Punjab Univ. J. Zool., Vol. 32 (2), pp. 229-235, 2017 ISSN 1016-1597(Print)
ISSN2313-8556 (online)

Original Article

The comparison of the Felidae species with karyotype symmetry/asymmetry index (S/A_I)

Halil Erhan Eroğlu

Department of Biology, Faculty of Science and Art, Bozok University, Yozgat, Turkey

Article history
Received: Sep. 21, 2017
Revised: December 11, 2017
Accepted: December 11, 2017

Authors' Contribution
HEE: conceive the idea, execute the research and draft manuscript

Key words
Carnivora
Felidae
Karyotype
Phylogeny
Symmetry/asymmetryindex

Abstract
The S/A_I is a new formula for the measurement of the karyotype symmetry/asymmetry index. Especially in higher animals and humans, it is important to know the values of the karyotype symmetry/asymmetry, so that species, genera, families and orders can be compared. Also the evolutionary relationships of higher organisms can be determined. The symmetry/asymmetry index is applied to the Felidae species. After a comprehensive literature search, karyotype formulae, S/A_I values and karyotype types of 23 species were determined. According to the S/A_I values, a phylogenetic tree was drawn showing relationships among the species.

To cite this article: EROĞLU, H.E., 2017.The comparision of the felidae species with karyotype symmetry/asymmetry index (S/A_1). *Punjab Univ. J. Zool.,* **32**(2): 229-235.

INTRODUCTION

Felidae is placed in the suborder Feliformia in the order Carnivora. There are both domestic and wild species in Felidae. The family consists of at least 36 wild species. They are distributed naturally in almost every area of the world except Antarctica and Australia (Lamberski, 2015). The growth of human population has badly impacted the animal species in many ways such as; deforestation, habitat loss, invasive species, urbanization, industrialization, human-avian negative interactions and climate change (Ali *et al.*, 2016).The number of Felidae taxa decreases with especially human impacts. According to the International Union for the Conservation of Nature Red List, the five species are categorized as Endangered (EN). These species are *Catopuma badia*, *Leopardus jacobita*, *Lynx pardinus*, *Panthera tigris* and *Prionailurus planiceps* (IUCN, 2017). The Felidae is one of the most important members of the world's wildlife. Therefore many taxonomic and cytotaxonomic studies have been reported related felids till now. The chromosome numbers of the taxa are $2n$ = 36 and $2n$ = 38 (Hsu *et al.*, 1963; Wurster–Hill and Gray, 1973; Wurster–Hill and Centerwall, 1982; Suedmeyer *et al.*, 2003; Keawmad *et al.,* 2007; Tanomtong *et al.,* 2008a, 2008b, 2008c, 2009). The chromosomes have been arranged as six groups based on size and centromeric position at the San Juan Conference (Jones, 1965). These groups are given in Table I.

Genetics play a major role in the determination of differences within a population (Tahir *et al.*, 2016). Chromosome number and the chromosome morphology are increasingly used in the taxonomy. Especially the karyotype symmetry/ asymmetry and chromosomal measurements are the most important taxonomic characters together with morphological characters (Eroğlu *et al.*, 2013) for the chromosome numbers of organisms are highly variable. The S/A_I is a new formula for the measurement of the karyotype symmetry/ asymmetry index in higher animals and humans (Eroğlu, 2015). The objective of this study is to

243-PUJZ-71021290/17/0229-0235

*Corresponding author:herhan.eroglu@bozok.edu.tr

determine the S/A_I of the Felidaespecies according to the chromosome types and centromeric position.

Table I: The chromosomal groups and chromosome types of the Felidae karyotypes

Chromosomal groups	Chromosome type
A	Submetacentric
B	Acrocentric*
C	Metacentric
D	Submetacentric
E	Metacentric
F	Telocentric

* Used as subtelocentric in some studies

MATERIAL AND METHODS

The karyotype symmetry/asymmetry index formula (S/A_I)

The formula was reported by Eroğlu (2015) and given below.

S/A_I = (1×M)+(2×SM)+(3×A)+(4×T)/*2n*(1)
or
S/A_I = (1×M)+(2×SM)+(3×ST)+(4×T)/*2n*(2)

In these equations, M = metacentric chromosome number; SM = submetacentric chromosome number; A = acrocentric chromosome number; T = telocentric chromosome number; *2n* = diploid chromosome number.

