Potential distribution of *Kinosternon cora* (Testudines: Kinosternidae) and implications for its conservation

Distribución potencial de *Kinosternon cora* (Testudines: Kinosternidae) e implicaciones para su conservación

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Abstract

Kinosternon cora, an endemic turtle of the Pacific Coastal Plain in Sinaloa and Nayarit, Mexico, is classified as "Endangered" due to its restricted distribution, habitat loss, and illegal collection. This study modeled its potential distribution using MaxEnt and 48 verified presence records, analyzing bioclimatic variables (mean annual temperature, diurnal temperature range, temperature of the warmest quarter, precipitation of the driest and coldest quarters). The LQPTH/β3 model showed high performance (AUC = 0.970, pROC = 1.51, p = 0.001), predicting 3,548.27 km^2 of suitable habitat with 85.9% overlap with the known distribution. Mean annual temperature (29.5–30.0°C) and low dry-season precipitation (<100 mm) were the most influential predictors, contributing 41.64% and 22.2% to the model, respectively, with optimal diurnal temperature ranges (10.0–16.0°C) and warmest quarter temperatures (28.5–30.0°C), reflecting reliance on thermally stable wetlands. Precipitation in the coldest quarter had no significant effect. These results identify climatically suitable areas for *K. cora*, highlighting the need to protect aquatic and semi-aquatic habitats threatened by wetland degradation and illegal trade. Unconfirmed predicted areas suggest zones for targeted surveys to refine distribution knowledge. This study supports conservation efforts by identifying priority areas for

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habitat protection and recommending the integration of non-bioclimatic variables, such as vegetation cover, to refine future distribution models.

Keywords: Endemic species, Freshwater turtles, MaxEnt, Nayarit, Sinaloa.

Resumen

Kinosternon cora, una tortuga endémica de la Planicie Costera del Pacífico en Sinaloa y Nayarit, México, está clasificada como “En Peligro” debido a su distribución restringida, pérdida de hábitat y recolección ilegal. En este estudio modelamos su distribución potencial usando MaxEnt y 48 registros de presencia verificados, analizando variables bioclimáticas (temperatura media anual, rango diurno de temperatura, temperatura del trimestre más cálido, precipitación de los trimestres más seco y frío). El modelo LQPTH/β3 mostró alto rendimiento (AUC = 0.970, pROC = 1.51, p = 0.001), prediciendo 3,548.27 km² de hábitat adecuado con un 85.9% de superposición con la distribución conocida. La temperatura media anual (29.5–30.0°C) y la baja precipitación en la temporada seca (<100 mm) fueron los predictores más influyentes, contribuyendo 41.64% y 22.2% al modelo, respectivamente, con rangos óptimos de temperatura diurna (10.0–16.0°C) y temperaturas del trimestre más cálido (28.5–30.0°C), reflejando la dependencia de humedales térmicamente estables. La precipitación en el trimestre más frío no tuvo efecto significativo. Estos resultados identifican áreas climáticamente adecuadas para *K. cora*, destacando la necesidad de proteger hábitats acuáticos y semiacuáticos amenazados por la degradación de humedales y el comercio ilegal. Las áreas predichas sin registros sugieren zonas para muestreos dirigidos para refinar el conocimiento de la distribución. Este estudio apoya los esfuerzos de conservación al identificar áreas prioritarias para la protección del hábitat y recomendar la integración de variables no bioclimáticas, como la cobertura vegetal, para refinar modelos de distribución futuros.

Palabras clave: Especie endémica, MaxEnt, Nayarit, Sinaloa, Tortugas de agua dulce.

INTRODUCTION

In Mexico, 19 species of the genus *Kinosternon* are recognized, of which 11 (60%) are endemic, highlighting the richness and uniqueness of this group in the country (Macip-Ríos, 2024). In Sinaloa, a state in northwestern Mexico, four species of this genus are distributed: *K. alamosae*, *K. cora*, *K. integrum* and *K. sonoriense* (Castro-Bastidas, 2024; Molina-Serrano et al., 2025). *Kinosternon cora*, locally known as Chacuanita cora (Figure 1), is an endemic species described in 2020 (Loc-Barragán et al., 2020), with a restricted distribution in southern Sinaloa and northwestern Nayarit,

Fig. 1. A male adult Chacuanita Cora (*Kinosternon cora)* from Escuinapa, Sinaloa, Mexico. Photo by JALB.

Fig. 1. Un macho adulto de Chacuanita Cora (*Kinosternon cora*) de Escuinapa, Sinaloa, México. Foto por JALB.

recently expanded to the municipality of San Ignacio in the central-southern region of Sinaloa (González-Bernal, Rojas-Aguilar, Rosales-Martínez, Loc-Barragán, 2025).

