A SURVEY OF THE NUTRIENT CONTENT AND INTAKE OF THE DRY SEASON DIET CONSUMED BY CAPTIVE GRAND CAYMAN IGUANAS (*CYCLURA LEWISI*)

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Abstract

Nutrient concentrations were determined in foods consumed by both free ranging and captive Grand Cayman iguanas (*Cyclura lewisi*). Plant collection and nutrient intake was measured during the dry season, when mating is known to occur. Fourteen species of plants known to be consumed by free ranging iguanas, or thought to be historically consumed when their distribution was not limited, were collected and analyzed. The plant parts were separated and categorized for analysis as flowers, fruits, or leaves. Mean nutrient concentrations and standard errors (SEM), on a dry matter basis (DMB), included protein (CP) 13.39% ± 1.28, acid detergent fiber (ADF) 25.12% ± 2.23, neutral detergent fiber (NDF) 37.23% ± 2.35, and crude fat (FAT) 3.82% ± 0.39. Nutrient concentrations were analyzed in diets offered and consumed by captive iguanas held for breeding at a headstart facility on Grand Cayman. Captive diets were comprised of plants collected on the island, and known to be consumed by free ranging iguanas. Diets consumed by a pair of adults and a pair of sexually mature juveniles respectively were 8.69 and 11.05% CP, 29.92 and 34.61 % ADF, 38.50 and 44.35% NDF, and 4.11 and 3.79% FAT. The adult pair consumed a lower protein level than that available in plants during the dry season. These captive consumption levels were low compared to those of juvenile headstart Jamaican (*Cyclura collie*) and Anegada (*Cyclura pinguis*) animals and more similar to adult Jamaican iguanas held in US zoos although dry matter intake (DMI g/d/kg body mass) and CP (g/d/kg/body mass) were the lowest for adult Grand Cayman iguanas.

Introduction

The critically endangered Grand Cayman iguana (*Cyclura lewisi*) exhibits poor reproductive performance (25% success rate) in captivity in the U.S. as compared to iguanas in a captive facility on Grand Cayman. The West Indian iguanas, particularly *Cyclura* spp, are considered the most critically endangered group of lizards in the world.[2,9] The Grand Cayman iguana specifically, has population estimates of only 10-25 animals in the wild. Extensive conservation and recovery efforts are underway with numerous *Cyclura* species. Key recovery activities include the reintroduction of head-started individuals and the expansion of the populations through captive reproduction.[15] Despite intensive captive breeding efforts for nearly 10 years, successful reproduction of these species has been inconsistent.[15] For the Grand Cayman iguana in U.S. zoos, 28 breeding attempts with 5 pairs over 6 years have resulted in 7 clutches at 2 institutions—a 25% success rate. Furthermore, 3 of these clutches have resulted in at least partial embryo death or significant immediate post-hatching mortality. Conversely, the Grand Cayman *in situ* headstart facility has successfully produced young 13 out of 14 years, with extremely low post-hatch mortality (less than 1% for the past two years).

Nutrient deficiencies of vitamins, minerals, protein and energy have been documented to impact reproductive success in a variety of species,[11,12,17,18,19,20,21] and the health and viability of hatchlings is dependent on the status of the reproductive female. Unfortunately, few studies exist that measure the effects of nutrient deficiencies/toxicities on the reproductive success of reptile species, including iguanas. Insufficient protein and energy affect reproduction. A protein deficiency is often difficult to separate from an energy deficiency due to the decrease in dietary intake limiting energy intake. A decreased food intake, resulting in an energy deficiency, has a significant affect on reproduction. In mammals challenged energetically, calories consumed are prioritized to basic functions including, cellular functions, locomotion for foraging and thermoregulation. Less critical functions may include growth, body fat stores and reproduction. Inadequate energy intake affects not only the production of ova and hormones,[20] but also reproductive behavior and estrous.[24]

Scientists and captive managers have speculated that the poor captive reproduction of West Indian iguanas is due to inadequate nutrition and environmental conditions.[8,13,16,26,27] Despite their potential importance these variables have yet to be quantified in captive Grand Cayman iguanas. The most in depth information currently available on iguana diets is for the green iguana (*Iguana iguana*). Recommendations for dietary nutrient levels that would support growth, maintenance and reproduction in green iguanas have been made.[3] Data are also available on the diets consumed by captive and free-ranging Jamaican iguanas (*Cyclura collei*),[26,27] Anegada iguanas (*Cyclura pinguis*)[25], and green iguanas (*Iguana iguana*).[4,23] The purpose of this study was to begin an evaluation of the nutrient content of foods consumed by free-ranging and captive Grand Cayman iguanas during the dry season, when mating occurs.

