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POPULATION ECOLOGY OF THE ROUGH-FOOTED MUD TURTLE (*KINOSTERNON HIRTIPES*) IN A HIGH-ALTITUDE LOCALITY IN MICHOACÁN, MÉXICO

ECOLOGÍA POBLACIONAL DE LA TORTUGA DE FANGO DE PATA RUGOSA (*KINOSTERNON HIRTIPES*) EN UNA LOCALIDAD DE GRAN ALTITUD EN MICHOACÁN, MÉXICO

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Resumen.– La tortuga casquito de pata rugosa (*Kinosternon hirtipes*) se distribuye desde el oeste de Texas hasta el Valle de México. A lo largo de su distribución habita en diversos ambientes, desde estanques en el desierto, hasta arroyos de montaña. Durante dos temporadas de lluvias (2017 y 2018) estudiamos una población en *K. h. murrayi* en las montañas de Michoacán, específicamente en la Laguna de Loma Caliente. Estimamos el tamaño y la estructura de la población por medio de un estudio de captura-marca-recaptura. Se obtuvieron placas de rayos X a cada hembra capturada para determinar el largo y ancho del huevo. En total se capturaron 139 individuos con una tasa de recapturas del 32.85 %. El tamaño poblacional estimado fue de 330 individuos, mientras que la proporción de sexos no fue distinta de 1:1. La población está estructurada principalmente por adultos e inmaduros. Diecinueve hembras presentaron huevos en los oviductos. El tamaño máximo de la nidada fue de cinco huevos y el mínimo de dos huevos. El tamaño promedio de la nidada fue de 3.2 huevos. Se presenta evidencia parcial de restricción pélvica en el tamaño del huevo en las hembras estudiadas.

Palabras clave.– Centro de México, abundancia, estructura de la población, restricción pélvica, proporción de sexos.

Abstract.– The Rough-footed mud turtle (*Kinosternon hirtipes*) is distributed from Western Texas through the Valley of Mexico. Along with its distribution, this turtle inhabits several types of environments, ranging from desert ponds to mountain creeks. During two wet seasons (2017 and 2018) we studied a population of *K. h. murrayi* in the lagoon of Loma Caliente, in the highlands of Michoacán. We estimated population size and structure with a capture-mark-recapture study and obtained X-ray photographs for each mature female captured to determine clutch size and egg size. A total of 139 turtles were captured and marked, with a recapture rate of 32.85 %. The estimated population was 330 individuals, and the sex ratio was not different from 1:1. The population structure was composed mainly of adults and immature individuals. Nineteen females have eggs in their oviducts. Clutch size ranges from five to two eggs. The average clutch size was 3.2. We provide partial evidence for pelvic constraint on egg size in the studied population.

Keywords.– Central México, abundance, population structure, pelvic constraint, sex ratio.

INTRODUCTION

Mud turtles (*Kinosternon*) in Mexico have been understudied for several years. Recently, Mexican Government informed of important seizures of turtles of several genera, but most of them were mud turtles (PROFEPA, 2020). Therefore, it is imperative to gather and analyze the population and reproductive data of turtles from Mexico, since this is one of the most threatened vertebrate groups in the world (Stanford et al., 2020). Among Mexican mud turtles, the Rough-footed mud turtle *Kinosternon hirtipes* has a distribution range from Southwest Texas to Central Mexico, and its distribution is associated with the inner basins (Conchos, upper Bravo, Lerma-Santiago, Nazas, and the endorheic lakes of central Mexico) between the two main mountain ridges of Mexico (TTWG, 2021). This turtle inhabits permanent bodies of water such as small rivers, streams, springs, and dams. This turtle species occurs from 800 to 2600 meters (in the highlands of Central Mexico) above sea level (Legler & Vogt, 2013). Typical land habitats of this turtle species are from scrubland in the Chihuahuan desert, highland grasslands, temperate forests (oak and pine forests) to highly modified habitats in central México.

Six subspecies (one already extinct) have been described for *Kinosternon hirtipes* (Iverson, 1981). Among the remaining subspecies, *K. h. murrayi* has the largest distribution and variation in body size and sexual size dimorphism (Iverson, 1985). *Kinosternon hirtipes murrayi* occurs from western Texas to the State of México in the Mexican Transvolcanic Belt. Very little information is available on their reproduction and population ecology, with scarce data from northern limit of its distribution (Iverson et al., 1991; Platt et al., 2016a, 2016b; Smith et al., 2018) and very few studies conducted in Central México (Enríquez-Mercado et al., 2018). Recently, a study on the population viability analysis on *K. h. murrayi* along the Mexican Transvolcanic Belt (Macip-Ríos et al., 2021) suggested further studies on subspecies of *K. hirtipes* be conducted to identify healthy populations and to develop head-starting programs when populations are declining.

The data available on the basic population ecology of *K. h. murrayi* and other subspecies of *K. hirtipes* (Enríquez-Mercado et al., 2018; Macip-Ríos et al., 2021) suggests that these taxa could share the habitat with *K. integrum*, which could outnumber most of the sites where these turtles occur in sympatry; which indicates that populations living alone and without the presence of other potential competitors (introduced) are important assets to understand basic population dynamics of *K. hirtipes* subspecies populations, which could be useful for future conservation strategies.

