

1 **Advancing North: White-nosed coati's *Nasua narica* Range**

2 **Expansion in Arizona**

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4 Kinley Ragan^{1,2} (kinleyragan@gmail.com; orchid: 0000-0002-7534-5420),

5 Faith M. Walker³ (faith.walker@nau.edu; orchid: 0000-0001-8435-4452),

6 Lawrence E. Stevens⁴ (LStevens@musnaz.org; orchid: 0000-0003-4377-974X),

7 Jan Schipper¹ (jschipper@phoenixzoo.org; orchid: 0000-0002-8338-7874)

8

9 ¹ Field Conservation Research Department, Arizona Center for Nature Conservation / Phoenix

10 Zoo, Phoenix, Arizona, USA

11 ² School of Life Sciences, Arizona State University, Tempe, Arizona, USA

12 ³ School of Forestry, Northern Arizona University, Flagstaff, Arizona, USA

13 ⁴ Museum of Northern Arizona, Flagstaff, Arizona, USA

14

15 Corresponding Author:

16 Kinley Ragan¹

17 455 N Galvin Pkwy, Phoenix, Arizona, 85008, USA

18 Email address: kinleyragan@gmail.com

19

20 Keywords: climate change, species distribution, Southwestern U.S., *Nasua narica*,

21 mesocarnivore

22

23 **Abstract**

24 Over the past century, the white-nosed coati (WNC; *Nasua narica*) has expanded its
25 northernmost range from the United States-Mexico border into northern Arizona. WNC are
26 medium-sized, opportunistic omnivores that often occur in large groups (“bands”) and forage on
27 insects, fruits, and small vertebrates. We compiled data from iNaturalist, published literature,
28 Arizona Game and Fish records, museum collections, personal communications, and our own
29 camera trap photography to chronicle this range expansion. Historical records documented WNC
30 populations in mountainous areas along the US-Mexican border but rarely north of Tucson, AZ.
31 The popularity of using wildlife cameras in both research and recreation, paired with the
32 advancement of citizen science projects like iNaturalist have generated a vast amount of new
33 data on species distributions. With this new body of information we report the range of WNC
34 now occurs over 400 km farther north, extending north of Flagstaff, Arizona. Recent records
35 include occurrence in ponderosa pine forest that sustain sometimes heavy winter snow – an
36 environment vastly different from the species’ normal range. The northward expansion of this
37 meso-carnivore invites many questions about drivers of range expansion, including climate
38 change, mesopredator release, or simple opportunism. More research into the behavior and
39 ecology of WNC in the northern extent of their range is needed to guide understanding and
40 potential future management of this species, its impacts, and prediction of other such range
41 expansions.

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47 **Introduction**

48 White-nosed coatis (WNC; *Nasua narica* Linnaeus 1766) are semi-arboreal meso-
49 carnivores that range from northern South America to southwestern United States (US), with a
50 recently expanded distribution into northern Arizona. A member of Procyonidae, WNC are the
51 only coati species found in North America (Hoffmeister 1986, Cuarón et al. 2016). Originally
52 described by Linnaeus (1766) as *N. narica*, Handley (1966) reported that Linnaeus' description
53 was of a specimen with a unicolored tail, while Linnaeus' *N. nasua* had a black and white
54 banded tail. Hoffmeister (1986) reported that the Arizona *N. nasua* were likely the subspecies *N.*
55 *n. molaris* Merriam, but Hershkovits (1951) considered that subspecies to be synonymous with
56 *N. n. pallida* Allen. A more detailed taxonomic treatment remains outstanding.

