Research article

Conservation of Colombian primates: an analysis of published research

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Abstract

In Colombia, there are approximately 27-31 primate species, including at least five endemic ones and a high proportion of threatened species. Differences in these primates' distribution, abundance, ecology, and charisma, among many other things, have led to large variation in the amount and nature of investigations performed on the different species. Basic information on each native primate species is necessary to build adequate conservation plans; therefore, knowledge of the quantity and type of information available on each species can be helpful to identify possible research gaps. Based on publications from 1900 to 2008 on 25 primate species present in Colombia, we evaluated primate research in this country in terms of quantity, type, and topics of investigation. Additionally, we comparatively assessed the role of Colombian primatology within all scientific production on primate species present in this country. Our analyses indicate that in Colombia, primate research has developed mainly in the field-work area, with studies focused primarily on ecology and behavior. Investigations of topics such as karyology, anatomy, and physiology are very limited, and molecular biology is understudied compared to research on this subject in other countries. Captive studies are also comparatively scarce. Our analyses also suggest that those species distributed in areas where research stations are located have been the focus of a greater proportion of investigations. A few study sites (PNN La Macarena, Rio Peneya Station, PNN Tinigua, and Caparu Biological Station) stand out as primate research "hot-spots" within Colombia; however, field work in these stations is frequently jeopardized by the constant threat imposed by revolutionary armed forces in the rural and forested parts of Colombia.

***Key words**:* Colombian Primatology, primate conservation, research-types and research-topics

Resumen

En Colombia actualmente existen aproximadamente 27-31 especies de primates, incluyendo al menos cinco endémicas y una alta proporción de especies amenazadas. Las diferencias en la distribución, abundancia, ecología y carisma de estas especies, han derivado en una alta variación en la cantidad y naturaleza de las investigaciones realizadas sobre éstas. Para poder construir planes de conservación adecuados, se necesita información básica sobre cada especie nativa; por lo tanto, conocimiento sobre la cantidad y tipo de información disponible sobre cada especie, puede ser útil para identificar posibles vacíos en las investigaciones. Basados en publicaciones de 1900 a 2008 sobre 25 especies de primates presentes en Colombia, evaluamos la investigación primatológica en este país en términos de cantidad, tipo y temas de investigación. Adicionalmente, evaluamos comparativamente el rol de la primatología colombiana dentro de las producciones científicas sobre las especies presentes en Colombia. Nuestros análisis indican que en Colombia, la primatología se ha desarrollado principalmente en el área de los estudios de campo, con investigaciones centradas principalmente en ecología y comportamiento. Los estudios sobre temas tales como cariología, anatomía y fisiología son muy pocos, y la biología molecular está sub-estudiada en comparación con las investigaciones sobre este tema en otros países. Los estudios en cautiverio también son comparativamente escasos. Nuestros análisis también sugieren que, aquellas especies distribuidas en áreas donde se encuentran localizadas estaciones de campo, han sido objeto de una mayor proporción de estudios. Unas pocas estaciones (PNN La Macarena, Estación del Rio Peneya, PNN Tinigua, y Estación Biológica Caparú) sobresalen como principales centros de investigación dentro de Colombia; sin embargo, el trabajo de campo en estas estaciones se ve frecuentemente amenazado por deforestación y la presencia de grupos al margen de la ley en las áreas rurales.

Palabras Claves: Primatología colombiana, conservación de primates, tipos de investigación y temas de investigación

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Introduction

Colombia is a mega-diverse country, ranking within the top 12 countries in terms of species diversity [1, 2]. Colombia has been reported to be the country with the highest number of bird and amphibian species, the second of plants, third of reptiles and fifth of mammals [2]. For many groups of organisms, this diversity has been associated with ecosystem diversity and topographic variability [3], as well as the confluence of several bio-geographical units, allowing the presence of Central American, Amazonian, and Andean biota. Regarding neotropical primates, Colombian forests are inhabited by a large number of species as well [4]. In the third edition of *Mammal Species of the World* (2006), Colin Groves listed 31 species for Colombia [5], while in *Primates of Colombia* (2004) [6] Thomas Defler listed 27 species. The variation in the number of species recorded for the country is mainly caused by taxonomic uncertainties, differences in taxonomic considerations between authors, or species that have still not been officially acknowledged as such (e. g., *Callicebus caquetensis*; Defler et al. in preparation). It is likely that this number will continue to change as we keep learning more about the primate populations present in Colombia, in terms of both their ecology and genetics. In addition to its primate species richness, we recognize at least five endemic species including *Aotus brumbacki*, *Saguinus leucopus, S. oedipus, Callicebus ornatus* and *C. caquetensis* in Colombia. However, most primate species found in Colombia have globally declining populations [7], and many are vulnerable to extinction as a consequence of habitat loss and hunting, among other causes [6]. Since most primate populations in the country face several threats, it has become necessary to implement conservation strategies to maintain native populations. The history of primate research in Colombia has resulted in a widely variable assemblage of information available today on each of the native species, and thus conservation efforts may be restrained in cases where little or no information is available. Most of the species present in Colombia are also distributed in other countries, allowing for the integration of information between national and foreign research; however, knowledge of native populations and endemic species is crucial to assess the conservation status of primates within the country.

Factors such as species distribution, population size, species ecology and behavior, researcher accessibility to locations within species distribution, and availability of research centers, among many others, can influence in different ways the numbers, types, and topics of studies performed on the different primate species. For instance, it is expected that abundant and more widely distributed species will tend to be more studied due to practical reasons. Species attractiveness and charisma can also influence a researcher's interests, while differences in species' ecology and behavior can encourage research on certain topics over others. On the other hand, the type of studies carried out is expected to vary according to the accessibility to field stations, laboratories, and/or captive centers; and it may be also influenced by the continuity of established lines of investigation that focus on certain types and topics of study, and on particular locations or research centers (e.g., major projects within specific study sites). In Colombia, in particular, there is an

additional and determinant factor that greatly alters research activity: the presence of revolutionary armed forces and intense drug-trafficking activities in several rural areas, which impose several limitations on field studies. All these factors relating to the amount and kind of information available on the different primate species present leads to fragmented knowledge, and in many cases it also leads to misconceptions of the conservation status of species and populations. Critically endangered or endemic species such as *Ateles hybridus* and *Saguinus leucopus* still lack basic biological information, exposing important gaps in Colombian primatological studies. Awareness of the present situation in Colombia regarding primate research is, therefore, essential to orient future studies towards the species, types, and topics of investigation that have received little or no attention. Through high-quality research, basic information on the biology and habitat needs of the different primate species should be attainable for the implementation of proper conservation strategies.