The International Union for Conservation of Nature (IUCN) classifies *K. cora* as "Endangered" due to its limited geographic range (~8,895 km^2 in the Pacific Coastal Plain), illegal collection for the pet trade, and habitat loss (Procuraduría Federal de Protección al Ambiente [PROFEPA], 2025; Loc-Barragán, Woolrich-Piña, López-Luna, Iverson, in press). With only 48 individuals recorded across 15 localities, knowledge about its distribution and ecology is limited, and its cryptic behavior complicates ecological studies and conservation strategies (Loc-Barragán and Iverson, 2024).

Turtles of the genus *Kinosternon* are known for their dependence on aquatic and semi-aquatic habitats, such as rivers, ponds, and wetlands, which are often subject to strong anthropogenic pressures in tropical and subtropical regions (Berriozábal-Islas et al., 2023). In the case of *K. cora*, the ephemeral nature of the lentic aquatic ecosystems it inhabits, formed only during the rainy season, combined with its restricted distribution, poses a significant threat to its survival (Loc-Barragán and Iverson, 2024).

The 'Wallacean shortfall,' or lack of geographic distribution data (Hortal et al., 2015), is critical for turtles, including endangered species like *K. cora*, which face limited distribution knowledge and high susceptibility to anthropogenic pressures (Brooks, Brown, Galbraith, 1991; Stanford et al., 2020; Saunders, Cuthbert, Zipkin, 2024). In this context, species distribution models are key tools for predicting potential presence areas, identifying priority habitats for conservation, and guiding field surveys by integrating presence data with environmental variables to estimate ecological suitability, especially when field data are scarce (Elith et al., 2006; Phillips and Dudík, 2008; Peterson and Soberón, 2012).

Given the threatened status of *K. cora* and its restricted distribution, this study aims to model its potential distribution using the MaxEnt algorithm, selected for its robustness with species with limited data. The model is based on verified presence records and high-resolution bioclimatic variables, with the objectives of: (1) identifying geographic areas with suitable climatic conditions for the species, and (2) evaluating the congruence between the predicted and known distribution. This work identifies areas with suitable climatic conditions for *K. cora*, supporting conservation planning and guiding targeted survey efforts.

MATERIALS AND METHODS

Data Source

Presence records for *K. cora* were obtained through systematic field monitoring, employing active visual searches and capture traps in wetlands and temporary water bodies (Loc-Barragán et al., 2020; Loc-Barragán and Iverson, 2024; González-Bernal, Rojas-Aguilar, Rosales-Martínez, Loc-Barragán, 2025; JALB, unpublished data, 2024). From an initial total of 56 records, the database was refined by removing eight spatially duplicated records, resulting in 48 unique records used for modeling.

Accessibility Area

The study area was delimited using Level III ecoregions of the Sinaloa and Nayarit Coastal Plain, including Hills of Sonora and Sinaloa with xerophytic scrub and tropical dry forest, Coastal Hills and plains of Nayarit and Jalisco with evergreen tropical forest, and Coastal plains of Nayarit and Sinaloa with thorny scrub forest (CONABIO, 2020). These ecoregions were selected for their confirmed *K. cora* records and homogeneous vegetation (e.g., tropical deciduous forest) and environmental conditions (Soberón, 2010; Bakx et al., 2019; Loc-Barragán et al., 2020). This approach was preferred over basin delimitation to avoid over-restricting the area for a microendemic species and to facilitate exploration of potential habitats (see Figure 2A for the ecoregion map).

Bioclimatic data from CHELSA v2.1 (~1 km^2 resolution, period 1980–2018) were used as predictor variables (Brun, Zimmermann, Hari, Pellisier, Karger, 2022). To avoid redundancy among variables, a Variance Inflation Factor (VIF) analysis, a statistical method that assesses multicollinearity among predictor variables by identifying those that are highly correlated and could bias model results, was conducted using the 'sdm' package in R Studio (Abdelaal, Fois, Fenu, Bacchetta, 2019; Naimi and Araújo, 2016; R Core Team, 2016). This analysis led to the elimination of 14 variables with significant multicollinearity (VIF > 5; see Table 1). Five key variables were retained: mean annual temperature (bio01), diurnal temperature range (bio02), temperature of the warmest quarter (bio10), precipitation of the driest quarter (bio17), and precipitation of the coldest quarter (bio19). Although bio01 had a VIF of 7.71, it was included due to its biological importance for ectothermic species like turtles (Dormann et al., 2013; Marn, Jusup, Legović, Kooijman, Klanjšček, 2017).

Model Configuration

The species distribution model was generated using MaxEnt v3.4.4 software (Phillips, Dudík, Schapire, 2017), selected for its high performance in modeling species distributions (Elith et al., 2006). Ten bootstrap replicates were implemented, using 75% of the 48 presence records for training and 25% for testing. Eight combinations of feature classes (linear, quadratic, product, threshold, and hinge: LQHTP, LQHP, LQHT, LQH) and regularization multipliers ($\beta = 1$ and 3) were tested to adjust model complexity, keeping other parameters at MaxEnt's default values.