Eroğlu (2015) reported the new classification model for karyotype symmetry/ asymmetry. There are 5 types of karyotype symmetry/asymmetry in the classification model. They are full symmetric, symmetric, between symmetric and asymmetric, asymmetric and, full asymmetric. A full symmetric karyotype is characterized by completely median chromosomes and the S/A_I value is 1.0000. In contrast, an asymmetric karyotype consists of a complete set of telocentric chromosomes and the S/A_I value is 4.0000 (Eroğlu, 2015).

Sample application of symmetry/asymmetry on species

The karyotypes of Felidae species were used for the example application. The Felidae includes the carnivorous mammals commonly known as cat, panthera and puma. After a comprehensive literature search, karyotype formulae, index values and karyotype types of 23 species have been identified (Table II). Also, Table II contains the scientific name, common name and author of the species. The scientific names were checked from IUCN Red List (IUCN, 2017), because the scientific names of some species can be reported differently in the literature. Snow leopardis an important example. This species is named as both *Panthera uncia* (Johnson *et al.*, 2006) and *Uncia uncia* (Bagchi and Mishra, 2006; Herrin *et al.*, 2012). Jaguarundi is another example. This species is named as both *Herpailurus yagouaroundi* (Agnarsson *et al.*, 2010; Segura *et al.*, 2013) and *Puma yagouaroundi* (Johnson *et al.*, 2006; Eizirik *et al.*, 2008).

According to the index values in Table II, a phylogenetic tree was drawn showing relationships among the species of Felidae (Fig. 1). In Fig. 1 the female karyotype index values of 23 species are located. The male index data are insufficient for two reasons. (i) There is no male in the karyotype studies of *Felis silvestris*, *Felis catus*, *Caracal caracal, Catopuma temminckii*, *Panthera leo*, *Acinonyx jubatus*, *Prionailurus rubiginosus* and *Prionailurus viverrinus*; only the female karyotype has been reported (Wurster–Hill and Gray, 1973; Wurster–Hill and Centerwall, 1982; Tanomtong*et al.*, 2009). (ii) There are males and Y chromosomes in the karyotype studies of *Lynx lynx*, *Panthera tigris*, *Leopardus geoffroyi*, *Leopardus pajeros* and *Herpailurus yagouaroundi*, but the Y chromosome is very small. The type of chromosome was not reported (Wurster–Hill and Gray, 1973; Suedmeyer *et al.*, 2003; Nie*et al.*, 2012).

RESULTS AND DISCUSSION

The ancestral carnivore karyotype is *2n* = 38 (Nash *et al.*, 2008). The predominant diploid number of chromosomes in Felidae is *2n* = 38. Another common chromosome number is *2n* = 36. Although there are 38 chromosomes in many species, there are 36 chromosomes in only four (*Leopardus geoffroyi*, *Leopardus pajeros*, *Leopardus tigrinus* and *Leopardus wiedii*) of the 23 species in the Table II. As an interesting note, these species have the different chromosome numbers and the smallest indexvalues (1.8889) together with *Herpailurus yagouaroundi* (1.8421). The karyotypes of genus *Leopardus* are symmetric types together with

Neofelis, *Acinonyx*, *Prionailurus* and *Herpailurus*. The karyotype type is between symmetric and asymmetric in the other 6 genera and 13 species.

