Body condition index in breeding black iguana females (*Ctenosaura pectinata*) in captivity

Índice de condición corporal en hembras reproductoras de iguana negra (*Ctenosaura pectinata*) en cautiverio

José Luis Arcos-García [1*], Jesús Núñez Ordaz [1], Jesús García Grajales [1], Rocío del Pilar Rueda Zozaya [2], Héctor Santiago Romero [1], Roberto López Pozos [1]

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Abstract

The body condition index is a measure that attempts to describe energy storage compared to body length. This research was carried out with the aim of obtaining a body condition index in *Ctenosaura pectinata*. We used 40 adult females distributed between two groups. The iguanas were fed with four types of commercial food. They were also weighed in grams, their body lengths were measured in centimeters (total, snout-vent and head), body diameters were measured in centimeters (tail base, hip, leg, and pelvis) and body volume was measured in milliliters. Descriptive statistics were performed and variables were checked for normality. A Pearson correlation analysis was carried out to identify any related variables. A body condition index classification was obtained from the mean value and standard deviation (I: 2S-μ, II: S-μ, III: μ+S and IV: μ+2S) and a prediction equation for volume was obtained by Stepwise analysis. The body condition index turned to be highly accurate ($r=0.98$, $p<0.0001$). A body condition index classification in black iguana (*Ctenosaura pectinata*) was established, which will be useful for monitoring the body reserves of the species.

Keywords
Ctenosaura pectinata • body condition • index • black iguana

1 Universidad del Mar. Campus Puerto Escondido. Ciudad Universitaria. Puerto Escondido. Mixtepec. Juquila. Oaxaca. México. 71980. * jarcos@zicatela.umar.mx
2 Universidad Autónoma Metropolitana Xochimilco. Departamento de Producción Agrícola y Animal. México D. F. Calzada del Hueso 1100. D. F. C. P. 04970. México.

Resumen

El índice de condición corporal intenta describir el almacenamiento de energía comparado con una longitud del cuerpo, por ello se realizó la presente investigación con el objetivo de obtener un índice de la condición corporal en *Ctenosaura pectinata*. Se utilizaron 40 hembras adultas distribuidas en dos grupos. Las iguanas fueron alimentadas con cuatro tipos de alimento comercial. Las iguanas se pesaron (g), se midieron las longitudes (total, hocico cloaca y de cabeza cm), los diámetros (base de la cola, de cadera, pierna y pelvis cm) y el volumen del cuerpo (ml). Se realizó estadística descriptiva, se verificó la normalidad de las variables. Se llevó a cabo un análisis de correlación de *Pearson* para identificar las variables que tuvieron mayor relación. Se obtuvo una clasificación del índice de condición corporal a partir del valor promedio y la desviación estándar (I: 2S-μ, II: S-μ, III: μ+S y IV: μ+2S) y se obtuvo una ecuación de predicción para el volumen por medio del análisis de *Stepwise*. El índice de condición corporal presentó alta precisión (r=0,98, p<0,0001). Se estableció una clasificación del índice de condición corporal en *Ctenosaura pectinata*, que será útil para vigilar las reservas corporales de la especie.

Palabras clave

Ctenosaura pectinata • condición corporal • índice • iguana negra

Introduction

Body condition is a method to evaluate the energy reserves of animal subcutaneous fat tissues in their productive and reproductive state (9, 14). It influences animal welfare, physical condition and wildlife conservation (5, 27). In some species, body condition is evaluated before the reproductive stage as this information provides an important insight into productivity (15). Their body condition can affect fertility rates (26). Adequate body condition in livestock helps to cover maintenance and production needs at any physiological stage (3). In reptiles, body condition affects the females' survival (21), egg size and brood size (8, 28). Reproductive studies have been carried out regarding the black iguana (*Ctenosaura pectinata*); however, body condition has not been taken into account in these studies due to lack of information about the species (15). Obtaining an index and body condition classification in reproductive females black iguana (*C. pectinata*) may serve to increase reproductive efficiency in production units, as leaner or more corpulent females may present lower efficiency in the production of eggs and hatchlings. Therefore, the objective was to obtain an index and classification of body condition in *C. pectinata* females bred in captive conditions.