In this study, we conducted 19 sampling events in a population of *K. h. murrayi* in the highland of Michoacán (2203 meters above sea level), where the population is free of the presence of *K. integrum* in Michoacán. Along with other reported records for *K. hirtipes* (Estado de México and Mexico City Valley), the studied population represents the altitudinal limit of the studied taxon. Since the studied population occurs at high altitude locality, trends such small body size (slow growing), reduced reproductive output, and reduced mating season are expected, while other life history traits could also be associated with the limitation of inhabiting high-altitude environments. Therefore, the aims of this paper were to explore the population size, structure, sex ratio, and describe the basic reproductive ecology of *Kinosternon hirtipes murrayi* in a high-altitude locality in Michoacán, México.

MATERIALS AND METHODS

Study site

Data were collected in two rainy seasons, from middle August to mid-November 2017, and from early August to early November 2019. Both seasons sum 19 sampling events (three in 2017 and 16 in 2019). We surveyed a population of *K. h. murrayi* at the Loma Caliente locality (19.5880556° N, -101.1630555° W; WGS84) in the municipality of Morelia, Michoacán (Fig. 1). The study site is a lagoon (with a very small dam) with associated wetlands and narrow interconnected canals. The site is 2203 meters above sea level. The Loma Caliente lagoon has an area of 108.62 has (Rendon et al., 2007). The study site is part of the Loma Caliente-Umécuaro subbasin (at the highlands of the larger Cuitzeo basin). Loma Caliente lagoon along with the Umécuaro dam is part of a system of man-made reservoirs used for a small and old (1907) electricity production station (Guevara-Santamaría & Gómez Tagle-Chávez, 2012; Pantoja-Iturbide & López-Núñez, 2017).

The climate in the study site is temperate sub-humid (Cb)(w2)(w)(i) (g). Annual average temperature oscillates between 12-14° C, occasionally reaching a monthly average of 16-18° C, with an increase of temperature from March to May and dropping again in June with the rainy season. Annual precipitation ranges from 1000 to 1200 mm, with sporadic frosts falling from November to March (Carlón-Allende and Mendoza, 2007). The main terrestrial habitat is composed of pine and oak forests with patches of secondary vegetation and induced grassland. This study site represents one of the limits of altitude distribution for *K. h. murrayi* (Iverson, 1981; Berriozabal-Islas et al., 2020).

Sampling protocol

We conducted a total of 19 sampling events (see above for details). At least two people went every week to the study site. On each sampling event, nine funnel traps (304.8 mm width x 914.4 mm length and 10 mm of net opening) were settled along the canals and the streams flowing out of the Loma Caliente lagoon. Traps were settled according with water availability and the required dept. Distance between traps was variable, but roughly variate

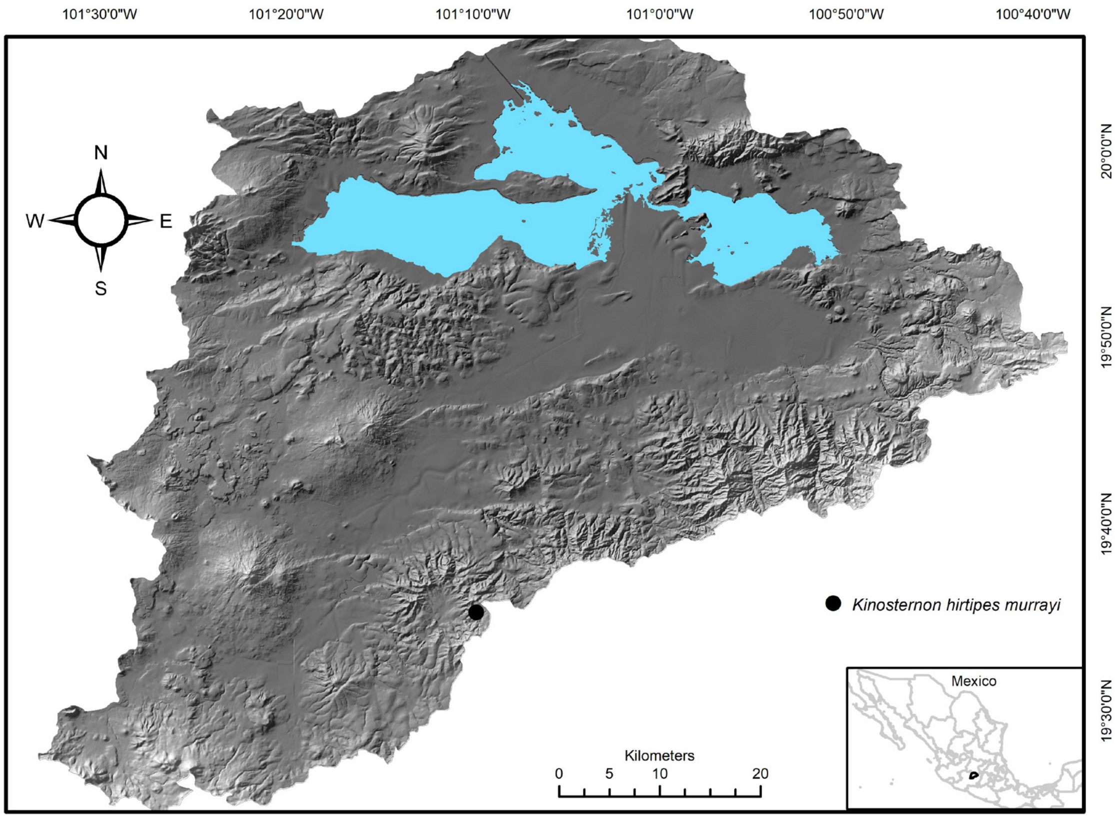

Figura 1. Localización del área de estudio en la cuenca alta de Cuitzeo. El punto negro indica la localidad de Loma Caliente, Michoacán. Área azul = Laguna de Cuitzeo.