Table II: Karyotype formulae, index values and karyotype type of species

No	Species Scientific name/common name	*2n*	Autosomes and sex chromosomes	S/A$_I$	Karyotype type	References
1	*Felis silvestris* (Schreber, 1777) (Wildcat)	38	10M + 14SM + 8A + 4T X = SM, Y ?*	2.1579 (F)	Between symmetric and asymmetric	Wurster–Hill and Gray, 1973
2	*Felis catus* (Linnaeus, 1758) (Domestic cat)	38	10M + 14SM + 8A + 4T X = SM, Y ?*	2.1579 (F)	Between symmetric and asymmetric	Wurster–Hill and Gray, 1973
3	*Felis chaus* (Guldensteadt, 1776) (Jungle cat)	38	10M + 14SM + 8A + 4T X = SM, Y = SM	2.1579 (F) 2.1579 (M)	Between symmetric and asymmetric	Wurster–Hill and Gray, 1973; Tanomtong*et al.*, 2008c
4	*Lynx lynx* (Linnaeus, 1758) (Eurasian lynx)	38	10M + 14SM + 8A + 4T X = SM, Y minute**	2.1579 (F)	Between symmetric and asymmetric	Nie*et al.*, 2012
5	*Lynx rufus* (Schreber, 1777) (Bobcat)	38	8M + 16SM + 8ST + 4T X = M, Y = ST	2.1579 (F) 2.2105 (M)	Between symmetric and asymmetric	Hsu *et al.*, 1963
6	*Caracal caracal* (Schreber, 1776) (Caracal)	38	10M + 14SM + 8A + 4T X = SM, Y ?*	2.1579 (F)	Between symmetric and asymmetric	Wurster–Hill and Gray, 1973
7	*Catopuma temminckii* (Vigors and Horsfield, 1827) (Asian golden cat)	38	10M + 14SM + 8A + 4T X = SM, Y ?*	2.1579 (F)	Between symmetric and asymmetric	Wurster–Hill and Gray, 1973; Tanomtong*et al.*, 2009
8	*Puma concolor* (Linnaeus, 1771) (Cougar)	38	8M + 14SM + 12ST + 2T X = M, Y = ST	2.1579 (F) 2.2105 (M)	Between symmetric and asymmetric	Hsu *et al.*, 1963
9	*Panthera leo* (Linnaeus, 1758) (Lion)	38	10M + 14SM + 8A + 4T X = SM, Y ?*	2.1579 (F)	Between symmetric and asymmetric	Wurster–Hill and Gray, 1973
10	*Panthera pardus* (Linnaeus, 1758) (Leopard)	38	10M + 14SM + 8A + 4T X = SM, Y = SM	2.1579 (F) 2.1579 (M)	Between symmetric and asymmetric	Tanomtong*et al.*, 2008b
11	*Panthera tigris* (Linnaeus, 1758) (Tiger)	38	10M + 14SM + 8A + 4T X = SM, Y minute**	2.1579 (F)	Between symmetric and asymmetric	Suedmeyer*et al.*, 2003
12	*Panthera uncia* (Schreber, 1775) (Snow leopard)	38	10M + 14SM + 8A + 4T X = SM, Y = SM	2.1579 (F) 2.1579 (M)	Between symmetric and asymmetric	Soderlund*et al.*, 1980

Continue…

No	*Species Scientific name/common name*	2n	Autosomes and sex chromosomes	S/AI	Karyotype type	References
13	*Panthera onca* (Linnaeus, 1758) (Jaguar)	38	10M + 16SM + 6A + 4T X = M, Y = SM	2.0526 (F) 2.0789 (M)	Between symmetric and asymmetric	Ledesma*et al.*, 2004
14	*Neofelis nebulosa* (Griffith, 1821) (Clouded leopard)	38	12M + 14SM + 8A + 2T X = SM, Y = SM	2.0000 (F) 2.2000 (M)	Symmetric	Tanomtong*et al.*, 2008a
15	*Acinonyx jubatus* (Schreber, 1775) (Cheetah)	38	12M + 14SM + 8A + 2T X = SM, Y ?*	2.0000 (F)	Symmetric	Wurster–Hill and Centerwall, 1982
16	*Prionailurus bengalensis* (Kerr, 1792) (Asian leopard cat)	38	12M + 14SM + 8A + 2T X = SM, Y = M	2.0000 (F) 1.9737 (M)	Symmetric	Wurster–Hill and Gray, 1973; Keawmad*et al.*, 2007
17	*Prionailurus rubiginosus* (I. Geoffroy Saint-Hilaire, 1831) (Rusty-spotted cat)	38	12M + 14SM + 8A + 2T X = SM, Y ?*	2.0000 (F)	Symmetric	Wurster–Hill and Centerwall, 1982
18	*Prionailurus viverrinus* (Bennett, 1833) (Fishing cat)	38	12M + 14SM + 8A + 2T X = SM, Y ?*	2.0000 (F)	Symmetric	Wurster–Hill and Gray, 1973; Tanomtong*et al.*, 2009
19	*Leopardus geoffroyi* (d'Orbigny and Gervais, 1844) (Geoffroy's cat)	36	12M + 14SM + 8A X = SM, Y minute**	1.8889 (F)	Symmetric	Wurster–Hill and Gray, 1973
20	*Leoparduspajeros* (Desmarest, 1816) (Pampas cat)	36	12M + 14SM + 8A X = SM, Y minute**	1.8889 (F)	Symmetric	Wurster–Hill and Gray, 1973
21	*Leopardustigrinus* (Schreber, 1775) (Oncilla)	36	12M + 14SM + 8A X = SM, Y = SM	1.8889 (F) 1.8889 (M)	Symmetric	Seibt, 2009
22	*Leoparduswiedii*(Schinz, 1821) (Margay)	36	12M + 14SM + 8A X = SM, Y = SM	1.8889 (F) 1.8889 (M)	Symmetric	Seibt, 2009
23	*Herpailurus yagouaroundi* (É. Geoffroy Saint-Hilaire, 1803) (Jaguarundi)	38	14M + 14SM + 8A X = SM, Y minute**	1.8421 (F)	Symmetric	Wurster–Hill and Gray, 1973

