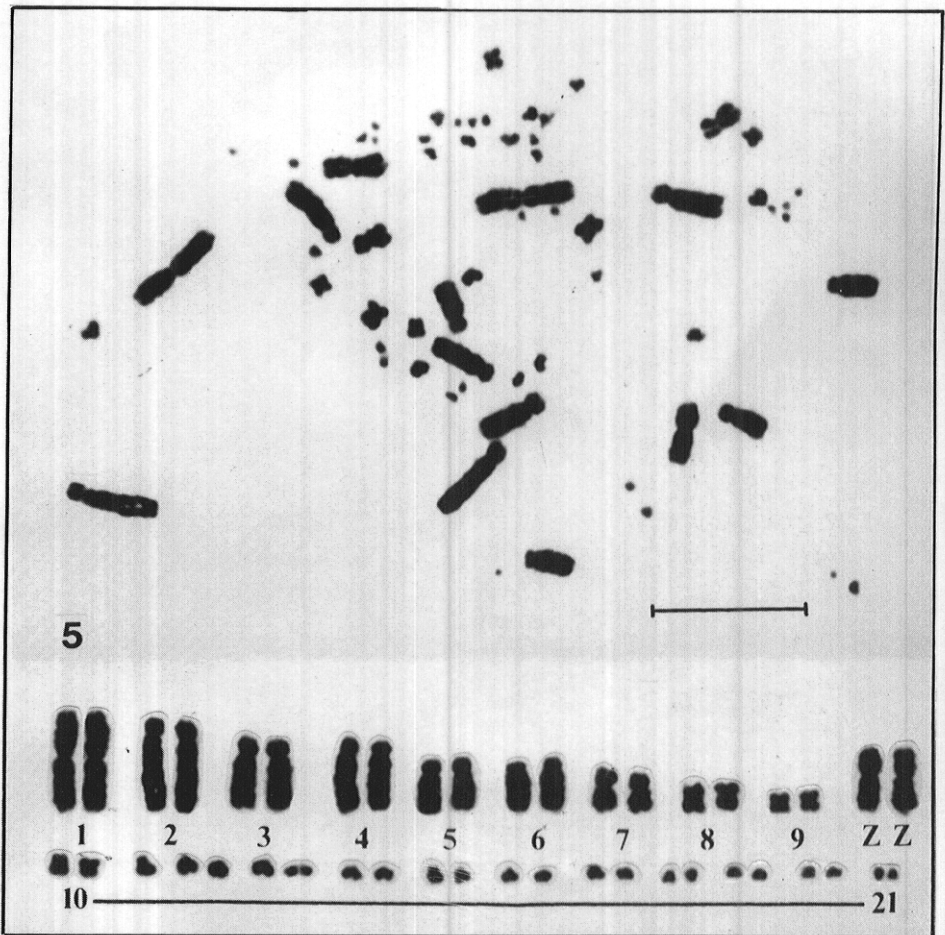


Figure 5 - Metaphase plate and karyogram of a male *Ara arauna*.

telocentrics. There is a very sharp boundary between the macro- and microchromosomes. The Z-chromosome is easily identifiable, metacentric (arm ratio 1.0) and slightly smaller than those of pair 4. The W is metacentric as well (arm ratio 1.0) and about the size of the seventh pair of autosomes.

The diploid chromosome number of *B. versicolorus* (Figure 8) is considerably higher than those of the above species: approximately 82. There is no clear boundary between macro and micro-chromosomes. Pair 1 consists of large metacentrics (arm ratio 1.2) and there is an unusual secondary constriction quite evident in all metaphase plates. Pairs 2 and 3 are large telocentrics (arm ratio 7.0). Pairs 4 and 5 are medium-

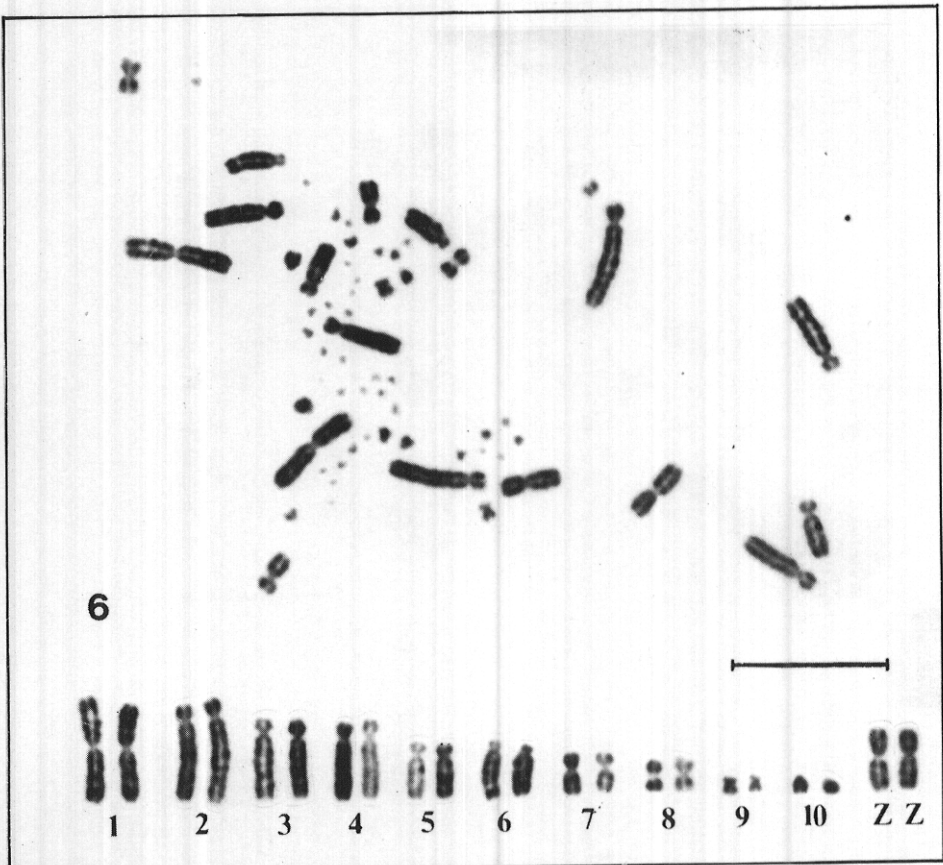


Figure 6 - Metaphase plate and karyogram of a male *Aratinga jandaya*.

sized subtelocentrics. Pairs 6 and 7 are medium-sized telocentrics and pairs 8 and 9 are smaller telocentrics. Pair 10 consists of small metacentric elements (arm ratio 1.0). The W chromosome is a small metacentric and Z-chromosome is a metacentric element (arm ratio 1.0) and slightly smaller than the autosomes of pair 4.

The diploid chromosome number of *E. roratus* is estimated to be 68 (Figure 9). Pair 1 consists of large metacentrics (arm ratio 1.). Pairs 2 and 3 are submetacentric (arm ratio 2.8 and 2.5 respectively). Pair 4 is a medium-sized telocentric. Pair 5 consists of metacentrics (arm ratio 1.0). Pairs 6 and 7 are smaller telocentrics (arm ratio 7.0 and 8.0) and pair 8 is a small submetacentric chromosome (arm ratio 2.7). The remaining chromosomes are of small to minute size, telocentric or of uncertain centromeric position.

