

## Natural History Observations in the Puerto Rican Dwarf Anole, *Anolis occultus* Williams and Rivero 1965 (Squamata: Dactyloidae): Nectar-Feeding, Bird Predation, and a Review of the Species' Natural History with Implications for Its Conservation<sup>1</sup>

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**Abstract:** We document the first record of nectarivory and bird predation in the Puerto Rican Dwarf Anole, *Anolis occultus*, which expands our knowledge on the natural history in the most diverse genus of Neotropical lizards. In addition, we conducted a literature review on all recorded information about this species, which revealed that little is known about the natural history and the ecology of *A. occultus* since its description in 1965. A discrepancy exists between the International Union for the Conservation of Nature's (IUCN) and the Puerto Rico's Department of Natural and Environmental Resources' (DNER) listings of *A. occultus*: 'Least Concern' in the former, 'Data Deficient' in the latter. This discrepancy in international and state listing categories, along with the lack of ecological and historical information on the species, warrants a change of the species' status to 'Data Deficient' by the IUCN, and we recommend areas of ecological research with conservation implications for the species.

**Key Words:** Anole conservation, lagartijo enano, land-use history, twig anole, *Anolis occultus*, nectarivory, nectivory, bird predation, natural history, conservation

There are 42 species of lizards documented for Puerto Rico by 2016 (including the main island of Puerto Rico and on Mona Island, Desecheo Island, Vieques, Culebra, and satellite islets and cays) of which 13 belong in the genus *Anolis* (notables: two subspecies, *A. cristatellus cristatellus* and *A. c. wileyae*; *A. roosevelti*, which is presumably extinct). Of those 13 species, ten occur in the mainland of Puerto Rico, with Mona Island, Desecheo Island, and Culebra Island having an endemic anole each. We have garnered field observations about one of the least noticed lizards of Puerto Rico, the Dwarf Anole, *A. occultus* Williams and Rivero 1965. Herein we include a detailed account on nectarivory by *A. occultus*, the first case reported for this species. Also, we

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document the first case of predation on *A. occultus*. Given that there is a discrepancy between the International Union for the Conservation of Nature's (IUCN) and the Puerto Rico's Department of Natural and Environmental Resources' (DNER) designations of *A. occultus*, we undertook a thorough literature review on the species' biology. Based on this review, we recommend that the IUCN changes the status of the *A. occultus* to 'Data Deficient'.

**Nectar-feeding on the Camasey Almendro, *Mecranium latifolium* ([Cogn.] Skean 1993) (Myrtales: Melastomataceae), by the Dwarf Anole, *Anolis occultus***

On October 4, 2016 at 1015h, coauthor JDAO observed an adult male *Anolis occultus* at a height of 1.8 m above the ground on a branch of the 'Camasey Almendro'—an evergreen shrub to small tree that can reach 7.6 m in height and 13 cm in diameter at breast height—lapping nectar from flowers and from the half-round greenish cuplike base (hypanthium) of unopened flowers in clusters (panicles, Figure 1). The anole deliberately lapped several flowers before crawling up and moving out of sight. This event took place in the vicinity of the road near the main gate that leads to Cerro La Santa (18°06'38.20" N, 66°03'16.40" W; WGS84), at 829 m above sea level, adjacent to road PR-184, Barrio Farallón, Cayey municipality, southeastern Puerto Rico.



Figure 1. A male Dwarf Anole, *Anolis occultus*, on an inflorescence of the Camasey Almendro, *Mecranium latifolium*, showing detail of plant (upper left panel), lapping nectar with its curled tail (upper right panel), and lapping nectar from flower buds (lower panels). This specimen shows typical day-time body coloration (see Thomas 1965 for a thorough description of body coloration in live specimens), with greenish and yellowish tones, and black specs on a gray-light brownish background body coloration.

