Chapter 7

Herbivory by Lizards

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Additional information is available at the end of the chapter

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Abstract

The extent of herbivory in lizards is influenced by several factors. Plant tissues are more difficult to digest than invertebrates due to the presence of cellulose. Thus, so many lizards exhibit carnivorous diet. Nevertheless, some species consume vegetables. Essentially herbivorous diet occurs in about 3% of lizards, while most omnivores add plants in their diets. Omnivorous species tend to eat more fruits, flower, and nectar, because they are easier to digest and provide more nutrients than leaves, which are rich in cellulose. The main factors influencing the consumption of plant material are related to the habitat of the species. Insular and arid environments favor the consumption of plants because such locations have low amount of arthropods available and present water scarcity. It is also possible to observe ontogenetic changes in the lizard's diet, in such a way that young individuals consume only invertebrates, whereas the adults supplement their diet with plant material. When consuming fruits and nectar, lizards become potential dispersers and pollinators. In this sense, some studies have already corroborated seed dispersal and pollination events by lizards. In islands where other species are absent, these interactions are essential for the maintenance of communities.

Keywords: herbivory, lizard ecology, ontogenetic, seed dispersion, diet, omnivory

1. Introduction

Due to lower consumption of vegetables by lizards, often the groups are overlooked in studies that discuss herbivory. However, it is important to discuss this matter in order to obtain a better understanding with regard to lizards/plant interaction, inasmuch as there are determinants physiological characteristics for the occurrence or absence of such interaction. Considering that the plants compose the diet of lizards, it is worth emphasizing the ecological importance of this relationship, which composes the trophic chain.

A few species of living lizards currently present are essentially herbivores, especially when compared with the extensive fauna of herbivorous reptiles of the Mesozoic [1]. Regarding diet, most lizards consume small animals and rarely plant material. On the other hand, there are omnivores species and some exclusively herbivores [2]. Accordingly, many factors can influence the consumption of plants, such as seasonal availability of food items, digestibility, and components from the consumed plants [3].

The nutrient assimilation capacity in herbivores is less than in omnivores, while such capacity is lesser in omnivores than in carnivores [1]. The low nutrient assimilation capacity in lizards reduces growth rates and reproductive capability, causing a reduction in egg production by females [2, 4]. Thus, the consumption of plants can make them more susceptible to predation, influencing in the adaptive radiation of the species.

2. Vegetables in composition of the lizard's diet

An herbivorous diet requires adaptations, physiological or behavioral, for the digestion of cellulose. Such adaptations may be: specialized dentition, elongated intestines, colic valves, intestinal flora, and thermoregulation to maintain high body temperature [5], inasmuch as gut fermentation, which is necessary for plant digestion, requires prolonged periods of high body temperature [6]. Every part that makes up a plant requires different adaptations for digestion because the parts vary significantly in their structure and composition. Leaves and stems are more difficult to digest than nectar, pollen, flowers, and fruits, due to the greater amount of cellulose present.

The consumption of plant material by lizards is less frequent than in other groups, such as mammals and birds. Many species consume vegetables, but they are considered omnivorous (capable of metabolizing different food items) and the majority of their diet is composed of small animals, consisting essentially of arthropods. Less than 3% of lizard species are considered essentially herbivorous [1, 2, 4, 7]. Lizards are considered strictly herbivorous only if more than 90% of its diet is composed of plant materials [3]. The ectothermy[1] is one of the reasons for the lower consumption of vegetables by the lizards, compared to mammals and birds, insofar as the temperature variations according to the environment difficult digestion of these materials. For the occurrence of the digestion of plant material, a long time of thermoregulation is necessary, because at low temperatures the absorption of nutrients is compromised, reducing the energetic efficiency. On the other hand, a long exposure time for thermoregulation increases the risk of predation. As an example, it can be cited that the lizard *Dipsosaurus dorsalis* (Baird and Girard, 1852), a herbivorous lizard from the desert, maintains higher temperatures than other iguanids insectivorous lizards and is active for a long period of the day [8].