Figure 1. Location of the study area at the upper part of Cuitzeo basin. The closed circle indicates Loma Caliente, Michoacán. Blue area = Cuitzeo lagoon.

between 15 and 30 m. A fyke net (6000 mm length and 500 mm high, with 20 mm of net opening) was used in a wetland that connects Loma Caliente lagoon with the Umécuaro dam system. Funnel traps and fyke net were baited with fresh fish. Traps were set for 48 hours and checked every 24 hours.

Turtle handling and measurements

Each captured turtle was measured and weighed following the standard measurements for turtles such: straight-line carapace length (CL), straight-line carapace width (CW), carapace high (CH), plastron length (PL), plastron width (PW), and body mass (BM). Each turtle was individually marked using the code proposed by Cagle (1939). Morphological measurements were taken using a dial caliper (Swiss Precision Instruments, Altstätten, Switzerland; 0.1 mm) and weighed with an electronic scale (American Weigh Scales, Cumming, Georgia; 1g). Males were identified from females due to typical secondary sexual characters such as longer tail, the presence of a strong and developed nail in the tip of the tail, concave and reduced plastron, and a large head, whereas females have larger and wider plastron (enclose all limbs, head, and tail), and shorter tails (Iverson, 1981). Individuals were considered immature if secondary sexual characteristics were not evident.

Captured males and immature turtles were returned to the habitat immediately after being processed, while females were brought to the laboratory (only those captured in 2019) to take X-ray photographs (Gibbons & Greene, 1979). Females were held for 8 days in the lab and returned to the original capture site at the next sampling event. When females were recaptured within two weeks from the previous capture, they were brought back to the laboratory to take another round of X-ray photographs to look for subsequent clutches. So far, there is no evidence of harm caused using X-ray on turtles and their eggs. This is a nondestructive sampling technique that allows gather important reproductive and morphological data (Gibbons, 2017). Clutch size was estimated by directly counting eggs in the X-ray photographs, also eggs were measured for length and width directly in the radiograph using a dial caliper (Swiss Precision Instruments, Altstätten, Switzerland; 0.1 mm).

Data analysis

Due to the short period of time sampled, population size was estimated using a jackknife estimate model of heterogeneity Mh (Chao, 1989). The system was considered a close population since we only conducted three sampling events in 2017 (one each month from September to November and captured 30 adults); nevertheless, we used all 19 sampling events (including 2017 and 2029). To choose the best model of population size we used the Akaike Information Criterion (AIC). Calculations were conducted using Rcapture ver. 1.4-3 under the function closedp.0 (Rivest & Baillargeon, 2019) implemented in R (R Core Team, 2018). Additionally, we explored a simple open loglinear population model (Rivest & Diagle, 2004; Baillargeon & Rivest, 2007) implemented in Rcapture ver. 1.4-3 under function openp (Rivest & Baillargeon, 2019). Capture probabilities (p) were also calculated in Rcapture under a loglinear model under function openp (Rivest & Baillargeon, 2019). The expected 1:1 sex ratio was tested using a Chi-squared test also in R version 4.1.2 (R Core Team, 2018). To describe population structure, we used Enríquez-Mercado et al. (2018) body size categories, which were: < 50 mm in CL for hatchlings/yearlings, 50-90 mm CL for immatures, 90-140 mm CL for adults, and > 140 for old adults (asymptotic adults).

Body size (CL, CH, CW, PL, and PW) and body mass were compared between adult males and females with a Student *t*. Normality (tested with Shapiro-Wilk) and homoscedasticity (tested with Bartlett) tests were conducted to assure parametric assumptions (Zar, 1999). We ran a regression analysis between body size (CL) with clutch size to determine if there was an association between body size and reproductive output and to test if the clutch size was correlated with egg size (length and width).

Finally, we tested if the egg size was constrained by pelvic aperture following Congdon et al. (1983) and we looked for two types of evidence: 1) greater egg elongation (egg length/egg width ratio) in small females and 2) equality in the slopes of the regression lines between egg width and pelvis width (aperture) with body size. A greater egg elongation in small females evaluated with a negative correlation between egg length/egg width ratio with body size is considered as evidence of pelvic constraint on egg size (King, 2000). Pelvic apertures were directly measured in the radiographs; accordingly, egg size and pelvic aperture will be referred to as XEW (X-ray egg width) and XPW (X-ray pelvic width). We used an ANCOVA to compare the slopes of XEW with CL and XPW with CL. All statistical tests were conducted in R version 4.1.2 (R Core Team, 2018) with an alpha = 0.05.

RESULTS

A total of 139 *Kinosternon hirtipes murrayi* turtles were captured in two seasons from middle August to mid-November in 2017 (30 individuals captured; 14 males, 14 females, 2 immatures) and from early August to early November of 2019 (109 individuals captured; 58 males, 37 females, 14 immatures) in Loma Caliente, Michoacan. Forty-six turtles were recaptured (32.85 %). Two turtles were recaptured seven times, one turtle five times, two turtles four times, nine turtles three times, 10 turtles twice, and 22 turtles were recaptured only once.

