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Jaguar (*Panthera onca*) food resource use and its interaction with humans: scoping review

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Abstract

A scoping review was conducted to map, summarize, and understand the extent of evidence on jaguar (Panthera onca) food resource use and its interaction with humans. A total of 105 studies were identified in electronic databases: 57 analyzed jaguar food resource use, and 48 described jaguar interactions with humans. The studies were published in 51 journals, mainly in English, from 1993–2021 in 14/19 countries where jaguars live. The evidence demonstrated the variability and prey consumption of the jaguar; there are contrasting results regarding the diversity of prey consumed. The frequency of livestock predation was found to be related to the abundance and availability of natural prey and the distance of ranches from the jaguar habitat. The interaction of the jaguar with humans presented an interesting and contrasting picture, since the perception of the jaguar varied depending on the sociocultural context and the study site. The results showed a negative effect of human activities on the distribution and density of the feline, and there was evidence of poaching and attacks on humans, although the information was insufficient to determine the causes in depth. More research and dissemination are needed on these issues at the local level in the regions where the jaguar lives, as these are the areas where decisions and actions are needed to conserve the jaguar in coexistence with communities and livestock.

Keywords: Conservation; Predators; Livestock; Perceptions; Spatial ecology; Large cats.

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Study contribution

Jaguar is the largest feline in the Americas. Its distribution and abundance are related to the presence of prey and the type of vegetation, although its habitat range has decreased due to anthropogenic activity, which threatens its permanence and ecological function as a predator. We conducted a scoping review to map and summarize research on jaguar food resource use and its interaction with humans. Our results suggest a variable perception of the jaguar, depending on the study site and sociocultural aspects. We identified potential negative effects on jaguar distribution and density in different scenarios due to the impact of human activities on the jaguar. We found variability and differential patterns of jaguar prey consumption and detected that the frequency of predation on livestock is related to the abundance of their natural prey.

Introduction

The jaguar (*Panthera onca*) is the largest feline in the Americas, inhabiting 8.7 million hectares that correspond to 46 % of its original distribution[1] and has an estimated population that ranges between 30 000 and 170 000 individuals,[2] which are distributed mainly in the Amazon basin.[3] Several studies have exposed the degree of vulnerability of the jaguar to the loss and fragmentation of its habitat,[4-6] that has had negative effects on its distribution, abundance and genetic diversity.[7] Therefore, the species has been cataloged as threatened,[8] its trade is prohibited,[9] and in several countries such as Argentina, Costa Rica and Mexico, it is considered a species in danger of extinction.[6, 10, 11]

To prevent the extinction of the jaguar, it is necessary to maintain its local populations and the connectivity of its distribution area,[3, 12] as well as to make human activities compatible with the conservation of its habitat and natural prey.[13] The alteration of the forests and jungles where jaguar lives is mainly due to changes in land use, landscape transformation, and increased human activity.[14] These factors have not only negatively affected the habitat and distribution of the feline but have also generated a growing human-jaguar conflict that threatens its conservation.[13] In addition, the population variability of its prey, linked to the decrease in prey due to hunting by humans,[15] has increased the risk of livestock predation that regularly ends with the killing of the jaguar in retaliation for the alleged attacks.[16, 17]

Understanding the feeding habits and prey consumption of the jaguar is important to propose conservation strategies that avoid the reduction of its prey and mitigate predation on livestock.[17, 18] In this sense, abundant and diverse information has been generated on the feeding habits and prey use of the jaguar.[19, 20]

Likewise, because human-jaguar interaction is one of the main threats facing jaguar populations,[13] it is necessary to understand the perceptions and perspectives of people living in areas close to jaguars or even affected by jaguars. Negative perceptions are generated by the fear of livestock predation and accidental attacks on people,[21] which influence attitudes and behavior, such as the killing of jaguars, and can affect social acceptability, which also varies regionally.[22] However, there are also positive perceptions associated with the ecological value of the species that facilitate the coexistence and conservation of the feline.

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Due to the importance of the social component in jaguar research, recently, the interaction of the jaguar with humans has been studied more intensively, which has been fundamental to understanding and evaluating the perceptions and attitudes of people toward the jaguar. This has provided the basis for addressing the problem of extinction of the species and defining conservation strategies that allow for peaceful coexistence between predators, local communities, and livestock.[23]

The results of this study represent a basis for a better understanding of the extent of jaguar studies within both approaches, since it will allow us to know how the jaguar is perceived, as well as the main characteristics of its feeding habits and its main prey. This summary of the evidence is important to better understand the jaguar-human interaction and to establish strategies to reduce hunting of jaguar prey and thus potentially reduce attacks on livestock.

Methods

In this research, a scoping review was conducted to classify, summarize, and disseminate the results of research addressing jaguar use of food resources and their interaction with humans. A scoping review is a secondary study representing a current and novel way to gather, synthesize, and present abundant volumes of studies of a specific topic.[24] Scoping reviews are based on an explicit methodology that follows a rigorous systematic process to search, select, and synthesize the most relevant sources of evidence within a field of study.[25]

Additionally, scoping reviews allow summarizing findings from a body of evidence that is heterogeneous in its methods or approaches.[26] Consequently, they are an appropriate methodology for making evidence-based recommendations to stakeholders involved in decision making.[27]

