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Neotropical primates from the Cologne Zoo in the collections of the Zoologisches Forschungsmuseum Alexander Koenig: noteworthy specimens, taxonomic notes and general considerations

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Abstract. Cologne Zoo was a major place for the captive care of primates of the family Pitheciidae in the second half of the last century. Various species of the genera *Cacajao*, *Chiropotes* and *Pithecia*, which until then had a poor survival record in human care, lived at the Cologne Zoo for years. This offered the unique possibility to gather important information on their biology and care in captivity. Moreover several individuals were featured in a diverse array of technical publications and/or were mentioned in respective texts. However, at that time knowledge on the taxonomy of South American primates was still incomplete. New species and subspecies were named, some of which were kept in the zoo unnoticed. After their death Cologne Zoo donated specimens as vouchers to the Zoologisches Forschungsmuseum Alexander Koenig. We evaluate their species identity in the context of the ongoing debate on the taxonomy of these three genera and also address the potential importance of zoo specimens for the scientific study of taxonomic and biological questions. Furthermore, based on our data the status of *Chiropotes israelita* and *C. sagulatus* as valid species is questioned.

Key words. Primates, Pitheciidae, Neotropics, zoo biology, museum vouchers, taxonomy, identification.

INTRODUCTION

From the very beginning of the existence of zoological museums, menageries and zoos have been an important source of specimens for their collections, especially for exotic species (Jahn 1994; Landsberg 1994; Oppermann 1994). Compared to specimens collected in their natural distribution area (with appropriate documentation) those originating from captivity usually have shortcomings in respect of their informative value, significance as vouchers, and thus also for many research topics typically carried out in zoological museums. Although here is not the place to discuss this in detail, specimens in museum collections that come from a zoo can be important in various aspects. Here we address this issue exemplarily for a few Neotropical primate specimens in the mammal collections of the Zoologisches Forschungsmuseum Alexander Koenig, Bonn (ZFMK) that were donated by the Cologne Zoo after the animals had deceased. The present report is also a supplement to the catalogue of mammalian types and other important voucher specimens in the ZFMK (Hutterer & Peters 2010).

Two recent publications (Pauly 2010; Pagel & Spieß 2011) animated us to write the present report and to put forward some general considerations in this context. Pauly (2010) discussed the species determination of a primate individual that lived in Cologne Zoo between 1974 and 1992 in view of a recently published taxonomic reassessment of the black-headed uacari (*Cacajao melanocephalus*; Boubli et al. 2008). Pagel & Spieß (2011) provided a complete list of all mammal (sub-) species kept at Cologne Zoo since its opening in 1860 with contemporary and current scientific names. By discussing specific examples within a wider perspective we hope to increase awareness both in zoological museums and zoos that the lasting deposition of deceased zoo specimens in a zoological museum and their subsequent scientific curation is the most reasonable 'fate' for zoologically important/interesting specimens of such origin. Only in doing so their significance can be saved and their sustained scientific use warranted. The same issue was addressed by Gippoliti & Bruner (2007) and Gippoliti & Kitchener (2007) in particular.

BACKGROUND

Cologne Zoo was a major place for the captive care of primates of the family Pitheciidae (taxonomy as in Groves 2005) outside their natural range in South America for sev-

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eral decades in the second half of the last century (cf. Hick 1965b, 1966, 1968a, b, 1973, 1974; Hershkovitz 1985, 1987a, b). Various species of the genera *Cacajao*, *Chiropotes* and *Pithecia*, for which relatively little information was available at that time and which until then had a poor survival record in human care, lived at the zoo for years and important information on their biology and care in captivity was gathered and published (Hick 1965b, 1966, 1968a, b). Hershkovitz (1985: 17) named a new subspecies of bearded saki *Chiropotes satanas utahicki* after Ms. Uta Hick (subsequently and correctly, the name was changed to *utahickae*, following the International Code of Zoological Nomenclature; ICZN 1999), the then-curator of primates at Cologne Zoo. Hershkovitz (1985) did so to acknowledge her achievements in the captive care of Pitheciidae and of her major contributions to the knowledge of these primates. Photos of several live individuals of these three genera from Cologne Zoo were presented in technical publications and/or they were mentioned in their text (e.g. Hill 1960; Napier & Napier 1967; Mittermeier & Coimbra-Filho 1981; van Roosmalen et al. 1981; Hershkovitz 1985, 1987 a, b). At that time the taxonomy of *Cacajao*, *Chiropotes* and *Pithecia* was far from being settled (Hershkovitz 1985, 1987 a, b). In the context of the recent 'revival' of the debate on the taxonomy of *Chiropotes* (Boubli 2002; Silva-Jr. & Figueiredo 2002; Bonvicino et al. 2003; Veiga et al. 2008; Ferrari et al. 2013; Silva-Jr. et al. 2013), *Cacajao* (Boubli et al. 2008; Ferrari et al. 2013; Silva-Jr. et al. 2013) and *Pithecia* (Marsh 2004, 2006, 2014), some specimens of these taxa, which the ZFMK received from Cologne Zoo, regain significance. Unfortunately, the ZFMK received only a minor fraction of the individuals that lived in the Cologne Zoo between 1954 and 2005, and for none of these specimens verifiable data as to their geographic origin are available. Therefore statements with respect to agreement/disagreement of their characteristics with those reported for specimens from specific geographic areas are made conditionally. A revision of the genus *Pithecia* (Hershkovitz 1987b) includes a photo of a live individual of this genus from Cologne Zoo. Although it was not given to the ZFMK after its death, it will be addressed in the present report as well to indicate the potential importance of such zoo specimens for the scientific community.

MATERIAL AND METHODS

Our study is based on the voucher specimens of Neotropical primates deposited in the mammal collections of Zoologisches Forschungsmuseum Alexander Koenig (ZFMK_MAM). Species of *Cacajao*, *Chiropotes* and *Pithecia* that originated from Cologne Zoo were analysed in the context of published and unpublished zoo records and photographs made available by the zoo archivists R. Becker and W. Spieß. We are aware of the limited significance of photos in drawing fully substantiated conclusions as to the 'actual' colour in cases where (fur) colour characteristics are diagnostic criteria for the differentiation of taxa and will address this issue where relevant. The same applies to the fading and possible change of colours in long-term museum specimens, especially those on exhibit.

Nomenclature

English common names of taxa used in the present publication are those given in the primate chapter of Mammal Species of the World (Groves 2005). Some names coined in Ferrari et al. (2013) are in conflict with the taxonomic views expressed here. Vernacular names with adjective characterizations of the species' body coat colour are adopted with reservations because they imply that it is a diagnostic character. This can be delusive, though, as will be detailed below.

Molecular methods

DNA extraction, amplification and sequencing

To determine a questionable *Chiropotes* specimen from Cologne Zoo (ZFMK_MAM_2008.244), whose species affiliation could not be clearly determined based on external characters, we extracted DNA from a small piece of skin in the ancient DNA laboratory at York University following the protocol of Haus et al. (2013). We used 0.09 mg sample and incubated it for about 24h in 1.5 ml of a Guanidinium thiocyanate (GuSCN) buffer (5M GuSCN, 25 mM NaCl, 50 mM Tris, 20 mM EDTA, 1% Tween 20, 1% beta-mercaptoethanol), which was modified from Rohland et al. (2004). To purify the DNA we applied a combination of a batch-based silica and a column-based method according to Rohland & Hofreiter (2007) and Rohland et al. (2010). Finally we eluted the DNA in 50 µl TE buffer. To monitor for possible contamination we additionally performed a blank extraction without sample.