Estimated population size under the Mh model for 19 sampling events was 330 (± 58.1 SE) individuals (AIC = 43.134, 95% lower confidence interval = 241.2 – 95% upper confidence interval = 481.4). Estimated abundance under the open population model was 232 (± 32.4 SE) individuals. Capture probabilities (p) during sampling events ranged from 0.14 to 0.37, with an average p = 0.26 (± 0.084 SE). The sex ratio was 1.35:1 with 72 adult males and 53 adult females, nevertheless, the sex ratio was not statistically different from 1:1 ($\chi^2 = 2.88$, $p = 0.0892$) (Table 1).

Tabla 1. Modelos log-lineales explorados para estimar el tamaño de una población cerrada de K. h. murrayi en Loma Caliente, Michoacán. La última fila resume el modelo log-lineal explorado para una población abierta. SE = error estándar, DF = grados de libertad, AIC = criterio de información de Akaike, BIC = criterio de información bayesiano.

Table 1. Explored loglinear close population models used to estimate the population size of *K. h. murrayi* at Loma Caliente, Michoacán. The line in the bottom summarizes the loglinear open population model explored. SE = standard error, DF = degrees of freedom, AIC = Akaike`s information criterion, BIC = Bayesian information criterion.

Model	Abundnace	SE	Diviance	DF	AIC	BIC
M0	198.4	13.2	50.883	17	81.619	87.503
Mh Chao (LB)	330.2	58.1	6.398	14	43.134	57.842
Mh Poisson2	198.4	13.2	50.798	16	83.534	92.359
Mh Darroch	273.8	28.3	17.404	16	50.14	58.965
Mh Gamma3.5	615.7	155	8.266	16	41.002	49.827
Open population estimate	232.6	32.4	168.086	1001	322.28	-

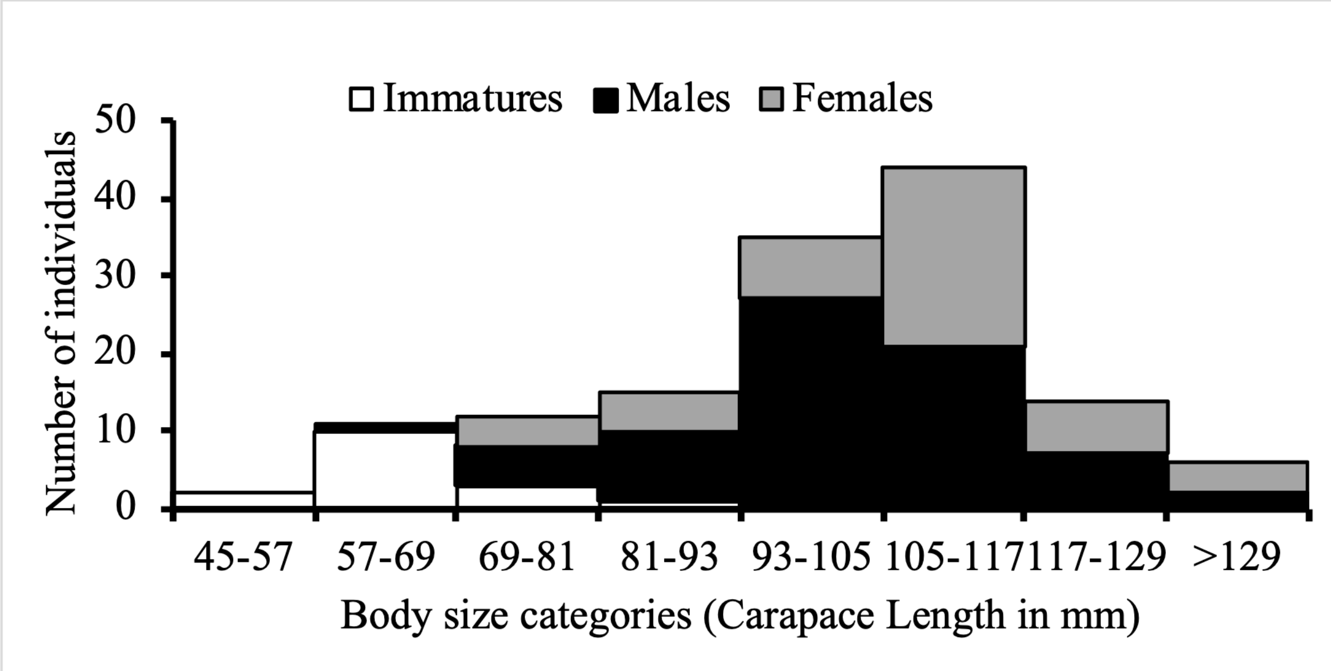

Figura 2. Estructura de la población basada en intervalos de clase (largo de carapacho) de 12 mm de la población de *Kinosternon hirtipes murrayi*, en Loma Caliente, Michoacán.

Figure 2. Population structure based on 12 mm body size (carapace length) intervals of the *Kinosternon hirtipes murrayi* studied population at Loma Caliente, Michoacán.