Protocol and research objectives

The research was conducted following a protocol that was developed a priori in accordance with the PRISMA-P (Preferred Reporting Items for Systematic Reviews and Meta-analysis Protocol) statement[28] and is available upon request to the corresponding author. The study was reported in compliance with the PRISMA-ScR extension for scoping reviews.[26] The objectives of the scoping review were stated according to the methodological framework proposed by Arksey & O'Malley.[25] The study aimed to summarize and disseminate research findings from publications reporting jaguar use of food resources and their interaction with humans. To accomplish this objective, we first classified and mapped the research into the different fields of study and then summarized the research findings according to particular areas of study to generate a summary of results for decision-makers.[25]

Eligibility criteria

Due to the nature of the research, the POS approach (Population, population; Outcomes, study variables; Study, type of study) of the PRISMA statement[29] was chosen to define the inclusion criteria. Table 1 summarizes the definitions of each criterion. In brief, primary and secondary research available in full text and published

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in English, Portuguese, or Spanish from 1980 to December 2021 that included jaguar (*Panthera onca*) as a primary or secondary subject either in the wild, in captivity, or in theoretical/modeling studies was considered. Additionally, the studies had to include at least one of the defined variables: 1) interaction with humans and 2) food resources. This study excluded gray literature (unpublished studies) to ensure a homogeneous and comparable level of methodology among the selected studies.[30]

Sources of information

To obtain the publications, we searched PubMed, Scopus, Virtual Health Library (VHL), ScienceDirect, Web of Science, and CAB abstracts. To this end, the search terms were defined on the basis of pilot searches in which the terms that yielded the best results were evaluated and selected, judging by the number of records found and their relevance to the topic evaluated. Table 2 presents representative examples of search commands for two electronic databases according to the groups of variables included in the study.

Search process

The search process in the electronic databases was performed by a single reviewer from February 22 to March 05, 2020, and then updated on December 2021. In all databases, the searches were limited to the title and abstract of the records, and the methodological filters available in each database were used (for example: type of document, language, search period, availability of the study, among others). Additionally, to find additional studies that were not identified by the search process, a second reviewer cross-checked the references of some articles. Once the search process was completed, the records of the studies found were downloaded and added to an EndNote X9 library (Clarivate, USA).

Selection of the sources of evidence

Before the study selection stage, duplicate records were removed from the library, first automatically and then manually, by reviewing the records for repeated studies. To complete the study selection process, we first applied the selection criteria to the titles and then to the abstracts, thus eliminating all studies unrelated to our topic. Second, full-text articles were obtained for the eligibility process, for which an eligibility form based on the inclusion criteria was applied. Before its application, pilot tests were carried out with the eligibility format using 5 % of the total number of studies to be evaluated. The evaluation process of the eligibility format as well as the final selection of the studies included in the scoping review was performed by a single reviewer.

Data chart creation

To create the data tables, a single reviewer extracted the most relevant information from the selected studies, which was then verified by a second reviewer. To conduct the process, the reviewers developed an extraction format that was standard-

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Table 1. Eligibility criteria with the POS approach and search commands for electronic databases

Criteria	Definition	Search terms
(P) Population	Studies that directly or indirectly include jaguar (Panthera onca) individuals, either in preservation (management in facilities created for this purpose) or conservation (free living in natural habitat), as well as any related aspect.	jaguar OR *Panthera onca* OR panther OR felidae OR neotropical mammals OR felids OR big cats OR big carnivores
(O) Outcomes*	**Human interaction:** includes studies reporting jaguar hunting, attacks on humans, predation of domestic animals (mainly cattle), habitat loss and fragmentation due to agriculture or community expansion.	human-jaguar OR poachers OR conflict OR perception OR attacks
	Food resources: includes studies describing the presence and density of natural jaguar prey in the habitat used by jaguars, as well as feeding patterns.	diet OR feces OR prey OR depredation OR food availability OR foraging ecology OR feeding OR hunt OR peccary OR deer OR tapir
(S) Study	Only primary and secondary studies published as full-text peer-reviewed articles in English, Portuguese or Spanish will be included. The publication period considered was from 1980 to December 2021.	

* The studies included at least one of the defined variables.

Table 2. Examples of search commands in electronic databases

Database	Search command
PubMed	**Food resources:** ((jaguar[Title/Abstract] OR Panthera onca[Title/Abstract] OR panther[Title/Abstract] OR felidae[Title/Abstract] OR neotropical mammal[Title/Abstract] OR felids[Title/Abstract] OR big cats[Title/Abstract] OR big carnivores[Title/Abstract]) AND (diet[Title/Abstract] OR feces[Title/Abstract] OR prey[Title/Abstract] OR depredation[Title/Abstract] OR food availability [Title/Abstract] OR foraging ecology[Title/Abstract] OR feeding[Title/Abstract] hunt[Title/Abstract] OR peccary[Title/Abstract] OR deer[Title/Abstract] OR tapir[Title/Abstract])) **Human interaction:** ((jaguar[Title/Abstract] OR Panthera onca[Title/Abstract] OR panther[Title/Abstract] OR felidae[Title/Abstract] OR neotropical mammals[Title/Abstract] OR felids[Title/Abstract] OR big cats[Title/Abstract] OR big carnivores[Title/Abstract]) AND (human-jaguar[Title/Abstract] OR Poachers[Title/Abstract] OR conflict[Title/Abstract] OR perception[Title/Abstract] OR attacks[Title/Abstract]))
Scopus	**Food resources:** TITLE-ABS-KEY (jaguar OR Panthera AND onca OR panther OR felidae OR neotropical AND mammal OR felids OR big AND cats OR big AND carnivores) AND (diets OR feces OR prey OR depredation OR food AND availability OR foraging AND ecology OR feeding OR hunt Or deer OR tapir OR peccary) **Human interaction:** TITLE-ABS-KEY (jaguar OR panthera AND onca OR panther R felidae OR neotropical AND mammals OR felids OR big AND cats OR big AND carnivores) AND (human-jaguar OR poachers OR conflict OR perception OR attacks)

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ized by pilot testing in 5 % of the randomly selected studies. The authors of the studies were not contacted to corroborate the extracted information.

