

Natal dispersal, home range and habitat use of hatchlings of the Mona Island iguana (*Cyclura cornuta stejnegeri*)

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Abstract. In the last two decades our knowledge of the biology of the highly threatened rock iguanas (*Cyclura*) has been expanding. However, most studies have focused on the adults and none has been conducted to document the biology of the younger stages. In some instances, such as the Mona Island iguana (*Cyclura cornuta stejnegeri*), the biology of young stages has been overlooked due to their low relative abundance in the population. The causes of this population trait remain unknown and their extent from the conservation perspective is important because the scarcity of young stages has been considered a symptom of a declining population. We used radio telemetry to document life history of Mona Island iguana hatchlings during the first five months of life. Hatchlings dispersed following specific individual bearings from 102 m to 5080 m from the releases sites. Hatchlings settled down in diverse habitats used or not used by adult iguanas. Once settled, hatchlings spent most of the time (63%) in trees or perch locations above the ground. We report a conservative survival rate of 22% during the study period and Minimum Convex Polygon home ranges that vary from 0 m² to 530 m² (mean = 297). Our results suggest that the low relative abundance of the juvenile stages in the population is caused both by high predation rates during their dispersal phase, and hatchling microhabitat selection which precludes their detection in population surveys.

Key words: *Cyclura*; hatchling biology; natal dispersal; survival.

Introduction

Dispersal is defined as the one-way movement of an animal from the place of birth to the place where it will reproduce (Howard, 1960). Dispersal is a critical factor in evolution, population dynamics, behavior and conservation (Krebs and Davies, 1993; Small et al., 1993). Among the factors motivating the dispersal of individuals are: competition (Tonkin and Plissner, 1991; Lambin, 1994; Gundersen and Andreassen, 1998), inbreeding depression and habitat quality (Dobson and Jones, 1985; Ruckeshaus et al., 1997). Most studies of animal dispersal have been conducted with birds (Giesen and Braun, 1993) and mammals (Krohne et al.,

1984; Harrison, 1992; Van Vuren and Armitage, 1994; Gundersen and Andreassen, 1998), whereas only a few have been conducted with reptiles (Clobert et al., 1994; Boudjemadi et al., 1999).

The rock iguana *Cyclura cornuta stejnegeri* is endemic to Mona Island, Puerto Rico and is currently listed as endangered by the IUCN (2006). The Mona Island iguana population has one of the lowest densities (0.96 iguanas/ha) reported for *Cyclura* iguanas and has a very low representation of mid-size iguanas (Wiewandt, 1977; Pérez-Buitrago and Sabat, 2000). These demographic traits contrast with other *Cyclura* populations that are characterized by higher densities (>60 iguanas/ha) (Goodman et al., 2005) and the presence of all size classes in their populations. It has been suggested that the low densities and the skewed demography of the Mona Island iguana population is a consequence of low juvenile survival that may cause low, and perhaps not self sustainable, levels of recruitment to adult stages (Wiewandt, 1977; Wiewandt and García, 2000). It is believed that the low abundance of young iguanas is due to threats imposed by several exotic animals (pigs, rats and cats) introduced to the island 400 years ago. Particularly, pigs reduce hatching success by consuming nests (Wiewandt, 1977; Wiewandt and García, 2000), and feral cats prey heavily on the youngest stages (Wiewandt, 1977; Iverson, 1978). Another stated hypothesis is that young stages use different habitats and/or microhabitats than adults, resulting in their omission in population surveys (Wiewandt, 1977). None of these hypotheses have been formally tested and thus, at present the biology of hatchlings remained unknown because after hatching in October they apparently “vanish” quickly from the population. To determine the fate of newborn Mona Island iguana hatchlings we used radio telemetry to document the dispersal phase, habitat preferences and survival of these individuals during their first five months of life.

