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The chromosomes of the Order Falconiformes: a review

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ABSTRACT. Falconiformes are a cosmopolitan Order of birds of prey, ranging in size from small hawks to large eagles. Many species are sexually monomorphic as adults, and so sex determination is important for reproduction in captive populations. The Order Falconiformes comprises a cytogenetically heterogeneous group, with karyotypes differing among Accipitridae, Falconidae, Sagittaridae, Pandionidae and Cathartidae; karyotypes may then be useful for characterization and differentiation of these groups. Approximately 10% of Brazilian raptors were karyotyped by 1992. Here it is shown that this percentage has not grown significantly since that time. In this review, a genetic research summary of Falconiformes shows a list of 66 species analyzed from 1966 to 2001. Genetic and karyotypic information for each family is described herein.

KEY WORDS: Chromosomes, Cytogenetic,. Falconiformes.

RESUMO. **Os cromossomos da Ordem Falconiformes.** Falconiformes são aves de rapina cosmopolitas de diferentes tamanhos, desde os pequenos falcões até a harpia, onde um grande número de espécies são sexualmente monomórficas na vida adulta. Daí a importância da sexagem na reprodução em cativeiro. Do ponto de vista citogenético, a Ordem Falconiformes constitui um grupo heterogêneo, mostrando grandes diferenças no cariótipo entre Accipitridae, Falconidae, Sagittaridae, Pandionidae e Cathartidae. Assim, o cariótipo é um importante elemento para caracterização e diferenciação desses grupos. Por outro lado, através da análise de seqüência de DNA, os abutres do Novo Mundo (Cathartidae) seriam mais proximamente relacionados com as garças (Ciconiiformes) do que com os abutres do Velho Mundo. Em 1992, foi estimado que 10% das aves brasileiras tinham os seus cariótipos descritos. A presente revisão mostra que esta porcentagem não sofreu alteração considerável nos últimos anos. Um diagnóstico da pesquisa genética da Ordem Falconiformes é ilustrado na tabela 1, que mostra uma lista de 66 espécies de Falconiformes, analisadas por diferentes autores, desde 1966 até 2001. A caracterização de cada família é mostrada no texto e nas tabelas.

PALAVRAS CHAVE: Citogenética, Cromossomos, Falconiformes.

The Class Aves has several distinctive characteristics among the group of vertebrates, not only morphologically but also regarding the genetic material.

In 1982, only 3% of all birds had their karyotypes described (Shields 1982). In 1992, it was estimated that only 10% of the Brazilian birds had their karyotypes known (Lucca and Rocha 1992). In a literature review starting in 1992, accomplished by us, this percentage did not suffer significant alterations.

From the cytogenetic point of view, the species of the Order Falconiformes constitute a very heterogeneous group, showing great differences in karyotypes betwwen Accipitridae, Cathartidae, Falconidae, Sagittaridae and Pandionidae. Karyotypes serves then as an important element for characterization and differentiation of these groups. According to Boer and Sinoo (1984) karyotype differences between those groups are so great to the point that some authors (Boer 1975, 1976, Takagi and Sasaki 1974) defend the idea of some taxonomists which prefer to identify the birds of prey families into Orders (Falconiformes, Cathartiformes, Sagittariformes and Accipitriformes) and not into different families.

The avian karyotype is composed of both macro (mac) and microchromosomes (mic). Mics are very small in size and, in general, appear in a large number in the species with high diploid number. These chromosomes are mostly indistinguishable from each other and with a terminal centromere. In chickens, they correspond to 35% of the genome (Basrur *et al.* 1998a). Mic are also present in some reptiles, suggesting a common ancestor for birds and reptiles (Ohno 1969). The Accipitridae family (Falconiformes), is an exception to the rule since most species exhibit a small number of mic.