Regarding this issue, for some species, to increase the body temperature is not the main mechanism used for digestion of plant material. The lizard *Cnemidophorus murinus* (Laurenti,

[1] An ectothermic animal vary its body temperature according to the ambient temperature but control this variation by behavioral methods. For example, the lizards remain exposed to the sun in the morning, and they hide from the sun during the rest of the day in order to prevent overheating.

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1768) keeps the body temperature similar to other teiids lizards but it remains active much longer to facilitate the digestion of plant [9], in that way the body temperature is maintained constant at about 37°C, predominantly during the day [6].

Since plant tissues are more difficult to digest than animal tissue, lizards require mechanisms that facilitate the digestion. Moreover, birds and mammals that are exclusively herbivores have high energy efficiency due to temperature maintenance and digestive symbiotic associations [4].

Then, it raises the following question: what are the factors that allow some species of lizards feed on plants and not others? The first studies that have sought to elucidate this query, consider the size of the animal as decisive in choosing the type of diet. Theoretically, harder items need greater strength and efficiency in chewing, and to have a larger and more robust head, allowing a stronger bite [10]. Campos, in a work about the lizards of *Microlophus* genus, found differences in cranial morphology associated with their diet: species that consume plant material have larger and wider skulls than the insectivorous ones. In this sense, large lizards could employ greater strength in their jaws, producing a better grinding of the food. For a time, it was assumed that only large lizards would be able to reduce plant material into digestible portions [7]. Several recent studies have shown that smaller species are able to consume plant material. Nevertheless, the adaptations which allow these species consume plants are lesser known [5].

Besides the initial process of tissues breaking by chewing, for digestion of more resistant materials, it is necessary a more elongated digestive tract and, the presence of symbiotic relationships. More elongated intestines, as well as chewing ability, are related to the body size of the animal. It is known that most herbivorous lizards belong to Iguanidae family. This is one of the few groups of lizards known which have expertise to digest plant material. The iguana intestine contains colic valves in order to increase the area of absorption and residence time of food in the intestines as well as intestinal flora suitable for cellulose degradation [3].

In a manner contrary to the trend related to body size, *Liolaemus lutzae* (Mertens, 1938), a species of small size, consumes large amounts of plant material, presenting evidence of capacity to cut leaves to consume them [11]. The same author concluded that the consumption of leaves by the species does not occur indiscriminately, inasmuch as the most common plant species in the stomach contents are less frequent in the studied area, suggesting that there is selection of the items to be consumed by their qualitative properties: amount of cellulose, sugars, fibers, tannins, and other components of the plant.

Omnivores Lizards, which include plant materials in their diets, tend to consume the softer parts of the plant, such as flowers and fruits containing large amounts of lipids, carbohydrates, sugar, and protein [12].

The selection of certain plant parts is also observed in other species, such as *Tropidurus torquatus* (Wied-Neuwied, 1820), species of omnivorous diet which also consumes plant material, tends to consume fruits, since they have a good digestibility [13]. Similarly, *Tupinambis teguixin* (Linnaeus, 1758) in a population of eastern Chaco, Argentina, presented plant material as its main diet composition (over 60%), in which most were fruits [14], even though it is a species of large size. Therefore, there is not an only factor, but a set of factors that influence the herbivory in the lizards.

Leiocephalus carinatus (Gray, 1827), another omnivorous species, has on your diet 47% of plant material. Kircher *et al.* [15] reported the use of *Ipomoea pes-caprae* flowers by adults of the species, in the Cayman Islands, Cuba.

2.1. Food preference in herbivorous and omnivorous lizards

Omnivorous species, as well as the herbivorous ones, can select parts of plants rich in nutrients and low cellulose content to consume, according to their physiological demand or digestive adaptations. Lizards that consume plant material in small quantities, or that do it occasionally, choose parts easier to digest or that which do not require specific adaptations to digestion. Lizards of omnivorous diet consume fruits and flowers intentionally when their preys are scarce. Conversely, the consumption of fragments of plant material by carnivorous animals occurs accidentally [3].

