



Testicular Abnormalities in the Invasive Argentine Black-and-White Tegu (*Salvator merianae*) in the Florida Everglades

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The Argentine Black-and-White Tegu (*Salvator merianae*) is a terrestrial lizard native to South America that has become established in central and southern Florida (Meshaka 2011; Krysko et al. 2016). The species was introduced to Florida through the exotic pet trade, and the first wild population was discovered in 2006 in Hillsborough and Polk Counties in west-central Florida (Hardin 2007). In 2012, Pernas et al. (2012) observed a female tegu nesting in south-eastern Florida’s Miami-Dade County. Since then (through 2022), over 6,000 verified tegu sightings have been recorded in that county, based on reports to the Early Detection and Distribution Mapping System (EDDMapS 2023). Research on the morphology and reproductive anatomy of individuals from Florida’s invasive tegu populations is scarce, as most of the research conducted has focused on their spatial ecology and diet (e.g., Klug et al. 2015; Mazzotti et al. 2015; Jarnevich et al. 2018; Offner et al. 2021). Furthermore, despite its broad native range and abundance, little research on wild tegus exists other than on distribution, reproductive habits, management, or how those factors relate to their commercial harvesting for skins (Fitzgerald et al. 1991; Naretto et al. 2015). Efforts to eliminate invasive populations in Florida, however, present opportunities to examine non-captive individuals on a finer scale — including internal anatomy — and create a baseline to which abnormalities can be compared. A recent observation of egg retention in wild-caught Burmese Pythons (*Python bivittatus*) in Florida, also an invasive species in the state, demonstrates the value of these types of observations, especially as egg retention had previously been observed only in captive pythons and its occurrence could affect the population dynamics of the species (Anderson et al. 2022).

Due to the increasing prevalence of tegus in southern Florida, removal of individual tegus from the environment is an important component of population suppression, especially to limit expansion into Everglades National Park (ENP), where they are anticipated to have detrimental effects on native flora and fauna. As part of the tegu mitigation efforts by the National Park Service (NPS), tegu traps are set across the eastern portion of ENP and along nearby canals to the east of the park (e.g., Pernas et al. 2012; Udell et al. 2022). Individuals caught in these traps are transferred to the U.S. Geological Survey (USGS) for euthanasia and necropsy. During the necropsy, measurements and samples are collected for various collaborative research projects. From February to October 2022, we necropsied 490 tegus, 275 of which were males. Due to resource limitations, full necropsies, which consist of checking for parasites, weighing fat stores, measuring and recording the status of reproductive organs, and examining digestive contents, in addition to standard morphological measurements of weight, snout-vent length (SVL), and total length, are primarily performed on sexually mature individuals with SVLs of at least ~27 cm and on any individuals caught within ENP. Of the 275 male tegus, we performed full necropsies on 109 individuals and observed notable abnormalities in the testes of two (1.8%).

The first of the two individuals was captured on 3 June 2022 from a trap along a linear water management canal just east of ENP. The tegu had a SVL of 41.1 cm and weighed 2,750 g. Upon necropsy, we noted an enlarged right testis, which was hard, dark brown/purple in color, and significantly larger than the left testis, which was flaccid, off-white in color, and smaller than typically observed in males of that size and

time of year (Figs. 1A, 1B). Upon bisecting the right testis to examine its internal structure, we found that the discoloration was uniform, and the inside of the testis had a granular texture (Fig. 1C). This was contrary to the more typical light tan color and gel-like texture of testes found in tegus from this population (Fig. 2). The right testis was 3.69 g in mass, with a length of 2.4 cm and a width of 1.8 cm. The left testis was 0.45 g, with a length of 1.2 cm and a width of 0.9 cm. No hemorrhaging or discharge from the enlarged right testis was evident.

The second case of testicular abnormality was observed in an individual captured on 17 August 2022 along another canal (approx. 3.0 km south-southwest of the first). This tegu had a SVL of 38.4 cm and weighed 2,056 g. In this case, the testes were laterally fused and oriented medially in the body (Fig. 2). The testes were similar in size and condition, semi-turgid to turgid, but fused asymmetrically at an angle. A thin layer of connective tissue between the fused testes connected the intestines to the tegu's internal dorsal surface. The efferent ducts were thickened/convoluted, which is typical of tegus during the breeding season (Meshaka et al. 2019).