In this paper we evaluate primate research in Colombia in terms of number, type, and topics of study, based on publications from 1900 to 2008 on 25 native primate species. Our principal aim was to assess generally the patterns and tendencies that have driven the development of primate research in Colombia, by examining how many and what type of studies have been undertaken on each species; and by establishing which have been the central topics of these investigations. Finally, we evaluate the relative contribution of Colombian research to the information available on the different primate species found in Colombia, compared to the contribution of foreign publications.

Methods

Database

We generated a bibliographic database composed of a sample of publications (n=3149) from 1900 to 2008, on 25 primate species occurring in Colombia. The compilation of publications was composed of articles, books and book chapters (official publications), and theses, reports, and abstracts ("gray" literature) obtained from different sources including: (1) international online databases such as Web of Science and Google Scholar, (2) open journal web sites, (3) personal archives, and (4) specialized databases (i.e., Primate Lit, University of Wisconsin: http://primatelit.library.wisc.edu/). Complete bibliographic information is available from the authors upon request. We also gathered information on the dates and locations (political and geographical regions) where field studies were carried out in Colombia.

Publications reporting research on more than one species were assigned to all the Colombian native species included in the document. *Aotus griseimembra*, *A. zonalis*, *Lagothrix lugens, and Callicebus caquetensis* were not included in the database as separate species since they had not been officially recognized as such until recently, and therefore any studies about them were carried out under another species identity; *A. griseimembra* and *A. zonalis* were formerly identified as *A. lemurinus* [2]. *L. lugens* was traditionally considered to be a sub-species of *L. lagothricha* [8] and since 2001 a species status was proposed [5]; however, the status is still matter of debate. Recent molecular and caryological studies have shown high genetic exchange between populations of *lugens* and *lagothricha*, suggesting that the subspecies status is appropriate [9].

Classification

Each publication was assigned to one of four types of research: review, laboratory, captivity, and field studies. Review studies were defined as research based mainly on previously published information; laboratory studies were defined as any type of research with an approach carried out in laboratory settings or requiring special equipment during data gathering in captivity; captive studies were defined as research carried out in zoos, research centers, or confinement facilities; and field studies were defined as any type of

research carried out at field locations within the natural distribution area of the studied species. We encountered a few cases where the primary type of research was not evident (e.g., a laboratory phase and a field phase of similar proportions within a single investigation), therefore these publications were classified as mixed-type study.

Each publication was assigned to one of seven possible research topics: (1) anatomy and physiology, (2) behavior and social organization, (3) conservation and monkey-human interactions, (4) ecology and natural history, (5) evolution and systematic, (6) geographic distribution, and (7) parasitology and veterinary (including studies when primates are study subjects in medical tests). Publications addressing different topics were assigned to each of the corresponding topics. Additionally, each publication was assigned a country of origin according to (1) the country in which the field work was carried out in the case of field studies, or (2) the author(s) affiliations at the time of the study, in the case if laboratory, captivity, or review papers.

Analyses

Publications were organized based on the four different types of research (review, captivity, laboratory, and field studies), and in order to compare the relative proportion of each of the different types of publications, we used association G tests. Since a single publication could be assigned to several species and more than one research topic, these were treated as several records according to the different number of included species and assigned topics (n=4396). A record was therefore defined as a single entry for a particular publication. A single publication could thus generate many entries depending on the number of species and topics included. For example, a publication titled "Activity patterns and diet of woolly and spider monkeys" would be assigned to four records (two topics: behavior and ecology, for each species).

In order to compare the number of field study records between Colombia and other countries we generated an expected number of studies for each primate species. This number was calculated assuming that the proportion of studies in the country should be proportional to the percentage of the species' geographic range corresponding to Colombian territory. Maps for the distribution of the 25 primate species were obtained online form the IUCN Red List web page [7]. For each species, the percentage of the species' total area of distribution within Colombian territory was calculated as a proportion of total distribution area using the image processing software ImageJ (2008) (**Appendix 1**).

Table 1. Types of literature registered for Colombia and other countries. Comparison between the number of studies and records in the form of articles, book chapters, books, theses, abstracts and reports on 25 primate species found in Colombia.

	COLOMBIA		OTHER COUNTRIES	
	Studies	Records	Studies	Records
Articles	195	300	1772	2184
Book chapters	42	131	230	442
Books	3	174	14	109
Theses	62	83	84	105
Abstracts	90	119	625	695
Reports	17	26	24	28
TOTAL	409	833	2749	3563

Results

General description

Overall, a total of 4,396 records were registered out of 3,157 primate publications. For Colombia 833 records were obtained from 409 publications, compared to 3,563 records out of 2,748 publications for other countries. The most common type of research in Colombia is field studies, which represent almost 80% of the total research carried out in this country. Even though we found a higher number of field studies in other countries, the percentage represented by this type of research in Colombia almost doubles its percentage for other countries. In contrast, very few captivity and laboratory studies were found for Colombia compared to other countries, with more than four and three times fewer publications in these areas respectively (Fig. 1).

A significant association was found between Colombia and other countries in terms of types of publications (official publications = articles, book chapters and books; and "gray" literature, which includes abstracts, theses, and reports) (n=3157, G=35.2, 1df, p<0.0001). From the 409 registered publications for Colombia, 169 corresponded to "gray" literature and 240 to official publications, compared to 733 and 2,016 respectively for other countries out of a total of 2,749. This means that primate research in Colombia has less tendency to be formally published (1.4 publications per registered "gray" literature research project) compared to foreign research (2.8 publications per registered "gray" literature research project) (Table 1). When considering officially published records only for Colombia, we found that *Lagothrix lagothricha* (78 records) has been the most studied species in Colombia, followed by *Alouatta seniculus* (68) and *Cebus apella* (56) (Fig. 2). In contrast, *Callimico goeldii*, *Saguinus geoffroyi* (11), *Ateles geoffroyi, Cebus capucinus* and *Aotus brumbacki* (12) have been the least studied species in the country. On the other hand, in other countries *Saguinus oedipus* (337), *Cebus apella* (299) and *Alouatta palliata* (283) have been the most studied species, while *Saguinus leucopus* (8), *Aotus brumbacki* (10), *Saguinus inustus*, *Ateles hybridus* (14) have been the least studied (Fig. 2).

Our evaluation on the topics addressed by primate studies in Colombia indicates that ecology and natural history (200 records) has been the preferred topic, while parasitology and veterinary (8) appears as the least explored topic in national research. In contrast, foreign research shows a tendency towards behavioral and social organization-oriented studies (870), whereas geographical distribution and conservation and monkey-human interaction studies (113 and 116 records, respectively) have been addressed less often (**Appendix 2**).