Methods

Fourteen species of plants, consumed by free-ranging iguanas and fed to captive headstarted iguanas in Grand Cayman, were collected during the dry season. Plants were separated and categorized for analyses as flowers, fruits, or leaves. Seeds appeared to pass through the gastrointestinal tract undigested as evidenced by their appearance in scat samples. In some plants, seeds were so small and abundant that their removal would have resulted in too little fruit for analysis. For those fruits, seeds were included in the analysis.

Two breeding pairs of iguanas, divided into 2 outdoor enclosures were subjected to a 4-day intake study. The pairs were chosen due to their history of successful breeding, an adult pair (ages 11 and 20 years) and a reproductively mature juvenile pair (ages 3 and 4 years). The intake study was a quantification of current feeding practices. Iguanas were fed whole plants and/or plant parts of 3 to 8 species collected the previous afternoon. Morning glory leaves (*Ipomoea pes-caprae*), scaevola leaves *(Scaevola seriacea),* common purselane whole plant (*Portulaca oleracea*), shoreline seapurselane whole plant (*Sesuvium portulacastrum*), graceful sandmat whole plant (*Chamaescyce hypericifolia*), coastal beach sandmat whole plant (*C. mesembrianthemifolia*), yellow root leaves (*Morinda royoc*), ganges primrose whole plant (*Asystasia gangetica*), Asian pigeonwings leaves and vine (*Clitoria ternatea*), and Indian mulberry fruit (*Morinda citrifolia*) were fed.[22] The plant species and amount offered to each enclosure was weighed and recorded. A representative sample of each plant was collected once at the sites frequently harvested. After a 24-hour period, food remaining in each enclosure was collected and contamination from dirt and sand was removed. Food always remained at the end of each feeding period. Samples were immediately ground, subsampled and dried prior to analysis. Plant parts, samples of diets offered, and orts were analyzed for dry matter (DM), crude protein (CP), acid detergent fiber (ADF), neutral detergent fiber (NDF), and crude fat (FAT) by wet chemistry methods through a commercial laboratory (DHI Forage Testing Laboratory, 730 Warren Rd., Ithaca, NY 14850).

Results and Discussion

Plant Analysis

Table 1 designates the mean DM and nutrient content of plants consumed by free-ranging Grand Cayman iguanas in comparison with data from Anegada iguanas,[25] Jamaican iguanas[26,27] and green iguanas.[4] Means represent all plant parts consumed. SEM for all nutrients were high with many values overlapping making comparisons difficult. Concentrations of CP consumed by Grand Cayman iguanas were similar to those consumed by free-ranging Jamaican. Plants consumed by free-ranging green iguanas were considerably higher in CP concentration than those consumed by the other species presented. ADF, NDF and FAT concentrations consumed by Grand Cayman iguanas were similar to those consumed by free-ranging Jamaican, Anegada and green iguanas.

Restriction to areas unsuitable for agriculture development may limit Grand Cayman iguanas to less than optimal diets or protein content. The average analyzed CP of plants was similar to the CP concentrations (13%-14%) that resulted in poor growth in captive green iguanas.[10,14] Consumption of animal matter by green iguanas is only documented by isolated observations, or incidentally, as summarized by Baer.[6] The Caicos ground iguana (*Cyclura carinata*) ingests animal material deliberately, though at a very low level (4% of diet), as estimated from examination of stomach contents.[5] Similarly, the Grand Cayman iguana may use limited consumption of animal material, either deliberately or incidentally, as a method of supplementing an herbivorous, low protein diet. Although nutrient content was similar to Jamaican and Anegada plants, those iguanas, as well, may not consume optimal diets during the dry season. While data are lacking, it is possible a better plane of nutrition may be achieved during the wet season.