57 The earliest record of WNC in the US was in 1892 at Fort Huachuca, just north of the
58 US-Mexico border (~31°19'57"N; Wallmo and Gallizioli 1954). At that time, it was considered
59 a rare sighting. WNC were established in the Chiricahua and Huachuca Mountain ranges during
60 the early 20th century (Cahalane 1939). However, as extensive mining and settlement took place
61 across southeastern Arizona, sightings of WNC were still considered rare, suggesting at least that
62 WNCs were rarely seen (Wallmo and Gallizioli 1954). A deputy game warden of the Chiricahua
63 Mountains, Bill Lee, called WNC "infrequent" at that time, referring to it as the "Mexican
64 cholugo" (Cahalane 1939).

65 By 1940, breeding WNC populations were well-described in southeastern AZ. Taber
66 (1940) wrote that a "northern invasion" of WNC was occurring, and in 1934 WNC was added to
67 the US mammals list because it was known to occur "sporadically on the American side of the
68 Mexican border" (Taylor 1934, Taber 1940). Thereafter, bands of WNC began being commonly
69 noted in the Chiricahua, Huachuca, Patagonia, and Tumacacori mountains (latitudes ~

70 31°29'20.72"; Cahalane 1939, Wallmo and Gallizioli 1954, Hall and Kelson 1959). By 1954, the
71 local community of the Huachuca Mountains began to view WNC as a nuisance species because
72 of injuries to dogs, depredation on chickens, and foraging on orchard fruit (Wallmo and
73 Gallizioli 1954).

74 Since then, the range of WNC has continued to expand northward. More bands have
75 become established at northerly latitudes, such as the San Carlos Indian Reservation (Kaufmann
76 et al. 1976). Hoffmeister (1986) reported WNC from Walnut Canyon National Monument and
77 Petrified Forest National Park; however, there are few further publications recognizing this
78 expansion. In 2008, the International Union for Conservation of Nature and Natural Resources
79 (IUCN) listed WNC habitat as following the oak woodlands of the southeastern region of the
80 United States, with WNC mainly in the Chiricahua and Huachuca Mountains (~31°33'18.58"N)
81 because of their affinity with "hardwood riparian canyons over 1,400 m" (Samudio et al. 2008).
82 In 2016, the updated IUCN range of WNC was drawn north of Interstate 40 in Flagstaff, AZ
83 (~35°11'51.93"N), showing an expansion from their records in 2008 to 2016 (Cuaron et al.
84 2016).

85 Today, WNCs have been consistently recorded in and north of Flagstaff, Arizona, a city
86 at a longitude of ~35°11'51.94"N (about 400 km north of the US-Mexico border) and at an
87 elevation of 2100 m, a substantial climate difference from their primary range (Cuaron et al.
88 2016). These reports of coati north of the southern margin of the Colorado Plateau stimulated
89 our inquiry into historical and recent records of their occurrence and changes in distribution. We
90 conducted a review of databases, literature, and museum specimens to document range changes
91 for WCN. Our records illuminate this species expansion into Arizona over the past century, as
92 well as confirming the northernmost distribution of the species.

93 **Methods**

94 To track occurrence records across time for WNC we collated data from 6 different
95 sources: iNaturalist, peer-reviewed literature, Arizona Game and Fish Department's (AZGF)
96 Heritage Data Management System (HDSM) records, Museum of Northern Arizona collections,
97 personal communications, and opportunistic camera trap photographs. For all records we
98 collected the year of sighting, latitude, longitude, individuals sighted (i.e., band or a single
99 individual), and photographic proof of presence. Only records with complete information were
100 included. When roadkill or WNC tracks were recorded, we categorized these as a single
101 individual.

102 iNaturalist is a citizen scientist project that encourages citizens with a cell phone to
103 photograph and document species around the world. These web-based platforms are commonly
104 used as a tool to document species distribution, phenology, and seasonal events, among many
105 other observations. Because records are georeferenced, have attached photographs, and are
106 reviewed by professionals to earn the title of 'research grade', their authenticity is confirmed. We
107 downloaded 322 research grade iNaturalist results in March 2021 with the parameters of "*Nasua*
108 *narica*" and the filter of "Arizona" were applied (GBIF 2021). The timing of records ranged
109 from 1999 to 2021.