Model Evaluation

Model performance was assessed using partial ROC (pROC) with 500 bootstrap iterations and a 5% omission error threshold, utilizing the pROC package in R Studio (Lobo, Jiménez-Valverde, Real, 2008; Peterson et al., 2008). This metric reduces spatial biases present in traditional ROC (Barve et al., 2011). Additionally, the Area Under the Curve (AUC) was calculated to evaluate model discriminatory ability. The AUC values range from 0 to 1, where a value between 0.80–0.90 is considered good, and a value greater than 0.90 indicates excellent model fit (Araújo and Guisan, 2006). Models with statistical significance ($p < 0.05$) were evaluated for parsimony using the AICc criterion (Warren and Seifert, 2011) with the ENMval package.

To assess the relative importance of each bioclimatic variable, we conducted a contribution and permutation importance analysis, which evaluates the percentage contribution of each variable to the model fit and the impact of permuting each variable's values on model accuracy, respectively (Phillips, Dudík, Schapire, 2017). Final projections were converted into binary presence/absence maps using a minimum logistic threshold with a 5% omission error (Peterson et al., 2008).

Comparison of Geographic Areas

The area predicted by the selected model was compared with the known distribution of *K. cora* (8,895 km^2; Loc-Barragán and Iverson, 2024) by summing the presence polygons generated in QGIS v3.42.1 (using the "calculate geometry" function) (QGIS, 2025). Spatial congruence was quantified using the Sørensen-Dice Coefficient to measure similarity between the predicted and known areas (Marrugan, 2004; Real, Barbosa, Vargas, 2006; Barve et al., 2011), defined as:

$$D = \frac{2x(A \cap B)}{A + B}$$

Where:
A = area predicted by the model,
B = known distribution area, and
$A \cap B$ = spatial overlap.

We considered this index suitable for our study, as it does not excessively penalize unsampled areas. Additionally, the percentage of Commission Error was calculated to identify predicted areas without confirmed records, relevant for future surveys (Peterson et al., 2011):

$$Commision\,\% = \frac{A - (A \cap B)}{A}\, x\, 100$$

The analyses were conducted using the "raster" package in R Studio and spatial algebra tools in QGIS, providing robust validation of the model's accuracy and its utility for the conservation of *K. cora*.

RESULTS

Model Calibration Evaluation

The comparative analysis of the eight models (Figure 2) revealed that the LQPTH/β3 combination exhibited the best overall performance (Figure 3B), with exceptional values across all evaluation metrics (AUC = 0.970, pROC = 1.51, p = 0.001, AICc = 250.1). Although the LQH/β1 combination showed a slightly higher AUC (0.983), its lower robustness (pROC =

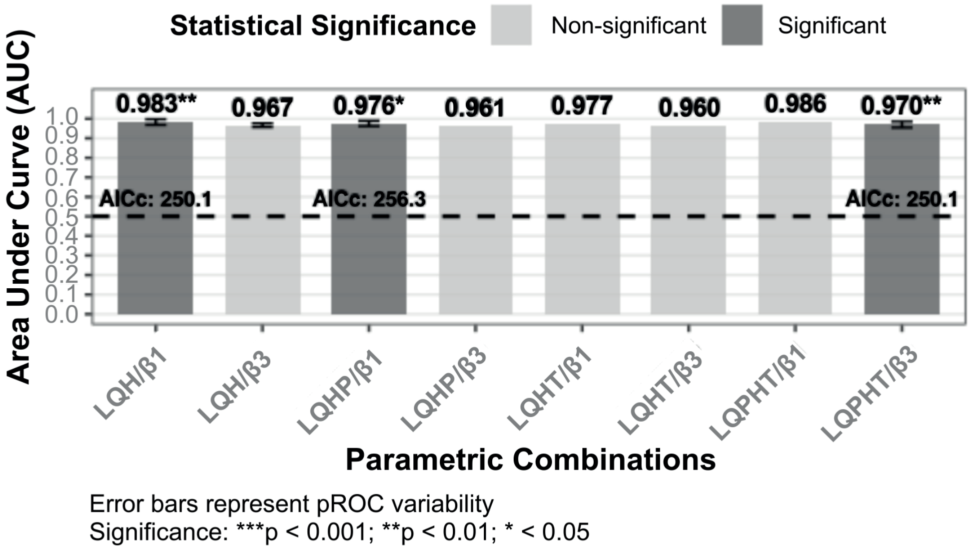

Fig. 2. Comparison of Area Under the Curve (AUC) values for different parametric combinations (LQH/β1, LQHP/β1, LQH/β3, LQHP/β3, LQHT/β1, LQHT/β3, LQPTH/β1, LQPTH/β3) of the MaxEnt model. Bars represent AUC values, with error bars indicating pROC confidence intervals. Statistical significance is denoted as non-significant (ns, p > 0.05), * (p ≤ 0.05), ** (p ≤ 0.01), or *** (p ≤ 0.001). AICc values are shown above each bar. The LQPTH/β3 combination shows the best performance (AUC = 0.970, AICc = 250.1).