Methods

Mona Island is located in the deep-sea channel between the Hispaniola and Puerto Rico. It is predominantly a limestone island and its perimeter is delimited by 45-60 m vertical cliffs. Along the southwest part of Mona, the cliffs demarcate two major habitats found in the island: a plateau, and the sandy coastal plain. The plateau habitat has been impacted very little by humans (Wadsworth and Gilormini, 1945) but a substantial proportion of the coastal plain vegetation on the western side of the island has been replaced with introduced *Casuarina equisetifolia* and *Swietenia mahogani* (Diaz, 1984; Cintrón and Rogers, 1991). Mona is classified in the subtropical dry forest life zone (Ewel and Whitmore, 1973).

The study was conducted from October 1998 to March of 1999. Ninety-eight hatchlings were collected from 11 nest chambers. At collection time, hatchlings did not show evidence of external yolk sacs and the umbilical scar was completely closed. The SVL (to 0.1 mm), tail length (to 0.1 mm) and body mass (to 1 g) of each hatchling were measured. From the collected hatchlings, 40 individuals were

selected and outfitted with 6 g collar radio transmitters (Model LF-1-357-RS-T, L.L. Electronics Company, Mahomet, IL) and the others were released at the collection place. Mean SVL of hatchlings used for radio-telemetry was 11.45 cm (SD = 0.39) and mean body mass was 78.25 g (SD = 3.39). Radio-collars weighed from 7.0-8.3% of total hatchling body mass, which is less than the maximum of 10% recommended for telemetry studies (Heyer et al., 1994). Radio marked hatchlings were released three days after they were collected. Two groups of 20 hatchlings were released, one group on the coastal plain nesting area where all hatchlings were collected, and the other group on the plateau environment (fig. 1). We chose these sites to determine the effect of the suitability of contrasting environments on the dispersal and survival of the Mona Island iguana hatchlings. The coastal plain release site is a known nesting area where all hatchlings were collected and it is located in a patch where native vegetation was replaced by the exotic tree *Casuarina equisetifolia*. Except during the nesting season in July, the *C. equisetifolia* plantation lacks adult iguanas (0 iguanas/ha), Pérez-Buitrago and Sabat (2000). The plateau re-

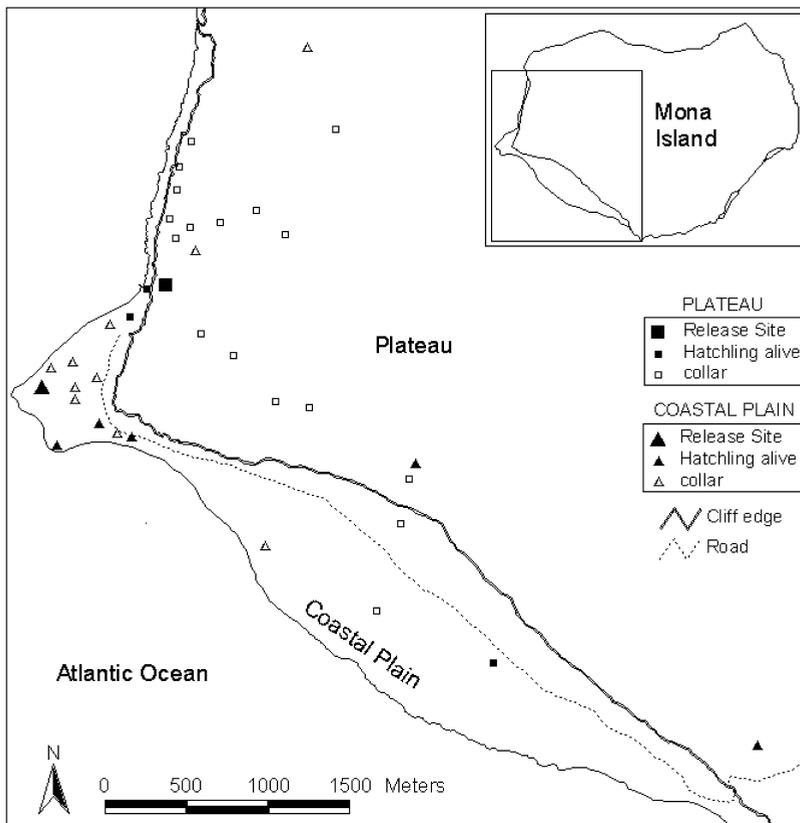


Figure 1. Map showing the coastal plain and plateau release sites and the last locations of 35 Mona Island iguana hatchlings (*Cyclura cornuta stejnegeri*) radio tracked from October 1998 to March 1999.

