



Artículo

TRENDS IN RESEARCH ON TERRESTRIAL SPECIES OF THE ORDER CARNIVORA

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ABSTRACT. Information regarding trends in research on terrestrial species of the order Carnivora can provide an understanding of the degree of knowledge of the order, or lack thereof, as well as help identifying areas on which to focus future research efforts. With the aim of providing information on these trends, this work presents a review of the thematic focuses of studies addressing this order published over the past three decades. Relevant works published in 16 scientific journals were analyzed globally and by continent with respect of topics, species, and families. We found a total of 2117 articles referencing this order, which focused on the families Ursidae, Felidae, Canidae, and Hyaenidae, with a lesser representation of Eupleridae, Herpestidae, and Mephitidae. The highest number of articles per species was found in Europe, and the lowest in Asia and Africa. In the Americas, studies were most frequent on the families Ursidae and Canidae, whereas in Europe, studies concentrated on Mustelidae and Canidae. In Africa, studies of Felidae and Hyaenidae were prevalent, and in Asia, these were Ailuridae and Felidae. The most studied topics were distribution, diet, ecology and natural history, whereas the most studied species were *Meles meles*, *Canis latrans*, *Vulpes vulpes*, *Lutra lutra*, *Panthera leo*, and *Canis lupus*. Further research is needed, especially on genetics, and taxonomic aspects.

RESUMEN. Tendencias en la investigación sobre especies terrestres del orden Carnivora. La información respecto a las tendencias en la investigación sobre especies terrestres del orden Carnivora puede permitir comprender el grado de conocimiento, o falta del mismo, así como identificar las áreas en las cuales enfocar los esfuerzos futuros de investigación. Con el objetivo de proveer información sobre esas tendencias, este trabajo presenta una revisión de los temas abordados en los estudios conducidos sobre especies de este orden, publicados durante las tres décadas pasadas. Los trabajos publicados en 16 revistas científicas se analizaron de manera global y por continente con respecto a los temas, especies y familias. Se encontraron 2117 artículos, que se enfocaron a las familias Ursidae, Felidae, Canidae y Hyaenidae, con una baja representación de Eupleridae, Herpestidae y Mephitidae. El número de artículos por especies fue alto en Europa y bajo en Asia y África. En América los estudios fueron más frecuentes para las familias Ursidae y Canidae, mientras que en Europa se concentraron en Mustelidae y Canidae. En África, los estudios sobre Felidae y Hyaenidae fueron más numerosos, y en Asia, lo fueron para Ailuridae y Felidae. Los temas más estudiados fueron distribución, dieta, ecología e historia natural, y las especies más estudiadas *Meles meles*, *Canis latrans*, *Vulpes vulpes*, *Lutra lutra* y *Canis lupus*. La investigación futura es necesaria en aspectos sobre genética y taxonomía.

Key words: Articles published. Continents. Families. Species.

Palabras clave: Artículos publicados. Continentes. Especies. Familias.

INTRODUCTION

The members of the order Carnivora display great diversity in their demography, body size, feeding habits, behavior, home range, and habitats (Gittleman et al., 2001). Frequently, members of this order are essential in determining the structure of the terrestrial communities, primarily as a result of their ecological role in trophic webs and their effects on the different groups present in the environments they inhabit (Terborgh et al., 1999; Gittleman and Gompper, 2005).

Many conservation strategies may be based on carnivorous mammals (Loyola et al., 2008). Nevertheless, for these strategies to be effective, they require reliable information on the population dynamics, distribution, and ecological requirements of the species of interest, as well as the impact they have on their ecosystems (Ray et al., 2005).

However, the degree of information for each species is often not homogeneous (Ginsber, 2001), and the compilation and analysis of the issues addressed in the scientific literature are available only for some groups. In previous works, some studies have analyzed the information about particular groups in specific regions, such as those conducted for the family Canidae and Felidae in South America (Medel and Jaksic, 1988; Lucherini et al., 2004; Clavijo and Ramírez, 2009). For some species, such as puma *Puma concolor* (López-González and González, 1998), polecat *Mustela putorius* (Blandford, 2008), genet *Genetta genetta* (Virgós et al., 1999), and European badger *Meles meles* (Rope and Mickevicius, 1995), reviews of particular issues, such as diet, are available.

These studies show the advance of knowledge in one or more disciplines, as well as areas where more research is needed for each group. But there is no previous work to provide a perspective on this situation for the order Carnivora as a whole. This work aims to provide information on trends in research on the order Carnivora in terms of topics and species that have been addressed in the scientific literature in the last three decades, and to make recommendations to guide future research.

