REPTILES & AMPHIBIANS

Invasion History of the Moorish Gecko, *Tarentola mauritanica* (Squamata: Phyllodactylidae), in the USA, with New Records of an Established Population in Texas

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Human-mediated dispersal of organisms has been well-documented and is a major route for the introduction of non-native species around the world (Meyerson and Mooney 2007; Hulme et al. 2008). If conditions are favorable, introduced species may become established in an area. The exact effects of introduced species on ecosystems can be difficult to understand, often depending on specific characteristics of the ecosystem, native community, and climate, as well as the complex interactions among these factors (Parker et al. 1999). Geckos of the genus *Hemidactylus* (Reptilia: Gekkonidae) are among the most widespread and successful colonizing reptiles in the world due to their proclivity for human-mediated jump dispersal (Weterings and Vetter 2017). However, other genera of geckos, including *Cyrtopodion* and *Phelsuma* (both Gekkonidae), *Sphaerodactylus* (Sphaerodactylidae), and *Tarentola* (Phyllodactylidae), have also established numerous populations outside of their native range (Lever 2003).

The Moorish Gecko, *Tarentola mauritanica* (Linnaeus 1758), is a large (60–90 mm SVL, 7–16 g; Fig. 1), robust species native to the western Mediterranean region, including parts of Europe and North Africa (Naulleau 1990; Barbadillo et al. 1999). At home in hot and dry climates, this species can be seen both day and night and may be active in parts of its native range for ten or more months each year (Barbadillo et al. 1999; Rodda 2020). *Tarentola mauritanica* is often found on vertical surfaces in both natural (cliffs, trees) and human-made (rock walls, buildings) habitats and is primarily insectivorous, although the diet can include small lizards, including conspecifics (Barbadillo et al. 1999). Females can lay 4–6 clutches of 1–2 eggs per year in multiple different microhabitats, including treeholes and cracks in buildings (Henkel and Schmidt 1995), facilitating relatively rapid population growth.

Tarentola mauritanica has been introduced at numerous localities across the globe (Lever 2003), including sites both relatively proximate (e.g., Mizerakis and Strachinis 2017; Strachinis and Pafilis 2018; Deso et al. 2020) and those at much greater distances from its native range, such as the Americas. For example, *T. mauritanica* has been introduced in Argentina (Navas 1987; Cabrera and Guerra 2006; Díaz-Fernández et al. 2019), Chile (Arredondo and Núñez 2014), Mexico (Ortiz-Medina et al. 2019), Uruguay (Achaval and Gudynas 1983), and the USA. *Tarentola mauritanica* was first documented in the USA by Conant (1945), who reported multiple individuals arriving in New Jersey with cork bark shipments from the Mediterranean region, although he also noted that no evidence suggested that a population was successfully established. The first confirmed, reproducing population of *T. mauritanica* was reported in the USA from San Diego County, California, in 1997, where a population had been observed since at least 1995 (Mahrdt 1998). Later, *T. mauritanica* was reported from Lee and Miami-Dade counties, Florida, by Bartlett and Bartlett (1999). Meshaka et al. (2004) reported a specimen from Lee County housed at the Florida Museum of Natural History, University of Florida (collection date unknown; searches by DRD did not reveal this specimen in the museum database), but at that time it remained unclear if a population was indeed established. Subsequently, Bartlett and Bartlett (2006) and Bartlett and Bartlett (2011) added Broward and Sumter counties, respectively, to a list of known occurrences in Florida and commented that established populations were known to occur. The first vouchered records with specific locality data were collected in 2009 and 2010 from Broward County, Florida (Krysko et al. 2011), which included several documented individuals, including juveniles, suggesting an established population. Later, Rochford and Krysko

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Figure 1. Representative Moorish Geckos (*Tarentola mauritanica*) collected from San Antonio, Bexar County, Texas, USA: (A) TNHC 117150 (DRD 11175), juvenile; (B) TNHC 117149 (DRD 11174), juvenile; (C) TNHC 117155 (DRD 10926), adult; (D) TNHC 117113 (DRD 11112), adult; (E) TNHC 117112 (DRD 11111), adult; (F) TNHC 117157 (DRD 10928), adult. Photographs by Drew R. Davis (A–D) and Benjamin W. Genter (E–F).

(2019) and Meshaka et al. (2022) commented that populations of *T. mauritanica* had been established in Broward, Lee, and Miami-Dade counties, Florida, although they presented differing dates of introduction and vouchered specimens exist only from Broward County. Outside of California and Florida, no other records exist of *T. mauritanica* in the USA. Herein we present the first record of an established population of *T. mauritanica* in Texas, USA.

