ON THE PRESENCE OF THE SPINY CHUCKWALLA *SAUROMALUS HISPIDUS* (STEJNEGER, 1891) IN RASA ISLAND, MEXICO

PRESENCIA DEL CHACHORÓN ESPINOSO *SAUROMALUS HISPIDUS* (STEJNEGER, 1891) EN LA ISLA DE RASA, MÉXICO

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Abstract.— In 2006 and 2013 two different individuals of the Spiny Chuckwalla (*Sauromalus hispidus*) were found on the small, flat, volcanic and isolated Rasa Island, located in the Midriff Region of the Gulf of California, Mexico. This species had never been recorded from Rasa Island prior to 2006. A new field study in 2014 revealed the presence of a single female chuckwalla inhabiting the Tapete Verde Valley, in the south-central part of the island, occupying a territory no bigger than 10000 m2. A scat analysis shows that the only food consumed by the animal is the Alkali Weed (*Cressa truxilliensis*) that forms patches of carpets in its habitat. The individual is in precarious condition, as it seems to starve on a seasonal basis, especially during El Niño cycles; also, it is missing fingers and toes, which appear to be intentional markings by amputation. We conclude that the two individuals were introduced to the island intentionally by humans.

Keywords.— Chuckwalla, Gulf of California, Rasa Island.

Resumen.— En 2006 y 2013 se encontraron dos individuos diferentes del cachorón de roca o chuckwalla espinoso (*Sauromalus hispidus*) en la pequeña, plana, volcánica y aislada isla Rasa, localizada en la Región de las Grandes Islas, en el Golfo de California, México. No se había registrado la ocurrencia natural de esta especie en la isla antes de 2006. Una nueva prospección de campo en 2014 reveló la presencia de un único individuo hembra de la especie habitando la parte sur-central de la isla, localidad llamada Valle del Tapete Verde, y en un territorio no mayor a 10000 m2. El análisis de heces revela que el único alimento consumido por el animal es la hierba alcalina (*Cressa truxilliensis*) que forma alfombras discontinuas en el valle. El individuo se encuentra en condición regular de salud y parece que pasa por fases de hambruna, sobre todo en los años en que ocurre El Niño; asimismo, carece de varias falanges tanto en manos como en patas, que parecen ser marcas intencionales por amputación. Se concluye que los dos individuos observados fueron introducidos intencionalmente por humanos a la isla.

Palabras clave.— Cachorón, Golfo de California, Isla Rasa.

INTRODUCTION

The lizards of the genus *Sauromalus*

Chuckwallas, or "cachorones" in local Mexican Spanish, are medium to large-sized lizards closely related to the spiny-tailed, desert and green iguanas, basilisks, and common spiny lizards, among other members of the infraorder Iguania (iguana-allied lizards). More specifically, their genus *Saromalus* are closely related to *Ctenosaura* and *Dipsosaurus*, among other genera of big lizards, in the family Iguanidae (Lemos et al., 2015). Chuckwallas, however, lack the typical dorsal crest, large tympanum, dewlap, and long tail of the common green iguana, *Iguana iguana* (Grismer, 2002; Hollingsworth, 1998, p. 65). Their bodies are

rather robust and compacted with granular to mucronated (sharp-tipped) body scales, with a thick, medium-sized tail that is used as a fat reservoir. They are completely herbivorous, feeding on flowers, fruits, and leaves of various desert plants (Lemos et al., 2015). Consequently, they have long intestines full of starch-degrading bacteria and look like fat, big-bellied lizards. Being rock dwellers, chuckwallas retreat inside cracks or crevices or under big rocks when threatened, where they gulping air to inflate their bodies and clog themselves between the rocks. This defensive technique proves nearly impossible for predators to pry chuckwallas out of the crevice. Their skin, especially on the sides, is loose and has wrinkles to facilitate the air intake for inflation (Grismer, 2002; Hollingsworth, 1998).

Chuckwallas belong to the genus *Sauromalus* and are indigenous to southwestern United States and northwestern Mexico, where they are restricted to the Mojave and Sonoran Desert ecosystems (Hollingsworth, 1998). In this highly biodiverse desert, they occupy rocky outcrops in valleys and foothills where they are completely terrestrial, in contrast to other iguanid lizards such as the San Esteban Island Spiny-tailed Iguanas (*Ctenosaura conspicuosa*), often seen atop cardón cacti foraging for flowers and fruits (Grismer, 2002).

The Sonoran Desert chuckwalla, *Sauromalus ater*, is broadly the southwest United States, continental Mexico, and the peninsula of Baja California. Apart from *Sauromalus ater*, there are other 4 species endemic to different insular islands in the Gulf of California, Mexico, with no additional representatives on the mainland or the peninsula. These include: *Sauromalus klauberi*, endemic to Santa Catalina island; *S. hispidus*, endemic to Angel de la Guarda and 10 satellite or associated islands; *S. varius*, endemic to San Esteban island and Roca Lobos; and *S. slevini*, endemic to Carmen, Montserrate and Coronados islands. In total, they form 14 island populations in the gulf (Case, 1982; Hollingsworth, 1998, Grismer, 2002; Murphy and Aguirre, 2002; Case, 2002).