Abbreviations: M, metacentric; SM, submetacentric; A, acrocentric; ST, subtelocentric; T, telocentric; F, female; M, male. * There is no male in the karyotype study.** Could not determine the type of chromosome.

The karyotype symmetry/ asymmetry values of 13 species are 2.0526–2.1579. The species of the same genus are located close in Figure 1. The karyotypes of *Felis*, *Lynx*, *Caracal*, *Catopuma*, *Puma* and *Panthera* are the type between symmetric and asymmetric. Although between symmetric and asymmetric, the index value of *Pantheraonca* is different from other *Panthera* species. The karyotype types and index values are determined the close genus and species. The karyotypes between symmetric and asymmetric of the Figure are evaluated with reported the morphologic and genetic analysis (Kitchener and Rees, 2009). There is no definitive classification and no clear consensus with regard to *Felis* species showing a worldwide distribution. However the genetic relationship of wildcats and domestic cats is similar (IUCN, 2017). Sunquist and Sunquist (2002) reported that there is a relationship in terms of morphological characters between *Felis chaus* and genus *Lynx*. The caracal is close lynx, domestic cats, golden cat and serval (Johnson *et al.*, 2006). Johnson *et al.* (2006) reported that the snow leopard is a species in the genus *Panthera* according to the genetic analysis. It is most closely related to the tiger, having diverged over 2 million years ago (O'Brien and Johnson, 2007). However genetic analysis studies of the Snow Leopard have not yet been done. According to the karyotype symmetry/asymmetry value, the snow leopard is located in the same group with genus *Panthera*.

