



The Asian House Gecko (*Hemidactylus frenatus*) Established in Natural Vegetation of Oaxaca, Mexico

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The Asian House Gecko (*Hemidactylus frenatus*) is the most widely introduced gecko in the world (Weterings and Vetter 2018). While native to tropical Asia and the Indian Subcontinent (Bansal and Karanth 2010), the current extent of its distribution also includes the Neotropics between Mexico and Ecuador, coastal East Africa, Madagascar, and northern and eastern Australia (Fig. 1). This species is also a highly successful colonizer of islands and is established on many islands in the Pacific, Indian, and Atlantic Oceans. The range is still expanding and new distributional records are published every year.

Outside Asia, *H. frenatus* is still largely confined to artificial environments associated with human settlement, especially buildings, but also vehicles and piles of hard materials or rubbish (McKay et al. 2009; Norval et al. 2012). The willingness of the species to rapidly take up residence in a newly arrived refuge has been an important factor in its suc-

cessful long-distance dispersal (Norval et al. 2012). Other traits that contribute to its success in establishing new colonies include the ability of females to store viable sperm for as long as 54 weeks (Yamamoto and Ota 2006), tolerance of the eggs to saltwater, year-round reproduction in tropical zones (Ramírez-Bautista et al. 2006; McKay and Phillips 2012), and females laying as many as three clutches of 1–2 eggs per year (Yamamoto and Ota 2006).

Establishment of *H. frenatus* in areas outside Asia is of conservation concern. In much of its non-native range, *H. frenatus* is the only lizard occupying buildings and thus filling a previously unoccupied niche. However, in places where other geckos occupy artificial structures, *H. frenatus* may outcompete and displace prior residents, as has been seen with *Lepidodactylus lugubris* in Hawai‘i (Case et al. 1994), *Phyllodactylus palmeus* on Utila in the Honduran Bay Islands (Powell 2003), and *H. turcicus* in northern Mexico (Farr et al.

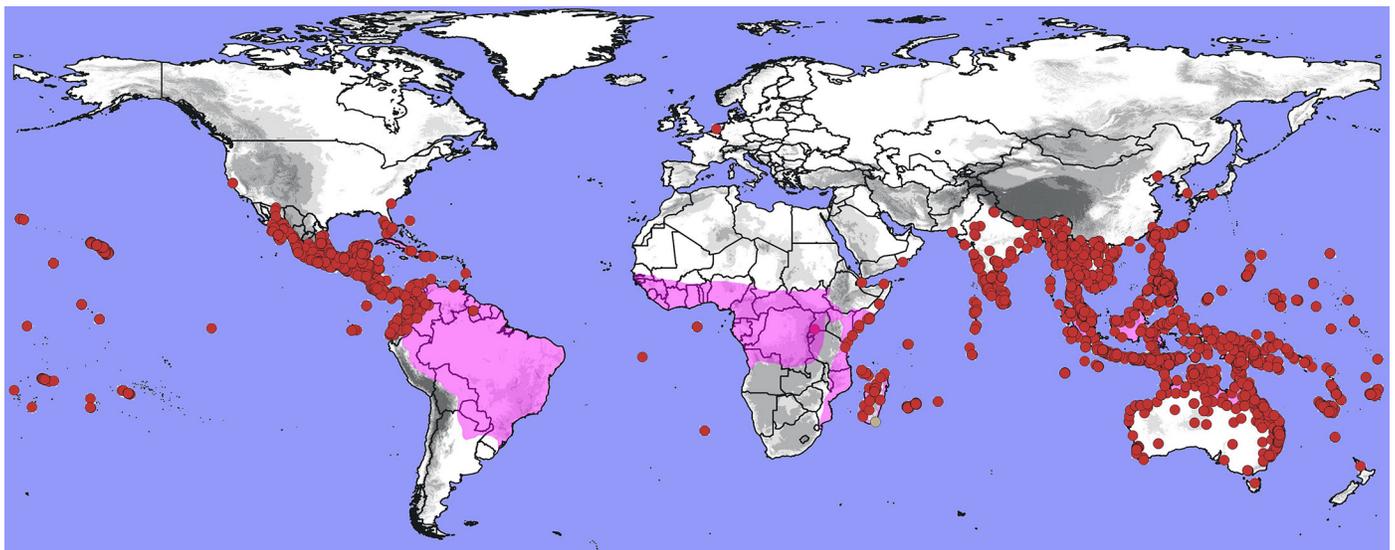


Fig. 1. Global distribution records of the Asian House Gecko (*Hemidactylus frenatus*). Red dots mark records derived from GBIF (2019). Predicted range (pink) was redrawn from Rödder et al. (2008) and Weterings and Vetter (2018).