Some lizard species have food preferences according to the presence or absence of certain components. *Dicrodon guttulatum* (Duméril and Bibron, 1839), from Teiidae family, prefers the *Prosopis pallida* tree. Velásquez *et al.* [16], examining the *D. guttulatum* diet, in the *P. pallida* absence, found predominantly leaves of *Acacia* sp. and fruits from *Scutia spicata* and *Capparis* sp. In a study carried out by Leeuwen et al. [5] about the diet of the same lizard species in an environment with *P. pallida*, it was detected mainly this plant species in stomach contents and rarely other plants, even if they were available in the environment.

The presence of water in the fruit is also an important factor for consumption. Figueira et al. [17], investigating the interaction between *T. torquatus* with *Melocactus violaceus* (Cactaceae) reported the consumption of fruits always that they were available. These fruits have elevated water content and low sugar levels, indicating that the plant can be important to supply the need for water.

Although less frequent, some studies have looked for to understand how the lizards detect or choose vegetables to be consumed. Vasconcellos-Neto et al. [18], using models of artificial fruit, concluded that *T. torquatus* consume fruits that have higher color contrast in relation to the substrate or plant where they are, as well as they prefer conic fruits to other forms. It should be noted that the species has accurate visual perception, used for catching prey. As previously mentioned, *T. torquatus* consumes fruits of *M. violaceus*, which is a cactus whose fruits are conical, colorful, and close to the ground. That fact supports the hypothesis that lizards can to use visual perception to the fruit location and for identification of the ideal shape for the extrusion process [17].

The chemical perception ability for plant identification is correlated with the evolution of herbivory in Scleroglossa [3]. For Iguania lineage there are records of using of chemical samples collected by language in *D. dorsalis* [19]. In iguanas, the chemical discrimination of food has a strong correlation with the evolution of herbivory [20]. The use of chemical perception is important in the consumption of plant material, as these food items are motionless, making difficult the visual identification. Similarly, if different parts of the plant and different species have distinct compositions, the act of identifying the food before eating increases energy efficiency and also may avoid the consumption of species with toxins [3].

Although small fruits tend to be more easily handled and eaten by frugivorous, studies with lizards have not confirmed this trend. Rodríguez-Pérez and Traveset [21] studied the interaction between *Daphne rodriguezii*, an endemic shrub from Menorca Island (in Spain), with the lizard *Podarcis lilfordi* (Günther, 1874), which is its disperser. In such study the seeds size was not an important factor for the selection of fruits, because seeds are not predictors of the amount of pulp mass.

The chameleon *Furcifer oustaleti* (Mocquard, 1894) consume plant parts using different mechanism of collection if compared with animal prey. The capture of arthropods occurs through the projection of his tongue, while the consumption of fruit, for example, takes place by direct collection of the jaws. The mechanism indicates that the individuals identify the food item before consuming them and, since there is no need to capture vegetables items, the chameleons opt for direct collection, saving energy spent on the tongue projection [22].

Benítez-Malvido et al. [23] in an investigation about seed dispersal by *Iguana iguana* (Linnaeus, 1758), have observed that individuals of the species select the items from their diet, consuming fleshy fruits. The reason is that fleshy fruits have higher amount of water, sugars and less material of hard digestion. In the same study it was observed that puppies of *I. iguana* have difficulty eating large fruits or coriaceous ones because of the reduced body size.

It is worth mentioning that the presence of flowers and fruits in the diet of lizards is strongly influenced by the period in which the study was developed, due to seasonal availability of these items [24]. For that reason, the relative importance of consumption of plant material is dependent on the period of the sample, which limits discussions about the subject.

Some lizards choose to consume nectar or pollen in order to have a higher concentration of nutrients. That enables individuals pollinate plants, since they visit different flowers. The consumption of nectar for lizards is rarer, but there are some records. Although not common, such interaction is important, as it allows for pollination events. And, since the consumption occurs mainly on islands [25], environments that often lack pollinators, the lizards are fundamental in the maintenance of communities.