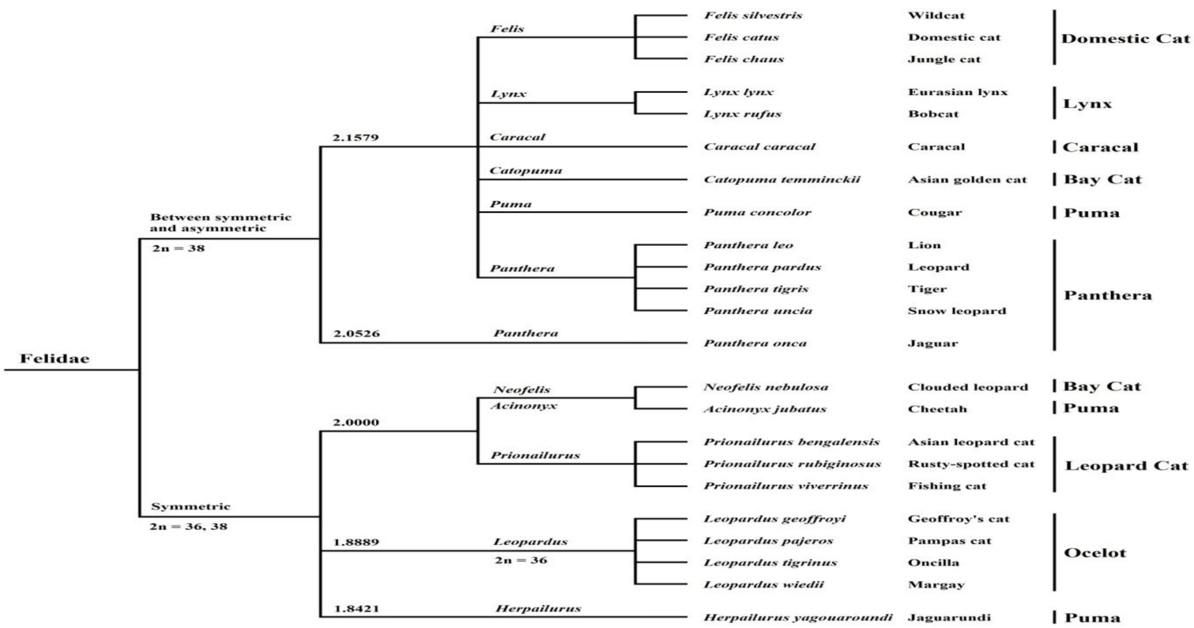

Figure 1: The phylogenetic tree showing relationships of the index values among the species of felids.

The karyotypes of *Neofelis*, *Acinonyx*, *Prionailurus*, *Leopardus* and *Herpailurus* are symmetric types. While the highest index value is 2.000 (*Neofelis*, *Acinonyx* and *Prionailurus*), the lowest index value is 1.8421 (*Herpailurus*) at symmetric type. Genus *Leopardus* has different chromosome number ($2n$ = 36) and different index value (1.8889) from all genus. The symmetric type karyotypes in Figure 1 are evaluated with the morphologic and genetic analysis. It is reported that the cheetah, puma and jaguarundi are close species in the tribe Acinonychini (Johnson and O’Brien, 1997; Bininda–Emonds *et al.*, 1999; Mattern and MacLennan, 2000). There is no relationship among these three species in Figure. The heterogeneous distribution of these species can be explained with some reasons. Different authors may report different results, due to chromosomal polymorphism or changes in chromosome structure. For example, the karyotype formula of *Herpailurus yagouaroundi* (Wurster–Hill and Gray, 1973) used in the present study is different from that described by Novillo–González (2010). The index values from Novillo–González (2010) are 1.7895 (female) and 1.8158 (male). When using these values, the position of *Herpailurus yagouaroundi* will not change in the Figure 1. Both in the present study and in other studies (Eiziriket *al.*, 1998) reported that there is no relationship between genus *Leopardus* and other genus. The yagouaroundi is a species in the genus *Puma* (Johnson *et al.*, 2006; Eizirik *et al.*, 2008), but Agnarsson *et al.* (2010) reported that the Jaguarundi is not a similar species to the Puma. Segura *et al.* (2013) noted that the Cheetah and Puma are similar species, unlike Jaguarundi is quite different from Puma. The IUCN SSC Cat Specialist Group classifies the yagouaroundi in the genus *Herpailurus* according to the phylogenetic uncertainties and morphological and behavioral differences (IUCN, 2017). In Figure 1 the yagouaroundi is located quite far away from genus *Puma*. As a result, the karyotypes of Felidae species were used for the comparison with karyotype symmetry/ asymmetry index. As shown in Fig. 1, SA_I together with the other parameters will contribute to phylogenetic trees of mammals.

REFERENCES

AGNARSSON, I., KUNTNER, M. AND MAY-COLLADO, L.J., 2010.Dogs, cats, and kin: a molecular species–level phylogeny of Carnivora. *Mol. Phylogenet. Evol.*, **54**: 726-745.

ALI, A., ALTAF, M. AND KHAN, M.S.H., 2016. Winter survey of birds at Keti Bunder, district Thatha, Pakistan. *Punjab Univ. J. Zool.*, **31**: 203-208.

BAGCHI, S. AND MISHRA, C., 2006.Living with large carnivores: Predation on livestock by the snow leopard *(Uncia uncia)*. *J. Zool.*, **268**: 217-224.