To our knowledge, nectar-feeding has been documented in several species of *Anolis*, including: Green Anole, *A. carolinensis* Voigt 1832 (Liner 1996, Campbell and Bleazy 2000, Okochi et al. 2006); Graham's Anole, *A. grahami* Gray 1845 (Losos and de Queiroz 1997); Saddle Anole, *A. stratulus* Cope 1861 (Perry and Lazell 1997); Grand Cayman Blue-Throated Anole, *A. conspersus* Garman 1887 (Echternacht and Gerber 2000); Allison's Anole, *A. allisoni* Barbour 1928 (Valido 2006); Grenadian Bush Anole, *A. aeneus* Gray 1840 and Grenadian Tree Anole, *A. richardii* Duméril and Bibron 1837 (Timmermann et al. 2008); Emerald Anole, *A. evermanni* Stejneger 1904 (Colón-Archilla 2010); Panther Anole, *A. bimaculatus* Sparrman 1784, Anguilla Bank Anole, *A. gingivinus* Cope 1864, Anguilla Bank Bush Anole, *A. pogus* Lazell 1972, and Saban Anole, *A. sabanus* Garman 1887 (Powell et al. 2005). In addition, extrafloral nectarivory has been documented in only two anoles, that are present also in the Puerto Rican Bank: *A. stratulus*, feeding on nectar from minute round yellow-green glands present between each pair of leaflets (from 3 to 5 leaflets per leaf) on the winged axis of the alternate pinnate hairy leaves of the Guaba, *Inga vera* Willdenow 1806 (Fabales: Fabaceae) (Ríos-López 2004), and *A. pulchellus*, feeding on nectar from the small elongate gland on the petiole of the bipinnate leaf of the Acacia, *Leucaena leucocephala* [Lamarck] de Wit 1961 (Fabales: Fabaceae) (Perry and Lazell 2006). This report on nectarivory in *A. occultus* agrees with Perry and Lazell's (1997) assertion in that nectarivory is far more common among anoles than it is reflected in published accounts.

**Bird predation on the Dwarf Anole, *Anolis occultus*, by the Loggerhead Kingbird, *Tyrannus caudifasciatus tylori* (P. L. Sclater 1864) (Passeriformes: Tyrannidae)**

On April 27, 2014 at approximately 1500h, coauthor EBA observed an adult Loggerhead Kingbird preying upon an adult *Anolis occultus* at a height of 4.5 m above the ground on a branch of a 'Flamboyán' or Flame Tree, *Delonix regia* (Hook.) Raf. 1837 (Fabales: Leguminosae) (Figure 2). The bird came from an adjacent forest area with the anole in its beak already and flew to this tree, which is planted in the parking lot of the of the 'Hotel Treasure Island' (18°11'04.47" N, 66°08'57.64" W; WGS84), an area that lies at 421 m above sea level, Barrio Bayamón, Cidra municipality, central-eastern Puerto Rico. A second Loggerhead Kingbird arrived and perched close to the bird with the anole, which flew out of sight presumably to complete ingestion elsewhere.

Bird predation on West Indian reptiles has been reviewed by Powell and Henderson (2008) and documented the Loggerhead Kingbird preying upon the Caymans Blue-fanned Anole, *Anolis conspersus* Garman 1887, and the Jamaican Giant Anole, *A. oculatus* Cope 1879. Ríos-López et al. (2015) reviewed saurophagy (lizard predation) by Puerto Rican vertebrates, including avian predators of Puerto Rican anoles, and found no accounts for the Dwarf Anole. Consequently, the account described herein expands the list of reptile

preys for the Loggerhead Kingbird in the West Indies (all anoles) and represents the first predation account on *A. occultus*.



Figure 2. An adult Loggerhead Kingbird, *Tyrannus caudifasciatus tylori*, with a recently captured adult Dwarf Anole, *Anolis occultus*.