In the birds, the sexual chromosomes are designated by Z and W, being the females the heterogametic sex (Z and W) and the males, homogametic (ZZ). In the chicken the Z is the 5th pair of chromosomes and represents about 7% of the genome; the W is one of the mic and represents 1.5% of the genome (Fechheimer 1990, Tone *et al.* 1984). In the 50's, mic were not considered as true chromosomes. Nowadays it is known that they have structures and functions of regular chromosomes, with centromere, telomere and hetero and euchromatic regions (Bloom *et al.* 1993). Mc Queen *et al.* (1996) noticed that, in chickens, the euchromatic regions of mic are rich in CpG islands, indicating the presence of genes in these chromosomes.

The identification of the sex in birds is important in conservation programs. In Falconiformes, a great number of species are sexually monomorphic in adult life (Basrur *et al.* 1998b), hence the importance of sexing for reproduction in captivity. The identification of the sex for chromosome analysis has great application when the Z and W chromosomes differ significantly in size (Ellegren and Sheldon 1997). However, the utilization of C banding technique allows to identify W chromosome which is heterochromatic for the whole long arms (Oliveira 2000). In Ratitas, it is believed that the sexual chromosomes are indistinguishable or very similar (Ellegren 2000). Ogawa *et al.* (1998) found the genes ZOV3 and IREBP1, which are linked in Z in Carinatas and are linked in the Z and W, respectively, in emu (Ratita).

Falconiformes are cosmopolitan birds of prey, and most species do not show sexual dimorphism. When this occurs, they are distinguished by the size, being the female larger than the male. Most of the species still lack the correct identification for the Z and W, for later application in sexing.

The most important papers in the recent years deals with molecular sexing based on W chromosome an in specific sequences of DNA and mapping of the W (Griffiths *et al.* 1996, Ellegren 1996, Ellegren and Sheldon 1997, Griffiths and Korn 1997, Basrur *et al.*1998a, b, Ellegren 2000). One of these proteins (CHD-W-DNA-CHROMO-HELICASE) was identified in several birds species in the Order of Carinatas.

The Falconiformes is open for extensive studies since cytogenetic studies are scarce and only 3% of the species have been described. They are ecologically important, they have a great karyotype heterogeneity, and there are questions about the systematics and function of polymorphisms in speciation.

The present work is a review of cytogenetics of Falconiformes with regard to the diploid number, the number of macro and microchromosomes and identification of the Z and W chromosomes.

SYSTEMATICS OF THE FALCONIFORMES

The usual system of systematic classification, is based mostly on physical characteristics, allowing grouping of birds with morphological similarities. However, characters such as the feather coloring, shape of the beak or length of the legs can be modified by environmental variations, making it necessary to use interior structures which are generally more subtle.

Sick (1997) classifies the Order Falconiforines in three families: Accipitridae, Falconidae and Pandionidae. Other authors (Frisch 1981, Stotz *et al.* 1996, Faaborg 1988) place the family Cathartidae (vultures), into the Falconiformes. Stresemann and Amadon (1979), Storer (1971), cited by Griffiths (1994 a,b), consider Falconiformes as monophyletic with differences in the classification of the families.

The morphology of seringe was used by Griffths (1994 a,b) to know whether the Order Falconiformes is monophyletic and the data strongly support this theory. In this work, the author classify Cathartidae as Falconiformes. They also consider Falconidae, Accipitridae, Sagittaridae and Pandionidae, a unique group.