Extracted variables and summary of results

The following was extracted from the included articles: 1) general characteristics of the study, main author, year of publication, journal, journal focus and country of origin where the study was conducted; 2) main characteristics of the study population, species evaluated, conservation/preservation status of the animals (free-living or captive) and study focus (includes jaguars or based on records, theoretical models or questionnaires); 3) objective, a brief description of the main objective, 4) methodological description, a brief description of the methods and techniques used to develop the research; and 5) main findings, a detailed description of the results of the research. All the information extracted was entered into an Excel database to facilitate data management. Additionally, graphs were constructed in Prism 9 (GraphPad, Inc. Software, CA, USA) to map the jaguar research.

Results and discussion

Selection of the sources of evidence

In total, 1 096 publication records were obtained from the database searches. PubMed and VHL contributed 71.7 % of the records (786/1 096). Additionally, another 24 publications were identified from cross searches. After the elimination of duplicates, 645 publications were included in the selection process. Subsequently, 493 publications were discarded based first on title review and then on the abstract, leaving 151 records that were retrieved in full text. During the eligibility process, the inclusion criteria were applied to the full texts, and as a result, 46 publications were excluded for the following reasons: they did not include the defined population (15), they presented a different approach to that defined (9), they did not correspond to the defined type of study (14), and they did not include the defined variables (8). Finally, 105 publications were included in the narrative synthesis, of which 57 focused on evaluating feline feeding habits and 48 addressed the study of jaguar-human interactions (Figure 1).

Except for two studies with a global focus, the rest of the publications were conducted within the Americas (Figure 2B). Regionally, research was conducted across the continent, with half of the publications (51.4 %) coming from South America and a similar number of studies were conducted in North and Central America (21 and 22 studies, respectively). A total of 88.6 % of the publications (93/105) were from a single nation and included 14 of the 19 countries in the Americas where the jaguar is distributed. Brazil and Mexico contributed the largest number of studies on the subject (30 and 21 studies, respectively), followed by Costa Rica, Belize, and Venezuela with 10, 8 and 6 publications, respectively. Argentina, Bolivia, Colombia, Colombia, Guatemala, and Paraguay contributed between 4 and 2 studies each, while Ecuador, Guyana, French Guyana, and Nicaragua contributed one study each.

Although our review identified sources of evidence from all three regions of the continent and at least 14 different countries in which at least one study on the jaguar was reported, most of the research was conducted in North and South America,

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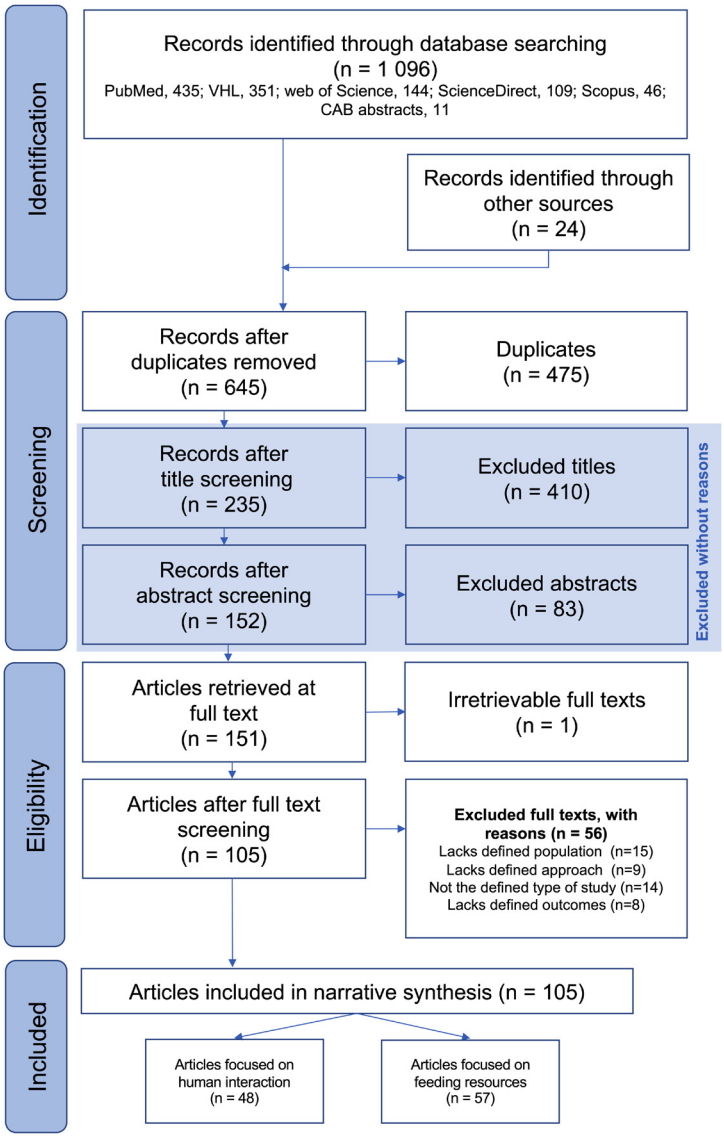

Figure 1. PRISMA flow diagram of the selection of articles included in the scoping review.

mainly in countries such as Brazil and Mexico. This result not only demonstrates a great interest in jaguar research in both countries but also highlights the disparity of publications among the other countries of the continent; consequently, it is necessary to encourage research and publication on the jaguar in those countries where no research was found, as well as to increase the number of studies in countries that have few sources of evidence.