There has been considerable debate among specialists in relation to the origin of chuckwallas on these islands. Some have postulated that all or at least some of these species originated through the process of vicariance — the appearance of a barrier, splitting a single population apart to form two subpopulations. Both subpopulations, isolated from each other, follow different evolutionary paths to become new species. This happens when portions of a large landmass become isolated by the formation of a seaway (Murphy and Aguirre, 2002; Whittaker and Fernández, 2007; Thornton, 2007).

This phenomenon has been hypothesized for many taxa inhabiting continental islands. These islands were once connected to larger landmasses, but due to sea level rising, continental sinking, or as result of plate motions, the connection was lost. The existence of many islands in the Gulf of California are explained by this process, and their current faunal assemblages formed between 12,000 to 9,000 years ago at the end of the Pleistocene when sea level rose and engulfed pieces of the peninsula and mainland Mexico, forming the present-day islands (Murphy and Aguirre, 2002; Carreño and Helenes, 2002).

Researchers offer a different explanation for biotas in the most remote, isolated islands known as "oceanic islands". They propose overwater or maritime dispersal — the drifting of individual animals in the ocean on rafts of vegetation that eventually reach an island — as being responsible for colonization events of oceanic islands (Thornton, 2007; cf. Murphy and Aguirre, 2002). Oceanic islands are those that never had a land connection to larger landmasses (Nunn, 1994), and the only way of reaching them is by flight or by drifting in the sea. Thus, the biotas that exist on oceanic islands were not present when the island formed, but colonized them later. Arriving taxa follow a successional series of steps that includes dispersal, establishment, colonization and subsequent speciation due to new niches provided by the island or islands (Williamson, 1981; Whittaker and Fernández, 2007).

Despite the competing theories of the origins and formation times of insular populations, the impressive adaptive radiation experienced by chuckwallas on islands of the Gulf of California has continually fascinated herpetologists, evolutionary biologists and biogeographers alike, who have studied their taxonomy, distribution, natural history, ecology, population genetics, demography, and behavior (Tracy, 1999; Murphy and Aguirre, 2002; Case, 1982, 2002). Studying these populations in situ involves many inherent difficulties for reaching islands (distance, extreme isolation, high temperatures, lack of water, etc. (Carreño and Helenes, 2002, pp. 24-25)).

Chuckwallas remain as perfect examples to study evolutionary trends on islands, specifically changes in body size and changes in morphological features (Tracy, 1999; Case, 1982). Change in body size is an adaptation to insular conditions known as "gigantism" or "dwarfism", phenomena that have been explained by character release related to the lack of predators, lack of or reduced interspecific competition, and food type, annual availability, abundance and size (van der Geer et al., 2010). Two endemic insular species of chuckwallas, *S. varius* and *S. hispidus*, show interesting changes in size towards gigantism, as well

as changes in other morphological features, such as color: the former is yellow with black, and the latter is completely black, both colors being very distinctive from the "normal" pattern of the Sonoran Desert chuckwalla (Grismer, 2002).

More importantly, as most island populations have reduced individuals, they are easier to study and than their continental counterparts (Whittaker and Fernández, 2007). Thus, chuckwalla island populations can and have been monitored, and any change in geographical distribution, increase / decrease in population size, extinction, genetic change, and other population / species traits, are more detectable. For example, some important changes in chuckwalla distributions and taxonomic identities have been documented over the last 30 years on islands in the Gulf of California. The cases are:

1. *Sauromalus hispidus*. Because of the anomalous distribution of this species on islands, it is believed that some populations have been introduced by humans, presumably by Seri people, on the islands of Bahia de Los Angeles with the intention of establishing insular stocks that can be used as sources of food (Grismer, 2002). This hypothesis, however, has not been proven and remains speculative (Bowen, 2000).

2. *Sauromalus varius*, *Sauromalus hispidus* and *Sauromalus ater* live sympatrically on Alcatraz Island producing a mixed population of "pure" and hybrid animals. From these species, only *Sauromalus ater* is thought to be autochthonous, and the other two a product of deliberate introduction by humans (Grismer, 2002).

3. *Sauromalus varius*, endemic to San Esteban Island, seems to have been deliberately translocated to Roca Lobos by humans. (Grismer, 2002)

4. A fourth example, which motivated the research for the current study, is the presence of individuals of the Spiny Chuchwalla, *Sauromalus hispidus*, on Rasa Island as recently as 2006 and 2013 (Velarde, *pers. comm.*; Velarde et al., 2008; Reynoso et al., 2017; Cerdá and Langarica, here).

The unexpected presence of *Sauromalus* on Rasa Island is of relevance in various fields: in biogeography, because it illustrates an example of over-water dispersal or anthropogenic introduction; in evolution, because it illustrates the adaptive radiation of organisms to new niches, and the phenomenon called "character release" from which many interesting adaptations derive; in population genetics, because it illustrates the genetic bottlenecks and random genetic drift that a small number of individuals on islands experience or have experienced; in ecology, because it illustrates the way a species adapts and responds to a new environment; and in conservation biology, because it illustrates the way a newly introduced species alters and modifies a stable environment.