On 8 October 2022, at 2222 h, an adult male *T. mauritanica* was collected by DRD in San Antonio, Bexar County, Texas. This individual was collected from within a storm drain located beneath the junction of Wurzbach Parkway and Starcrest Drive (29.54606, -98.45454; WGS 84; 226 m elev.) and deposited at the Biodiversity Collections, The University of Texas at Austin (TNHC) as TNHC 116965 (DRD 9886; Table 1). All specimen collection (here, and subsequently)

Table 1. Voucher specimens of Moorish Geckos (*Tarentola mauritanica*) collected in Bexar County, Texas, USA. Numbers in brackets indicate incomplete or regenerated tails. TNHC = Biodiversity Collections, The University of Texas at Austin; DRD = Drew R. Davis Field Series; M = male; F = female; J = juvenile.

TNHC Catalog #	DRD Field #	Latitude	Longitude	Date	Time	Sex	Mass (g)	SVL (mm)	Tail Length (mm)
116965	9886	29.54606	-98.45454	8 Oct 2022	2222 h	M	18.5	81	[53]
116966	9904	29.54479	-98.45804	12 Oct 2022	2303 h	F	8.3	64	69
116967	9905	29.54455	-98.45870	12 Oct 2022	2308 h	J	2.4	43	51
116968	9906	29.54442	-98.45807	12 Oct 2022	2321 h	J	0.6	29	[11]
117153	10924	29.38479	-98.57025	5 July 2023	0206 h	F	4.1	52	57
117154	10925	29.39028	-98.56145	5 July 2023	0133 h	F	6.8	60	69
117155	10926	29.39034	-98.56170	5 July 2023	0135 h	M	13.8	72	82
117156	10927	29.38464	-98.57249	5 July 2023	0203 h	F	8.2	64	68
117157	10928	29.38229	-98.56879	5 July 2023	0151 h	F	7.8	63	70
117158	10929	29.38236	-98.56875	5 July 2023	0151 h	F	5.8	57	63
117104	11103	29.54448	-98.45757	8 Sept 2023	2342 h	J	0.35	26	24
117105	11104	29.54455	-98.45879	8 Sept 2023	2309 h	J	0.54	26	29
117106	11105	29.54450	-98.45754	8 Sept 2023	2344 h	F	8.46	62	[25+35]
117107	11106	29.54450	-98.45751	8 Sept 2023	2347 h	M	10.32	71	[12+(25+35)]
117108	11107	29.54441	-98.45828	8 Sept 2023	2339 h	M	12.4	75	[13+48]
117109	11108	29.54726	-98.44686	8 Sept 2023	2325 h	M	18.68	80	[19+36]
117110	11109	29.54718	-98.44937	8 Sept 2023	2334 h	F	8.87	65	[51+19]
117111	11110	29.54457	-98.45766	8 Sept 2023	2335 h	M	14.8	78	[45+33]
117112	11111	29.54454	-98.45760	8 Sept 2023	2343 h	M	25.18	90	[80+14]
117113	11112	29.54451	-98.45853	8 Sept 2023	2320 h	M	18.59	84	97
117114	11113	29.54448	-98.45761	8 Sept 2023	2344 h	M	13.3	76	[85]
117115	11129	29.40132	-98.57599	9 Sept 2023	2248 h	J	0.45	27	27
117116	11130	29.40118	-98.57565	9 Sept 2023	2242 h	J	0.72	30	[9+16]
117117	11131	29.40086	-98.57549	9 Sept 2023	2246 h	J	1.62	40	47
117118	11132	29.40117	-98.57564	9 Sept 2023	2241 h	F	3.99	55	63
117119	11133	29.40130	-98.57576	9 Sept 2023	2253 h	M	5.14	60	[53]
117120	11134	29.40153	-98.57568	9 Sept 2023	2300 h	F	5.85	61	70
117121	11135	29.40106	-98.57546	9 Sept 2023	2244 h	F	7.41	66	71
117122	11136	29.40118	-98.57570	9 Sept 2023	2242 h	F	8.05	66	76
117123	11137	29.40054	-98.57553	9 Sept 2023	2248 h	F	7.57	66	[42+20]
117124	11138	29.40055	-98.57552	9 Sept 2023	2248 h	M	10.53	71	80
117125	11139	29.37633	-98.53630	9 Sept 2023	0035 h	J	0.47	26	[5+22]
117126	11140	29.37632	-98.53620	9 Sept 2023	0036 h	J	0.65	28	30
117127	11141	29.37633	-98.53637	9 Sept 2023	0035 h	J	0.84	32	39
117128	11142	29.37642	-98.53737	9 Sept 2023	0045 h	J	1.03	33	[5+21]
117129	11143	29.37638	-98.53773	9 Sept 2023	0043 h	J	1.00	33	38
117130	11144	29.37661	-98.53782	9 Sept 2023	0051 h	F	5.93	57	69
117131	11145	29.40274	-98.49042	9 Sept 2023	0155 h	J	0.66	28	30
117132	11153	29.32310	-98.47986	10 Sept 2023	0045 h	J	0.67	29	[14]
117133	11154	29.32321	-98.48060	10 Sept 2023	0015 h	J	2.39	42	[33+11]
117134	11155	29.32320	-98.48222	10 Sept 2023	0039 h	J	2.46	44	53
117135	11157	29.33162	-98.49264	10 Sept 2023	0157 h	J	0.72	30	[17]
117136	11158	29.33155	-98.49264	10 Sept 2023	0157 h	J	0.90	32	38
117137	11159	29.33074	-98.49276	10 Sept 2023	0205 h	J	0.83	32	36
117138	11160	29.33125	-98.49287	10 Sept 2023	0142 h	M	7.07	61	64
117139	11162	29.40585	-98.49358	10 Sept 2023	0321 h	J	1.03	32	[19+8]
117140	11163	29.40579	-98.49350	10 Sept 2023	0319 h	J	2.68	46	52
117141	11164	29.40529	-98.49279	10 Sept 2023	0316 h	F	7.37	64	72
117142	11166	29.40412	-98.49040	10 Sept 2023	0335 h	J	0.70	28	[22]
117143	11167	29.40418	-98.49053	10 Sept 2023	0350 h	J	2.61	43	49
117144	11168	29.40374	-98.48993	10 Sept 2023	0331 h	F	11.16	69	[12+38]
117145	11169	29.40421	-98.49058	10 Sept 2023	0337 h	F	10.46	69	[60+18]
117146	11170	29.40369	-98.48900	10 Sept 2023	0331 h	M	16.96	82	[10+54]
117147	11171	29.40416	-98.49050	10 Sept 2023	0349 h	M	16.63	79	[6+50]
117148	11173	29.40377	-98.49020	10 Sept 2023	0358 h	M	12.43	74	[16+44]
117149	11174	29.40397	-98.49373	11 Sept 2023	0416 h	J	0.46	26	[22]
117150	11175	29.40389	-98.49309	11 Sept 2023	0415 h	J	0.71	30	32
117151	11176	29.40394	-98.49415	11 Sept 2023	0418 h	J	0.61	28	28
117152	11178	29.39846	-98.49508	10 Sept 2023	0430 h	J	1.92	40	[35+4]