MATERIALS AND METHODS

We reviewed the contents of fifteen internationally circulating scientific journals and recorded the number of articles published between 1980 and 2010 that made reference to one or more species of the order Carnivora. This was considered as the adequate period of time to provide an overview on recent research with this group.

The journals consulted were Studies on Neotropical Fauna and Environmental, The Southwestern Naturalist, Journal of Animal Ecology, Journal of Zoology, Journal of Mammalogy, Mammalia, Mammal Review, Mastozoología Neotropical, Small Carnivore Conservation, Canid News, Cat News, African Journal of Ecology, Journal of East African Natural History, South African Journal of Wildlife Research, and Raffles Bulletin of Zoology. These journals were selected because of their relevance, availability, and because they published a wide range of topics, including diversity in general (two journals), zoology (six), mammals (four), and carnivores specifically (three). To avoid bias in the percentage of subjects covered, we did not include journals that address a specific topic such as conservation, distribution or diseases, to name a few. Although these journals are edited mainly in Europe (9), the Americas (3), and Africa (3), they include studies addressing species from around the world.

For each article, we recorded the species, general topic, and country in which the study was performed. The articles were classified into 16 topics (Table 1), according to the content expressed in the title and abstract. In the classification of the topics we followed Guevara Chumacero et al. (2005), with some modifications.

The studies were analyzed on both a global level and by continent, as well as by the most studied topics, species, and families, with respect to the total number of published articles. As species richness varies across continents, the number of articles published on each continent was expressed as a proportion (PAC = the number of articles published in each continent / the number of species present in that continent). Likewise, when comparing the number of studies for each family, the number of contributions referring to a given family was expressed as a proportion of the number of species each family contains (PAF = the number of articles published per family / the number of species per family). In addition, the publication Mammalian Species, which includes monographs of species from around the world, was reviewed to get an idea of

Table 1

Percentage of articles on different research topics for the order Carnivora, from 1980 to 2010.

Topic	Subtopic	The Americas	Africa	Asia	Europe	Total
Abundance	Density, relative abundance	3.3	2.1	2.8	5.3	3.5
Home Range	Territory	4.0	2.3	0.7	2.9	2.6
Diet	Preference, habits	14.7	17.4	7.9	16.0	13.7
Natural History	Metabolism, reproduction, physiology	12.8	9.0	5.7	13.0	10.7
Conduct	Activity patterns, behavior	8.5	12.3	4.8	7.1	7.9
Conservation	Species at risk, programs, risk	6.6	12.1	18.2	8.4	10.6
Distribution	New records, zoogeography, dispersal	13.7	14.4	32.6	14.9	17.4
Ecology	Diversity, predation, competition	14.7	9.5	11.2	8.0	11.1
Evolution	Phylogeny, paleontology	1.8	0.8	0.4	0.6	1.5
Genetics	Alleles, genetic variation	4.9	1.8	0.9	3.2	3.1
Zoosanitary Issues	Diseases, zoonosis, parasites	1.5	2.8	1.6	5.0	2.6
Methods	Efficiency, comparisons, new techniques	2.1	3.8	2.9	5.3	3.4
Morphology	Morphometry, size, weight	5.6	3.4	2.9	6.7	5.7
Taxonomy	Classification, systematic	1.3	0.3	2.4	0.0	1.1
Habitat Use	Selection, preference	2.9	5.9	1.6	1.9	2.9
Other	Ethnozoology, hunting/poaching, literature reviews	1.6	2.1	3.2	1.7	2.2

progress in knowledge of species of this order. We considered that the species included in this publication are relatively well understood in terms of natural history, distribution and ecology. In this study we followed the taxonomy proposed by Wilson and Mittermeier (2009).

RESULTS

We recorded a total of 2117 studies and of these, the 14.8% were published in the 1980s, the 29.9% in the 1990s, and the 55.3% in the 2000s. Of the 2117 studies found, 758 (35.8%) were performed in the Americas, 476 (22.48%) in Europe, 390 (18.42%) in Africa, and 417 (19.7%) in Asia. The remaining (3.6%) were works spanning more than one continent (72 studies), or were conducted in Oceania (five studies). The most studied topics were distribution, diet, ecology, and natural history, both globally and in each continent (Table 1). In contrast, the topics less addressed were taxonomy, evolution,

genetics and zoosanitary issues. Considering the number of contributions as a proportion with respect to the number of carnivore species present on each continent, Europe displayed the highest value (PAC = 20.7), followed by the Americas (PAC = 9.5). Asia and Africa displayed low and similar values (PAC = 4.0 and PAC = 4.6, respectively).

