



## EVALUATION OF LIVESTOCK MANAGEMENT PRACTICES AND THEIR RELATIONSHIP WITH PREDATORS IN CAMPECHE, MEXICO †

### [EVALUACIÓN DE LAS PRÁCTICAS DE MANEJO GANADERO Y SU RELACIÓN CON DEPRADADORES EN CAMPECHE, MÉXICO]

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## SUMMARY

**Background:** The management of negative interactions between livestock farming and predators is complex because of the multifactorial and dynamic nature of the underlying causes, which include human elements that complicate their management. Previous studies have shown that modifications in livestock management practices can significantly reduce these interactions. Therefore, it is crucial to identify the factors that promote these negative interactions to develop effective management strategies. **Objective:** To diagnose livestock management practices and their relationship with predators, exploring how these practices influence predation events and farmers' capacity to manage them. **Methodology:** Interviews and surveys were conducted with livestock farmers to gather information on their socioeconomic characteristics, livestock management practices, and perceived losses. The qualitative approach captured farmers' perceptions and their relationship with predators on their farms. **Results:** The results suggest that the interactions between livestock farming and predators are influenced by management practices that increase predation events and by farmers' limited capacity to manage them. The location of farms in fragmented landscapes exacerbates this situation, indicating the need to strengthen farmers' capacities. The meaning of the livestock and dependence of ranchers on diverse activities hinder the implementation of new livestock management practices. **Implications:** The study identifies possible key strategies, such as forage banks, electric fences, and vaccination programs, to reduce predation risks and improve livestock farming sustainability. These strategies should consider the economic and cultural contexts of ranching communities for effective implementation. **Conclusion:** Ranchers' management decisions are strongly shaped by cultural and traditional factors. Including ranchers in the codesigning of conservation strategies, together with education and capacity-building, is essential for align conservation efforts with their values and needs to ensure long-term success.

**Key words:** tropics; human-wildlife conflicts; carnivores; livestock; conservation.

## RESUMEN

**Antecedentes.** El manejo de las interacciones negativas entre la ganadería y los depredadores es complejo debido a la naturaleza multifactorial y dinámica de las causas subyacentes, que incluyen elementos

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humanos que complican su gestión. Sin embargo, estudios previos han demostrado que las modificaciones en las prácticas de manejo ganadero pueden reducir significativamente estas interacciones. Por lo tanto, es fundamental identificar los factores que favorecen estas interacciones para desarrollar estrategias de manejo eficaces. **Objetivo:** Diagnosticar las prácticas de manejo ganadero y su relación con los depredadores, explorando cómo estas prácticas influyen en los eventos de depredación y la capacidad de los ganaderos para gestionarlos. **Metodología:** Se realizaron entrevistas y encuestas con ganaderos para recopilar información sobre sus características, prácticas de manejo del ganado y pérdidas percibidas. El enfoque cualitativo permitió captar las percepciones de los ganaderos y su relación con los depredadores en sus ranchos. Resultados: Los resultados sugieren que las interacciones entre la ganadería y los depredadores están influenciadas por prácticas de manejo que incrementan los eventos de depredación y por la limitada capacidad de los ganaderos para gestionarlos. La ubicación de los ranchos en paisajes fragmentados agrava esta situación, lo que indica la necesidad de fortalecer las capacidades de los ganaderos. El significado y la dependencia de los ganaderos en diversas actividades dificultan la implementación de nuevas prácticas de manejo ganadero. **Implicaciones:** El estudio identifica estrategias clave, como bancos de forraje, cercas eléctricas y programas de vacunación, para reducir los riesgos de depredación y mejorar la sostenibilidad de la ganadería. Estas estrategias deben considerar los contextos económicos y culturales de las comunidades ganaderas para su implementación efectiva. **Conclusión:** Las decisiones de manejo de los ganaderos están fuertemente influenciadas por factores culturales y tradicionales. Involucrarlos en el codiseño de estrategias de conservación, junto con la educación y el fortalecimiento de capacidades, es esencial para alinear los esfuerzos de conservación con sus valores y necesidades, asegurando el éxito a largo plazo.

**Palabras claves:** trópicos; conflictos humanos-fauna silvestre; carnívoros; ganado; conservación.

## INTRODUCTION

Livestock farming in tropical regions is primarily extensive, relying on traditional practices and minimal technological inputs. Small and medium-sized ranches often experience limited economic returns, which are primarily influenced by the management practices employed by ranchers (Herrera-Tapia, 2009). Furthermore, the detrimental impacts of cattle ranching on the environment and biodiversity are well-documented and include soil compaction and depletion (Cingolani *et al.*, 2008), greenhouse gas emissions, the conversion of humid forests into pasturelands (Ellis, Hernández-Gómez and Romero-Montero, 2017), and landscape simplification (Williams *et al.*, 2017).

At the species level, livestock farming negatively interacts with certain wildlife, such as *Desmodus rotundus* bats, which are commonly regarded as significant rabies virus vectors (Silva-Caballero, Bender and Rosas-Rosas, 2022). Additionally, large carnivores like jaguars (*Panthera onca*) and pumas (*Puma concolor*) are involved in these negative interactions, which result in livestock predation and the retaliatory killings of these felids (Zarco-González, Monroy-Vilchis and Alaníz, 2013; Balbuena-Serrano *et al.*, 2021). Such conflicts have become meaningful threats to the conservation of these carnivore species, alongside the illegal trafficking of jaguar parts like tusks, skins, and teeth (AMMAC and WWF, 2022).

The drivers contributing to negative interactions between livestock and carnivores include various factors such as landscape characteristics

(Balbuena-Serrano *et al.*, 2021), the health conditions of the predators, and the availability of natural prey (Burgas, Amit and Lopez, 2014). The type and age of livestock also play a significant role in determining their vulnerability to predation, as younger animals and certain species are more susceptible to attacks due to factors like size, strength, or behavior. For example, most predation events for cattle occur with animals less than 1 year old (Amit, Gordillo-Chávez and Bone, 2013), while predators like coyotes primarily prey on sheep (Torres-Romero *et al.*, 2023). Deficient livestock management practices, however, are widely acknowledged as the primary drivers of predation events (Zarco-González *et al.*, 2018). Practices such as exposing the most vulnerable animals to predators in remote locations far from human settlements or allowing livestock to graze within carnivore habitats significantly increase the risk of predation (Peña-Mondragón *et al.*, 2017). Improving reproductive management, grazing systems, disease prevention, and parasite control not only enhances ranch productivity but also reduces livestock losses.

The conservation of predators like jaguars, pumas, and ocelots (*Leopardus pardalis*) within ranching landscapes depends on transforming current livestock management practices. This represents significant challenges and necessitates new research to contribute to establishing novel paradigms for livestock production and their mechanisms of adoption (Galindo *et al.*, 2016). One must understand how livestock farming is managed, the significance that ranchers attribute to this activity, and how they perceive the presence of felines on their ranches. In the

southeastern Mexico state of Campeche, where some ranches practice intensive cattle raising, most livestock farming in the state remains a low-tech activity with minimal management, stemming from national development policies promoted in the 1970s (Castillo *et al.*, 2014). Currently, livestock farming is considered one of the primary activities responsible for forest loss in Campeche (Ellis, Hernández-Gómez and Romero-Montero, 2017). At the landscape level, pasturelands are embedded in a matrix composed of arboreal vegetation fragments with varying degrees of disturbance close to large forest reserves of protected natural areas, which results in diverse landscapes that foster constant interactions with the surrounding biodiversity (Torres-Romero and Bender, 2024).