Geckos of the *Hoplodactylus* genus, in New Zealand, consume pollen from native plant species [26]. Geckos increase the consumption of flowers as enhance the viscous nectar (53% sugar). *P. lilfordi* are also potential pollinators of flowers belonging to the *Euphorbia dendroides* species, at island environments [27]. Furthermore, there are records of pollen consumption for the lacertid lizards *Gallotia simonyi* (Steindachner, 1889), *P. lilfordi*, and *Podarcis pityusensis* (Bosca, 1883) and the gecko *Rhacodactylus auriculatus* (Bavay, 1869) [3, 27].

2.2. Environmental factors

Factors related to the habitat of species may have direct influence on the consumption of vegetables by lizards, such as the availability of prey, aridity [3] and island environments [15].

The evolution of plant consumption may be favored by habitat factors that reduce the availability of prey [3]. It is observed on islands with low predation rates [4]. Another factor that likely influences in vegetable consumption is the intraspecific competition. When the density of the population increases, reducing the availability of prey, the feeding of alternative items favors the maintenance of the species.

Herbivorous in lizards evolves more commonly in species that occur in small islands, and appears to result from a lower abundance of arthropod preys available in these habitats [15]. An evidence is that when the diets of two populations of *T. torquatus* were compared, one continental and another insular, they were the same. This is likely because the availability of arthropods in both environments was similar [28].

In addition, as in islands, the species diversity is smaller, the occurrence of predators is reduced; therefore, the risk of exposure to the sun for thermoregulation is also reduced. Considering that, in that case, the lizards are able to maintain higher body temperatures, the energy efficiency rises, becoming advantageous the consumption of vegetables.

Fossil records of *Gallotia* clade, a group of lacertid lizards that inhabit the Canary Islands, shows that island environments are crucial in the development of herbivory, since even the individuals which are primitively of large body, the herbivory just has developed after the colonization of the islands [29]. Before the colonization they were carnivores. This study highlights the effect of abiotic factors on the ecology of the species.

However, all the evidence that island environments favor the development of herbivory are hypothesis, they have not been tested [3].

There are evidences that an arid environment favors the development of herbivory because of seasonal and unpredictable scarcity of prey. On the other hand, it is not possible to assess the effect of this factor on diet in an isolated way, since many islands are arid, becoming impossible to isolate the factors.

Anyway, the main factor directly related to the consumption of plants, predominantly in omnivorous species, is the availability of prey. About 80% of species respond to that factor.

The availability of prey is so decisive for the establishment of populations of insectivorous species that lizards of Liolaemidae family have a tendency to herbivory, related with the climate, which is contrary to the other groups. Espinoza et al. [30], in an article concerning the evolution of herbivory in individuals belonging to that family, concluded that vegetable consumption is directly correlated with cold climates while most herbivores live in habitats with hot and dry climate. Herbivorous tropical lizards (*Iguana*, *Ctenosaura*, and *Amblyrhynchus*) live in environments where the temperature remains high in most of the day.

2.3. Distribution of vegetable consumption by taxon

Living lizards are divided into two large lineages: the Iguania (e.g., iguanas and chameleons) and Scleroglossa (all other lizards). These groups have pronounced differences in foraging behavior: Iguania presents ambush foraging, consuming mainly insects, with some herbivores and omnivores individuals, which is a behavior derived from ambush forage. On the other

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hand, Scleroglossa includes mostly individuals with active foraging, a few ambush foragers, and a small amount of herbivores and omnivores [20].

The consumption of plant material occurs in the families of both lineages: Iguania and Scleroglossa. In Iguania it is present in almost every family with known data. Except in Chamaeleontidae and Crotaphytidae, the vegetable diet is of universal occurrence in Iguanidae (occurs in all species) and frequent in the species of the Tropiduridae family. In Scleroglossa the herbivory is absent in Pygopodidae, Eublepharidae, Gymnophthalmidae, Cordylidae, and most families of Anguimorpha [3].