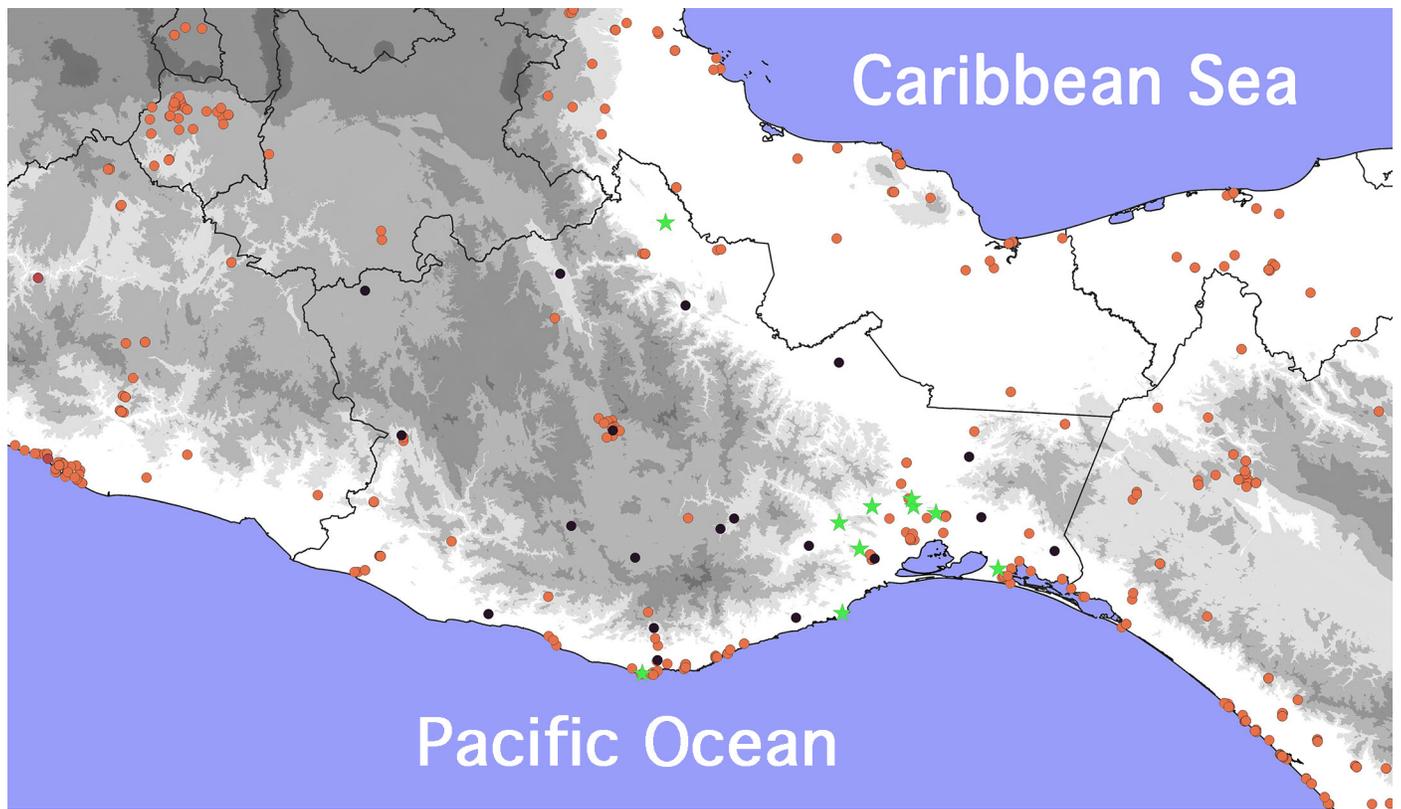


Fig. 2. Records of the Asian House Gecko (*Hemidactylus frenatus*) from the Mexican state of Oaxaca. Orange dots mark locations from GBIF (2019), black dots indicate the authors' opportunistic records from artificial structures, and green stars denote authors' records from natural vegetation communities. Terrestrial elevational zones are mapped in white (sea level–500 m asl), pale gray (501–1,000 m asl), gray (1,001–2,000 m asl), dark gray (2,001–3,000 m asl), and very dark gray (above 3,001 m asl).