involved euthanizing specimens through injection and immersion in chloretone, collecting liver tissue, fixing specimens in 10% buffered formalin for ≥72 h, and transferring specimens into 70% ethanol for long-term storage. Surveys for additional *T. mauritanica* at this site continued for one hour (until 2322 h), but only a single *H. turcicus* was observed and collected (TNHC 117159 [DRD 9878]). Another site, ca. 0.4 airline km WSW of the first site, was sampled by DRD, BWG, and Michelle Genter on 12 October 2022. This site, the underside of the Wurzbach Parkway bridge over Salado Creek (ca. 29.54454, -98.45812; WGS 84; 227 m elev.), was surveyed for 40 minutes (2241–2321 h). A total of eight *T. mauritanica* were observed, three of which were collected (TNHC 116966–116968 [DRD 9904–9906]; Table 1). This series of observed specimens included both large adults and juveniles, suggesting that a population of *T. mauritanica* was established at the site. During the survey, no *H. turcicus* were observed.

On 3 July 2023, additional sites were sampled by DRD and BWG in southwestern San Antonio, Bexar County, ca. 17–20 airline km SW of the previously sampled locations. We observed five *T. mauritanica* (two collected; TNHC 117154, 117155 [DRD 10925, 10926]; Table 1) during a 15-minute survey (0126–0141 h) at Winston Intermediate School of Excellence, 2525 S General McMullen Drive (ca. 29.39043, -98.57062; WGS 84; 210 m elev.). Following this, several buildings in the Kelly Field Historic District (ca. 29.38281, -98.57088; WGS 84; 207 m elev.) were sampled for 17 minutes (0149–0206 h), and a total of 12 *T. mauritanica* were observed across three buildings (four collected; TNHC 117154, 117156–117158 [DRD 10924, 10927–10929]; Table 1). No *H. turcicus* were observed during surveys at these sites.