The two records of *Sauromalus hispidus* from Rasa Island are previously reported in literature (Velarde et al., 2008; Reynoso et al., 2017). The possibility of a small, recently established population of *Sauromalus* on Rasa Island has stimulated the scientific interest to investigate further. Any information gathered is useful for conservation measurements on the island. For these reasons, a research party was organized in April, 2014 to obtain important information that is described in here.

Our objectives were: 1) search for additional individuals of *Sauromalus* on Rasa Island and collect tissue, feces and other samples; 2) identify the species present; 3) determine its distribution and populations parameters on the island; and 4) document the interesting and valuable story of *Sauromalus* on Rasa Island since 2006 for historical reasons.

MATERIALS AND METHODS

One of the authors (ACA) has thorough knowledge of the Gulf of California and its islands through previous field trips. These include many short visits to Rasa Island aboard Lindblad Expeditions/National Geographic cruise ships (Sea Bird, Sea Lion, and Sea Voyager) throughout 23 years; research cruises aboard the Mexican Navy's Oceanic Patrols in 1985 and 1986 (organized and led by Dr. Enriqueta Velarde); and cruises aboard the Pacific Monarch ship. Consequently, it was relatively easy to plan the scale and characteristics of the field survey, such as distances and type of terrain. Additionally, maps from the previous experiences were very useful for determining size, position, and number of quadrangles (quadrants) used for surveying and to identify reptile species.

We divided Rasa Island and surrounding waters on a map into 40 quadrants or quadrangles of 130 meters per side (Caughley, 1977, pp. 28-29). The artificial "center" of the island was designated to be the researchers' house. From there, we traced lines to the north, south, east and west and derived the different vertices and quadrants at scale, including those located in the sea. A total of 44 vertices were marked on a map and connected by straight lines to form the 40 quadrants. We then selected 28 quadrangles that embraced land or parts of land and discarded 12 that contained only or primarily ocean, such as those located in the northern and southwestern portions of the island. Quadrants with potential habitat for chuckwallas were

selected for sampling (N = 19). During the field survey we verified each vertex, adjusting the distances and obtaining coordinates using a GPS. Each vertex was painted with blue acrylic paint on medium-sized rocks for visual reference.

We surveyed each quadrangle by walking in zigzags from one side to the other in order to cover as much area as possible and locate any sign of the animal's presence. Waxed bags were used to preserve collected feces, dead animals, bones, and/or dry skin of other organic samples. Field sampling was performed from 08:00 to 14:00 and again from 16:00 to 18:00 daily for 14 days. Fresh body tissue samples we stored in a laboratory kit with 90% alcohol. To estimate population abundance, we used the capture-recapture method and the Lincoln Index (Caughley, 1977, pp. 133-167). Individuals were marked numerically with acrylic white paint, starting with the number 1. We also gathered ecological data from each sampled quadrant, such as physiography and type / abundance of vegetation.

RESULTS

Characteristics of Rasa Island

Rasa Island is one of 1003 islands, islets, and rocks that dot the Gulf of California (INEGI, 2015). It is located in one of the most productive regions of the gulf, called the "Midriff Islands Region," a few miles south of Angel de la Guarda and Partida Norte islands, and 21 km east of Bahia de Los Angeles (Carreño and Helens, 2002; Álverez-Borrego, 2002). It is a small (0.68 km2), low-lying, dry, and rocky island with several hills not exceeding 30 m a.s.l. The rocky hills consist mainly of large and small fragments of basaltic rock, among which a scant soil has accumulated. The shoreline consists of basaltic boulders and a few low cliffs. The island formed from massive lava flows from a submerged volcano, and its age is estimated to be less than 10,000 years, being one of the youngest islands in the gulf (Carreño and Helenes, 2002; Velarde et al., 2014).

Rasa Island also has several flat, guano-filled, valleys used for nesting by Elegant Terns (*Sterna elegans*) and Hermmann's gulls (Larus heermanni), among other marine birds. There are as many as 11 valleys, 10 of which have received local names. These include: Valle Gran Estación Central, Valle del Estero, Valle del Esterito, Valle de la Casita, Valle de los Gallitos, Valle del Fin, Valle de la W, Valle de Casitas Viejas de Abajo, Valle de Casitas Viejas de Arriba y Valle Tapete (Verde et al., 2014).

Tapete Verde is the most southwestern of all the valleys, and lies between a northern rocky, cholla cactus-covered hill and a southern rocky shore of no more than 4 meters a.s.l. Due to the massive numbers of seabirds that nest every year, the island is painted white from guano. It has corresponding high levels of nitrogen and phosphorus that largely determine the plant species that can persist on the island. There are three tidal lagoons, all on the northwestern end of the island. The easternmost lagoon was artificially opened to the sea to allow access for small boats, and drains completely at low tide. The other two lagoons are open to the sea only at high tide and remain partially full at low tide. Geologic studies indicate that the island is slowly rising and the lower elevation valleys once were lagoons, as soil-core studies revealed mollusks in the process of fossilizing in the lower strata of sand, overlaying basaltic rock. Soil profiles elsewhere on the island show only guano over the basaltic rock (Velarde et al., 2014).

