

Livestock predation by jaguars *Panthera onca* in south-eastern Mexico: the role of local peoples' practices

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Abstract Inadequate livestock husbandry practices threaten the maintenance of global biodiversity and provoke conflicts between people and wildlife, and large carnivorous mammals are among the most affected. The jaguar *Panthera onca* is one of the most threatened species in the Americas, being targeted by livestock producers who suffer economic losses as a result of predation. The way in which rural producers in countries such as Mexico conduct husbandry practices may influence levels of predation by jaguars. Our objective was to understand how such practices are conducted in the Selva Lacandona in south-eastern Mexico, to identify their influence on the vulnerability of livestock to predation by jaguars. We characterized local husbandry practices through participant observation, interviews and surveys. Our results show that the most important practices that make livestock vulnerable to predation include the location of grazing lands close to forested areas and water sources, the absence of practices for the proper disposal of carcasses, and poor control of calving and care of calves. Our recommendations include monitoring of livestock movements and synchronization of calving. Economic investment and behavioural change can be accomplished through capacity building and providing people with the means to monitor and manage their livestock. Small actions can reduce livestock losses and improve the economic circumstances of rural people, and thus increase their tolerance and respect towards jaguars.

Keywords Human–carnivore conflict, jaguar, livestock husbandry, Mexico, *Panthera onca*, social–ecological approach, vulnerability to predation

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Introduction

Large carnivores play an important role in ecological processes. They affect the density and dynamics of prey species, with cascade effects on ecosystems (Ripple et al., 2014). Habitat fragmentation disturbs the behaviour of carnivores with large home ranges (Woodroffe, 2000), and brings them into conflict with people (Thirgood et al., 2005). Inadequate livestock husbandry is considered a major threat in this regard, particularly in non-industrialized countries (Hull et al., 2014) where livestock production is badly managed (Ripple et al., 2014). On the American continent, jaguars *Panthera onca* are considered to be a threat to livestock, and conflicts between rural communities and jaguars are common (Caso et al., 2008; Peña-Mondragón & Castillo, 2013). In Mexico the jaguar has been extirpated from 60% of its original distribution (Chávez & Ceballos, 2006); meanwhile livestock production has developed extensively (Chauvet, 2001), and in 2003 cattle occupied 110 million ha (INE, 2004). The land occupied by jaguars is owned by rural inhabitants, with 60–70% of Mexico's forested areas owned by indigenous and mestizo communities (Bezaury-Creel & Gutiérrez Carbonell, 2008). The term peasant is commonly used (corresponding to *campesino* in Spanish) to refer to these groups, and denotes a way of living that includes multiple uses of natural resources.

The tropical rainforest of the Selva Lacandona in the state of Chiapas is a priority site for jaguar conservation in Mexico (Chávez & Ceballos, 2006), although illegal hunting occurs throughout the species' range in Mexico (Amador-Alcalá et al., 2013). In 1978 the 3,312 ha Montes Azules Biosphere Reserve was designated to secure the long-term maintenance of regional biodiversity (SEMARNAP, 2000). Agriculture and livestock production are important livelihood activities in the region, with the latter representing one of the main sources of income for rural people. Thus, perceived and actual predation of livestock by jaguars puts the species at risk of persecution and elimination (SEMARNAT, 2009). Although predation of livestock by large mammals has been widely studied (Conforti & Azevedo, 2003; Hoogesteijn & Hoogesteijn, 2008; Rumiz et al., 2011; Peña-Mondragón & Castillo, 2013) it remains unclear which livestock husbandry practices may trigger predation. If livestock husbandry influences levels of predation by carnivores such as jaguars, there is clearly a need to understand the motivations and needs of the people