To compare our data with already published sequences of other *Chiropotes* taxa we amplified and sequenced a 390 bp long fragment of the cytochrome (cyt) *b* gene. Bonvicino et al. (2003) used a 372 base pair (bp) long fragment of the cyt *b* gene to distinguish between different species of *Chiropotes*. Accordingly, we amplified the same cyt *b* fragment using primers Cytb_fwTGATATGAAAAACCATCGTTG (modified from Bonvicino et al. 2001) and Cytb_rvACCTATAAATGCTGTAGCTAT in a 20 µl mix (3 U AmpliTaq Gold 360 (Applied Biosystems, Germany), 1x reaction buffer, 2 mM $MgCl_2$, 0.25 mM for each dNTP, 0.75 µM for each primer, and 0.1 mg/ml BSA) and following PCR conditions: 94°C for 10 min, followed by 60 cycles of 94°C for 30 s 62°C for 45 s, 72°C 45 s,

and 72°C for 5 min. Due to the length of our amplified product (390 bp) and the usually high degradation of DNA retrieved from museum samples, the possibility that our sequence represents a putative nuclear insertion of mitochondrial DNA (numt) is low. To control for possible contamination with modern DNA, the PCR reaction was conducted with two PCR blanks (HPLC-purified water) in addition to the extraction blank. We ran the PCR product on a 1.5% agarose gel, and purified it with the Qiagen Gel Extraction Kit (Qiagen, Germany) after excision. Subsequently, forward and reverse sequences were run on an ABI 3130*xL* sequencer using the BigDye Terminator Cycle Sequencing Kit (Applied Biosystems, Germany) and respective primers. The *Chiropotes* sequence can be downloaded from GenBank (GenBank accession number: KF989492).

Phylogenetic analysis

To examine phylogenetic relationships we used sequences of six related taxa as outgroups (*Alouatta belzebul* AF289515, *Saimiri sciureus* U53582, *Callicebus personatus* AF289988, *Callicebus donacophilus* FJ85423, *Cacajao melanocephalus* AY226184, *Pithecia irrorata* AY226183) and further included all *Chiropotes* cyt *b* sequences available from GenBank: *Chiropotes albinasus*: KC757393; *C. utahickae*: AY226185, AY226186; *C. israelita*: AY226187-AY226190; *C. chiropotes/sagulatus*: FJ531667). We used the same *Chiropotes* sequences as in Bonvicino et al. (2003), except for *Chiropotes albinasus* (Finstermeier et al. 2013) and the cyt *b* gene of *C. chiropotes*/ *sagulatus* from Rio Trombetas east of Rio Branco (Figueiredo-Ready et al. 2013). All sequences were aligned using the program Mega 5.0 (Tamura et al. 2011). We also used Mega 5.0 to check for putative numts; we translated all sequences into amino acid sequences to detect possible unexpected stop codons in our alignment, which was not the case. Best fit nucleotide substitution models were estimated with jModeltest (Guindon & Gascuel 2003; Posada 2008) and chosen based on the Akaike Information Criterion (AIC). Correspondingly, we used the TrN+G model to reconstruct neighbor-joining (NJ; Mega 5.0, Tamura et al. 2011), maximum-likelihood (ML; Garli 2.0, Zwickl 2006; Paup*4b10, Swofford 1993) and Bayesian (MrBayes 3.1.2, Huelsenbeck et al. 2001, Ronquist & Huelsenbeck 2003) phylogenetic trees. For NJ and ML we used 1000 and 500 bootstrap replications, respectively. We applied 10 million generations for the Bayesian approach and sampled parameters every 10,000 generations; the first 25% of sampled trees and parameters were discarded as burn in. Phylogenetic trees were finally visualized and edited in FigTree1.4.0 (Rambaut 2008).

RESULTS & DISCUSSION

Cacajao Lesson, 1840

After the past argument on whether red and white uacaris are the same or different species (Napier & Napier 1967; Chiarelli 1972) had been provisionally settled (Hershkovitz 1972, 1987a), the genus was generally considered to include two species, the black-headed uacari *Cacajao melanocephalus* (Humboldt, 1811) (not 1812, as in Groves 2005), and the bald uacari *Cacajao calvus* (I. Geoffroy, 1847), the latter encompassing the white and the red form (Barnett & Brandon-Jones 1997; Groves 2001, 2005; Barnett 2005). More recently, based on genetic, morphological and ecological data Boubli et al. (2008) described two new species of black-headed uacari, *Cacajao hosomi* Boubli et al., 2008, and *Cacajao ayresi* Boubli et al., 2008. Moreover, they argued that *ouakary* (Spix, 1823) presents a junior synonym of *melanocephalus* according to the original description of pelage colour of both specimens, the uncertainty of the type locality of Humboldt's specimen of *melanocephalus* and to the now knowledge of the geographical distribution of different pelage patterns in this group. This taxonomic arrangement was not followed by Ferrari et al. (2010) and Silva-Jr. et al. (2013), who proposed to recognise three species *Cacajao calvus*, *C. melanocephalus* and *C. ouakary* (Ferrari et al. 2010), and additionally the newly described species *Cacajao ayresi* Boubli et al., 2008 (Silva-Jr. et al. 2013). However, since no published data exist to support findings of Ferrari, Silva-Jr. and colleagues, for now we will retain the taxonomy of Boubli et al. (2008). Their publication is also relevant for a specimen the ZFMK received from Cologne Zoo, which we will discuss below in more detail.

Cacajao melanocephalus (Humboldt, 1811) sensu lato – Black-headed uacari

According to the annual animal registers of Cologne Zoo (Spieß, pers. comm. 2011; Becker, pers. comm. 2011) two individuals were received in 1958 and one in 1959. All three individuals only lived for a short time and no more specific documentation for these specimens is left. Further, no material was transferred to a zoological museum or another scientific institution after their death. Therefore it is not possible to retroactively assess their actual species identity in the light of the recent publication of Boubli et al. (2008).

Cacajao hosomi Boubli et al. 2008 – Neblina uacari

Material: ZFMK_MAM_2002.032; adult male, received by Cologne Zoo 15.III.1974, † 23.IX.1992, carcass passed to ZFMK on 12.VI.1997; skull, postcranial skeleton.