Fig. 2. Comparación de los valores del Área Bajo la Curva (AUC) para diferentes combinaciones paramétricas (LQH/β1, LQHP/β1, LQH/β3, LQHP/β3, LQHT/β1, LQHT/β3, LQPTH/β1, LQPTH/β3) del modelo MaxEnt. Las barras representan los valores de AUC, con barras de error que indican intervalos de confianza pROC. La significancia estadística se denota como no significativa (ns, p > 0.05), * (p ≤ 0.05), ** (p ≤ 0.01) o *** (p ≤ 0.001). Los valores AICc se muestran sobre cada barra. La combinación LQPTH/β3 muestra el mejor rendimiento (AUC = 0.970, AICc = 250.1).

1.45) and statistical significance (p = 0.003) ranked it as the second-best option. The LQHP/β1 model showed adequate results (AUC = 0.976, pROC = 1.32, p = 0.021) but with greater complexity (AICc = 256.3), while LQH/β3, despite an acceptable AUC (0.967), did not achieve statistical significance (p = 0.152). The remaining four combinations (LQHP/β3, LQHT/β1, LQHT/β3, and LQPTH/β1) showed AUC values between 0.960–0.986 but lacked statistical significance (p > 0.05) and robustness (pROC < 1), and were therefore discarded for predictive applications.

Analysis of variable importance (Table 1) indicated that mean diurnal temperature range (bio02) was the most influential variable, contributing 52.24% to the model fit and accounting for 46.71% of permutation importance, followed by mean annual temperature (bio01) with 41.64% contribution and 40.82% permutation importance. Temperature of the warmest quarter (bio10) and precipitation of the driest quarter (bio17) had minor contributions (3.02% and 3.09%, respectively) and permutation importance values (4.70% and 7.77%, respectively). Precipitation of the coldest quarter (bio19) showed no contribution or permutation importance (0.0%), suggesting it has minimal influence on the model's predictions for *K. cora*.

Table 1. Bioclimatic variables from the CHELSA climate dataset, Variance Inflation Factor (VIF) analysis, percentage contribution, and permutation importance for the MaxEnt model of *Kinosternon cora*.

Tabla 1. Variables bioclimáticas del conjunto de datos climáticos CHELSA, análisis del Factor de Inflación de la Varianza (VIF), contribución porcentual e importancia por permutación para el modelo MaxEnt de *Kinosternon cora*.

Code (Unit)	Variable name	VIF	Contribution %	Permutation importance
Bio1 (°C)	Mean annual air temperature	7.705	41.64%	40.818
Bio2 (°C)	Mean diurnal air temperature range	1.793	52.24%	46.712
Bio3 (°C)	Isothermality	Inf	-	-
Bio4 (°C)	Temperature seasonality	Inf	-	-
Bio5 (°C)	Mean daily maximum air temperature (warmest month)	Inf	-	-
Bio6 (°C)	Mean daily minimum air temperature (coldest month)	Inf	-	-
Bio7 (°C)	Annual range of air temperature	Inf	-	-
Bio8 (°C)	Mean daily mean air temperatures (wettest quarter)	Inf	-	-
Bio9 (°C)	Mean daily mean air temperatures (driest quarter)	Inf	-	-
Bio10 (°C)	Mean daily mean air temperatures (warmest quarter)	3.844	3.01%	4.701
Bio11 (°C)	Mean daily mean air temperatures (coldest quarter)	Inf	-	-
Bio12 (mm)	Annual precipitation amount	Inf	-	-
Bio13 (mm)	Precipitation (wettest month)	Inf	-	-
Bio14 (mm)	Precipitation (driest month)	Inf	-	-
Bio15 (mm)	Precipitation seasonality	Inf	-	-
Bio16 (mm)	Mean monthly precipitation (wettest quarter)	Inf	-	-
Bio17 (mm)	Mean monthly precipitation (driest quarter)	1.168	3.09%	7.767
Bio18 (mm)	Mean monthly precipitation (warmest quarter)	Inf	-	-
Bio19 (mm)	Mean monthly precipitation (coldest quarter)	2.651	0.00%	0.000

Characterization Of The Geographic Area

The LQPTH/β3 model predicted a total area of 3,548.27 km^2, of which 3,048.60 km^2 (85.9%) overlapped with the known distribution (8,895 km^2; See the geographic areas comparison subsection in the Materials and Methods section). Spatial congruence indices revealed a Sørensen-Dice Coefficient (D) of 0.41, indicating moderate overlap between predicted and known areas. Additionally, the commission error was 14.1% (499.67 km^2), corresponding to habitats that could be climatically suitable for *K. cora* (Figure 3C).