Headstart Facility Intake Study

Diets fed in Grand Cayman in April 2005 consisted completely of native and introduced plants. All other diet analysis for *Cylcura* to date have included diets ranging from mostly commercial produce and dry nutritionally complete feeds (Jamaican headstart facility, zoos)[26,27] to a combination of commercial produce, dry nutritionally complete feeds and native plants (Anegada headstart facility).[25] Iguanas were considered adults if they were greater than 5.5 years of age and juveniles if less than 5.5 but more than 2 years of age.

Nutrient content of the diets offered and consumed as a percent of DM are presented in Tables 2 and 3 for Grand Cayman adult and juvenile iguanas, respectively. Body measurements, dry matter intake (DMI) in grams per day per kilogram body mass (DMI g/d/kg BM), DMI as a percent of body mass per day (DMI %BM/d), and nutrient intakes (g/d/kg BM) for CP, ADF, NDF, and FAT are presented in Tables 4 and 5 for adult and juvenile iguanas, respectively. One day of intake for the juvenile pair was eliminated as a result of possible unrepresentative plant collection or contamination of samples for that day.

Each of the Tables 2 through 5 include comparisons to previous published data for *Cyclura* species. Diets varied between species/studies as well as number of days on study. Number of animals varied per enclosure, as indicated. For all studies, SEM tended to be high. Consequently, it is difficult to draw concrete conclusions from these comparisons. Although collected during different years, data for all species were collected in April-June.

Grand Cayman adults consumed lower CP than that available in the diet offered (Table 2); while ADF, NDF and FAT consumed were all similar to that offered. The CP concentration in diets consumed by the Grand Cayman adults was also lower than that consumed by Jamaican adults.

Grand Cayman juveniles consumed all nutrients measured at similar concentrations to that offered (Table 3). Grand Cayman juveniles consumed lower CP and higher ADF and NDF as compared to other species. FAT consumed appeared similar amongst juveniles of all species, however the values were highly variable.

The Grand Cayman iguana is considered one of the largest *Cyclura* species. Due to low numbers in the wild and captivity, incomplete data exists on weight ranges. Mean body mass of the headstart adult Grand Cayman iguanas exceeded those reported for Jamaican iguanas (Table 4). Likewise, juvenile headstart Grand Cayman iguanas had greater body mass than Jamaican and Anegada iguanas (Table 5).[25,27]

There was considerable variation in intakes for each pair of Grand Cayman iguanas over the 4-day measuring period. With a few exceptions, DMI and nutrient intakes for both adult and juvenile Grand Cayman iguanas (Table 4 and 5, respectively) had considerable variation and overlap. While DMI (both g/d/kg BM and %BM/d) for Grand Cayman adults was similar to that of Jamaican adults, the Grand Cayman adults consumed approximately half as much CP, due to the lower concentration of CP in the diet consumed. The variation of intakes, both published and measured, makes it difficult to draw any concrete conclusions from much of this data. However, this was a pilot study, and as more data is collected the picture should become clearer.

Most notable in this study, the CP consumed (% of dry diet, g/d/kg BM) by both the adult and juvenile pair was lower than reported for other *Cyclura* species. These levels were also below published recommendations for sub-adult green iguanas (22% CP) and non-reproductive adults (15-17% CP).[3] Additionally, CP consumed by both pairs was lower than concentrations of CP (13%-14%) which resulted in poor growth in captive green iguanas.[10,14] Although intake data for Grand Cayman adults was similar to intake reported for growing green iguanas, the green iguanas were fed a more nutrient dense diet (100% dry nutritionally complete feed approximately 30% CP, 20% ADF and 27% NDF). This more nutrient dense diet would have facilitated growth at this level of DMI for the green iguanas.[7]

Nutrient intakes for the Grand Cayman iguanas were measured in April. Both pairs laid eggs in June all of which successfully hatched. Subjective observation by the animal caretakers up until lay, noted that intakes for males and females remained similar or lower than those measured in April. Following lay, all animals significantly increased intake.[1] Free ranging green iguanas in Curacao, consume more energy during the wet season which supports body stores to be utilized in the dry season for egg production in females or increased locomotion in breeding males.[23] It is speculated *Cyclura* also significantly increase body stores during the wet season to facilitate energy expended in the dry season for egg production/mating. However, nutrient intakes and body weights have not yet been measured during the wet/nonmating season.