In 1974 the zoo received another individual of black-headed uacari from Venezuela, a male (Windecker 1975), which lived until 1992, the highest longevity recorded for a black-headed uacari (Weigl 2005). Published photographs of the animal, then identified as *Cacajao melanocephalus*, show this male at various stages of its life (Hick 1974; Mittermeier and Coimbra-Filho 1981; Pauly 2010). In a black-and-white photograph of the adult individual taken in 1985 by Hershkovitz (1987a: 30, fig. 16) it is identified as *Cacajao melanocephalus ouakary* (Spix, 1823). The diagnostic back pelage colouration of this subspecies given by Hershkovitz (1987a: 25) as 'Mid-back pale orange, golden or buffy and contrasted with reddish brown or tawny of lower back and thighs' was not present in this individual, though (cf. colour photographs of it mentioned subsequently), i.e. its subspecies identification is unfounded. Colour photographs taken subsequently, observations of the live animal by one of us (G.P.) and of the carcass revealed no orange tinge on the back at all. It is possible that this mistake slipped in on the occasion of the later subspecies identification based on the black-and-white photograph of Hershkovitz (1987a) as the animal's back seems brightened because of the lighting conditions when the photo was taken and/or the exposure time used.

Only after the publication of Boubli et al. (2008) it became evident that this uacari individual at Cologne Zoo belonged to the newly described species *Cacajao hosomi* Boubli et al., 2008 (Pauly 2010). Therefore, the common name proposed by its authors is used here. Various colour photographs of the live individual in publications by Cologne Zoo (zoo guides, title page of the journal 'Zeitschrift des Kölner Zoo' 26(4), 1983) and in Pauly (2010: 186, Abb. 6) support its identification as *C. hosomi* in showing its diagnostic colouration (Boubli et al. [2008]: fig. 3: 4, 5, p. 737 [description]): ' fur with bright reddish brown mid to lower back, thighs and tail, in contrast to Aracá black uacari specimens that have a much darker general coloration and to *C. melanocephalus* as redefined here, which present a golden brown general appearance.'

Chiropotes Lesson, 1840

Contrary to an earlier statement by Mittermeier & Coimbra-Filho (1981: 74) that '[t]he genus *Chiropotes* … does not present any particular problems', the species status of various taxa of *Chiropotes satanas* (Hoffmannsegg, 1807) sensu lato has been the subject of recurring discussions (Hershkovitz 1985; Rylands et al. 1995; Rylands et al. 2000; Groves 2001, 2005; Silva-Jr. & Figueiredo 2002; Bonvicino et al. 2003; Figueiredo et al. 2006; Veiga et al. 2008; Rylands & Mittermeier 2009; Ferrari et al. 2013; Silva-Jr. et al. 2013). As the diagnostic characteristics (nasal region and upper lip flesh-coloured, with whitish or yellowish hairs [Hershkovitz 1985]) of *Chiropotes albinasus* (I. Geoffroy and Deville, 1848) are clearly defined and unambiguously observable, its status as a distinct species has not been debated (Hill 1960; Chiarelli 1972; Napier 1976; Hershkovitz 1985; Groves 2001, 2005). Based on the taxonomic review of Hershkovitz (1985), in which he also described the new subspecies *Chiropotes satanas utahicki*, all other taxa of the genus *Chiropotes* were likewise classified as subspecies of *Chiropotes satanas* by subsequent authors (e.g. Rylands et al. 1995, 2000; Rowe 1996; Groves 2001).

By contrast, *Chiropotes albinasus, C. satanas*, *C. chiropotes*, and *C. utahickae* were regarded as distinct species by Bonvicino et al. (2003). Moreover, these authors listed *Chiropotes israelita* (Spix, 1823), the brown-backed bearded sakis of northwestern Brazil, north of the Rio Negro and west of the Rio Branco, as an additional species. In the primate chapter of 'Mammal Species of the World' Groves (2005) adopted this view, a procedure not followed by Norconk (2007) who like Hershkovitz (1985) or Groves (2001) listed only two species in the genus, *C. albinasus* and *C. satanas*. Both last-mentioned authors regarded *israelita* as a synonym of *Chiropotes satanas chiropotes*. More recently, Silva-Jr. et al (2013) and Ferrari et al. (2013) supported a five species concept as proposed by Bonvicino et al. (2003), but they considered the taxon west of the Rio Branco to be *Chiropotes chiropotes* and that east of the river to be *Chiropotes sagulatus* (Traill, 1821). There are no published data so far that clearly underpin the taxonomic conclusions of Ferrari et al. (2013) and Silva-Jr. et al. (2013) preventing us from drawing any final conclusions on the taxonomy of *Chiropotes.*

Bonvicino et al. (2003) explicated in detail why they consider the genus *Chiropotes* to include five distinct species and why the name *israelita* ought to be applied to the Rio Negro population, as also done by Boubli & de Lima (2009). The remarks of Bonvicino et al. (2003) in this latter context contain two material misapprehensions, though: 1. There is no substantial evidence that Spix's (1823: 11–12) original description of *Brachyurus israelita* (first in Latin and then in French) refers to two different specimens as claimed by Bonvicino et al. (2003: 132). The specification of the type locality in the Latin text as 'Habitat ad Rio-Negro' (p. 11) and that – as opposed to this – at the end of the more detailed French text (p. 12) as 'On trouve ce singe vers le Pérou dans les forêts de Japura rivière laterale de Solimöens' must have been an error in the case of the latter statement since there is not a single record known for the occurrence of bearded sakis south-west of the Rio Negro (Hershkovitz 1985; Veiga et al. 2008; Ferrari et al. 2013; Silva-Jr. et al. 2013). Therefore we argue that this information cannot be taken as evidence of the existence of two different specimens on which the respective descriptions were based. Indeed, there is also no clear difference between characters de-

tailed in the Latin text of Spix's (1823) original description of *Brachyurus israelita* and those described in the subsequent French text as claimed by Bonvicino et al. (2003). Furthermore, there is no indication for the (past) existence of a second specimen of bearded saki in the Spix collection (M. Hiermeier, ZSM, pers. comm. 2012). 2. Contrary to the assumption/statement of Bonvicino et al. (2003: 132) that the holotype specimen of *Brachyurus israelita* Spix, 1823 is lost, it is preserved in the collection of the Zoologische Staatssammlung München (ZSM) (Kraft 1983); pertinent information as well as its colour photo are available on the internet (see http:// www.zsm.mwn.de/mam/ptypes.htm, and http://www.zsm.mwn.de/mam/i/Brachyurus_israelita_34_D.jpg). Additional colour photos of the holotype specimen of *Brachyurus israelita* Spix, 1823, kindly provided by M. Hiermeier (cf. Fig. 1), show the typical coat colouration of *Chiropotes satanas chiropotes* as given in the key to the geographic forms of *Chiropotes* (Hershkovitz 1985: 13): 'Head, nape, lower arms, and legs blackish, sharply contrasted with orange of dorsum'.

Moreover, the statement by Bonvicino et al. (2003: 131) that '... Hershkovitz [1985] commented that there was no assigned *C. s. chiropotes* holotype or type locality. ' is formulated inappropriately and mistakable. In listing the type locality of *Simia chiropotes* as 'Said to be the upper Rio Orinoco south of the cataracts, Amazonas, Venezuela' according to Humboldt (1811) and in stating that the type is not preserved (i.e. was lost during its transport from South America to Europe), as already reported by Humboldt (1811), Hershkovitz (1985: 16) rendered the issue correctly. Thus, all available evidence supports the perception that *Chiropotes israelita* (Spix, 1823) is a junior synonym of *Chiropotes chiropotes* (Humboldt, 1811).