110 To gain historical and peer-reviewed context of coati presence in Arizona we used
111 Google Scholar and the search terms "*Nasua narica*" and "Arizona" to explore the literature.
112 Over 700 results were returned; however, fewer than 50 mentioned WNC sightings in the state of
113 Arizona, and only 38 of them were unique records. Publications and accounts dated from early
114 1892 to October 2019. When specific coordinates were not provided, an estimated geographic

115 reference from the paper was used. If an account was repeated in the literature, only the initial
116 publication was recorded.

117 We secured Heritage Data Management System (HMS) records of confirmed WNC
118 sightings by AZGF and US Fish and Wildlife Service biologists from 1983 to 2018.
119 Additionally, wildlife camera trap photos with geographic coordinates from the Verde were
120 obtained from wildlife biologists for photographic evidence of WNC. Lastly, several personal
121 communications from reliable biologists were included of WNC sightings in northern Arizona.

122 **Results**

123 We documented 626 records of coati sightings in Arizona from 1892 to 2021, including:
124 322 from iNaturalist; 242 from HDMS reports; 39 from peer-reviewed literature (Table 1); 16
125 from wildlife cameras; 4 Museum of Northern Arizona specimens; and 3 from personal
126 communications. The Museum of Northern Arizona specimens expanded our WNC distribution
127 and history data. An adult male WNC specimen (MNA Z9-698) was collected on the Babbitt
128 Brothers Spur Ranch at the edge of Anderson Mesa near Flagstaff, at an elevation of 1825 m on
129 30 January 1955. An adult male WNC specimen was recovered as a salvaged roadkill 29 km NW
130 of Flagstaff on Highway 180 at 35°20'46.86"N on 8 July 2016. At 2,437 m, this specimen
131 appears to be the highest elevation reported for WNC in Arizona. This specimen is curated at the
132 Museum of Northern Arizona as MNA Z9-5512. Additional observations and photographs of
133 WNC and their tracks were taken along the Rio de Flag Canyon at MNA, and at Walnut Canyon
134 National Monument during the winter of 2015 and 2016.

135 Most of the literature records in the early 1900s were of individuals (e.g., Taylor 1934,
136 Cahalane 1939, Wallmo and Gallizioli 1954), suggesting that only dispersing males were moving
137 northward into new territories at that time (Table 1, Fig. 1). However, by the mid-1900s

138 sightings of bands became more prevalent, although those records remained closer to the US-
139 Mexico border (Table 1). Locations used from iNaturalist confirmed observations farther north
140 than historically recorded (Fig. 1). In 2015, WNC records at latitudes north of Phoenix began
141 appearing more commonly (Fig. 2). All northern sightings were of individuals, until 2018 when
142 records of bands were reported south of Sedona, Arizona at a latitude of 34°43'35.98"N (GBIF
143 2021). In 2014, a research project along the Verde River (latitude: ~ 34°2'36.78"N) recovered
144 numerous camera trap photos of WNC, primarily in sites along river canyons (Fig. 3).
145 Additionally, photographs of WNC along the Mogollon rim in Payson, Arizona were
146 documented in 2017 and 2018 (Fig. 4). We received verified photos of an individual WNC from
147 citizen scientists at two locations near houses within the city of Flagstaff (latitudes: 35°13'45.98"
148 N and 35°13'17.47"N). Lastly, in Fall of 2019, two additional WNC sightings were reported by
149 biologists in northern Arizona: one at Bear Lake Campground (latitude: 34°17'2.51"N) and the
150 other near upper Lake Mary (latitude: 35°4'51.67"N) (Haight personal communication 2019,
151 Tellez personal communication 2019, respectively).

