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The bobcat (*Lynx rufus*) in the Nayarit Coastal Plain, México: presence, relative abundance and activity patterns

El gato montés (*Lynux rufus*) en la llanura costera de Nayarit, México: presencia, abundancia relativa y patrones de actividad

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The bobcat, *Lynx rufus*, is one of the six wild cats that inhabit México. It is distributed from sea level up to 3,600 m, occupying a wide variety of habitats including deserts, mountain ecosystems and wetlands. However, to date, there is no ecological information on the species in coastal wetlands. The general objective of this work is to provide the first ecological information systematically obtained on the bobcat in the Coastal Plain of Nayarit (NCP). We evaluated their historical and current presence, relative abundance, and activity patterns. We determined the historical presence of the bobcat in the NCP through a search of the words using the keywords "Lynx", "rufus", "lince", "bobcat" and "Nayarit" in electronic databases. We implemented the protocol of the National Jaguar Census using camera traps in a 72 km^2 area to document the bobcat's presence, relative abundance, and activity patterns. Through the database search we find 23 bobcat's records in area of at least 3,000 km^2 of the NCP. From our fieldwork we obtained 30 independent records with a relative abundance of 1.28 bobcat photographs / 100 camera days. We documented the presence of at least 10 different individuals, including adults of both sexes, and possibly a pregnant female. Its activity is nocturnal; 40 % of the records occurred between 00:00 - 06:00 hr. The bobcat inhabits the coastal wetlands of Nayarit. The high values of relative abundance suggest a stable population in the NCP with respect to what has been reported in suitable habitats such as temperate forests and scrubs. Its nocturnal activity coincides with other studies on the species. Although, in general, the bobcat adapts well to disturbance generated by human activities, the impacts that these have on their populations in tropical wetlands are unknown. To ensure the permanence of the species, future work is recommended to know in depth its diet, reproduction, home range and genetic connectivity of this species in the tropical wetlands of western México.

Key words: *Lynx rufus*; presence; species distribution models.

El gato montés, *Lynx rufus*, es una de las seis especies de felinos silvestres que habitan en México. Se distribuye desde el nivel del mar hasta los 3,600 m, ocupando una gran variedad de hábitats entre los que se encuentran los desiertos, ecosistemas de montaña y humedales. Sin embargo, a la fecha, no existe información ecológica de la especie en humedales costeros. El objetivo general de este trabajo es proveer la primera información ecológica obtenida de forma sistemática sobre el gato montés en la Planicie Costera de Nayarit (PCN). Evaluamos su presencia histórica y actual, su abundancia relativa y patrones de actividad. Determinamos la presencia histórica del gato montés en la PCN mediante una búsqueda en bases de datos electrónicas utilizando las palabras: "Lynx", "rufus", "lince", "bobcat" y "Nayarit". Implementamos el protocolo del Censo Nacional del Jaguar usando cámaras trampa en un área de 72 km^2 para documentar la presencia, distribución, abundancia relativa y patrones de actividad del gato montés. A través de la búsqueda en bases de datos encontramos 23 registros de gato montés en un área de al menos 3,000 km^2 de la PCN. A partir de nuestro trabajo de campo obtuvimos 30 registros independientes con una abundancia relativa de 1.28 fotografías de gato montés / 100 días cámara. Documentamos la presencia de al menos 10 individuos diferentes, incluyendo adultos de ambos sexos y una hembra presuntamente embarazada. Su actividad es nocturna; 40 % de los registros ocurrieron entre las 00:00-06:00 hr. El gato montés habita los ecosistemas costeros de Nayarit. Los valores elevados de abundancia relativa sugieren una población estable en la PCN con respecto a lo que ha sido reportada en hábitat ideales para la especie tales como los matorrales y bosques templados. Su actividad nocturna coincide con lo que reportan otros trabajos para la especie. Aunque, en general, el gato montés se adapta bien al disturbio generado por actividades humanas, los impactos que estas tienen sobre sus poblaciones en los humedales costeros aún se desconocen. Para asegurar la permanencia de sus poblaciones es necesario realizar futuros estudios sobre su dieta, reproducción, ámbito hogareño y conectividad genética de la especie en los ecosistemas costeros del occidente de México.