### **Review of recorded information on the natural history and ecology in the Dwarf Anole, *Anolis occultus*, prior to this study**

The Puerto Rican Dwarf Anole, *Anolis occultus* Williams and Rivero 1965, is one of the thirteen species described for the region, is the smallest of all Puerto Rican anoles (range of snout-vent length [SVL] = 34–42 mm; Rivero 1998; mean SVL: 38.1 mm  $\pm$  0.5mm,  $N = 11$ ; Losos 1990), and one of the most primitive Puerto Rican anoles (along with the presumably extinct Culebra Island Giant Anole, *A. roosevelti* Grant 1931, and the Giant Green Anole, *A. cuvieri* Merrem 1820 (Williams 1972, Rivero 1998, Ojeda-Kessler 2010, Castañeda and de Queiroz 2013). Our literature review revealed that two specimens of *A. occultus* were collected by Williams and Rivero (1965) while Thomas (1965) reported capturing 34 specimens in the original description. All but two of these specimens were collected while animals were sleeping. In his field observations, Thomas (1965) reported that specimens were found on twigs and vines associated with an opening in the canopy (forest gaps), and along narrow path cuts in forest edges (none in closed-canopy areas). Specimens were found at heights from the forest floor (on a leaf axil of the bromeliad *Werauhia sintenisii* [Baker] J. R. Grant 1995; Williams and Rivero 1965) to ~4.5m above the ground in tangles of vines and twigs (Thomas 1965). A specimen “may emit a rather persistent squeaking during its struggles to escape” (i.e. release call) when caught or handled (Thomas 1965). Williams and Rivero (1965) and Thomas (1965) provided a detailed description of specimens’ external morphology, dewlap shape and color, display and movement (in captivity), chameleon-like eyes and independent movement, and their habit of curling the tail about the vine or twig used as a sleep-site. No reference was made on juveniles, and all specimens collected by Williams, Rivero, and Thomas came from the Cordillera Central: from the Sierra de Cayey in the southeast, to Maricao’s upland forests in the central-western mountain range in Puerto Rico. The species’ altitudinal distribution ranges from 50 m to the highest mountain top >1,300 m above sea level (Rivero 1998; Henderson and Powell 2009, de Queiroz and Mayer 2011a).

Webster (1969) added observations of 15 specimens, collected from the Sierra the Luquillo, northeastern Puerto Rico, and confirmed Thomas’ observations on sleep posture and release call. In addition, Webster (1969) provided the first observation of a juvenile found on a dead fern during the evening. Gorman (1980) provided observations based on about 25 additional specimens. On several occasions, he observed a male and a female sleeping “within inches from each other” and suggested pair-bonding behavior because the relatively rarity of this species, compared to other species from the island, precluded chance alone (Gorman 1980). Locomotor performance (jumping, clinging, acceleration, and sprint speed) was documented by Losos (1990) based on 11 specimens (jumping and clinging performance), and by Vanhooydonk et al. (2006) based on four specimens (two for acceleration performance and two

for sprint speed). The species shows no sexual size dimorphism (based on 18 females and seven males, Butler et al. 2000). Molecular and morphological data of *A. occultus* exist for examining phylogenetic relationships among anoles (e.g., Brandley and de Queiroz 2004, Nicholson et al. 2005, Losos 2009, Kolbe et al. 2011, Nicholson et al. 2012, Castañeda and de Queiroz 2013).

Webster (1969) recorded the first observation of a specimen of *Anolis occultus* lapping liquid for a short time, when a specimen became active approximately at 0700h. He described the event: "..., it seemed to drink from raindrops on two occasions and prowled with frequent long pauses over an area of largely bare and exposed twigs, eventually wandering upward and out of sight". Coincidentally, and in support of nectarivory in this species, leaves and flower buds of a shrub of the Melastomataceae (species unknown) is also shown in the foreground in a black and white photograph of a sleeping pair of this species documented in Gorman (1980).