It is also necessary to strengthen international collaboration between academic and government institutions, as well as to seek sources of funding to conduct studies in low-income countries, as is done by the Mexican Ministry of the Environment and Natural Resources,[31] which, through its Action Program for Jaguar Conservation, allocates funds for research and conservation. Similarly, collaboration between the social sector and academia is fundamental to foster participation and linkages between communities and local authorities to support jaguar conservation efforts.[2]

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In total, 100/105 studies included in the review were primary research, of which 60 % included free-living jaguars and conducted monitoring or field collections, while 35.2 % of the research was based on theoretical aspects, databases, records, or interviews. The five secondary investigations were based on literature reviews, systematic reviews, or meta-analyses to analyze different aspects related to jaguars and other felids (Figure 2C).

Results of the sources of evidence of the approaches analyzed.

The 105 research papers were published in 51 journals, among which nine journals accounted for 51.4 % of the total publications, with *Biological Conservation* (18), *Plos One* (8), *Revista de Biologia Tropical* (6) and *Oryx* (5) being the top four. The remaining journals had 1-2 publications each (Figure 2D).

Most of the sources of evidence we identified were published in journals specializing in conservation, wildlife, species biology, biodiversity, and ecology, indicating the importance of research in these areas to improve our knowledge on the jaguar. However, it also highlights the fact that 51.4 % of the sources of evidence we included were published in only 9 of the 51 journals we identified in the review, reflecting that research on the feline is concentrated in a small group of journals. Additionally, most of the research (91.5 %) was published in English, which is important in terms of knowledge dissemination. At the same time, however, it implies a restriction in communicating the results to non-English speakers, who predominate among the countries where the jaguar is distributed and where most of the research is carried out.

Studies focused on the use of jaguar food resources

According to Figure 3A, the 57 studies that evaluated the use of jaguar food resources were subdivided into natural food sources (45) and livestock predation (12). Within the first category, 33 studies focused on describing the feeding habits of the jaguar, of which 26 studies evaluated the consumption of jaguar prey in different scenarios,[32-57] and seven determined the predation habits of the jaguar on some aquatic species.[58-64] The remaining 12 studies that evaluated natural food sources analyzed the variability and availability of the jaguar's prey base, which refers to the richness and abundance of the prey most frequently consumed by this feline.[65-76] Finally, of the 12 publications that focused on livestock predation by the jaguar, seven studies described and analyzed the characteristics of attacks,[77-83] while the remaining five evaluated the risk factors for attacks.[84-88]

Synthesis of results from evidence of food resource use

Table S1 summarizes the main results of the 57 studies that evaluated jaguar food resource use. The studies that examined jaguar prey consumption show that felids prey most frequently on large mammals such as deer (*Odocoileus virginianus*), followed by medium-sized animals such as peccaries (*Pecari tajacu*) and capybaras (*Hydrochoerus hydrochaeris*), and less frequently on smaller mammals such as coatis (*Nasua narica*) and armadillos (*Dasypus novemcinctus*).[89] However, studies present contrasting results regarding the diversity of prey consumed by

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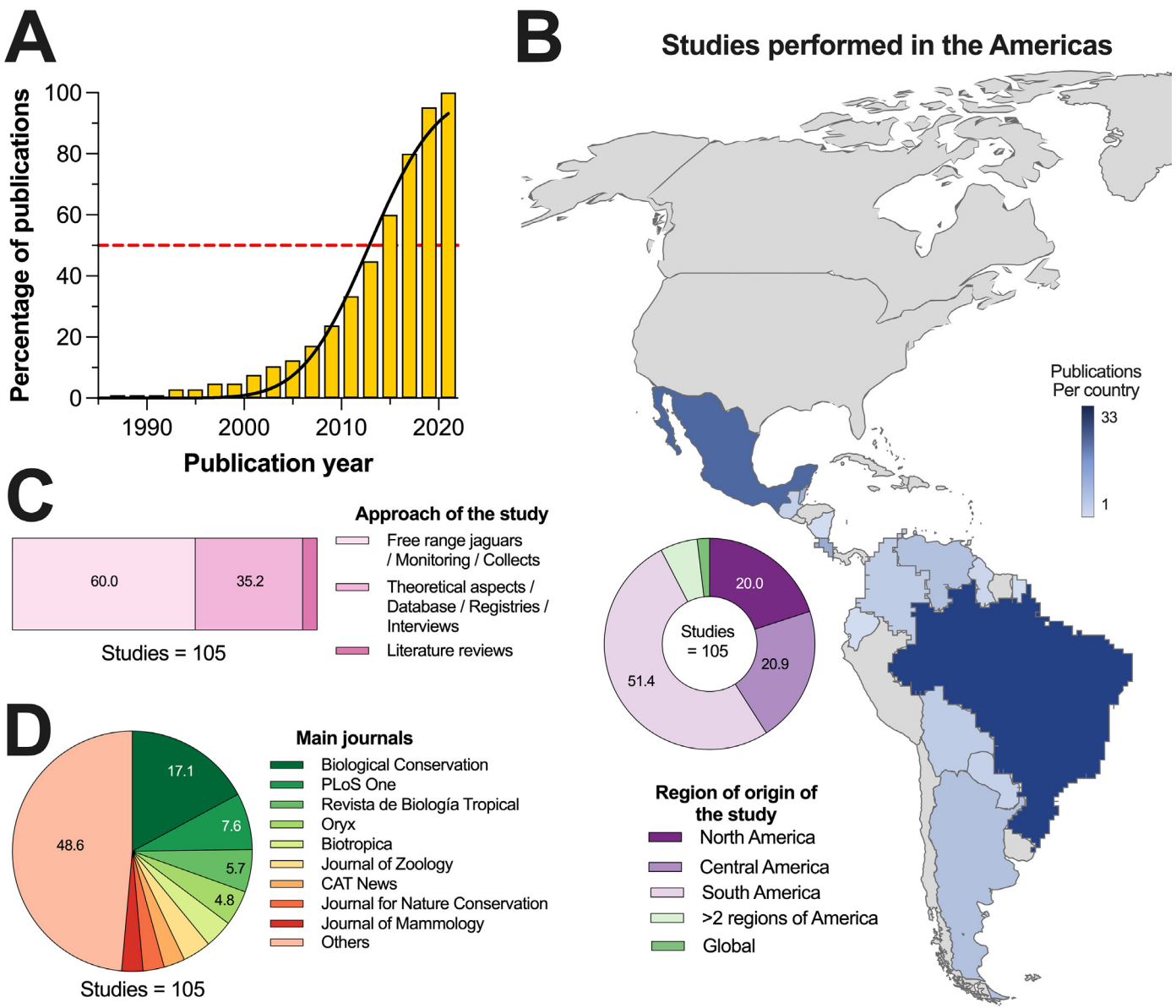