Sibley and Ahlquist (1990), proposed a new classification for the birds based on molecular data using the DNA hybridization method. A total of 1.700 species were analyzed and clustered according to the genetics similarity of their DNA. Falconiformes was shown to have great similarity with Ciconiiformes and the authors suggested the following classification:

- Ciconiiformes
  - Accipitridae
    - Pandioninae: Osprey
    - Accipitrinae: Hawks, Eagles, Old Word Vultures;
  - Sagittariidae: Secretary-bird
  - Falconidae: Falcons, Caracaras
  - Ciconiidae
    - Cathartinae: New World Vulture or Condor
    - Ciconiinae: Storks, Openbills, Adjutants, Jabiru

SYSTEMATICS OF THE CATHARTIDAE

Avise *et al.* (1994) showed, through sequence analysis of the mitochondrial DNA of the cytocromo b gene (cyt b), that the vultures of the New World (Cathartidae) would be more closely related to the family Ciconiiformes (storks) than to the vultures of the Old World. Wink (1995), using the same methodology, analyzed the sequence of cytocrome b of 12 members of the Order Falconiformes and 10 members of Ciconiiformes and verified that the vultures of the New World are clearly separated from the vultures of the Old World (Accipitridae, genus Gyps).

The vultures of the New World are separated into two anatomically different groups. For the vultures of the Americas a separate family (Cathartidae) was created, while the vultures of the Old World were included in the family Accipitridae of the Order Falconiformes.

CYTOGENETICS OF THE ORDER FALCONIFORMES

Table 1 shows a list of 66 species of Falconiformes studied by several authors from 1966 to 2001, and the description of their 2n, Z and W, macro and microchromosomes.

Accipitridae. The individuals of this family are birds of prey of different size from small hawks to harpy eagle, easily recognizable by the curved beak and sharpened talon. In general, they are solitary, but some species migrate

Table 1. Karyotype characterization of Falconiformes.

Species	2n	Mac	Mic	Z	W	Author	Main remarks
Accipitridae							
Accipiter badius	66	–	–	1st sm	?	Kaul and Ansari 1975	W not identified
A. badius	66	32	10	1st sm	? t	Misra and Srivastava 1976	W is a small t, difficult to identify
A. gentilis	76	–	–	4th sm	? m	Jovanovic and Molosevic 1972	W not identified
A. gentilis	78	70	8	?	?	Boer 1976	Z and W not identified. Sat 4th pair
A. nisus (?) *	64	–	–	1st m	6th ?	Renzoni and Vegni-Talluri 1966	W is tentatively
Accipiter novaeholhandiae	66-68	–	–	?	?	Boer and Sinoo 1984	Z and W not identified. Sat 5th pair
Aegypius monachus	66	58	8	1st sm	?	Boer and Sinoo 1984	W not identified. Sat 16th pair
Aquila adalberti	82	58	24	1st sm	? sm	Padilha *et al.* 1999	W not distinguish between 3th and 4th pair
A. audax	66	58-60	6-8	1st sm	? m	Boer 1976	W not identified
A. rapax	68	58	10	1st sm	?	Boer and Sinoo 1984	W not identified
A. chrysaetos	62	56	6	?	?	Takagi and Sazaki 1974	Z and W not identified
A. chrysaetos	66	56	10	?	?	Hoffmann 1976	Identical
A. heliaca	68	58	10	?	?	Takagi and Sazaki 1974	Identical
Buteo albicaudatus	68	–	–	?	?	Lucca 1985	Z and W not identified. Sat 7th pair
B. buteo	68	–	–	4th m	?	Renzoni and Vegni-Talluri 1966	W not identified
B. buteo	68	60	8	?	?	Boer 1976	Z and W not identified. Sat 6th pair
B. jamaicensis	70	–	–	?4th m	? m	Shoffner 1974	Z tentatively. W not identified. Sat 5th pair
B. lagopus	68	–	–	?	?	Bulatova 1977	No information on the Z and W. Sat 4th pair
B. magnirostris	68	60	8	?	?	Lucca 1983	Z and W not identified. Sat 5th pair
B. magnirostris(Rupornis magnirostris)	68	60	8	1st sm		Amaral and Jorge (pers. comm. 2001)	W not identified
B. nitidus	68	–	–	?	?	Schmutz *et al.* (1993)	Z and W not identified. Sat 4th pair
B. platypterus	68	–	–	? 1st m	?	Schmutz *et al.* (1993)	Z tentatively. W not identified
B. regalis	68	–	–	?	?	Schmutz *et al.* (1993)	Z and W not identified
B. swainsoni	68	–	–	? m	?	Schmutz *et al.* (1993)	identical
Circaetus gallicus	66	58	8	? m	? st	Boer and Sinoo 1984	Z and W not identified. Sat mic 29th pair
Circus aeruginosus	70-72	62	8-10	1st sm	?	Boer and Sinoo 1984	W not clearly identified. Sat 2th pair
C. cyaneus	72	62	10	?	?	Boer and Sinoo 1984	Z and W not clearly identified
C. pygarpus	70-72	62	8-10	1st sm	?	Boer and Sinoo 1984	W not clearly identified
Geranoaetus melanoleucus	68	60	8	1st sm	?	Boer and Sinoo 1984	W not clearly identified. Sat 5th pair
Geranospiza caerulescens	66	58	8	1st sm	15th m	Williams and Benirschke 1976	
Gypaetus barbatus	60	52	8	? 1st sm	? m	Boer 1976	Z tentatively. W not distinguish between 7th, 8th and 9th pair
Gyps bengalensis	66	58	8	? 1st sm	?	Boer and Sinoo 1984	Z tentatively. W not identified. Sat 16th pair

