Colegio de Postgraduados

Community Monitoring: Promoting Conservation in Candelaria, Campeche, Mexico

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ABSTRACT

Objective: To engage agricultural producers in the implementation of a community-based wildlife monitoring system aimed at generating citizen science.

Design/Methodology/Approach: Community monitors were trained in bird observation and identification techniques, as well as in the operation and management of camera traps. Photographic trapping stations were installed adjacent to milpas to identify the wildlife species frequenting these agroecosystems.

Results: Eight local individuals were trained as community monitors. Over 811 trap-nights, a total of 32 species were identified, eight of which are listed under some category of protection. The species with the highest number of records are classified as generalists. Most of the recorded species exhibit nocturnal or crepuscular activity patterns. The data confirm the effectiveness of photographic trapping as a method for detecting wildlife species in milpa systems.

Study Limitations/Implications: The communities involved in the study are located in remote areas without access to the electrical grid and are characterized by irregular land tenure conditions, factors that contribute to social distrust and certain levels of community apathy.

Findings/Conclusions: A high diversity of species interacting with milpa systems was observed. The photographic trapping method proved effective for wildlife detection in milpas in Campeche and successfully facilitated the integration of local participants as community monitors.

Keywords: Milpa, photo-trapping, mammals, participatory monitoring, Southeastern Mexico.

INTRODUCTION

Throughout history, human beings have interacted in various ways with the ecosystems surrounding them. These interactions whether through hunting and gathering of available fauna and flora, agriculture, or the extraction of non-renewable resources involve a certain degree of management (Ruggerio, 2021). In the contemporary era, the need to manage

ecosystems and the ways in which people engage with them has become particularly evident as a strategy to adapt to environmental change, mitigate industrial activities, and conserve biodiversity (Thompson *et al.*, 2020). Community-based wildlife monitoring offers significant benefits, such as promoting local ownership of conservation initiatives and projects, thereby increasing the likelihood of success due to higher acceptance and participation from local communities (Danielsen *et al.*, 2022). This approach is especially relevant in countries where resources are often limited and where a structured culture of volunteerism may not exist. In such contexts, local volunteer-based monitoring can enhance awareness, foster management interventions, and improve the efficiency and reach of conservation efforts (Danielsen *et al.*, 2022). In parallel, technological advancements and particularly the widespread access to the Internet have paved the way for biological monitoring through citizen science, a tool increasingly used to document and study wildlife (Moustard *et al.*, 2021). A central objective of citizen science (also referred to as community science) is to support scientific research by providing data that exceed the spatial and temporal capacities of professional researchers (Shirk *et al.*, 2012). This approach has significantly advanced the understanding of wildlife patterns, including species distribution, phenology, and behavior. In the southeastern region of Mexico, northern Guatemala, and northeastern Belize lies the Maya Forest, a shared trinational tropical forest considered the largest continuous tropical forest mass in Mesoamerica, with more than 30,000 km^2 under some category of protection. The Maya Forest maintains the best-preserved plant and animal communities in Mesoamerica (Reyna-Hurtado *et al.*, 2022). The region of Candelaria, located in the southwestern part of Campeche, was originally characterized by medium sub-evergreen tropical forest. However, in recent decades, much of this area has been converted into agricultural fields and pastures, causing severe changes in forest cover (Sánchez-Dzib *et al.*, 2009; Ellis *et al.*, 2020). The aim of this study was to promote the participation of local communities and milpa producers in the implementation of a wildlife monitoring system to foster citizen awareness and facilitate coexistence between wildlife and local residents, particularly among producers supported by the Sembrando Vida program an initiative promoted by the federal government of Mexico. Given that the region is classified as highly marginalized, local inhabitants frequently resort to deforestation to establish their production systems. This study hypothesizes that community-based monitoring carried out by local residents could serve multiple purposes: generating valuable information to attract tourists and researchers (thus stimulating local economic benefits), and fostering ownership and empowerment over the natural resources they possess.