Palabras clave: *Lynx rufus*; modelos de distribución; presencia.

The bobcat (*Lynx rufus*) is one of the 6 wild cats that inhabit México (Ceballos and Oliva 2005). Its geographical distribution extends from the border of the United States of America, including the Baja California Península, both slopes (Pacific and Gulf of México), narrowing towards the Mexican Central Highlands with its southern limit being the state of Oaxaca (Hall 1981; Lariviere and Walton 1997; Phillips *et al.* 2004; Ceballos *et al.* 2006; Sánchez-Cordero *et al.* 2008; Roberts and Crimmins 2010; Monroy-Vilchis *et al.* 2019). Bobcats are extant in México from sea level up to 3,600 m, occupying a wide variety of habitats including wetlands, deserts and mountain ecosystems (Romero 2005). In all these ecosystems the bobcat is considered a mesopredator (Conner *et al.* 2001) and therefore are essential for the maintenance of biodiversity and proper-functioning ecosystems (Ripple *et al.* 2014). Due to the bobcat's wide distribution, abundance, and adaptability, it is not listed in any threaten category, international or nationally. However, some populations in México are experiencing genetic isolation as a result of habitat fragmentation resulting from human activities that may eventually result in local extinctions (López-González *et al.* 2015).

Previous studies of bobcats in México have documented diet, abundance and density in desert, semi-desert and temperate ecosystems at intermediate elevations (Delibes *et al.* 1997; Aranda *et al.* 2002; Burton *et al.* 2003; Medellín and Bárcenas 2010; Elizalde-Arellano *et al.* 2012; López-Vidal *et al.* 2014; López-González *et al.* 2015; Sánchez-González *et al.* 2018), but nothing about coastal wetland populations in the tropics.

In 1903, Allen described a new subspecies of bobcat (*L. r. escuinapae*) whose type locality is Escuinapa, Sinaloa, located in the Pacific Coastal Plain ecoregion, an extensive area of floodplains and marshes that extend from southern Sinaloa to central Nayarit on the Pacific Coast of México (INEGI 1991). Later, Leopold (1959) included bobcats in a mapped range distribution that included the entire state of Nayarit, with no supporting observational information. Similarly, Hall (1981), included the state of Nayarit within the bobcat's range. Prior to this study, there has been no data published on bobcats inhabiting the Pacific Coastal Plain. Therefore, our aim in this work was to provide the first ecological information systematically obtained on the bobcat in the Coastal Plain of Nayarit, confirming its presence along this area. We evaluated their historical and current presence, relative abundance, and activity patterns.

The Pacific Coastal Plain is an elongated and narrow plain (it covers a strip of up to 65 km wide), which extends along the coast from Sonora to Nayarit in western México. It is characterized by being an almost flat relief formed by large flood plains, lakes and swamps aligned parallel to the coast (INEGI 1991). Our study area is located within the Nayarit Coastal Plain (NCP), delimited from the north of Nayarit (Municipality of Tecuala) to the Rio Grande de Santiago (Municipalities of Santiago Ixcuintla and San Blas; Figure 1). The camera trapping study was carried out in 72 km^2 within the sub-province called "Delta of the Rio Grande de Santiago" (INEGI 1991; Figure 2). The northern limit of the study area was the town of Los Corchos (21° 43' 57" N, 105° 28' 12" W, 3 m; Municipality of Santiago Ixcuintla), south of the mouth of the estuary called "La Boca Cegada" (21° 35' 46" N, 105° 24' 0" W, 0 m; Municipality of San Blas), to the west the Pacific Ocean and to the east the boundary was established at a distance of approximately 6 kilometres from the coastline (Figure 1). The climate is warm and humid with an average annual temperature of 31.7 °C. The predominant native vegetation is the mangrove (*Avicennia germinans* and *Conocarpus erectus*) with patches of low deciduous forest, palapar, secondary vegetation, farmland, and livestock land (CONAFOR 2015).