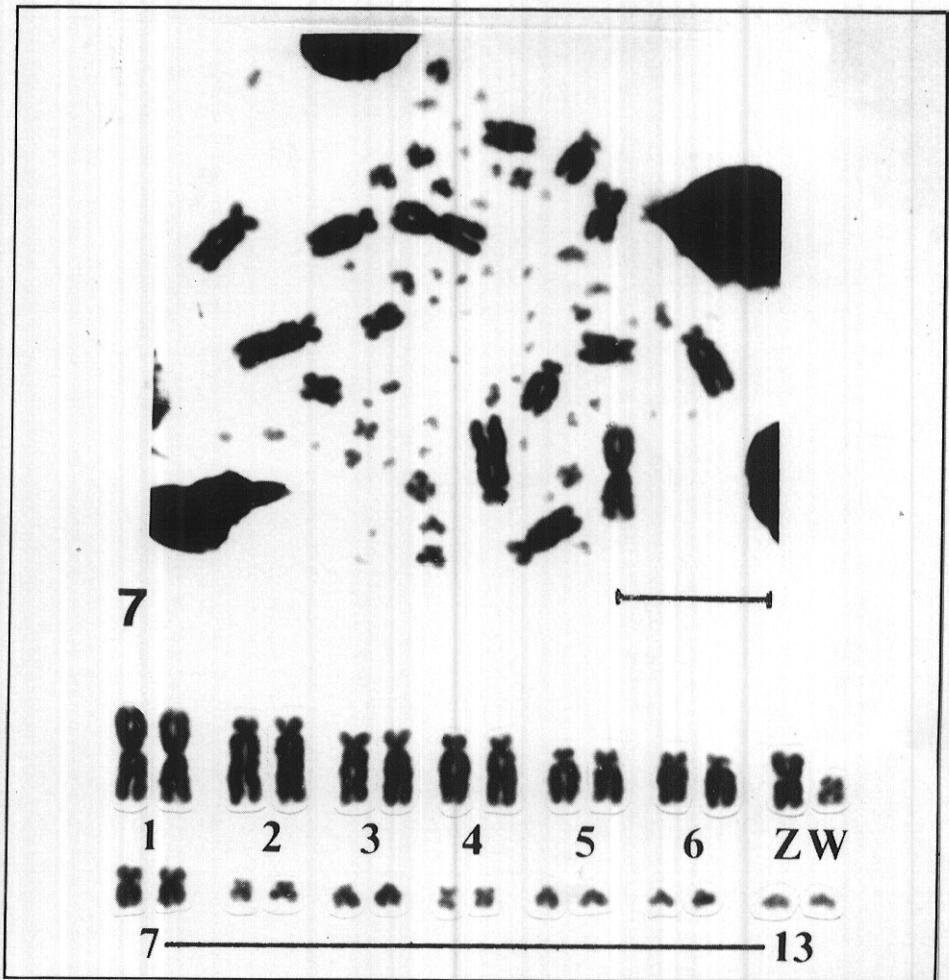


Figure 7 - Metaphase plate and karyogram of a female *Aratinga aurea*.

F. xanthopterygius with $2n = 86$ (Figure 10) has one of the highest diploid numbers as yet recorded in Psittaciformes. Lucca and Marco (1983) described a chromosomal polymorphism in this species. The observed polymorphism resulted from a translocation involving pairs 1 and 5. Pair 1, 2 and 5 are metacentric (arm ratio 1.2, 1.3 and 1.2), whereas pair 4 is subtelocentric and pairs 3, 6 and 7 are telocentric. Some of the small chromosomes are clearly biarmed but most of them are telocentric. The Z-chromosome is a metacentric (arm ratio 1.2) and slightly smaller than the autosomes of pair 4. The W chromosome is metacentric as well (arm ratio 1.3) and about the size of the sixth pair of autosomes.

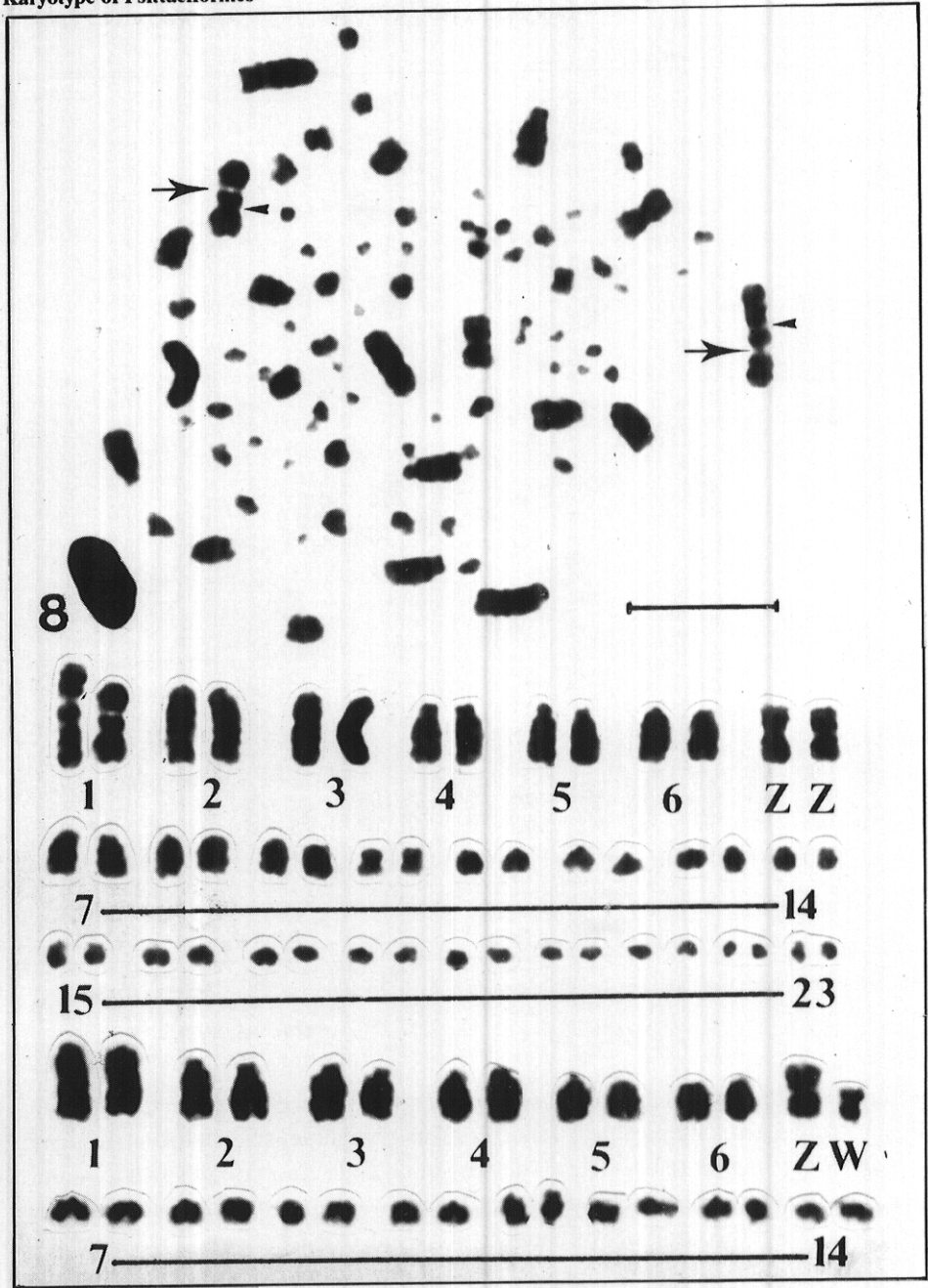


Figure 8 - Chromosomes of *Brotogeris* with a metaphase plate and partial karyotype of a male *B. versicolorus*. Note a secondary constriction in the 1st chromosome pair (large arrows; small arrows: centromere). Bottom line: representative karyogram of a female *B. sanctithomae*.