MATERIALS AND METHODS

The Calakmul Biosphere Reserve (CBR) is located within the Yucatán Peninsula in the southeastern region of the state of Campeche (coordinates: 18° 29"N, 89° 47"W). It forms part of the Greater Calakmul Region, which includes the Maya Biosphere Reserve in Guatemala and the Río Bravo Dos Milpas Conservation Area in Belize. The CBR spans an area of 723,185.12 hectares (Reyna-Hurtado *et al.*, 2022). The reserve is characterized by a warm, sub-humid climate (Aw), with an average annual temperature of 24.6 °C. The highest elevation is found at Champerico Hill, reaching 390 meters above sea level, while the lowest elevation ranges from 100 to 150 meters. The dominant vegetation types include medium sub-evergreen tropical forests, medium semi-deciduous tropical forests, and low semi-deciduous tropical forests (Martínez and Galindo, 2002; Martínez-Kú *et al.*, 2008). The community of Balankax has a population of 84 inhabitants, 14 of whom are beneficiaries of the Sembrando Vida program. Meanwhile, the community of Chilam Balam has 116 inhabitants, with 31 participants enrolled in the same program.

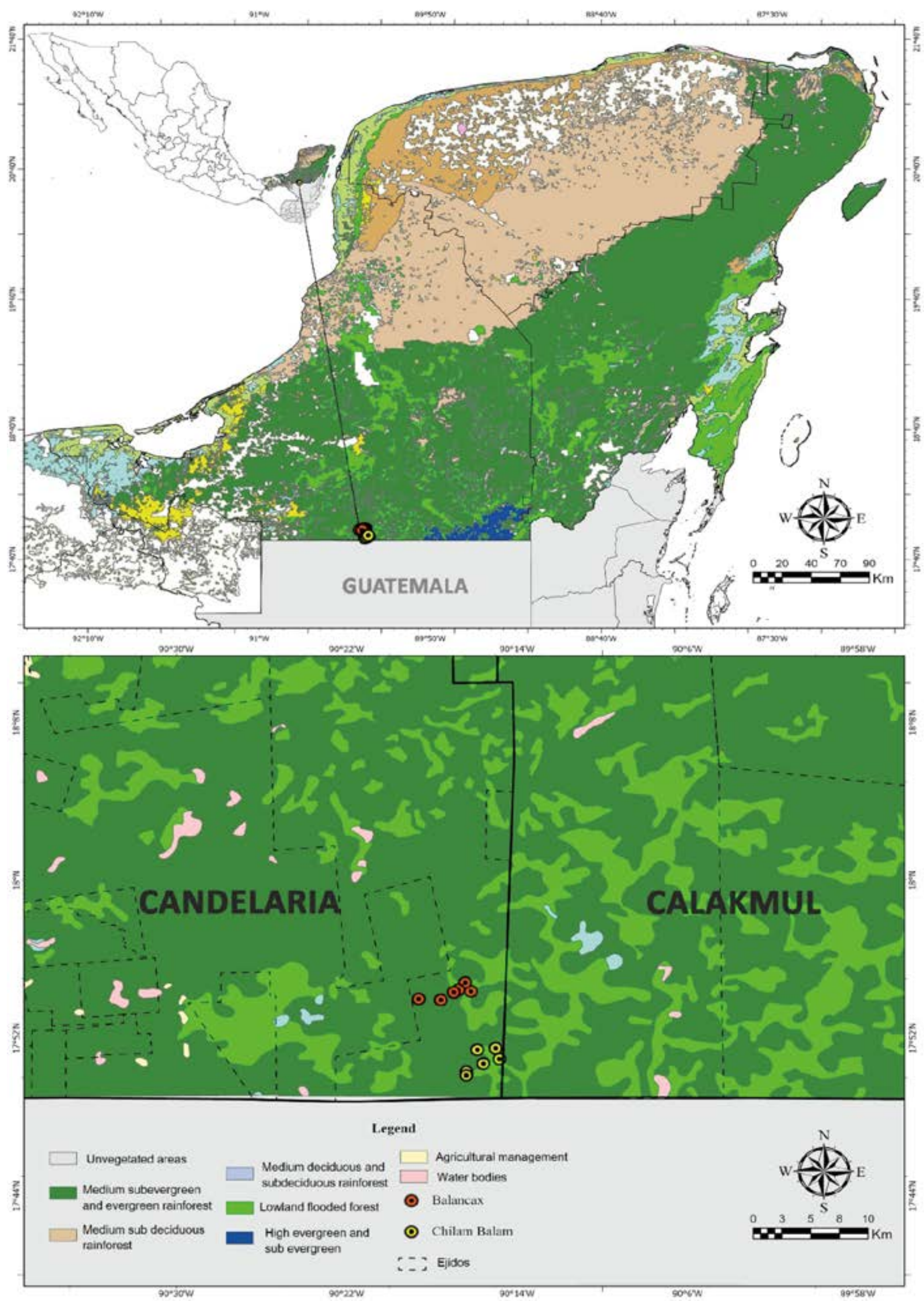

Figure 1. Location of the camera trap stations. Red circles indicate the stations in the community of Balankax, while yellow circles represent the stations in the community of Chilam Balam, in Candelaria, Campeche.

Selection of communities

To ensure the participation of producers at the site of interest, meetings (two meetings) were held in the communities of Chilam Balam and Balankax, where the project was presented, and its intended objectives were explained. During these meetings, producers who met the desired conditions were identified: a) maintaining a plot with polyculture milpa, b) participating in the Sembrando Vida program, c) preserving patches of original vegetation near the plot, d) having identified the presence of wildlife on their plots, and e) expressing interest in participating. Finally, 10 plots of 2.5 hectares were selected to establish the wildlife monitoring network, with 5 plots in the community of Balankax and 5 in the community of Chilam Balam (Figure 1).

Training of Community Monitors in Camera Trap Installation

Once the producers were identified, practical training sessions were conducted on the handling of camera traps, with participation from both the producers and local youth interested in learning (Figure 2).

Once the plots where the study would be conducted were defined, 10 camera traps were installed (one in each plot), which remained active for seven consecutive months (from December 2021 to June 2022).