Continued

Table 1. Continued.

Species	2n	Mac	Mic	Z	W	Author	Main remarks
G. coprotheres	66	58	8	1st sm	4th st	Boer (1975, 1976)	Sat 16th pair
G. fulvus	66	58	8	1st sm	4th st	Boer 1976	identical
G. rueppellii	66	58	8	1st sm		Boer and Sinoo 1984	W not identified. Sat 16th pair
Haliaeetus alacanus	66	58	8	? 4th sm	? m	Au *et al.* 1975	Z is between 3th and 4th pair W not identified Sat 4th pair
H. albicilla	66	58	8	? 2nd sm	? sm	Omura 1976	Z tentatively. W not identified
H. albicilla	66	58	8	1st sm	? m	Boer 1976	W not identified
H. albicilla	66	58	8	1st sm	? m	Boer and Sinoo 1984	W not identified. Sat 4th pair
H. leucocephalus	66	58	8	?	?	Takagi and Sazaki 1974	Z and W not identified
H. leucocephalus	66	58	8	? 4th sm	? sm	Au *et al.* 1975	Z is between 3th and 4th pair. W is tentatively. Sat 4th pair
H. leucocephalus	66	58	8	4th sm	? sm	Hoffmann *et al.* 1975	W not identified
H. leucocephalus	66	58	8	1st sm	? m	Boer and Sinoo 1984	W not identified. Sat 4th pair
H. leucoryphus	66	58	8	? sm	? m	Boer and Sinoo 1984	Z and W not identified
H. leucogaster	66	58	8	1st sm	? m	Boer and Sinoo 1984	W not identified
H. pelagicus	66	58	8	1st ?	? st	Takagi and Sazaki 1974	Z tentatively sm or st. W not identified
H. vocifer	68	58	10	1st sm	11th m	Hoffmann *et al.* 1975	Discrepancy 2n compared with other species of genus
H. vocifer	66	58	8	1st sm	? 11th m	Boer 1976	W tentatively. Sat 9th pair
H. vocifer	66	58	8	?1st sm	?11th m	Boer and Sinoo 1984	Z and W tentatively. Sat 4th pair
Haliastur indus	66	58	8	1st sm	? m	Boer 1976	W not identified. Sat 4th pair
Harpia harpyja	58	52	6	1st sm	9th ?	Amaral and Jorge (pers. comm. 2001)	W tentatively
H. harpyja	58	52	6	?	?	Hoffmann *et al.* (1975)	Z and W not identified
Lophoaetus occipitalis	66-68	56-58	8-10	1st sm	? m	Boer and Sinoo 1984	W not identified probably between 7th and 9th pair
Milvus migrans	66	58	8	2nd sm	? sm	Takagi and Sazaki 1974	W not identified
M. migrans	66	56	10	?	?	Misra and Srivastava 1976	Z and W not identified
Morphnus guianensis	54	48	6	3rd sm	? 19th m	Williams and Benirscke 1976	W tentatively
Necrosyrtes monachus	66	58	8	?	?	Boer and Sinoo 1984	Z and W not identified. Sat 16th pair
Parabuteo unicinctus	68	–	–	? m	?	Schmutz *et al.* 1993	Z tentatively a large m pair. W not identified. Sat 4th pair
Pernis apivorus	66-68	58	8-10	1st ?	? st	Takagi and Sazaki 1974	Z not defined probably sm or st. W not identified
P. apivorus	66-68	58	8-10	1st sm	? sm	Boer and Sinoo 1984	W not identified. Sat mic 29th pair
Pithecophaga jeffery	66	58	8	1st ?	? st	Takagi and Sazaki 1974	Z tentatively sm or st. W not identified
P. jeffery	66	58	8	1st sm	?	Hoffmann *et al.* (1975)	W not identified
P. jeffery	66	58	8	1st sm	?	Boer 1976	Identical
Sarcogyps calvus	66	58	8	1st sm	4° st	Boer 1976	
S. calvus	68	58	10	1st ?	? st	Takagi and Sazaki 1974	Z tentatively sm or st. W not identified
Spizaetus nipalensis	68	60	8	1st ?	? t	Takagi and Sazaki 1974	Identical