Figure 2. A) Cumulative distribution of studies published between 1985 and 2021, B) percentage of studies by region of origin of the research and distribution of studies by country in the Americas, C) percentage of studies according to focus and D) top ten journals where the studies were published.

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jaguars, as some studies indicate that prey diversity was low, while other studies indicate a high diversity because 12 to 15 remains of different species consumed by jaguars were found.

Evidence sources showed that jaguars commonly consumed 15 to 28 different prey species.[33,43,48] At some sites in South America, 61 species[76] and up to 153 prey were recorded for the Pantanal region of Brazil.[53] Furthermore, studies analyzing predation on aquatic species show that jaguars also consume turtle eggs and adult turtles, as well as crocodile (Crocodylia) eggs and specimens,[63,64] without posing a threat to these populations. Furthermore, the results suggest that jaguars tend to share prey with other jaguars during the turtle nesting off-season.[58,59]

Taken together, the results of this scoping review demonstrate that jaguars may exhibit diverse patterns of prey consumption, which not only depend on prey size but also vary depending on prey availability and the sites where research was conducted. It also highlights the fact that the jaguar's food resources are shared with at least four other large predators: puma (*Puma concolor*), ocelot (*Leopardus pardalis*), jaguarundi (*Herpailurus yagouaroundi*) and margay (*Leopardus wiedii*).[75] In some sites, competition between the two felids is not reported,[57] and coexistence between them is a function of temporal segregation,[73] biotope partitioning[32] and prey size spectrum.[47,52]

Research focused on analyzing the effect of prey richness and availability on jaguar feeding habits not only shows the relationship between the selection of different types of prey available within an environment but also reveals an association between habitat characteristics, its degree of conservation and prey availability, which affects jaguar feeding patterns.[36,42] For example, livestock predation occurs more frequently in areas distant from ranches, while human activities such as agriculture limit the presence of the jaguar and its prey base.[86] Studies show that in different nations, there are favorable conditions to be used as potential habitats for the jaguar and its prey, in addition to the fact that a greater diversity of prey is reported in conserved areas, as well as a higher density of jaguars where there is greater prey abundance.[84]

Targeted and constant consumption by poachers of large jaguar prey such as deer (Cervidae) and bush pigs (Tayassuidae)[70] predicts an unsustainable wildlife exploitation model and puts jaguar populations at risk.[41] In addition, a positive correlation between jaguar density and prey availability has been previously documented,[67] as well as the existence of anthropogenic activities that limit the presence of jaguars and their larger prey.[44] Therefore, more information is needed by country or region regarding jaguar population parameters and prey availability to make predictions about the needs of this feline.

Studies that provide evidence on livestock predation by jaguars suggest the existence of different factors that increase the risk of attacks, including reduced diversity and abundance of natural prey, as well as the disturbance of the natural environment, the distance of pastures or feeding areas from forests (the shorter the distance, the greater the predation) and the season of the year (greater predation during the dry season).[79-81]

Regarding jaguar preference toward livestock characteristics, studies presented contrasting information because some studies indicate that all age classes are consumed,[77,83] while other studies indicate consumption of adult animals and finally, other studies indicate a selection based on biomass and prey size due to