BININDA-EMONDS, O.R.P., GITTLEMAN, J.L. AND PURVIS, A., 1999.Building large trees by combining phylogenetic information: a complete phylogeny of the extant Carnivora (Mammalia). *Biol. Rev. Camb. Philos. Soc.*, **74**: 143-175.

EIZIRIK, E., BONATTO, S.L., SALZANO, F.M., JOHNSON, W.E., O'BRIEN, S.J., CRAWSHAW JR, P.G., VIE, J.C. AND BROUSSET, D.M., 1998. Phylogeographic patterns and evolution of the mitochondrial DNA control region in two neotropical cats (Mammalia, Felidae). *J. Mol. Evol.*, **47**: 613-624.

EIZIRIK, E., HAAG, T., SANTOS, A.S., SALZANO, F.M., SILVEIRA, L., AZEVEDO, F.C.C. AND FURTADO, M.M., 2008. Jaguar conservation genetics. *Cat News*, **4**: 31-34.

EROĞLU, H.E., ŞIMŞEK, N., KOÇ, M. AND HAMZAOĞLU, E., 2013. Karyotype analysis of some Minuartia L. (Caryophyllaceae) taxa. *Plant Syst. Evol.*, **299**: 67-73.

EROĞLU, H.E., 2015. Which chromosomes are subtelocentric or acrocentric? A new karyotype symmetry/ asymmetry index. *Caryologia*, **68**: 239-245.

HERRIN, K.V., ALLAN, G., BLACK, A., ALIAH, R. AND HOWLETT, C.R., 2012. Stifle osteochondritis dissecans in snow leopards (*Uncia uncia*).*J. Zoo. Wildl. Med.*, **43**: 347-354.

HSU, T.C., REARDEN, H.H. AND LUQUETTE, G.F., 1963. Karyological studies of nine species of Felidae. *Am. Nat.*, **97**: 225-234.

IUCN, 2017. The IUCN Red List of Threatened Species (2017-3). http://www.iucnredlist.org/

JOHNSON, W.E. AND O'BRIEN, S.J., 1997.Phylogenetic reconstruction of the Felidae using 16S rRNA and NADH–5 mitochondrial genes. *J. Mol. Evol.*, **44**: 98-116.

JOHNSON, W.E., EIZIRIK, E., PECON-SLATTERY, J., MURPHY, W.J., ANTUNES, A., TEELING, E. AND O'BRIEN, S.J., 2006.The late Miocene radiation of modern Felidae: a genetic assessment. *Science*, **311**: 73-77.

JONES, T.C., 1965. San Juan Conference on karyotype of Felidae. *Mamm. Chrom. News.*, **15**: 121-122.

KEAWMAD, P., TANOMTONG, A. AND KHUNSOOK, S.A., 2007.Study on karyotype of the Asian leopard cat, *Prionailurus bengalensis* (Carnivora, Felidae) by conventional staining, G-banding and high-resolution technique. *Cytologia*, **72**:101-110.

KITCHENER, A.C. AND REES, E.E., 2009.Modelling the dynamic biogeography of the wildcat: implications for taxonomy and conservation. *J. Zool.*, **279**:144-155.

LAMBERSKI, N., 2015. Felidae. In: *Fowler's zoo and wild animal medicine, volume 8* (ed. R.E. Miller and M. Fowler.), Elsevier Inc., Amsterdam, pp. 467-476.

LEDESMA, M.A., LEDESMA, C.O., SCHIAFFINO, K., RINAS, M.A. AND GUNSKI, R.J., 2004.

Análisiscitogenético de *Pantheraonca* (Felidae: Pantetherinae) de la provincia de Misiones, Argentina. *Mastozool. Neot.*, **11**: 85-90.

MATTERN, M.Y. AND MCLENNAN, D.A., 2000.Phylogeny and speciation of felids. *Cladistics*, **16**:232-253.

NASH, W.G., MENNINGER, J.C., PADILLA-NASH, H.M., STONE, G., PERELMAN, P.L. AND O'BRIEN, S.J., 2008.The ancestral carnivore karyotype (2n = 38) lives today in ringtails.*J. Hered.*, **99**: 241-253.