Our literature review revealed that little is known about the natural history of *Anolis occultus* since its description in 1965; even less is recorded about its ecology (see also Henderson and Powell 2009). Puente-Rolón et al. (unpublished data) characterized nocturnal microhabitat, sleeping posture, sleep-site fidelity, and provided the first estimate of population size for the species in Puerto Rico, specifically in a reforested limestone valley, northern Puerto Rico. Their estimate, 56.1 individuals/ha (A. R. Puente-Rolón, personal communication), represents the lowest population size estimate among all Puerto Rican anoles, only comparable with that from the Giant Anole, *A. cuvieri*, which is between 39 and 74 individuals/ha in a karst forest (Ríos-López and Puente-Rolón, 2007), and 30 individuals/ha max. in a rain forest (Dial et al., 1994). To contrast, population estimates of other Puerto Rican anoles include (in descending order of population density): between 21,333 and >25,870 individuals/ha in the Saddle Anole, *A. stratulus* Cope 1861 (Reagan 1992); between 20,000 and 25,000 individuals/ha in the Grass Anole, *A. pulchellus* Duméril and Bibron 1837 (Gorman and Harwood 1977); between 2,308 individuals/ha in the Emerald Anole, *A. evermanni* Stejneger 1904, in a rain forest (Dial et al., 1994), and >94 individuals/ha in a karst forest (Ríos-López and Aide 2007); up to 2,000 individuals/ha in the Yellow-Shinned Anole, *A. gundlachi* Peters 1876 (Turner and Gist 1970); between 1,256 individuals/ha in the Crested Anole, *A. cristatellus* Duméril and Bibron 1837, in a karst forest (Ríos-López and Aide 2007), and ~262 individuals/ha in a dry forest (Genet 2002); between 178 individuals/ha in the Mountain Garden Anole, *A. krugi* Peters 1876, in a lowland reforested karst valley (Ríos-López and Aide 2007), and 100 individuals/ha in an upland coffee plantations (Borkhataria et al. 2012); and up to ~198 individuals/ha in the Dry Forest Anole, *A. cooki* Grant 1931 (Genet 2002). As far as we know, there are no estimates of population size for: the Desecheo Island Anole, *A. desecheensis* Heatwole 1976; Mona Island Anole,

*A. monensis* Stejneger 1904; Dryland Grass Anole, *A. poncensis* Stejneger 1904; and the Culebra Island Giant Anole, *A. roosevelti* Grant 1931.

*Anolis roosevelti*, which is presumably extinct (Ojeda-Kessler 2010), is listed as Critically Endangered by the Puerto Rico's Department of Natural and Environmental Resources (DNER 2015) and as Endangered by the U.S. Fish and Wildlife Service (the only Puerto Rican anole listed by the federal agency). In addition, the DNER (2015) lists *A. cooki* as Endangered, *A. poncensis* as Vulnerable, and *A. cuvieri* and *A. occultus* as Data Deficient. Only two Puerto Rican anoles, however, have been assessed by the International Union for the Conservation of Nature (IUCN) in its Red List of Threatened Species: *A. roosevelti*, listed as Critically Endangered (de Queiroz and Mayer 2011b), and *A. occultus*, which is listed as Least Concern (de Queiroz and Mayer 2011a). As for *A. occultus*, however, there is no estimate of population size and density for the species elsewhere on the island except that estimated by Puente-Rolón (unpublished data and personal communication), nor data on home range, demography and reproductive phenology, longevity, physiology, mating behavior, feeding ecology, parasites and pathogens, intra- and inter-specific interactions, nor molecular data on the species' genetic structure and gene flow within and among populations. While some of these data are lacking for most anoline species from Puerto Rico, the whole suit of data is lacking for *A. occultus*, except that now we know it has the lowest estimated population size among all Puerto Rican anoles for which this data exist.

**Research needs, Puerto Rico's land-use history, and climate change:  
Implications for conservation status of *Anolis occultus***

Williams' (1972) considered *Anolis occultus* among the ten species that are "ecologically well studied on the mainland of Puerto Rico." In contrast, Gorman (1980, p. 30) mentioned that "I suggest that compared to most of the other species of Puerto Rican anoles, *A. occultus* is relatively rare; although in the complete absence of demographic studies I hesitate to define this expression." From that moment on, several authors have listed the species' population status, either as 'Stable' (Moreno 1991) or 'Least Concern' (de Queiroz and Mayer 2011a). Specifically, de Queiroz and Mayer (2011a) in the International Union for the Conservation of Nature (IUCN) mention that "*Anolis occultus* has been assessed as Least Concern due to its relatively wide range across Puerto Rico, protection from managed forests and the national park, and a lack of current threats. Furthermore, it is unlikely that any population declines are being experienced by *A. occultus*. Monitoring of this species population and distribution should be carried out to ensure declines are highlighted and the appropriate conservation measures put in place". However, neither Moreno (1991) nor de Queiroz and Mayer (2011a) provided data to support the recommended listing categories, 'Stable' and 'Least Concern', respectively. Authors de Queiroz and Mayer (2011a) do mentioned that "In the past there had

been much deforestation across Puerto Rico, but in recent decades reforestation has occurred and therefore land destruction and degradation are no longer a major threat to this species.” We believe that Puerto Rico’s land-use history is worth noting next from the context of the species’ ‘Least Concern’ listing.