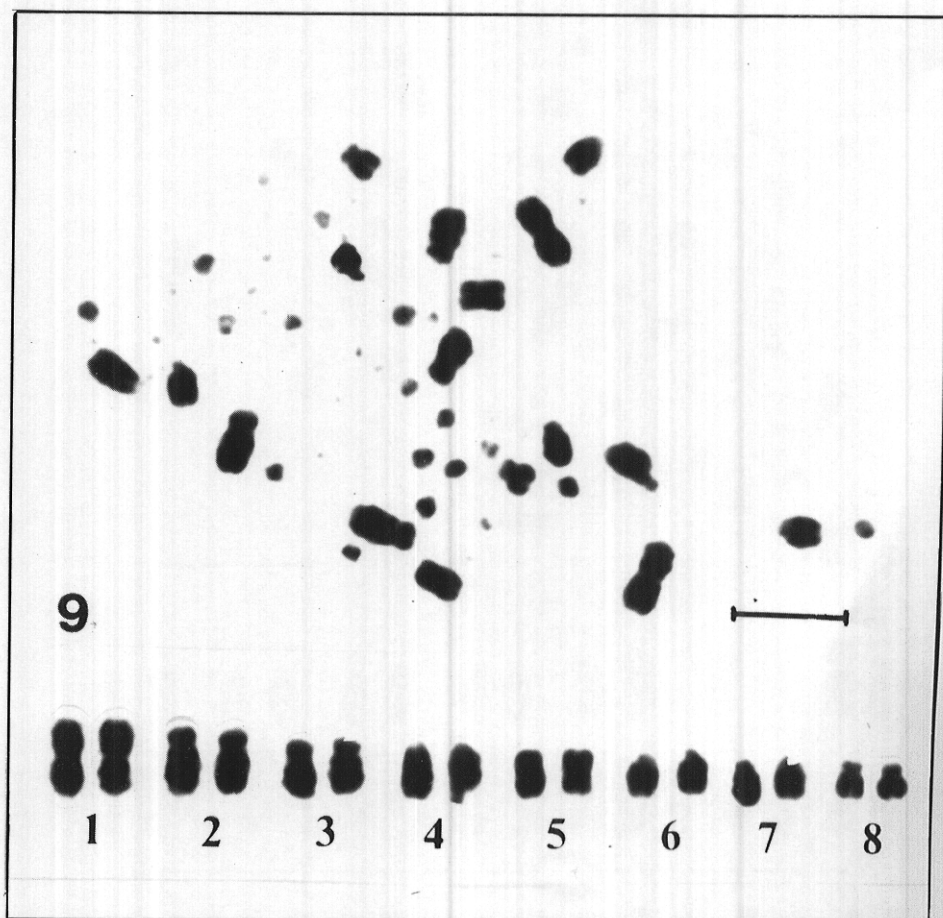


Figure 9 - Metaphase plate and karyogram of a male *Eclectus roratus*.

The diploid number of *P. maximiliani* appears to be approximately 72. Pairs 1, 2, 3, 4 and 5 are subtelocentric. Pair 6 consists of medium-sized telocentrics. Pairs 7, 8 and 9 are smaller telocentrics. The remaining autosomes are of small to minute size and telocentric. The Z-chromosomes, as in *P. seniloides*, are subtelocentric (arm ratio 3.2) and of the same size as pair 4.

In as far as detectable the karyotype of *P. menstruus* (Figure 11) is similar to that of *P. maximiliani*.

The diploid chromosome number and morphology of chromosomes of *P. senilis* is quite similar to those of *P. maximiliani* and *P. menstruus*.

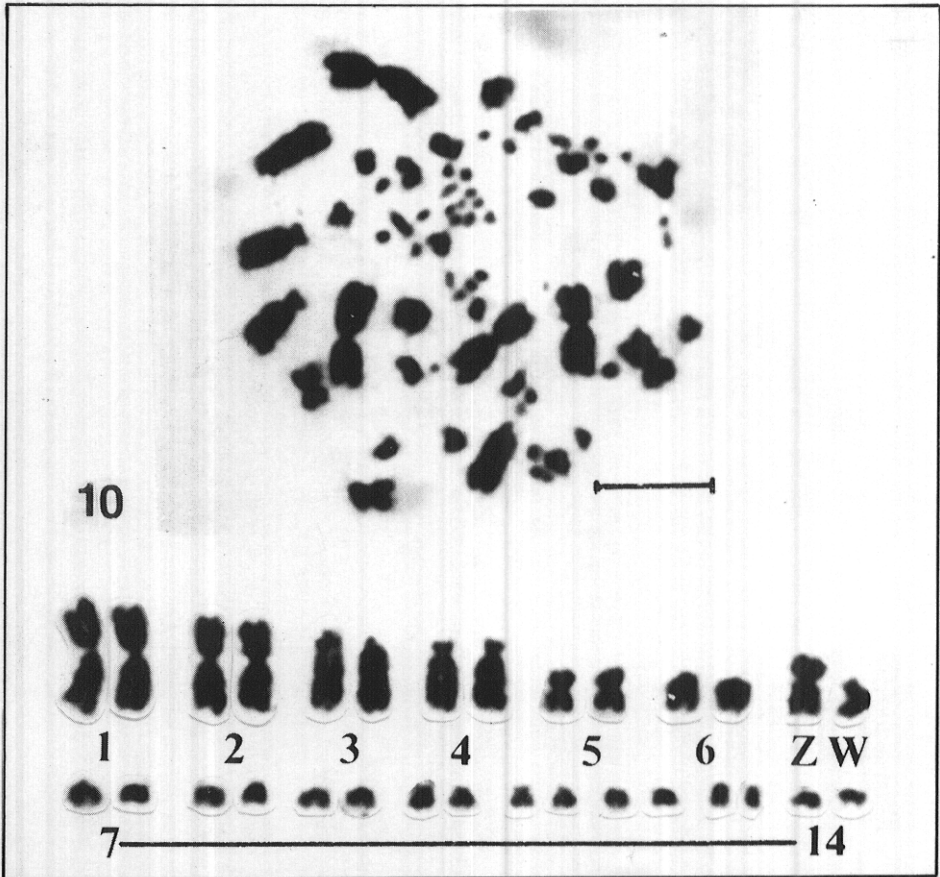


Figure 10 - Metaphase plate and karyogram of a female *Forpus xanthopterygius*.

The diploid number of *P. seniloides* (Figure 12) appears to be 72 and pairs 1, 2, 3, 4 and 6 are subtelocentric (arm ratio 3.7, 4.8, 4.2, 4.8 and 3.6 respectively). Pair 5 consists of medium-sized telocentrics (arm ratio 15.0). Pairs 7, 8 and 9 are smaller telocentrics. The Z-chromosome is subtelocentric (arm ratio 3.2) and of the same size as pair 4. The W is the only metacentric chromosome (arm ratio 1.1), somewhat larger than pair 7. In this species there is a sharply demarcated boundary between pairs 6 and 7.

There is a great uniformity among *Pionus* karyotypes.

