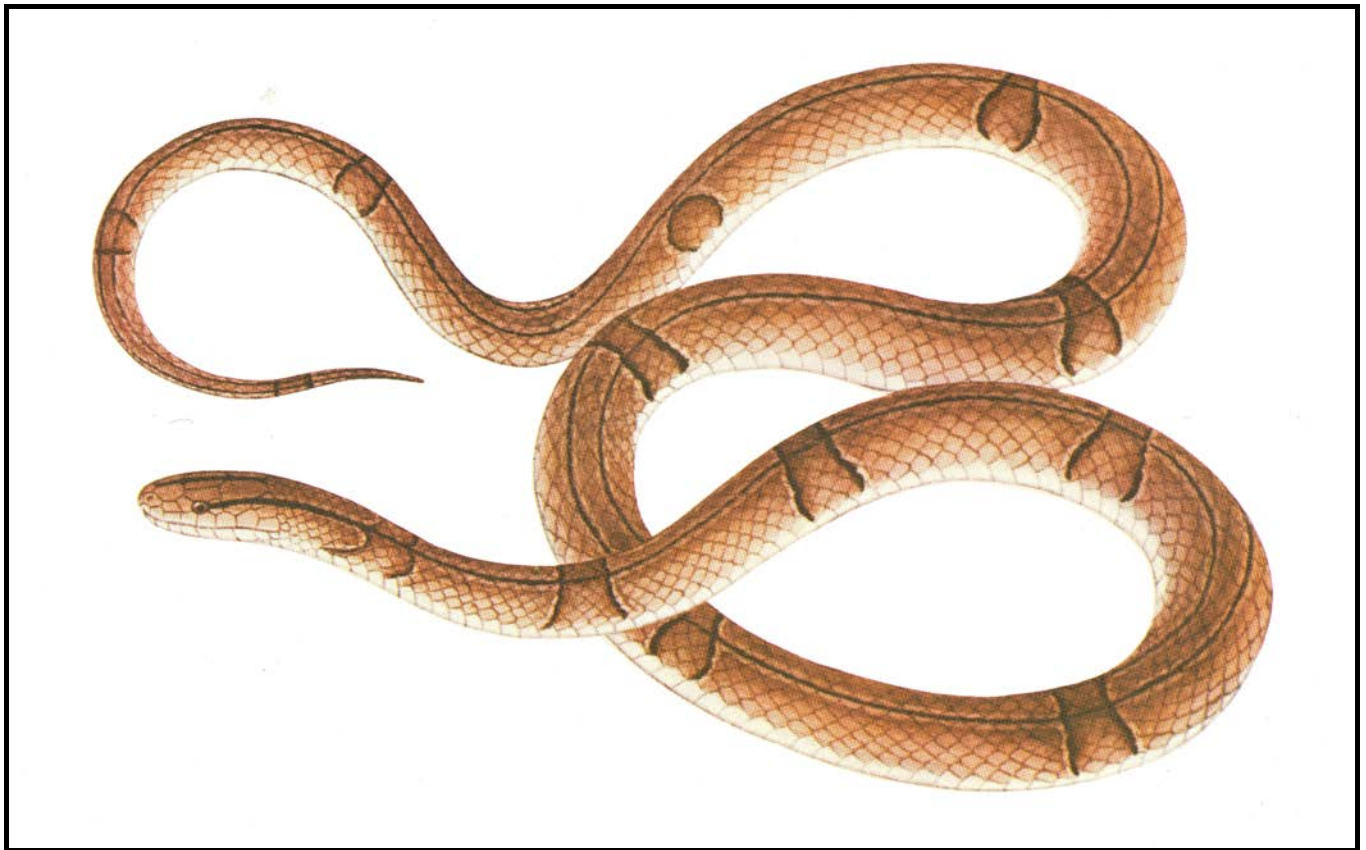


BULLETIN
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Cover: Black-banded trinket snake, *Oreocryptophis porphyraceus*. Drawing (as *Elaphe porphyracea pophyracea*) from from *A Monograph of the Snakes of Japan* by Moichiro Maki, 1931.

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Reptile Fauna of Kungulu and Mbiye Islands, Upper Congo River: Current Knowledge and New Records

Gabriel Badjedjea¹, Jeannot Bodongola Akuboy², Marc Colyn³ and Olivier S. G. Pauwels⁴

Abstract

We present new records of reptiles (Testudines and Squamata) from Kungulu and Mbiye Islands on the upper Congo River in the vicinity of Kisangani, Tshopo Province, northeastern Democratic Republic of the Congo. Mbiye Island's currently documented herpetofauna includes 19 species (two turtles, seven lizards and ten snakes), all but two recorded here for the first time from the island. At least three additional snake species are reported by the villagers of Mbiye Island but they are not yet documented. Kungulu Island's herpetofauna includes at least 13 species (one turtle, four lizards and eight snakes). Unpublished reports listed nine additional reptile species from Kungulu Island, but they require confirmation.

Keywords

Biodiversity, herpetofauna, Squamata, Testudines, river island, Equatorial Africa, Tshopo, Democratic Republic of the Congo.