The causes of these gonadal abnormalities or their effect on the health and reproduction of the individual tegus are unknown. Ample evidence demonstrates that various chemicals can disrupt thyroid hormones and therefore gonadal development across vertebrates (Rivera and Lock 2008).

Hormonal irregularities originating from another organ would normally be expected to cause bilateral abnormalities so, while hormones may not explain the first case, where only one of the testes was enlarged and discolored, they may hold more relevance to the second case. Several studies have examined the link between hormonal disruption and gonadal irregularities in reptiles (Guillette et al. 1995; Cheek 2006). Endocrine-disrupting contaminants from environmental chemicals are among several triggers of thyroid dysfunction (Guillette et al. 1994; Crain et al. 1998; Parsley et al. 2015; Wotherspoon and Burgin 2015) and malformations associated with teratogenic processes (Browder et al. 1993; Ferraz et al. 2021). These two individual tegus were captured near canals adjacent to agricultural land associated with pollutants from agricultural runoff like nitrogen, phosphorus, heavy metals, and chlorinated hydrocarbons used in pesticides (Perry 2008; Daroub et al. 2011; Orem et al. 2019; Yoder et al. 2020; Janssen et al. 2022; Zacharias and Kaplan 2022). However, the extremely low frequency with which we observed testicular abnormalities makes a broad-scale environmental cause seem unlikely. A deformity incidence of >15% in a population is thought to be indicative of an environmental cause (Tave et al. 1983), a notion that was implicated in the high rate of morphological deformities (18.3%) documented in an invasive catfish population in a region of Brazil where aquatic ecosystems experience anthropogenic