We determined the historical presence of the bobcat in the NCP through an electronic search using the keywords "Lynx", "rufus", "lince", "bobcat" and "Nayarit" in the following databases: Open Data Portal of the Biological Collections of the National Autonomous University of México (IBUNAM 2020); Community of Natural History Collections of Vertebrates (VertNet 2020); and the Citizen science portal of the National Commission for the Knowledge and Use of Biodiversity (Naturalista 2020). Only georeferenced records and those confirmed by experts (in the case of Naturalista) were considered as credible records. Finally, we estimated the total area with a presence of bobcat in the NCP as a convex polygon.

To determine the abundance of the bobcat we used camera trapping methodologies that have previously been applied to other felines (*e. g*., National Jaguar Census, CENJAGUAR; Chávez *et al.* 2013). In October 2018, using Google Earth Pro®, a grid was applied to our study area covering an area of 72 km^2, which was subsequently then divided into 8 quadrants of 9 km^2 each. In each 9 km^2 quadrant, 3 sites were selected where a camera trap would potentially be placed. Each site selected was separated by a minimum of 1 km. Between November and December 2018, the previously chosen sites were verified in the field while looking for evidence of feline sign (footprints, scrapes). A total of 24 sites (stations) were selected where camera traps were then placed (Figure 2). We used Cuddeback® Model Color C1 (Non Typical, Inc., Park Falls, WI) camera traps. We placed 17 single-camera stations and 7 double-camera (2 cameras at the same point, 1 on the opposite side of the other) stations. Cameras were attached to trees 35 to 50 cm above ground level and were placed perpendicular to wildlife passages (Chávez *et al.* 2013). Cameras remained active for 60 days during each sampling session (February-March, 2019 and February-March, 2020).

The resulting images were stored and classified using the methodology proposed by Harris *et al.* (2010). Relative abundance was calculated using the Relative Abundance Index (RAI) using the formula proposed by Maffei *et al.* (2004) and Jenks *et al.* (2011): RAI = (C / SE) x 100 where C = number of photographic captures, SE = sampling effort (number of cameras per monitoring day) per unit of time