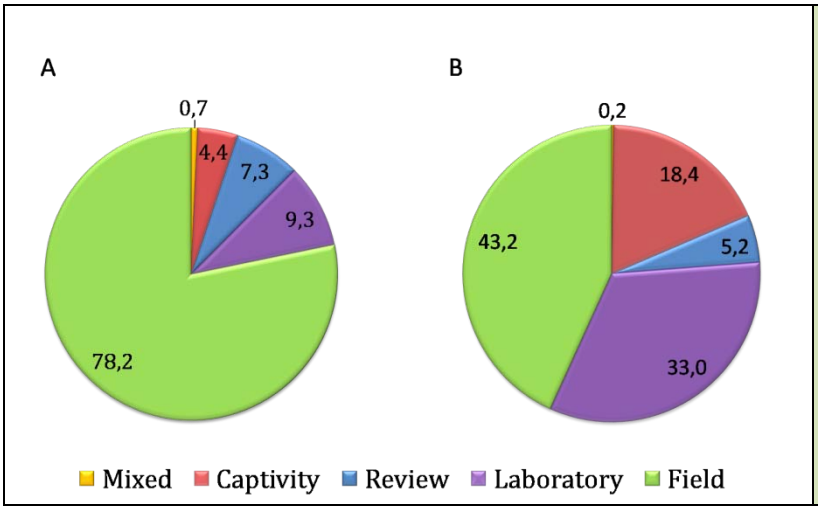


Fig. 1. Comparison between the percentages of review, laboratory, captivity, field and mixed-type of publications on 25 primate species found (A) in Colombia (N=409) and (B) other countries (N=2,748).

Review studies

Altogether, reviews added up to a total of 173 publications and 766 records. Of the 729 officially published records, 247 corresponded to publications from authors affiliated to Colombian institutions, while 482 were from authors affiliated to institutions elsewhere. The number of records out of foreign publications corresponded mainly to American (273), followed by Brazilian (71), and British (51) affiliations. Reviews have been focused primarily on primate ecology and natural history (231), followed by conservation and monkey-human interactions (153) as the second preferred topic of study. Parasitology and veterinary was the least reviewed topic with less than 10 registered records. Even though review studies usually include several species, *Cebus apella* (49 records) appears to be the best reviewed species over the years, both in Colombia and other countries, whereas *Ateles hybridus* (12), *Saguinus leucopus* (14) and *Aotus brumbacki* (15) have been the least reviewed ones. It is important to underline that similar reviews by a given author were included only once for analysis (e.g., Primates de Colombia, 2003; and Primates of Colombia; 2004 by Thomas R. Defler [6]).

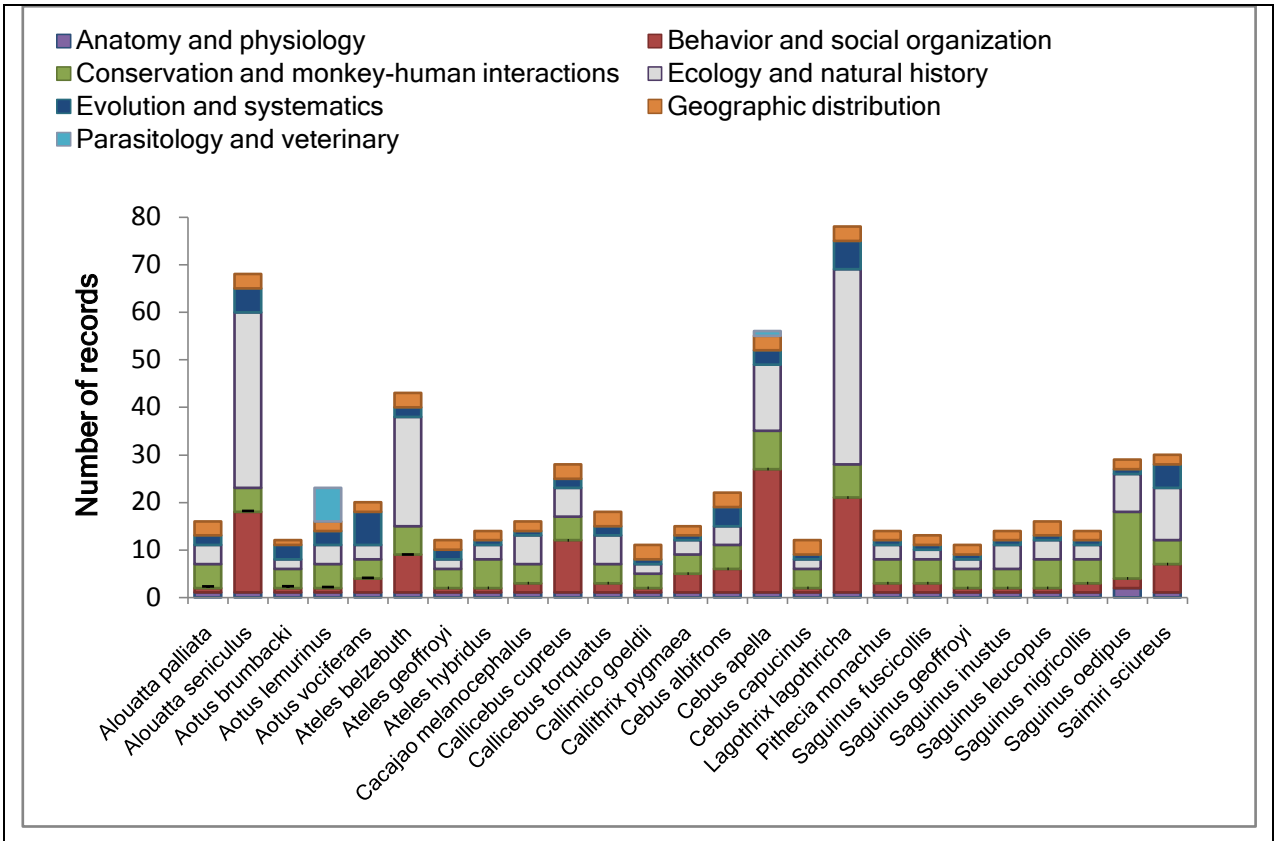


Fig. 2. Comparison of the published study topics for different primate species in Colombia.

Laboratory and captive studies

The laboratory and captive research sample consisted of a total of 1,687 records obtained from 1,471 publications. Of these, 1,304 were from official publications and the majority was found to be focused on behavior and social organization (426 records), followed by anatomy and physiology (325), evolution and systematics (245), and parasitology and veterinary (192). *Saguinus oedipus* (312) has been by far the most studied species among this type of research studies, with *Cebus apella* (163) and *Saguinus fuscicollis* (119) following next. Contrastingly, *Saguinus inustus*, *S. leucopus,* and *Pithecia monachus* (less than 10 records each) are the least studied species through this type of research. Additionally, we observed that *Aotus* and *Saguinus* are the preferred genera for medical testing and experimentation.