152 **Discussion**

153 It comes as no surprise that WNC, a versatile, highly adaptable, social omnivore, whose
154 males disperse and are solitary between breeding seasons, is readily capable of colonizing new
155 territory. Additionally, the geography of central Arizona lends itself well as a conduit for
156 northern expansion, as hardwood river canyons connect higher and lower elevations through
157 riparian habitat corridors (Frey et al. 2013). Our data indicate that WNC are now occurring
158 farther north more frequently.

159 The opportunistic ecology and diet of WNC have likely facilitated their ability to expand
160 into new regions. WNC occur in bands averaging 12 individuals, typically consisting of females

161 with their young, while males are solitary or join a small bachelor troop (Smythe 1970, Hass and
162 Valenzuela 2002). Bachelor males only interact with females during the mating season in April,
163 and young are born in June (Smythe 1970, Hoffmeister 1986, Trovoti et al. 2010, Cuaron et al.
164 2016, Emmons and Helgen 2016). Outside of the mating season, adult WNC males disperse to
165 find new territories, which enables range extension. Additionally, WNC are omnivorous,
166 consuming insects, fruits, seeds, and forest litter invertebrates, and occasionally small- to
167 medium-sized vertebrates (Wallmo and Gallizioli 1954, Smythe 1970, Kaufmann et al. 1976,
168 Gompper 1995, Valenzuela 1998). It is probable that this expansive diet has facilitated their
169 ability to exist in different habitats, adapting to local food sources as resource conditions allow
170 (Kaufmann et al. 1976, McColgin et al. 2003, McColgin et al. 2018).

171 WNC have high affinity to riparian areas, especially in dry regions, which provide
172 discrete corridors for their expansion into northern regions (Hoffmesiter 1986; Frey et al. 2013).
173 While they have been documented in a wide array of habitats, WNC most often occupy stands of
174 pine forest (*Pinus*), oak-pine woodland (*Quercus*), chaparral, sycamore (*Plantanus*), walnut
175 (*Juglans*), maple (*Acer*), and other coniferous forests between 1,400 and 2,450 m elevation
176 (Wallmo and Gallizioli 1954, Kaufmann et al. 1976, Frey et al 2013). Riparian areas provide
177 diverse dietary and habitat needs, including: tree canopy cover, presence of water, availability of
178 food resources, and seasonal dispersal, particularly in more arid river corridors, like the Verde
179 River and its many tributaries (Hass 2002, Valenzuela and Ceballos 2000; Frey et al. 2013).
180 WNC have been recorded in Organ Pipe Cactus National Monument at what has been described
181 as their “lowest, driest, and hottest” reported location, with only 186 mm/yr of precipitation
182 (Kaufmann et al. 1976).

183 WNC are one of many Mexican-Neotropical species moving northwards as climate
184 changes, including invertebrates and other vertebrates (Brown and Davis 1995). For example, all
185 butterfly species added to the Grand Canyon National Park list in the past 70 years, and which
186 are native to North America, have been Mexican-Neotropical species (Garth 1950, Stevens
187 2012). A similar case may be that of the Central American Masked Clubskimmer dragonfly
188 *Brechmorhoga pertinax*, which has been reported breeding in northern Arizona (Stevens and
189 Bailowitz 2009). Several bird species native to North America also are undergoing northward
190 range expansion, such as Great-tailed Grackle *Quiscalus mexicanus* (Wehtje 2003). Other non-
191 flying mammals expanding their ranges northward in the US Southwest (in addition to coyote
192 *Canis latrans*) include collared peccary *Pecari tajacu* and American hog-nosed skunk *Conepatus*
193 *leuconotus leuconotus* (Holton et al. 2021). Peccary range expansion appears to be related to the
194 slightly warmer winter temperatures to which the Southwest is now subject (Bender et al. 2014),
195 and both peccary and hog-nosed skunk have been detected on the north side of the Colorado
196 River in the Grand Canyon (Stevens 2013; Holton et al. 2021). Too few distributional data are
197 available to understand the ranges of many bats, but the phyllostomid Mexican long-tongued bat
198 *Choeronycteris mexicana* has been detected in Grand Canyon National Park (Stevens 2013).
199 Lastly, jaguar *Panthera onca* have recently been documented moving between the borderlands
200 into southeastern Arizona along the same approximate route as WNC (Culver et al. 2016). Thus,
201 WNC appears to be one of many Mexican-Neotropical taxa expanding their ranges northward
202 into the southwestern US.