Livestock management practices in Campeche, combined with its landscape context, have fostered predation events involving jaguars, pumas, and ocelots (Piña-Covarrubias, Chávez and Doncaster, 2022). In recent years, coyotes (*Canis latrans*) have also emerged as a significant predator in the area, which is attributed to habitat fragmentation and forest's conversion into pastures and exacerbates livestock production challenges (Hidalgo-Mihart *et al.*, 2004; Torres-Romero *et al.*, 2023). Promoting and implementing coexistence strategies between livestock and carnivores requires a comprehensive understanding of the underlying processes, their significance, and their interactions with these species. Identifying the areas where management and conservation efforts should be directed is paramount. Given the significant influence of livestock management practices on carnivore-livestock coexistence, this study aims to construct a diagnostic of livestock management and its relationship with wild predators from the perspective of livestock ranchers. This understanding will inform the development of culturally and socially acceptable strategies to promote the coexistence between livestock farming and predator conservation in diverse and fragmented landscapes.

## MATERIALS AND METHODS

### Description of the study area

The study was performed in the Miguel Colorado (90° 39' 18.25''W, 18° 47' 7'' N) and San Pablo Pixtun ejidos (90°43'49.4" W, 19°08'05.9" N), both located in southeastern Mexico (Figure 1). These ejidos are considered key to maintaining connectivity because they spatially conserve forest remnants and secondary vegetation that enhance the connectivity between the protected areas of Laguna de Términos and the Balam-kú-

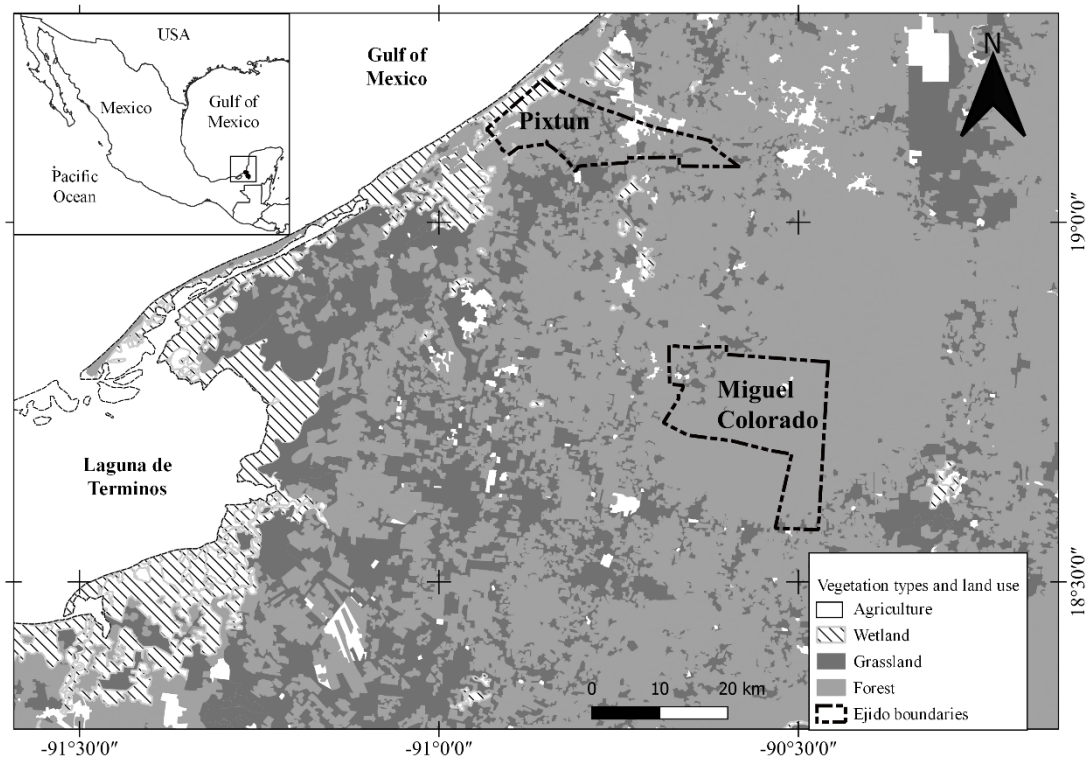
Balam kin-Calakmul protected area complex (Hidalgo-Mihart *et al.*, 2018). The ejido is a land tenure regime resulting from Mexican agrarian legislation with property rights based on rural settlements' common use of resources (Fig 1). The climate in the region is warm and subhumid, with an annual average temperature of 27°C. Annual precipitation ranges between 1,200 and 1,500 mm, mostly during summer. The rainy season goes from June to October, with intense rainfalls from tropical storms. The average rainfall is less than 60 mm during the driest months of the year (January to May) ((Instituto Nacional de Estadística Geografía e Informática (INEGI), 2017).

The area's relief is primarily flat with small hills, and the areas near the coast are subject to annual flooding during the rainy season, which can last up to 8 months. Both ejidos possess sub-evergreen medium forest cover and flood-prone lowlands with different degrees of disturbance (Arteaga-Aguilar *et al.*, 2014; Contreras-Moreno *et al.*, 2016). The main productive activities are agriculture, semi-extensive cattle and sheep raising, and apiculture (Arteaga-Aguilar *et al.*, 2014).

Twenty-nine medium- and large-sized mammal species have been reported in the region (Rangel-Negrín *et al.*, 2014). Among those that stand out are the tapir (*Tapirus bairdii*), the spider monkey (*Ateles geoffroyi*), the white-tailed deer (*Odocoileus virginianus*), the red brocket (*Mazama temama*), and the gray brocket (*Mazama pandora*). In addition, predators such as the puma, jaguar, and coyote in both localities are reported in conflicts of livestock predation, leading to some felines being killed in retaliation (Zarco-González *et al.*, 2018; Torres-Romero *et al.*, 2023).

### Diagnostic of livestock farming

Semi-structured interviews (Sierra, 1998) and the questionnaires (López, 1998) were used to describe the ranching practices. First, a semi-structured interview was applied to key actors from both ejidos (10 people per ejido). In this study, these stakeholders included ejido authorities, cattle ranchers who have been involved in raising livestock for more than 30 years, community leaders, representatives of cattle associations, field technicians who have participated in training programs in the study area, and representatives of the Campeche Secretary of Rural Development (currently Secretary of Agricultural Development). The social research instruments provided information about ranching management, its problems, and its relationship with predators.



**Figure 1.** The location of the ejidos where the livestock was raised in Campeche in Mexico. Map created by the authors based on cartographic data from the: Instituto Nacional de Estadística Geografía e Informática (INEGI, 2013 and 2019).

The semi-structured interview results with key actors were the basis for designing the questionnaire questions and adjusting the interview process used for the diagnostic. The social research instrument consisted of open-and closed-ended questions organized into six sections: 1) data from the interviewee, 2) the ranch's management, 3) the reproductive management of the livestock, 4) animal health, 5) feeding, 6) losses, and relationship among ranchers and predators, and the origin and meanings of livestock (See supplementary material 1-A). Interviewees were identified and selected by initially contacting farmers who had previously participated in a preliminary scoping exercise aimed at understanding local ranching practices. Following these initial interviews, snowball sampling (Sierra, 1998) was used to obtain references for other potential participants. The criterion for selecting respondents was that they were actively engaged in ranching, regardless of whether it was their primary activity, and that they were willing to participate in the study. A total of 31 ranchers were interviewed in the sampling phase. Each interview lasted an average of 90 minutes and was recorded with the participants' informed consent.