The karyotype of *P. senegalus* (Figure 13) consists of approximately 68 chromosomes. There is a very sharp boundary between the macro- and

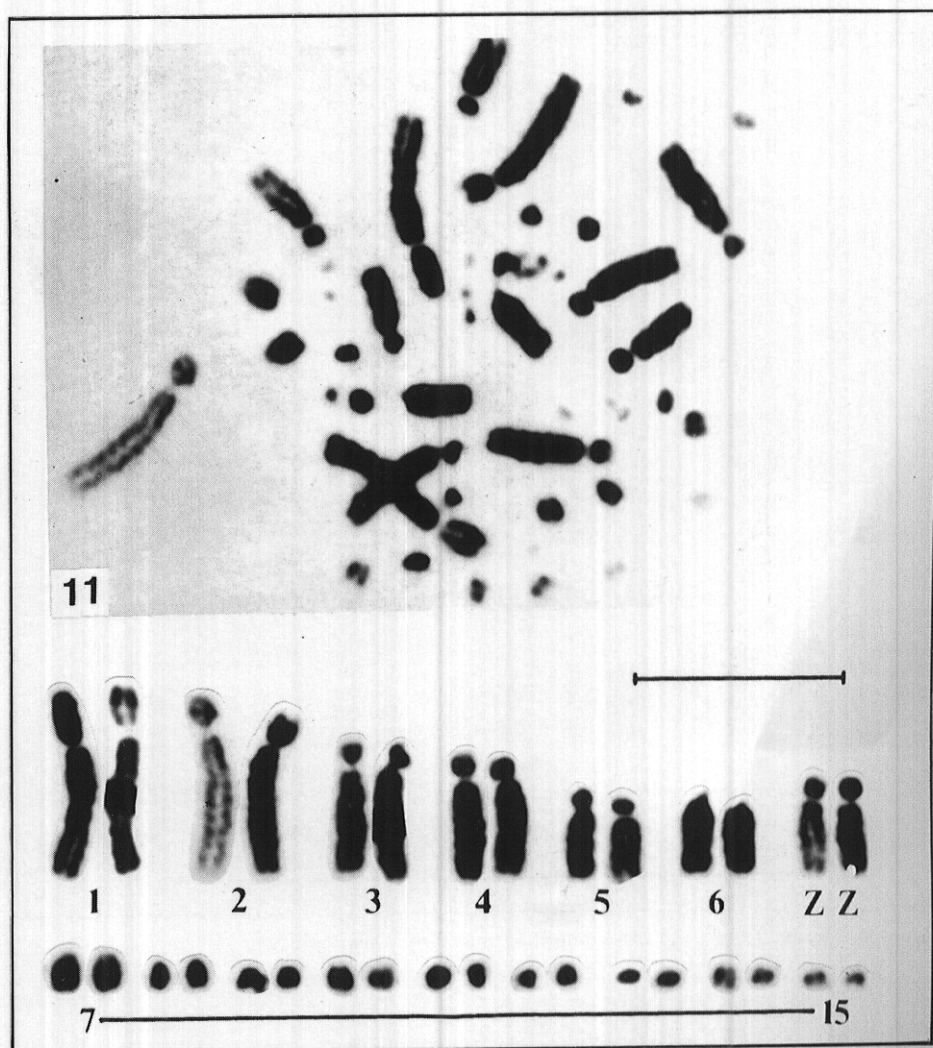


Figure 11 - Chromosomes with a metaphase plate and partial karyotype of a male *Pionus menstruus*.

microchromosomes. There are 8 pairs of macrochromosomes. Pair 1 consists of two metacentric elements (arm ratio 1.2). Pairs 2, 3 and 4 are made up to subtelocentrics (arm ratio 5.0, 4.0, 4.0). Pair 5 consists of two medium-sized metacentrics (arm ratio 1.2). Pair 6 is telocentric and pairs 7 and 8 consist of somewhat smaller subtelocentrics (arm ratio 4.0 and 3.8). Lacking the karyotype of a female animal, the exact identification of the Z and W is impossible.

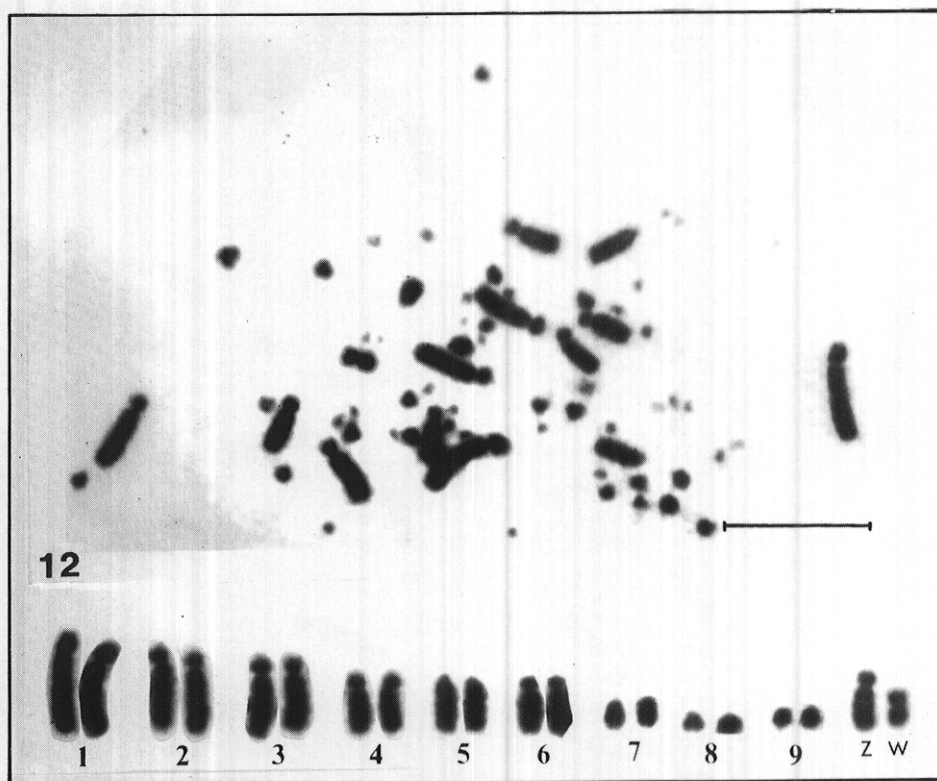


Figure 12 - Chromosomes with a metaphase plate and partial karyotype of a female *Pionus seniloides*.

The diploid chromosome number of *P. alexandrae* (Figure 14) is approximately 70. This species has an unusual karyotype. There are 9 pairs of macrochromosomes and many of them are metacentric (pairs 1, 2, 4 and 6). Pairs 5, 7 and 8 are submetacentric. Pair 3 is a large subtelocentric and pair 9 is a medium-sized telocentric. The remaining autosomes (approximately 68; the diploid number is 76) are of small to minute size and telocentric as far as their centromeric position can be determined. Lacking the karyotype of a female animal, the exact identification of the Z and W was impossible.