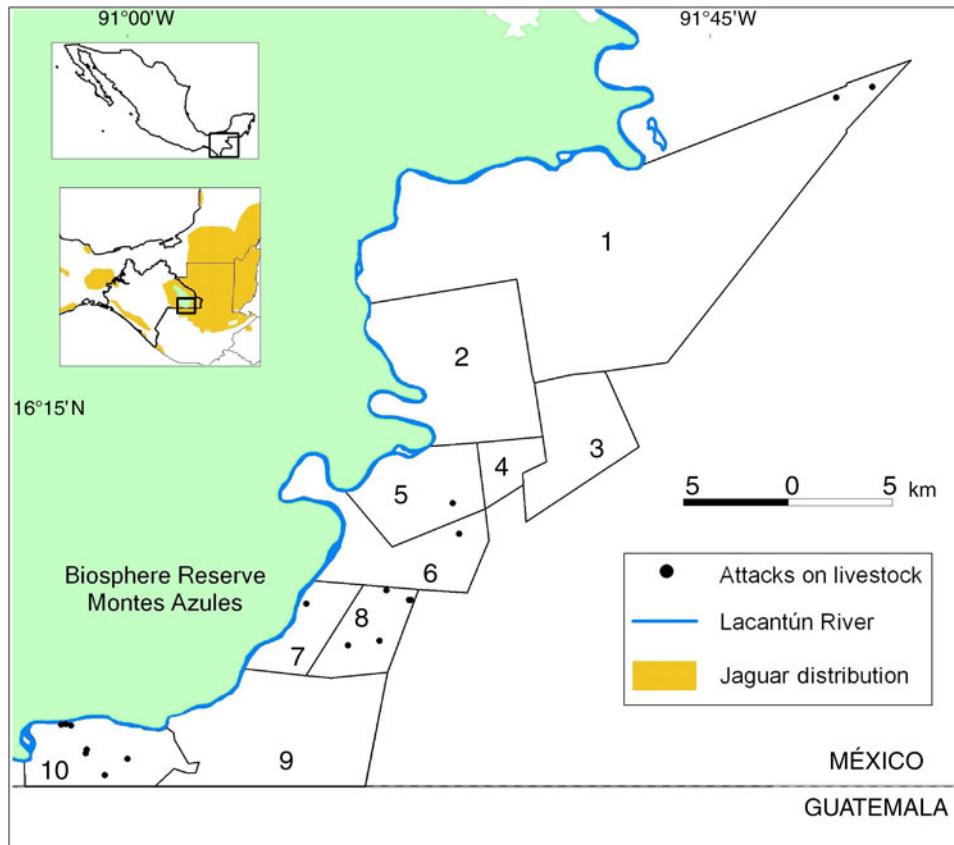


FIG. 1 Sites where livestock were attacked by jaguars *Panthera onca* in ejidos adjacent to the Montes Azules Biosphere Reserve, in the Mexican state of Chiapas. 1, Zamora Pico de Oro; 2, Reforma Agraria; 3, Nuevo San Isidro; 4, López Portillo; 5, Adolfo López Mateos; 6, Galacia; 7, Playón de la Gloria; 8, Flor Marques; 9, Boca Chajúl; 10, Loma Bonita.

involved, and the various aspects of their practices. Thus our main objective was to characterize livestock husbandry practices to identify those that increase the risk of predation of livestock by jaguars in the rural communities adjacent to the Montes Azules Biosphere Reserve.

Study area

The study was conducted in ‘*ejidos*’ (a system of land tenure that combines individual and communal possession; Warman, 2001) adjacent to the Montes Azules Biosphere Reserve in the Selva Lacandona (Fig. 1), which hosts a high diversity of Neotropical flora and fauna (Miller et al., 2001). Deforestation rates of up to 33% were recorded in the study area during 1986–2010 (Carabias et al., 2010). Culturally, the Selva Lacandona comprises indigenous and mestizo communities, which have migrated there since the beginning of the 20th century, mainly from the mountainous regions of Chiapas (De Vos, 1988). The Reserve is important for jaguar conservation (Chávez & Ceballos, 2006) but there may be only 51–132 individuals remaining there (de la Torre & Medellín, 2011).

Methods

We used a socio-ecological systems research approach (Berkes & Folke, 2000). As our questions were related to

human practices we used research instruments from the social sciences applied to the environmental sciences (Supplementary Material 1; Newing et al., 2011). We also collected ecological information related to the identification of sites of livestock predation and landscape fragmentation, to construct an overview of the human–jaguar conflict.