Figure 1. The first individual of *Sauromalus hispidus* found in Rasa Island, in 2006, by Velarde and Ruz. Photo by Enriqueta Velarde.

Figura 1. Primer individuo de *Sauromalus hispidus* encontrado en Isla Rasa , en 2006, por Velarde y Ruz. Foto por Enriqueta Velarde.

History of the *Sauromalus* individuals on Rasa Island

Th The following account is intended for the sake of increasing the recent historical knowledge of Rasa Island and to document the whole story of *Sauromalus hispidus* on it. On May 17th, 2006 (Fig. 1), ornithologist Enriqueta Velarde and accompanying graduate student Francisco Ruz fortuitously found a large, adult chuckwalla at Tapete Verde Valley while checking for seabird nests. This constituted the first time the species was observed on Rasa Island. Tapete Verde is a guano-filled valley surrounded by rocky hills, except in the southern part, which is made of a rocky shore of about 30 to 40 m wide.

The chuckwalla found by Velarde and Ruz was immediately hand-captured from between the big cobbles that form the

Figure 2. Individual of *Sauromalus hispidus* captured in April 2014 in Rasa Island, Gulf of California, Mexico. Photo by Adrián Cerdá.

Figura 2. Individuo de *Sauromalus hispidus* capturado en abril del 2014 en Isla Rasa , Golfo de California, México. Foto por Adrián Cerdá.

beach, and taken back to a little stone research station, 397 m to the north. The individual was put inside an enclosure made of eight fruit-carrying plastic containers or crates and kept by the biologists in order to determine if the lizard should or should not be on the island. The following day the reptile defecated, and the feces was collected and analyzed. It was determined that the only food item consumed by the reptile was the Alkali Weed (*Cressa truxilliensis*), that forms a small carpet in Tapete Verde Valley. Researchers offered Alkali Weed to the animal for the following 4 days, which it ate avidly.

The chuckwalla (named "Chucky" by the biologists) defecated four more times, and in all samples *Cressa* was always present as the only food. Velarde and Ruz took several pictures of Chucky but did not record body measurements, rendering vital information regarding this individual unavailable.

On the fifth day, Chucky was taken out to be released. Velarde and Ruz walked to the rocky foothills surrounding the southern end of Gran Estación Central Valley to paint stalks for bird research. The location is approximately 303 m southwest from the research station, and 286 m northwest from where the reptile was originally captured. They left Chucky inside one of the crates while performing their tasks. A large rock was set on top the crate to avoid being moved by the animal. When Velarde and Ruz came back to pick Chucky up an hour later, they found that it had escaped by digging a hole below the side of the crate. From this moment onwards, the first individual of *Sauromalus* ever found on Rasa Island was lost and apparently never seen or captured again. Velarde wrote a brief note in Herpetological Review about the event, published in 2008. By means of photo vouchers, Adrian Cerdá identified the individual as *Sauromalus hispidus*, not previously known from Rasa island.

Seven years later (May 2013), Verlarde found a second chuckwalla in Tapete Verde Valley during the seabirds' breeding season, 382 m south of the research station. This time the animal was not captured, only photographed. The location of this observation was only 8 m west from where Chucky was found. No morphological measurements or tissue samples were taken. This second sighting was reported in *Herpetological Review* by Reynoso et al. (2017).

With the gathered evidence it was initially postulated that a very low number of chuckwallas was living and had probably established as a breeding population on Rasa Island. This hypothesis led us to speculate on the possible consequences for the general ecological equilibrium of the island and its biota, as the presence of large herbivorous lizards known could disperse seeds of different desert plants. Additionally they might provide opportunities to study colonization events and founder effects.

Arrival to Rasa

Reptile researchers arrived Rasa Island on April 10, 2014, during which no seabirds were nesting. This was vital, as the colonial nesting of Heermann's gulls and Elegant and Royal terns would have impeded the exploration of the island. The absence of nesting birds was attributable to the occurrence of El Niño climatic phenomenon, and had been observed in previous years, according to Velarde et al. (2004).

Once established on the island, we traced straight lines using a GPS to the north, south, east and west from the research station, which was designated as the center of the island, as described above. The station is located in the central, northwestern portion of the island, with the recorded coordinates 28.824611 N, W112.980639 W. From there we derived the different vertices and quadrants as explained. Minor adjustments of vertices were made in the field that did not affect our estimates of the surveyed area.

As described, a total of 19 of 28 quadrants, each 130 m per side, were sampled during 14 days of fieldwork. We surveyed 16 quadrants completely, and another 3 were surveyed partially due to the presence of dense patches of cholla cacti (*Cylindropuntia* sp.). Each quadrangle had an area of 18,225 m2, equivalent to 1.8 hectares. In total, we surveyed 30.9 hectares, representing approximately 57% of the island's surface. Each quadrant had

Figure 3. Normal adult male *Sauromalus hispidus* from Angel de la Guarda Island. Photo by Adrián Cerdá.