### Analysis of questionnaires and interview

A comprehensive analysis of the questionnaire responses was conducted, employing both descriptive statistics (means, percentages, and ranges) using R software version 3.6.1 (R Core Team, 2020) for closed-ended questions and interpretative research procedures for open-ended questions. Initially, the interview responses were transcribed and imported into ATLAS.ti version 7.5.18 software. Each interview response was carefully read line by line and analyzed to identify relevant sentences related to the research question or topic (referred to as quotations in the analysis). These quotations were then assigned codes or categories, represented by concise phrases. For instance, one rancher said: *"the last years I lost three sheep predated by puma."* This sentence was coded as: "feline losses", regardless of the predator species. The feline loss code groups all mention livestock losses attributed to any feline species. Thus, responses related to predation by jaguars, pumas, or ocelots were all included under this common code. As this analytical process is iterative, some codes were modified or reorganized throughout the analysis. Most codes were predefined, while others emerged from the data (a code that directly emerged from the patterns, ideas, or meanings identified during the

analysis of the interview content). See supplementary material 1-B) (Strauss and Corbin, 2002). For a more comprehensive understanding of the qualitative analysis following the interpretivist approach, please refer to Strauss and Corbin, (2002) and Newing *et al.* (2011).

After completing the coding process, relationships between the codes were established to form a conceptual model based on the principle of causality. The codes were organized into direct and indirect causes affecting felines. The researchers' experience and prior knowledge gained from scientific literature were used to identify, classify, and establish causality between these causes. This initial organization permitted representing the causal relationships between livestock and felines, and later, some recommendations were made.

## RESULTS

Thirty-one cattle and sheep livestock ranchers were surveyed and interviewed, with 14 from Ejido San Pablo Pixtun, and 17 from Ejido Miguel Colorado. Five were women. Results showed that 45.16% of the interviewed farmers were dedicated to bovine production, 54.84% to sheep production, and 25% practiced both types. The farmers, however, are also involved in agriculture and beekeeping. The average age of those surveyed was 58 (range=39 to 85 years). Moreover, 44.8% of them studied in elementary school, and, 31.4% in middle school. Furthermore, 10% completed high School, and 13.8% did not attend any school, being unable to read or write. On average, the interviewees had 23.6 years of ranching experience (ranging from 4 to 75 years), and they were mainly self-taught, which they describe as a process of trial and error. Additionally, they have learned by imitating or seeking advice from other ranchers whom they consider more knowledgeable.

At the ejido level, the main differences stem from how livestock farming developed in each community and the learning processes that ranchers have undergone since they began raising livestock. In the ejido San Pablo Pixtún, livestock farming was promoted through government programs. Initially, access to these programs was facilitated by groups known as livestock clubs, where ranchers shared the profits from cattle farming. Later, this production model disappeared, and livestock farming began to develop on an individual basis. However, currently in San Pablo Pixtún, there is a production system locally known as a *la par*, where one rancher gives their cattle to another. The second rancher is fully responsible for the

care of the cattle, and the profits are split equally. In contrast, the residents of Miguel Colorado, who primarily engaged in the felling of trees for railroad ties and the extraction of resin from the chicle tree, were influenced by the arrival of settlers from other states from Mexico. These new settlers, with prior knowledge of livestock farming, sparked the interest of the locals through a process of imitation and learning. This knowledge transfer, from more experienced ranchers to those just starting out in the activity, eventually turned many into ranchers themselves.

## Cattle raising

On average, the ranches had 78.5 ha pastures (range=17 to 600 ha), with cattle herds of 50.5 animals (range=7 to 250 cattle). The cattle breeds include *Bos taurus* (Simmental, Swiss, Charolais, and Holstein) and *Bos indicus* (Zebu, Indo-Brazilian, and Brahman), as well as crossbreeds of *B. taurus* with *B. indicus* (Beefmaster and, Simbrah). None of the ranches used horses to manage the livestock. Furthermore, 100% of those surveyed only keep records of the increases and decreases of their stock in notebooks that they dedicate exclusively for this. Most farmers have a semi-extensive management system. The predominant type of livestock farming practiced is beef cattle production; however, only three farmers engage in dual-purpose livestock farming. However, in the San Pablo Pixtun ejido some ranchers (n=5), influenced by neighboring ejidos that practice dual-purpose livestock farming and also purchase milk, are beginning to show interest in adopting this type of farming.

Reproductive management on the ranches primarily involves bull replacement, and calves are weaned before reaching 1 year. On average, bulls are replaced every 5 years (range: 2 to 5 years). Usually, the ranchers acquire new bulls by buying them from other ranches (59.4%) or livestock auctions that offer registered bulls (28.10%). A minority opt for bull exchanges with other ranchers (6.3%) or select bulls from their herd (6.3%). Calves are born throughout the year, and all the farmers who supervise their livestock daily let the animals sleep in the paddocks. However, during the rainy season herd supervision decreases, and producers may sometimes not see their animals for a week.

Veterinary management is typically conducted by the producers themselves and includes annual vaccinations, as well as the control of ectoparasites such as flies and ticks. Endoparasite treatment primarily involves using Ivermectin, with Levamisole employed if the Ivermectin

treatment proves ineffective. Ranchers do not follow a fixed vaccination and deworming schedule; instead, their veterinary management is based on experience, consultations with other ranchers, or guidance from veterinary supply store personnel. If a farmer does not observe improvements in their cattle with the treatment, they typically seek advice at an agro-veterinary store to address specific diseases or injuries in their animals, although these stores are not always staffed by trained professionals.

Livestock feeding relies heavily on seasonal fodder's availability, which varies between the ejidos, because of differences in water resources. During the dry season, ranchers use secondary vegetation fragments to supplement grazing when pasture is limited. In San Pablo Píxtun, where water scarcity is more pronounced, 85.71% of ranchers must transport water from the town every third day, significantly increasing cattle maintenance costs. This scarcity also forces ranchers' livestock to graze near feline occupied areas, further increasing predation risks. In contrast, water is not a limiting factor in Miguel Colorado, allowing for more consistent pasture availability throughout the year. Some ranchers also resort to alternatives like cutting grass, utilizing sugar cane, or incorporating chicken manure when grass is scarce. Across both ejidos, only 25% of ranchers provide salt to their livestock, and of those, 75% use table salt as a substitute for mineral salt, a practice believed to contribute to the animals' docility.

### **Farmers' perceptions of ranching profitability and personal significance**

Seventy percent of the ranchers consider ranching a profitable activity. Nevertheless, only two ranchers mentioned that they could live solely from their cattle-raising income. For 93% of the ranchers, livestock raising represents an activity they like, with a tradition that gives them identity and status. Others continue the practice as an inheritance from their parents or as a way to earn extra income through animal sales. Additionally, ranching is a form of savings, offering financial support when other economic activities fall short. Expressions such as "*cattle ranching are the best. and first, you have savings*" and "*I was born with cattle ranching, and I am going to leave it to my son when I die*" were common cattle ranchers' statements.