Material and methods

This research was conducted at the Iguana Conservation and Reproduction Center of the Universidad del Mar (CECOREI-UMAR), located at kilometer 128.1 of Federal Highway No. 200, Pinotepa Nacional-Puerto Escondido, Oaxaca, México. Located at 15°55'23.1" N and 97°09'05" W, with an elevation of 12 m above sea level (12).

The climate was warm sub-humid with an average annual rainfall of 1550 mm, mostly concentrated in summer. The average temperatures ranged between 24°C in the coolest month and 26°C in the warmest month, with an average temperature greater than 18°C in the coldest month.

Selection of iguanas

Forty adult females of *C. pectinata*, were distributed between two groups. Half of the females were measured during the mating season, during which iguanas are at their heaviest due to their storage of energy reserves. The other half were evaluated after the egg-laying stage when females have lost body reserves due to reproductive effort. All iguanas were randomly selected from a group of 200 females that presented reproductive activity. The age of the specimens was not taken into account. In order to obtain adequate information, the experiment lasted eight months. The male:female ratio of 1:3 (15) was used for reproductive management in each group.

Cages

The iguanas were kept in two 5x6x3m cages (wide, length and height respectively). Each contained a slope down to two pools built with 1.0 m galvanized sheet material, almond trees (*Terminalia catappa*) to provide shade, pools of drinking water and artificial nests for egg-laying in the respective stage (20). The entire cage was covered with a mesh screen. These provisions aimed to avoid any stress.

Food

The iguanas were fed with four types of commercial feed mixed in a ratio of 1:1:1:1, which provided an average content of 21.6% of crude protein on a dry basis. Food I: 26.0% crude protein (CP), 12.0% moisture (M), 2.8% fat (F), 5.0% crude fiber (CF), 10.0% ash (A), 44.2% nitrogen free elements (NFE), 1.3% calcium (Ca) and 1.1% phosphorus (P). Food II: with 16.0% CP, 12.0% M, 2.5% F, 7.0% CF, 15.0% A, 47.5% NFE, 3.5% Ca and 0.5% P. Food III: 16.0% CP, 12.0% M, 3.0% F, 17.0% CF, 10.0% A and 42.0% NFE. Food IV: 18.0% of CP, 12.0% of M, 3.5% of F, 15.0% of CF, 12.0% of A, 39.5% of NFE, 2.5% of Ca and 0.4% P. In addition, mineral salts were offered containing 120 g kg^{-1} P, 4.0 g kg^{-1} Zn, 2 g kg^{-1} Fe, 1.33 g kg^{-1} Cu, 0.08 g kg^{-1} I, 12.5 g kg^{-1} S, 120 g kg^{-1} Ca, 10.0 g kg^{-1} Mg, 4.0 g kg^{-1} Mn, 0.013 g kg^{-1} Co, 0.022 g kg^{-1} Se. Nutrient information was obtained from product labels.

All animals were fed and offered water everyday *ad libitum* at 8:00 am and cage cleaning was performed every third day throughout the experiment.

Evaluated variables

The iguanas were weighed on scales (with a capacity of 20 ± 0.001 kg; model MFQ-40, brand TORREY from México). Total lengths and snout-vent length were measured with a tape measure (with an approximation of 0.1 cm) and head length was measured with a plastic vernier calibrator (Model CVQ1315, with an approximation of 0.1 mm). Body volume was recorded using a PVC tube, of four inches in diameter, which was cut and replaced with a graduated transparent plastic strip. The tube was filled with a measured amount of water and the iguana was introduced, the difference between the values before and after provided the volume. Tail base, hip, leg and pelvis diameters were measured, with a tape measure (11).

Analysis of results

In order to analyze the results, descriptive statistics were carried out, and the normality of the studied variables was verified. A Pearson correlation analysis was carried out to identify the most related variables and to determine a prediction equation and the body condition classification with mean values and standard deviation (I: 2S-μ, II: S-μ, III: μ+S and IV: μ+2S). A Stepwise analysis was conducted to select the best variables to predict volume (25).