The karyotype of *P. krameri* (Figure 15) consists of approximately 70 chromosomes. There is a very sharp boundary between the macro- and microchromosomes. There are eight pairs of macrochromosomes. Pair 1 consists of two metacentric elements (arm ratio 1.3). Pair 2 is almost of the same size as pair 1, but subtelocentric (arm ratio 5.6). Pairs 3, 4 and 6 are made up of subtelocentrics (arm ratio 3.6, 4.0 and 3.3). Pair 5, consisting of two submetacentrics (arm ratio 2.0,

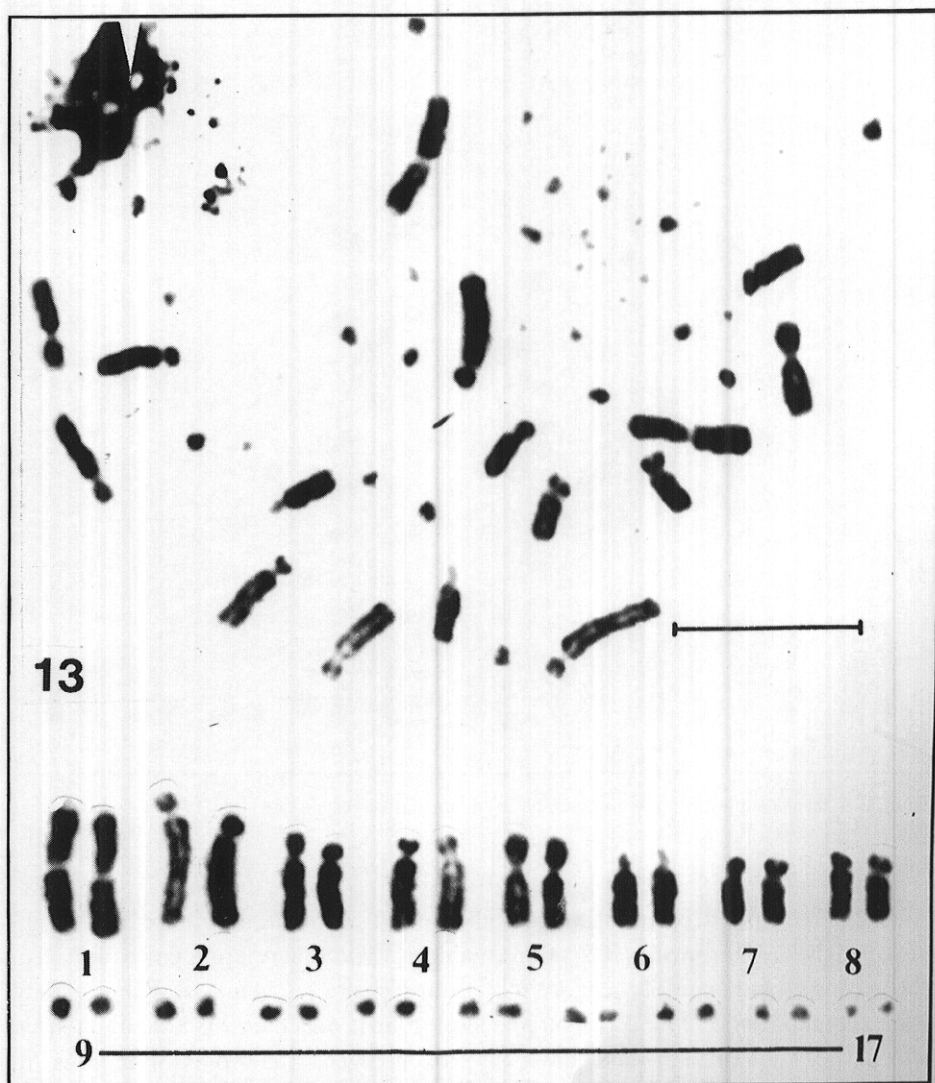


Figure 13 - Metaphase plate and karyogram of a male *Poicephalus senegalus*.

slightly larger than the elements of pair 6), is probably the Z-chromosome pair, because of the similarity in size and structure to the Z-chromosomes of other species of parrots. Pairs 7 and 8 consist of somewhat smaller telocentrics (arm ratio 12.0 and 9.0 respectively). The remaining chromosomes are microchromosomes and most of them are telocentric. Ray-Chaudhuri *et al.* (1969) described the karyotype of *P. krameri*.

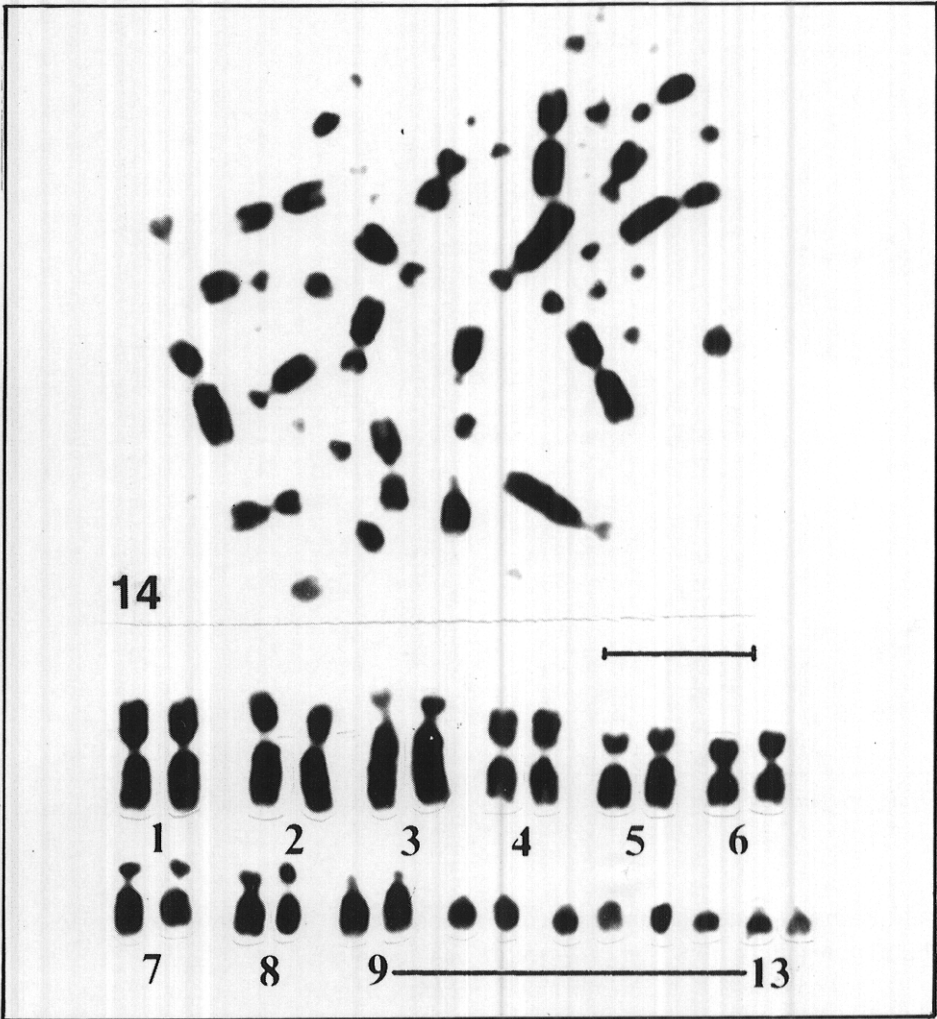


Figure 14 - Chromosomes of a male *Polytelis alexandrae* with a metaphase plate and partial karyotype.