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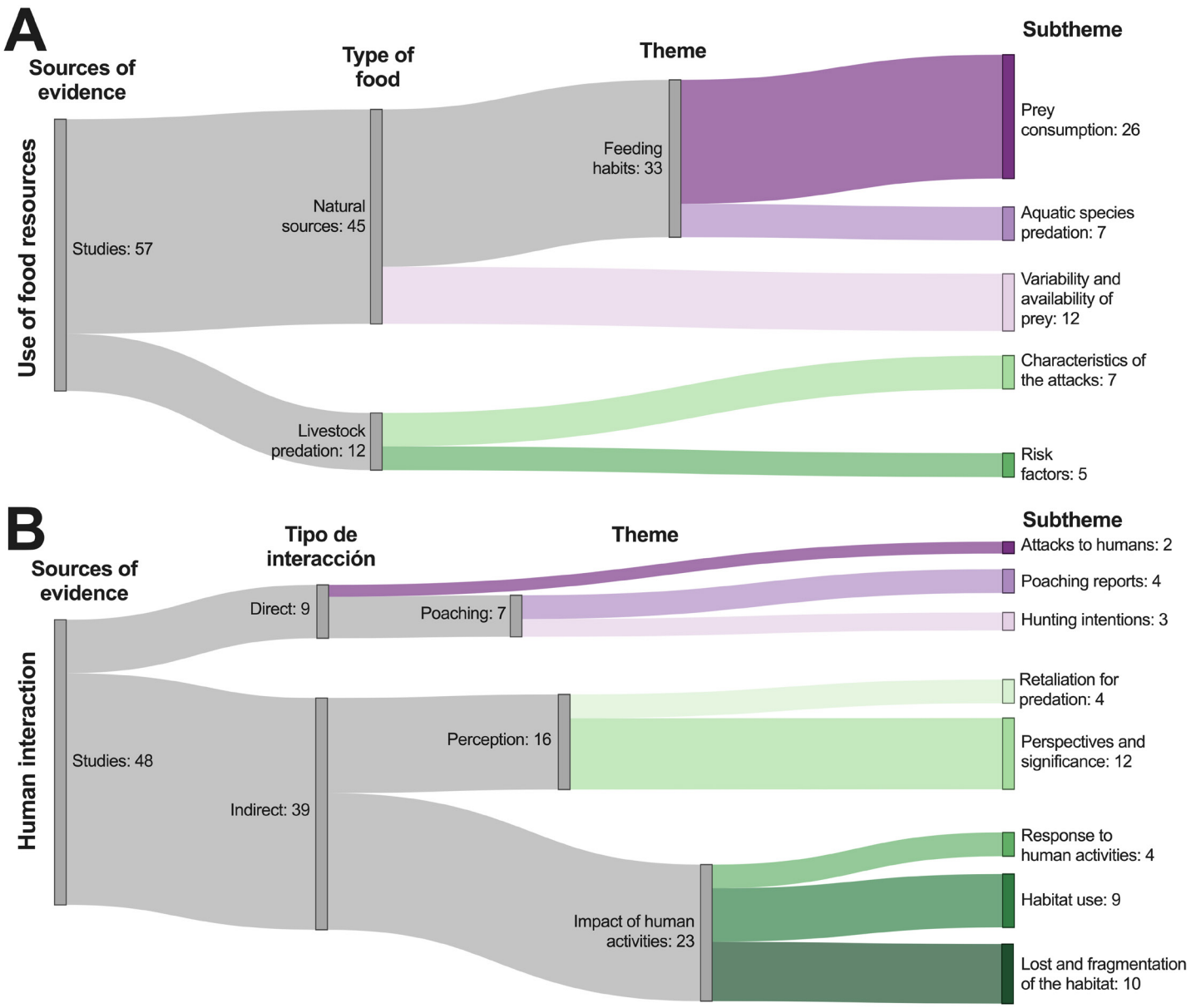

Figure 3. Sankey plot of the classification of the 105 studies included in the scoping review according to research focus and subthemes: A) jaguar food resource use and B) human interaction.

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the consumption of young, low weight calves.[82] In relation to attacks on domestic animals, the studies we included provide evidence of livestock predation by the jaguar.[79,87,90] Attacks were associated with low prey abundance and proximity to conserved forests; however, according to some estimates, livestock losses are not significant, as they ranged from 0.9 to 2.8 % of the total herd size.[83,86]

The sources of evidence suggest heterogeneity with respect to the size of cattle preferred by jaguars, since this can vary from calves to adult specimens of greater body mass, some studies have evidenced the tendency of attacks toward calves from 3 to 9 months of age.[80,82] In our review, no reports of cattle predation by jaguars were found in any of the countries where this species is distributed. Consequently, it is possible that the prevalence of attacks on cattle could be higher when extending research on the subject to the rest of the countries or even when evaluating other natural predators such as the puma, which present higher predation rates than the jaguar.[55]

In some cattle-ranching regions of Brazil, no attacks or livestock consumption have been recorded for more than 20 years thanks to improved livestock practices.[43] In addition, it is also necessary to consider that most livestock depredation events are not reported because ranchers retaliate directly against the feline, resulting in killings. Mexico is the only country that has economic funds to compensate for damage from attacks and losses derived from jaguar and other wild carnivore predation.[91] Nevertheless, ranchers rarely report predation-associated losses to the authorities. Perhaps, they are either not aware of the program, or they are reluctant to go through cumbersome bureaucratic requirements, which usually have long response times.

In any case, it is necessary to make a pertinent evaluation to determine the reasons why the compensation program is not working as expected for the good of the farmers. Additionally, it is essential to maintain continuous monitoring in places where there is greater conflict between ranchers and jaguars, as well as to better understand the perception of the jaguar on the part of the affected people, so that potential solutions and alternatives can be proposed to avoid retaliatory hunting.

Studies focused on aspects of jaguar interaction with humans.

A total of 48 publications focused on topics related to jaguar interaction with humans. As shown in Figure 3B, publications were classified according to the type of interaction: direct interactions, with nine studies subdivided into attacks on humans (2) and poaching (7); and indirect interactions, with 39 studies distributed in the subcategories impact of human activities (23) and perceptions of the jaguar (16).