Results and discussion

Table 1 shows the values of morphometric variables such as weight (695.7±197.4 g), volume (723.3±185 g), and lengths, along with average diameters of the most important variables. All variables were distributed normally except for the snout-vent length ($p<0.05$).

The results of weight, length, and diameter are consistent with other studies (11, 15). Female iguanas of *C. pectinata* were measured between the ages of three and a half to seven and a half years. The females' weight at the beginning of the reproductive cycle is an important variable as an indicator of efficient reproduction. It reflects parameters in brood size and offspring weight at birth in such a way that small iguanas have less reproductive efficiency than large ones (2). This corresponds with the present study because the minimum (408 g) and maximum (1199 g) weights reached in iguanas correspond with first-time iguanas and with several reproductive periods respectively. No information was found in *Ctenosaura pectinata* describing the volume of iguanas as a dependent variable. Total length is a trait that varies, mainly due to the loss of the tail derived from handling carried out in captivity. Tail losing is also used as a defense strategy when iguanas are being handled (6, 20).

Table 1. Descriptive statistics and normality in morphometric variables of black iguana (*Ctenosaura pectinata*) in captivity (n=40).

Tabla 1. Estadística descriptiva y normalidad en las variables morfométricas de iguana negra (*Ctenosaura pectinata*) en cautiverio (n=40).

Variable	Mean	SD	Minimum	Maximum	Shapiro-Wilk	Prob
Weight (g)	695.7	197.4	408.0	1199.0	0.948	0.065
Volumen (ml)	723.3	185.0	440.0	1180.0	0.952	0.089
Total length (cm)	67.7	10.6	40.3	82.5	0.945	0.052
Snout-vent length (cm)	27.2	1.4	24.0	29.5	0.940	0.034
Head length (cm)	6.0	0.4	5.3	6.6	0.957	0.134
Pelvis length (cm)	3.2	0.3	2.6	4.2	0.955	0.115
Tail base diameter (cm)	11.0	1.2	8.9	14.1	0.971	0.393
Diameter of the leg (cm)	9.0	1.2	6.0	11.4	0.985	0.878
Diameter of hip (cm)	14.9	1.4	12.2	18.7	0.973	0.442

SD: Standard deviation. / SD: Desviación estándar.

Thus, total length is discarded as a variable that helps to define if a female is suitable to be used as a reproducer (20).

A problem that often arose when measuring the length of the snout-vent is that iguanas have the ability to bend their spines, which can lead to errors if patience and care are not taken into account while measuring. Although head length can be obtained with a high degree of precision in relation to total length and snout-vent length, it is not widely used as an important variable in the management of black iguanas (1), nor are the diameter of the base of the tail, leg, and hip (11).

In general terms, all evaluated variables are positively correlated ($p<0.05$) (table 2). However, the total length was not correlated with the variables pelvic length ($r=0.17$, $p=0.30$), tail base diameter ($r=0.27$, $p=0.9$) diameter of the leg ($r=0.22$, $p=0.17$) and diameter of the hip ($r=0.31$, $p>0.053$). The length of the snout-vent was not correlated with the variables length of the pelvis ($r=0.20$, $p=0.23$), base diameter of the tail ($r=0.28$, $p=0.08$) and diameter of the leg ($r=0.16$, $p=0.31$). The variables that had the best correlation were weight:volume ($r=0.98$, $p<0.0001$), weight:tail base diameter ($r=0.95$, $p<0.0001$) and volume:tail base diameter ($r=0.93$, $p<0.0001$).

A positive correlation between two variables indicates that both increases as time passes (15, 20). The decision to use linear mass regression on volume was to produce a linear condition index (13), which separates the effect of condition against body size.

Table 2. Correlation analysis between morphometric variables in black iguana (*Ctenosaura pectinata*). (n=40).

Tabla 2. Análisis de correlación entre las variables morfométricas en iguana negra (*Ctenosaura pectinata*). (n=40).