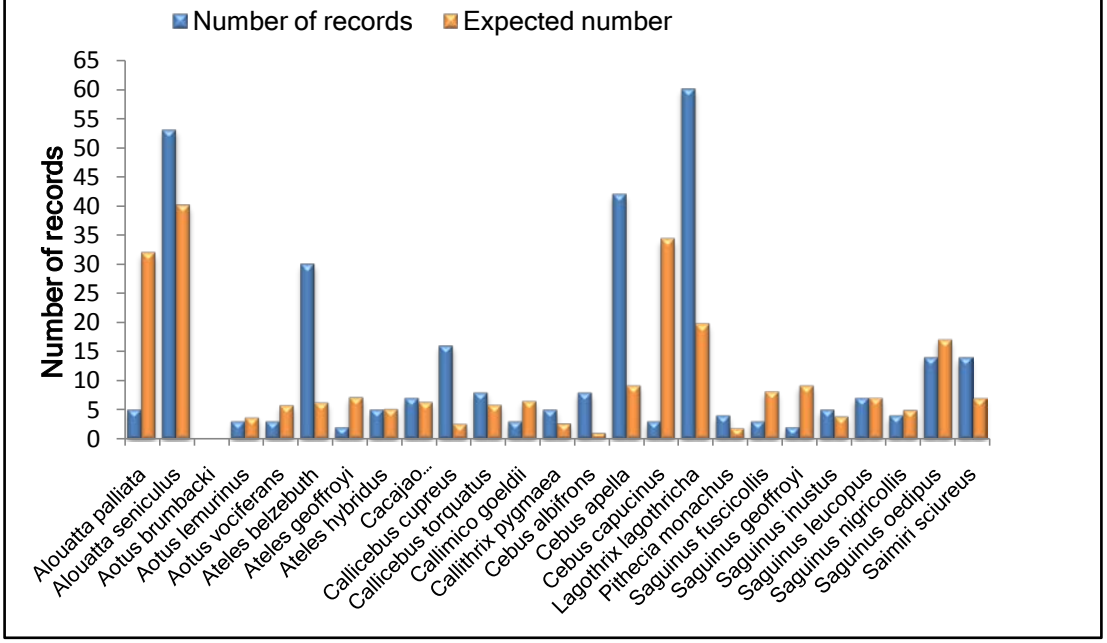


Fig. 3. Comparison between the number of published-records for primate field research carried out in Colombia and the expected number, according to proportion of total geographic range in Colombian territory.

Field studies

Overall, 323 publications were listed for field studies in Colombia, resulting in a total of 489 records. For other countries we found total of 1,466 records representing 1,194 publications. Official publications for Colombia generated up to 310 records, while records from official foreign publications summed up to 1,004.

Our analysis of official publications shows that ecology and natural history was the most examined topic among field studies both in Colombia and other countries (200 and 522 records, respectively), with behavior and social organization as the second most studied topic (122 and 382. respectively). Our results also reveal *Lagothrix lagothricha* (50) and *Alouatta seniculus* (35) as focal species for field studies in Colombia, while the *Aotus* species together with *Saguinus fuscicollis* (fewer than 5 records) appear as the least scrutinized ones. Regarding other countries, *Alouatta palliata* (218) has been by far the predominant species in field research studies, whereas *Ateles hybridus* and *Aotus lemurinus* (fewer than 5 records) have almost no registered records for this type of study.

We found a high number of records corresponding to field studies in Colombia (310), compared to the expected number (247). Taking into account total distribution ranges and the proportion of total area within Colombian territory for each of the 25 primate species considered in the analysis, it is clear that *Cebus capucinus* and *Alouatta palliata* have been significantly understudied in this country. For both species the expected number of records (based on geographic range) is far above the actual number of records obtained for the country. In contrast, species such as *Lagothrix lagothricha*, *Cebus apella* and *Ateles belzebuth* have been well studied in the field, displaying a considerably higher number of records than expected (Fig. 3).

In relation to the regions in Colombia where the highest number of studies has been carried out, we found that Meta department represents more than half of all the field studies performed in the country. Meta, Vaupés, and Caquetá appear as the next preferred locations for primate research studies (Fig. 4). However, when looking into the timeline of field study research in Colombia, our results show a pulsing tendency with several research peaks across the years. These peaks appear to be associated with periods of major field projects that are in turn related to particular research stations and generally include several primate species (Fig. 5). However, our results also show a recent decrease in the number of field studies carried out in Colombia compared to other countries (Fig. 5). This decline is clearly associated with the civil conflict affecting the regions where key stations are located, some of which have been closed (e.g., CIEM station in Tinigua National Park in Meta, closed in 2002; Estación Investigaciones Primatológicas del INDERENA in Sucre, closed in the early 1990s).

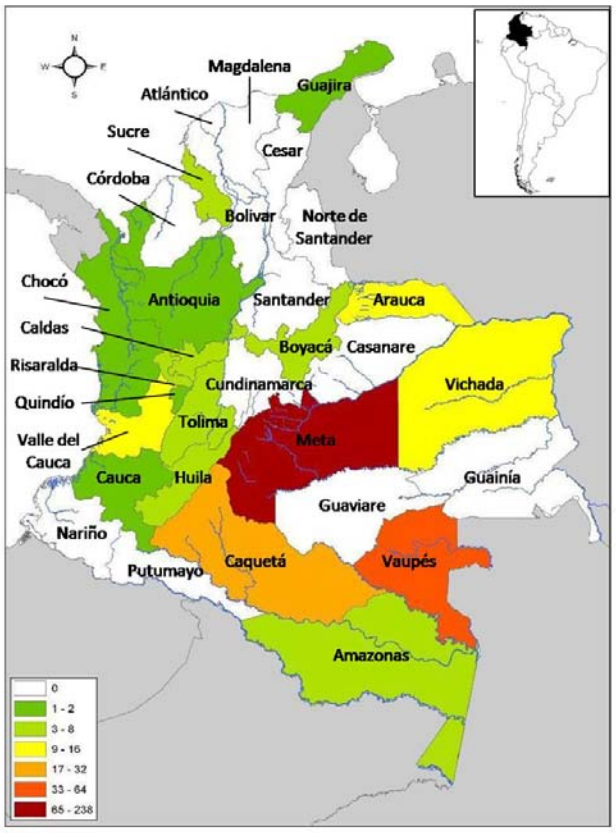


Fig. 4. Frequency of study records from field studi carried out in different regions of Colombia (state departments) between 1900 and 2008.