203 During the last century, the Arizona landscape has changed dramatically (Hutchinson et
204 al. 2000, Jenerette and Wu 2001, Turner et al. 2003). Humans have altered habitat conditions,
205 allowing allowed WNC to cross some of the arid landscape gaps that previously restricted them

206 to southern Arizona. Wildlife populations and habitat availability also have greatly changed
207 during this interval. With fewer large carnivores and less intact riparian forest cover,
208 mesocarnivore release may have occurred, allowing WNC to proliferate and expand their range.

209 Today, WNC populations in the Chiricahua and Huachuca Mountains are well-
210 established and often attract public attention in the Chiricahua National Monument, where they
211 are seen daily by visitors. Continued individual sightings in Flagstaff north of Interstate 40, and
212 with bands documented at higher latitudes indicate that WNC will continue to move northward.
213 WNC are well studied in Central America; however, data on their behavior and ecology at the
214 northernmost extent of their range are outstanding. Although we can speculate on driving factors,
215 we have no direct evidence to suggest why they are expanding northward now. If the current
216 trends observed in our data continue, WNC may soon disperse to Grand Canyon National Park
217 and the Colorado River corridor, and other suitable habitats in northern Arizona. Such changes
218 may be of interest to land managers, who might see WNC as welcome guests or regard them as
219 invading “southern pests”.

220 Dispersal and range expansion are natural processes; however, relatively rapid range
221 expansions also can indicate larger issues that may warrant scientific and managerial attention.
222 Further research is needed to understand WNC habitat selection and interactions with northern
223 species. Cuarón et al. (2016) stated that large-scale habitat loss threatens US populations of
224 WNC, and warn that US populations may be becoming genetically isolated from Mexican
225 populations. To better understand the potential impact of WNC on other wildlife and WNC
226 movement corridors, camera trapping, animal collaring, genetic assessments of population
227 connectivity, and diet assessment should be conducted to develop information about their
228 distribution, home range size, and behavior. However, in the short term it will be important to

229 conduct research on the mechanisms driving WNC range expansion, and how their presence and
230 occurrence in developed areas might impact existing management actions. Such data can provide
231 the basis for a predictive habitat model to forecast WNC movement and habitat use, and to
232 improve prediction of adaptive management options for future vertebrate communities (e.g., Frey
233 et al. 2013). With global climate change continuing to reshape southwestern landscapes, more
234 information on transient and rapidly adapting species like WNC and their responses to these
235 changes is essential for understanding the future of southwestern biotic assemblages.

236

237 **ACKNOWLEDGEMENTS**

238 We thank the Museum of Northern Arizona for supporting L. Stevens' work, and Janet
239 Gillette for assistance with specimen data from the MNA collection. We also thank Arizona
240 Game and Fish's Heritage Data Management department for their contribution of records. Lastly,
241 we thank the field volunteers (Chelsey Tellez, Ray Tellez, Samantha Lloyd, and Sandy Leander)
242 who helped manage and retrieve cameras and our pilot from the Arizona Pilots Association
243 Tommy Thomason.