NIE, W., WANG, J., SU, W,.WANG, D., TANOMTONG, A., PERELMAN, P.L., GRAPHODATSKY, A.S. AND YANG, F., 2012. Chromosomal rearrangements and karyotype evolution in carnivores revealed by chromosome painting. *Heredity*, **108**: 17-27.

NOVILLO-GONZÁLEZ, M., 2010. Determinacióncariotípica e ideograma en tinciónestándar de *Puma yagouaroundi* (É. Geoffory Saint–Hilarie, 1803). *Bol. Téc. Ser. Zool.*, **9**: 65-77.

O'BRIEN, S.J. AND JOHNSON, W.E., 2007.The evolution of cats. *Sci. Am.*, **1**: 68-75.

SEGURA, V., PREVOSTI, F. AND CASSINI, G., 2013. Cranial ontogeny in the *Puma lineage, Puma concolor, Herpailurus yagouaroundi,* and *Acinonyx jubatus* (Carnivora: Felidae): a three-dimensional geometric morphometric approach. *Zool. J. Linn. Soc.*, **169**: 235-250.

SEIBT, C., 2009. Análisecitogenética de*Leopardustigrinus* (Schreiber, 1775) e*Leoparduswiedii* (Schinz, 1821) (Carnivora, Felidae) do Vale do Itajaí, Estado de Santa Catarina, Sul do Brasil. Trabalho de Conclusão de Curso (GraduaçãoemCiênciasBiológicas).FundaçãoUniversidade Regional de Blumenau.Thesis, Santa Catarina, Brasil

SODERLUND, V., GRIPENBERG, U., WAHLBERG, C. AND BLOMQVIST, L., 1980. Chromosome studies in the snow leopard (*Pantherauncia*). In: *International pedigree book of snow leopards* (ed. L. Blomqvist.), Helsinki Zoo, Helsinki, pp. 168-182.

SUEDMEYER, W.K., HOUCK, M.L. AND KREEGER, J., 2003. Klinefelter syndrome (39 XXY) in an adult Siberian tiger (*Panthera tigrisaltaica*). *J. Zoo. Wildl. Med.*, **34**: 96-99.

SUNQUIST, M. AND SUNQUIST, F., 2002. *Wild cats of the world*. University of Chicago Press, Chicago.

TAHIR, D.S., NASIR, W., BUSHRA, S. AND BATOOL, F., 2016. Height trends in the population of Rabwah, district Chiniot, Pakistan and comparison with WHO standards. *Punjab Univ. J. Zool.*, **31**: 131-136.

TANOMTONG, A., KHUNSOOK, S., KEAWMAD, P. AND BUNJONRAT, R., 2008a.Standardized karyotype and idiogram of the clouded leopard, *Neofelisnebulosa* (Carnivora, Felidae) by conventional staining, G-banding and high-resolution technique. *Cytologia*, **73**: 71-80.

TANOMTONG, A., KHUNSOOK, S., KEAWMAD, P. AND PINTONG,K., 2008b.Cytogenetic study of the leopard, *Panthera pardus* (Carnivora, Felidae) by conventional staining, G-banding and high-resolution technique. *Cytologia*, **73**: 81-90.

TANOMTONG, A., KHUNSOOK, S., KEAWMAD, P. AND SIRIPIYASING, P., 2008c. Karyological study of the jungle cat, *Felis chaus* (Carnivora, Felidae) by conventional staining, G-banding and high-resolution technique. *Cytologia*, **73**: 61-70.

TANOMTONG, A., KEAWMAD, P., KHUNSOOK, S. AND KAEWSRI, S., 2009.Cytogenetic studies of fishing cat, *Prionailurus viverrinus* (Bennett 1833) and asiatic golden cat, *Catopuma temminckii* (Vigors and Horsfield 1827) by conventional staining, G-banding and high-resolution techniques. *Cytologia*, **74**: 3-15.

WURSTER-HILL, D.H. AND GRAY, C.W., 1973.Giemsa banding patterns in the chromosomes of twelve species of cats (Felidae). *Cytogenet. Cell Genet.*, **12**: 388-397.

WURSTER-HILL, D.H. AND CENTERWALL, W.R., 1982.The interrelationships of chromosome banding patterns in canids, mustelids, hyena, and felids. *Cytogenet. Cell Genet.*, **34**: 178-192.