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Table 1. Comparison of mean nutrient concentrations of plants consumed by free-ranging Grand Cayman iguanas (*Cyclura lewisi*), Anegada iguanas (*Cyclura pinguis*), Jamaican iguanas (*Cyclura collei*) and free-ranging green iguanas (*Iguana iguana*).[a]

Nutrient	Grand Cayman	Anegada[b]	Jamaican[c]	Green[d]
DM %	20.43±2.29	40.85±3.15%	44.78±6.71%	16.50±1.98%
CP %	13.39±1.28	9.61±0.85%	10.68±1.66%	22.63±5.61%
ADF %	25.12±2.23	29.17±2.30%	34.27±5.70%	26.95±5.83%
NDF %	37.23±2.35	37.48±3.07%	37.48±5.10%	45.15±4.92%
FAT %	3.82±0.39	4.87±0.81%	Not Available	5.35±1.39%

[a]Means of all plant parts, values expressed on a dry matter basis as mean ± SEM.
[b]Values from Ward et al. 2003.
[c]Values from Ward et al. 1999.
[d]Values from Allen et al. 1989.

Table 2. Mean nutrient concentration of diets offered and consumed by captive, adult Grand Cayman iguanas (*Cyclura lewisi*) compared to nutrient concentrations of diets consumed by captive, adult Jamaican iguanas (*Cyclura collie*).[a,b]

Nutrient	Grand Cayman		Jamaican	Jamaican
	Headstart		Indianapolis Zoo[c]	Fort Worth Zoo[c]
	1 enclosure/2 animals		1/3	2/4
	Offered	Consumed	Consumed	Consumed
CP %	12.61±1.88	8.69±2.40	21.38±2.62	25.11±4.98
ADF %	27.36±1.24	29.92±0.67	19.81±2.77	20.09±3.47
NDF %	38.97±1.24	38.50±4.67	24.44±3.07	19.66±3.15
FAT %	3.92±0.35	4.11±0.75	3.30±0.68	2.29±0.63

[a]Values expressed on a dry matter basis as mean ± SEM.
[b]Mean dry matter (DM) content of diets offered was 16.58 ± 0.40% for Grand Cayman adults, 12.11 ± 0.01% for Indianapolis Zoo and 11.01 ± 0.01% for Fort Worth Zoo Jamaican adults.
[c]Data from Ward et al. 2001; corrected.

Table 3. Mean nutrient concentration of diets offered and consumed by captive, juvenile Grand Cayman iguanas (*Cyclura lewisi*) compared to nutrient concentrations of diets consumed by captive, juvenile Jamaican iguanas (*Cyclura collie*) and Anegada iguanas (*Cyclura pinguis*).[a,b]

Nutrient	Grand Cayman		Jamaican	Jamaican	Jamaican	Anegada
	Headstart		Headstart[c]	Sedgwick County Zoo[d]	San Diego Zoo/CRES[d]	Headstart[e]
	1 enclosure/2 animals		4/34	1/1	3/6	2/9
	Offered	Consumed	Consumed	Consumed	Consumed	Consumed
CP %	12.80± .78	11.05±1.74	17.45±0.28	16.23±1.79	23.26±2.48	19.67±3.26
ADF %	28.18± .99	34.61±5.08	15.10±0.34	24.39±2.81	11.80±2.70	26.60±11.82
NDF %	39.89±1.71	44.35±3.79	20.86±0.94	26.73±2.49	15.52±3.60	27.33±12.38
FAT %	4.04±0.40	3.79±1.21	Not Available	2.79±0.41	4.26±2.07	3.24±1.59

[a]Values expressed on a dry matter basis as mean $\pm$ SEM.
[b]Mean dry matter (DM) content of diets offered was 16.55 ± 0.69% for Grand Cayman juveniles, 14.85 $\pm$ 0.05% for Jamaican headstart, 20.38 ± 0.01% for Sedgwick County Zoo, 12.67 $\pm$ 0.02% for San Diego Zoo/CRES, and 16.30 $\pm$ 0.04% for Anegada headstart juveniles.
[c]Data from Ward et al. 1999.
[d]Data from Ward et al. 2001; corrected.
[e]Data from Ward et al. 2003.