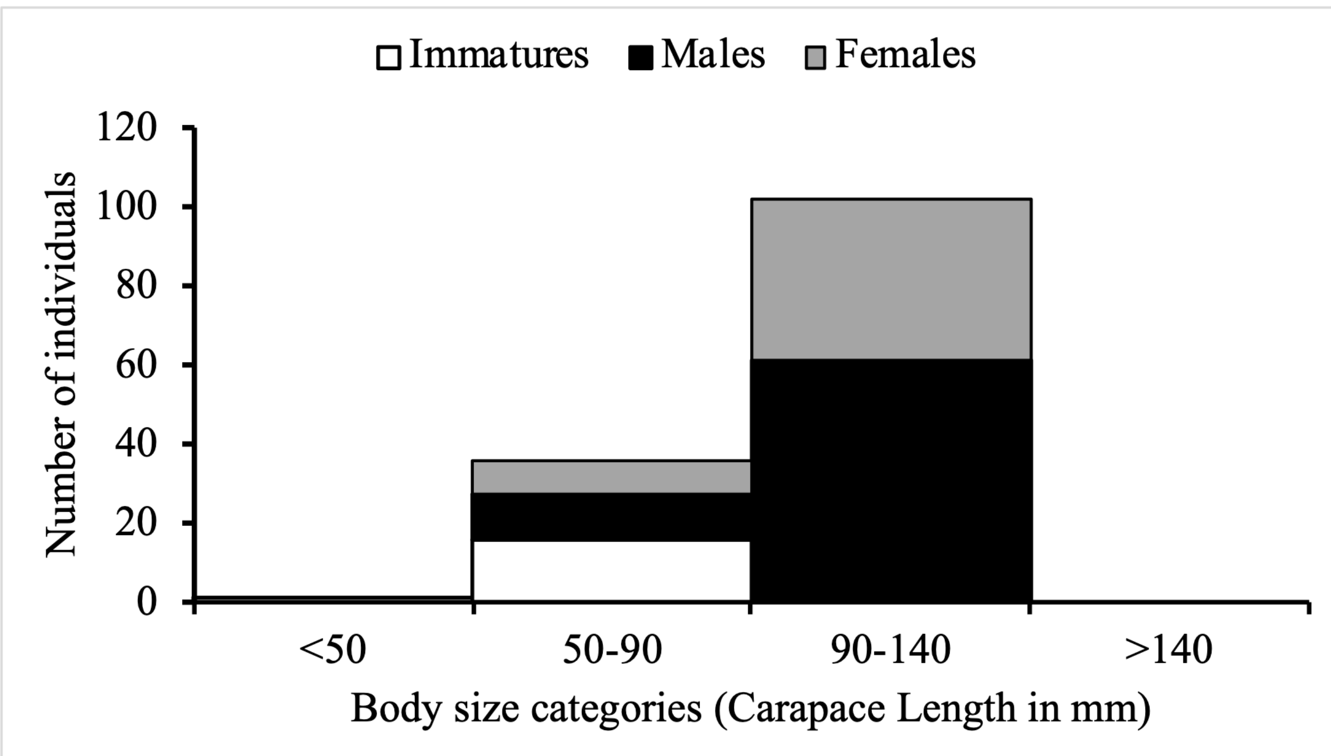

Figura 3. Estructura de la población de *Kinosternon hirtipes murrayi* en Loma Caliente, Michoacán. La estructura de la población está basada en la categorias de Enríquez-Mercado et al. (2018).

Figure 3. Population structure of *Kinosternon hirtipes murrayi* at Loma Caliente, Michoacán. The population structure is based on Enríquez-Mercado et al. (2018) categories from a previous study on a different population of *Kinosternon hirtipes murrayi* in La Mintzita, Michoacán

We followed the size categories proposed by Enríquez-Mercado et al. (2018) for the same species in a nearby locality to describe the population structure. The population structure was composed mainly by adults. We captured 101 individuals in the 95 - 140 mm size category (adults), followed by 39 immature individuals. No old adults (asymptotic), and only one hatchling/yearling was captured (Fig. 2). Individuals in this population seems to have a very small body size, consequently we explored other approach to describe the population structure. To accomplish that, we used the Sturges rule to identify categories in a series of continuous data (Daniel, 2001). Using Sturges' approach for this population we find eighth size categories starting at an interval of 45 - 57 mm through those individuals larger than 129 mm of CL. When using this approach, now the population is structured by immatures, young males and females, and large adults (Fig. 3). We consider keeping both approaches of population structure is valuable to compare with alike studies like that of Enríquez-Mercado et al. (2018).

Carapace length of males and females did not show significant differences (t = 0.54, P = 0.58); CW (t = 1.36, p = 0.17) and BM also did not show statistical differences (t = 1.46, p = 0.14). Females had higher carapaces (t = 3.13, p = 0.002), larger PL (t = 2.42, p = 0.017), and wider PW than males (t = 2.04, p = 0.04). Overall morphological measures are presented in Table 2.