Figura 3. Macho adulto de *Sauromalus hispidus* de la isla Ángel de la Guarda. Foto por Adrián Cerdá.

different vegetation and physiographic characteristics. Most quadrants fell in the eastern half of the island. The western side contains three lagoons and flat, low-lying flooding areas and rocky hills covered by dense patches of cholla cactus.

The surveys consisted of searching for any indication of the chuckwallas' presence, such as tracks, feces, and signs of digging or tail dragging. In 18 of the 19 sampled quadrants, no signs of *Sauromalus* were found. Only the quadrangle assigned as number 24 (that partially corresponds to Valle Tapete Verde) yielded feces as well as a sinlge live individual that we describe in the next section.

Live individual

Velarde and Ruz led the party to Tapete Verde Valley where the two chuckwallas were previously found. Tapete Verde lies at the central southern part of the island. It is about 150 m in its east-west axis and about 100 m in its north-south axis. Most of the valley is about 3 m a.s.l. It is mostly a plain, flat valley covered by guano and organic soil a few meters thick., There is a water-table with brackish water. Approximately 20% of the valley is covered by *Cressa truxillensis*, and about 5% is covered with *Batis maritima*. Rocky foothills surround the western, northern, and eastern sides. The northern side is the highest, at about 35 feet high. This side is also nearly covered by cholla cactus and some 30 cardón cacti of various sizes.

The southern side consists of a rocky beach about 40 m wide. Most rocks are medium to large sized, with an average of 2 to 3 foot in diameter. In the boundary between the flat guano valley and the rocky beach, there are thick patches of chollas and *Atriplex barclayana*. At the location were Chucky was found in 2006, there is a single cardón cactus and a single individual of guayacán, a greasewood-related plant.

At approximately 100 m west of where Chucky and the second individual were originally found,we captured a third specimen on April 12th, 2014 at 14:10 local time (Fig. 2). Climatic conditions were partially cloudy but warm with no winds, and a temperature of 24.3° C at one m above ground. Coordinates were 28.821361 N, 112.981556 W, and a height of 2 m above sea level. The animal was a female, determied by the number (15), size and shape of the femoral pores, as well as the shape and thickness of the tail. Abdominal palpation showed no signs of eggs, and the individual appeared to be in poor health condition. It was skinny with very dry skin. Some old skin was still attached in several layers, indicating that the molting process did not develop well, especially at the tympanum. In fact, the tympanum was partially covered with a thick layer of dead skin tightly attached, and when we tried to take it apart with pincers it seemed to cause pain to the individual. Also, some skin was missing at the left side of the lower mandible, exposing some bone and flesh, but the wound was not bleeding or infected, and seemed not to bother the animal. Measurements were as follows: snout-vent length: 290 mm; head width: 57 mm; and weight: 994 g. Using

Figure 4. The individual *Sauromalus hispidus* found in Rasa in April 2014 was measured and weighed, and skin samples were taken from its tail, legs and back. It was assigned 01 and then released where it was captured. "Pancha", as was called, was seen again two more times. Photo by Adrián Cerdá..

Figura 4. Se midió y pesó el *Sauromalus hispidus* encontrado en isla Rasa en abril de 2014, y se tomaron muestras de piel de la cola, piernas y espalda. Se asignó 01 y luego se soltó donde fue capturado. "Pancha", como se le nombró, fue visto nuevamente dos veces más. Foto por Adrián Cerdá.

dichotomic keys for identification, we assigned this individual to the species *Sauromalus hispidus*, endemic to Angel de la Guarda Island (Fig. 3).

Interestingly, the individual was missing digits almost symmetrically: the fifth (outer) finger of each hand; the fifth toe of the right foot; and the first (inner) phalange of the fourth toe on the left foot. Several portions of skin from different parts of the body were taken as samples and preserved in tubes with alcohol to conduct genetic analyses.

This chuckwalla was marked as 01 with acrylic white paint for purposes of the capture-recapture protocol, and later released exactly in the same place where it was found. We decided to call it "Pancha" honoring Francisco Ruz, who first spotted it (Fig. 4). "Pancha" laid on the rock for at least 20 minutes upon being released and appeared stressed. It was decided that, for the second part of the survey, the recapture procedure would be only "visual recapture" to avoid further disturbing the animal.

"Pancha" was seen again two more times, one on April 13th (a day after the capture and marking), at 12:45, under a partially cloudy but warm day, and a temperature of 25 °C. It was sunbathing and alert, and did not run away from researchers, but kept an eye on us for about 25 minutes. The second "visual capture" was made by Francisco Ruz on April 24th, but no data on time of the day and temperature, or animal behavior, were recorded.

Figure 5. General view of Tapete Verde Valley, southcentral part of Rasa Island. Photo by Adrián Cerdá.

Figura 5. Vista general del Valle Tapete Verde, en la parte centro sur de la Isla Rasa. Foto por Adrián Cerdá.

Figure 6. General view of Tapete Verde Valley, southcentral part of Rasa Island. Photo by Adrián Cerdá.