We conducted four exploratory visits during 2008–2010. As a first step, following our ethical code of conduct, we explained the project to local people and asked the local authorities for permission to conduct the research. Gaining trust and empathy was essential, as jaguars are a protected species and their elimination is sanctioned with fines and prison sentences (Tarrés, 2004). We collected data during five 20-day visits, in February and October 2011, March and September 2012 and January 2013, using participant observation, surveys (closed-ended questionnaires) and semi-structured interviews in which we asked open questions and allowed participants to talk freely (Table 1; Taylor & Bogdan, 1987; Patton, 2002). For practical purposes the surveys and interviews were integrated into a single instrument, and we recorded the answers to both types of questions on a form. Localities were selected based on evidence of jaguar presence nearby; key actors were identified as those whose livestock had been attacked by jaguars. Thirty-two heads of families agreed to participate in the study; these were enlisted using the snowball sampling method (Newing et al., 2011), where participants were asked to refer others who

TABLE 1 Methods used for data collection.

Method	Objective
Informal talks in the community (Sanchez, 2004)	To establish initial contact with local people, gain access to the community & identify stakeholders
Participant observation (Sanchez, 2004)	To record observations, events & daily activities in relation to livestock management (including talking to people while participating in local activities)
Surveys (Hernández-Sampieri et al., 2008)	To obtain information regarding specific aspects of cattle herds, economic investments, products & derivatives
Semi-structured interviews (Sierra, 1998)	To obtain detailed information regarding processes, motivations & needs of producers, which is difficult to obtain through surveys

may have had similar problems. People were willing to talk and were open to providing information. During the fieldwork 17 attacks on livestock by jaguars were confirmed through examining carcasses (Fig. 1).

Data analysis consisted of quantifying responses to specific closed-ended questions, and constructing categories based on the responses provided to open questions (Strauss, 1995; Newing et al., 2011). The categories are intended to reflect the ideas and actions of people according to their own perspectives, motivations and needs. Frequencies and percentages were calculated for each category. As participants could give more than one response to the same question, in some cases the percentages exceed 100%. A first analysis consisted of spatially locating each category of livestock practices reported. A qualitative indicator of the vulnerability of livestock to predation by jaguars was constructed to identify the variables involved and their relative importance, which was useful for informing recommendations (Table 2). Forage, capture and prey consumption were the three elements used to determine whether vulnerability was high, medium or low, following optimal foraging theory (Gutiérrez, 1998). A value was then assigned for each activity involved in livestock management.

Results

Figure 2 relates livestock practices with the type of surroundings where these take place (i.e. human settlement, corral, pastureland, border or transition zone, or tropical rain forest). Decisions concerning issues such as the location of family plots and rainforest units are taken at the *ejido* community level. In the corral zone, animals may be removed and kept closer to the family home to avoid the spread of disease or attacks by predators. Livestock are

grazed on plots of pasture delimited by barbed wire fences, which in some cases are adjacent to borders or transition areas with forest patches. Livestock reproduction occurs in the corral and pasture units. Livestock move within border zones and forested lands to obtain water from streams or natural springs.

The various aspects of livestock husbandry practices are illustrated in Fig. 3. Four broad themes emerge from the data: (1) general aspects of livestock practices, (2) herd improvement, (3) economic income, and (4) economic losses. These themes encapsulate the main aims of rural families in raising livestock: to increase production and economic income to improve their well-being.

More than half of those interviewed (62%) had subdivisions within their fenced grazing areas, and rotated livestock every 15–30 days within each subdivision. Access to water for livestock was limited to natural sources such as rivers, streams and springs, which are abundant in the area; all participants expressed a commitment not to log trees, and to protect vegetation surrounding sites that provided water. The disposal of animal waste was another important aspect of animal husbandry; dead animals were left where they were found and were not buried or burned. Reproduction was carried out through free mounting, in which a male is released close to females. Sometimes directed mounting was carried out with a borrowed male stud. Reproduction was conducted in corrals and in the grazing zones (Fig. 2). None of the interviewees reported a schedule of vaccinations, and veterinary assistance would be sought only after considerable losses had occurred. Only 18% of interviewees had control of their herd (by means of ear tags or burn marks); 46% reported individual numbering of each head of livestock, mainly to meet the requirements of governmental assistance programmes, such as the Program of Stimuli for Livestock Productivity. Ear tags or brands are used to identify individuals within a herd. In relation to infrastructure, possession of corrals (59%) and internal subdivisions (50%) were most commonly reported by interviewees (Table 3).