Shortly before the study by Bonvicino et al. (2003) was published Silva-Jr. & Figueiredo (2002) had reintroduced the name *Chiropotes sagulatus* (Traill, 1821), originally described from Guiana, as a distinct species. Bonvicino et al. (2003: 132) thereupon argued 'Silva-Jr. and Figueiredo (2002) recently proposed species status for *C. sagulatus*; however, they did not provide sufficient data to justify that taxonomic arrangement. ' Therefore Bonvicino et al. (2003) did not list *sagulatus* as a distinct species of *Chiropotes*. Husson (1957, 1978), in previous specific surveys of the mammal fauna of Guiana, had treated *sagulatus* as a synonym of *Chiropotes satanas chiropotes*, like most other authors of later pertinent technical publications (e.g. Hershkovitz 1985; Groves, 2001, 2005). Bonvicino et al. (2003) rightly pointed out that no substantial data – in effect no specific data at all – was presented by Silva-Jr. & Figueiredo (2002) in the published abstract of their contribution to the Xth Congresso Brasileiro de Primatologia and that therefore this abstract cannot be the proper basis for the resurrection of *sagulatus* as a distinct species. On the other hand, this does not rule out that the study of Silva-Jr. & Figueiredo (2002) underlying their congress contribution yielded data supporting such a view. In return, it does not have any relevance in supporting the view of Bonvicino et al. (2003) that the name *israelita* ought to be applied to the *Chiropotes* population west of the Rio Branco and north of the Rio Negro, and that it represents a distinct species.

Unlike Groves (2005) who adopted the concept of Bonvicino et al. (2003) in its entirety, a more recent review of the diversity of New World primates (Rylands & Mittermeier 2009: 40-41) pointed out that the cause of such discrepancies may be '… a possible confusion concerning the correct names.' Indeed, the distribution map published by Bonvicino et al. (2003: 125, fig. 1) shows localities of *Chiropotes satanas chiropotes* only considerably east of the Rio Branco in Brazil. All localities west of it and north of the Rio Negro are entered as *Chiropotes* sp. The locality of a 'possibly new taxon of *Chiropotes*' reported by Boubli (2002) and previously mentioned by Rylands et al. (2000) is still further northwest, close to the southernmost border of Venezuela. All these locality records are within the distribution range of *Chiropotes satanas chiropotes* as given by Hershkovitz (1985: 2, Fig. 1). In applying the name *israelita* to their 'new form of *Chiropotes*' the taxonomic views of Bonvicino et al. (2003) were apparently put forward without observance of the statement of the type locality ('On les trouve dans les vastes déserts de l'Alto-Orinoco, au sud et à l'est des Cataractes.') in Humboldt's (1811: 313) original description of *Simia chiropotes*. It is usually rendered as upper Rio Orinoco, south of the cataracts, Amazonas State, Venezuela (Cabrera 1961; Hershkovitz 1985; Groves 2001, 2005). Incidentally, the *Chiropotes* sp. individual from the lower Rio Marauiá, Amazonas, Brazil, reported and pictured in a colour photograph by Boubli (2002: fig. 3) clearly shows the typical coat colouration of *Chiropotes satanas chiropotes* as listed by Hershkovitz (1985: 13). The conclusion of Bonvicino et al. (2003: 129) that of the four *Chiropotes* taxa they studied the western two differ in dorsal coat colour (tawny-olive to buffy-brown in the westernmost versus orange or ochraceus in the eastern taxon) obviously contravenes that by Hershkovitz (1985: 17): 'All types of chromatic variation are fully intergrading and may occur in the same population. Geographic variation is not evident.' Of the original descriptions of the relevant *Chiropotes* taxa named, only the one of *israelita* (Spix 1823: 11–12) is sufficiently detailed (in its subsequent French version) to provide pertinent information in this respect: 'Les poils du dos sont très épais, peu longs, d'un roux jaunâtre, ceux des côtés d'un fauve plus foncé'. This clearly indicates a 'reddish-yellowish' hue of the back fur (as still detectable in the type specimen, see Fig. 1). Aside from the question whether *israelita* is a synonym of *chiropotes* there can be no doubt that its type locality places *israelita* into the westernmost form of bearded saki. So,



Fig. 1–3. **1.** (Left) Back view of the mounted type specimen of *Brachyurus israelita* Spix, 1823 in the Zoologische Staaatssammlung München ZSM (Photo: M. Hiermeier, ZSM). **2.** (Center) Back view of mounted adult male *Chiropotes chiropotes* specimen ZFMK_MAM_66.001 (Photo: M. Weigt). **3.** (Right) Tanned skin of *Chiropotes* sp. specimen ZFMK_MAM_2008.244 (Photo: M. Weigt).

a reddish/orange tinge of the dorsal pelage colour may also be present in this population.

Gregory (2011) who kindly provided colour photos of living bearded sakis from Suriname opines that these animals have 'a much brighter orange dorsum' (visible in the photos) than the more western populations of bearded sakis (pers. comm. 2012); she uses the name *Chiropotes sagulatus* for them (Gregory 2011; Gregory & Norconk 2011). Concerning dorsal pelage colour the original description of *Simia sagulatus*, the Guianan bearded saki, states 'back well clothed with an ochry-coloured fur' (Traill 1821: 167), and in more detail (p. 168) 'The colour is brightest on the shoulders, where it is intermediate between wood-brown and yellowish-brown; and, on the back and sides, passes into the latter.' Traill (1821: 169) expressly states that these characteristics equally apply to five more specimens from the same geographical area (Demerara/Demerary in today's Guayana; originally a Dutch colonization area, later occupied by the British) as the holotype. Husson (1978: 210) describes the colour of the back pelage of nine *Chiropotes satanas chiropotes* specimens from Suriname as '… a dull brownish colour varying from yellowish umber to mummy brown.' which suggests quite some variation in this (distinctive?) character even among individuals from within a restricted portion of the distribution range of this taxon. Apart from colour fading likely to have occurred in museum specimens, these discrepancies may be due to differences in the relative coverage of the whole distribution range of *Chiropotes satanas* sensu lato surveyed and in over-all sample size and that for specific populations in these studies. Thereby the study of Hershkovitz (1985) is based on more specimens from a wider geographic range than any other published study so far.

Rylands & Mittermeier (2009: 41) stated that 'Silva-Jr. and Figueiredo (2002) argue that the form west of the Rio Branco is correctly *C. chiropotes*, according to its type locality, and the form to the east of the Rio Branco, extending through the states of Pará and Amapá, and into the Guianas (Guyana, Suriname, French Guiana) is *C. sagulatus* (Traill, 1821) from Demerara.'. However, they provided more detailed information on the issue than the published abstract by Silva-Jr. & Figueiredo (2002) actually contains. It may be assumed that it was obtained from these latter authors personally. The same is true of the statement in Veiga et al. (2008): '… *Chiropotes sagulatus* Traill, 1821, the latter representing the eastern form of *C. chiropotes*, which occurs to the east of the rio Branco, in Brazil, Suriname and the Guianas '. Unfortunately there are also no relevant data presented in the most recent publications of Silva-Jr. et al. (2013) and Ferrari et al. (2013) , which might support their taxonomic arrangement. Yet, to the best of our knowledge no 'proper' pertinent study has been published so far presenting evidence

that *C. chiropotes* and *C. sagulatus* represent different species, or that they possess different distributional ranges. The name has recently been used, though, for bearded sakis from Suriname (e.g. Gregory & Norconk 2011) and the state of Pará (north of the Amazon), Brazil (e.g. Oliveira et al. 2009). The karyotypic differences between three *Chiropotes* taxa (not including *C. s. satanas* and *C. albinasus*) reported by Bonvicino et al. (2003), which in their view strongly indicate their status as distinct species, may actually support this concept. They found that the Rio Branco is the parting line of the two karyotypically different *Chiropotes* forms north of the Amazon.