In as far as detectable the karyotype of *P. erithacus* (Figure 16) is quite similar to that of *P. cyanocephala*. It differs because of the presence of small but distinct short arms in pairs 7 and 8, the absence of short arms in pair 6 and the fifth pair of macrochromosomes, consisting of two metacentrics (arm ratio 1.6). De Boer and Belterman (1980) described the chromosomes of *P. erithacus*. Two submetacentrics (arm ratio 1.7), as large as pair 5, are tentatively placed as the possible Z chromosome

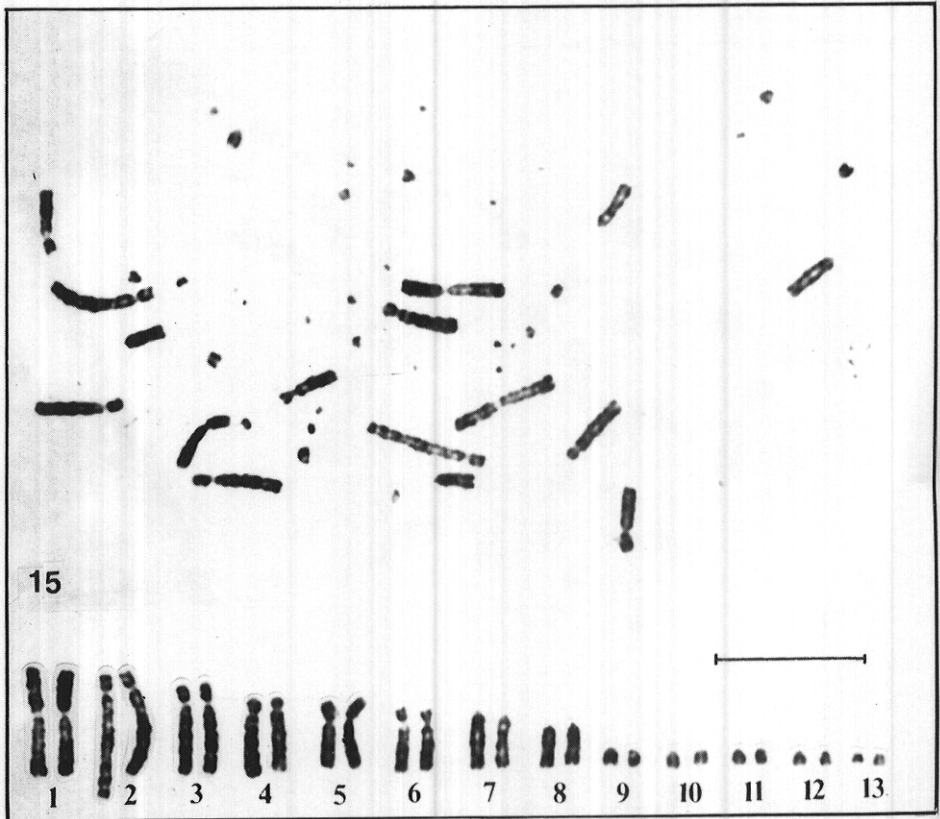


Figure 15 - Chromosome of a male *Psittacula krameri* with a metaphase plate and partial karyotype.

pair. Probably, the fifth pair of macrochromosomes is the Z-chromosome. Most of the 50 remaining chromosomes appear to be telocentric.

The chromosome number of *P. molinae* (Figure 17) is estimated to be 70. Pairs 1 and 2 have the same size and for this reason the large subtelocentric was placed as number 1 (arm ratio 4.8) and the metacentrics (arm ratio 1.1) as second pair. According to the morphology of the third pair, one of the homologues shows an arm ratio of 7.0 (telocentric) and the other one shows an arm ratio of 3.4 (subtelocentric). Probably a pericentric inversion is responsible for this difference in morphology. The karyotypes shown in Figure 17A, 17B and 17C, are of one of the females and Figure 17D is of the male analysed (pair 3, subtelocentric). Pair 4 consists of subtelocentrics (arm ratio 3.2). Pairs 5 and 6 are clearly smaller and submetacentric (arm ratio 2.3) and telocentric (arm ratio 8.5), respectively. The Z-chromosome is a metacentric (arm ratio 1.3), somewhat smaller than pair 4. The W is submetacentric (arm ratio