From 7–11 September 2023, additional surveys were conducted by DRD and BWG for *T. mauritanica* across San Antonio. On 7 September 2023, a total of 21 individuals were observed (11 collected; TNHC 117104–117114 [DRD 11103–11113]; Table 1) during a 42-minute survey (2305–2347 h) at the Wurzbach Parkway bridge over Salado Creek, the same site surveyed on 12 October 2022 (see above). On 8 September 2023, 31 individuals were observed (10 collected; TNHC 117115–117124 [DRD 11129–11138]; Table 1) during a 20-minute survey (2240–2300 h) at warehouses located from 2603–2613 SW 36th Street (ca. 29.40123, -98.57578; WGS 84; 214 m elev.). On 9 September 2023, *T. mauritanica* was collected at two new sites; a total of ten individuals were observed (six collected; TNHC 117125–117130 [DRD 11139–11144]; Table 1) during an 18-minute survey (0033–0051 h) at warehouses from 1734–1826 Centennial Boulevard (ca. 29.37642, -98.53737; WGS 84; 201 m elev.), and a single juvenile was observed and collected (TNHC 117131 [DRD 11145]; Table 1) during a 6-minute survey (0152–0158 h) at a warehouse at 673 Lone Star Boulevard (29.40274, -98.49042; WGS 84; 191 m elev.). On 10 September 2023, 39 individual *T. mauritanica* were observed (21 collected) from an additional five localities: (1) four individuals were observed (three collected; TNHC 117132–117134 [DRD 11153–11155]; Table 1) from 0014–0054 h near the intersection of TX Hwy 536 and US I-410 (ca. 29.32320, -98.48060; WGS 84; 188 m elev.); (2) eight individuals were observed (four collected; TNHC 117135–117138 [DRD 11157–11160]; Table 1) from 0142–0228 h at Schulze Elementary School, 9131 Yett Avenue (ca. 29.33162, -98.49264; WGS 84; 183 m elev.); (3) 20 individuals were observed (10 collected; TNHC 117139–117148 [DRD 11162–11164, 11166–11171, 11173]; Table 1) from 0307–0405 h at an apartment complex located at 423 Blue Star Street (ca. 29.40529, -98.49279; WGS 84; 192 m elev.); (4) six individuals were observed (three collected; TNHC 117149–117151 [DRD 11174–11176]; Table 1) from 0414–0421 h at a warehouse at 410 Probandt Street (ca. 29.40397, -98.49373; WGS 84; 192 m elev.); and (5) a single individual was observed and collected (TNHC 117152 [DRD 11176]; Table 1) during surveys from 0428–0432 h at a warehouse at 816 Probandt Street (29.39846, -98.49508; WGS 84; 191 m elev.). All sites sampled in September where more than one individual was observed consisted of a mix of both juveniles and adults, and at sites where only one individual was observed, it was always a juvenile, suggesting juvenile dispersal to newly established sites. *Hemidactylus turcicus* was not observed at sites where *T. mauritanica* was detected from 7–9 September 2023. However, *H. turcicus* was observed at all five sites sampled on 10 September 2023, although generally in low abundance, especially when numerous *T. mauritanica* were observed nearby. Voucher specimens of *H. turcicus* from these five sites were collected (TNHC 117092 [DRD 11156], 117093 [DRD 11161], 117095 [DRD 11172], 117096 [DRD 11177], 117097 [DRD 11179]).

In total, 59 vouchered specimens of *T. mauritanica* have been collected at 11 separate, distinct sites across the San Antonio metropolitan area (Bexar County) (Fig. 2; Table 1). Additionally, photographic observations of *T. mauritanica* submitted to the Herps of Texas project on iNaturalist provided additional records of individual occurrence (iNaturalist 2023). In sum, these data suggest that *T. mauritanica* is relatively well established across San Antonio, possibly even into outlying areas. Observations of *T. mauritanica* have been reported since November 2018 across Bexar County, although the exact date when the species became established in the area is unclear. Single observations of *T. mauritanica* have been reported from adjacent Atascosa and Guadalupe counties as well (Fig. 2), although we were unable to determine if these observations represented established populations or single, transient individuals.