There is little data on fur colouration in juvenile individuals (Hershkovitz 1985); so it is not possible to evaluate whether, to which extent and how this characteristic changes during ontogeny in the respective taxa. Anyhow, an in-depth comprehensive revision based on as large a number of specimens as possible from the entire distributional range, integrating classical morphological and modern genetic methods, in combination with all other evidence, is still required to clarify the taxonomy of the various forms of *Chiropotes satanas* sensu lato.

Chiropotes albinasus (I. Geoffroy & Deville, 1848) – White-nosed saki

Material: Three of five females of *Chiropotes albinasus* that lived at Cologne Zoo are in the ZFMK mammal collection. ZFMK_MAM_71.97b: adult female, † 1971, received from Cologne Zoo 1971; skull, flat skin. This is probably the individual the zoo received as a juvenile in 1968 (Windecker 1969). ZFMK_MAM_81.1815: adult female, † 17.VI.1981, received from Cologne Zoo VI-II.1981; skull, postcranial skeleton, flat skin. This is the individual 'Bella", the mother of four of the *Chiropotes* hybrids born at the zoo. This female arrived at the zoo in 1965 (Hick 1965a) and thus attained an age of >16 years. Most of the photos published of *Chiropotes albinasus* from Cologne Zoo (with its hybrid offspring) show this individual. ZFMK_MAM_89.480: adult female, † 01.IX.1988, received from Cologne Zoo IX.1989; skull, postcranial skeleton, flat skin. This is the female with the Zoo house name 'Bianca' which arrived there 08.X.1970 (Windecker 1971) and is the individual with the maximal longevity (> 18 years) attained by this species in any zoo (Weigl 2005). During the time this female lived at the zoo it gave birth to two offspring. Its estimated age of about 20 years noted by Weigl (2005) would imply that it was roughly 2 years old when it arrived at the zoo.

The first documented individual of *Chiropotes albinasus* in the care of Cologne Zoo, an adult female, arrived in 1965 (Hick 1965a; Pagel & Spieß 2011). In 1968 the zoo received a juvenile female (Windecker 1969, another female which arrived in 1966 only survived for a few months) and in 1970 another two juvenile females (Windecker 1971). Apart from popular print products of the Cologne Zoo with photos (black-and-white and colour) of several of these individuals (e.g. Hick 1968a: 35, 1973; Windecker 1969; front pages of the journal 'Freunde des Kölner Zoo' 9[3], 1966 and 11[2], 1968), photos of them also appeared in technical publications (Hick 1968b: Fig. 31; Roosmalen et al. 1981: 420; Hershkovitz 1985: 26).

Two of the white-nosed saki females gave birth successfully to hybrid young: a male out of a mating of *Chiropotes albinasus* female x *Chiropotes chiropotes* male in 1968 (Hick 1968a) and five more hybrids (2 males, 3 females) out of matings of *Chiropotes albinasus* female x *Chiropotes satanas* male in 1973 (2), 1975, 1976, and 1979; in 1978 one female had a miscarriage after such a mating. Like the first hybrid born in 1968 (Hick 1968a), some of the others born later were figured in photos, usually together with their mother (Kullmann 1976). The first hybrid born in 1968 is mentioned and also figured in technical publications (Roosmalen et al. 1981: 420; Hershkovitz 1985: 26). Hershkovitz's statement is not correct; the sire of this hybrid offspring was a *Chiropotes chiropotes* male (Becker, pers. comm. 2014). Four of the hybrid offspring were born by the female 'Bella', two by the female 'Bianca', and the same *Chiropotes satanas* male was the sire of 4 of the 5 hybrids born since 1973. A female hybrid born in 1975 lived at Cologne Zoo for more than 26 years (Weigl 2005). Occasionally one of these juvenile hybrids was wrongly labelled as *Chiropotes albinasus*, resp. no mention was made that the juvenile is a hybrid, e.g. in the publications of Kullmann (1976) and Mittermeier & Coimbra-Filho (1981: Fig. 53, p. 86) or in a figure legend (Zeitschrift des Kölner Zoo 17 (1), p. 1). The same is probably true for a colour photo of an adult 'female white-nosed saki (*Chiropotes albinasus*)' in Pauly (2010: 182, Abb. 1). If the date when the photo was taken (24.V.1990 as stated in the figure legend) is correct, this individual is a hybrid of *Chiropotes albinasus* female x *Chiropotes satanas* male because according to the zoo archives the last female white-nosed saki at Cologne Zoo died in 1988. In 1990 only two female hybrids were living at the zoo (Spieß, pers. comm. 2011; Becker, per. comm. 2012). Unfortunately, none of the altogether six hybrids born at the zoo was given to the ZFMK, another zoological museum or a scientific institute after their death.

Chiropotes chiropotes (Humboldt, 1811) – Red-backed bearded saki

Material: ZFMK_MAM_66.001; adult male, † 04.01.1966, received from Cologne Zoo 1966; skull, taxidermy mount (Fig. 2).

This individual arrived at the zoo as a juvenile in 1961 and was originally registered as a female which was later corrected. It is mentioned in Anonymous (1962) and

shown at different ages in two black-and-white photographs, the earlier taken in May 1962, the later in September 1963 (Anonymous 1963: 87). Comparing both photographs the pronounced growth of the typical thick split tuft of hair on the head and that of the eponymous beard during the time span of about one year becomes obvious. Photos of *Chiropotes chiropotes* individuals kept at Cologne Zoo and published from 1964 onwards by zoo employees (Hick 1965a, 1966) very likely show other individuals of this species living there, as two more individuals arrived at the zoo in 1964 and 1965.

Description of the specimen (Fig. 2): As the specimen was on exhibit in the museum for a few decades, a general fading of its pelage colouration is likely to have occurred, especially in respect of possible yellowish/reddish hues that may have been present in the living animal. Following statements are made under this qualification. There is a marked contrast between the homogeneous light buffy ochre of the back and the dark brown to black colouration of the fur of the head, extremities and the tail. The colouration of the back extends into the flanks and the arms and thighs. On the upper arms pelage colour gradually changes into blackish brown of the more distal portion of the arms, on the upper side interspersed with lighter hairs. This colour change is more abrupt on the proximal part of the thighs. The backs of hands and feet are covered by brown hair. The venter is black. The fur colour on the head (with the beard and the split tuft of hair on top of it), nape and tail is basically black. The change in fur colour from the trunk to these body regions is abrupt.