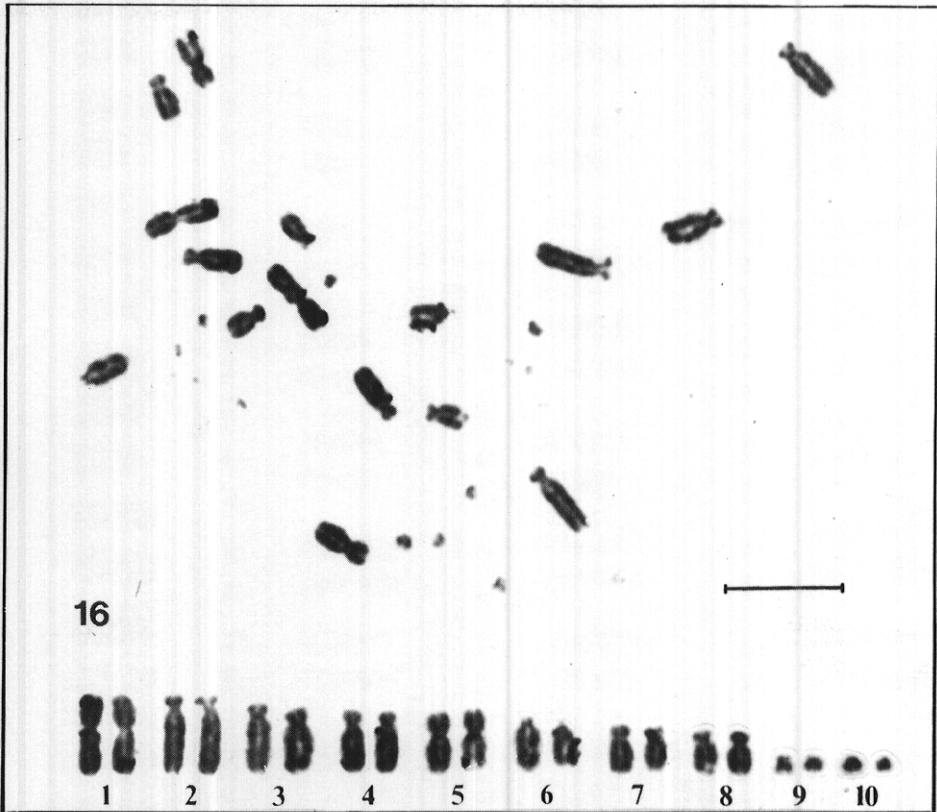


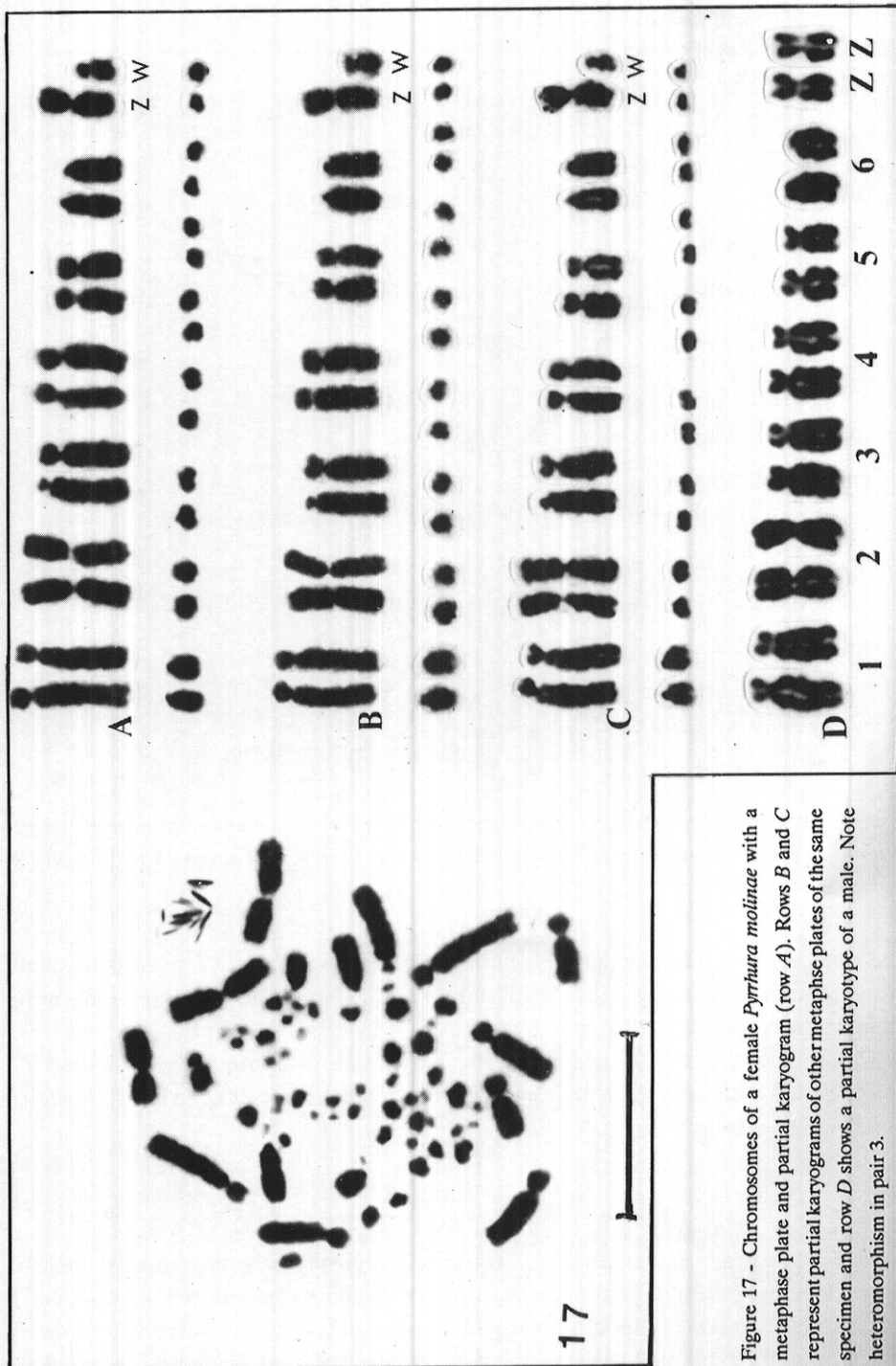
Figure 16 - Chromosomes of a male *Psittacus erithacus* with a metaphase plate and the first 10 pairs of macrochromosomes.

2.3) and somewhat larger than the chromosomes of pair 7. Pair 7 consists of small telocentrics which are clearly distinguishable from the smaller remaining microchromosomes.

Valentine (1987) described the karyotypes of *Pyrrhura frontalis* and *P. molinae* and found an identical inversion of one chromosome three in five *P. frontalis* and two *P. molinae*.

DISCUSSION

The order Psittaciformes is known cytologically from the study of twenty-seven species of thirteen genera belonging to the families Cacatuidae (three species) and Psittacidae (twenty-four) species. This paper describes the karyotype of three species from the family Loriidae and nineteen species from the family Psittacidae.



The karyotypes of *A. ochrocephala*, *A. ararauna*, *A. macao*, *P. krameri*, *P. erithacus* and *P. molinae*, described here, are identical to those recorded for these species earlier (Ray-Chaudhuri *et al.*, 1969; De Boer and Belterman, 1980; Van Dongen and de Boer, 1984; Valentine, 1987). The karyotypes of *A. aurea*, *B. sanctithomae*, *B. versicolorus* and *F. xanthopterygius* were described previously (Lucca and Marco, 1983; Lucca, 1984; Lucca, 1985). Twelve newly described parrot karyotypes include the genera *Lorius*, *Phigys*, *Amazona*, *Aratinga*, *Eclectus*, *Pionus*, *Poicephalus* and *Polytelis*.

In Psittaciformes, the diploid number of chromosomes ranges from 62 in *Melopsittacus undulatus* to 86 in *F. xanthopterygius*. Although belonging to the same genus, *B. sanctithomae* and *B. versicolorus* have a slightly different karyotype. The same situation can be seen between *Psittacula cyanocephala* and the other two species of the same genus, *P. krameri* and *P. alexandri* (Ray-Chaudhuri *et al.*, 1969). There are some species with a karyotype entirely made up of telocentrics with the exception of a single pair of metacentrics (proved to be the Z- and W-chromosomes) as in *Cacatua galerita*, *Calyptorhynchus magnificus*, *Probosciger aterrinus* (Van Dongen and De Boer, 1984) and *B. sanctithomae* (Lucca, 1985). Otherwise, in species such as *M. undulatus* (Rothfels *et al.*, 1963; Van Dongen and De Boer, 1984), *P. solitarius*, *L. hypoinochrous*, *L. lory* and *P. alexandrae* (present paper) there are many pairs of metacentric and submetacentric chromosomes. An examination of the karyotypes shows very convincingly that the Psittaciformes exhibit a heterogeneous karyotypic morphology in contrast to several other avian orders in which very uniform karyotypes are found.

In some genera such as *Amazona*, *Ara*, *Aratinga*, *Lorius* and *Pionus*, the species analysed so far, belonging to the same genus, are very closely related because they have almost identical karyotypes. However, species belonging to different families like *Loriculus vernalis* (Psittacidae) and *C. magnificus* and *C. galerita* (Cacatuidae) also have almost identical karyotypes (Van Dongen and De Boer, 1984).

Karyotypes with a morphology comparable to that of *P. alexandrae* have not been reported so far. Karyotypes of all Psittacidae studied except *Loriculus* and *Brotogetis* possess three pairs of large subtelocentric chromosomes (pairs 2, 3 and 4). In *P. alexandrae* (Figure 14) pairs 2 and 4 are metacentric. In *P. solitarius* (Figure 3) and *P. molinae* (Figure 17) pair 2 consists of two large metacentric elements. In *Amazona*, *Pionus*, *Phigys*, *Pyrrhura* and *B. sanctithomae* the first pair is made up of large subtelocentrics and in all the remaining species it is a metacentric chromosome. In some species (*L. lory*, *P. molinae* and *P. senegalus*) it was very difficult to establish which one was the first pair because the first and second pairs were of the same size or chromosome 2 was slightly smaller than the elements of pair 1. Small metacentric chromosomes are found in some species belonging to the genera *Ara*, *Amazona*,

Forpus, *Aratinga*, *Lorius* and *Phigys*. Metacentric microchromosomes are quite evident in *B. versicolor* (Figure 8), *P. erithacus* (Figure 16), *A. aurea* (Figure 7) and *A. jandaya* (Figure 6). Pairs 5, 6 and 7 showed a great variation in size and morphology. In *Amazona*, *Ara*, *Aratinga*, *P. krameri*, *P. senegalus*, *E. roratus*, *Lorius*, *P. solitarius*, *P. alexandrae*, *P. erithacus* and *B. versicolor* pairs 5, 6 and 7 are medium-sized chromosomes. Pair 7 consists of small chromosomes in *Pionus*, *B. sanctithomae* and *P. molinae* and pairs 5, 6 and 7 are clearly small in *F. xanthopterygius*. In *P. alexandrae*, from the family Psittacidae, there is a large telocentric chromosome (pair 9) not found in any other species described so far. As a matter of fact this species shows an unusual karyotype (Figure 14).