lease site is located in the “Plateau Forest” (Cintrón and Rogers, 1991) and has an adult density of 0.95 iguanas/ha (Pérez and Sabat, 2000).

Hatchling movements were recorded daily at the beginning, but soon afterwards some animals were tracked every two days because they were moving so fast that the monitored area had to be expanded making it difficult to track all hatchlings in a single day. We used a three-component Yagi antenna and receiver (L.L. Electronics Company, Model MNS-100, Mahomet, IL). At the beginning of the radio-telemetry monitoring, while the animals were dispersing rapidly, they were not detected visually to avoid disrupting their normal dispersal behavior. During this period, hatchling positions were established by triangulation by taking 3-4 bearings, and then mapped on 1:10 000 or 1:20 000 scale maps. When a signal of an individual was recurrently detected in the same area, a visual check was conducted to verify the condition of the animals (dead or alive). These locations were recorded with a GPS (Trimble Navigation) to calculate the dispersal distance traveled from the release point. We used the Rayleigh test (Batschlet, 1991) for testing the directionality of hatchling movements while dispersing.

Surviving hatchlings were used as focal animals to estimate home range area, and habitat selection of juveniles under natural conditions. Home range was estimated based on locations (no more than two recorded locations per day) obtained from multiple sightings of each animal. During each visit to the area where the animals settled, we recorded the location of the individual with a GPS, the height of the perch and time. The 100% Minimum Convex Polygon (MCP) procedure (Jennrich and Turner, 1969) was used to calculate home range size as implemented in the Animal Movement extension analysis in the ArcView v.3.2 (Hooge et al., 1999). The monitoring phase was performed for five months, the expected battery life of the radio-transmitters. After this period, the radio-collars of the surviving hatchlings were removed and the animals released.

Results

Our sample size was reduced substantially in the first week due to the signal loss of five individuals released in the coastal plain. Of the remaining 35 radios, 23 were recovered without animals attached between the second and the ninth week. All dispersal distances are reported making the distinction between hatchlings found alive or collars found alone. Home range and habitat use was documented for the eight animals that settled down in specific areas after dispersing and stayed alive long enough for collecting home range data.

Dispersal

Four of the 15 hatchlings released in the coastal plain moved to the plateau, whereas five of the 20 hatchlings released in the plateau moved to the coastal plain (fig. 1). Hatchlings released on the coastal plain dispersed from 160-5010 m (mean =

1033 m, SD = 1300) and these distances did not differ significantly from those of the hatchlings released on the plateau, which traveled from 102-3120 m (mean = 714 m, SD = 848) (Mann Whitney U -test = 139, $z = 0.713$, $p = 0.47$). Dispersal distances of hatchlings that survived the dispersal phase and settled varied from 102-5080 m (mean = 1556 m, SD = 1784) (fig. 1) and did not vary from the distances recorded when only the radio transmitters were found (mean = 874 m, SD = 1092), (Mann Whitney U -test = 92, $z = 0.76$, $p = 0.45$). On average, iguanas traveled around 250 m per day during the dispersal phase. Surviving iguanas ($n = 8$) traveled for 1-25 days (average = 6.9 days, SD = 8.3), apparently without stopping during a single day, before settling down in a specific location. There was no relationship between the initial SVL or body mass and the distance traveled by surviving hatchlings during the dispersal phase ($r = 0.27$, $n = 8$, $p = 0.502$; $r = 0.027$, $n = 8$, $p = 0.97$, respectively).