### **Livestock-predator relationship**

A conceptual model was developed to illustrate the relationships between livestock management practices and predator interactions (Fig. 2). This model highlights the causal links between

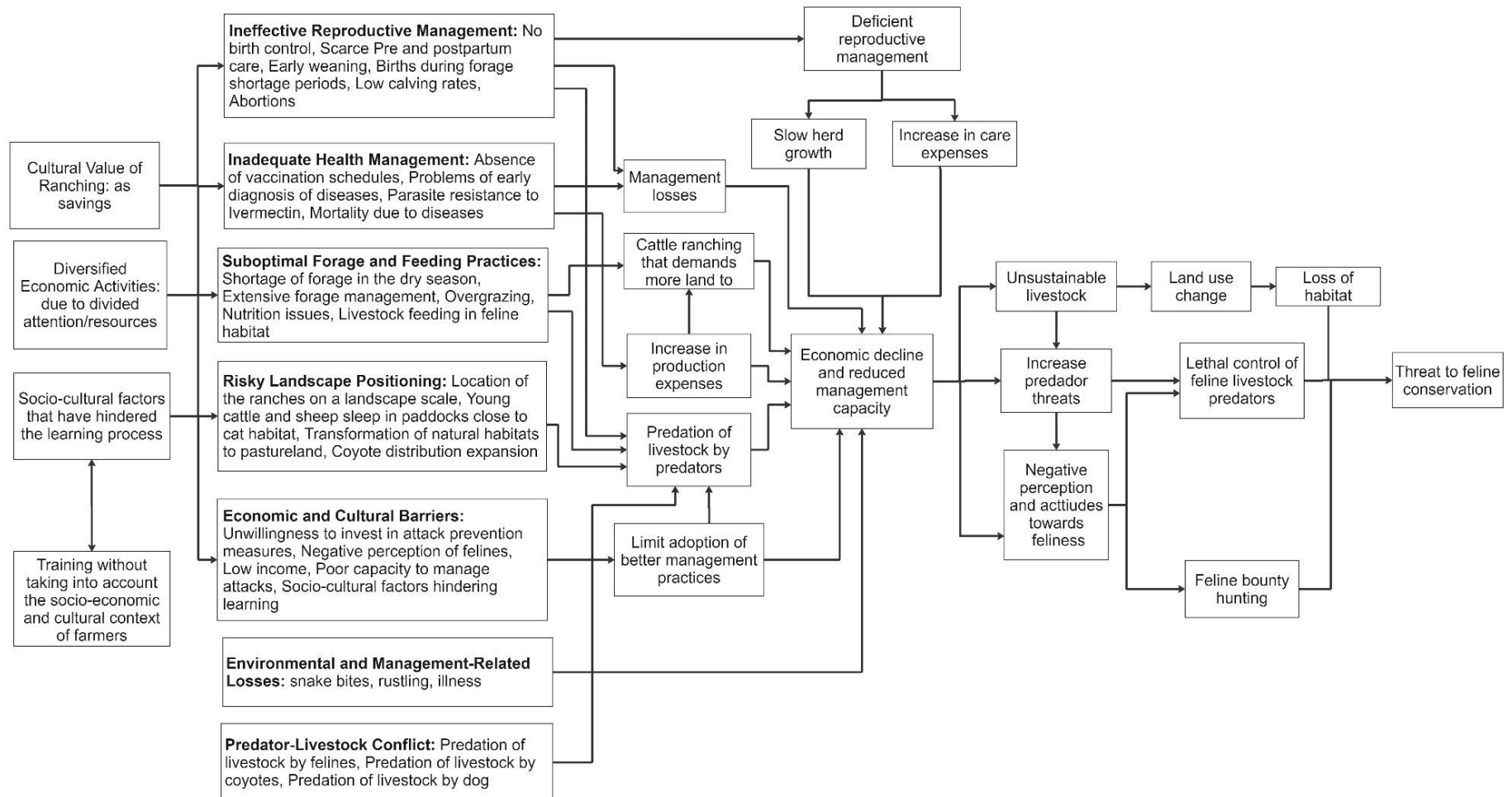
various factors identified in the interviews, including reproductive management, feeding practices, and veterinary care, along with their direct and indirect effects on livestock predation by felines and other predators. Grounded in the principle of causality, the model shows how inadequate management practices, shaped by broader socioeconomic and cultural factors—such as economic limitations and reliance on traditional knowledge—directly contribute to predator-livestock conflicts.

The model also incorporates two significant feedback loops. The first demonstrates how increased predation exacerbates economic decline, which further limits ranchers' capacity to improve management practices. Poor management practices, including insufficient vaccination schedules, inadequate reproductive control, and ineffective disease prevention, lead to higher livestock losses, worsening the economic decline. The second feedback loop illustrates how these economic constraints are reinforced by the persistence of traditional practices, the reliance on multiple income sources, and training programs that fail to consider the socio-cultural context of ranchers. This issue is reflected in statements such as, "We get training, but it's for big farmers," perpetuating the cycle of conflict.

Additionally, the model shows how the location of ranches near predator habitats, combined with a lack of investment in preventive measures, increases predation by both felines and other predators, including coyotes and dogs. These factors not only intensify economic losses but also fuel negative perceptions of felines, leading to lethal control measures that further threaten predator conservation. For a more detailed visualization of the conceptual model, refer to Supplementary Material 2.

### **Description of sheep farming**

The mean herd size is 94.6 sheep (range=17 to 430 sheep) and includes Pelibüey, Dorper, Black Belly, and Katahdin crossbreeds are used. The sheep are de-wormed with Ivermectin every 3 to 6 months. Ranchers attribute losses to illness, parasites, anti-parasite medication overdoses, and predator attacks. The producers do not use preventive vaccinations, and the diseases are treated based on their own experience or the experiences of other ranchers. Among the conditions that they report are pneumonia, diarrhea through infections, gastrointestinal parasites, nose worms, and pododermatitis.



**Figure 2.** Conceptual model illustrating the relationships between livestock management practices, socio-cultural factors, and predator interactions, particularly focusing on feline species. The diagram outlines how inadequate health and reproductive management, risky landscape positioning, and economic and cultural barriers lead to unsustainable livestock practices. These factors, coupled with ineffective training that does not account for the socio-economic and cultural context of farmers, result in increased predation risks, negative perceptions of predators, and ultimately the lethal control of felines, threatening their conservation. For more detailed descriptions of the specific interactions between these factors and their implications for both livestock management and predator conservation, see Supplementary Material 2.



The producers usually replace the rams every 1 to 2 years, and weaning is performed when the lamb is 3 months old. The ranchers buy the rams from other ranchers in the same ejido to replace deceased rams. The reproductive period of the ewes ranges between 6 and 7 months, with a birth rate of 1 to 2 lambs per year. Sheep are primarily grazed, with two standard practices. In the first approach, ranchers who own plots feed their animals in the morning and afternoon and then enclose them in on-site pens. Some of these plots are within the town's periphery and others over 8 km away (range: 0.1 km to 8 km). Residents who do not own land or are not ejido landholders graze their animals on ejido land, supervised by the landowner, and then house the sheep in corrals in their backyards. Moreover, 78.6% of the ranchers provide mineral salt to their sheep. Of these, 45.5% use table salt as a substitute. Ranchers believe salt helps keep the sheep docile and use it as bait to facilitate the animals' movement, particularly encouraging them to enter the corrals.