Despite the lack of known robust phylogenetic relationship in the lizards, which makes difficult to trace the exact epoch that occurred the vegetable consumption evolution in these reptiles, the discovered patterns allow to infer that such evolution happened in several periods of their evolutionary tree.

In the following, some comments about the main families are presented, for which studies have been carried out concerning herbivory.

2.3.1. Iguanidae

Most herbivorous lizards belong to the Iguanidae family. The majority of species are strictly herbivorous. Others present ontogenetic changes, consuming plant material when they are adults. This family also has folivorous feeders. It is worth remembering that some species have their adaptations proper to the consumption of plant material, as previously mentioned. Another fact is that the herbivory is present in the common ancestor of Iguanidae [3].

2.3.2. Tropiduridae

In Tropiduridae family, the consumption of plant material is well known. Most genera are omnivores. And the degree of consumption varies considerably between genera and species. Many studies have shown data about the Tropidurus genus, stating that its diet has ontogenetic, seasonal and geographical variations [13, 31], as well as it reflects to local availability of foods [28]. *Liolaemus lutzae* also presents ontogenetic change in its diet [11].

2.3.3. Agamidae

The Agamidae family, which comprises lizards known as Australian Water Dragon, has some omnivores genera and only two herbivores genera while *Hydrosaurus pustulosus* is an exclusively folivorous species [3]. The other species that include plant material in their diet tend to consume the parts easier to digest, such as fruit and leaves.

2.3.4. Gekkonidae

Many species of the Gekkonidae family consume small amounts of plant material. Some geckos from New Zealand have omnivorous diet with consumption of different parts of the plant. Wotton [24] described the diet of *Mokopirirakau granulatus* (Gray, 1985), while for *Naultinus grayii* (Bell, 1843) it was reported by Whitaker [26].

2.3.5. Teiidae

Most species of Teiidae family are carnivorous. The species considered omnivorous belong to *Cnemidophorus*, *Tupinambis* [3] and *Ameiva* genera [32]. *Tupinambis teguixin* includes in its diet all parts of the plant, with predominance of fruits [14].

2.4. Ontogenetic and seasonal variations in vegetable consumption

The diet of lizards presents variations in response to different factors. Some species show changes between the sexes, possibly because of morphological differences, as in many species the males have larger body size than females. Other studies have indicated the seasonal variation in the diet. The species with such variation, in general, live in environments where there is rainfall variation over the year. However, a large part of the diet variation in lizards is explained by the availability of food in their living area. Considering that the main plant components in the diet of lizards are fruits and flowers, it is expected a seasonal influence on the diet [24].

There is still, in a long term, ontogenetic changes in the diet of lizards, when young individuals have a different diet in comparison to the adults from the same species. This fact occurs due to the difference in energetic demands during the growth of individuals. Most lizards which are omnivorous and also consumes vegetables, as young they feed basically on insects. Only *I. iguana* has an exclusively herbivorous diet, both in adults and young ones [25].

The evidences of ontogenetic change in the consumption of vegetables can be observed if it is considered the quantity of vegetables consumed or in relation to the plant parts that make up the diet such as leaves, fruits, flowers, or nectar. Since each component has a different proportion of protein, water, fiber, glycides, and cellulose (the most difficult component to digest). During the period, the demand for protein is higher thus, a diet plant-based would not supply the energy needs. Therefore, puppies tend to look for food items with higher amounts of protein [3].

As adults, certain species begin to add larger amount of plant material in the diet. There are several reasons for that. It may be the greater availability of these items, since in certain environments, such as islands, the availability of arthropod is reduced; presence of water in the fruits (in arid environments is an essential feature for maintaining the species metabolism); more facility of handling when compared to prey, inasmuch as in order to capturing small invertebrates it is necessary a higher energetic spent than the consumption employed only in collecting fruits. For example: reduced competition, as youth and adults consume different food items, they will not compete for the same niche, and nutritional content.