Herd improvement Herd improvement is based on nutrition, and the only food supplement interviewees could provide was mineral salt. Stud males, used to maintain the genetic health of livestock herds, are acquired at livestock auctions or are loaned from other producers (Table 3). Females are returned to their reproductive condition through early weaning of calves, and are crossed with a new male.

Family income Families seek to increase their herds to sell animals or derivatives. For 96% of interviewees, live animals < 6 months of age were the most lucrative product; only 6% of respondents produced milk and cheese. Other sources of income included economic support from governmental agencies (21% of interviewees) and self-employment (12%). Families also engaged in agricultural activities such as the cultivation of maize (71%) and beans (75%; Table 3).

TABLE 2 Indicator of vulnerability of livestock to predation in relation to various management activities, with recommendations for mitigation, and the type of change needed.

Management activity	Indicator of vulnerability ¹				Vulnerability level ²	Recommendations for mitigation	Type of changes needed
	Easy access	Easy capture	Quick consumption				
Livestock grazing areas near conserved forests	3	3	3		High	Relocate grazing areas away from forested lands. If this is not possible, create a double perimeter fence in areas adjacent to forested areas.	Economic investment
Cattle drink water in riparian zones	3	3	2		High	Build drinking troughs away from riparian areas; water can be extracted from streams & moved through gravity systems.	Economic investment
Inappropriate handling of cattle carcasses	3	3	2		High	Bury or burn livestock carcasses.	Behavioural change
No control of reproduction & births	2	2	2		Medium	Synchronize mating seasons for better control of births.	Behavioural change
Poor veterinary supervision	2	2	1		Medium	Establish vaccine schedules. Carry out veterinary monitoring of herds throughout the year.	Behavioural change
Poor control of herd	2	1	1		Medium	Establish adequate recording of sales, deaths, births, & losses from various causes.	Behavioural change
Poor handling	1	1	1		Low	Keep mature females with experience in defending their calves. Avoid dehorning.	Behavioural change
Poor infrastructure for mitigating livestock predation	2	1	0		Low	Invest in perimeter fencing to improve separation between pasture lands & forested areas. Invest in nocturnal confinement corrals to protect young animals.	Economic investment
Nutritional management	2	2	0		Medium	Invest in food supplements that fortify animals. When possible, use native forage plants as supplements.	Economic investment
Fertility management	1	1	0		Low	Do not wean early. Seek veterinary advice to establish strategies for fertility increase.	Behavioural change
Sourcing of stallions	0	1	0		Low	Source males from various places to improve genetic pools.	Economic investment & behavioural change

¹0, no influence; 1, low influence; 2, medium influence; 3, high influence

²Sum of vulnerability indicators: 1–3, low; 4–6, medium; 7–9, high vulnerability

Economic loss Diseases were perceived to be one of the main factors affecting livestock production; 56% of interviewees reported rabies (viral encephalomyelitis) and 50% reported anthrax (*Bacillus* sp.). Predators were another relevant factor in economic losses, according to 50% of interviewees. Although we did not ask directly about livestock theft, as it is a sensitive subject, it was mentioned by at least 15 interviewees (Table 3).

Vulnerability to predation The management practices that expose livestock to risk of predation by jaguars are outlined in Table 2. The qualitative indicator of livestock vulnerability

allows us to identify factors that impede or restrict changes in practices that could mitigate predation.