#### **Livestock mortality and its relationship to predators.**

Ranchers cite illness (45.2%), carnivore predation (16.7%), snake bites (14.3%), rustling (11.9%), miscarriages (7.1%), and malnutrition (4.8%) as the primary causes of cattle and sheep mortality. According to the information provided by the ranchers, carnivore predation resulted in the loss of 10 cattle and 149 sheep over the past 5 years. Cattle attacks are infrequent and typically involve calves under 1 year old. Ranchers did not identify specific locations, ages, or genders in sheep, but predation events mainly occur at night and are more common on ranches far from human settlements. These predation incidents are most frequent from September to January, coinciding with decreased ranch visits because of rain-related difficulties in accessing remote areas.

Additionally, 26.67% of the interviewees mentioned experiencing puma predation, resulting in the loss of 3 to 11 animals in a single night. Pumas and jaguars were reported as responsible for the most significant losses, accounting for 41.51% (n=66; sheep=39.62%, cattle=1.89%) and 25.15% (n=40; sheep=20.75%, cattle=4.4%) respectively. In contrast, ocelots and dogs were reported to prey specifically on sheep, resulting in losses of 5.03% (n=8) and 16.98% (n=27) respectively. Predation by ocelots was reported by five ranchers, which affected 8 sheep under 2 months old. Additionally, three interviewees admitted to killing ocelots to

control predation events. Coyotes were responsible for 11.32% (n=18) of deaths perceived by ranchers.

Most producers (90%) described distinctive feeding patterns they associate with pumas and jaguars when explaining how they identify the predators responsible for attacking their animals. When visible tracks are found, ranchers commonly attribute the damage to jaguars or pumas, but they are less likely to attribute attacks to dogs and coyotes when only deceased animals are discovered. Some ranchers reported being able to identify the specific dog or group responsible, and a few even mentioned witnessing dog attacks on their sheep. In cases of ocelot predation, one rancher observed an ocelot attacking his sheep, while others noted the presence of ocelots near their herds, often finding tracks at the site as further indication. For coyotes, ranchers rely on cues such as vocalizations in grazing areas, the presence of droppings, and occasional sightings.

During interviews, ranchers reported retaliatory killings of at least 6 large felines in response to sheep predation in the past 5 years. They included poisoning a female jaguar with cubs using Furadan (Carbofuran). Over a decade, one rancher mentioned culling more than 10 animals, including pumas and jaguars. Some ranchers also described preventive predator hunting for jaguars and pumas in exchange for monetary rewards. In such cases, hunters who locate and eliminate a big cat within or near a ranch experiencing predation issues receive compensation ranging from \$20.4 to 40.9 USD from the ranch owner. This mentality is further illustrated by ranchers stating the following: *"Well, the tiger affects others, not me, but it's better to shoot it"*. In addition, *"It's beautiful, but if it's harming me, I have to kill it,"* reflects their deep-seated attitudes that drive such lethal measures, even in cases where the individual rancher may not have directly suffered losses.

Ranchers employ various strategies to address livestock depredation in the study area, including lethal control, transitioning from sheep to cattle ranching, relocating their livestock closer to or within their homes (often referred to as their yard or backyard), or, to a lesser extent, abandoning sheep ranching altogether. Notably, we did not document cases of ranchers temporarily leaving and later returning to the activity, although this behavior has been observed in other regions. Only 9.6% of the interviewed ranchers reported using the livestock insurance fund (LIF), which is a National Confederation of Livestock Organizations program



designed to compensate losses by different factors, including those caused by predators. Ranchers cited complex procedures associated with the LIF, and payouts may not consistently cover the losses resulting from depredation. These challenges add to the complex interactions between livestock management practices and predator dynamics, as identified in the interviews. Factors such as reproductive management, feeding practices, and veterinary care directly and indirectly affected livestock predation by felines and other predators. Figure 2 provides a visual summary of these interactions, illustrating the causal links between the identified management practices and their effects on livestock predation. For more detail, see Supplementary Material 2.

## DISCUSSION

The average age of the ranchers in this study was 58 years, with most having only a basic level of education. Previous studies suggest that these factors may hinder the success of initiatives aimed at promoting sustainable livestock practices (Anta-Fonseca *et al.*, 2008; Castillo *et al.*, 2014). This aligns with findings from Anta-Fonseca *et al.* (2008) and Góngora-Pérez *et al.* (2010), who observed that the perception of ranching as a source of savings among small- and medium-scale ranchers significantly influences their management practices. In the study area, ranchers' economic activities are often diversified, resulting in minimal investment in livestock management, limited cost reductions, and a reliance on family labor (Anta-Fonseca *et al.*, 2008). Furthermore, the lack of financial record-keeping impedes ranchers' ability to accurately assess their income, expenses, and areas for improvement (Anta-Fonseca *et al.*, 2008; Castillo *et al.*, 2014). Therefore, improving financial record-keeping practices is essential for more efficient livestock management.

Although most ranchers consider livestock raising to be profitable, only two stated that they could rely solely on ranching for their livelihood. This apparent contradiction arises from the multifaceted role that livestock plays, particularly as a source of savings, which explains the common sentiment expressed during interviews: “*Whenever you don't have money, you sell a sheep and get some cash.*” Additionally, the study reveals that livestock farming is deeply intertwined with the ranchers' cultural identity, often being a tradition inherited from their parents. These factors contribute to their reluctance to adopt innovative practices, favoring traditional methods perceived as safer and more

reliable (Amador-Alcalá, Naranjo and Jiménez-Ferrer, 2013; Cuervo-Osorio *et al.*, 2020). Addressing these barriers requires conservation programs that are sensitive to the cultural values and preferences of ranchers (Lecuyer *et al.*, 2018).

A key aspect identified in this study was the role of experienced ranchers as knowledge and practice transmitters within their communities. This transfer process, in which more experienced ranchers share their learnings and strategies with less experienced ranchers, not only facilitates the incorporation of these individuals into livestock management practices but also contributes to strengthening community ties. Moreover, this form of knowledge transfer can be adapted into broader strategies aimed at enhancing livestock management practices. For instance, it provides an opportunity for initiatives such as Farmer Field Schools (Ortiz *et al.*, 2016), which focus on training community members to disseminate knowledge throughout their networks. By leveraging local expertise, this approach empowers community members to become key actors in promoting sustainable practices, thereby improving the overall effectiveness of ranch management strategies.

Even though traditional livestock management practices in the region are deeply rooted in local culture, the adoption of additional strategies could further improve ranch efficiency. For example, research by Hoogesteijn and Hoogesteijn, (2011) has demonstrated that concentrating births during favorable periods enhances the efficient use of medication and allows for focused care of animals vulnerable to predation. In the study area, this management practice could be a long-term strategy to protect the most susceptible animals and optimize ranch resources (Palmeira *et al.*, 2008). For instance, just before the rains, calving late in the dry season ensures calves and their mothers benefit from peak water and forage availability during critical early growth stages (Rouquette, Corriher-Olson and Smith, 2020). In addition, managing parturition seasons could enhance both animal survival and ranch profitability. Scheduling calving dates to coincide with higher cattle prices could also be advantageous, but this approach would need to be supported by effective pasture management to ensure successful synchronization.