Continued

Table 1. Karyotype characterization of Falconiformes.

Species	2n	Mac	Mic	Z	W	Author	Main remarks
Stephanoaetus coronatus	66	56	10	? 1st sm	?	Boer and Sinoo 1984	Z is tentatively. W not identified. Sat 29 th pair
Terathopius ecaudatus	66	58	8	1st sm	?4th st	Bed´Hom *et al.* 1998	W is tentatively 4 th pair. Sat 16th pair
Torgos tracheliotus	66	58	8	1st sm	?	Boer and Sinoo 1984	W not identified. Sat 16th pair
Falconidae							
Falco biarmicus	52	–	–	? ac	? ac	Boer 1975-1976	Z and W not identified
F. chiquera	50	–	–	?	?	Schumutz and Oliphant 1987	Just the diploid number described
F. columbarius	40	20	20	?	?	Longmire *et al.* 1988	Z and W not identified
F. jugger	48	–	–	? 9th ac	? ac	Belterman and Boer1984	Z is tentatively. W small ac
F. mexicanus	48	–	–	?	?	Schumutz and Oliphant 1987	Z and W not identified
F. peregrinus	48	–	–	?	?	Schumutz and Oliphant 1987	Identical
F. rusticolus	52	–	–	?	?	Schumutz and Oliphant 1987	Identical
F. sparverius	80	–	–	7th t	10th sm	Shoffner 1974	Discrepancy between the diploid number
F. sparverius	50	18	32	4th t	10th m	Lucca 1983	(2n = 80 and 2n = 50)
F. tinnunculus	52	–	–	1st ?	6th?	Renzoni and Vegni-Talluri 1966	Discrepancy on the Z and W
F. tinnunculus	50	–	–	9th t	? t	Bulatova and Radjabli 1974	
Milvago chimachina	? 84	–	–	?	?	Belterman and Boer 1984	Diploid number is tentatively. Z and W not identified
Phalcoboenus megalopterus	? 90	–	–	?	?	Belterman and Boer 1990	Identical
Polyborus plancus	84	–	–	? ac	? ac	Boer (1975, 1976)	Z and W not identified
Pandionidae							
Pandion haliaetus	74	52	22	1st sm	7th sm	Kohler and Schaadt 1989	
Sagittariidae							
Sagittarius serpentarius	80	36	44	?	?	Boer (1975, 1976)	Discrepancy between diploid
S. serpentarius	74	–	–	?	?	Hoffmann *et al.* 1975	Number Z and W not identified