Taking into account the unsettled taxonomic issues addressed earlier, the actual species identity of all relevant specimens that lived at Cologne Zoo cannot be verified resp. refuted retroactively, even more for those for which no photos are available and/or no material was given to the ZFMK or to another scientific institution after the animals' death. In addition, it is difficult to determine the species identity of juvenile bearded saki individuals retrospectively on the basis of photographic portraits with adequate certainty. Therefore we use the scientific names here under which they are registered in the zoo archives. According to these (Spieß, pers. comm. 2011; Becker, pers. comm. 2011) Cologne Zoo received four specimens of *Chiropotes chiropotes* between 1961 and 1977, three males and one individual of unknown sex which died a few months after its arrival whereas the other individuals all lived at the zoo for several years. One of these males (house name 'Ringo'), which arrived at the zoo as a juvenile in 1964, was the father of the first hybrid saki (mother *Chiropotes albinasus*) born at Cologne Zoo in 1968 (Hick 1968a). This male, given to a private animal husbandry in 1982, was figured in Hick (1968a: 38 & 39), van Roosmalen et al. (1981: 421; fig. 2); photos in Napier and Napier (1967: 121, plate 33) and Hershkovitz (1985: 14, fig. 8) probably also show it. Unfortunately, no remains of this individual are conserved in a scientific institution.

Chiropotes sp. – Bearded saki

Material: ZFMK_MAM_2008.244; adult male, † 1991, received from Cologne Zoo 5.IX.1991; skull, postcranial skeleton, flat skin (Fig. 3). Animal received by Cologne Zoo as a present from the defunct Dierenpark (zoo) Wassenaar, Netherlands, in 1978 and originally listed as *Chiropotes satanas chiropotes* in the zoo archives (Kullmann 1979). A colour photo of this individual alive, taken 24.V.1990 and referred to as *Chiropotes chiropotes*, was published by Pauly (2010: 183, Abb. 2). However, the dor-

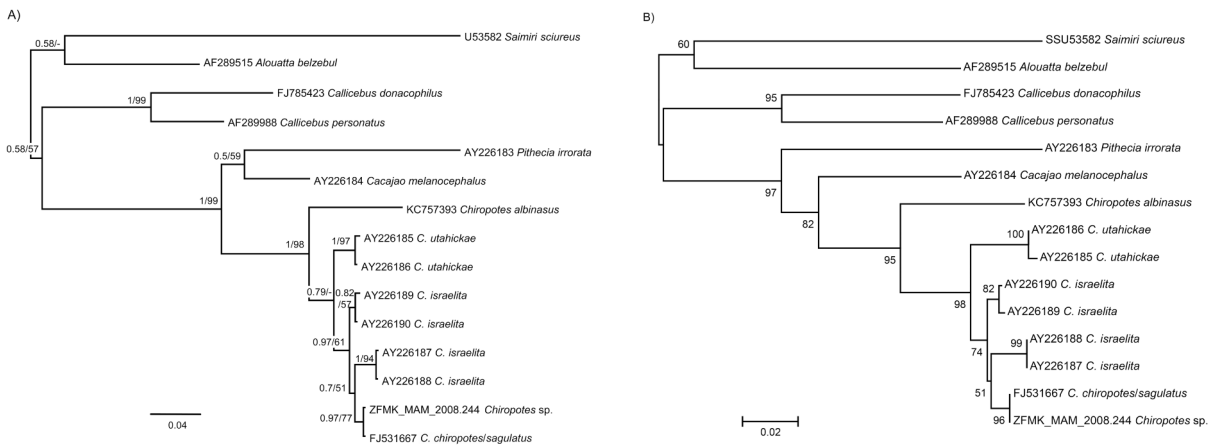

Fig. 4. Cytochrome *b* phylogeny of the genus *Chiropotes*. A, Posterior probabilities of the Bayesian approach and bootstrap support values of the maximum-likelihood analysis before and after the slash, respectively. B, Phylogenetic relationships and bootstrap support values based on the neighbor-joining approach. Sample IDs correspond to GenBank accession numbers.

sum of this specimen is light buffy to ochre contrasting the dark brown to blackish colour of the outer side of the upper and lower arms, legs, the fur of the head, and the outer side of the thighs. According to Hershkovitz (1985:13) characters of *chiropotes* and *utahickae* are described as 'Dorsum dominantly orange or pale brown to dark brown; outer side of upper arms and proximal part of outer side of thighs orange to dark brown, not blackish' and as 'Head, nape, lower arms, and legs blackish, sharply contrasted with orange of dorsum' in *chiropotes* vs. 'Head, nape, lower arms, and legs pale brown to dark brown and not sharply contrasted with brown of dorsum' in *utahickae*. Based on these external characters and the fact that no geographical origin is known, the species designation of the ZFMK specimen remains questionable. The results of our genetic study of this specimen is shown in Fig. 4. Except of relationships among *Cacajao*, *Pithecia* and *Chiropotes*, which cannot be correctly resolved based on the short cyt *b* fragment using the ML and Bayesian approaches, we obtained the same pitheciine phylogeny as Bonvicino et al. (2003). *Chiropotes albinasus* forms a basal taxon to all remaining *Chiropotes* members and *C. utahickae* forms a sister clade to *C. israelita*. However, irrespective of the phylogenetic approach and of uncertainties among basal pitheciine relationships, our sample from the ZFMK clusters together with the *C. chiropotes*/*sagulatus* sample from east of the Rio Branco causing paraphyletic relationships between *C. israelita* (sensu Bonvicino et al. 2003; also Darc et al. 2011) and *C. chiropotes*/*sagulatus* west and east of the Rio Branco, respectively (Fig. 4).

Chiropotes satanas (Hoffmannsegg, 1807) – Black bearded saki

Material: ZFMK_MAM_60.108; juvenile male, † 11.IV.1960, received from Cologne Zoo 20.VII.1960; taxidermy mount. The animal died at the zoo shortly after its arrival. A photo each of a juvenile individual of *Chiropotes satanas* from Cologne Zoo published in Hill (1960) and in Anonymous (1963) may be this animal but it may also show one of the other two juveniles of this species which the zoo received in 1954 resp. 1959, each of each survived for a short time only.

Description of the specimen: With the exception of the back which is covered with relatively long chestnut brown hair, the hair-coat of all other body parts is black. ZFMK_MAM_81.1819; adult male, † 04.VII.1981, received from Cologne Zoo VIII.1981; skull, skeleton, taxidermy mount. When this individual (house name 'Nicky') arrived at the zoo as a young juvenile on 26.VI.1970 it was originally registered as a female but this was corrected in the archives in 1971. Its black-and-white portrait taken soon after arrival was published (Windecker 1971: 4). No other photo published later of a bearded saki from Cologne Zoo or one kept in the zoo archives can be related to this individual with certainty; therefore its characters as an adult are not documented. It is the father of all hybrids of *Chiropotes satanas* and *Chiropotes albinasus* females born at Cologne Zoo between 1973 and 1978 (see above).