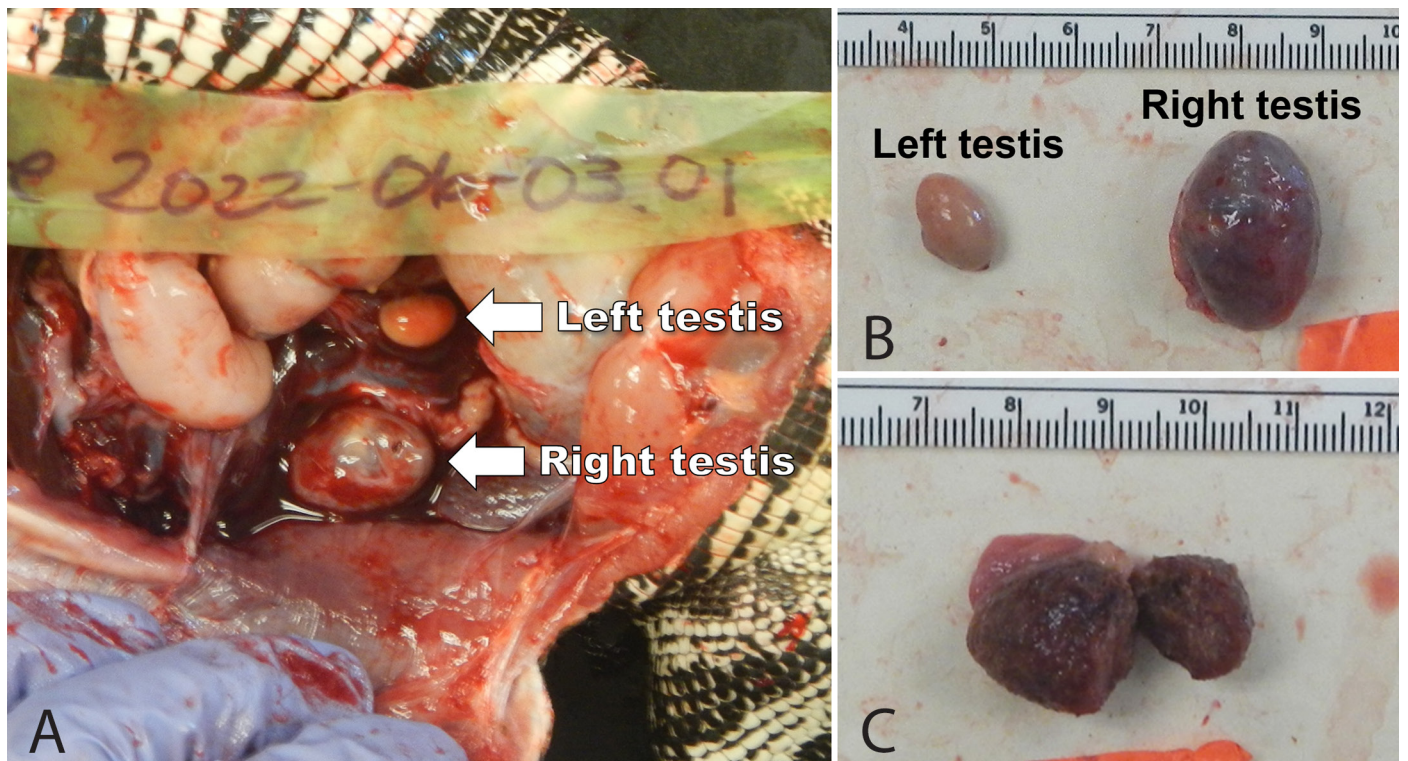


Figure 1. Testes of an Argentine Black-and-White Tegu (*Salvator merianae*) captured on 3 June 2022 along a canal directly east of Everglades National Park in Florida, USA: Both testes (including the abnormal right testis) in the abdominal cavity of the tegu, whose head is to the left of the photograph (A); both testes removed from the tegu and placed side-by-side (B); and bisected right testis to reveal its uniform discoloration and granular texture (C). Photographs courtesy of U.S. Geological Survey.