Of the nine studies that evaluated direct jaguar-human interactions, two publications reported attacks on humans,[92,93] four studies presented reports of hunting[94-97] and three other studies analyzed the intention to hunt the feline by ranchers and residents of areas adjacent to jaguar habitat.[98-100] Among the 16 publications that focused on perceptions of the jaguar, 12 studies evaluated the meaning and perspectives that people have about the jaguar and its conservation,[90,101-111] and four studies analyzed perceptions of the cat associated with livestock predation and potential retaliation.[112-115]

Of the 23 investigations that included the impact of human activities on the jaguar, four studies evaluated the response of jaguars and their populations to dif-

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ferent human activities,[116-119] nine studies determined jaguar habitat use and the factors that affect its distribution according to changes induced by human activity in different scenarios[120-128] and finally, 10 studies analyzed the effect of habitat loss, fragmentation and transformation of jaguar habitat due to human activities.[129-138]

Synthesis of evidence of jaguar-human interaction

Table S2 summarizes the main results of the 48 studies that evaluated jaguar-human interactions. Among the publications that reported poaching or intention to hunt jaguars in rural regions or natural protected areas, two studies presented no reasons why the cats were hunted, while two other studies presented several potential causes for hunting: hunting trophies, commercial or subsistence hunting, and the risk posed to human life.

Among the studies, contrasting evidence was presented regarding the intention to hunt the jaguar; in some cases, disagreement with the killing of the feline was reported, while in other cases, interviewees expressed their dislike for jaguars and their intention to hunt them, mainly out of fear, to prevent possible attacks on livestock and as hunting trophies. Similarly, retaliatory hunting for attacks on livestock was occasionally mentioned as the main factor for killing, whereas in other studies, this factor was not the most common cause of killing. In our review, only four studies that reported jaguar poaching were included, so it is possible that the search results do not largely reflect the reality faced by jaguar populations with respect to this threat.

It is therefore necessary to increase field work and build confidence so that people will dare to cooperate. In addition to intensifying literature searches with broader criteria that allow the integration of valuable information that may be in theses, reports and other documents published with guidelines that do not correspond to the criteria and search engines defined for this publication.

It is necessary to apply greater efforts to achieve the conservation of the species, integrating the needs of people and communities, including the livestock sector that in some cases have been willing, with information and incentives, to improve their practices and conserve the jaguar.[102] Recently, a systematic review on the livestock-natural predator conflict reported that economic compensation and livestock management strategies were the most effective measures to promote jaguar conservation.[107]

The two studies that reported attacks on humans included three nonfatal attacks (of which one person was attacked on two occasions)[92,93] and one fatal attack.[93] Both studies described the characteristics of the victims, as well as the place where the attack occurred, although they do not present the possible causes for which the people were attacked, so there is no evidence on the reaction of jaguars in the wild when they are in proximity to humans or the specific reasons that provoke attacks on humans. In the two studies that reported jaguar attacks on people, there is not enough evidence to point to the jaguar as an element of constant and imminent danger to humans. The cited cases provide valuable evidence to inform about the risk of hunting and the possible situations of jaguar presence and/or attacks in dense jungles. Despite these cases in South America, it is not possible to point to the jaguar as an element of constant and imminent danger to humans, for which more evidence is needed. Fortunately, in the literature reviewed,

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no similar facts were found for North and Central America; perhaps it is necessary to intensify the search for case reports or consider other search criteria to generate more information on both topics. It is necessary to conduct a review with another approach that incorporates both gray literature and specialized web pages that open this panorama.

Studies focused on analyzing the perception toward jaguars have evidenced a contrasting perspective, which varies between the different regions where jaguars are distributed and the human populations in those areas. People working in forested areas or near protected areas think of the jaguar as a beneficial species because it attracts tourism, help reduce crop depredation and are in favor of protecting the species. In contrast, ranchers and people living in urban areas perceive the jaguar as a predator of livestock and as an animal they are afraid of, so they would intend to kill a specimen; for the most part, their opinions were based on their own experiences and not on situations they have experienced.[90, 101] Rural populations do not perceive the jaguar as a threatening species, although some ranchers believe the opposite. Indigenous populations see the jaguar as a species with which they can share their habitat but also as an animal that they can use for food, medicinal purposes and ornaments, although in some cases, it is also perceived as a dangerous animal.[105, 110]

Research on the perception of the jaguar is scarce and with contrasting results, so there is not sound evidence to generalize how these felines are perceived by humans that coexist with them in neighboring areas or within the reserves. Furthermore, research results suggest that the perception of the jaguar varies among the different regions and countries where research was conducted and even among cultural groups.[90, 106] For example, in Mexico, the jaguar has emerged as a species of great biocultural value recognized for its edible and medicinal use,[105] as well as for its beauty and role in ecosystems, reasons for which local people suggest that it deserves to live.[15, 102] However, it is also recognized as a noxious animal.[81] In a study on jaguar perception in Brazil, the authors found a gradient ranging from a positive perspective (it deserves to live) to a negative one (killing it for predation to livestock or fear).[104]

Research focused on the impact of human activities shows that jaguars avoid areas with high human impact because their prey populations are reduced or absent in those areas; in addition, roads represent a danger to jaguars because they affect the abundance (by being run over) and distribution (habitat fragmentation) of jaguar populations. In areas where cattle ranching predominates, male individuals tend to be attracted to these places. Evidence suggests that these felids prefer forested areas and protected areas where human presence is almost nonexistent.