Discussion

Our evaluation of primate research in Colombia indicates that field studies constitute the main type of research in the country, while laboratory and captivity studies are quite uncommon. However, even though numerous publications have been produced through this type of research, there appears to be a bias for particular species, disregarding many others. One potential explanation for these differences may relate to researchers' and students' preferences. In general, in Colombia there is the possibility of carrying out observations in natural conditions on a wide variety of ecosystems; therefore, this type of research may be chosen over captive or laboratory studies since it allows the possibility to study the species in their natural habitat. Publications based on field studies may also be the most important sources of information when looking for the most relevant aspects of a species' biology for the design of conservation plans.

Species biases among field studies are also generated by the availability of suitable study sites. For instance, the three most studied species in Colombia, woolly monkeys, brown capuchins, and red howler monkeys, were all subject to investigations at the CIEM (Centro de Investigaciones Ecológicas La Macarena) and Caparú research stations, the most productive sites in terms of ecological and behavioral publications. In contrast, the paucity of studies on mantled howler monkeys (*Alouatta palliata*) and white-faced capuchins (*Cebus capucinus*) reflects the absence of permanent research stations in the Chocó biogeographic region of Colombia. Similarly, the scarcity of studies on *Callimico goeldii*, *Callithrix pygmaea*, *Saguinus fuscicollis* (also known as *Saguinus fuscus),* and *Pithecia monachus* may be associated with the lack of long-term research stations in the southern part of Colombia (e.g., Amazonas and Putumayo regions, Fig. 4 and [10]). Therefore, we can conclude that advances in primatological studies in Colombia have been tightly linked to the existence of long-term research field stations. These results allow us to stress the importance of the development of permanent field stations in different regions to stimulate the development of primate research in Colombia. However, we must also emphasize that, to achieve this goal, primatologists conducting research in Colombia must not only overcome the inherent difficulties of constructing new research stations, but also of facing the restrictions imposed by the country's civil conflict.

Our analyses make evident the lack of information from captive and laboratory studies in Colombian primate research. We believe that, in the short term, primatologists in Colombia should regard some of the available zoos in the country as possible sites for captive studies, but in the long term construction of more specialized captive research centers should be considered to promote knowledge of primates. More importantly, this would also contribute to relieving the urgent need to have holding stations for confiscated wildlife in the country. On the other hand, laboratory studies (focused mainly on phylogenetic relationships and systematics) are now more common in Colombia than they were several years ago [11]. However, from our analyses it is evident that, in Latin America, Brazil is leading the research in this area. Laboratory studies, particularly the ones resulting from the recent implementation and diffusion of molecular techniques, are crucial in the determination of a population's taxonomic status, and are also relevant for conservation plans. Some populations may need extreme protection if it is confirmed that they belong to independent evolutionary units, such as of *Ateles geoffroyi* in the Choco and Carribean region and several *Aotus* populations. A continuous growth of studies dedicated to the phylogeny and systematics of primate species in the country should be further stimulated by an increase in the financial support for this type of research.

Regarding the potential to produce official scientific literature, the country exhibits a low proportion of successful official publications originated from "gray" literature [11]. This also seems to be the case in other Latin-American countries, such as Mexico (Serio-Silva, pers. comm.). Attempts to achieve publications of high-quality research in journals and books must therefore be encouraged among Colombian researchers

and students in order to make a real contribution to primate knowledge. The understudied *Aotus brumbacki*, endemic to Colombia, stands out as an example of the lack of information resulting from the poor diffusion of Colombian primate studies, since the only publication available remains as "gray" literature [12]. Lack of experience or poor direction may affect the quality of investigations and/or the resulting documents, thus lowering the probability of acceptance when submitting papers for publication. A recent increase in the number of better quality masters´ degree and even doctoral projects in the country has improved the number of successfully published papers.

Our review identifies a set of species that remains greatly understudied both in Colombia and other countries, including *Aotus brumbacki*, *Ateles hybridus, Saguinus leucopus,* and *Saguinus inustus* (Table 2); and a group of well-studied species such as *Cebus apella, C. capucinus, Alouatta palliata, A. seniculus, Ateles belzebuth, Lagothrix lagothricha, Saguinus fuscus,* and *S. oedipus.* Even though particular attention should be paid to those species that lack information on most aspects of their biology, in the case of these well-studied species further research is also necessary to understand socio-ecological patterns and generate models that will help in the formulation of ecological hypotheses. For instance, there are few studies able to successfully predict the population densities based on environmental characteristics, and only a few species present enough data to generate analyses of population viability [13]. It is important to highlight that in this study we assumed that all publication records have the same value in terms of contribution to Colombian primate knowledge, but this is not necessarily true.