The cameras were placed 50 cm above ground level, attached to trees adjacent to the milpas, and programmed to capture photographs 24 hours a day, with a 5-second interval between each image. Camera inspections were carried out every 20 days. During each inspection, the photographs were downloaded and assigned a registration code number; finally, the correct functioning of the cameras was verified, and batteries were replaced if

Figure 2. Training of community monitors in the use of camera traps.

necessary (Contreras-Moreno *et al.*, 2024). Species identification was performed manually by entering the data into a spreadsheet (Excel®), including station, camera trap name, date, time, species, image file name, and number of individuals.

Data Analysis

Once the photographs were captured, a database was constructed using the CamtrapR package in R version 3.4.0 (R Core Team, 2017; Niedballa *et al.*, 2019). The Visit Photographic Index (VPI) was estimated for each species using the formula:

$$VPI = NR / EM * 1000$$

where NR represents the number of independent records, EM is the total number of active cameras throughout the study period, and 1000 trap-nights is used as a correction factor. An independent record was defined as a photographic capture of a species within a one-hour interval. The analysis also included records of domestic animals (dogs, horses, cattle).

Activity patterns and the degree of overlap among the species with the highest number of records were evaluated through Kernel density analysis, and statistical differences between peak activity times among species were assessed using the Wald test, supported by the Activity package version 3.5.1 and the overlap package in R version 3.4.0 (Ridout and Linkie, 2009; Rowcliffe, 2016). Community monitors were trained in the use of the OfflineMaps® application (APP) for georeferencing the plots and locating the cameras. The training sessions also included the use of plaster for footprint casting, the use of the iNaturalist® APP, and nocturnal monitoring activities.

RESULTS AND DISCUSSION

Eight local residents were trained in bird observation, including two from the community of Balankax, five from Chilam Balam, and one from Laguna de Oro. The community monitors established a working framework through which they uploaded all their observations to NaturaLista México. With a sampling effort of 2,100 trap-nights, a total of 32 species were identified, corresponding to 16 orders and 24 families. Mammals were the most diverse group with 22 species, followed by 10 species of birds. According to their conservation status, five species were classified as Endangered (E) and three as Threatened (T), based on the NOM-59-SEMARNAT-2010. Under the criteria of the International Union for Conservation of Nature (IUCN), one species was listed as Vulnerable (VU), three as Near Threatened (NT), and 28 as Least Concern (LC). Regarding habitat type, 14 species were recorded in plots surrounded by pastures, 19 in forested areas, and seven in both habitat types (Table 1).