Introduction

Mbiye Island (Figure 1) is located in the upper Congo River, three km upstream of Wagenia Falls which mark the upper limit for navigation. It is inhabited and lies at about three km from Kisangani city in Tshopo Province, northeastern Democratic Republic of the Congo. It is 14 km long and its maximal width is four km, its surface is about 5600 ha. It is separated from the northern bank of the Congo River by 200 to 250 m of water, and from the southern bank by about 700 to 900 m. The island's elevation varies between 370 and 423 m above sea level (Nshimba, 2005). A large proportion of the eastern part of the island was declared a forest sanctuary in 2008, under management by the University of Kisangani (Mbangilwa Mukombe, 2009). Originally covered with lowland evergreen wet forest, its vegetation has been much degraded by human activities, mainly forest conversion to agricultural farmlands, wood charcoal production and illegal logging. Firewood is also collected on the island to bake bricks used for building constructions in nearby Kisangani. The dominant tree species of the remaining forest patches are: *Coelocaryon botryoides* Vermeulen; *Gilbertiodendron dewevrei* (De Wildeman) J. Léonard; and *Scorodophloeus zenkeri* Harms (Gembu Tungaluna et al., 2013).

Kungulu Island (= Kongolo Island), lies 14 km west-northwest, thus downstream, from Kisangani. It is much smaller than Mbiye Island, about 4 km long with a maximum width of about 500 m, and with a surface area of about 100 ha. The elevation of the island is about 390 m above sea level. The dominant forest tree species are *Celtis mildbraedii* Engler and *Piptadeniastrum africanum* (J. D. Hooker) Brenan (Amani et al., 2013). Kungulu

Island is located below the Wagenia Falls. Its forest cover, long degraded by human activities, increased when it was acquired by the University of Kisangani in 1976 (Mwana-Kimbulu, 1982). Kungulu Island lies at the confluence of the Lindi and Congo Rivers, along the northern bank of the Congo River, from which it is separated by about 200 m of water.

Kisangani (once known as Stanleyville) and its surroundings have been the subject of a number of dedicated herpetological studies for over a century (see Laurent [1965] and literature cited therein). However, Kungulu Island has been only superficially surveyed for herpetofauna in the 1970s and 1980s, and Mbiye Island has been so far totally neglected. In the course of



Figure 1. Swamp forest on Mbiye Island. Photograph by G. Badjedjea.

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several recent field surveys (2016–2018) with the primary objectives to document the amphibian and small mammal faunas of Mbiye Island, reptiles were encountered, and occasionally preserved. We detail hereafter this small but diverse collection, representing new herpetological records for the island. In addition, we present unpublished material collected in the 1980s on Kungulu Island and review the currently available data on its herpetofauna.

Material and Methods

Mbiye's voucher specimens were injected *in situ* with 90% ethanol then preserved in 70% ethanol. They are permanently deposited in the herpetological reference collections of the *Centre de Surveillance de la Biodiversité* (CSB:Herp) in Kisangani, Democratic Republic of the Congo, and of the Royal Belgian Institute of Natural Sciences (RBINS), Brussels, Belgium. Kungulu's voucher specimens were injected with 4% formalin then preserved in 70% ethanol. Photographic and preserved material was identified using the keys and morphological information provided by Schmidt (1919, 1923), Gans (1959), Broadley and Wallach (2009), Wagner et al. (2009), Ceriaco et al. (2016), Wüster et al. (2018) and Greenbaum et al. (2021). Snake ventral scales were counted according to the method of Dowling (1951). Snake dorsal scale rows were counted at one head length behind head, at midbody (above the ventral corresponding to half of the total number of ventrals), and at one head length before vent; subcaudal counts exclude the terminal pointed scale. Paired meristic characters are given left/right.

Morphological abbreviations: DSR = number of dorsal scale rows; IL = number of infralabials (for snakes, followed in brackets by the number of IL in contact with the first pair of sublinguals); LF4 = subdigital lamellae beneath 4th finger; LT4 = subdigital lamellae beneath 4th toe; MSR = number of scale rows at midbody; PoO = (number of) postocular(s); PreO = (number of) preocular(s); PV = (number of) preventral(s); SC = (number of) subcaudal(s); SL = supralabial(s) (for snakes, followed in brackets by the SL in contact with orbit); SupO = supraocular(s); SVL = snout–vent length; TaL = tail length; VEN = (number of) ventral scales. Other abbreviations: asl = above sea level; DRC = Democratic Republic of the Congo.

Results

New material from Mbiye Island

Testudines

Pelomedusidae

Pelusios gabonensis (Duméril, 1856)

Voucher: RBINS 20734, 9 Nov. 2018 (field # NGLA-72: 0°27'50.5"N, 25°17'27.9"E). Juvenile. Carapace straight length (along the vertebral axis) 60.7 mm. Maximal width of carapace 54.6 mm. Maximal depth of body (carapace and plastron combined) 23.8 mm. Carapace flattened, with a low vertebral keel, most pronounced on the 3rd to 5th vertebral scales. Five vertebral scales, the 2nd to the 4th distinctly wider than long. Four pairs of costals, 12 pairs of marginals. Intergular length 11.9 mm. Length of suture between humerals 9.9 mm, between pectorals 4.7 mm, between abdominals 7.4 mm, between femorals 11.7 mm, and between anals 9.4 mm. Plastron articulation forming an

obtuse angle. Claws long and recurved. Carapace background color light brown, with a contrasting black vertebral line, prolonged on the head by a black Y-shaped mark whose arms lie above the orbits. Plastron entirely black except for the lighter longitudinal sutures.