Hill (1899), a prominent and pioneer Texan geologist at the time, vividly described the forest conditions of Puerto Rico by the time of arrival of the United States to Puerto Rico in 1898. Several passages from Hill (1899, pp. 16–17) are highlighted here: “Owing to this soil the mountains were originally wooded and are now cultivated to their very summits, verticality of slope presenting no obstacle to cultivation in the minds of the natives. The writer has seen the steepest possible slopes cultivated to the highest degree in coffee and tobacco; in fact, the most productive crops of this character are grown upon declivities upon which the American farmer would not risk limb and life.” Hill (1899, pp. 17–18) continues: “Much of the soil of Porto Rico is now abandoned and in the condition known throughout the English-speaking West Indies as “ruinate.” This has resulted from long cultivation, from the failure to apply fertilizers, and, in some cases, from erosion.”...“In the western part of the island, in the high summit region, seen in passing from Adjuntas to Lares, many abandoned fields were observed, which are now entirely denuded of trees and cultivated crops.” Domínguez-Cristóbal (2000) reported that this wide-scale deforested status of Puerto Rican forests (mainly for agriculture and timber extraction) was already evident by the early 1800s. Lugo (2004) reported that by the 1940s, approximately 6% of forest cover remained because of the Puerto Rican economy was still based on agriculture, with just about 1% of the original forest area remaining unmodified at the time. After the 1940s, the Puerto Rican economy then shifted, from agriculture to industry (Dietz 1987), resulting in a 42% forest recovery by natural means ~60 years afterwards because of abandonment of deforestation for large-scale agriculture and a corresponding rural-urban migration (Grau et al. 2003, Grau and Aide 2007, Parés-Ramos et al. 2008).

Regeneration of Puerto Rican forests, however, was possible because of introduced plant species, which created new forests of different species composition compared to native forests (those without introduced species) (Martinuzzi et al. 2013). In addition, these secondary forests reached environmental and microclimatic conditions similar to native forests in about 40 years after abandonment (Grau et al. 2003, Martinuzzi et al. 2013), with species richness and physical structure similar to native forest stands of similar age, but between 60 and 80 years after abandonment (Lugo and Helmer 2004). On the other hand, evidence suggest that *Anolis occultus* is a rare forest-interior species (Borkhataria et al. 2012) that seems to prefer native-forest gaps and edges (Thomas 1965, de Queiroz and Mayer 2011a). Therefore, we believe that despite this “rapid” forest recovery time, novel forests of different plant composition that resulted from this recovery may have isolated populations of *A.*

*occultus* mostly in native forest patches for a considerable time span—yet unknown—in relation to the species' presumably short generation time. Currently, estimates of native forests coverage in Puerto Rico (reviewed by Martinuzzi et al. 2013) that could be suitable for finding *A. occultus* is 4.2% of Puerto Rico's land area (thus representing the smallest geographic distribution among anoles on the mainland of Puerto Rico). The IUCN reports *A. occultus* as having a wide geographic distribution (de Queiroz and Mayer 2011a), but land-use history revealed that this is not equivalent to a continuous geographic distribution nor a corresponding species' high abundance. Consequently, with no population size data on the species along its geographic distribution, we may tentatively suggest that populations of the species may have remained fragmented mostly in those patches of isolated native mountain forests, at least from the species' discovery time to most of present time. In fact, we believe *A. occultus* may have a presumably limited recolonization capacity to these novel forests that characterized post-agriculture Puerto Rico. To illustrate, Borkhataria (2001) mentioned on anoles that “Although all species were seen on coffee plants during the course of this study, *A. occultus* was extremely rare and recorded only once during all sampling occasions.” We believe that population expansion by *A. occultus* to adjacent regenerated forests, particularly in the northern karst region, may have occurred, but at some considerable time after land abandonment: as variation in ambient temperature decreased and relative humidity increased with increasing vegetation cover during secondary succession (see Ríos-López and Aide 2007 for a discussion on animal assembly rules during secondary succession). Nonetheless, the lack of ecological and physiological data on the species (particularly that relevant for estimating home range) precluded us to state a definitive colonization time and population expansion after land abandonment.