(m) Metacentric, (sm) submetacentric, (st) subtelocentric, (ac) acrocentric, (t) telocentric, (Mac) macrocromosome, (Mic) microcromosome, (Sat) Satellites, (–) absence of distinction between mac and mic, (?) not identified, (?t, ?m, ?st) not clearly identified. (*) Unknown species, probabely *A. nisus*.

in groups (Sick 1997). The family Accipitridae is represented by 57 species in South America, 44 only in Brazil (Andrade 1997). The hawks, in its majority, are threatened by environmental destruction and indiscriminate hunt.

This family is characterized for having a high variation in the number of chromosomes, from 54 to 82; however species with 2n = 66 to 68 are the majority. They exhibit a low number of mic, from 6 to 10, except for *Aquila adalberti*, with 24 mic (Padilha *et al.* 1999). The absence of actual mac and the presence of medium and small chromosomes (meta and submetacentrics) are characteristic of this family. In most of the analyzed species, the Z chromosome is shown as one of the largest chromosome, and a pair of chromosomes with satellites is also present.

Genus *Circus* – Three species of this genus were karyotyped from the nine living species: *C. aeruginosus* and *C. pygarpus* which do not possess a defined diploid number due to variation in the number of mic (2n = 70 or 72). In both species the Z chromosome is the largest element. The 2nd pair is the largest chromosome with a satellite. The species *C. cyaneus* shows 2n = 72 chromosomes with 10 mic. The autosomes of this species differ from the others by the fact that the 2nd sattelized pair is smaller (Boer and Sinoo 1984).

Genus *Haliaeetus* – All species of this genus have been karyotyped, with 2n = 66 and 8 mic. The greatest variation between the karyotypes of this genus is in the number of acrocentric chromosomes. The species *H. albicila*, *H. leucogaster, H. leucocephalus, H. leucoryphus, H. vocifer, H. alacanus* and *H. pelagicus* exhibit 9 acrocentric pairs. *H. leucoryphus* and *H.vocifer* show 8 and 6 acrocentrics, respectively. Most species of this genus display the 4th pair sattelized. In this genus, a great discrepancy between some reports exists regarding the Z and W chromosomes in the species *H. albicilla* (Omura 1976, Boer 1976, Boer and Sinoo 1984) and *H. leucocephalus* (Hoffmann *et al.* 1975, Au *et al.* 1975, Boer and Sinoo 1984).

Genus *Accipiter* – Four out of the 33 species of this genus were karyotyped. The species *Accipiter gentilis* have an uncommon karyotype of the family Accipitridae, with a high diploid number (Boer and Sinoo 1984), 2n = 78, being 8 mic and satellites are present in the 4th pair (Boer 1976). Jovanovic and Molosevic (1972) described the same species with 2n = 76 (Lucca 1983). The species *A. badius* was described with 66 chromosomes (Misra and Srivastava 1976, Kaul and Ansari 1975). Renzoni and Vegni-Talluri (1966) analyzed the karyotype of an unidentified species of the genus *Accipiter*, probably *A. nisus*, with 2n = 64.

Genus *Gyps* – Four out of the six living species were karyotyped, all with 2n = 66 and with satellites in the pair 16.

Genus *Aquila* – Five out of the eleven species living of this genus are karyotyped. The group is characterized by the karyotype heterogeneity with 2n = 62 to 82 chromosomes and mic varying from 3 to 12 pairs. In this genus the species *A. adalberti* represents an exception in the family Accipitridae with larger number of mic (12 pairs) and high diploid number (2n = 82). The karyotype of the species *A. adalberti* confirmed his recent separation as the subspecies *A. heliaca*, based on molecular data (Padilha *et al.* 1999).