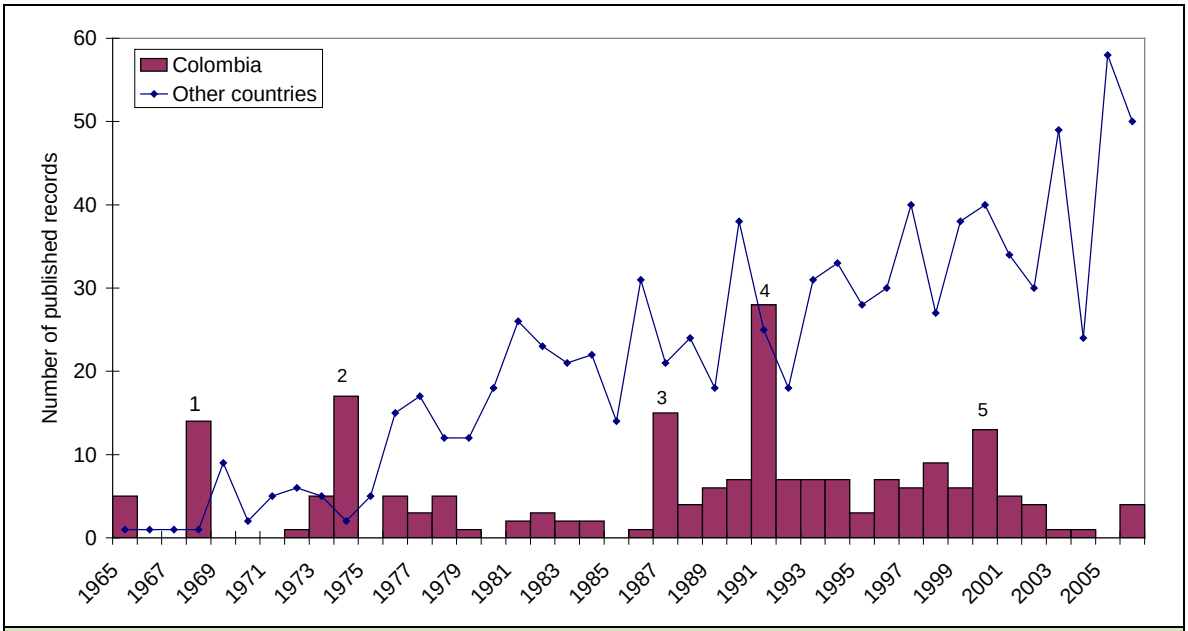


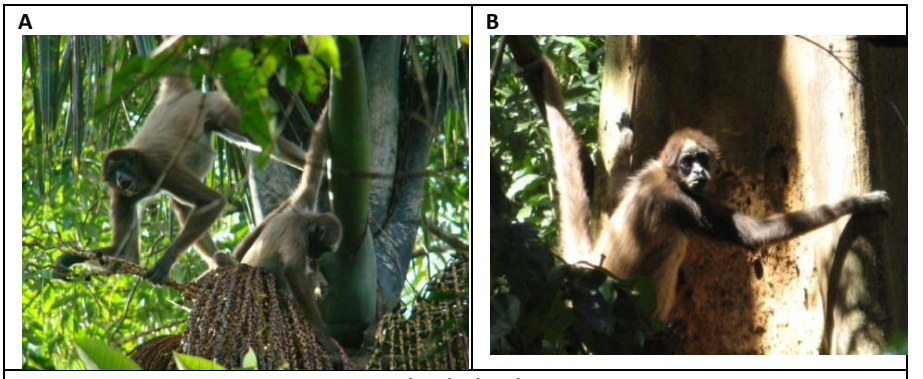
Fig. 5. Number of field study records generated through time from primate studies in Colombia. It is important to note that the year represents the time when field work was done and not the year of publication. The peaks in field work can be associated with particular projects: (1) Klein & Klein in PNN La Macarena, Meta, (2) Izawa & Nishimura's studies in Rio Peneya, Caquetá, (3) First studies at CIEM, PNN Tinigua, Meta; and some studies by Defler in Caparu, Vaupés, (4) Stevenson, Quiñones & Ahumada studies with four species in Tinigua NP. 5. Stevenson's final year for his PhD thesis in Tinigua NP, Meta). The line showing information from other countries was based on publication years.

Implications for conservation

It is clear that the conservation of Colombian primates depends in part on scientific knowledge that is the basis for management plans. Despite the efforts of many primatologists, we are far from generating accurate models that can predict the viability of populations inhabiting complex tropical forests, even for the most studied species. Given the variable ecological and behavioral knowledge available for primates in the country, we recommend studies of species with the least available information (see above) and for species with the highest risk of extinction. According to the international IUCN conservation rankings (**Appendix 3**), the critically endangered and endangered taxa correspond mainly to populations with restricted geographic ranges (*Ateles hybridus, A. geoffroyi fusciceps*, *Lagothrix lagothricha lugens, Saguinus oedipus* and *S. leucopus*) (Fig. 6). These species are distributed throughout the northern and central parts of the country, in areas with intense human activities and, in various cases, within unprotected areas (i.e., areas not considered in the Colombian National Natural Parks system), such as La Serranía de San Lucas [6]. This suggests that the efforts made by the Colombian government to establish protected areas are insufficient to guarantee the survival of some of the most endangered primate species (i.e., neither *Ateles hybridus* nor *Saguinus leucopus* are found within National Natural Parks) [6]. Thus, primatologists should be greatly involved in research endeavors on these and other vulnerable species, and new habitat and species management strategies should be strongly promoted and implemented in the country.

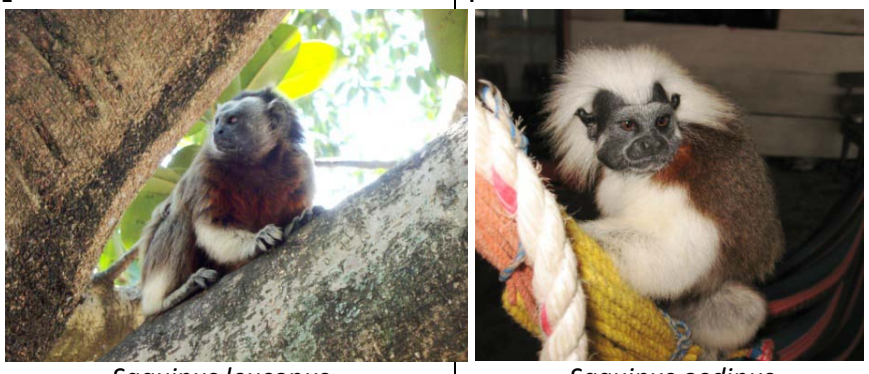
Concomitantly, there are specific projects focusing on the conservation of some of the most vulnerable species. Proyecto Titi, is a long term project led by A. Savage focusing on the conservation of *Saguinus oedipus* [14]. A. Link and P. Stevenson have been leading field research on *Ateles hybridus* in the Magdalena valley since 2005, and have published the first papers on diet, habitat use, and behavior [15-16]. Moreover, several researchers have already proposed an action plan for the species [17]. Other researchers (e.g., M. Santamaria, A.L. Morales, N. Roncancio, and A. Link) are undertaking field studies on *Saguinus leucopus* on the left bank of the Magdalena River. P. R. Stevenson, M. Bueno, and S. Botero are working on a phylogeographical study on *Lagothrix*, to find out how many species of woolly monkeys may be present in Colombia. The evidence therefore suggests that there are some current efforts to increase the knowledge of endangered taxa, with few exceptions (*Ateles geoffroyi fusciceps* and *A. belzebuth*). Nevertheless, the endangered *Ateles geoffroyi grisescens* has never been confirmed for the country, nor had its populations evaluated. Assessments of the state of *Ateles geoffroyi rufiventris* are urgently needed as a basis for an eventual conservation plan, and habitat and reserve evaluations are also absent for *Ateles hybridus,* a critically endangered species.

Based on our experience, we believe that to ensure the conservation of Colombian primates it is not only necessary to acquire integral scientific knowledge on each species, but also essential to protect the forests and ecosystems inhabited by the monkeys. In Colombia, about 9.65% of the terrestrial area corresponds to parks within the national system of protected areas [2], and this area has been increasing through the years, but primate protection is not guaranteed in protected areas. For example, annual deforestation rates of 1.5-4.1% have been reported in the National Parks including the critically endangered cotton-top tamarin in Northern Colombia [18]. Increasing deforestation rates have been reported for Tinigua National Park [19], where the highest population densities of the endangered Colombian woolly monkeys have been reported [6]. In 7 out of 51 national protected areas, more than half the territory has been transformed by man. In 29 of them, the percentage disrupted area lays between 1% and 50%. The remaining protected areas show natural habitats in fairly good conditions [2]. Therefore, since habitat loss is the single most critical factor affecting diversity throughout the country, additional efforts are needed to prevent forest destruction within and outside national parks.