2009). Where *H. frenatus* has invaded natural habitats, it also can exert a negative impact on native geckos. For example, *H. frenatus* was responsible for the decline of native species of *Nactus* in the Mascarene Islands (Cole et al. 2005) and has been implicated in declines of *Phelsuma guimbeaui* and *P. ornata* on Mauritius (McKeown 1983; Cole and Harris 2011). Additionally, *H. frenatus* may serve as a vector of parasites (Barnett et al. 2018; Norval et al. 2018), and its impact on native biodiversity via predation or other interspecific interactions is largely unknown. The potential for harmful impact, both on other geckos and more broadly on ecosystems, is higher where *H. frenatus* becomes established in natural vegetation communities.

Despite its enormous range, few examples of *H. frenatus* occupying natural vegetation exist outside Asia. The majority of these are from northern Australia, where *H. frenatus* is established in eucalyptus woodland, riparian vegetation communities, mangrove, coastal forests dominated by *Casuarina* spp., and monsoon forests in the Northern Territory (Kikkawa and Monteith 1980; Woinarski et al. 1999; Keim 2002; McKay et al. 2009) and in coastal *Casuarina* woodland and vine scrub in northern Queensland (Clarke 2006). Many of these locations are adjacent to sites with regularly arriving vehicular traffic (e.g., carparks and boat ramps), but others, particularly those

in monsoon forests, are far from any point of regular human contact. Cogger et al. (2005) mentioned a record of *H. frenatus* from “a natural area” on Norfolk Island, but provided no further details. The species is also a common resident of low coastal shrubs on West Island of Ashmore Reef, Western Australia (Somaweera et al. 2020). In the Mariana Islands, *H. frenatus* has been recorded from coconut palms lining a beach on the island of Tinian (Wiles et al. 1989) and from native tropical forest on the island of Aguiñan (Esselstyn et al. 2002). Werner (1990) described *H. frenatus* as the most conspicuous reptile in natural habitats on Oahu, Hawai'i. In Mexico, Hardy and McDiarmid (1969) listed *H. frenatus* from tropical thorn forest in the vicinity of Los Mochis, Sinaloa. In Tamaulipas, Farr et al. (2009) recorded the species from an area of tropical deciduous and gallery forests at Poza Madre (11 km SE of Ocampo), where individuals were found inside logs and in abandoned palapas, and from beneath the bark of a dead tree in a park, about 0.5 km from any artificial structure, in the city of Tampico. In Jalisco, Cruz-Sáenz et al. (2013) recorded these geckos from Estero El Salado, a small nature reserve within the urban bounds of Puerto Vallarta, where it inhabits semi-deciduous forest and thorn forest. Herein we present data on the distribution and habitat use of *H. frenatus* in the Mexican state of Oaxaca.

From 2015 to 2020, we opportunistically recorded the presence of *H. frenatus* in Oaxaca. We confirmed the presence of the species when an individual was positively identified either by sight or call. *Hemidactylus frenatus* is readily distinguishable from other geckos occurring in Oaxaca by a combination of toe shape (expanded section ovoid in *Hemidactylus*, square in *Phyllodactylus*), overall size and form (*Coleonyx* much larger and more robust, *Sphaerodactylus* much smaller and more attenuate), and by the absence of rows of large trihedral tubercles on the dorsum (present in its congener, *H. turcicus*). In Mexico, only three species of geckos (*H. frenatus*, *H. turcicus*, and *Lepidodactylus lugubris*) are known to use a multiple click call. The latter is not known from Oaxaca (Mata-Silva et al. 2015), so we excluded it from consideration. While we acknowledge that a multiple click call in Oaxaca could be *H. turcicus*, we assumed for this work that it was *H. frenatus*. This is a reasonable assumption because *H. turcicus* is currently known from only a single specimen taken in Juchitán (Mata-Silva et al. 2016) and we

never visually identified *H. turcicus* in Oaxaca while visually identifying many *H. frenatus*.