244

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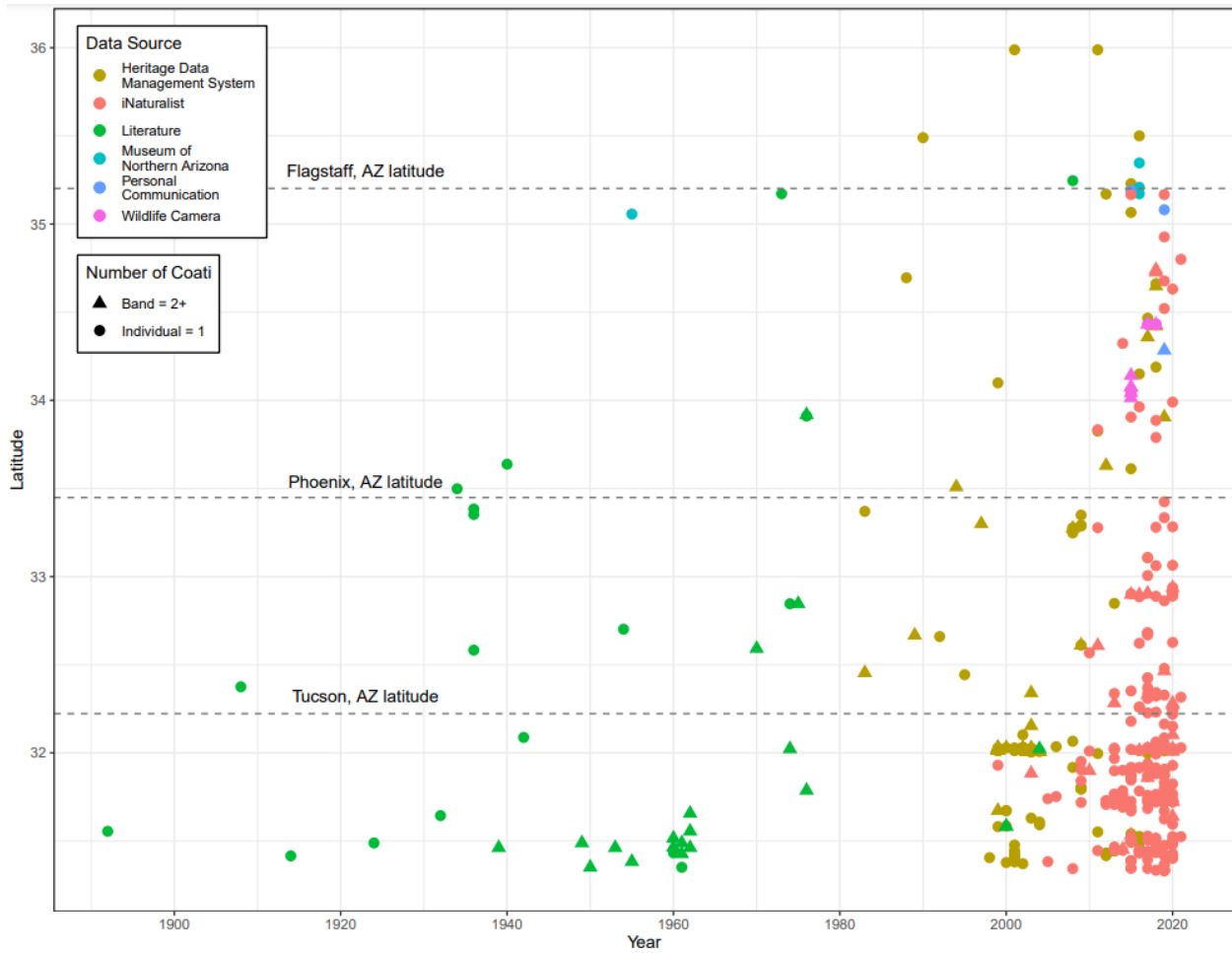
Tables & Figures

343 **Table 1: Records from literature of white-nosed coati *Nasua narica* in Arizona, United**
 344 **States of America.**