Genus *Buteo* – Nine out of the 22 living species of this group were karyotyped. All of them have 2n = 68, except for *B. jamaicensis* described by Shoffner (1974) with 2n = 70. All of the species exhibits satellites in the 4th, 5th, 6th or 7th pairs. The karyotypes of the genus *Buteo* differ from the other species of the family Accipitridae, with the presence of the seventh pair, mostly acrocentric. An exception to this is the species *B. platypterus, B. swainsoni* and *B. buteo* which exhibit the chromosome 7 as submetacentric or metacentric (Schumutz 1993). According to Sick (1997), the species *Buteo magnirostris* had a taxonomic change for *Rupornis magnirostris* which differs from real buteos. It has been demonstrated through cytogenetic studies that *R. magnirostris* exhibit 2n = 68 and the 7th pair is acrocentric, showing a karyotype similar to the most of the buteos, what supports the inclusion of this species in the genus *Buteo.*

The only species of the genus *Parabuteo* (*Parabuteo unicinctus*) has 2n = 68 chromosomes, with karyotype similar to most buteos.

Genus *Harpia* and *Morphnus* – The karyotypes of *Hapia harpyja* and *Morphnus guianensis* resemble each other in the morphology of chromosomes and also because the exhibit the lowest diploid number of the family, with 58 and 54 chromosomes, respectively.

Falconidae. They are the hawks and similar birds. They have narrow and sharp-pointed wings least adequate to plane. They are separated from Accipitridae not only by morphological traits, but also by the way they make the dumb, and by biochemical analysis and behavior (Sick 1997).

This family is characterized by the low diploid number (40-52) in the genus *Falco*, explained by Belterman and Boer (1990) as translocations and fusions of the genetic material of mic to larger chromosomes. On the other hand, the species *Mivalgo chimachima, Polyborus plancus* and *Phalcobuenus megalopterus*, have the greatest diploid number of the Order Falconiformes (84-90). They are also characterized by the presence of chromosomes that vary in length from medium to microchromosomes.

Pandionidae. This family has sigle species, *Pandion haliaetus* (Sick 1997). It does not present sexual dimorphism. The karyotype of the osprey *Pandion haliaetus* was studied using banding techniques (2n = 74). Mac, mic, Z and W were clearly identified.

Sagittariidae. This Family is constituted by a single species *Sagittarius serpentarius*. Boer (1976) has described it with 2n = 80, 36 mac and 44 mic, however Hoffmann *et al.* (1975) had related it with 74 chromosomes.

Table 2 shows the four species of Cathartidae analysed up to date.

Cathartidae. There are four species karyotyped from the 7 living species (table 2), with 2n = 80, except for the species *Cathartes aura* (vultures of red head) with 2n = 76.

DISCUSSION AND CONCLUSION

The main characteristics of karyotype of the birds is the great diploid number (about 80), presence of peculiar tiny size microchromosomes (about 32 pairs). The other chromosomes (6 to 8 pairs), so-called macrochromossomes have equivalent size to autosomes of the mammals (figure 1).

Most studies in the family Falconidae was in the gender *Falco* that presents low diploid number, all acrocentrics (40-52). The evolution of karyotype in this group probably has occurred by fusion of mic arising to larger acrocentrics. The other three genders (*Milvago, Polyborus and Phalcoboenus*) exibit a karyotype with great similarity regarding to morphology (all acrocentrics) however the diploid number considerably larger. Concerning to Z and W there is not yet a definition about them.

Table 2. Karyotype characterization of Cathartidae.