We recorded locations in datum WGS 84 and elevations using Google Earth. We mapped our records alongside occurrence data from GBIF (2019), which collates data from many sources, including museums, government agencies, and citizen science projects such as iNaturalist. We mapped all localities using the open source application QGIS 3.8.

We documented the presence of *H. frenatus* over a wide range of elevations and in a variety of habitats across much of Oaxaca (Fig. 2). We found geckos in habitats ranging from artificial sites (e.g., buildings) to natural vegetation communities, including intact natural habitats as well as those at otherwise anthropogenically modified sites (e.g., natural vegetation growing over a dam wall). All of our records from natural vegetation communities were at lower elevations (5–282 m asl), whereas all higher-elevation records were from artificial sites (Fig. 2). Our ten records of *H. frenatus* in natural vegetation communities are detailed in Table 1.

Table 1. New records of Asian House Geckos (*Hemidactylus frenatus*) in natural vegetation in Oaxaca, Mexico. Locations for all sites are in datum WGS 84.

Date	Location and Details
11 Feb 2017	Guiengola ruins, 11 km NW of Tehuantepec (16.381819°N, 95.309673°W) (167–282 m asl) Numerous individuals calling from thorn forest at dusk and in the first hour of darkness.
20 Aug 2018	Concepcion Bamba (16.013394°N, 95.408493°W) (5–74 m asl) Numerous individuals calling after dark in tropical semi-deciduous forest (Fig. 3) within a 1-km radius of the town. The same area was re-visited on 18 January 2020; two individuals were heard calling from tropical semi-deciduous forest approximately 1 km from the village. An adult female with two developing eggs was active on the ground.
21 Aug 2018	Mazunte (15.667606°N, 96.553449°W) (5–52 m asl) Geckos were abundant around the town, in trees and vegetation adjacent to buildings, and in the tropical semi-deciduous forest of the Punta Cometa Reserve. This area was re-visited on 15 January 2020, when multiple individuals were calling from tropical semi-deciduous forest near the town.
27 Dec 2019	3 km NE of Presa Benito Juarez (16.531108°N, 95.426377°W) (175 m asl) Three individuals were calling in agricultural fields and over-grazed thorn forest at mid-morning.
28 Dec 2019	Ojo de Agua Tolistoque (16.585587°N, 94.873440°W) (79 m asl) Five adults (two in sun, three in shade) were active on trunks of large trees (Fig. 4). Numerous individuals were calling in the same area. The habitat consists of riparian vegetation at the bases of hills vegetated with tropical semi-deciduous forest and thorn forest (Fig. 5).
28 Dec 2019	10 km S of San Francisco Ixhuatán (16.267560°N, 94.517655°W) (10 m asl) Many individuals were calling from scrubby trees and marginal vegetation along edges of fields at sunset.
03 Jan 2020	4 km SE of Nizanda (16.624987°N, 95.001838°W) (78 m asl) A few individuals were calling in the first hour after dark from thorn forest.
03 Jan 2020	Nizanda (16.666343°N, 95.012529°W) (114–129 m asl) Numerous individuals were calling at dusk and after dark from riparian vegetation in an area of tropical semi-deciduous forest and thorn forest. One individual was active on a tree trunk after dark.
22 Jan 2020	Rio Los Perros, 5.5 km NW of Santiago Loallaga (16.623957°N, 95.238521°W) (119 m asl) A small number of individuals were calling from riparian vegetation around sunset.
02 Feb 2020	Temascal (18.248427°N, 96.420252°W) (70 m asl) Many individuals were calling from shrubs and boulders of a dam wall.



Fig. 3. Habitat of Asian House Geckos (*Hemidactylus frenatus*) in natural vegetation communities at Concepcion Bamba, Oaxaca, Mexico. Tropical semi-deciduous forest featuring large cacti in the foreground, thorn forest in the distance (left). Tropical semi-deciduous forest (right). Photographs by J. Lindley McKay.