Regarding the visit rate, the species with the highest visit rates among mammals were the gray fox (*Urocyon cinereoargenteus* Schreber), the coati (*Nasua narica* Linnaeus), the agouti (*Dasyprocta punctata* Illiger), and the common opossum (*Didelphis marsupialis* Linnaeus) (Figure 3). Among birds, the plain chachalaca (*Ortalis vetula* Wagler) exhibited the highest visit rate (Figure 4).

Table 1. Diversity of fauna recorded in the community of Balankax through the use of camera traps.

Order	Family	Group	Common N.	Scientific N.	NOM 059	UICN
Pelecaniformes	Ardeidae	Bird	Heron	*Ardea alba*[1]	-	LC
		Bird	Cattle Egret	*Bubulcus ibis*[1]	-	LC
		Bird	Night Heron	*Nyctanassa violacea*[1]	-	LC
Galliformes	Cracidae	Bird	Chachalaca	*Ortalis vetula*[1,2]	-	LC
	Phasianidae	Bird	Ocellated Turkey	*Meleagris ocellata*[2]	A	NT
Columbiformes	Columbidae	Bird	Mountain Dove	*Leptotila verreauxi*[1,2]	-	LC
Accipitriformes	Accipitridae	Bird	Buzzard Eagle	*Rupornis magnirostris*[1]	-	LC
Strigiformes	Strigidae	Bird	Brown Owl	*Ciccaba virgata*[2]	-	LC
Cuculiformes	Cuculidae	Bird	Tick-Eyed Owl	*Crotophaga sulcirostris*[1]	-	LC
Passeriformes	Corvidae	Bird	Pea	*Psilorhinus morio*[1]	-	LC
Didelphimorphia	Didelphidae	Mammal	Opossum	*Didelphis marsupialis*[2]	-	LC
Cingulata	Dasypodidae	Mammal	Armadillo	*Dasypus novemcinctus*[1,2]	-	LC
Pilosa	Myrmecophagidae	Mammal	Anteater	*Tamandua mexicana*[2]	-	LC
Lagomorpha	Leporidae	Mammal	Rabbit	*Sylvilagus floridanus*[1,2]	-	LC
Carnivora	Felidae	Mammal	Ocelot	*Leopardus pardalis*[2]	A	LC
		Mammal	Margay	*Leopardus wiedii*[2]	P	NT
		Mammal	Puma	*Puma concolor*[2]	-	LC
		Mammal	Jaguarundi	*Herpailurus yagouaroundi*[2]	A	LC
		Mammal	Jaguar	*Panthera onca*[1,2]	P	NT
	Canidae	Mammal	Coyote	*Canis latrans*[1]	-	LC
		Mammal	Gray Fox	*Urocyon cinereoargenteus*[1,2]	P	LC
	Mustelidae	Mammal	Old-Flying Woodpecker	*Eira barbara*[2]	P	LC
	Mephitidae	Mammal	White-backed Skunk	*Conepatus semistriatus*[2]	-	LC
	Procyonidae	Mammal	Coatiel	*Nasua narica*[1,2]	-	LC
		Mammal	Raccoon	*Procyon lotor*	-	LC
Perissodactyla	Tapiridae	Mammal	Tapir	*Tapirus bairdii*[2]	P	LC
Artiodactyla	Tayassuidae	Mammal	Collared Peccary	*Pecari tajacu*[2]	-	LC
	Cervidae	Mammal	Gray Goat	*Mazama pandora*[2]	-	VU
	Cervidae	Mammal	White-tailed Deer	*Odocoileus virginianus*[2]	-	LC
Rodentia	Sciuridae	Mammal	Squirrel	*Sciurus yucatanensis*[2]	-	LC
	Dasyproctidae	Mammal	Sereque	*Dasyprocta punctata*[1,2]	-	LC
	Cuniculidae	Mammal	Tepezcuinte	*Cuniculus paca*[2]	-	LC
Chiroptera	-	Mammal	Bats	*Murcielagos* sp.[1]	-	LC

The superscripts indicate the type of vegetation where the species were recorded: [1] Pasture and [2] Jungle.