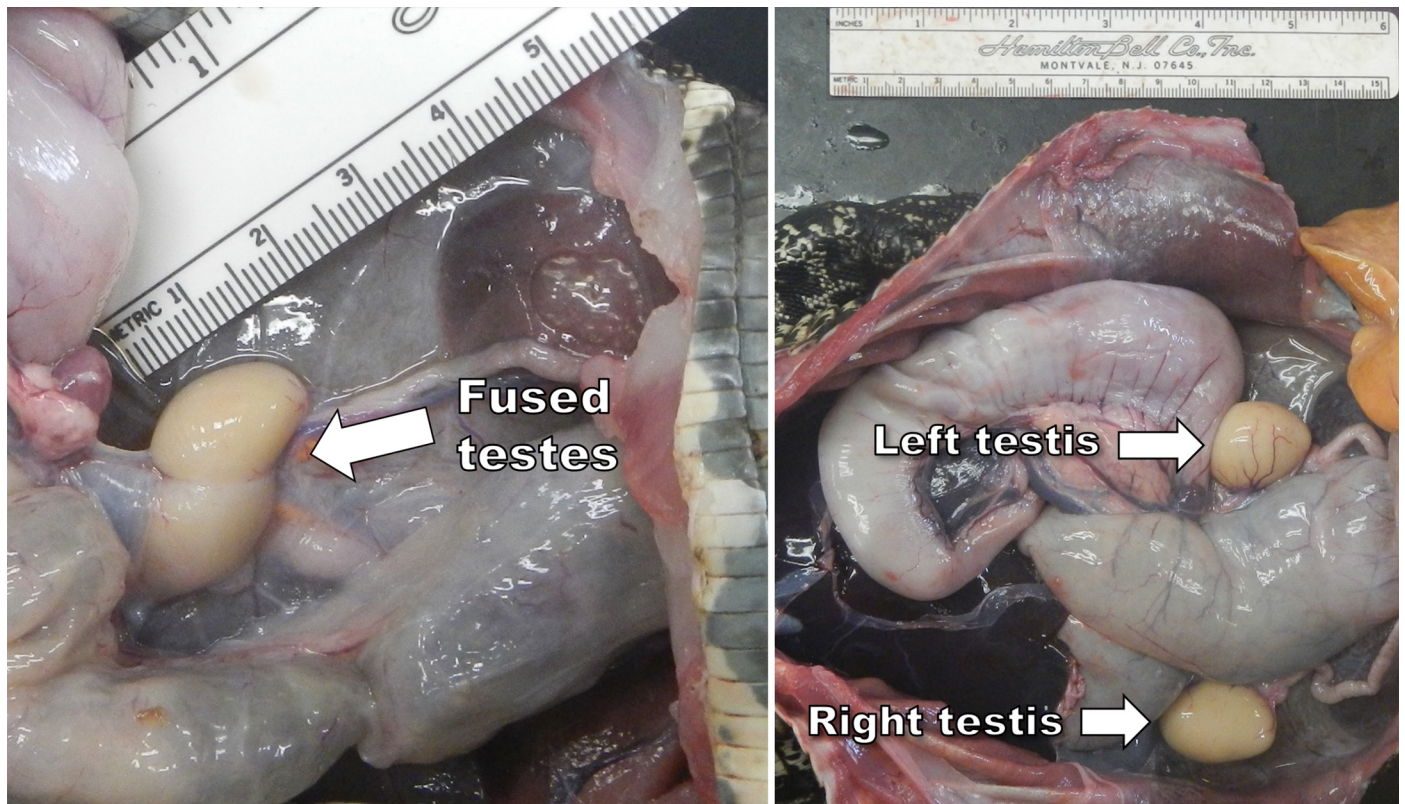


Figure 2. Fused testes (left) of an Argentine Black-and-White Tegú (*Salvator merianae*) captured on 17 August 2022 along a canal east of Everglades National Park in Florida, USA, and an example of the typical appearance of testes (right). Photographs courtesy of U.S. Geological Survey.

pollution and extensive fragmentation by dams (Ferraz et al. 2021). Contrarily, a genetic factor might have played a role in the case of the fused testes, possibly related to reduced gene flow of introduced species, which can increase endogamy or inbreeding and any associated abnormalities. Not enough research has been done on wild tegu populations in native or invasive ranges to determine the baseline rate of such abnormalities and whether the 1.8% frequency we observed can be considered normal.

Without histopathological information on the enlarged and discolored testis seen in the first case, which was disposed of before such analyses could be performed, we cannot determine the cause of its condition. Potential causes of the unusual appearance include infection (by parasite, virus, or bacterium), granulomatous inflammation (typically triggered by a tuberculosis-inducing bacterium), abscesses, or neoplasia (abnormal tissue growth; Terio et al. 2018). Limited research addresses the presence of tumors and neoplasia in reptiles, and the existing research has focused on captive reptiles (Hernandez-Divers and Garner 2003; Garner et al. 2004). During our literature review, we did not find any examples of abnormalities similar to what we observed. Goldberg (1989) documented an instance of granulomatous orchitis in the left testis of a Western Fence Lizard (*Sceloporus occidentalis*), but the affected testis was smaller than the other testis and was light yellow in color, which does not match our observation.

Morphological measurements and necropsies obtained during removal of invasives affords a unique monitoring opportunity to assess ecosystem health for native species that would be similarly affected by contaminants or other anthropogenic factors (e.g., Ferraz et al. 2021). Additional sampling over time would be necessary to determine whether either of these instances are reoccurring throughout the population or could be linked to any associated environmental or genetic phenomena. The trapping and necropsy of tegus in the eastern region of ENP and along nearby canals is ongoing, thus allowing for further sampling of the tegu population in southern Florida. Also valuable would be the documentation of similar occurrences in wild tegus and closely related species in their native range. Given their potential to become established across the southeastern United States (Jarnevich et al. 2018; Haro et al. 2020; Currylow et al. 2021; Goetz et al. 2021), we need to gain a better understanding of *S. merianae*, including their reproductive biology and any associated abnormalities that may affect their ability to proliferate. The more that is known about this species and its invasive populations, the more effectively their impact can be mitigated.

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