Figura 6. Vista general del Valle Tapete Verde, en la parte centro sur de la Isla Rasa. Foto por Adrián Cerdá.

Samples

A total of 43 samples of fecal feces were collected from Rasa Island, all of them at Tapete Verde. All samples were collected around or near the site where this chuckwalla was captured during the field survey, at distances that range from a few centimeters to 50 meters northwest, with just 3 samples found on the *Cressa* carpet.

They are still in a laboratory at the Faculty of Sciences of the National University of Mexico (UNAM) for dietary analyses to determine plant species content and frequency. With the coordinates of fecal samples, we are working to determine the possible home range of "Pancha". This will show the distance and direction the animal moves to forage on patches of *Cressa truxlliensis* (Fig. 5), probably the only food item consumed by it.

DISCUSSION

The field survey on Rasa Island was successful in achieving one of the initial objectives. More than 50% of the island's surface was carefully surveyed for individuals, feces, skin, dead bodies, smells, dens, markings on the ground, and other strong and definite evidence of the presence of *Sauromalus*. Only the locality known as Tapete Verde (Fig. 6) yielded a live chuckwalla, alongside her fecal and skin samples.

We initially postulated that an unknown, but certainly low, number of chuckwallas had established a breeding population on Rasa Island. This hypothesis led us to speculate on the possible consequences for the general ecological equilibrium of the

island and its biota by the presence of several giant herbivorous lizard that are known to be seed dispersers of different desert plants (Case, 1982; Tracy, 1999). The first concern was about the way in which the animals arrived to the island (Whittaker and Fernández, 2007). The second was about the interactions of the chuckwallas with the seabirds during the nesting time (Velarde, *pers. comm.*). And the third was about the impact of the *Sauromalus* habits on the general vegetation.

During the field research, we found no evidence for an established chuckwalla population, and conclude that such a population is not sustainable on the island. We attribute this to two different reasons: there is only a suitable place for *Sauromalus*, and there is a severe scarcity of food.

In terms of potential habitat, we found a few places that may be good and safe retreats for these large lizards, mostly rocky shores where there are medium to large boulders that form many spaces between them where the chuckwallas can hide (Hollingsworth, 1998). These retreats are deep enough as to offer very good shelter and protection, ventilation, and cooler temperatures than the exposed shores. These retreats also maintain stable temperatures with small variation.

The foothills do not offer a suitable habitat for chuckwallas (Case, 1982, 2002; Hollingsworth, 1998; Grismer, 2002). In general, the hills are covered with small rocks, all of them of volcanic origin (Carreño and Helenes, 2002; Velarde et al., 2014). There are small spaces between them were only the side-blotched lizards of the genus *Uta* can accommodate themselves to hide momentarily. The small retreats, therefore, are very hot, and the lizards use them just in case of emergency (the very safe places for side-blotched lizards are the holes they excavate in the sand of the valleys; Cerdá, *pers. obs.*). None of these retreats are useful and safe for the larger chuckwallas.

More importantly, however, is the fact that only 12 species of plants have been recorded on the island (Velarde et al., 2014), and only four may be considered part of the chuckwalla diet. The guayacán (*Vizcainoa* sp.) may constitute an occasional food item in other islands, but there is only one individual plant on Rasa Island. The cardón (*Pachycereus pringlei*), on the other hand, has been proven to form part of the chuckwalla diet on other islands and in the peninsular and continental populations, which eat the ripe fruits once it falls (for example, on San Esteban Island; Cerdá, *unpublished data*; Case, 2002, p. 256). However, most cardón trees on Rasa Island are not accessible from potential *Sauromalus* habitat, mainly because either are far away from Tapete Verde (at least 100 m away) or are localized in the middle of dense patches of cholla cacti. We found no evidence that Pancha can access the cardón cacti through the cholla patches.

The cholla itself could be more favored by the chuckwallas because of its abundance, but this needs to be corroborated by the analysis of the fecal samples (*in progress*). On other gulf islands, chollas may play an important role in the chuckwalla diet (Case, 2002, p. 256). The animals feed on flowers and fruits, and serve as seed dispersers (Cerdá, *pers. obs.*; Case, 1982, 2002).

However, the chollas in Rasa do not seem to be eaten by the chuckwalla, although they are found in extremely large quantities due to the unpreventable transportation of stems by birds (vegetative propagation). Gull and terns, both juveniles and adults, often get the spiny stems snagged on their bodies, eventually causing their death (Velarde, *pers. comm.*), a phenomenon that has caused a lot of concern to companies dedicated to ecological tourism and exploration (for example, Lindblad Expeditions / National Geographic, personal communication). In the process, the chollas are transported and grow roots in other places where the birds visit. Therefore, the many dense and impenetrable patches of chollas are planned for removal from the island, according to Velarde (personal communication). It should be mentioned that Rasa Island was subject to intensive guano mining in the nineteenth and twentieth centuries (Bowen, 2000, p. 122-140), and the authors believe that these activities were the real cause of the great disturbance that led to the overabundance of cholla cactus.