## Ranching relationships and carnivore conservation

Our findings emphasize the pivotal role of management practices in influencing livestock-

predator dynamics. As Figure 2 illustrates, these practices form a feedback loop that can either exacerbate or mitigate predation risks, depending on their implementation. Semi-extensive livestock farming in the study area depends heavily on the seasonal availability of forage, a common feature of tropical regions (Magaña-Monforte, Ríos-Arjona and Martínez-González, 2006; Cingolani *et al.*, 2008). Ranchers often mitigate forage shortages during droughts by using secondary vegetation; however, this practice may unintentionally increase predation risks (Amit, Gordillo-Chávez and Bone, 2013; Silva-Caballero, Bender and Rosas-Rosas, 2022). In response, alternative management strategies, such as silos or fodder banks with high-quality forage like leucaena (*Leucaena leucocephala*) or ramon tree (*Brosimum alicastrum*), could offer practical solutions regarding forage shortages during dry seasons and reduce the necessity of moving livestock to high-risk areas (Casanova-Lugo *et al.*, 2014; Maya Martínez *et al.*, 2022).

Predator-related losses have a relatively smaller impact on cattle farming; however, they can be significant in sheep farming, especially for small and medium-scale farmers, where the loss of even one animal can have severe economic consequences (Amador-Alcalá, Naranjo and Jiménez-Ferrer, 2013). The relatively small size of sheep and their poor anti-predator capabilities, exacerbated by the location of grazing areas far from human settlements, make them particularly vulnerable to predation (Hansen *et al.*, 2001; Guerisoli *et al.*, 2021). This impact is further intensified by the behavior of surplus killing exhibited by pumas, where more than one animal is killed in a single predation event, a pattern observed primarily in domestic animals when prey is abundant and easily accessible (Lucherini, Guerisoli and Luengos Vidal, 2018). As shown in the conceptual model (Fig. 2), the cyclical relationship between economic pressures and predation risks often reinforces negative attitudes toward predators, leading to practices such as hunting predators for monetary rewards (Cavalcanti *et al.*, 2010; Zarco-González *et al.*, 2018). Implementing secure enclosures, electric fences, and surveillance grazing during high-risk hours in areas prone to carnivore predation could effectively reduce losses (Quigley *et al.*, 2015). As such, efforts to manage predation should prioritize sheep farming, particularly in regions with a high incidence of puma predation.

In the study area, the primary causes of livestock mortality are related to animal health issues, consistent with previous studies showing that felines are not the main contributors to these losses (Amit, Gordillo-Chávez and Bone, 2013). The findings reveal that ranchers do not follow regular vaccination and deworming schedules, resulting in a higher incidence of diseases such as rabies, which was specifically mentioned by ranchers. This lack of systematic veterinary management adversely affects livestock productivity. Encalada-Mena *et al.* (2008) documented that the absence of a vaccination schedule and the repeated use of a single dewormer, such as Ivermectin, contributes to the development of parasitic resistance, worsening health issues and increasing maintenance costs. Implementing regular health management practices, including diverse deworming strategies, could improve overall herd health and support more sustainable livestock management (Castillo *et al.*, 2014). In this context, initiatives like the mobile veterinary assistance unit for coexistence (S.P.E.C.I.E.S and ECOSUR) seen in Calakmul offer valuable technical support to livestock farmers to help mitigate losses and increase tolerance toward felines (Hoogesteijn and Hoogesteijn, 2011; Peña-Mondragón *et al.*, 2017a).

The frequency of jaguar, puma, and ocelot attacks on sheep has led to the death of several felines in the study area. Ranchers reportedly hunt for rewards, even in the absence of recent livestock attacks. Although such hunting has been previously described as a preventive strategy by ranchers in regions with high predation rates, it does not effectively address the root causes of the issue (Garrote, 2008). This behavior aligns with findings by Soto-Shoender and Giuliano (2011) and Garrote (2012) who suggests that the persecuting big cats, such as jaguars and pumas, is closely linked to the perceived extent of livestock damage. However, our results contrast with the conclusions of Lecuyer *et al.* (2023), who identified correlations between ranchers' age, education, and ethnicity, and their likelihood of implementing preventive measures or resorting to killing jaguars. A positive perception of felines alone does not ensure tolerance for the losses incurred (Álvarez and Zapata-Ríos, 2022). Therefore, it is crucial to collaborate with ranchers to develop solutions that enhance their tolerance toward felines (Zarco-González, Monroy-Vilchis and Alaníz, 2013; Quigley *et al.*, 2015). Additionally, incentives related to the welfare of livestock keepers should be considered, as these have been shown to positively impact livestock-feline coexistence (Kansky, 2022).

Coyote presence in Campeche was first confirmed in 2009 (Hidalgo-Mihart *et al.*, 2013), however, ranchers have reported that this predator has become a more significant concern in recent years, with notable increases in predation events over the past five years. The likely expansion of coyote distribution and their growing interaction with humans, particularly within protected areas such as Calakmul, suggests a broader trend of range expansion (Contreras-Moreno *et al.*, 2020). These observations agree with the findings of Hidalgo-Mihart *et al.*, (2013) and indicate more sheep ranching losses caused by coyote predation (Torres-Romero *et al.*, 2023). Dogs have also been identified as significant predators of sheep, particularly in grazing areas near ejidos. This pattern has been observed in both Argentina Gaspero *et al.*, (2019) and México (Torres-Romero *et al.*, 2023). In southeastern Mexico, coyote and dog predation has notably increased in recent years. Between 2017 and 2020, 50.3% of the predation reports received by the LIF (2075 cases) involved these two species (Torres-Romero *et al.*, 2023). The main cause of this conflict is attributed to irresponsible dog ownership, highlighting the need for sterilization and awareness campaigns for responsible pet ownership to mitigate the problem.

The effectiveness of economic compensation schemes for losses caused by wild predators as a conservation tool has been questioned, as they often fail to address the underlying issues and rely on the availability of resources for payouts (Ravenelle and Nyhus, 2017). In Mexico, a livestock insurance fund compensates such losses (see <https://fondocnog.com> for details). Despite being in operation for over two decades, only 9.6% of the farmers in this study have utilized it. Interestingly, this compensation scheme is negatively perceived, which contrast with findings by Marshall, Lecuyer and Calmé, (2021) and Méndez-Saint Martin *et al.* (2022), where more farmers in the Calakmul region viewed the LIF positively. Méndez-Saint Martín *et al.* 2022 attribute this difference to targeted insurance campaigns and support provided to farmers for preparing depredation reports.

The findings of this study highlight the intricate relationship between livestock management practices and predator interactions in the region. However, it is important to note that the livestock loss data were self-reported by the ranchers, which may introduce some subjective bias. Despite this, the consistency of the reported trends agrees with the existing literature, suggesting that these

perceptions provide a reliable reflection of the challenges face by ranchers. Future research could benefit from integrating direct monitoring of predation events to complement these insights and further validate the findings.

To foster sustainable change, it is essential to engage ranchers in the co-design of these strategies, while also providing education and capacity-building support (de la Torre *et al.*, 2021). Such collaboration will help ensure that conservation initiatives are both practical and culturally acceptable, ultimately contributing to long-term sustainability.

## CONCLUSIONS

This study highlights the critical relationship between livestock management practices and the increased vulnerability of livestock to predation. In particular, the lack of systematic veterinary care and the reliance on seasonal forage availability contribute significantly to this vulnerability. These factors not only reduce the profitability of livestock farming but also exacerbate the challenges faced by ranchers, who often rely on multiple income sources and traditional livestock management methods. Addressing these interconnected challenges requires the development of conservation strategies that are not only ecologically sound and economically viable but also culturally sensitive to the needs of ranching communities.