In this study, 22 mammal species were recorded in the plots of Candelaria, representing 19.81% of the mammal species present in the state of Campeche, which hosts a total of 111 species (Guzmán-Soriano *et al.*, 2013). The records highlight the effectiveness of the camera trapping method for detecting species in milpa systems, positioning it as an excellent complementary tool to conventional monitoring methods (Lira-Torres and Briones-Salas, 2012). Additionally, camera trapping allowed the community monitors from Balankax

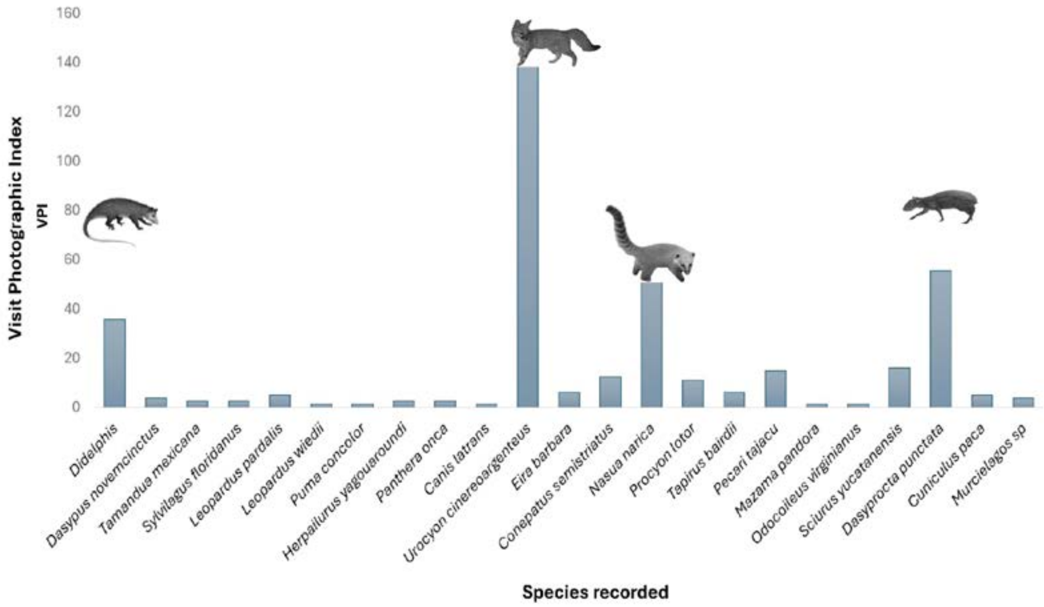

Figure 3. Visit Photographic Index (VPI) of mammals recorded through monitoring in plots from the studied communities in Candelaria, Campeche.