Since hatchlings were moving very fast and some of them settled down or lost their radios early after release, the Rayleigh test of directionality was only performed with data for six individuals that traveled more than 1.5 km from the release site, and for which the monitoring was not interrupted due to temporary failures in the tracking signal. For these six hatchlings, the Rayleigh test revealed that these animals were keeping a specific direction while dispersing (six hatchlings: all angle counts between 4-6, all angular concentration $R > 0.90$, all Rayleigh values $z > 3.87$ and all $p < 0.021$).

Survival rate

Eight hatchlings were found alive after the dispersal phase which lasted between two to five weeks. By the twentieth week, only four animals were still alive. Since most of the radios found without hatchlings probably fell off, it is difficult to make an accurate statement about survival rates. In only one case, a bone that matches the femur of another preserved hatchling was found close to the radio. However, fourteen radios (including the one found near to a femur bone) had major signs of structural damage that looked like teeth/beaks marks in the resin that covered the radio's electronic components. We believe that the damage could have been caused during a predation event, since none of the four radios recovered from surviving hatchlings showed that kind of damage. Assuming that the radios with physical damage reflected predatory events on the hatchlings, the survival rate was 0.22 at the end of the first 20 weeks of life.

Home-range and habitat use

Two of the surviving animals settled in the plateau forest, four in the coastal lowland forest, and two in the *Casuarina* plantation (following the vegetation types defined by Cintrón and Rogers, 1991). For all these animals, we recorded from 12-86 locations (mean = 54.7, SD = 24.8) per hatchling to calculate their home ranges. Home range sizes varied from 0 m² (from a hatchling that was visually recorded

Table 1. Body measurements and home range (Minimum Convex Polygon) of hatchlings of *Cyclura cornuta stejnegeri* that survived the dispersal period, settled down and established a home range.

Hatchling ID	Initial SVL (cm)	Initial body mass (g)	Release site	Distance traveled (m)	MCP home range (m ²)	No. of sightings
07-06	11.88	85	Coast	365	0 ¹	38
17-6	11.89	81	Coast	439	250.1	86
77-2	11.17	75	Coast	630	529.7	43
01-7	12.17	83	Coast	2430	307.2	71
67-7	11.95	91	Coast	5010	336.6	12
23-8	11.49	79	Plateau	102	280.6	73
65-5	11.19	74	Plateau	340	284.6	73
62-3	11.5	85	Plateau	3130	385.9	42
Mean	11.7	81.6		1556	296.8	54.8
SD	0.4	5.6		1784	148.6	24.8

¹ Hatchling never observed active (see results).

36 times in 15 weeks at exactly the same locality and in the same position on a *Casuarina equisetifolia* trunk) to 530 m² (mean = 297 m²; SD = 149) (table 1). There was no relationship between initial SVL or body mass and home range size ($r = -0.47$, $n = 8$, $p = 0.29$; $r = -0.3$, $n = 8$, $p = 0.72$, respectively).

Although perch locations of hatchlings that settled down and established a home range varied, individuals used some specific sites recurrently. In 63% (from 438 localities recorded for eight hatchlings) of the cases hatchlings were found resting in sinkholes, tree trunks, or among bromeliad leaves that varied in heights from 1.2-12 m. The other 37% of the sightings corresponded to hatchlings actively foraging, or walking on the ground.

Finally, body mass and SVL increase was minimal or absent for the four surviving hatchlings at the end of the study. After five months, three of these individuals had gain no weight (average = -1 g, SD = 2.6) and the SVL increase was only 0.4 cm (SD = 0.36). However, the fourth survival hatchling, which was recaptured 290 days after had been collected gained 119 g and increased its SVL by 4.11 cm.