Thirty-five radiographs were taken from females captured in 2019 (no radiographs were taken in 2017). Only 19 females (36%) had eggs in their oviducts. Maximum clutch size was five eggs, and the minimum were two eggs. Average clutch size was 3.22 ± 0.87 SD eggs. Average egg length was 29.26 ± 2.01 mm and the average egg width was 17.01 ± 0.69 mm. We did not find any correlation (χ^2=0.12, F=2.52, p=0.131) between body size (CL) and clutch size. Clutch size and egg length was negatively correlated (R^2 = 0.28, F = 6.93, p = 0.01; Fig. 4), whereas egg width was not correlated with clutch size (R^2 = 0.003, F = 0.05, p = 0.82). We find evidence for pelvic constraint in egg size, since both slopes of the regressions of XEW and XPW with body size (CL) did not show differences (F = 2.14, p = 0.16). Pelvic width (XPW) with body size (CL) slope was 2.05, while egg width (XEW) with body size slope was 3.35 (Fig. 5). However, egg elongation (average egg elongation per clutch and max elongation per clutch) was not correlated with body size (average egg elongation R^2 = 0.009, p = 0.685; max egg elongation R^2 = 0.057, p = 0.322).

DISCUSSION

The population of *K. h. murrayi* at the Loma Caliente locality seems healthy since we found an important number of reproductive adults structuring the population, with a non-skewed sex ratio, and evidence of reproductive activity. The studied population is abundant in the locality and, due to the extension of the Umécuaro reservoir nearby (therefor a high potential availability habitat), overall abundance is potentially high in the study area. No individuals of *K. integrum* were recorded during our sampling, which is relevant regarding other findings when *K. hirtipes* showed lower abundance when it occurs in sympatry with *K. integrum* (Macip-Ríos et al., 2021).

The studied population showed a slightly larger population size compared with other nearby population of the same species (conducted with the same methods; Enríquez-Mercado et al., 2018), or compared with other species of kinosternids in the tropics with also similar methods (Forero-Medina et al., 2007; Vázquez-Gómez et al., 2016; Macip-Rios et al., 2018). The equal sex ratio documented in our study was similar to those reported for *K. creaseri* (Macip-Ríos et al., 2018), but differ from other studies, when female-biased sex ratios were reported (Forero-Medina et al., 2007; Macip-Ríos et al. 2009; Vázquez-Gómez et al., 2016; Aparicio et al., 2018; Reyes-Grajales et al., 2021), or male biased sex ratios (3:1; Enríquez-Mercado et al., 2018). Regarding population structure, same as our results, long-term (Iverson, 1991a; Forero-Medina et al., 2007; Macip-Ríos et al. 2009) and short-terms studies (Macip-Ríos et al., 2018; Butterfield et al., 2020; Reyes-Grajales et al. 2021) on turtles reported adult structured populations. Hatchlings and yearlings are difficult

Tabla 2. Medidas morfológicas y razgos reproductivos de *Kinosternon hirtipes murrayi* en Loma Caliente, Michoacán. SD = Desviación estándar.

Table 2. Morphometrics and reproductive traits of the *Kinosternon hirtipes murrayi* in Loma Caliente, Michoacán. SD = Standard deviation.

	Males (mean, SD)	**Females (mean, SD)**
Carapace Length	107.77 (11.31) mm	109 (14.47) mm
Carapace Width	72.64 (11.76) mm	75.50(9.15) mm
Carapace High	41.74 (5.65) mm	46.36 (8.30) mm
Plastral Length	89.05 (11.87) mm	95.83 (15.10) mm
Plastron Width	54.53(10.67) mm	58.41(8.25) mm
Body Mass	201.71(66.07) gr	223(76.01) gr
	Mean (SD)	**Range**
Clutch Size	3.32 (0.87) eggs	2 - 5 eggs
Egg Length	29.26 (4.06) mm	27.70 - 32.55 mm
Egg Width	17.01 (0.69) mm	15.76 - 17.87 mm