Response curves further elucidated the ecological preferences of *K. cora* (Figure 4). The species exhibited a strong preference for mean annual temperatures (bio01) above 29.0°C, with probability of presence increasing sharply to ~0.9 between 29.5–30.0°C (Figure 4A). Mean diurnal temperature range (bio02) was optimal between 10.0–16.0°C, reflecting tolerance to moderate to high daily thermal variations (Figure 4B). Temperature in the warmest quarter (bio10) peaked at 28.5–30.0°C, declining rapidly beyond 30.0°C, while precipitation in the driest quarter (bio17) was most suitable below 100 mm, declining sharply thereafter (Figure 4C and D). Precipitation in the coldest quarter (bio19) showed no significant effect across its range (0–2500 mm) (Figure 4E), consistent with its null contribution to the model (Table 1).

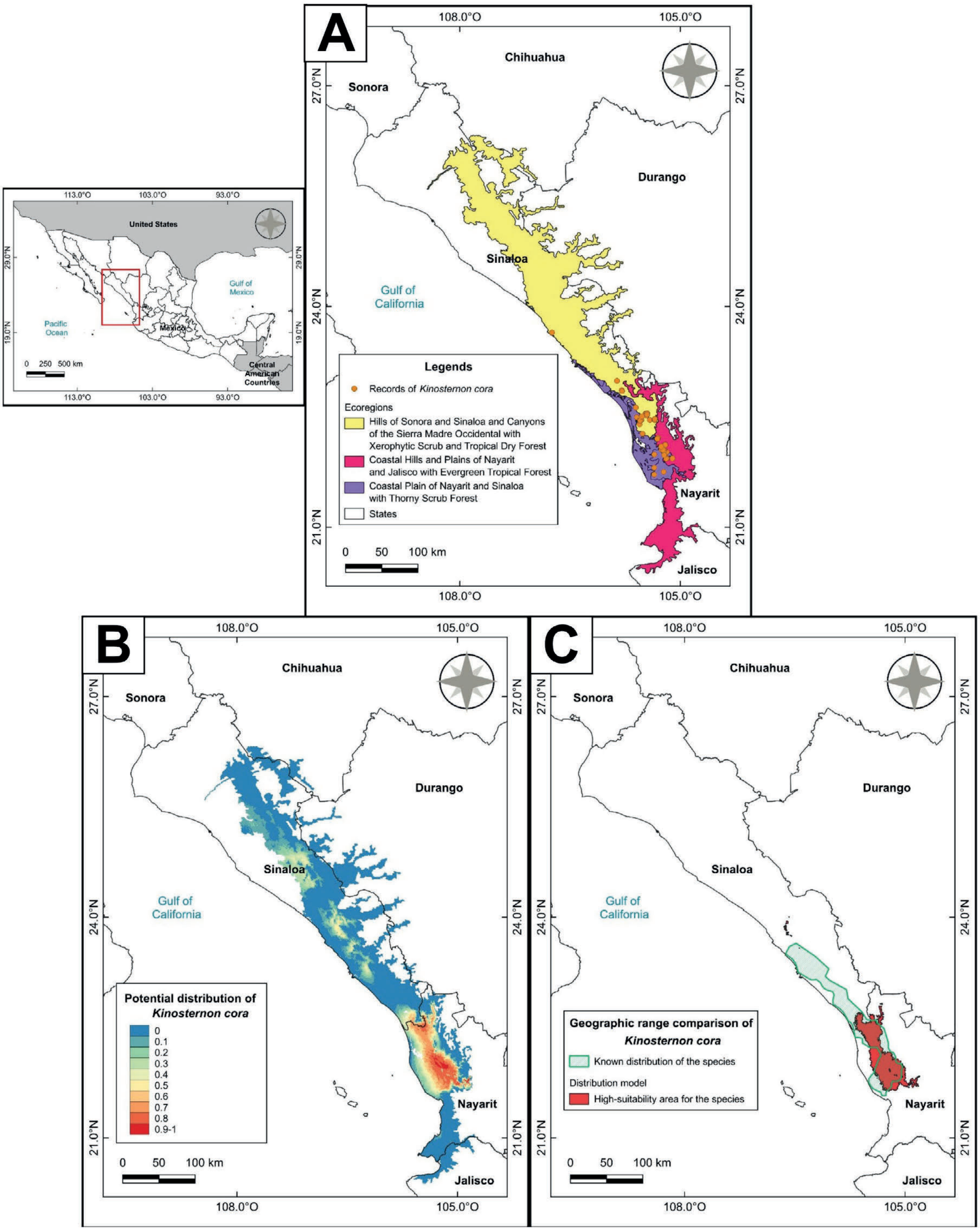

Fig. 3. Distribution and habitat suitability maps for *Kinosternon cora* in northwestern Mexico. A) Records of *K. cora* overlaid on ecoregions, including Hills of Sonora and Sinaloa and canyons of the Sierra Madre Occidental with xerophytic scrub and tropical dry forest, Coastal Hills and plains of Nayarit and Jalisco with evergreen tropical forest, and Coastal plains of Nayarit and Sinaloa with thorny scrub forest. B) Potential distribution model showing habitat suitability (0-1 scale). C) Geographic range comparison, highlighting the known distribution (light green) and the high-suitability distribution (red).

Fig. 3. Mapas de distribución e idoneidad de hábitat para *Kinosternon cora* en el noroeste de México. A) Registros de *K. cora* superpuestos sobre ecorregiones, incluyendo Lomerios de Sonora y Sinaloa y cañones de la Sierra Madre Occidental con matorral xerofito y bosque tropical seco, Lomerios costeros y llanuras de Nayarit y Jalisco con bosque tropical perennifolio, y Llanuras costeras de Nayarit y Sinaloa con matorral espinoso. B) Modelo de distribución potencial que muestra la idoneidad del hábitat (escala 0-1). C) Comparación del rango geográfico, destacando la distribución conocida (verde) y la distribución de alta idoneidad (rojo).

DISCUSSION