Discussion

Few studies have examined the role of rural peoples' livestock practices in relation to predation by jaguars. Our field experience indicates that the conflict is accepted among rural inhabitants, government authorities and conservationists working in the Selva Lacandona region. However, campaigns and mitigation programmes have been conducted

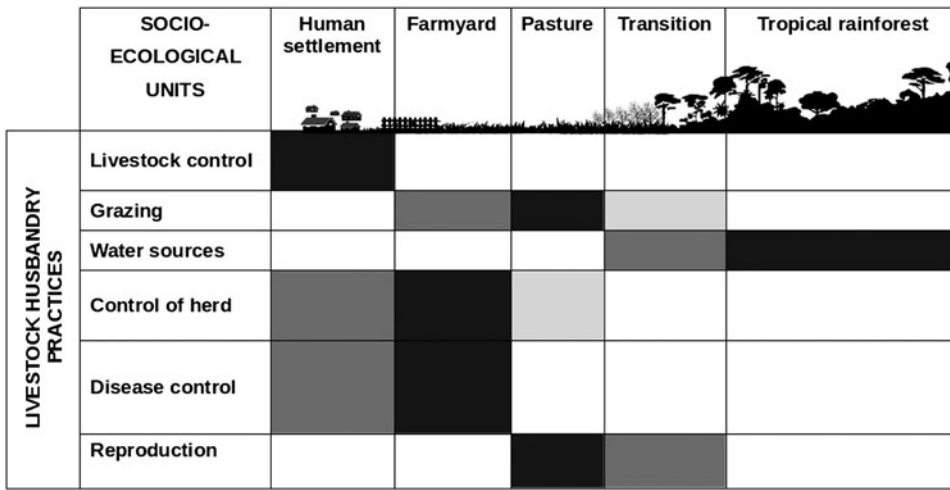


FIG. 2 Spatial distribution of the major components of livestock practices in ejidos adjacent to the Montes Azules Biosphere Reserve (Fig. 1). The shading indicates the intensity of the activity (black, high intensity; dark grey, medium intensity; light grey, low intensity).