Description of specimen ZFMK_MAM_81.1819 (Fig. 5): As the specimen was on exhibit in the Museum for nearly two decades, the same general qualifications as for the *Chiropotes chiropotes* specimen ZFMK_MAM_66.001 apply in respect of an assessment of the coat colour of this individual. Moreover, it lost hair in the tanning process, especially on the back. This is likely to result in a changed perception of the colour of the back coat as compared to that of a living animal. Generally, there is no sharp contrast in coat colouration between different parts of the body. The colour of the head (with beard and split tuft of hair on top of it), nape, tail, extremities and backs of hands and feet is black as is that of the venter. On the back, shoulders, upper arms and thighs a lighter dull brown shines through the blackish hue, dominating the general colour impression of the back.

Whereas the last in-depth revision of the genus *Chiropotes* by Hershkovitz (1985) listed two subspecies of *Chiropotes satanas* in addition to the nominate form, the current notion is that *Chiropotes satanas* represents a distinct species with no subspecies (Silva-Jr. & Figueiredo 2002; Bonvicino et al. 2003; Groves 2005; Figueiredo et al. 2006; Rylands & Mittermeier 2009; Ferrari et al. 2013;

Fig. 5. Back view of mounted adult male *Chiropotes satanas* specimen ZFMK_MAM_ 81.1819. The hair on the back is thinner than in the living animal (Photo: M. Weigt).

Silva-Jr. et al. 2013). As detailed above, the two remaining former subspecies and an additional one are accorded species rank each as well. We adopt this concept here. As in the case of *Chiropotes chiropotes* we have to rely on the species determinations in the Cologne Zoo archives for those individuals for which no detailed documentation and/or collection material is available, appreciating the fact that these may have been wrong, especially in young juveniles which are difficult to identify as to species in *Chiropotes satanas* sensu lato. Between 1954 and 1970 Cologne Zoo received 4 individuals of *Chiropotes satanas*, all as young juveniles: two males, one female and one individual the sex of which was not established with certainty and which died soon after its arrival. Only the male individual received by the zoo in 1970 lived to adulthood.

Concluding taxonomical remarks on *Chiropotes* specimens in the ZFMK collection

***Chiropotes chiropotes* ZFMK_MAM_66.001:** We consider this species identification to be well-founded. In consideration of the qualifications of such an appraisal the available evidence still documents an extensive similarity of this ZFMK specimen with the type specimen of *Brachyurus israelita* Spix, 1823 and the specimen referred to as *Chiropotes* cf. *satanas* in a colour photograph in Boubli (2002), both of which are synonyms of *Chiropotes chiropotes*.

***Chiropotes* sp. ZFMK_MAM_2008.244:** Our cyt *b* phylogeny shows a close genetic relationship of this specimen to an individual from Rio Trombetas east of the Rio Branco, i.e. within the distribution of *C. sagulatus* according to Ferrari et al. (2013) and Silva-Jr. et al. (2013). However, their description of *sagulatus* is 'Dorsum and upper limbs … are orange to reddish-brown. Head, nape, lower arms and legs are blackish' (Ferrari et al. 2013: 481), which does not fit to the general appearance of the ZFMK specimen. Despite the small amount of samples analysed, the unknown origin of the ZFMK specimen and of the low support values in reconstructed phylogenies, our data allow us to draw some preliminary conclusions. Our results support the existence of different colour variants within groups of closely related individuals and possibly within the same geographic region, here within the *Chiropotes* form occurring east of Rio Branco. This finding corresponds to the statement by Hershkovitz (1985) that no clear geographic separation between different pelage variants exists. Furthermore, our molecular results indicate that most probably both *israelita* and *sagulatus* do not deserve species status and may represent synonyms of *Chiropotes chiropotes*. Therefore, we highly recommend further genetic studies on diverse *Chiropotes* samples from a variety of geographical areas, including *Chiropotes satanas* to clarify the phylogeny of the genus, and most importantly, to allow final taxonomic conclusions.

***Chiropotes satanas* ZFMK_MAM_60.108:** There is very little reliable information on coat colour of juvenile individuals of *Chiropotes satanas* sensu lato. To the best of our knowledge no such data have been published for juvenile *Chiropotes satanas* sensu stricto; based on the relevant details provided for *Chiropotes chiropotes* (Hershkovitz 1985: 17) it seems possible that this ZFMK individual actually represents the latter species.

***Chiropotes satanas* ZFMK_MAM_81.1819:** In spite of the reservations with respect to the assessment of the fur colouration of the living animal, in light of the condition of this taxidermy mount we consider this species identification to be well-founded.

***Pithecia* Desmarest, 1804**

The first revision of the genus *Pithecia* by Hershkovitz (1979) recognized four species, a concept also followed by Buchanan et al. (1981). The current taxonomy of this genus as adopted by Groves (2001, 2005), Rylands & Mittermeier (2009) and Ferrari et al. (2013) is based on the earlier and more detailed revision by Hershkovitz (1987b) in which he recognized five species. However, there is also evidence that a further revision of this genus is required (Marsh 2004, 2006, pers. comm. 2012). In her final revision (Marsh 2014) 16 species are recognized.

***Pithecia mittermeieri* Marsh, 2014 – Mittermeier's Tapajós saki**

Hershkovitz (1987b: 427, Fig. 25) figured an adult male *Pithecia irrorata irrorata* (house name Sascha) from Cologne Zoo. Since its arrival at Cologne Zoo in 1966 until its death on 20.I.1981 it was registered as *Pithecia monachus* in the Zoo archives. Hick (1968b) published its black-and-white portrait and later on another photograph/portrait in colour (Hick 1973) under this name. The best photographic documentations of this individual referred to as *Pithecia monachus* are two black-and-white photographs and a colour photo in Tylinek and Berger (1984) and colour photos in several official guides of Cologne Zoo in the 1970es (Fig. 6). According to Weigl (2005), who listed this animal under the scientific name *Pithecia irrorata irrorata*, it reached the highest longevity known of any individual of this species in human care (more than 14 years and 7 months). In the recent revision of the genus this individual is identified as *Pithecia mittermeieri* sp. nov. (Marsh 2014: 5, Table 2). Regrettably no zoological material of it is preserved in the ZFMK, another zoological museum or a scientific institution.

Fig. 6–7. 6. (Left) Adult male *Pithecia mittermeieri* Marsh, 2014 in the Zoo Cologne; this animal may be the one shown in figure 7 (Photo: P. De Prins, reproduced from 'Wegweiser durch den Zoo Köln', c. 1976). **7.** (Right) Adult male specimen of *Pithecia aequatorialis* (lying individual on the left) (ZFMK_MAM_81.1818) in the Zoo Cologne (1973 or later); the individual sitting on the right may represent *Pithecia mittermeieri*, possibly the same animal as shown in figure 6 (Photo: G. Peters).

***Pithecia aequatorialis* Hershkovitz, 1987 – Equatorial saki**

Material: ZFMK_MAM_81.1818; adult male, † 1981 (?), received from Cologne Zoo VIII.1981; skull, postcranial skeleton, flat skin (Fig. 7, the living animal).

This specimen has the diagnostic pelage characteristics of *Pithecia aequatorialis*. It was received from Cologne Zoo as *Pithecia monachus* and classified as such in the ZFMK collection then. After the publication of the second revision of the genus *Pithecia* by Hershkovitz (1987b) the species determination of this specimen was reassessed and subsequently classified as *Pithecia aequatorialis*. This identification was confirmed by L. Marsh (pers. comm. 2011) on the basis of several colour photos of the ZFMK skin. Unfortunately, there is no photograph of the living animal or written record in the Cologne Zoo archives which can be unambiguously assigned to this individual (Spieß & Becker, pers. comm. 2011). However, a photograph by R. Mittermeier (in Marsh 2014: fig. 49) may show this individual.