Suitable habitat and a consistent food source for *Sauromalus* are lacking on Rasa Island, especially for the sustainment of a small reproductive population of the herbivorous lizard. We do not believe it possible that even a slight increase in the population size from a single pair (male and female) is possible without having high intraspecific competition that would lead to the starvation and death of the weaker. Territorial behavior has been reported amongst individuals of this and other *Sauromalus* species (Case, 1982, 2002; Hollingsworth, 1998; Grismer, 2002). In addition, we do not believe that there is enough food as to promote the fat storage that triggers the physiological mechanisms which produce hormones that lead to a breeding condition of the chuckwalla (Kardong, 2008, pp. 589-621).

In contrast to the chuckwalla situation, other type of reptiles, like the smaller, insect-eating lizards of the genus Uta sp. # 1 (Murphy and Aguirre, 2002, p. 588) survive very well and are extremely abundant on Rasa Island, where they might have also been introduced by humans (Murphy and Aguirre, 2002, p. 203). Uta lizards, or side-blotched lizards, inhabit flat, open, guano-

filled valleys as well as rocky foothills, and prey almost exclusively on insects, especially the dipterid flies called "bobitos" (Cerdá, personal observation). They are preyed upon by ravens (Corvus corax), which are represented by a resident couple and up to 8 visitors that might be descendants of the residents (Cerdá, personal observation). Ravens are often seen in the flat valleys feeding either on lizards or on the carcasses of Heermann's Gulls or terns (Cerdá, personal observation). They could pose a real threat for young chuckwallas (Case, 2002, p. 257). We analyzed ravens' crop regurgitations and found no evidence of chuckwalla's bones or skin.

The single individual chuckwalla found during the field research corroborated the conclusion that there is not enough food for the species. The animal was in a very bad health condition, indicating a lack of food supply. It barely survives on the island by feeding on small carpets of Cressa truxilliensis (Velarde et al, 2008). The inferred carrying capacity of the island to sustain reptiles the size of the chuckwallas is very low, almost inexistent, due basically to the lack of places to hide and the severe scarcity of food. El Niño events may increase this scarcity, as corroborated by Case (2002, pp. 248-255). However, Case (2002, p. 249-251) reports that individuals improve body condition after seasonal rains or rain following severe years of drought.

Another issue arose from the field observations — the single individual, Pancha, found on the island had mutilated digits on its hands and feet. These amputations did not seem natural, but artificial, and made us believe that the animal was marked intentionally (Plummer and Ferner, 2012).

Missing digits are observed in natural populations of chuckwallas, as they fight with each other and frequently bite the toes, or may lose them while escaping from predators (Case, 2002, p. 252), but it is hard to visualize how a single specimen, with no other conspecifics and no predators at all, could have lost 4 toes so symmetrically. One of the authors (ACA) has examined more than 1000 individuals of *Sauromalus* of all species on most islands they occupy, and has seen very few animals which are missing one to two toes maximum, except *Sauromalus varius* from San Esteban Island, which may be missing more than two, but almost always at the level of distal phalanges and claws (Cerdá, unpublished data).

These amputations changed our initial hypothesis about the way the chuckwallas could have reached Rasa Island, according to the Island Biogeography Theory. The nearest islands in which *Sauromalus hispidus* are present is San Lorenzo Norte, at almost 14 km from Rasa; San Lorenzo Sur, at 18 km; and Angel de la Guarda, localized some 22 km northwest of Rasa. These would have been the closest sources of individuals if these were to disperse naturally overwater. The local currents would have helped in that regard, as the ocean flows seasonally southeast from Angel de la Guarda towards Rasa, and northwest from San Lorenzo Sur to Rasa (Álvarez-Borrego, 2002). However, as stated above, only Angel de la Guarda, presumptively, harbors this chuckwalla species naturally (Hollingsworth, 1998; Murphy and Aguirre, 2002; Grismer, 2002), whereas in San Lorenzo Sur and North the species was introduced in historical times (Grismer, 2002).

The fact that natural overwater dispersal and colonization of Midriff islands by *Sauromalus hispidus* has not been scientifically recorded, the possibility that individuals of this species arrived on Rasa naturally must be rejected. On the other hand, San Esteban Island, that lies 37 km southeast of Rasa, and Tiburón Island, located at 40 km east-southeast of Rasa, hold different species: S. varius for San Esteban, and S. ater in Tiburón, which never have been reported occurring in Rasa (Hollingsworth, 1998; Murphy and Aguirre, 2002; Grismer, 2002).

The other option of the presence of *Sauromalus* on Rasa Island by means of vicariance is discarded a priori. It has been demonstrated that Rasa never had a land connection to other Midriff islands or the mainland, but it rose from the bottom of the sea (Carreño and Helenes, 2002, pp. 20 and 26; Velarde et al., 2014). Thus, how can we explain the presence of *Sauromalus hispidus* on this tiny island?

The most logical inference is by means of overwater dispersal. If we accept a natural dispersal from Angel de la Guarda (or the nearby islands where it has been introduced by humans), then how can we explain that it had not occurred before the year 2006? And how do we explain Pancha's missing digits?