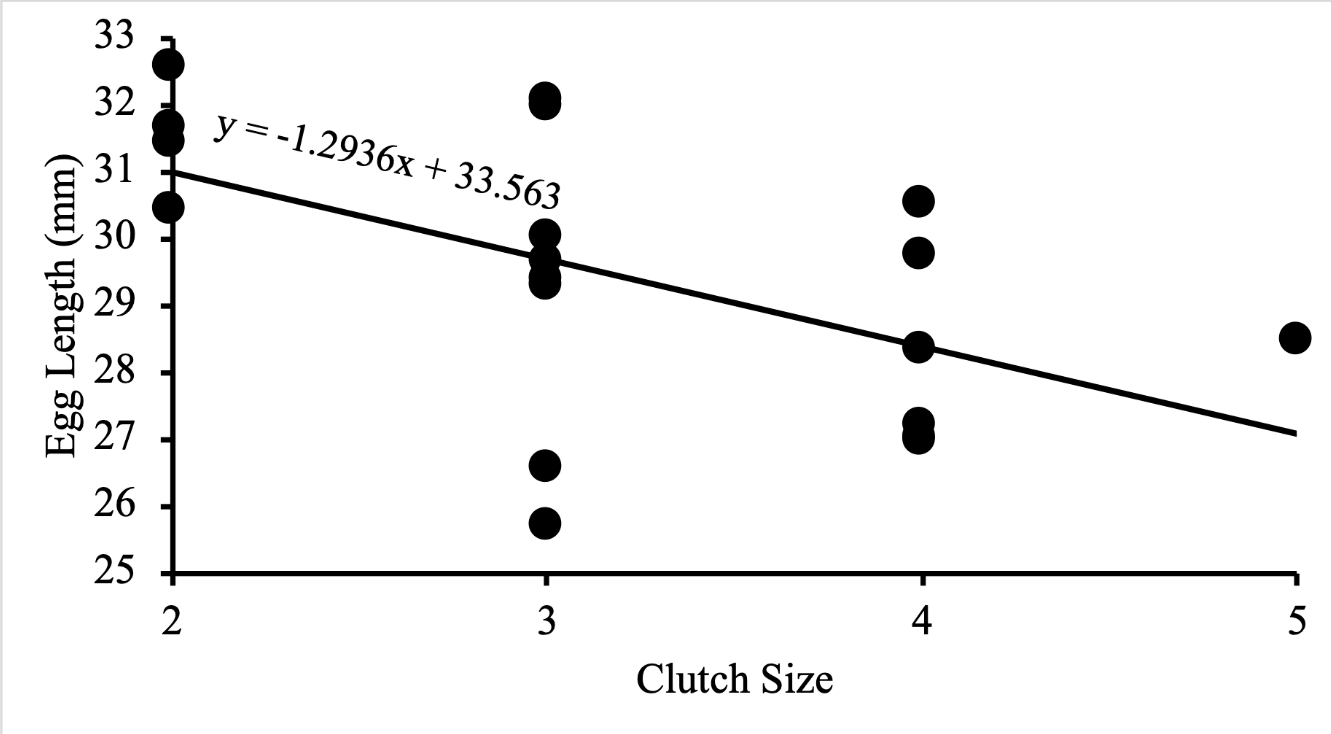

Figura 4. Linea de regresión entre la el tamaño de la nidada y el largo del huevo (mm) en la población de *Kinosternon hirtipes murrayi* Loma Caliente, Michoacán.

Figure 4. Regression line between clutch size and egg length (in mm) in the population of *Kinosternon hirtipes murrayi* at Loma Caliente, Michoacán.

Due to the reduced body size, pelvic constraint on egg size (mainly egg width) could be expected (Condong & Gibbons, 1987; Ryan & Lindeman, 2007; Macip-Ríos et al., 2012). We find partial evidence of egg size constraint due to pelvic aperture (parallel slopes on body size-egg size and body size-pelvic width correlations, but no negative correlation of egg elongation with body size), also egg width showed little variation across its range (17.04 x 0.69 SD; range = 15.76-17.87), being only 2.10 mm from the widest to the narrowest egg. Other small-sized kinosternids also showed egg width constraint such as *K. chimalhuaca*, while small sized populations of *K. integrum* also showed some degree of pelvic constraint (Macip-Ríos et al., 2013), *K. subrubrum* (Wilkinson & Gibbons, 2005), Chrisemys picta (Congdon & Gibbons, 1987), and the distinctive case of *Homopus signatus* (Hofmeyr et al., 2005); nevertheless, some small-size turtles also did not show pelvic constraint such *Sternotherus odoratus* (Wilkinson & Gibbons, 2005), *S. carinatus* (Iverson, 2002), *K. flavescens* (Iverson, 1991a), and the sister taxon of *K. hirtipes, K. sonoriense* (Lovich et al., 2012). It will be interesting to explore pelvic constraint in the smallest kinosternids such as *K. vogti* and *K. cora* to test the consequences of miniaturization and their within-clutch trade-offs as was explored by Heston et al. (2022).

Compared with other studies (Frazer et al. 1991; Iverson, 1991a; Forero-Medina et al., 2007), the sampling period of our study was very reduced, just covering the peak of the rainy season until temperatures dropped by mid fall. However, our weekly capture-recapture sampling (in 2019) allowed us to gather relevant information on reproduction, abundance, and population structure. If a population is abundant enough and fairly "catchable", the use of a standard method could assure good data, which is what we did in this study. We recognize the limitation of our study in the way we cannot deliver population dynamics results, annual survival (30 in 2017 and 109 in 2019), detection of age/size categories or multiple clutches, since we only collected turtles from the middle to final parts of the reproductive season (of 2019).

Our results let us conclude that the Loma Caliente population seems healthy, reproducing (and potentially recruits), and showed a smaller body size compared with other species of the genus and populations of the same subspecies, which suggest this population is adapted to temperate conditions, more like the species from higher latitudes, in contrasts with species from the tropics (Macip-Ríos et al., 2011; Vázquez-Gómez et al., 2016; Macip-Ríos et al., 2018).