Year	Latitude (N)	Longitude (W)	# Individuals	Data Type	Citation
1892	31° 33' 18.576"	- 110° 20' 58.848"	1	Photo	Wallmo & Gallizioli 1954
1908	32° 22' 29.9532"	- 109° 3' 24.2172"	1	Testimony	Cahalane 1939 (Bailey 1931)
1914	31° 24' 56.2608"	- 110° 43' 48.7812"	1	Photo	Wallmo & Gallizioli 1954
1924	31° 29' 20.724"	- 110° 24' 32.2992"	1	Photo	Taylor, 1934
1932	31° 38' 39.0264"	- 109° 10' 16.6872"	1	Photo	Cahalane 1939
1934	33° 29' 53.7216"	- 111° 27' 53.4744"	1	Testimony	Taylor 1934
1939	31° 27' 42.9408"	- 111° 14' 13.254"	band	Testimony	Taber 1940
1940	33° 38' 14.9784"	- 109° 19' 49.4004"	1	Testimony	Taber 1940; Taylor 1934
1942	32° 5' 15.6732"	- 112° 54' 24.3756"	1	Testimony	Kaufmann et al. 1976
1949	31° 29' 20.724"	- 110° 24' 32.2992"	band	Testimony	Wallmo & Gallizioli 1954
1950	31° 21' 2.8764"	- 110° 16' 51.6864"	band	Testimony	Risser 1963
1953	31° 27' 43.4412"	- 110° 58' 53.58"	band	Testimony	Fred Fendig, Risser 1963
1954	32° 42' 5.1372"	- 109° 52' 17.6916"	1	Testimony	Wallmo & Gallizioli 1954
1955	31° 22' 59.0232"	- 110° 35' 7.7136"	band	Testimony	Carl Yeager, Risser 1963
1960	31° 27' 54.1872"	- 110° 17' 5.3484"	band	Testimony	William Brown, Risser 1963
1960	31° 30' 57.456"	- 110° 33' 32.922"	band	Testimony	Don Havluk, Risser 1963
1960	31° 25' 59.3508"	- 111° 8' 52.386"	1	Testimony	Risser 1963
1960	31° 29' 46.7196"	- 110° 51' 44.352"	band	Testimony	Charles Morgan, Risser 1963
1961	31° 29' 20.724"	- 110° 24' 32.2992"	band	Testimony	Sewell Goodwin, Risser 1963
1961	31° 21' 2.8764"	- 110° 16' 51.6864"	1	Photo	Risser 1963
1961	31° 25' 37.3476"	- 110° 17' 28.0428"	band	Testimony	James Holt, Risser 1963
1962	31° 33' 18.576"	- 110° 20' 58.848"	band	Testimony	Pratt 1962
1962	31° 39' 24.84"	- 110° 52' 9.5952"	band	Photo	Risser 1963
1962	31° 27' 43.4412"	- 110° 58' 53.58"	band	Photo	Risser 1963
1970	32° 35' 30.4764"	- 109° 50' 59.5428"	band	Testimony	Kaufmann et al. 1976
1973	35° 10' 18.6888"	- 111° 30' 34.4736"	1	Testimony	Salomonson 1973
1974	32° 50' 45.3948"	- 110° 38' 11.4936"	1	Testimony	Kaufmann et al. 1976
1974	32° 1' 21.432"	- 109° 21' 51.7896"	band	Photo	Lanning 1976
1975	32° 50' 45.3948"	- 110° 38' 11.4936"	band	Testimony	Kaufmann et al. 1976
1976	31° 47' 13.6428"	- 111° 34' 56.6292"	band	Photo	Kaufmann et al. 1976
1976	33° 55' 3.18"	- 109° 28' 32.1744"	band	Testimony	Kaufmann et al. 1976
1976	33° 54' 38.502"	- 109° 35' 7.5732"	1	Testimony	Kaufmann et al. 1976
2000	31° 34' 59.9988"	- 110° 25' 0.0012"	band	Photo	Hass 2002
2000	31° 34' 59.9988"	- 110° 25' 59.9988"	band	Photo	Hass and Valenzuela 2002
2004	32° 1' 21.432"	- 109° 21' 51.7896"	band	Photo	McColgin et al. 2017
2016	North of	I-40	1	Testimony	Cuaron et al. 2016

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346 Fig. 1. Latitudinal expansion of white-nosed coati by year (1892 to 2021). Each data point
347 indicates either an individual or a band of coatis from one of six data sources: Heritage
348 Data Management System, iNaturalist, literature, Museum of Northern Arizona, personal
349 communications, and wildlife camera photos.