If normal overwater dispersals were common in this species, it would be easy to find chuckwallas of different species on different islands, mixed up, and probably speciation would never occur. That is not the case. Apparently, dispersals and subsequent colonization events are rare, like in most islands around the world. One or two founding events may account for most island endemic forms (Whittaker and Fernández, 2007).

If we consider another possibility, as explained in the introduction, transloacation of chuckwallas by humans have been recorded on several islands at different times (Grismer, 2002), combined by the fact of amputated digits, leads us

Figure 7. Amputated limbs of the individual found in April 2014. Photo by Adrián Cerdá.
Figura 7. Miembros con dígitos amputados del individuo encontrado en abril del 2014. Foto por Adrián Cerdá.

to a different conclusion. The amputated digits in "Pancha" are strong evidences of a permanently marked animal, since there is no other way to keep long-term track of this type of reptiles (Plummer and Ferner, 2012). This could mean that the animal was artificially marked and released in Rasa, or more probably, both recorded individuals (Chucky and Pancha) were introduced deliberately to the island by people, at the same time, and perhaps together. We suspect that this introduction was made by a person (either professional scientist or not), since such mutilations are used in long-term lizard studies. Possible reasons for this introduction include the chance to observe the colonization process, and all the demographic, genetic and ecological implications.

This view is reinforced by two facts: Dr. Velarde has been studying Rasa Island's breeding birds for more than 35 years, with no sights of chuckwallas before 2006; and the presence of these reptiles precisely in the place where there is some food available for them. It is highly improbable, under all these facts, for of a couple of vagrant chuckwallas to arrive safely to an empty island and to the right place where food is located.

Thus, the two individuals of *Sauromalus hispidus* found on Rasa Island do not reflect a natural overwater dispersal or a vicariance event, es explained by Island Biogeography Theory; the single individual found in 2013 and again in 2014 is subject to natural selection but has no relevance in evolutionary terms since it was not reproducing; the population genetics of this individual have not relevance since no population was found; in ecology, this individual shows how organisms can endure under harsh environmental conditions and illustrates the way they adapt to new environment and change in response to it; and finally , it seems than "Pancha" is not an issue in Conservation Biology since it does not seem to alter or modify the Rasa Island general environment nor the breeding of sea birds.

"Chucky", the individual found in 2006, could have been alive if he had not been captured and later accidentally released far away from its original location that provided food for it. Another reason for its absence, could be its death by starvation sometime after escaping, as often happens to reptiles on islands due to El Niño phenomenon (Case, 2002, pp. 248-255).

As it was also found at Tapete Verde, at only 108 m from Pancha's home, we believe that both Chucky, a male, and "Pancha, a female, were introduced together to the same location and simultaneously, or at least in two separate events not too far from each other in time. They probably remained unseen or unnoticed for a long time until Velarde and Ruz found Chucky in 2006. With Chucky's capture and disappearance, chances of reproduction (mating with Pancha) and subsequent establishment of a population were nullified, and the remaining individual, Pancha, is certainly condemned to live a solitary existence on Rasa.

In short, we conclude the following: 1) Tapete Verde is the only location suitable for life of individuals of the genus *Sauromalus* on Rasa Island. It provides the only source of permanent food, as well as shelter; 2) there is only one female individual of the Spiny Chuckwalla *Sauromalus hispidus* living on Rasa Island; 3) based on

the symmetrical amputation of the missing digits in the animal's hands and feet, we believe that she was intentionally marked (Fig. 7); and 4) based on the place where the female lives (that is only 108 meters from the location where the first chuckwalla was captured); the time span between the observation of the two individuals (8 years); the possibility that both were present at the same time, but seen by researchers in different years; and their recorded presence in the same location (Tapete Verde), we conclude that the two animals were intentionally relocated to Rasa island from another place in order to eyewitness the foundation of an island population with all the demographic, ecological, biogeographic and genetic implications. Additionally, mating was totally cancelled with the possibility that Chucky died of starvation after its escape from researchers at the Gran Estación Central valley.

A final note to this discussion is that, with this paper, we achieved a first-hand account of the story of these two animals in Rasa, that adds to the general history and conservation of the island. It also may serve as a warning to other biologists, field managers and local, state and federal governments on the possibilities that species are translocated between islands by still unknown reasons and actors. Constant monitoring of endemic species is needed on certain islands.

Recommendations

The only recommendation we make, derived from the analysis of results of the field survey, is that Pancha needs to be removed from Rasa Island. She should be relocated to Angel de la Guarda Island or to another satellite island where *Sauromalus hispidus* thrives, or should be maintained in captivity in any available facility interested in providing her with a good life under controlled conditions. These two possibilities must be evaluated further.

An additional suggestion, not derived from our objectives, but important for long-term conservation of the island biota as a whole, is that a temporal campaign to remove excess cholla cactus must be conducted, since the stems are apparently causing mortality in a great number of Heermann's gull and other seabirds that nest on the island. The expansion of cholla cactus was perhaps initiated by the disturbance caused by guano collectors in the nineteenth and twentieth centuries (Bowen, 2000, p. 122-140).

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