The families with fewer studies were Eupleridae, Mephitidae and Herpestidae, and the families most studied were Mustelidae, Canidae and Felidae, both globally and by continents (Table 2). The articles published on the global level made reference to 196 of the 245 known terrestrial species of Carnivora in the world (Wilson and Mittermeier, 2009). Of these 196 species, the most studied were the European badger *M. meles* and the coyote *Canis latrans*, followed by the red fox *Vulpes vulpes*, and the river otter *Lutra lutra*, the lion *Panthera leo*, the wolf *Canis lupus*, the leopard *Panthera pardus*, and the puma (Table 3).

Table 2

Species richness and the number of published works per family of mammalian carnivores between 1980 and 2010 on the global level and by continent. References: a = total species richness, b = number of species with at least one work, c = number of published articles, d = proportion of studies (PAF= the number of articles published per family / number of species of the family).

	Globally				The Americas				Europe				Africa				Asia						
	a	b	c	d	a	b	c	d	a	b	c	d	a	b	c	d	a	b	c	d			
Aluridae	1	1	10	10													1	1	1	1	9	9	
Canidae	35	30	457	13.1	18	17	267	14.8	4	7	76	19	14	9	82	5.8	11	11	11	37	3.3	3.3	
Eupleridae	8	6	13	1.6					2	3			8	6	10	1.2							
Felidae	37	36	530	14.3	15	11	152	10.1	4	5	49	16.3	10	10	139	13.9	21	20	155	7.4	7.4	7.4	
Herpestidae	34	20	58	1.7	1	3			2	3	6	6	25	13	29	1.7	9	7	20	2.2	2.2	2.2	
Hyaenidae	4	4	52	13									4	4	49	12.2	1	1	2	2	2	2	
Mephitidae	12	9	27	2.2	10	8	26	2.6	1	2							2						
Mustelidae	57	46	501	8.8	21	21	111	5.3	11	11	292	24.3	7	5	25	3.6	33	21	60	1.8	1.8	1.8	
Nandiniidae	1	1	3	3					1	1	3	3	1	1	3	3							
Prionodontidae	2	2	7	3.5													2	2	7	3.5	3.5	3.5	
Procyonidae	12	11	82	6.8	12	11	74	6.2		1													
Ursidae	8	8	134	16.7	4	4	86	21.5	2	3	21	10.5					6	5	23	3.8	3.8	3.8	
Viverridae	34	22	107	3.1					1	3	11	11	16	11	22	1.4	18	15	70	3.9	3.9	3.9	
Order			136				39			15					30					34			
TOTAL	245	196	2117		80	73	758		24	35	476		85	60	390		104	83	417				

Table 3

Species of the order Carnivora with the greatest quantity of published works from 1980 to 2010. References: A = refers to whether the species has a review in Mammalian Species, B = number of species by family to have a review within Mammalian Species, C = the value of B expresses as a percentage.

Family	Species	Number of Articles	Mammalian Species		
			Presence ^A	Number of Species Present ^B	Presence Percentage ^C
Ailuridae	<i>Ailurus fulgens</i>	10	X	1	100
Canidae	<i>Canis latrans</i>	84	X	28	80
	<i>Vulpes vulpes</i>	72	X		
	<i>Canis lupus</i>	60	X		
	<i>Lycan pictus</i>	35			
	<i>Vulpes macrotis</i>	23	X		
	<i>Lycalopex culpaeus</i>	19	X		
	<i>Vulpes lagopus</i>	17	X		
	<i>Canis mesomelas</i>	14	X		
	<i>Chrysocyon brachiurus</i>	14			
Eupleridae	<i>Cryptoprocta ferox</i>	5		1	12.5
	<i>Mungotictis decemlineata</i>	3			
Felidae	<i>Panthera leo</i>	62	X	13	35.1
	<i>Panthera pardus</i>	57			
	<i>Puma concolor</i>	55	X		
	<i>Acinonyx jubatus</i>	45	X		
	<i>Panthera onca</i>	41	X		
	<i>Lynx rufus</i>	33	X		
	<i>Panthera tigris</i>	31	X		
	<i>Lynx lynx</i>	25	X		
	<i>Leopardus pardalis</i>	16	X		
Herpestidae	<i>Ichneumia albicaudata</i>	4		11	32.3
Hyaenidae	<i>Crocuta crocuta</i>	17		3	75
	<i>Hyaena brunnea</i>	3	X		
Mephitidae	<i>Mephitis mephitis</i>	11	X	6	50
	<i>Spilogale putorius</i>	7	X		
Mustelidae	<i>Meles meles</i>	123		29	50.8
	<i>Lutra lutra</i>	70			
	<i>Neovison vison</i>	38	X		
	<i>Mustela lutreola</i>	32	X		
	<i>Martes pennanti</i>	13	X		
	<i>Martes americana</i>	12	X		
	<i>Mustela putorius</i>	12			

(Table 3 cont.)