Several individuals classified as *Pithecia monachus* lived at Cologne Zoo during the second half of the 1970's. Apart from the male individual of *Pithecia mittermeieri* mentioned above (and then wrongly classified as *P. monachus* at the zoo) none of the black-and-white photographs of '*Pithecia monachus*' individuals archived at the zoo shows an animal with the typical pelage characteristics of *Pithecia aequatorialis* males. In the five year period from 1977 until 1981 four individuals classified as *P. monachus* died at Cologne Zoo, one of which was the misidentified *P. mittermeieri* (Becker, pers. comm. 2012). The only photograph on file of a '*Pithecia monachus*' individual at the zoo which died between 1977 and 1981 (other than the *P.mittermeieri* male mentioned) is one taken in 1969 of a '*monachus*' that died in 1979. So, there is definitely no 'trace' of the ZFMK *Pithecia aequatorialis* adult male in the Cologne Zoo archives. A colour slide (Fig. 7) taken by one of us (G.P.) shows this individual alive (or another male of this species if there were more than one in the zoo at that time) and therefore is additional proof of its species identification (confirmed by L. Marsh, pers. comm. 2013, based on this slide). The photo can be roughly dated to the time period 1973 to 1977 because it was taken in the Lemur House of Cologne Zoo which opened in 1973, and on written entries in the animal records at the zoo.

This species was described as new to science after all *Pithecia* individuals (other than *P. pithecia*) at Cologne Zoo had been dead already for several years. In his earlier revision of the genus Hershkovitz (1979: 15, fig. 5) had figured a study skin of an adult male *Pithecia* as *P. monachus*, only to revise his taxonomic assessment of the same individual in the later revision and identify it as the new species *Pithecia aequatorialis* (Hershkovitz 1987b: 408, fig. 16). Diagnostic characteristics differentiating males of *aequatorialis* from male *monachus* are a ruff of orange hair and a horseshoe-like area of relatively short white dense hair around the sparsely haired facial disk in the former species (L. Marsh, pers. comm. 2011, Marsh 2014).

CONCLUDING REMARKS

Our paper is based on only a few Neotropical primate specimens from Cologne Zoo in the ZFMK mammal collection. Nevertheless, it provides an example of the value and of the conclusions that can be drawn from collections obtained from zoos and housed at zoological museums (or similar scientific institutions). The ZFMK received also primate specimens from other zoos, such as Duisburg and Frankfurt (see Appendix), which may be equally important. In the first place it shows that even today zoos may have scientifically important specimens in their care, sometimes unnoticed by the scientific community. To avoid such cases as far as possible it is desirable that zoos and zoological museums intensify their cooperation (cf. Gippoliti & Kitchener 2007). It is important that zoos are aware of the potential scientific importance of specimens in their care and try to gather and archive all pertinent information during the lifetime of such specimens: geographical origin (if known or if it can be traced back), colour photos at different ages, body mass, measurements, reproductive history, ISIS reports, CITES papers (if applicable), references of publications dealing with the specimen (if the specimen is mentioned/figured in a publication), or other. This is, however, more than usually recorded. It may be useful to agree on a uniform database, so that information from different zoos can be more easily combined.

Taking into account relevant veterinary and other legal regulations the most reasonable procedure would be that zoos pass such specimens immediately after their demise to a zoological museum. The condition of the specimen should thereby allow all standard museum procedures, e.g., collection of tissue and hair samples, preparation of skin and skeleton or any other method of conservation. Appropriate storage of such samples should allow subsequent genetic analyses. Furthermore, copies of all documentation of that specimen compiled at the zoo during the animal's lifetime should be provided, including veterinary treatments. A scientifically important specimen in/from a zoo can only maintain its 'voucher status' and its significance posthumously as a subject for later studies, if its remains are housed and curated properly in a zoological museum or another appropriate scientific institution in the long run. This ought to be in the genuine interest of the respective zoo and definitely is so for the scientific community, especially if specimens have been referred to in the scientific literature like several *Chiropotes* individuals from Cologne Zoo in the ZFMK mammal collection, which are listed here. The *Pithecia mittermeieri* individual discussed above exemplifies the deplorable ultimate loss of information and research options if this procedure is not followed after an animal's death. On the other hand, the specimen of *Pithecia aequatorialis* in the ZFMK collection detailed before illustrates that steady contact and information exchange between zoos and zoological museums may have resulted in the timely awareness of the significance of this individual, especially in the context of a taxonomical revision of the genus *Pithecia*.

Zoological museums with their taxonomic expertise ought to interact with (neighbouring) zoos regularly, including the offer to provide advice on matters of taxonomy if requested. Once a specimen that died in a zoo is given to a museum, the museum has the responsibility of its proper long-term documentation and curation, preserving as much and diverse material of the animal as possible to enable diverse kinds of (future) studies. This includes the repeated verification of a specimen's species identity on the basis of the most recent pertinent publications to ensure its scientific significance. If a specimen is affected by a taxonomical change, either during its lifetime or posthumously, this information ought to be circulated among the institutions involved.

Both zoos and zoological museums can only benefit from a closer cooperation as a means to increase taxonomic expertise and awareness of taxonomical problems as well as the proper long-term conservation of scientifically interesting and important zoological specimens.

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APPENDIX

List of Pitheciidae in the collections of ZFMK Bonn.

Cacajao calvus. ZFMK_MAM_66.612 (Cologne Zoo 1966); ZFMK_MAM_81.1816 (Cologne Zoo 1981); ZFMK_MAM_2001_147 (Cologne Zoo 1993); ZFMK_MAM_2012.427 (Cologne Zoo 2008).

Cacajao hosomi. ZFMK_MAM_2002.032 (Venezuela/Cologne Zoo 1992).

Chiropotes albinasus. ZFMK_MAM_71.097 (Cologne Zoo 1971); ZFMK_MAM_81.1815 (Cologne Zoo 1981); ZFMK_MAM_89.480 (Cologne Zoo 1989).

Chiropotes chiropotes. ZFMK_MAM_66.001 (Brazil/ Cologne Zoo 1961). ZFMK_MAM_74.155 (Duisburg Zoo 1974).

Chiropotes satanas. ZFMK_MAM_60.108 (Cologne Zoo 1960); ZFMK_MAM_ 81.1819 (Cologne Zoo 1981).

***Chiropotes* sp**. ZFMK_MAM_2008.244 (Cologne Zoo).

Pithecia aequatorialis. ZFMK_MAM_81.1818, male (Peru/ Cologne Zoo 1981).

Pithecia inusta. ZFMK_MAM_ 87.730, female (Peru, Panguana 1973; Hutterer et al. 1995).

Pithecia pithecia. ZFMK_MAM_71.097, male (Cologne Zoo 1971); ZFMK_MAM_2012.009, male (Frankfurt Zoo 2008).

***Pithecia* sp.** ZFMK_MAM_75.108, female (Duisburg Zoo 1975).