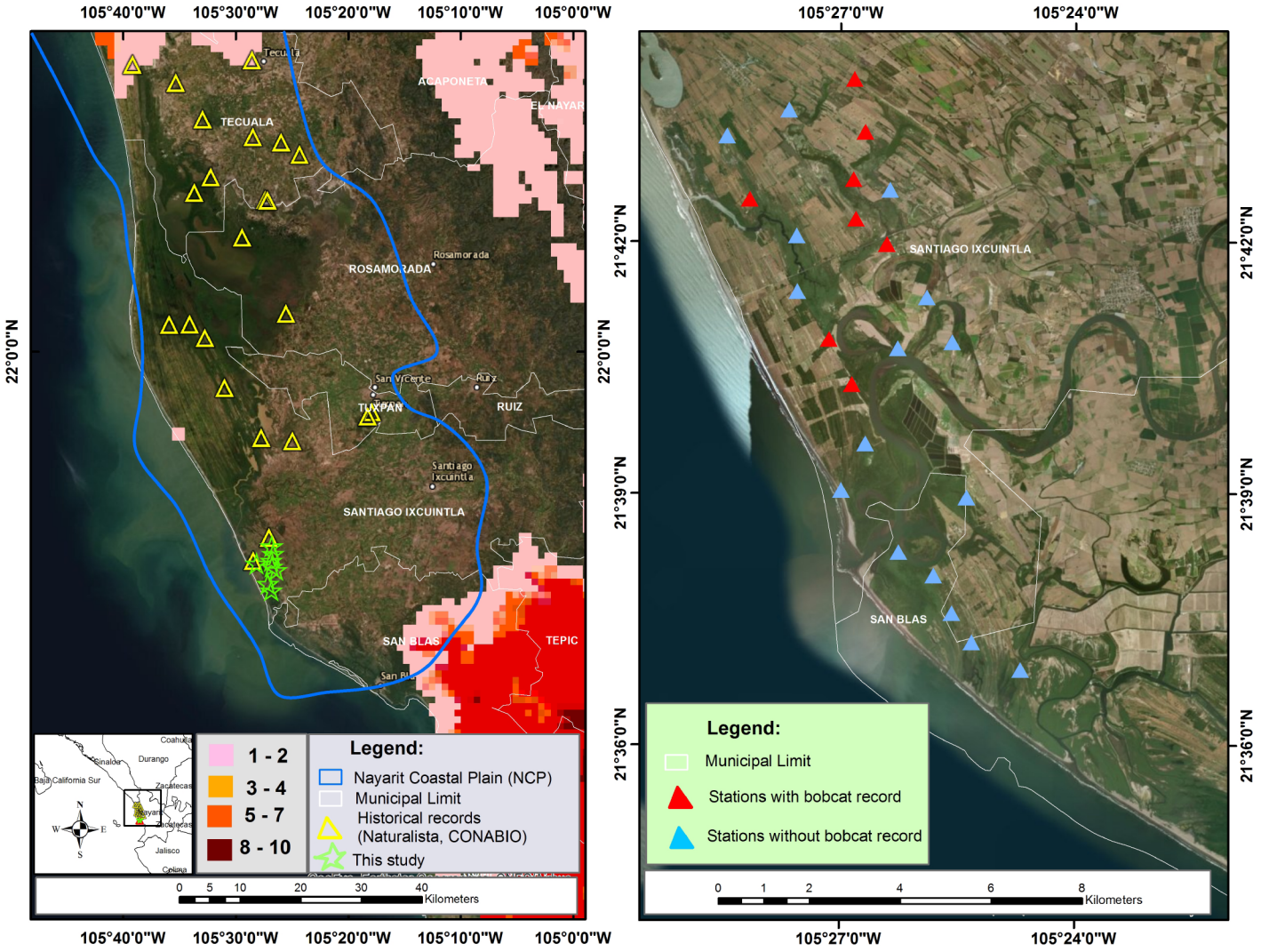

Figure 1. A) Map showing the layer generated by Comisión Nacional para el Conocimiento y uso de la Biodiversidad (CONABIO) with the potential distribution of the bobcat (1-2 low; 8-10 high presence probability), excluding the Nayarit Coastal Plain (blue line), México. The coordinates with the historical records (yellow triangles) and the location of the camera traps (green stars) where the bobcat was photographed in 2019 and 2020 for this study are shown. B) Location of the 24 camera trap stations in the Nayarit Coastal Plain used for monitoring in January-February 2019 and 2020. The red triangles show the presence of bobcat in the Nayarit Coastal Plains, México.

and per 100 camera days (standard correction factor). Naïve occupancy was calculated, which is defined as the proportion of cameras in which a species is registered in relation to the total number of cameras used during monitoring (O'Connell and Bailey 2011). The minimum number of individuals was determined from the identification of each individual by comparing their spot patterns, scars, sex and body sizes (Heilbrun *et al.* 2006). In all cases, at least three natural characteristics were used for the recognition of the same animal (comparing, for example, tail stripes, scars or facial marks on the same flank). Finally, the daily activity patterns were obtained using the Overlap package (Ridout and Linkie 2009) of the computational language R (R Core Team 2013).

We obtained 23 bobcats reported records for the NCP; all records come from CONABIO's Naturalist citizen science portal. The oldest record is from 2009 and the most recent from 2019. Table 1 presents the data from all bobcat records, including those obtained in this study during 2019 and 2020.

The sampling effort during this study was 2,740 camera days (2019: 1,367; 2020: 1,373). A total of 43 bobcat photographs were obtained derived of our fieldwork (Figure 2). Of these, 30 were determined to be independent records (photographs of the same species in the same station within a period greater than 60 minutes) and were used in the abundance and activity analysis. Bobcats were recorded in 8 of 25 stations, with a naïve occupancy of 0.32 (32 %) and a relative abundance of 1.28 bobcat photographs / 100 camera days. It was possible to identify at least 10 different individuals (6 females, 1 male and 3 unidentified). Of the 30 independent records obtained, 12 (40 %) occurred between 00:00-06:00 hr, 9 (30 %) between 06:00-18:00 hr, and 9 (30 %) between 18:00-00:00 hr (Figure 3).