The potential distribution model for *K. cora* generated with MaxEnt identified climatically suitable areas in the Pacific Coastal Plain, revealing key ecological preferences such as reliance on thermally stable habitats (mean annual temperatures of 29.5–30.0°C) and low dry-season precipitation (<100 mm), indicative of its adaptation to ephemeral wetlands. These findings provide critical insights into the ecology of this recently described, IUCN "Endangered" endemic species, enabling the prioritization of conservation strategies to address threats like habitat loss and illegal trade, thus optimizing efforts to protect a species with a restricted distribution.

Model Performance

The LQPTH/β3 model effectively captured the environmental conditions associated with *K. cora*, demonstrating high predictive capacity comparable to MaxEnt models used for other tropical turtles with limited data (Berriozabal-Islas et al., 2020; Cupul-Magaña et al., 2020). Despite relying on only 48 presence records across 15 localities, the model balanced accuracy and parsimony, though its moderate overlap with the known distribution suggests that additional sampling in unprospected areas of the Pacific Coastal Plain could enhance accuracy (Loc-Barragán and Iverson, 2024; González-Bernal et al., 2025).

The model identified mean diurnal temperature range (bio02) and mean annual temperature (bio01) as key predictors, reflecting the adaptation of *K. cora* to thermally stable aquatic habitats with annual temperatures around 29.5–30.0°C and diurnal ranges of 10.0–16.0°C. Although additional studies on their physiology and ecology are necessary to confirm whether they represent optimal conditions for their survival and reproduction. These preferences align with those of *Trachemys ornata*, which favors low diurnal temperature variation, and other *Kinosternon* species, where temperature-related variables like the wettest quarter's temperature are critical (Berriozabal-Islas et al., 2020; Cupul-Magaña et al., 2020). However, the narrower thermal and precipitation tolerances of *K. cora*, particularly its reliance on low dry-season precipitation, indicate greater specialization tied to its microendemic status and dependence on ephemeral wetlands, unlike the broader-ranging *T. ornata* or *K. integrum*.