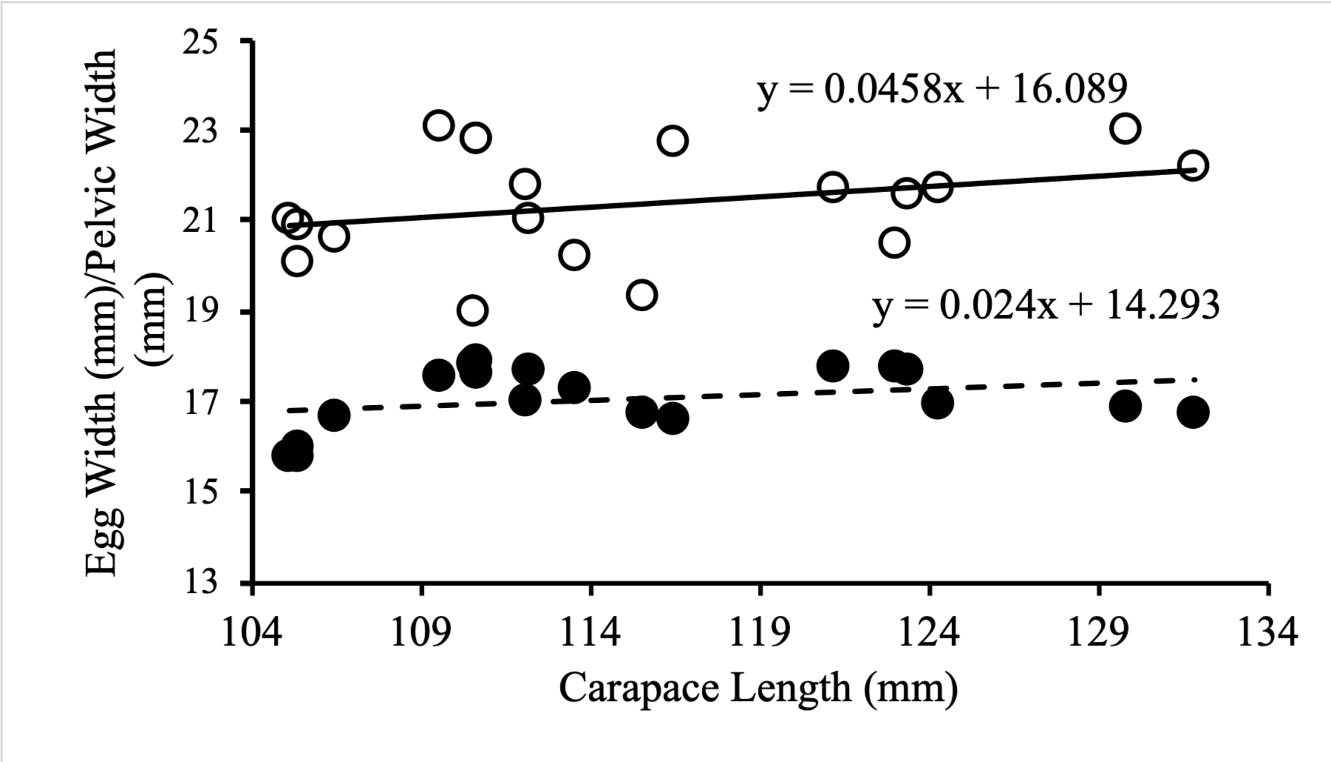

Figura 5. Línea de regresión entre el largo de carapacho (mm) y el ancho del huevo (mm; circulos cerrados), y entre el largo del carapacho y la apertura pélvica (mm, circulos abiertos) de la población de *Kinosternon hirtipes murrayi* en Loma Caliente, Michoacán.

Figure 5. Regression lines between carapace length (in mm) and egg width (in mm; closed circles), and carapace length and pelvic width (in mm; open circles) of the studied population of *Kinosternon hirtipes murrayi* at Loma Caliente, Michoacán.

to catch, especially in large aquatic habitats, very few studies reported a high number of hatchlings and yearlings, most of them from small ponds, when turtles are confined (Macip-Ríos et al., 2011; Aparicio et al., 2018; Macip-Ríos et al., 2018), this contrast with studies on lotic systems (like the presented here) when organisms move along the streams and creeks (Garrido et al. 2021), which could be correlated with low recapture rates.

According to Crouse et al. (1987) and Congdon et al. (1994), stable turtle populations tend to be structured by immature individuals rather than reproductive adults, however, we consider the Loma Caliente *K. hirtipes* population is stable since it has a non-skewed sex ratio, females showed evidence of reproductive activity (see results for clutch size), nevertheless, trapping methods could avoid hatchlings and yearlings, but our funnel and fike net have very small net opening. Otherwise, it could be that hatchlings could face low survivorship due to a high predation rate, which is expected according to its survivorship curve (Iverson, 1991b). Other studies such as Macip-Ríos et al. (2009) and Garrido et al. (2021) also showed a small number of hatchlings and yearlings in dense turtle populations, but low density of hatchling also could be related with a differentiated use of the habitat (Macip-Ríos et al. 2009).

One interesting finding of our study is the body size of males and females are smaller than other studied populations of *K. h. murrayi* from northern Mexico (Iverson, 1985; Iverson et al., 1991; Smith et al., 2015; Platt et al., 2016b) and even smaller than a nearby (16 km) population in La Mintzita spring (Enríquez-Mercado et al., 2018) with records of very small males (79.4 mm of CL for a fully developed male) showing secondary sexual characters.

We did not find sexual size dimorphism, which seems variable across the species range (Iverson et al., 1991). The temperate climate of Michoacan highlands, with a seasonal rainy season from June to September, could be related to shorter growing seasons for turtles, on the other hand, there are observations of immature individuals growing faster at low elevation in other species of *Kinosternon* (Macip-Rios et al., 2011), which could explain the small body size of the studied population.

Recently, Macip-Ríos et al. (2021) suggested that *K. hirtipes* subspecies are under threat, with several factors that locally affects the viability of the populations/subspecies. One of these threats is the presence of *K. integrum* in sympatry and outnumbering the populations of *K. hirtipes*. In the study site there is no evidence of the presence of *K. integrum* in the study area, also we did not detect other threats different from habitat degradation, which is generalized in Central Mexico, but there is no human use (food or medicine) of turtles in Loma Caliente.

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