Having reliable information to understand the distribution patterns of a species at different scales is useful for

Table 1. Bobcat (*Lynx rufus*) records obtained from electronic database searches. All the records were found on the Citizen science portal of the National Commission for the Knowledge and Use of Biodiversity (Naturalista 2020). The records product of the field work of the present study are presented in bold.

Source	Collection type	Date (year/month/day)	Geographical coordinates
This study	**Camera trap photo**	**2020/03/18**	**21° 43′ 57.73″ N, 105° 26′ 50.77″ W**
This study	**Camera trap photo**	**2020/02/27**	**21° 41′ 59.65″ N, 105° 26′ 25.85″ W**
This study	**Camera trap photo**	**2020/02/24**	**21° 40′ 51.57″ N, 105° 27′ 09.99″ W**
This study	**Camera trap photo**	**2020/02/02**	**21° 42′ 45.98″ N, 105° 26′ 51.34″ W**
This study	**Camera trap photo**	**2020/01/29**	**21° 43′ 19.89″ N, 105° 26′ 42.49″ W**
Naturalista	Footprint photo	2019/11/07	22° 12′ 31.43″ N, 105° 27′ 22.60″ W
Naturalista	Footprint photo	2019/11/07	22° 12′ 28.28″ N, 105° 27′ 10.24″ W
This study	**Camera trap photo**	**2019/03/25**	**21° 40′ 19.28″ N, 105° 26′ 52.42″ W**
This study	**Camera trap photo**	**2019/03/17**	**21° 42′ 31.76″ N, 105° 28′ 10.94″ W**
This study	**Camera trap photo**	**2019/02/04**	**21° 42′ 17.61″ N, 105° 26′ 49.51″ W**
Naturalista	*Lynx* in wildlife photo	2015/11/24	21° 55′ 00.94″ N, 105° 17′ 54.44″ W
Naturalista	Camera trap photo	2011/11/26	22° 09′ 25.12″ N, 105° 29′ 24.19″ W
Naturalista	Camera trap photo	2011/11/16	22° 20′ 43.09″ N, 105° 24′ 58.65″ W
Naturalista	Camera trap photo	2011/10/13	22° 17′ 16.10″ N, 105° 25′ 57.92″ W
Naturalista	Camera trap photo	2011/08/25	22° 01′ 08.43″ N, 105° 32′ 45.09″ W
Naturalista	Camera trap photo	2011/08/13	22° 02′ 16.31″ N, 105° 34′ 07.29″ W
Naturalista	Camera trap photo	2011/07/31	22° 02′ 13.71″ N, 105° 35′ 56.63″ W
Naturalista	Camera trap photo	2011/07/30	22° 03′ 08.74″ N, 105° 25′ 31.73″ W
Naturalista	Camera trap photo	2011/07/30	22° 19′ 07.80″ N, 105° 32′ 57.93″ W
Naturalista	Camera trap photo	2011/07/30	22° 14′ 24.04″ N, 105° 32′ 13.72″ W
Naturalista	Camera trap photo	2011/07/11	22° 13′ 06.40″ N, 105° 33′ 41.17″ W
Naturalista	Camera trap photo	2011/05/03	21° 42′ 45.18″ N, 105° 28′ 28.07″ W
Naturalista	Camera trap photo	2010/03/23	21° 47′ 36.65″ N, 105° 27′ 44.68″ W
Naturalista	Camera trap photo	2010/01/23	22° 17′ 41.65″ N, 105° 28′ 29.14″ W
Naturalista	Camera trap photo	2010/01/10	22° 22′ 09.35″ N, 105° 35′ 21.21″ W
Naturalista	Camera trap photo	2009/11/16	22° 24′ 00.21″ N, 105° 28′ 33.12″ W
Naturalista	Camera trap photo	2009/12/20	22° 23′ 39.66″ N, 105° 39′ 12.04″ W
Naturalista	Camera trap photo	2009/11/02	22° 16′ 15.23″ N, 105° 24′ 19.30″ W
Naturalista	Camera trap photo	2009/08/24	21° 54′ 39.89″ N, 105° 18′ 16.49″ W
Naturalista	Camera trap photo	2009/08/22	21° 57′ 00.93″ N, 105° 31′ 00.46″ W
Naturalista	Fecal sample photo	2009/06/03	21° 44′ 38.80″ N, 105° 27′ 02.08″ W

both biogeography and conservation (Chefaoui and Lobo 2008). Our results confirmed what was proposed historically by Allen (1903), Leopold (1959) and Hall (1981), who all stated the range of the bobcat included the NCP, where it is rather a common species.