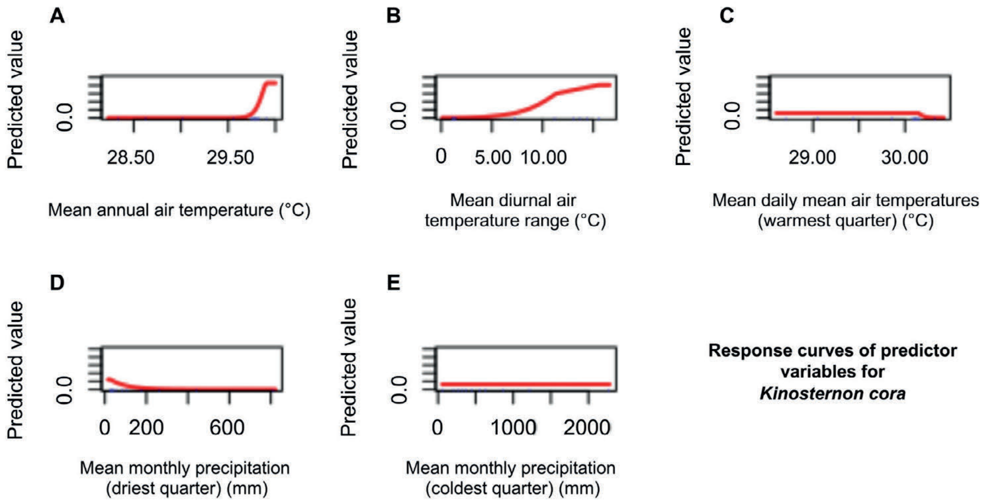

Fig. 4. Response curves of the variables selected after variance inflation factor (VIF) analysis identifying key environmental predictors for *Kinosternon cora*. The lines show the probability of presence (Y-axis) against the ranges of each variable (X-axis). A) The species favors mean annual temperatures (bio01) of 29.5–30.0°C; and B) diurnal temperature ranges (bio02) of 10.0–16.0°C. C). Temperature in the warmest quarter (bio10) is optimal at 28.5–30.0°C, and D) precipitation in the driest quarter (bio17) is suitable below 100 mm. Precipitation in the coldest quarter (bio19) had no significant effect across 0–2500 mm (see Table 1).

Fig. 4. Curvas de respuesta de las variables seleccionadas tras el análisis de factor de inflación de la varianza (VIF) que identificó los predictores ambientales claves para *Kinosternon cora*. Las líneas muestran la probabilidad de presencia (eje Y) frente a los rangos de cada variable (eje X). A) La especie prefiere temperaturas anuales (bio01) de 29.5–30.0°C; y B) rangos diurnos de temperatura (bio02) de 10.0–16.0°C. C) La temperatura en el trimestre más cálido (bio10) es óptima entre 28.5–30.0°C, y D) la precipitación en el trimestre más seco (bio17) es adecuada por debajo de 100 mm. La precipitación en el trimestre más frío (bio19) no tuvo efecto significativo entre 0–2500 mm (ver Tabla 1).

The limited response to winter precipitation further underscores its adaptation to seasonal wet-dry cycles.

While the selected bioclimatic variables are robust, incorporating fine-scale factors such as aquatic microhabitats, soil type, or land use could better capture the environmental heterogeneity preferred by *K. cora* (Loc-Barragán and Iverson, 2024; TTWG, 2025). Predicted areas without confirmed records represent potentially suitable habitats, offering opportunities for targeted surveys in Sinaloa and Nayarit, where wetland degradation from agriculture and sedimentation may hinder detection (González-García et al., 2009; Camacho-Valdez et al., 2013; Lemos-Espinal and Smith, 2020; CONABIO, 2021; Nájera-González et al., 2021). These specific ecological needs highlight the urgency of conservation efforts to mitigate climate-driven habitat loss and anthropogenic pressures in these regions.

Ecological Relevance of the Predicted Area

The predicted areas for *K. cora* in the Pacific Coastal Plain show conditions of thermal stability and low precipitation during the dry season, similar to those optimal for Trachemys ornata (Cupul-Magaña et al., 2020; Serrano et al., 2014). However, the dependence of *K. cora* on ephemeral wetlands is reinforced by unique traits such as terrestrial estivation, reflecting greater specialization compared to more widely distributed species like *T. ornata*, *K. flavescens*, *K. alamosae*, *K. sonoriense*, or *K. integrum* (Berriozabal-Islas et al., 2020; TTWG, 2025). This microendemic specialization heightens its vulnerability to habitat loss due to anthropogenic activities and climate change in these regions.

This microendemic status, likely compounded by low population density (48 individuals across 15 localities), heightens the vulnerability of *K. cora* to environmental changes, particularly thermal stress from temperatures exceeding optimal thresholds under climate change, a concern also noted for *K. chimalhuaca* under high-emission scenarios (Berriozabal-Islas et al., 2020; Nájera-González et al., 2020). Anthropogenic pressures, such as agriculture, sedimentation, and water body pollution, further threaten these seasonal wetlands, amplifying extinction risks (González-García et al., 2009; Camacho-Valdez et al., 2013; Lemos-Espinal and Smith, 2020; CONABIO, 2021; Nájera-González et al., 2021; JALB, pers. observation., 2024).

Compared to other microendemic *Kinosternon* species with restricted distributions, such as *K. oaxacae* and *K. chimalhuaca*, which are projected to lose substantial suitable areas under high-emission climate scenarios (e.g., up to 90% for *K. oaxacae* in RCP8.5 by 2070; Berriozabal-Islas et al., 2020), or the sympatric *K. vogti*, which faces severe threats from habitat loss and droughts exacerbated by climate change (Convention on International Trade in Endangered Species of Wild Fauna and Flora [CITES], 2022; López-Luna et al., 2018), the specific ecological needs and restricted distribution of *K. cora* underscore the urgency of targeted conservation efforts to mitigate climate-driven habitat loss and local disturbances in the predicted suitable areas.