On the other hand, jaguar populations living in fragmented areas prefer to stay close to water sources (such as rivers) and may use some areas of human activity as corridors when these are adequately managed and integrate areas or fragments of forest dispersed in the area (ecological islands). This series of results suggests certain sensitivity of the feline species to the destruction and fragmentation of its habitats[15, 137] and natural corridors,[128] as jaguar subpopulations have been reduced, affecting their abundance and distribution at local, regional and continental levels.[3, 139-141]

Various investigations based on field information with phototrapping,[47, 70, 73, 120, 137, 142] telemetry,[35, 60, 87] and compiled or published re-

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cords[48, 107] have modeled various scenarios for the subpopulations of the feline, thus providing further evidence for the hypothesis that the populations are negatively affected by the development of poorly planned anthropogenic activities executed under unsustainable schemes. Human activities that threat jaguar survival include cattle ranching, dam and road construction, and deforestation,[68, 128] while sport hunting and retaliatory killing[70] for livestock depredation[35,66,86,143] represent a cumulative risk to jaguars.

Contrasting results were found on some topics because some sources of evidence evaluated the possible negative impacts of anthropogenic activities on the jaguar and suggest that the cats may not adapt to the changes and perish as a result.[101, 128, 137] However, other studies have mentioned that the jaguar has the capacity to adjust to disturbances coming from ecotourism by modifying its periods and activities[123, 126] and using constructed trails.[76] However, it is also possible that the adaptation is due to the level and intensity of the disturbance,[121-124] and to the differentiated behavior between females and males.[128]

In the analysis of jaguar interaction with humans, particularly about the impact of human activities, we found 23 studies representing 48 % of the findings that show the impact of anthropogenic activities on jaguar populations. In this sense, we can mention that major changes in the landscape (such as the construction of dams) may not constitute a barrier for the jaguar, since being great swimmers, they may not limit their passage,[132] but they do destroy highly productive habitats and with it the richness and abundance of prey species on which the feline depends.[130]

Despite this, jaguars can survive in landscapes dominated by agricultural activities that are integrated by a network of preserved patches of natural vegetation that ultimately form a biological corridor that allows the jaguars, their prey, and the rest of the fauna to connect. These corridors include riparian environments, wetlands[120] and mountains or rugged terrain that allow jaguars and their prey to remain and protect themselves. Another risk factor is the loss of individuals due to road traffic collisions;[139, 144] however, it is necessary to conduct research on all these issues considering local scales and permanent monitoring to evaluate these assumptions in greater depth.

Limitations

Our scoping review has some limitations. First, to maintain an adequate and comparable methodological level among the studies, we only included sources of evidence published in full text in peer-reviewed journals, so all gray literature was excluded from the review. It is possible that this decision generates a bias on the information available on the topics covered in our review, since there are many reports, theses, registries, and other materials on the jaguar that were not included because they are considered gray literature. We also excluded chapters of published books, assuming the risk of excluding valuable information that contributes to the subject matter. Second, although we generated subcategories to classify the sources of evidence for each approach, there was occasionally great heterogeneity in the specific subtopics addressed in the studies. While such heterogeneity demonstrates the versatility of jaguar research, it also limits the ability to summarize the evidence and, in some cases, draw general conclusions about the body of evidence. Third, outside Brazil and Mexico, there was a huge disparity in the number of sources of

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evidence from the other countries where the jaguar lives, which may generate a picture of the jaguar-based mostly on the results of studies from both countries.

Conclusions

This scoping review demonstrated an interesting and sometimes contrasting picture of the evidence on jaguar-human interaction at the continental level. Generally, little evidence was found on poaching and attacks on humans, which did not allow us to understand in depth the causes of jaguar killing or the reasons why the feline attacked people. Our results showed a variable perception of the jaguar, which can be negative or positive depending on the study site and the previous experiences of the interviewees.

The evidence of the impact of human activities on the jaguar suggests negative effects on its distribution and density, which demonstrates the sensitivity of feline populations to anthropization of their habitats, although it also indicates a potential adaptation of the feline to human-induced changes in the environment. On the other hand, evidence on the use of food resources demonstrated the importance of research on the diversity and availability patterns of the jaguar's prey base and the way in which variations influence its diet. The frequency of attacks on livestock is related to the low abundance of the feline's natural prey, as well as the proximity of paddocks and feeding sites to conserved areas and away from ranches or human settlements. Nevertheless, the studies indicated that cattle predation does not represent significant losses in some cases, such as those involving large producers.

For small producers, in turn, who have less than thirty-five head of cattle or subsistence livestock, the loss of an animal may disrupt the family economy. Moreover, the compensation, or the time it takes to obtain it, does not compensate for the value of the lost animals.

This scoping review suggests the need to deepen socioenvironmental research, as a deeper understanding of the relationship between human communities and their environment is needed, with the valuation of the goods and services offered by biodiversity, especially the jaguar.

Efforts should include local scales with their sociocultural components that allow the evaluation of perceptions, attitudes, possible conflicts, and their solutions. Only in this way will it be possible to aspire to a possible and just conservation of the jaguar and its habitats based on scientific knowledge and the interests of the people and communities.

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Data availability

Databases for information mapping and evidence synthesis are available upon request from the corresponding author.

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Conflicts of interest

The authors have no conflict of interest to declare in regard to this publication.

Author contributions

For this study, we used the CRediT taxonomy to describe the Author contributions. Conceptualization, Research and Methodology: YRR, CB, DD. Data Curation, Software, and Visualization: YRR, CB. Project Administration and Supervision: SMG, DD. Writing-original draft: YRR, SMG, DD. Writing-reviewing and editing: YRR, CC, GC, DD.

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