Using a camera trap methodology, we documented for the first time the presence of at least 10 different individuals, including adults of both sexes, and possibly a pregnant female in a coastal wetland located in Nayarit. The relative abundance index obtained in this work (1.28 bobcat photographs / 100 camera days), is similar, for example, to that reported for the bobcat in coniferous forests in Virginia, USA (1.36; Kelly and Holub 2008), and in Tlaxcala, México (1.27; Flores-Morales *et al.* 2019). It is even higher than at sites defined in the species distribution models as ideal ecosystem for the species, such as Sierra Gorda in Guanajuato, where relative abundance values of 0.15 were reported in submontane scrub and 0.09 in pine-oak forest (Charre-Medellín *et al.* 2016). The high values of relative abundance are indicative of a stable population of the bobcat in the NCP with respect to what has been reported in suitable habitats for the species, such as temperate forests and scrubs. Our records are remarkable since the study area is highly fragmented and with patches of mangroves of different sizes connected by secondary vegetation. It is known the bobcat is tolerant and adaptable to some man-made environments, especially males and young bobcats as females had low levels of modified association which posteriorly affects the population viability (Riley *et al.* 2003). In addition, the threshold on habitat loss and fragmentation is in general unknown for the species although a study found that bobcats may occur in fragmented sites but not in small and iso-

Figure 2. A bobcat, *Lynx rufus*, photographed on March 18, 2020 in a mangrove-tropical deciduous forest-farmlands ecotone in the Nayarit Coastal Plains, México.

lated sites (Crooks 2002) while others found this mammal can show a higher degree of adaptation (Riley *et al.* 2003). It is strongly recommended to accounting for landscape connectivity as it is key for management of bobcat populations across fragmented landscapes (Jacques *et al.* 2019).

In general, the activity of the bobcat in the NCP is consistent with the activity that has been registered in populations from other ecosystems where they are extant: 30 % of the records correspond to daytime activity, and 70 % to twilight-night activity (Anderson and Lovallo 2003; Elizalde-Arellano *et al.* 2014; Flores-Morales *et al.* 2019; Serna-Lagunes *et al.* 2019).

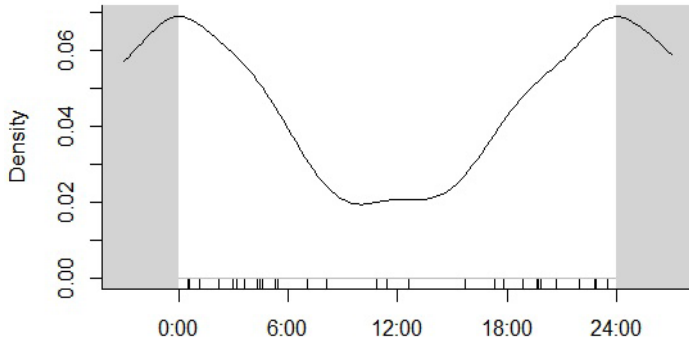

Figure 3. Histogram that shows the activity patterns, from 30 independent photographs, of the bobcat, *Lynx rufus*, in the Nayarit Coastal Plains, México.

The wetlands of the Coastal Plain of Nayarit face serious threats that endanger the permanence of the wildlife that inhabits them (Luja *et al.* 2017), among which is the bobcat. Deforestation for agriculture, livestock and, more recently, the boom in the establishment of shrimp farms, fragment the habitat and generate unfavourable encounters with humans. Although, in general, the bobcat adapts well to disturbance generated by human activities, the impacts that these have on their populations in tropical wetlands are unknown. To ensure the permanence of the species, future work is recommended to know in depth its diet, reproduction, home range and genetic connectivity of this species in the tropical wetlands of western México.

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