We emphasize the need to generate detailed ecological studies throughout the species' geographic distribution as these studies are of paramount importance for conservation considerations. Firstly, as we are living in a human-dominated world (*sensus* Vitousek et al. 1997), knowledge of land-use history is particularly important for conservation purposes in Puerto Rico and elsewhere. Secondly, reptiles are declining (Gibbons et al. 2000) and habitat loss is considered the leading cause of their declines globally (Todd et al. 2010). As for *Anolis occultus*—and many other mountain forest dwellers as well—a third fact threatening the species might be even more important today: climate change. To illustrate, Puerto Rico's 2010 census revealed that 61% of human population in Puerto Rican jurisdiction occurs in coastal municipalities (U.S. Census Bureau 2012). In addition, former agriculture lands and secondary forests in coastal areas are being transformed to urban and industry (Parés-Ramos et al. 2008). The Puerto Rico Climate Change Council (2013) agreed that coastal areas in Puerto Rico are already under imminent threat in the near future because of sea-level rise due to global warming. The question remained on

when and how much, but recently, Hansen et al. (2016) asserted that global warming has reached a global emergency mark, with sea-level rise reaching several meters in at least 50 years from now. Consequently, we might expect that the natural regeneration of secondary forests in mountain areas that characterized Puerto Rico during the past 70-80 years will be severely threatened, if not reverted, by a corresponding urban-rural migration due in large part to socio-economic dynamics (which is occurring already, Parés-Ramos et al. 2008, Borkhataria et al. 2012), along with ecological responses to sea-level rise, salt-water intrusion, coastal erosion, and a corresponding upland migration of mixed-vegetation forests as well (for examples on coastal forests and amphibians see Rivera-Ocasio et al. 2007 and Ríos-López 2008, respectively). In addition, current Puerto Rican economy so far experiences a ~10 years economic depression and the government sponsors wide-scale agriculture projects, particularly in state-owned abandoned agriculture uplands, as part of the island's economic recovery plan. Considering that much of our former agriculture land-cover was lost to urbanization and it is still being urbanized (Puerto Rico Environmental Quality Board 2014), we believe that regenerated forests, and most importantly, natural mountain forests suitable for a forest-interior species like *A. occultus* (and other forest-interior anoles), will be under tremendous pressure by human activities and climate in the imminent future.

We agree with de Queiroz and Mayer (2011a) in that *Anolis occultus*' population status is still unknown and that "further research into the threats, population, and habitat trends are needed to ensure this species is not in decline." In fact, we believe that such studies are strongly needed not only for *A. occultus*, but for the vast majority of reptiles (and amphibians) from Puerto Rico (and elsewhere). This may explain why the DNER reassessed Moreno's (1991) species' 'Stable' status, and lists *A. occultus* as 'Data Deficient' instead (DNER 2015). Moreover, the only references to the species' abundance highlight the rarity of the species (e.g., Gorman 1980, Borkhataria 2001, Borkhataria et al. 2012, A. R. Puente-Rolón et al. unpublished data and personal communication), and the acknowledgement of the lack of information on the species' abundance from a wide range on environmental conditions and of other biological aspects reviewed herein, calls for a reassessment of the IUCN's species population status, from 'Least Concern' to 'Data Deficient'. We recommend that 'Data Deficient' is a more accurate status for *A. occultus* because it may lead also to these much-needed ecological studies on the species for its effective conservation, considering the Puerto Rico's land-use history, socio-economic dynamics, and information on climate change projections and Puerto Rico's habitat modifications expected in the imminent future.

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