Discussion

Despite our small sample size and the methodological problems faced, this is the first study documenting the dispersal, habitat use, and home range of any *Cyclura iguana* hatchlings. Even though telemetry techniques have improved in the last years, telemetry on *Cyclura iguanas* is technically difficult and no standardized reliable methodology that overcomes these challenges has yet been developed (see Goodman et al., in press). This situation still imposes some limitations for understanding different aspects of the biology of *Cyclura iguana* hatchlings. Alternative methods such as mark-recapture methodologies are difficult to implement in hatchlings because of the low recapture rates, the iguanas' cryptic coloration and the harsh

environmental conditions where *Cyclura* species occur. For example, we intended to perform a mark-recapture study in 2003 and 2004 in which 158 Mona Island iguana hatchlings were pit-tagged and kept in captivity for a month (i.e. to prevent natal dispersal) before their release in a frequently surveyed area. At present, only one individual has been recaptured twice after spending more than eight months within the area over a period of three years. This shows that the mark-recapture techniques are not an effort-effective method for studying *Cyclura* iguana hatchlings; and alternative methodologies such as radio telemetry must be employed to study their biology and ecology.

Dispersal and survival

We found that Mona Island iguana hatchlings can disperse long distances. The highest recorded distance (5080 m) represents half of the east-west axis extent of Mona Island. Different studies have suggested that long distance dispersal may prevent genetic differentiation among subpopulations (Stacey et al., 1997). In fact, preliminary data indicates no genetic differentiation for the Mona iguana (Malone, pers. comm.). Similar results were obtained on *Iguana iguana* living in Barro Colorado Island where hatchlings disperse distances up to 1750 m from the nesting site (Bock, 1984). These distances were suggested to be enough to enhance gene flow among adjacent localities (Bock, 1984).

Our survival rate estimate should be taken with caution because of the methodological problems that were encountered. Nevertheless, a conservative estimate (assuming that radio transmitters with physical damage found without iguanas are evidence of predation events) is that 22% of the hatchlings survived the first 20 weeks of life. This estimate is in accordance with Wiewandt's (1977) suggestion that predation causes high mortality in the early stages of the Mona Island iguana. The native predator community of Mona Island is composed of two snakes (*Alsophis sp.* and *Epicrates sp.*) and two raptors (*Falco sp.*). Members of these genera have been reported as predators of *Cyclura* hatchlings (Levering and Perry, 2003; Knapp and Owens, 2004, respectively). In addition, it has been documented that feral cats also prey on hatchling iguanas (in 2003 three Mona Island iguana hatchlings were found in single wildcat stomach; unpublished data) and it is well known that cats can have dramatic negative impacts on island faunas in general (Vitousek, 1988), and specifically in small size classes of *Cyclura* populations (Iverson, 1978).

Our survival estimate is low when compared to published survival rates of other iguana species. Island populations of *Cyclura carinata* in Little Water Cay in Turks and Caicos Islands had a survival rate of 0.55 during the first three years of life (Iverson, 1977). Mainland populations of *Iguana iguana* in Colombia experience a survival rate of 0.15 during the first six months of life (Harris, 1982). In addition, survival rate of mainland populations of *Ctenosaura similis* in Costa Rica can range from 0.25 to 0.3 during the first year of life (Van Devender, 1982). In general, one would expect higher survival rates in island iguanas compared to mainland iguanas based on their contrasting life history strategies (i.e. egg number per nest, growth

rates and age at sexual maturity) (Andrews, 1976; Case, 1982). Nevertheless, the survival rate of Mona Island iguana hatchlings is closer to those of mainland species, although the species' life history traits are very different. This low rate of survival may result in low recruitment into adult stages, explaining the current age-biased population of the Mona Island iguana. However, other factors such as the arboreal habits of hatchling iguanas may also account for the apparently skewed population structure (see below).