	<i>Martes martes</i>	11			
	<i>Gulo gulo</i>	10	X		
Nandiniidae	<i>Nandinia binotata</i>	3		0	0
Prionodontidae	<i>Prionodon pardicolor</i>	6		0	0
	<i>Prionodon linsang</i>	1			
Procyonidae	<i>Procyon lotor</i>	32	X	5	41.7
	<i>Nasua narica</i>	9	X		
Ursidae	<i>Ursus americanus</i>	51	X	5	62.5
	<i>Ursus arctos</i>	24	X		
	<i>Ursus maritimus</i>	22	X		
	<i>Ailuropoda melanoleuca</i>	15	X		
Viverridae	<i>Genetta genetta</i>	14	X	3	8.8
	<i>Chrotogale owstoni</i>	13			
	<i>Viverricula indica</i>	6			

From a total of 73 species registered in this review for the Americas, the most studied species were the coyote (84 articles), the puma (55), the black bear *Ursus americanus* (51), the jaguar *Panthera onca* (41) and the wolf (38). In Europe, we recorded 35 species, included 11 non-native species, as for example the giant panda *Ailuropoda melanoleuca* native of Asia, and the fosa *Cryptoprocta ferox* native of Africa. The most studied species were the European badger (118 articles), the river otter (67), and the red fox (48). In Asia, the leopard and the tiger *Panthera tigris* (27 articles, each), the giant panda (13 articles), the European mink *Mustela lutreola* (11), and the Owston's palm civet *Chrotogale owstoni* (10) were the most studied out of a total of 83 registered species. In Africa, the most studied species were the lion (61 articles), the spotted hyena *Crocuta crocuta* (42), the cheetah *Acinonyx jubatus* (35), the African wild dog *Lycaon pictus* (34), and the leopard (28) out of a total of 60 registered species.

Of the 848 monographs published in Mammalian Species, 105 belong to the order Carnivora. Thus, 42.9% of the carnivores have a monograph: 28% of the monographs corresponds to mustelids (29 species), 26% to canids

(28 species), 12% to felines (13 species), and 10% to herpestids (11 species). The remaining 24% is distributed among the other families. For the families Canidae and Hyaenidae, between 80 y 75% of their species already have a monograph in this journal; for the families Ursidae, Mustelidae, and Mephitidae, between 50 and 60%; for the families Procyonidae, Felidae and Herpestidae, between 40 and 30%, and for the families Eupleridae and Viverridae, about 10%. No species of the families Nandiniidae and Prionodontidae (one and two species, respectively), have monographs to the date of this review.

DISCUSSION

Although the thematic analysis presented here does not represent the entirety of the studies performed on species of the order Carnivora on the global level, and although we did not take into account information published in regional journals, we think it does give a realistic and updated view of the research trends for this order.

Field work for the articles included in this study was concentrated in Europe and the Americas, leaving the remaining continents

with a low proportion of studies. The greatest proportion of studies was carried out in Europe (PAC=20.7), despite the fact that this continent has fewer terrestrial species (24 species). In contrast, the proportion of studies carried out in Asia was low (PAC=4.0) in spite of the fact that the species richness of this continent is quite high (104 species).

The production of published articles on a global scale has principally focused on few families. Of the 13 terrestrial families that make up the order Carnivora, just three summed 70.3% of the total number of publications: Felidae, Mustelidae and Canidae. Of the remaining ten families, six (Eupleridae, Herpestidae, Mephitidae, Nandiniidae, Viverridae, and Prionodontidae) were scarcely studied. This low number of studies may be due to the species richness of each family. However, the ursids, despite having the same species richness as euplerids (eight species), have a considerably larger proportion of studies. In contrast, although the viverrids constitute almost the same number of species as canids (34 vs. 35 species, respectively), they have a considerably smaller proportion of studies (3.1 vs. 13.1).