The ontogenetic change in alimentation is well marked in omnivorous species despite being also observed in essentially herbivorous species. *Microlophus thoracicus* (Tschudi, 1845), an omnivorous species, presents ontogenetic change in its diet, consuming insects as juvenile, adding vegetables when adult [10].

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Rocha [11] carried out a study about ontogenetic changes in *L. lutzae* diet in Barra do Baricá, coast of Rio de Janeiro (Brazil). Despite its small size during adulthood (60–80 mm), nearly half of the diet of the species was composed by vegetables material, and the presence of these items increased according to increase of age and body size of the individuals. This is reinforced by the fact that lizards with snout-vent-length (SVL) smaller than 38 mm consumed only arthropods. Such trend was present in both sexes. However, males tend to consume more plant material than females. The low availability of arthropods in beach environments and abundant presence of shrubs make the ontogenetic change an advantage in terms of digestive efficiency. Then, the species begin to explore new niche, limiting the consumption of arthropods by adults in order to not competing intraspecifically with juveniles.

Populations of *T. torquatus*, which inhabiting the same environment previously mentioned, have showed behavior similar to the *L. lutzae*, increasing gradually their diet with plant material during growth, and when adult they have almost half of the diet consisting of plant material [13]. The two papers, Rocha and Fialho et al., highlight the importance of environmental factors in the composition of the lizard's diet, leading the species to consume items that theoretically would be disadvantageous due to the difficulty of digestion, but that are more accessible.

In environments with seasonality marked by precipitation difference, as well as in tropical environments with dry and rainy seasons (Barra de Maricá), the volume of rain is decisive for the availability of arthropods and also for the plants cycle. Since the more rain the more availability of arthropods. Thus, the diet will vary according to the availability of food in each station. It should be noted also that both species (*L. lutzae* and *T. torquatus*) are omnivorous, opportunistic predators and their diets reflect the availability of food items in the habitat.

3. Lizards as a seed disperser

In order to consider an animal that consumes fruits as a disperser, it is necessary to validate quantitative and qualitative factors. Quantitative factors depend on the number of seeds consumed, while the qualitative ones depend on the location in which the seed is deposited and the effect of the passage through the digestive tract on seed germination [33–35]. The treatment that the seeds receive when they are consumed directly influences the capacity and the speed of germination [21]. In the same way that the distribution pattern of seeds on the microhabitats is a crucial aspect of the dispersion quality [36]. Inasmuch as different microhabitats provide different conditions (illumination, humidity, substrate characteristics, etc.), causing alterations in the rates of germination and seedling survival.

Similarly to the studies of herbivores, research about dispersion syndrome also focuses mainly on birds and mammals. Studies concerning that syndrome in reptiles are less common [23]. However, this group plays an important role, especially species which inhabit arid environments and islands.

Information on seed dispersal by lizards are known for: geckos in New Zealand islands [24, 26]; lizards in various environments in Brazil [31, 37], in the Mexico (Benítez-Malvido et al.), in island of the Western Mediterranean [21, 38] and iguanas in the Galapagos Islands [39] and dry forests of Costa Rica [40].

Many studies have shown a positive effect of the passage through the digestive tract of lizards on the ingested seeds. However, this effect varies with the species consumed.

The environment analyzed by Wotton [24], an island in New Zealand where the gecko *Woodworthia maculatus* lives (Gray, 1845), has reduced populations of birds and mammals that may disperse the seeds, and compete by the consumption of the fruits. In this sense, the gecko has fundamental importance for the maintenance of the local communities, due to its dispersal potential.

The seed dispersal by lizards is peculiar because, even though being characterized by local events or short distances, it has fundamental importance due to the tendency to eat fallen fruit, inaccessible to other vertebrates like birds [24].