Interventions such as forage banks, electric fences, and vaccination programs can significantly reduce predation risks and improve the sustainability of livestock management. However, for these strategies to be effective, they must be adapted to the specific socio-economic and cultural contexts of local communities. A promising approach for disseminating knowledge is through farmer field schools, which foster learning from within the community by training local leaders who, in turn, share this knowledge with other farmers. This methodology supports the adoption of innovative practices, as it builds on trust and local expertise—fundamental aspects for ensuring the acceptance of new management strategies. As the results suggest, this is how knowledge of livestock farming has traditionally been transmitted within these communities.

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**Conflict of interest statement.** All authors declare that they have no conflicts of interest.

**Compliance with ethical standards** The manuscript does not contain clinical studies or patient data. All interviewed farmers were informed about the study's objectives, the type of questions included in the interview, and the questionnaire.

To comply with ethical provisions and respect the autonomy and rights of individuals to choose whether or not to participate in our research, before each interview, the study's objectives were explained to the interviewees, and they were informed about the type of questions they would be asked if they agreed to participate. The questions were clearly articulated during the interview to ensure that each respondent understood them. The survey and interview were administered only to those individuals who, after understanding the study's objectives and the intended use of the information, voluntarily decided to participate by answering the interview questions and completing the survey.

**Data availability:** Data are available with E.J. Gordillo-Chávez. [elias.gordillo@ujat.mx](mailto:elias.gordillo@ujat.mx) upon reasonable request.

**Author contribution statement (CRediT).** **E.J. Gordillo-Chávez:** Conceptualization, Methodology, Investigation, Formal analysis, Writing - original draft and Writing: review and editing. **M.G. Hidalgo-Mihart:** Conceptualization, Methodology and Formal analysis, Funding acquisition, Writing: review and editing. **J. Peña-Mondragón:** Conceptualization, Methodology and Formal analysis, Writing: review and editing. **V.J. Colino-Rabanal:** Writing:

review and editing. **M. Lizana Avia:** Writing: review and editing.

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**Supplementary Material 1-A****Table 1. Themes and questions addressed during the interviews.**

Themes	Questions
Interviewee data	Name of participant, age, sex, level of education, years dedicated to livestock raising and how he or she became involved in it, how he or she learned ranching management size of ranch.
Ranch management	Type of cattle farming practiced, management system, livestock breeds, place where animals sleep overnight, frequency of animal supervision, sites where the animals graze, herd separation by animals' age class or purpose, systems of livestock branding, registering mechanisms for the control of activity and information that is recorded, paddock management, size and animal load per pasture. Profitability of the herd.
Reproductive management of the livestock	Type of fertilization, methods for increasing fertility, origin of the studs and time of replacement, control of births, number of bulls per cows in reproductive state, rest of the studs, control of cows' initial reproductive age, feeding care and and veterinarians prior to birth, during pregnancy and post-partum. Care of the offspring.
Veterinary management	Calendar of vaccinations, anti-parasite treatment, management of illnesses and medications and vaccinations employed. Means for diagnostic and illness control. Presence of illnesses and means of treatment.
Nutritional management	Species of grasses, availability of pasture during the year, mechanisms for compensating for the availability of pastureland in case it varies throughout the year, use of supplements, water sources for the livestock.
Presence of large carnivores on ranches and the perception toward the felines	Have you seen or know of the presence of a jaguar or puma on your ranch or in the ejido, your livestock or that of your neighbor has suffered attacks by big cats, which predator was responsible for the attack, type of proof, depredated species, age, sex, time of year, hour of the attack (day or night), place of attack, record of the predation events, methods used to control attacks, Do you know that if in the ejido it has been necessary to sacrifice a cat for attacked livestock, what do you think about the felines.
Presence of large carnivores on ranches and the perception toward the felines	Since when have you been involved in livestock farming? How did you learn about livestock management? When you don't know something about management, how do you acquire this knowledge? How did livestock farming begin in the ejido?

**Supplementary Material 1-B****Table 2. List of codes used during the analysis of the interviews in the atlas.ti program. The concept map was created from these codes and summarizes the narrative describing feline-livestock interactions.**

<b>Codes</b>	<b>Type of Threat</b>	<b>Source</b>
Loss of habitat	D	L
Land use change	I	A,L
Feline bounty hunting	D	A
Lethal control of feline livestock predators	D	A
Cattle ranching that demands more land to produce more	I	A
Negative perception of felines	I	A
Low tolerance	I	A
Deficient reproductive management	I	A
Slow herd growth	I	A
Low income	I	A,L
Management losses	I	A
Losses by other predators	I	A
High pasture coefficient	I	L
increase in production expenses	I	L
Mortality due to diseases	I	A
Increase in care expenses	I	A,L
Predation of livestock by felines	I	A,L
Predation of livestock by coyotes	I	A,L
Predation of livestock by dog	I	A
Births all year long	I	A
Births during forage shortage periods	I	A
Veterinary care cost	I	A
Abortions	I	A
Low calving rates	I	A
Nutrition issues	I	A
Livestock feeding in the feline habitat	I	A,L
Over grazing	I	A
Parasite resistance to ivermectin	I	A,L
Areas of opportunity to improve management are not know	I	A
Predation losses are not know	I	A
Predation losses are overestimated	I	A,L
Coyote distribution expansion	I	A,L
Not birth control	I	A
Scare Pre and Post partum care	I	A
The reproductive biology of cattle is unknow	I	A
Early weaning	I	A
Shortage of forage in the dry season	I	A
Extensive forage management	I	A
Young cattle and sheep sleep in paddocks close to cat habitat	I	A
Young cattle and sheep sleep grazing in pastures near the feline habitat	I	A
Absence of vaccination schedules	I	A
Problems of early diagnosis of diseases	I	A
Poorly detailed ranch management records	I	A
Other losses: snake bites, rustling, illness	I	A
Location of the ranches on a landscapes scale	I	A,L
Unwillingness to invest in attack prevention measures	I	A
Poor capacity to manage attack on livestock	I	A
Transformation of natural habitats to pastureland	I	A,L
Irresponsible dog ownership	I	A,l
Unattended sheep foraging in the ejido's vicinity	I	A

Type of relation: D= direct, I= indirect. A direct relation directly affects the conservation target, and indirect relation are the origin or cause of direct threats. Source: A= code or categories created from data analysis, L= code or categories created from a conceptual framework review.

## Supplemental Material 2

### Conceptual model illustrating livestock management-carnivore relationships

This conceptual model illustrates the causal relationships between livestock management practices and the factors that contribute to predation events. The model reveals how the combination of socio-cultural, economic, and environmental factors also contributes to livestock practices that hinder productivity and obstruct the adoption of improved management techniques.

#### 1. Socio-cultural and economic influences on livestock management

A significant limitation in the current livestock management, despite the training and assistance programs implemented in the ejidos, arises from the training programs that fail to consider the socio-cultural context of the ranchers (Anta-Fonseca *et al.*, 2008). This possibly explains the results in a low adoption rate of improved livestock practices. Cultural values that view livestock as a form of savings rather than a primary source of income further aggravate these deficiencies, leading to low investment in preventive measures and improvements in livestock management reliable (Amador-Alcalá *et al.*, 2013; Cuervo-Osorio *et al.*, 2020; Góngora-Pérez *et al.*, 2010).