Ateles hybridus

Lagothrix lagothricha (subspecies *lugens* and traditionally *lagothricha)*



Saguinus leucopus | *Saguinus oedipus*

Fig. 6. Pictures of four highly endangered primate species in Colombia. Pictures were taken by (A) Pablo Tovar, (B) Andres Link, (C) Sergio Vargas, (E) Juan Diego Garay-Hoyos, (D and F) Diego Alejandro Zárate.

Apart from forest destruction, endangered populations suffer from hunting, especially large-bodied monkeys such as *Ateles* and *Lagothrix* [20]. Hunting has an increasingly large impact on these species as it causes a large reduction in their population size. Since many legal reserves and national parks have little physical protection, primate species within them are routinely hunted by human populations. Also, the rights of various groups such as indigenous and Afro-Colombians allow free harvesting of meat animals and conflict with the conservation of primates such as *Lagothrix* and *Ateles*. Furthermore, recent studies have found that the reduction of primates by hunting affects plant diversity negatively, altering the composition of plant communities [21-23]. Our study revealed few studies on human-primate interactions and primate conservation, suggesting that the general public is not aware of the relevance or the importance of primate populations in the conservation of biodiversity. Thus, education and conservation-oriented projects are urgently needed and we believe that basic ecological research should be tightly linked with conservation campaigns, such as in the projects currently in progress for spider monkeys in the Magdalena Valley and woolly monkeys in Guaviare [24]. Finally, continuing insecurity and violence, particularly due to revolutionary armed forces, have turned some national parks into dangerous locations, and this discourages research and employment at those sites. We as scientists can make recommendations based on our best scientific knowledge, but the final outcome that will determine the persistence of these species into the future depends on the complex interaction between political decisions, social conflicts, and law enforcement [25].

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Appendix 1. Approximated values for total geographic distribution area, distribution area in Colombia, and percentage of total distribution belonging to Colombian territory, for 25 primate species. Maps were taken from http://www.iucnredlist.org/ (IUCN 2008) and analyzed with ImageJ 1.41 (2008).

SPECIES	TOTAL AREA (km^2)	AREA IN COLOMBIA (km^2)	PERCENTAGE OF AREA IN COLOMBIA
Alouatta palliata	346,260	49,410	14.3%
Alouatta seniculus[1]	3'672,610	596,170	16.2%
Aotus brumbacki	Endemic	72,050	100%
Aotus lemurinus[2]	336,750	246,290	73.1%
Aotus vociferans	612,170	218,720	35.7%
Ateles belzebuth[3]	2'546,710	217,430	8.5%
Ateles geoffroyi[4]	696,040	60,490	8.7%
Ateles hybridus	102,740	75,320	73.3%
Cacajao melanocephalus	303,170	106,530	35.1%
Callicebus cupreus[5]	154,620	17,090	11.1%
Callicebus torquatus[6]	995,390	254,430	25.6%
Callimico goeldii	320,660	50,960	15.9%
Callithrix pygmaea	1'029,100	97,200	9.4%
Cebus albifrons	2'247,760	114,240	5.1%
Cabus apella[7]	5'895,900	376,080	6.4%
Cebus capucinus	296,960	94,240	31.7%
Lagothrix lagothricha[8]	1'743,140	369,200	21.2%
Pithecia monachus	428,930	71,840	16.7%
Saguinus fuscicollis	1'080,220	79,480	7.4%
Saguinus geoffroyi	46,260	26,360	57.0%
Saguinus inustus	233,320	112,470	48.2%
Saguinus leucopus	Endemic	35,550	100%
Saguinus nigricollis	132,740	65,250	49.2%
Saguinus oedipus	Endemic	24,590	100%
Saimiri sciureus	2'694,930	328,990	12.2%

[1] ***Alouatta seniculus***. Includes distributions of *A. discolor*, *A. macconnelli*, *A. puruensis* and *A. sara*
[2] ***Aotus lemurinus***. Includes distributions of *A. lemurinus*, *A. griseimembra* and *A. zonalis*
[3] ***Ateles belzebuth***. Includes distributions of *A. b. belzebuth, A. b. chamek and A. b. marginatus*
[4] ***Ateles geoffroyi***. Includes distributions of *A. geoffroyi and A. fusciceps*
[5] ***Callicebus cupreus***. Includes distributions of *C. c. ornatus and C. c. discolor*
[6] ***Callicebus torquatus***. Includes distributions of *C. torquatus, C. regulus, C. purinus, C. medemi, C. lugens and C. lucifer*
[7] ***Cebus apella***. Includes distributions of *C. apella, C. macrocephalus and C. libidinosus and C. nigritus*
[8] ***Lagothrix lagothricha***. Includes distributions of *L. l. lagothricha, L.l. lugens, L. l. cana and L. l. poepiggi*

Appendix 2. Published study-records in different topics for the primate species found in Colombia. Numbers in parenthesis represent the number of records in other countries.