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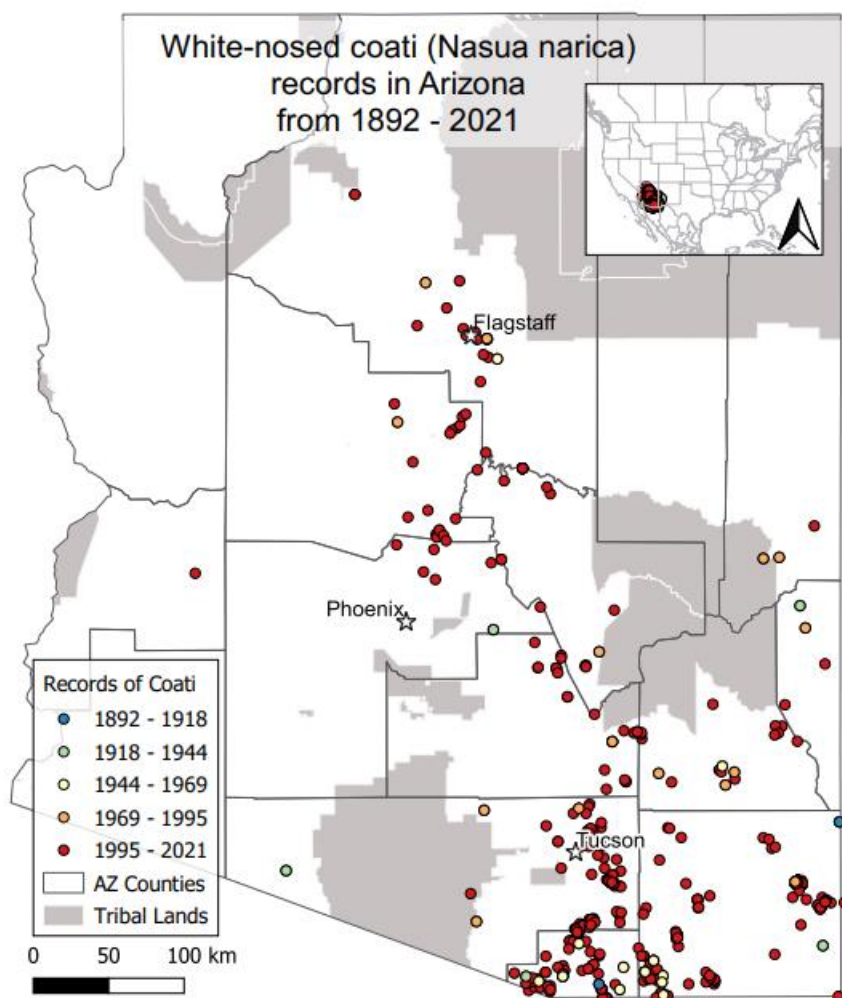
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356 Fig. 2. Coordinates of white-nosed coati in Arizona from 1892 – 2021. Each data point indicates
357 a documented sighting of one or more white-nosed coatis in Arizona based on records
358 from literature, iNaturalist, Heritage Data Management System, Museum of Northern
359 Arizona, personal communications, and wildlife camera photos.



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365 Fig. 3. Wildlife camera photo of an individual white-nosed coati along the Verde River, Arizona
366 in 2015.



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376 Fig. 4. A band of 5 white-nosed coatis along the Highline Trail in Payson, Arizona in 2018.



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