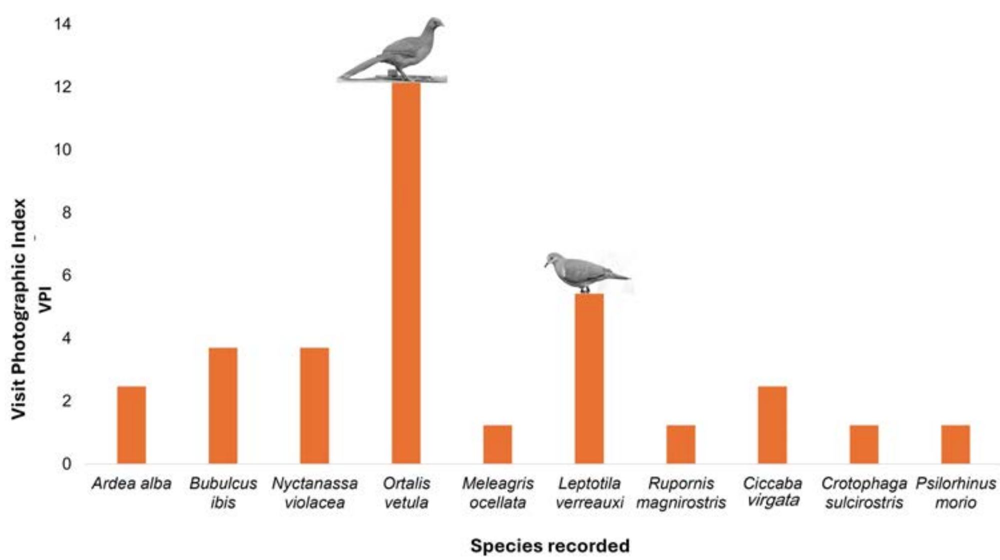

Figure 4. Visit Photographic Index (VPI) of birds recorded in plots in Candelaria, Campeche.

and Chilam Balam to deepen their engagement with natural sciences (Follett and Strezov, 2015), suggesting its potential as a positive strategy to foster closer interaction between rural populations and nature, while also generating technical-scientific data.

The species with the highest Visit Photographic Index (VPI) among mammals (gray fox, coati, agouti, and common opossum) and birds (plain chachalaca, common ground dove, cattle egret, and black-crowned night heron) are considered generalists. Some species, such as the agouti, have demonstrated high visit rates in the Maya Forest (Borges-Zapata *et al.*, 2020). The opossum, coati, and gray fox are frequently reported

Figure 5. Species recorded in milpa systems during community-based monitoring. a) jaguar, b) coati, c) gray fox, d) agouti, e) collared peccary, f) raccoon, g) dog, and h) horse with person.

as problematic species in productive systems of Tabasco, where they are associated with considerable economic losses due to crop damage (Rodríguez-Calderón *et al.*, 2018). Among birds, parrots are particularly recognized for their impact on crops. Certain psittacid species have been identified as serious agricultural pests in several Latin American countries, damaging grain, seed, flower, and fruit crops (Tracey *et al.*, 2007). In the studied communities, these birds are identified as conflict species, primarily because they feed on economically important fruits such as maize (*Zea mays* Schrad) and citrus (*Citrus* sp.), similar to reports from other regions in Tabasco (Rodríguez-Calderón *et al.*, 2018).