We draw several conclusions from our data about the status of *H. frenatus* in Oaxaca. Firstly, *H. frenatus* occurs in association with human habitation at elevations from sea level to 1,600 m asl (Oaxaca City) widely across the state. In sites with natural vegetation communities, our ten observations were confined to lower elevations, suggesting that *H. frenatus* is better established and/or more abundant at lower elevations. This is consistent with the species' thermal tolerance but does not exclude the possibility that they indeed exist at higher elevations at sites with natural vegetation. Our opportunistic sampling imposed some inherent limitations and a more systematic search for *H. frenatus* in higher-elevation natural vegetation communities is needed to understand their true distribution and habitat use across the entire elevational gradient. Secondly, our numerous records from 2018 and 2020 in the vicinities of Mazunte and Concepcion Bamba along the Pacific coast indicate that *H. frenatus* is established in tropical semi-deciduous forests in those areas. Lastly, the cluster of records from the Pacific Basin of the Isthmus of Tehuantepec suggests that *H. frenatus* is established or in the process of colonizing the tropical semi-deciduous forests and thorn forests in that region.

The record from Temascal in northern Oaxaca is the only Mexican record of *H. frenatus* in natural vegetation within a perennially humid climate. To date all other records come from tropical semi-deciduous forest, thorn forest, or gallery forest. The habitat at the Temascal site is a dam wall constructed with large boulders and overgrown with vines and shrubs. Geckos were abundant in this habitat but not recorded from adjacent rainforest or agricultural areas. We speculate that the relatively open environment at

the Temascal dam wall creates a less humid habitat than surrounding rainforest, reminiscent of the drier tropical semi-deciduous forest. Meanwhile, *H. frenatus* is commonly found in tropical rainforests in other parts of the world, raising the question as to why it is not recorded from such habitats in Mexico.

Invasive herpetofauna is sometimes regarded as unimportant or uninteresting and is therefore under-reported (Farr et al. 2009). That we were able without systematic effort to add many previously unreported points of occurrence to the distribution of *H. frenatus* in Oaxaca, especially in naturally vegetated sites, is suggestive of an ongoing trend of under-reporting. We postulate that a targeted effort might find *H. frenatus* in natural vegetation throughout most of western lowland Mexico and probably much of the northeastern part of the country.

Newly colonizing populations of *H. frenatus* show a common trend. After initial arrival, a population is largely confined to the immediate area of arrival and expands outwards slowly. In Mexico, the earliest record of the species is from Acapulco, Guerrero, in 1895, and the species was recorded only from the Pacific coastal lowlands until 1951 (Farr 2011). This is paralleled in Australia, where *H. frenatus* was present from at least 1841 (Fisher and Calaby 2009) but restricted to a few locations in the far north until the 1970s (Hoskin 2011). Subsequently, populations expand rapidly into optimal habitat, particularly artificial structures lit at night. In Mexico, records of *H. frenatus* more or less encompassed the current range by 2010, with a huge increase of reported localities in recent years (e.g., Hernández-Ordóñez et al. 2015; Ramírez-Reyes et al. 2015; Bañuelos-Alamillo et al. 2016).



Fig. 4. Asian House Geckos (*Hemidactylus frenatus*) active during the day on trunks of large trees at Ojo de Agua Tolistoque, Oaxaca, Mexico. Photographs by J. Lindley McKay.



Fig. 5. Habitat of Asian House Geckos (*Hemidactylus frenatus*) in tropical semi-deciduous forest at Ojo de Agua Tolistoque, Oaxaca, Mexico. Photograph by J. Lindley McKay.

In Australia, in the period between 1970 and 2010, *H. frenatus* expanded into humid tropical areas and southward along the eastern coast (Hoskin 2011). Finally, expanding populations invade suitable but less optimal habitat, including natural vegetation and human settlements with cooler temperatures. Prior to 2011, the highest elevational occurrence of *H. frenatus* in Mexico was 989 m asl (Castro Franco 1987) but it can now be found at elevations as high as 2,310 m asl (García-Alvarado 2016). In eastern Australia, from 1980 to

2010, *H. frenatus* has continued to proliferate southward into areas where overnight temperatures fall below freezing at least once a year (Hollis 2006). Natural vegetation communities, in Mexico and elsewhere, characterized by their scattered food sources and the many challenges of an unfamiliar biotic environment, are probably suitable but suboptimal habitat for *H. frenatus*.

Comparing the current range of *H. frenatus* to its predicted range (Rödder et al. 2008; Weterings and Vetter 2018), few records exist in large portions of predicted suitable habitat in western Africa and South America (Fig. 1). While some of this may be attributable to under-reporting, it may also reflect a truly lower prevalence. The Asian House Gecko has yet to achieve its ultimate global distribution and natural vegetation communities in its non-native range represent the final frontier for this invasive gecko.

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