Species	Anatomy and physiology	Behavior and social organization	Conservation and monkey-human interactions	Ecology and natural history	Evolution and systematics	Geographic distribution	Parasitology and veterinary
Alouatta palliata	1 (26)	1 (89)	5 (18)	4 (124)	2 (9)	3 (10)	0 (7)
Alouatta seniculus	1 (14)	17 (37)	5 (12)	37 (76)	5 (21)	3 (12)	0 (4)
Aotus brumbacki	1 (0)	1 (0)	4 (1)	2 (1)	3 (8)	1 (0)	0 (0)
Aotus lemurinus	1 (5)	1 (12)	5 (1)	4 (5)	3 (11)	2 (1)	7 (24)
Aotus vociferans	1 (2)	3 (4)	4 (2)	3 (15)	7 (8)	2 (1)	0 (18)
Ateles belzebuth	1 (4)	8 (14)	6 (4)	23 (45)	2 (10)	3 (5)	0 (2)
Ateles geoffroyi	1 (34)	1 (59)	4 (9)	2 (52)	2 (17)	2 (9)	0 (3)
Ateles hybridus	1 (1)	1 (0)	6 (2)	3 (1)	1 (6)	2 (3)	0 (1)
Cacajao melanocephalus	1 (2)	2 (2)	4 (0)	6 (11)	1 (9)	2 (7)	0 (0)
Callicebus cupreus	1 (3)	11 (20)	5 (1)	6 (14)	2 (8)	3 (3)	0 (0)
Callicebus torquatus	1 (3)	2 (5)	4 (1)	6 (21)	2 (9)	3 (5)	0 (1)
Callimico goeldii	1 (41)	1 (32)	3 (4)	2 (33)	1 (27)	3 (4)	0 (7)
Callithrix pygmaea	1 (15)	4 (32)	4 (3)	3 (32)	1 (21)	2 (5)	0 (2)
Cebus albifrons	1 (5)	5 (8)	5 (4)	4 (16)	4 (11)	3 (5)	1 (0)
Cebus apella	1 (24)	26 (161)	8 (13)	14 (71)	3 (10)	3 (12)	0 (8)
Cebus capucinus	1 (6)	1 (83)	4 (3)	2 (51)	1 (8)	3 (4)	0 (1)
Lagothrix lagothricha	1 (16)	20 (18)	7 (4)	41 (36)	6 (22)	3 (4)	0 (16)
Pithecia monachus	1 (2)	2 (1)	5 (1)	3 (15)	1 (3)	2 (2)	0 (0)
Saguinus fuscicollis	1 (60)	2 (82)	5 (3)	2 (74)	1 (18)	2 (6)	0 (9)
Saguinus geoffroyi	1 (6)	1 (10)	4 (4)	2 (14)	1 (7)	2 (1)	0 (3)
Saguinus inustus	1 (2)	1 (3)	4 (0)	5 (5)	1 (3)	2 (1)	0 (0)
Saguinus leucopus	1 (1)	1 (0)	6 (2)	4 (1)	1 (3)	3 (1)	0 (0)
Saguinus nigricollis	1 (5)	2 (2)	5 (2)	3 (12)	1 (3)	2 (5)	0 (1)
Saguinus oedipus	2 (69)	2 (131)	14 (14)	8 (27)	1 (31)	2 (1)	0 (63)
Saimiri sciureus	1 (27)	6 (65)	5 (8)	11 (35)	5 (8)	2 (6)	0 (14)
TOTAL	**26 (373)**	**122 (870)**	**131 (116)**	**200 (787)**	**58 (291)**	**60 (113)**	**8 (185)**
% in Colombia	6.5	12.3	53.0	20.3	16.6	34.7	4.1

Appendix 3. Conservation status history for 31 primate species occurring in Colombia, according to data taken from IUCN Red List of Endangered Species (IUCN 2008). Taxonomic notes for this classification are available in each species report at http://www.iucnredlist.org.

SPECIES		CONSERVATION STATUS HISTORY									
		1982[1]	1986[2]	1988[2]	1990[3]	1994[4]	1995[5*]	1996[6]	2000[7]	2003[3]	2008[3]
Alouatta palliata		-	-	-	-	-	LR	LC	LC	LC	**LC**
Alouatta seniculus		-	-	-	-	-	LR	LC	-	LC	**LC**
Aotus brumbacki		-	-	-	-	VU	VU	VU	VU	-	**VU** A2c
Aotus lemurinus	*A. griseimembra*	-	-	-	-	VU	EN	EN	EN	-	**VU** A2c
	A. lemurinus	-	-	-	-	-	VU	VU	VU	-	**VU** A2c
	A. zonalis	-	-	-	-	-	-	-	DD	-	**DD**
Aotus vociferans		-	-	-	-	-	LR	LC	-	LC	**LC**
Ateles belzebuth		VU	VU	VU	VU	VU	EN	VU	VU	VU	**EN** A2cd
Ateles geffroyi	*A. fusciceps*	-	-	-	-	-	VU	-	-	-	**CR** A2cd
Ateles hybridus		-	-	-	-	-	EN	-	EN	CR	**CR** A2cd+3cd
Cacajao melanocephalus		VU	VU	VU	VU	EN	LR	LC	LC	LC	**LC**
Callicebus cupreus	*C. discolor*	-	-	-	-	-	LR	LC	-	LC	**LC**
	C. ornatus	-	-	-	-	VU	VU	VU	VU	VU	**VU** A2c;B1ab(ii,iii)
Callicebus torquatus	*C. lucifer*	-	-	-	-	VU	LR	LC	LC	LC	**LC**
	C. lugens	-	-	-	-	-	LR	LC	-	LC	**LC**
	C. medemi	-	-	-	-	-	VU	VU	VU	LC	**VU** A2cd
Callimico goeldii		Rare	Rare	Rare	Rare	Rare	VU	VU	VU	NT	**VU** A3c
Cebuella pygmaea		-	-	-	-	-	LR	LC	-	LC	**LC**
Cebus albifrons		-	-	-	-	-	LR	-	LC	LC	**LC**
Cebus apella	*C. macrocephalus*	-	-	-	-	-	LR	-	-	LC	**LC**
Cebus capucinus		-	-	-	-	-	LR	-	LC	LC	**LC**
Lagothrix lagothricha	*L. lagothricha*	VU	VU	VU	VU	VU	LR	LC	LC	-	**VU** A3cd
	L. lugens	-	-	-	-	EN	CR	CR	VU	VU	**CR** A3cd
Pithecia monachus		-	-	-	-	-	LR	LC	LC	LC	**LC**
Saguinus fuscicollis		-	-	-	-	-	LR	-	LC	LC	**LC**
Saguinus geoffroyi		-	-	-	-	-	LR	LC	-	LC	**LC**

Appendix 3. Continued.

SPECIES	CONSERVATION STATUS HISTORY									
	1982[1]	1986[2]	1988[2]	1990[3]	1994[4]	1995[5] *	1996[6]	2000[7]	2003[3]	2008[3]
Saguinus inustus	-	-	-	-	-	LR	LC	-	LC	**LC**
Saguinus leucopus	VU	VU	VU	EN	EN	VU	VU	VU	VU	**EN** A2cd
Saguinus nigricollis	-	-	-	-	-	LR	-	LC	LC	**LC**
Saguinus oedipus	EN	EN	EN	EN	EN	EN	EN	EN	.	**CR** A2cd
Saimiri sciureus	-	-	-	-	-	LR	LC	-	LC	**LC**

[1]Thornback & Jenkins; [2] IUCN Conservation Monitoring Centre; [3]IUCN; [4]Groombridge; [5]Rylands *et al*.; [6]Baillie &Groombridge; [7]Hilton-Taylor . * Rylands conservation status classification is established according to the Mace-Lande System and is not included in the information available online. **Citation:** IUCN 2008. 2008 IUCN Red List of Threatened Species. <www.iucnredlist.org>. Downloaded on 17 December 2008