In addition, we found a wide variety of species groups that have not been researched within the areas in which they are distributed. For example, the proportions of studies generated on the families Viverridae, Herpestidae, and Eupleridae were low in Africa or in Asia, although these two continents include most of the range of these three families. The families Procyonidae and Mephitidae faced the same situation in the Americas. Heterogeneous representation of families was also seen in the percentage of appearance in Mammalian Species. More than half of the 105 species with a monograph in the journal belong to the families Canidae and Mustelidae, whereas the families Herpestidae, Procyonidae, Viverridae, and Eupleridae are little represented. That is, close to 70% of the species that makes up these families lack of the general descriptions provided by this journal.

The studies published over the last three decades are concentrated on few species, generally large in size, habitat generalists, or charismatic,

such as *M. meles*, *L. lutra*, *C. latrans*, *P. leo*, and *A. melanoleuca*. In contrast, other species groups, generally little charismatic, small sized, or those that may be difficult to observe and study due to their habitats or behavior, have received less attention. This is the case of many small cats, the procyonids *Nasua olivacea*, *Bassaricyon alleni*, and *B. gabbii*, the canid *Nyctereutes procyonoides*, the mustelids *M. felipei*, and *M. lutreolina*, and the viverrid *G. thierryi*, to mention a few.

In terms of research topics, this review revealed that the distribution and diet were the most recurrent aspect in studies within the order Carnivora, especially for the families Felidae, Mustelidae and Canidae. However, for some species even basic aspects such as natural history, breeding behavior and habitat association remain unknown (Wilson and Mittermeier, 2009), among which are the herpestids *Helogale hirtula* and *Herpestes semitorquatus*, the mustelids *M. felipei* and *M. lutreolina*, or the viverrids *G. bournoni*, *G. poensis*, and *G. thierryi*.

Added to this, the lack of knowledge of some aspects has contributed to discrepancies in the systematics of some species of the order Carnivora. In such circumstances are South American cats, which have a long history of changes in their taxonomy, even in recent years (Clavijo and Ramirez, 2009; Wilson and Mittermeier, 2009). A similar problem also face the procyonids *Procyon insularis*, *Nasua nelsoni* (Cuarón et al., 2004), *B. beddardi*, *B. lasius*, and *B. pauli*, or the mustelid *Lutra nippon* (Wozencraft, 2005; Wilson and Mittermeier, 2009). These differences are also present at the family level in various classifications, such as in the case of Prionodontidae (Wozencraft, 2005; Schipper et al., 2008; Wilson and Mittermeier, 2009). This suggests that studies on genetics, evolution, taxonomy, and morphology are required to help the clarification of the systematics of the order Carnivora (Cuarón et al., 2004; Clavijo and Ramírez, 2009).

Although some authors consider that conservation efforts do not require an understanding of all aspects for the species of interest (Ginsber, 2001), knowledge of ecological requirements is necessary, especially in cases where the risk

of extinction is found to be significant, to appropriately channel conservation actions and resources (Ginsberg, 2001; Meiri, 2005; Jennings and Veron, 2009). However, the lack of studies on groups of species may hamper the accurate identification of their conservation status within each region, there may be discrepancies in terms of risk category assessment between the local conservation perspective and the global conservation perspective (Dalerum et al., 2009). As a result of this situation, only a few of the species in this order have been classified in a higher risk category in the international context (Schipper et al., 2008; IUCN, 2010). Therefore it is advisable to collect information on various aspects of threatened species in order to make it possible to reevaluate the conservation status (Schipper et al., 2008).

FINAL RECOMMENDATIONS

Some research indicates that the regions of Asia, Africa and South America have high species richness (Mills et al., 2001; Dalerum et al., 2009). However, is in these places where a large number of species are at risk (Servheen et al., 1999; Cardillo et al., 2004; Mills et al., 2005). Despite this diversity and degree of threat, these regions do not excel in the number of published studies. It would be important to increase the number of studies on native species of these regions before the environmental changes drastically affect these populations.

Future research should be directed towards addressing topics other than natural history, such as genetics, habitat selection, activity patterns, or zoonotic issues. Similarly, it is advisable to expand the scope of future studies to include little studied groups, especially threatened species, small-sized species, and species which are not very abundant or charismatic. Given this situation, the study of aspects such as population trends or demography, as well as community level ecology, is needed in order to understand under what circumstances or through what ecological patterns, communities are developed and maintained, with the aim of maximizing the effectiveness of conservation actions and resources.

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