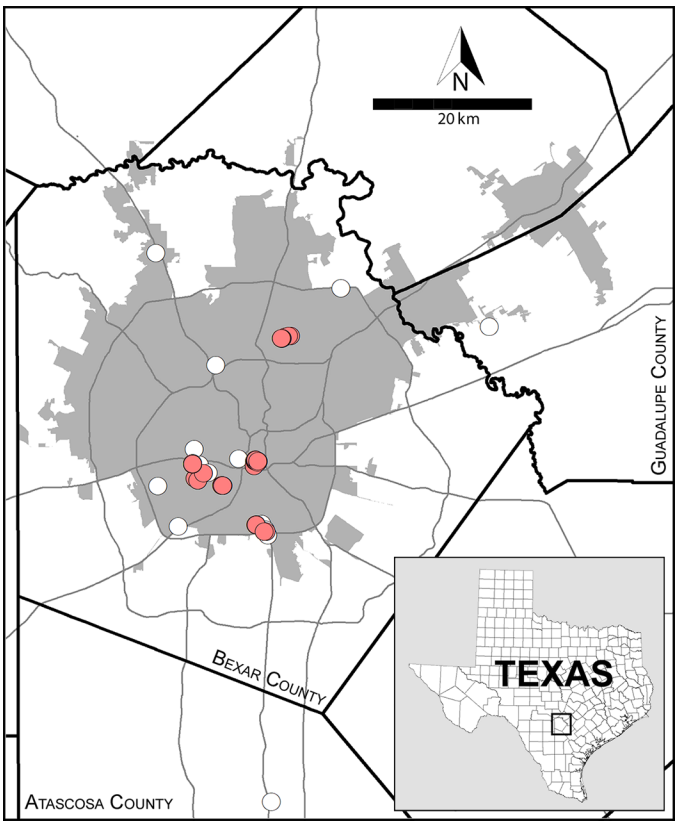

Figure 2. Map of San Antonio, Texas, USA, showing sites where Moorish Gecko (*Tarentola mauritanica*) voucher specimens (salmon circles) were collected and photographs (white circles) were taken in Bexar, Atascosa, and Guadalupe counties. Major roadways are marked by gray lines and San Antonio Urban Areas designated by the US Census are indicated by gray polygons.

When examining the spatial distribution of these observations, no clear trend or pattern emerges that helps to understand the origin of individuals or the population source. The locality of our specimens along Wurzbach Parkway is ca. 1.0 airline km north of the San Antonio International Airport, and multiple observations were near Joint Base San Antonio, which houses Kelly Field, a U.S. Air Force Base. The movement of commercial and/or military air cargo may present opportunities to introduce individuals outside their native range or spread individuals from previously established extralimital populations. The presence of hitchhiking individuals through the movement of goods and cargo has similarly been attributed to the introduction of *T. mauritanica* to Yucatán, Mexico (Ortiz-Medina et al. 2019) and Argentina (Díaz-Fernández et al. 2019). Given the absence of any nearby recognized, robust populations of *T. mauritanica*, individuals most likely were introduced in San Antonio as stowaways from further distances (e.g., locations within the native range of *T. mauritanica*), and if this was the case, individuals are likely to have been first introduced much earlier than 2018 to allow sufficient time for individuals to spread across large portions of San Antonio through diffusion dispersal.

San Antonio lies at a major intersection of commercial transportation. Interstate 35 runs southwest through San Antonio to Laredo (a major international commercial border crossing) and northeast to Austin and the Dallas–Fort Worth metropolitan area. Additionally, Interstate 10 runs east–west through San Antonio and connects Houston to El Paso, Texas, which has been recognized as a dispersal corridor for other non-native geckos (Davis and LaDuc 2019). Given that San Antonio is a nexus of transportation routes, *T. mauritanica* has an increased opportunity to rapidly spread throughout the state by hitchhiking on cargo or vehicles. Many individuals reporting introduced populations of *T. mauritanica* have speculated that populations have become established through the accidental and intentional release of captive individuals (e.g., Mahrdt 1998; Krysko et al. 2011; Arredondo and Núñez 2014), which could partially account for the widespread distribution of occurrence records throughout San Antonio. However, given that most of the locations where we collected our individuals were not associated with residential structures, individuals more likely became established while hitchhiking on construction materials (e.g., concrete piers, concrete drainage structures) or other cargo, although this remains uncertain.

The ecological effects of these established populations of *T. mauritanica* across Bexar County or other established locations are not fully known. These non-native geckos likely are consuming invertebrates (e.g., Barbadillo et al. 1999) and are indirectly competing with native insectivores. At sites where we found *T. mauritanica*, we generally observed few or no sympatric *H. turcicus*, but whether this is due to competition between the two species or predation, as *T. mauritanica* is known to consume lizards (Barbadillo et al. 1999), cannot be determined at this time.

Collectively, these 59 *T. mauritanica* voucher specimens are the first records of this species collected in Texas and in Bexar County, and they demonstrate that a large population has become established across San Antonio. Future studies should continue to survey for *T. mauritanica* across San Antonio, to understand the threat of dispersal of individuals into areas outside of the city, and to investigate both the risks this species poses to native species and the ecological interactions it has with local communities.

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