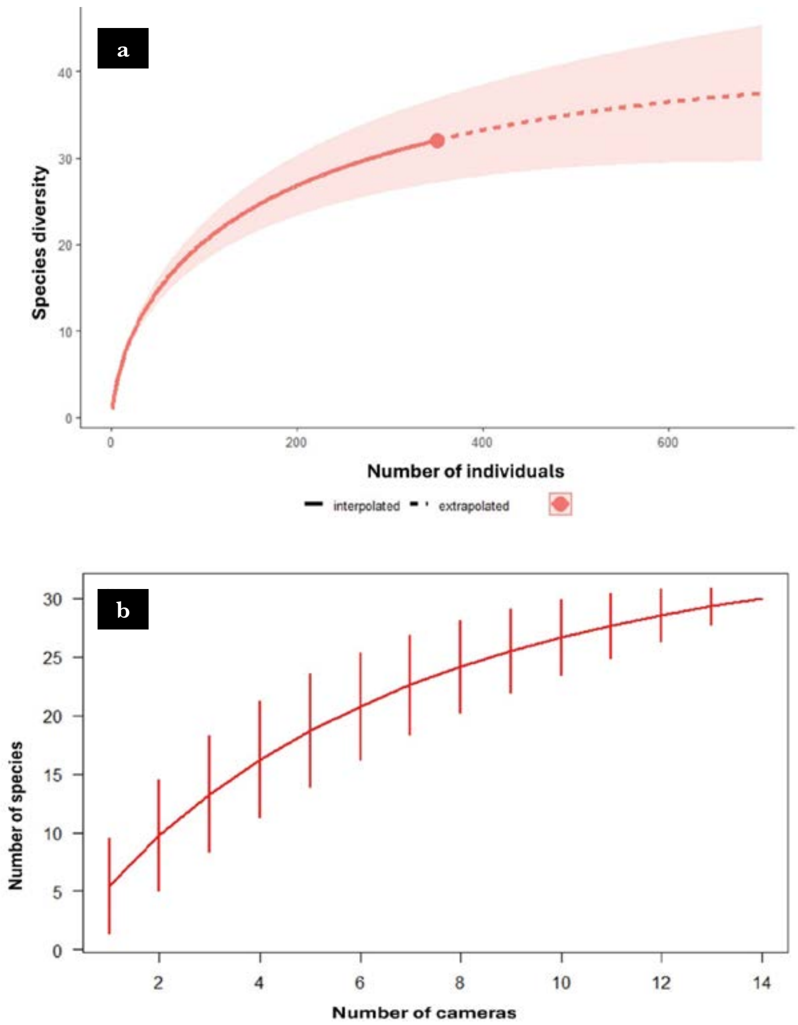

Figure 6. Species accumulation curves showing: a) the number of species and b) the number of cameras.

Despite the relatively limited sampling effort, species diversity was high. Although the asymptote of the species accumulation curve was not reached, this may be attributed to the specific characteristics of the sampling sites. Milpa systems, being active agricultural workspaces, maintain constant human activity, which could influence species detection patterns.

Activity Patterns

Activity pattern analyses were conducted for medium and large mammal and bird species that had more than five records. The plain chachalaca (*Ortalis vetula*) showed higher activity between 17:00 and 18:00 hours, while the white-backed skunk was most active between 00:00 to 06:00 and 21:00 to 22:00 hours. The agouti exhibited peak activity from 06:00 to 09:00 and 15:00 to 17:00 hours (Figure 7). The common opossum was more active from 00:00 to 06:00 and 19:00 to 22:00 hours. The coati displayed activity between 05:00 and 18:00 hours. The Yucatecan squirrel showed higher activity