Conservation Implications

The predicted areas that overlap with the known distribution of *K. cora* an opportunity for habitat protection, given its endangered status (Loc-Barragán, Woolrich-Piña, López-Luna, Iverson, in press). These areas face significant threats, such as illegal collection and wetland loss due to anthropogenic activities (González-García et al., 2009; Nájera-González, Carrillo-González, Morales-Hernández, Nájera-González, 2021; PROFEPA, 2025; Loc-Barragán, Woolrich-Piña, López-Luna, Iverson, in press).

The generated binary presence/absence maps can inform the design of ecological corridors or protected areas in Sinaloa and Nayarit, complementing specialized connectivity models to link fragmented habitats. The model's key predictors, such as mean annual temperature (29.5–30.0°C) and low precipitation in the driest quarter (<100 mm), underscore *K. cora*'s dependence on seasonal wetlands, prioritizing their protection to mitigate climate-driven habitat loss. Integrating these maps into local management plans, alongside sustainable practices and environmental education, can reduce pressure on habitats and mitigate the impact of illegal trade (e.g., Chaves-Quirós et al., 1996; Miorando, Rebêlo, Pignati, Brito-Pezzuti, 2013; Assis et al., 2024). Targeted surveys in predicted areas without confirmed records could confirm species presence and habitat suitability, thereby strengthening conservation strategies such as expanded monitoring and protected area designation (e. g., Saunders, Cuthbert, Zipkin, 2018; Šarić, Lauš, Burić, Koren, Koren, 2023; Assis et al., 2024; González-Bernal, Rojas-Aguilar, Rosales-Martínez, Loc-Barragán, 2025).

Future Perspectives

To expand knowledge about *K. cora*, targeted surveys in predicted areas without confirmed records are proposed, using techniques such as trapping and visual searches (Legler and Vogt, 2013). These efforts are crucial in hard-to-access regions, where bias toward previously sampled sites may underestimate the true distribution (González-Bernal, Rojas-Aguilar, Rosales-Martínez, Loc-Barragán, 2025).

Future distribution models should incorporate non-bioclimatic variables, such as vegetation cover, distance to water bodies, and anthropogenic disturbance indices (Harvey et al., 2005; Pearson et al., 2007; Tingley and Herman, 2009), to improve the accuracy of predictions for specific microhabitats (The inclusion of these variables suggests altitude would decrease habitat suitability in northern zones due to the rocky nature of the coastal plain; JBI, pers. comm., 2025). The current model's emphasis on means annual temperature (29.5–30.0°C) and low dry-season precipitation (<100 mm) as key drivers suggests that these additional variables should target the reliance on thermally stable wetlands by *K. cora*. For instance, the transformation of wetlands in southern Sinaloa and northern Nayarit due to historical land use for agriculture and livestock has limited the availability of natural habitats, restricting *K. cora* to disturbed ponds as the only available sites for its biological processes, as natural ponds have largely been filled by sedimentation (JALB, pers. observation., 2024). These variables would better capture environmental heterogeneity and anthropogenic impacts on the species' aquatic and semi-aquatic habitats.

Additionally, projections under climate change scenarios would be valuable to assess how alterations in temperature and precipitation could impact habitat suitability (Berriozabal-Islas et al., 2020). Finally, interdisciplinary collaborations with local communities can strengthen conservation through community monitoring and environmental education, promoting the conservation of *K. cora* in the Pacific Coastal Plain (Chaves-Quirós et al., 1996; Miorando, Rebêlo, Pignati, Brito-Pezzuti, 2013).

CONCLUSION

The potential distribution model for *K. cora* generated with MaxEnt has identified climatically suitable areas, validated its predictive capacity, and provided relevant information for its conservation. The model highlights the species' reliance on seasonal wetlands, emphasizing the need to protect these habitats from anthropogenic threats like habitat loss and illegal trade. However, the need for systematic surveys in predicted yet unconfirmed areas offers a key opportunity to expand knowledge about the species' distribution. These results support the design of targeted conservation strategies, including wetland restoration, establishment of protected areas, and creation of ecological corridors, complementing the IUCN Red List assessment of *K. cora*. Future studies should incorporate non-bioclimatic variables, such as vegetation cover and distance to water bodies, to refine predictions and strengthen long-term conservation efforts for this critically endangered endemic species.

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PARTICIPATION

JALB and HACB contributed equally to the conceptualization of the study. JALB participated in the logistics and fieldwork, while HACB was responsible for the data analysis. Both authors collaborated on drafting and revising the manuscript and approved its final version.

CONFLICTS OF INTEREST

Authors declare no conflict of interest.

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