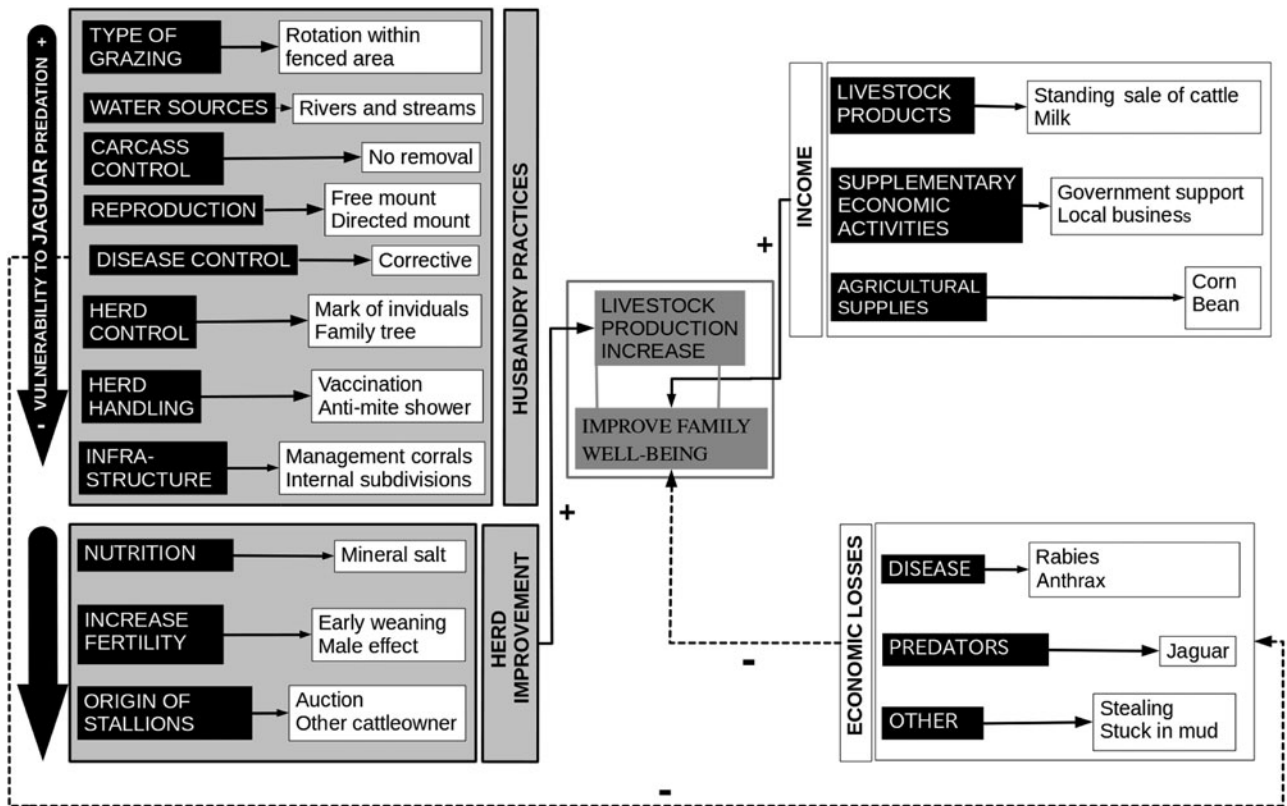


FIG. 3 Categories and specific practices relating to general livestock husbandry, herd improvement, income and economic losses in south-eastern Mexico (Table 3), and the relationships between them (solid and dashed lines represent positive and negative relationships, respectively). The categories within the grey-shaded boxes correspond to management practices that affect livestock predation by jaguars, and those within white boxes indicate responses of interviewees.

without a deep understanding of the views of those affected by the conflict. Our results may be restricted to the Selva Lacandona region but the context of our study is similar to that in other places in Mexico, as well as in Central and South America (Burgas et al., 2014; Tortato et al., 2015).

Livestock grazing near well-preserved portions of jaguar habitat has been reported as a major cause of predation

throughout the jaguar’s natural range (Azevedo & Murray, 2007; Palmeira et al., 2008; Donikar et al., 2011; Soto-Shoender & Giuliano, 2011; Garrote, 2012; Zarco-González et al., 2013; Soh et al., 2014). We also identified this pattern, with cattle becoming vulnerable to predation when they move near natural areas to obtain food and water. Another factor that contributes to livestock vulnerability is

TABLE 3 Categories and specific practices relating to the general management of livestock, herd improvement, income and economic losses, with the percentage of interviewees (n = 32) who used each practice.

Category	Specific practices	%
General management of livestock		
Type of grazing	Free within fenced area	100
	Grazing rotation	62.5
Water sources	Rivers & streams	100
Carcass control	Carcasses not moved	81.25
	Moved when useful	18.75
Reproduction	Free mount	100
	Mount directed	3.12
Disease control	When necessary (corrective)	100
Herd control	Individual marking	46.87
	Family tree	25
	Written control	25
	Record of individuals	18.75
	Record of deaths	9.37
Handling of herd	Vaccination	100
	Anti-mite shower	100
	Dehorning	37.37
	Castration	12.5
Infrastructure	Management corrals	59.37
	Internal subdivisions	50
	Internal roads	46.87
	Feeders	43.75
	Night corrals	12
	Barns	6.25
Herd improvement		
Nutrition	Mineral salt	100
Fertility increase	Early weaning	50
	Male effect	12.5
	Hormonal	9.37
Origin of stallion	Auction	46.87
	Other cattle owner	46.87
	Own	21.87
Income		
Livestock products	Sale of cattle	96.87
	Milk	6.05
	Cheese	6.25
Supplementary economic activities	Workforce	3.12
	Government support	21.87
	Local business	12.5
	Local transport	3.12
	Temporary employment	3.12
Agricultural supplies	Corn	75
	Subsistence	75
	Sale	50
	Bean	71.8
	Subsistence	71.8
	Sale	53
Economic losses		
Disease	Rabies (viral encephalomyelitis)	56.25
	Anthrax (<i>Bacillus anthracis</i>)	50.5
	Malignant edema (<i>Clostridium septicum</i>)	37.5
	Blackleg (<i>Clostridium chauvoei</i>)	21.87
	Dehydration	3.12
Predators	Jaguar <i>Panthera onca</i>	50
	Theft	
Other	Stuck in mud	9.37
	Attack by vultures	3.12