Table 4. Comparison of body measurements, dry matter intakes (DMI) and nutrient intakes for 2 species of captive, adult West Indian Iguanas: Grand Cayman (*Cyclura lewisi*) and Jamaica (*Cyclura collei*).[a]

Measurement	Grand Cayman	Jamaican	Jamaican
	Headstart	Indianapolis Zoo[b]	Fort Worth Zoo[b]
Number of enclosures/animals	1/2	1/3	2/4
Age Range (years)	11 - 20	5.5 – 6.5	5.5 – 6.5
BM (kg)	3.68 ± 0.04	2.15 ± 0.64	2.61 ± 0.63
DMI (g/d/kg BM)	5.01 ± 1.66	5.00 ± 0.55	3.97 ± 1.02
DMI (%BM/d)	0.50 ± 0.17	0.50 ± 0.06	0.40 ± 0.10
CP (g/d/kg BM)	0.48 ± 0.20	1.05 ± 0.55	0.95 ± 0.26
ADF (g/d/kg BM)	1.51 ± 0.52	0.97 ± 0.13	0.73 ± 0.15
NDF (g/d/kg BM)	1.98 ± 0.73	1.19 ± 0.12	0.79 ± 0.25
FAT (g/d/kg BM)	0.22 ± 0.09	0.16 ± 0.03	0.08 ± 0.03

[a]Values expressed on a dry matter basis as mean ± SEM.
[b]Data from Ward et al. 2001; corrected.

Table 5. Comparison of body measurements, dry matter intakes (DMI) and nutrient intakes for 3 species of captive, juvenile West Indian Iguanas: Grand Cayman (*Cyclura lewisi*), Anegada (*Cyclura pinguis*), and Jamaica (*Cyclura collei*).[a]

Measurement	Grand Cayman	Jamaican	Jamaican	Jamaican	Anegada
	Headstart	Headstart[b]	Sedgwick County Zoo[c]	San Diego Zoo/CRES[c]	Headstart[d]
Number of enclosures/animals	1/2	4/34	1/1	3/6	2/9
Age Range (years)	3 - 4	2 - 5	4.5[e]	4.0[e]	4 - 5
BM (kg)	1.11 ± 0.74	0.93 ± 0.18	1.01	0.77 ± 0.12	0.82 ± 0.25
DMI (g/d/kg BM)	9.36 ± 1.54	26.15±15.15	11.81 ± 1.37	8.46 ± 2.48	22.91±12.87
DMI (%BM/d)	0.94 ± 0.15	2.62 ± 1.52	1.18 ± 0.14	0.85 ± 0.23	2.29 ± 1.29
CP (g/d/kg BM)	1.04 ± 0.28	0.91 ± 0.41	1.88 ± 0.20	1.99 ± 0.67	3.26 ± 1.50
ADF (g/d/kg BM)	3.15 ± 0.36	0.93 ± 0.28	2.84 ±0.39	0.90 ± 0.17	4.94 ± 2.77
NDF (g/d/kg BM)	4.08 ± 0.39	1.12 ± 0.29	3.14 ± 0.45	1.17 ± 0.20	5.09 ± 3.01
FAT (g/d/kg BM)	0.38 ± 0.16	Not Available	0.33 ± 0.06	0.41 ± 0.27	0.57 ± 0.48

[a]Values expressed on a dry matter basis as mean ± SEM.
[b]Data from Ward et al. 1999.
[c]Data from Ward et al. 2001; corrected.
[d]Data from Ward et al. 2003.
[e]All animals in the group had the same hatch date.