In a paper about seed dispersal by *T. torquatus*, Pietczak *et al.* [37] have found that the seeds deposition of *Chomelia obtusa* (species consumed by the lizard at the studied site) usually occurs in a short distance from the mother plant, around five meters. But, despite the fact that the average dispersal distance is not too long, the species is benefited. The reason for this is that, according to Chapman and Chapman [41], seeds dispersed even in short distances germinate better than ones under the parent plant. The dispersion of seed in locations similar to that of natural occurrence of the species indicates favorable conditions for the germination. In this sense, Pietczak et al. verified that the population of *T. torquatus* studied merely remained in the areas around a rocky outcrop, depositing the seeds on the edges and clefts of the rocks. Therefore, the places where the lizard deposited the seeds favored the seed germination and seedling development.

Rodríguez-Pérez and Traveset [21], in a paper about the interaction of the bush *D. rodriguezii* and its disperser, namely, the lizard *P. lilfordi*, stated that the passage through the digestive tract neither increased nor decreased the germination capacity. Nevertheless, the passage through the digestive tract appeared to have caused a reduction in size of the seed, with an action on the coating thickness. Traveset [33] indicates that the reduction of the coating serves as a scarifying process, increasing the permeability of the seed and thus favoring the germination. However, such permeability was not evaluated in detail by Rodríguez-Pérez and Traveset.

Once again, regarding the work of Rodríguez-Pérez and Traveset [21], it was observed that seedlings of seeds deposited under the mother plant had lower survival rates compared to the seeds dispersed. Accordingly, even though the passage through the digestive tract of lizards does not significantly increase the germination rate, the deposition pattern of seeds increases the viability of seedlings survival. Thus, the action of lizards is characterized as a disperser. Another paper, studying the same disperser, has obtained similar conclusions, in which the effect of ingestion had neutral results on germination rates, but the seed deposition favored the development of seedling [38]. In this case in particular, since *P. lilfordi* é is the

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only disperser of *D. rodriguezii*, such interaction is essential for the maintenance of the species.

4. Concluding remarks

There are some studies that explain the consumption of vegetables by lizards. For a while it was considered the body size as a decisive factor for herbivory. It was thought that only large lizards were able to consume plant material. More recent publications, with small- and medium-sized species, have shown that there are various reasons for some species consume vegetables and others do not.

In relation to the anatomy, physiology and behavior of the species, it is necessary certain adaptations to consume vegetables, such as: specialized dentition, elongated intestines, colic valves, intestinal flora, and thermoregulation to maintain high body temperature. The Iguanas are the lizards with the most elaborate adaptations to herbivory.

Many lizards which have omnivorous diet consume plant material. For such a species of lizards, changes in their diet are strongly related to environmental factors. Vegetable consumption by lizards is more likely to occur in insular and arid environments, as well as in areas with reduced predators. But the deciding factor associated with the addition of vegetable items is the availability of prey. Insular and arid environments have lower availability of arthropods, which is the main food item of most lizards. Nevertheless, more studies are needed to isolate each of the following factors: insularity, aridity and availability of prey.

Environments with prey scarcity also favor the ontogenetic changes in the diet. If there are not enough arthropods for population maintenance, it is more beneficial that youth individuals maintain a diet richer in protein (arthropods) and adults change their diets for items with higher availability (vegetables). Since many species of omnivorous diet do not present physiological or anatomical adaptations to the digestion of plant tissue, they choose the parts of the plants easier for the digestibility, like fruits, flowers, and nectar.

During the consuming of fruits and nectar, some lizard species can disperse seeds and pollinate flowers. The main contribution of the lizards in the dispersal of seeds is on the deposition pattern of seeds. More studies are needed in order to investigate the dispersion syndrome in other species and draw a general profile of seed dispersal by lizards.

The pollination by lizards is rare, but very relevant, because the occurrence of such events is carried out on islands. These environments may have reduced diversity of other animal groups and are isolated. The interactions of the plants with lizards are fundamental to the maintenance of species on islands.

Therefore, the research conducted so far about herbivory by lizards have shown interesting results, but many hypotheses have yet to be formulated and tested.

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