the handling of dead animals. In the study area carcasses are not removed, and this can encourage carnivores to attack livestock, and may even create some dependency or preference for livestock as a source of food (Hoogesteijn & Hoogesteijn, 2011). Thus incineration or burying of dead animals is a recommended practice (Sander et al., 2002; Hoogesteijn & Hoogesteijn, 2011). Proper handling of reproduction activities and management of calves are also important factors in reducing predation by carnivores (Schuess-Meier et al., 2007). Providing special confinement corrals for vulnerable young calves (< 6 months) provides security (Van Bommel et al., 2007; Hoogesteijn & Hoogesteijn, 2011) and facilitates vigilance by livestock keepers.

A relevant issue that emerged is the need for a written record of every animal that is sold or has died, whether by natural or other causes (e.g. disease, drowning, snake bite or attack by a predator). This practice was not evident in our study, resulting in overestimation of the damage caused by jaguars (Hoogesteijn & Hoogesteijn, 2011). We found that the approach to disease management was remedial rather than preventive, and this behaviour has been passed down through generations. Good health management results in fewer losses at birth and in general, which in turn increases productivity, and thus losses caused by predation are not as devastating to the family economy. In most cases livestock losses to predators are fewer than those caused by other factors, including disease (Hoogesteijn & Hoogesteijn, 2011). At present, disease management is mostly confined to vaccination programmes administered by government agencies. This economic incentive accompanied by an educational campaign could raise awareness of the benefits of more efficient livestock practices.

Early weaning is a harmful practice used to increase animal production. It is not recommended as it can lead to low meat production; a young calf left with its mother can be more productive (Arias et al., 1998). It can also lead to digestive and respiratory illnesses, as well as diseases related to poor adaptation as a result of weak body state and/or retarded growth (Soni, 1998). Thus, early weaning produces weaker individuals that may be more susceptible to diseases, and vulnerable to predation by carnivores such as the jaguar. Changing this practice will require training to ensure that producers understand the infrastructure required for the appropriate management of both mothers and young.

Livestock production in the Selva Lacandona represents a source of complementary income for families, as in other parts of Mexico and elsewhere (FAO, 2009; Davies et al., 2010). There is a need to supplement the family economy with governmental support and subsistence agriculture partly because livestock production does not provide the yields expected. However, this creates a circular problem: because livestock does not provide the necessary earnings people do not invest in better management of their livestock, although this would increase their returns in the long term.

Taking into account factors such as disease and predation, livestock production becomes an activity that requires high levels of investment, which is impossible for the majority of families in the Selva Lacandona. Livestock theft must also be evaluated as it results in significant losses for producers, as has occurred in South America (Hoogesteijn & Arenas-Avella, 2008).

A broad conclusion derived from our findings is that several specific livestock husbandry practices make herds in the Selva Lacandona more vulnerable to attack by jaguars (these practices and our recommendations are outlined in Table 2). Two broad types of changes were identified to implement these recommendations: (1) economic investment, and (2) behavioural changes in communities and in relation to the cultural and educational histories of families. Both matters require technical and communication interventions, with the provision of financial support. Mitigation programmes already in existence should consider not only a payment for animals lost in attacks by carnivores (which is helpful) but also the implementation of a more integral strategy that includes a capacity-building perspective (Abella & Fogel, 2000). Training workshops that provide technical advice should be accompanied by visual educational materials designed for people with poor literacy skills or who have little experience of using written materials. Provision of certificates for good livestock practices may help people to get access to economic support and resources such as materials for fences or veterinary assistance. One important recommendation relates to the monitoring of livestock herds. We advise the use of written records of all livestock, which could be maintained by marking in special notebooks designed for those with a low level of literacy (Supplementary Fig. S1).

Finally, we recommend that agents such as the government and NGOs provide educational interventions (awareness-raising and training) as well as economic support to help families improve their livestock husbandry practices. Conversion to efficient and productive practices would improve families' economic circumstances, which could translate into greater investment in infrastructure and veterinary care, and ultimately increase productivity. Such actions can be effective in mitigating conflict, and may create a scenario of greater tolerance for jaguars in the Selva Lacandona.

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