Home-range and habitat use

In general, there is a positive relationship between home range size and body mass in lizards as a consequence of the differences in food requirements related to size (Christian and Waldschmidt, 1984). However, we failed to find a significant relationship between hatchling mass and home range size. An explanation could be the small differences in body mass among the hatchlings (Christian and Waldschmidt, 1984). Another factor that could have obscured this relationship in the present study is that body mass did not correspond to body mass during occupancy of their home ranges, but rather their original pre-dispersal body mass. However, and as expected, hatchling home ranges are much smaller than those recorded for adults which average 0.46 ha for both sexes (Pérez-Buitrago et al., 2007).

It has been proposed that the low apparent abundance of juveniles in the population may be due to microhabitat selection, which could differ from that of adult iguanas (Wiewandt, 1977). Our data partially supports this hypothesis since hatchlings are mostly arboreal, spending most of the time in locations above the ground. This contrasts with the predominant terrestrial habits of adult iguanas (Wiewandt, 1977; Pérez-Buitrago and Sabat, 2000). Wiewandt (1977) also suggested that the relative low abundance of juveniles could be a consequence of young iguanas occupying areas that were not surveyed during his research, for example environments associated with the cliffs that separate the coastal plain and the plateau environments. From the eight individuals in our study that survived the dispersal phase and settled down, only two did so in the cliff environment, another three apparently did not reach the cliffs, and the remaining three crossed the cliffs to settle down far away from them (fig. 1). Thus, our data suggest that no habitat specific preferences are exhibited by hatchlings after ending the dispersal phase. Since all major Mona Island habitats have been systematically surveyed (Pérez-Buitrago and Sabat, 2000), the lack of this life stage in the population may then partially be explained by the microhabitats (i.e. arboreal) used by hatchlings, together with their cryptic coloration that makes it difficult to detect them while conducting population surveys.

Management implications

The long distance dispersal of hatchlings we measured may have management implications for headstart (HST) programs. Releases conducted as part of the

ongoing Mona HST program started in 1999 by the Department of Natural and Environmental Resources of Puerto Rico have been done on the nesting areas where the hatchlings were originally collected. A major reason to perform the HST releases in these sites was not to disrupt the genetic structure of the population. However, the fact that Mona Island iguana hatchlings are able to disperse up to 5 km on an island that is only 5×11 km in size provides strong evidence that no genetic differentiation among different Mona localities exists. If true, sites for HST releases could be selected by more practical criteria such as the feasibility of monitoring the destiny of HST released iguanas and the certainty of the suitability of the release sites for iguanas to live.

Particularly on Mona Island, the HST program has released captive raised iguanas in the areas where they were collected, but in many instances those areas are located in very highly human-impacted zones in which the native vegetation was replaced with exotic tree species and where no iguanas live year-around (Pérez-Buitrago and Sabat, 2000). Recent results of radio tracking of HST iguanas released in these zones showed that after release they moved across larger areas than adult and wild mid-size Mona Island iguanas (García et al., 2007). In addition, HST iguanas moved in erratic paths until they “escaped” from these unsuitable areas before settling down in contrast to well-defined bearing routes followed by hatchlings in this study.

On the other hand, the little evidence of nesting by HST Mona Island iguanas in the wild indicates that they did not return to the nesting place where they were originally collected as hatchlings or to the same place where they were released after being grown in captivity. This implies that HST iguanas lost their capability to return to their birth and/or release site and thus they were no longer imprinted to their birth/release place as occurs in other taxa such as marine turtles (Freedberg et al., 2005).

Finally, all previous population surveys of the Mona Island iguana have found a very low relative abundance of the young stages. Our data concerning the arboreal microhabitats of hatchlings imply that they can be easily overlooked in population surveys and thus the under-representation of this stage may be a methodological artifact. The unknown extent of this bias, coupled with the low survival rate reported here, means that the implications for conservation are not completely clear. Nevertheless, in 2003-2004 more than 150 Mona Island iguana hatchlings were pit-tagged and released after a month in captivity, and the ongoing research program may provide evidence whether their apparent disappearance from the population is real, or due to low probability of detection.

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