Variable	Volume (ml)	Length (cm)				Diameter (cm)		
		Total	Snout-vent	Head	Pelvis	Tail base	Leg	Hip
Weight	0.977 <.0001	0.355 0.025	0.399 0.011	0.695 <.0001	0.898 <.0001	0.950 <.0001	0.803 <.0001	0.904 <.0001
Volume	-------	0.431 0.005	0.435 0.005	0.707 <.0001	0.844 <.0001	0.933 <.0001	0.806 <.0001	0.905 <.0001
Total length	-------	-------	0.694 <.0001	0.391 0.009	0.168 0.301	0.269 0.093	0.219 0.174	0.308 0.053
Snout-vent length	-------	-------	-------	0.579 <.0001	0.196 0.225	0.280 0.080	0.163 0.314	0.362 0.022
Head length	-------	-------	-------	-------	0.629 <.0001	0.677 0.0001	0.582 <0.0001	0.689 <.0001
Pelvis length	-------	-------	-------	-------	-------	0.875 <.0001	0.768 <.0001	0.845 <.0001
Tail base diameter	-------	-------	-------	-------	-------	-------	0.868 <.0001	0.897 <.0001
Diameter of leg	-------	-------	-------	-------	-------	-------	-------	0.817 <.0001

In other studies with *Sphenodon punctatus*, it has been necessary to resort to the logarithmic transformation of the variables studied so that the data set could meet the linearity assumption (19).

The diameter at the base of the tail showed correlation in other species of lizards (18); however, it was not used as an important variable to determine body condition.

Body condition assessment in wild animals is a good indicator of the rate of previous food consumption and therefore of their amount of energy reserves (13, 16). In the case of reptiles, weight, total length, snout-vent length, skull length, and tail base diameter (16, 23, 24) are considered adequate variables. Therefore, the body condition index for *C. pectinata* was taken from the weight and volume variables, which were the best correlated.

Figure 1 shows the distribution of volume in relation to weight in females of *C. pectinata* from the first reproductive stage and with multiple stages. The regression equation and the upper and lower limit were obtained, from which two equations were created to predict volume, 1) V=86.08826 + 0.91586 W, (r^2=0.96, p<0.0001) and 2) V= -6.49377 + 0.88359 W + 1.69991 TL, (r^2=0.96, p=0.007). Where: V=Volume (ml), W= Weight (g) and TL= Total length (cm).

Volume prediction is important because its prediction is important because its measurement is difficult both in captivity or wildlife. Iguanas can increase volume by inhaling air during the process of measurement, which causes the actual value to be overestimated.

Table 3 (page 355) shows the proposal of a body condition index, based on weight/volume variables (r=0.98, p< 0.0001), providing four categories (I, II, III and IV) from the leanest black iguana to the most excessively corpulent. The body condition index performed for *C. pectinata* uses a similar methodology for determination in other species (9, 17, 24).

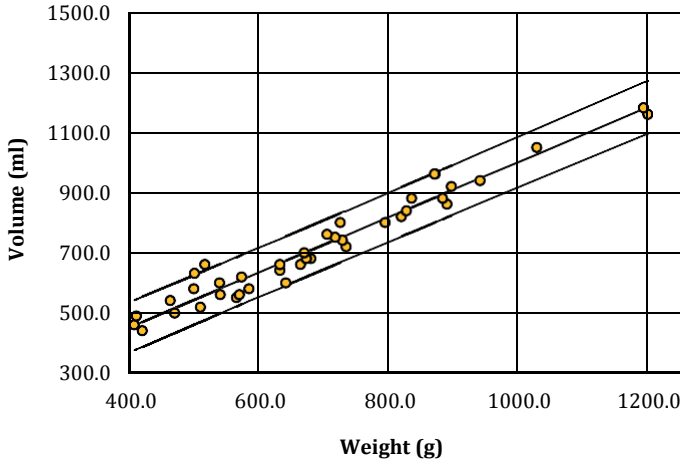

Figure 1. Relationship between the variables weight and volume in *C. pectinata* (black iguana) in captivity conditions.

Figura 1. Relación entre las variables peso y volumen en *C. pectinata* (iguana negra) en condiciones de cautiverio.

Table 3. Proposed body condition index in female iguanas of the species *Ctenosaura pectinata* in captive conditions.

Tabla 3. Propuesta de índice de condición corporal en iguanas hembras de la especie *Ctenosaura pectinata* en condiciones de cautiverio.