The diversified economic activities of ranchers, often driven by the need for multiple income streams, divide their attention and resources, reducing the focus on effective livestock management. This results in a reduced capacity and willingness to invest in practices that require more time or resources than they are currently accustomed to allocating to livestock farming (Anta-Fonseca *et al.*, 2008).

#### 2. Challenges in reproductive and veterinary livestock management

The model highlights livestock's deficient reproductive management, including the absence of birth control, inadequate pre- and post-partum care, and insufficient disease diagnosis, which increase mortality from diseases or lead to higher treatment costs for sick animals. Calving occurs throughout the year, including during periods of forage scarcity, which increases veterinary care and feeding costs for weakened livestock. These costs are further aggravated in females with offspring, as they have higher energy demands to produce quality milk. The absence of vaccination schedules and the overuse of a single treatment, such as Ivermectin, has increased parasitic resistance, raising animal care expenses. Moreover, the negative effects of Ivermectin on soil microfauna exacerbate this problem (Encalada-Mena *et al.*, 2008).

The location of ranches near predator habitats increases the risk of predation, especially for sheep and, to a lesser extent, cattle calves. These risks are heightened when vulnerable animals spend the night in paddocks near the habitats of felines and coyotes or are moved into forested vegetation fragments to compensate for pasture shortages.

#### 3. Environmental pressures and predation risks

Extensive forage management, combined with overgrazing, leads to the transformation of natural habitats into pastureland (Ellis, Hernández-Gómez and Romero-Montero, 2017), contributing to the loss of predator habitats and increasing the proximity of livestock to carnivores (Maillard *et al.*, 2020). This shift not only reduces the availability of natural prey for felines but has also favored the presence of coyotes, another important predator in sheep farming (Friedeberg-Gutierrez *et al.*, 2022; Torres-Romero *et al.*, 2023b).

Predation events are often overestimated by ranchers, leading to misguided lethal control practices. The bounty hunting of felines and the lethal control of livestock predators are direct consequences of the perceived threat carnivores pose to ranchers (Knox *et al.*, 2019; Chinchilla *et al.*, 2022).

#### 4. Management and economic losses

The combination of predation losses, environmental degradation, and poor livestock management results in economically unsustainable livestock farming. High veterinary costs, coupled with increased predation risks

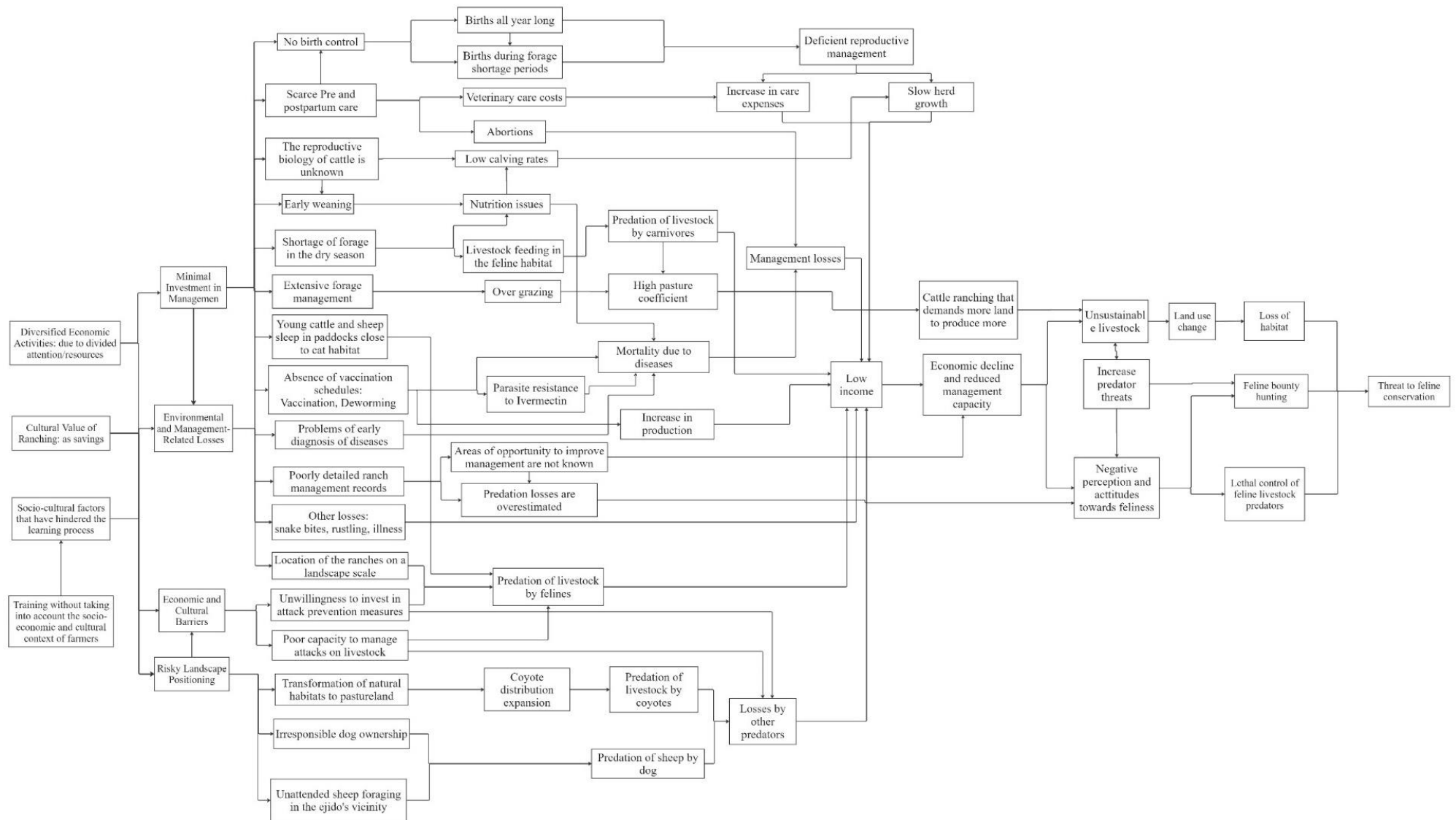
lead to significant production losses. Abortions, low calving rates, and mortality from diseases are exacerbated by the lack of detailed management records on ranches, preventing the identification of areas for improvement (Peña-Mondragón *et al.*, 2017b).

The decline in income and management capacity creates a vicious cycle, in which ranchers are unable to invest in better management practices, further increasing the threats of predation and the need for more land to maintain production levels. The model indicates that these barriers to effective management are deeply rooted in both the economic limitations and cultural values of the ranchers.

## **5. Impact on predator conservation**

The final component of the model focuses on the impact of livestock management practices on predator conservation. Land-use changes driven by pasture expansion represent a significant threat to predator habitats, contributing to habitat loss. Livestock predation has generated negative attitudes towards felines, resulting in practices such as bounty hunting of felines, further threatening conservation efforts (Zimmermann, Walpole and Leader-Williams, 2005; Zimmermann, McQuinn and Macdonald, 2020; Chinchilla *et al.*, 2022). This model highlights the need for a holistic approach to addressing livestock-predator interactions and emphasizes the importance of considering both socio-economic and environmental factors that influence livestock management practices.





**Figure S1.** Conceptual model illustrating livestock-feline relationships and factors that decrease the profitability of livestock farming.