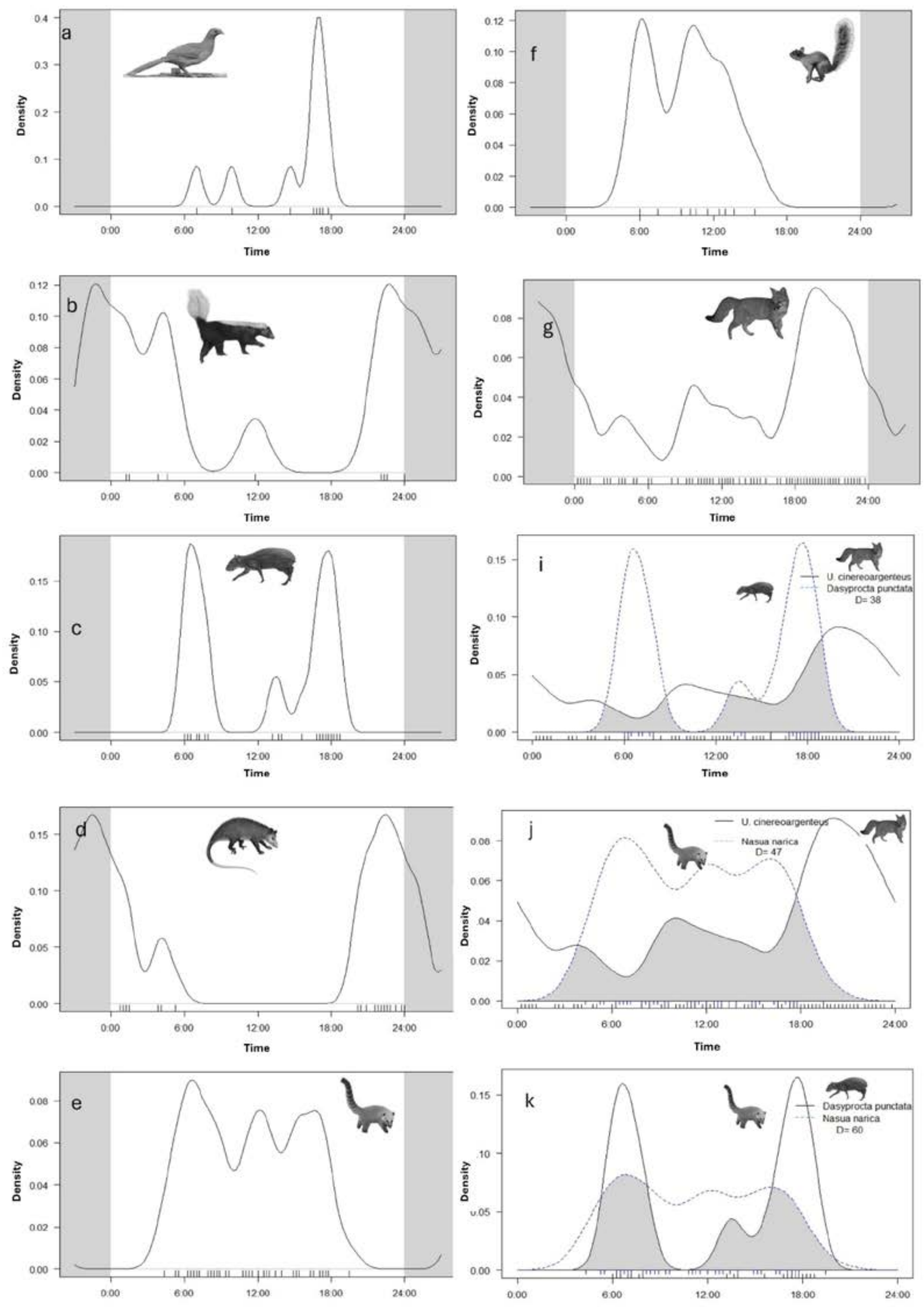

Figure 7. Activity patterns estimated during the study in the communities of Candelaria, Campeche. a) plain chachalaca, b) white-backed skunk, c) agouti, d) common opossum, e) coati, f) Yucatecan squirrel, g) gray fox. Additionally, the figure includes the graphs of temporal overlap analysis: i) gray fox and agouti, j) gray fox and coati, and k) agouti and coati.

from 06:00 to 15:00 hours (Figure 7). The gray fox was observed to be active continuously throughout the 24-hour period.

Several studies have documented that prey mammals exhibit various behavioral adjustments to minimize the risk of predation by their natural predators (Mukherjee and Heithaus, 2013). In some cases, hunting pressure forces ungulates to shift their visits to water sources from daytime to nighttime or vice versa. These changes are influenced by the predation risk imposed by large carnivores (Crosmary *et al.*, 2012). Certain carnivore species may sometimes show higher daytime activity, which is unusual compared to other wild carnivores that tend to be crepuscular or nocturnal. This adaptation is closely related to prey availability and the need to avoid competition with other predators (Carrera-Treviño *et al.*, 2018). The coati is one of the diurnal mammals that local people often recognize as a pest in milpa systems; being a medium-sized mammal that lives in groups, it can cause significant damage (Rodríguez-Calderón *et al.*, 2018). Community-based monitoring and citizen science, supported by the camera trapping method, proved effective in several ways. The involvement of local people from remote communities in Candelaria, Campeche, was successfully achieved, generating valuable technical-scientific information on the wildlife visiting milpa systems, while also fostering community engagement in citizen science initiatives. The integration of multidisciplinary groups addressing topics such as conservation, education, and psychology consistently strengthens community participation in environmental projects. Thanks to the implementation of inclusive engagement strategies, the project was able to approach local inhabitants more effectively, delivering key messages about the importance of conserving the wildlife present in their communities. The synergy and alignment of objectives between the World Wildlife Fund (WWF) and Sembrando Vida were pivotal to the evident success of this project. This initiative stands as a clear example that future conservation actions should be implemented directly in the field, with the active involvement of local stakeholders at various levels.

CONCLUSIONS

The diversity of species interacting with the milpa systems was high, including the presence of ecologically important species such as the jaguar. The findings of this study indicated that the camera trapping method is effective for detecting species in milpa systems in the southern region of Campeche and successfully facilitated the integration of local residents as community monitors. Wildlife species visit the plots at various times throughout the day, which exerts constant pressure on the crops.

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