Body condition categories	Main feature	Body condition index values*
I	Extremely lean	0.827 - 0.892
II	Lean	0.893 - 0.957
III	Excellent	0.958 - 1.022
IV	Excessively corpulent	1.023 - 1.088

* Weight (g)/volume (ml). / *Peso (g)/volumen (ml).

The advantage of this proposal is that only the weight of the iguanas is required, in addition to the fact that this index is appropriate only for *Ctenosaura pectinata*, as indicated by Falk *et al.* (2017) who mention that each index is exclusive for a particular taxon. Body condition values outside of the lower or upper ranges are rounded to the most immediate category. For example, a body condition value of 0.810 is assigned category I, which corresponds to extremely lean. The proposed body condition in females of black iguana *C. pectinata* is detailed in figure 2 (page 356).

Body condition I, *Ctenosaura pectinata* is extremely lean: The vertebrae (base of the head to the tip of the tail), hip bones and ribs, are clearly visible. Loose skin can be seen all over the body, mainly on the front and hind limbs. The scales rings of the tail are very inclined in the shape of an inverted V, and the coccygeal vertebrae are shown of concave form. Arms, legs and tail muscles are barely observed. The latter presents depressions (figure 2a, page 356).

Body condition II, black iguana (*C. pectinata*) is lean: The cervical, thoracic, lumbar and coccygeal vertebrae, as well as the ribs and hip are visible. In the four limbs and the body in general, there is evident loose skin due to the lack of subcutaneous fatty tissue. However, visible muscle tone is noted. The scale rings of the tail are less concave. The accumulation of muscle is noted in the coccygeal vertebrae and there are no depressions between the scale rings of the tail (figure 2b, page 356). In body condition III, the *C. pectinata* has excellent body condition. The bones of the vertebrae, ribs, and hip are undetectable to the naked eye. These are only discernible when direct pressure is applied to the iguana. In the limbs and body, in general, the accumulation of subcutaneous fat tissue and loose skin is not noticeable. The rings of tail bones are shown with flesh and the concave arrangement is not observed (figure 2c, d, page 356).

In body condition IV, *C. pectinata* is observed to be excessively corpulent. The excessive accumulation of subcutaneous fat tissue is evident. At touch, no part of the bones is perceptible. The animal is obese between the coccygeal vertebrae and the lumbar vertebrae. The accumulation of muscle and fat is perceived by the bulge of the area (figure 2e, f, page 356).

Figure 2. Body condition in females of black iguana (*Ctenosaura pectinata*) in captivity conditions: I, extremely lean (a); II, lean (b); III, excellent (c and d) and IV, excessively corpulent (e and f).

Figura 2. Condición corporal en hembras de iguana negra (*Ctenosaura pectinata*) en condiciones de cautiverio: I, extremadamente delgadas (a); II, delgada (b); III, excelente (c y d) y IV, excesivamente gorda (e y f).

It has been described that animals can decide whether they should reproduce since under limited feeding conditions they endanger reproductive survival and success. However, the inability to reproduce under favourable conditions also endangers reproductive fitness (7).

In this study three excessively corpulent and two excessively lean non-reproductive female *C. pectinata* were recorded. This information provided certainty that body condition classification served to recognise potentially successful reproductive iguanas. The opposite was found in snakes, whereby body condition does not differ between reproductive and non-reproductive females (7).

The reproductive period is the biological event that demands the greatest amount of energy for the black iguana since it represents a third of the weight that she invests from copulation to oviposition (4). The response pattern during the reproductive period suggests a critical point in terms of the adaptation of females to their life cycle (22). Thus, the body condition index is important for the females' reproductive efficiency.

Conclusions

A body condition index was obtained for black iguana (*Ctenosaura pectinata*) kept in captive conditions. This index will be a useful tool for the support of reproductive events of the species since its monitoring will allow adjustments of nutritional management. This information could be useful to similar programs managing wild and captive iguana populations both for iguanas in their first reproductive stage and those who have produced various offspring. In addition, iguanas of different weights were taken into account, from the leanest to the biggest and most corpulent.

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