Ray-Chaudhuri (1973) suggested one of the medium-sized pairs of acrocentrics to represent the Z-chromosome in *Loriculus vernalis* although it is a metacentric or submetacentric chromosome in all the remaining parrots studied to date. In *Pionus*, the Z chromosome is subtelocentric (Figures 11 and 12) and proved to be metacentric in the remaining species. The W-chromosome was submetacentric in *P. molinae* and metacentric in all other parrots so far studied.

The karyotype of *B. sanctithomae*, *C. magnificus* and *C. galerita* (Van Dongen and De Boer, 1984) are very much alike. The last two species belong to the family Cacatuidae. Van Dongen and De Boer (1984) suggested that the karyotypes of *Loriculus vernalis* (Psittacidae), *C. magnificus* and *C. galerita* would be almost identical. *L. vernalis* possesses a karyotype entirely made up of telocentrics with the exception of a large pair of metacentrics (Ray-Chaudhuri et al., 1969). It is not possible that the only pair of metacentrics are the Z-chromosomes since in all species studied to date the Z-chromosome showed a size intermediate in length between pairs 3 and 4 or 4 and 5.

Van Dongen and De Boer (1984) stated that karyotypes with a morphology comparable to those of both species of *Ara* (*ararauna* and *macao*) and *Psittichas fulgidens* have not been reported so far. Lucca (1984) described the karyotypes of 5 species of *Aratinga*, which are identical to the karyotypes of *Ara*. There is a uniformity of types in parrots of the South America and this is in contrast to the diversity present in parrots of the Pacific. The uniformity is well illustrated by the fact that of the 138 extant species in South America no less than 92 belong to only six genera, among which *Ara* and *Aratinga* are closely related (Forshaw, 1977). In the present paper, the karyotypes of *A. aurea* (Figure 7), *A. jandaya* (Figure 6) and *A. ararauna* (Figure 5) corroborate this statement. Probably, the fifth pair in *E. roratus* is the Z-chromosome and in that case the karyotypes of *Psittichas fulgidens* and *E. roratus* would be almost identical.

In the genus *Brotogeris* there is an obvious tendency to reduction in the number of chromosomes and this tendency is clearly expressed in other genera of

Psittaciformes such as *Melopsittacus*, *Psittacula* and *Nestor*. In *Melopsittacus undulatus* and *Ara* the small metacentrics, probably, have been created by Robertsonian translocations between larger microchromosomes. Ray-Chaudhuri *et al.* (1969) state that in *P. cyanocephala* a single translocation of the Robertsonian type is the most simple explanation of the derivation of the large metacentric chromosome number 2. The same would explain the karyotype of *P. alexandrae* (Figure 14). In *Nestor notabilis* de Boer and Belterman (1980) found a diploid number of 62 chromosomes and Van Dongen and De Boer (1984) mentioned that in *Amazona* and *Nestor* the largest microchromosomes are clearly larger than those in *Psittacula*, *Psittacus*, *Melopsittacus*, *Ara* and *Psitrichas* but no explanation was found for the significantly lower diploid number of *Nestor*. The authors suggested that this low chromosome number was derived independently from the lower number in *Melopsittacus*. In some species of Psittaciformes with low chromosome number there is a very sharp boundary between the macro- and microchromosomes (*P. erithacus*, *P. solitarius*, *P. alexandrae*, *Pionus*, *P. molinae*, *Lorius* and *P. senegalus*) and the smaller macrochromosomes are lacking, which accounts for the sharp macro-microchromosome boundary in these species. Lucca and Marco (1983) described a chromosomal polymorphism in *Forpus xanthopterygius* involving two pairs of chromosomes. It was suggested that the observed polymorphism resulted from a translocation involving pairs 1 and 5. A significant correlation was found between pericentromeric heterochromatin block and the internal structural complexity for some chromosomes both in Psittaciformes and Columbiformes (Lucca, 1983). The data obtained suggest that a more intense modification of the karyotype may have occurred in Psittaciformes with fusion of the larger microchromosomes which would lead to: a) reduced diploid number, b) increased size, and consequently increased relative length of some macro- and microchromosomes; c) creating a new small metacentric macrochromosomes; d) not creating new macrochromosomes but shifting the centromeric position in the macrochromosomes; e) reduced microchromosome numbers, and f) sharp boundary between macro- and microchromosomes. De Boer (1976) and De Boer and Sinoo (1984) shows that the Falconiformes, especially the family Accipitridae is characterized by an extremely low number of microchromosomes, the absence of really large macrochromosomes, the presence of a high number of medium to small sized banded macrochromosomes and a considerably lower number of subtelocentrics. This tendency to chromosomal fusion might be connected with the speciation process (that is of selective advantage) and, consequently, rapidly evolving orders would show this tendency more than others. The chiasmata are scarce or absent in microchromosomes and this probably reduces the amount of genetic variation present in a species. The microchromosomal translocation might reflect an

increase in genetic variation. This hypothesis remains to be proved because we do not know much about microchromosomal genes.

According to Valentine (1987) *P. molinae* and *P. frontalis* possess identical karyotypes. One striking finding, however was the discovery of an identical inversion of one chromosome three in five *P. frontalis* and two *P. molinae*. These two species do occur sympatrically in at least part of their ranges. Since they also share an identical derived chromosomal condition, it would seem likely that the inversion seen in these two species has a common origin and, probably, there must be gene flow between them. This being the case, then these two groups do not fulfill the requirements for species status, they may, in fact, be only subspecies of the same species.

Probably, pericentric inversions are responsible for the variation in morphology of pair 1 in *Amazona*, *Pyonius*, *P. molinae*, *B. sanctithomae* and *P. solitarius* and in the morphology of some other chromosome pairs.

Van Dongen and De Boer (1984) proposed one of the possible phylogenetic trees of the Psittaciformes based on karyological data. These data still remain extremely limited since the karyotypes of only 39 species of the order Psittaciformes have been studied. According to Forshaw (1977) there are 332 extant species of parrots in the world. The karyological heterogeneity of the order and the uniformity of types in parrots of the South America in marked contrast to the diversity present in parrots of the Pacific underlines the importance of collecting more karyological data on these birds.

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RESUMO

São descritos os cariótipos de 12 espécies de Psittaciformes não relatados na literatura: *Lorius hypoinochrous*, *Lorius lory* e *Phigys solitarius*, da família Loriidae e *Amazona autumnalis*, *Aratinga jandaya*, *Eclectus roratus*, *Pionus maximiliani*, *P. menstruus*, *P. senilis*, *P. seniloides*, *Poicephalus senegalus* e *Polytelis alexandrae*, da família Psittacidae. Os cariótipos de *Amazona ochrocephala*, *Ara ararauna*, *Ara macao*, *Psittacula krameri*, *Psittacus erithacus* e *Pyrrhura molinae* da família Psittacidae, já foram descritos

anteriormente. Para melhor comparação dos cariótipos, descreve-se ainda os cariótipos de *Aratinga aurea*, *Forpus xanthopterygius*, *Brotogeris sanctithomae* e *B. versicolorus*, da família Psittacidae. Estes cariótipos são comparados com aqueles já descritos na literatura e faz-se uma ampla discussão sobre as relações cariotípicas nos Psittaciformes. Fusões e translocações envolvendo microcromossomos e inversões pericêntricas provavelmente são responsáveis pela heterogeneidade cariotípica nos Psittaciformes.

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