Cathartidae	2n	mac	mic	Z	W	Autores	Observation
Cathartes aura	76	–	–	4th sm	9th m	Williams and Benirschke (1976)	
Coragyps atratus	80	–	–	6th m	10th ac	Cornélio *et al.* (pers. comm. 2001)	
Sarcorhampus papa	80	–	–	4th sm	?m	Takagi and Sazaki (1974)	Discrepancy on the Z. The W is not identified
Sarcorhampus papa	80	–	–	5th sm	? m	Boer (1975, 1976)	The diploid number is tentatively
Vultur gryphus	80	–	–	4th sm	?m	Takagi and Sasaki (1974)	
Vultur gryphus	80	–	–	5th sm	? m	Boer (1975, 1976)	The diploid number is tentatively
Vultur gryphus	80	–	–			Williams and Benirschke (1976)	

(m) metacentric, (sm) submetacentric, (st) subtelocentric, (ac) acrocentric, (t) telocentric. The dash (–) in the table means absence of distinction between mac and mic, (?m) not clearly identified.

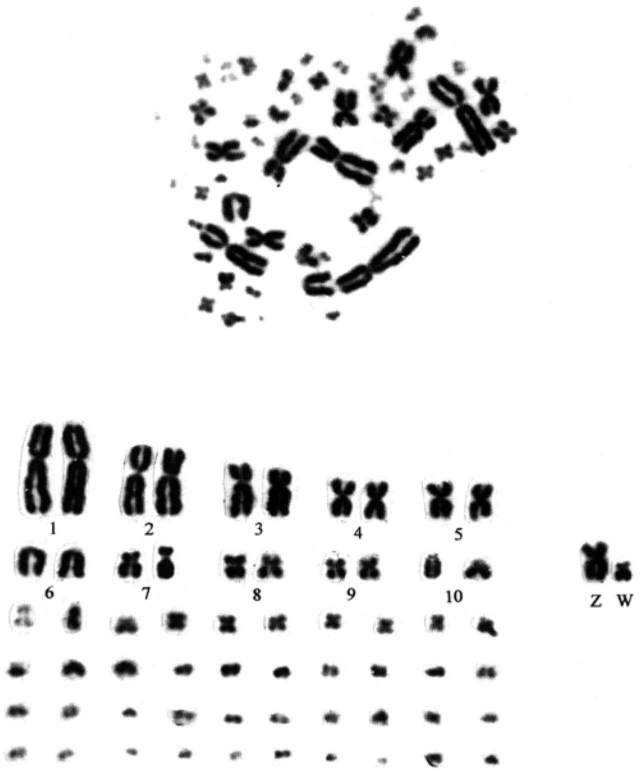

Figure 1. Metaphase and karyotype of *Syrigma sibilatrix* (Ciconiiformes) female 2n = 62.

The evolution of the karyotype in this family still lacks a study of larger number of species. However, hypothesis of a common ancestral with great number of chromosomes should not be discarded.

The chromosomes of the family Accipitridae differentiates from Falconidae, Pandionodaee and Sagittariidae, for exibit a low diploid number of mics, and most species presents 2n = 66 to 68 chromosomes and 8 to 10 mics. The evolution of karyotype in this family should be by fission of macs and fusion of mics arising to telocentrics of small and average size. That would explain the reduction of the diploid number of mics, which is uncommon in the majority of the birds.

The family Cathartidae exibit a typical karyotype of birds with diploid number (about 80), and great number of mics.

By the cytogenetic data, Ligon (1967) suggested affinities between Cathartidae and Ciconiiformes what is confirmed by sequence analysis of mitocondrial DNA (Avise *et al.* 1994). The investigation of karyotype of the species can be of great importance in cytotaxonomy. Thus, european eagle was considered as an unique species, *Aquila heliaca* with two subspecies *A. heliaca heliaca* and *A. heliaca adalberti*. The results of karyotyping in these two species contribute in recent separation of *A. adalberti* and *A. heliaca*, basing in the molecular data (Padilla *et al.* 1999), since that *A. heliaca* (2n = 68 and 10 mic) showed be typical of the Family, while A. adalberti represents an exception (2n = 82 and 24 mic).

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