This species has previously been reported from Kisangani, among others by Schmidt (1919), but not yet from Mbiye Island, although it was expected due to its presence in the Congo River.

Squamata

Agamidae

Agama agama (Linnaeus, 1758)

Vouchers: RBINS 20736 (field # MBY-163), adult male. SVL 106.4 mm, TaL \geq 162.8 mm (tail possibly incomplete, tip original or healed). 9/10 SL, 9/13 IL. 69 MSR. 18/19 LF4, 21/22 LT4. No vertebral stripe. No reticulate pattern on the throat; throat immaculate. Tail tip black. RBINS 20737 (field # MBY-207), pregnant female with four well-developed eggs. One of the eggs was extracted and shows a maximum length of 24.2 mm and a maximum width of 10.8 mm. SVL 83.4 mm, TaL 123.0 mm. 9/8 SL, 9/9 IL. 68 MSR. 18/19 LF4, 20/21 LT4. Throat with a poorly contrasted reticulate pattern. RBINS 20738 (field # MBY-187), subadult. SVL 62.2 mm, TaL 105.4 mm. 10/9 SL, 10/10 IL. 66 MSR. 20/20 LF4, 23/23 LT4. Throat immaculate. RBINS 20739 (Figure 2) (field # MBIYE-298), subadult. SVL 68.8 mm, TaL 111.5 mm. 8/9 SL, 9/10 IL. 66 MSR. 18/18 LF4, 20/22 LT4. Throat with a poorly contrasted reticulate pattern. All have their nostril on the canthus rostralis; a low nuchal crest; no dorsal crest; no caudal crest; dorsal scales homogeneous in size. All four were collected on 9 Nov. 2018 (near 0°27'50.5"N, 25°17'27.9"E, 394 m asl).

The two subadults were found asleep at night on the branches of a fallen tree on the edge of a small stream. The adults were caught on tree trunks. This anthropophilic species was observed in numbers on trees and on the walls of the island's primary school. New record for Mbiye Island. The records from "Stanleyville" of *Agama planiceps* Peters, 1862 by Boulenger (1919) and of *A. colonorum* Daudin, 1830 by Schmidt (1919) are probably attributable to the species we found on Mbiye Island and that we refer to *A. agama*, pending



Figure 2. Freshly preserved subadult *Agama agama* (RBINS 20739) from Mbiye Island. Photograph by G. Badjedjea.



Figure 3. Freshly preserved adult female *Hemidactylus ituriensis* (RBINS 20733) from Mbiye Island. Photograph by G. Badjedjea.

a revision of the *Agama* of northeastern DRC.

Gekkonidae

Hemidactylus ituriensis Schmidt, 1919

Voucher: RBINS 20733 (Figure 3), 25 Oct. 2016 (field # MBIYE-353: near 0°27'50.5"N, 25°17'27.9"E, 394 m asl), adult female. SVL 78.3 mm, TaL 69.6 mm. Head length 20.9 mm (right side), maximum head width 14.5 mm. 11/11 differentiated SL (9/9 to mid-orbit length); 10/10 IL. Postmentals separated by one scale. About 44 rows of ventrals between ventrolateral folds at midbody. 11/11 LF4, 13/12 LT4. A median row of widened subcaudals, their width about a third of tail width. Two dorsal bands are strictly located between the posterior insertion point of the arms and the anterior insertion point of the legs; the third dorsal band extends posteriorly beyond the anterior insertion point of the legs. The band on the nape stops anteriorly just beyond the tympanum, i.e., it does not extend anteriorly to the eye. The length of the 1st band on dorsum (i.e., the one located posteriorly to the band on nape) is 7.5 mm, the length of the interspace between the 1st and 2nd bands on dorsum is 5.9 mm, the length of the 2nd band on dorsum is 7.5 mm, and the length of the interspace between the 2nd and 3rd bands on dorsum is 5.0 mm. The bands are thus longer than the spaces between them; they do not show a median notching.

This is the first and only individual of this arboreal gecko found so far on Mbiye Island. It was hunting on a tree trunk at night. Its morphology and dorsal pattern agree with the diagnosis provided by Schmidt (1919) and Wagner, Leaché et al. (2014) for *Hemidactylus ituriensis*. Mbiye Island is located about 200 km SW of the westernmost locality listed for this species by Wagner et al. (2014).

Hemidactylus mabouia (Moreau de Jonnés, 1818)

Voucher: RBINS 20735, 9 Nov. 2018 (field # NGLA-17: near 0°27'50.5"N, 25°17'27.9"E, 394 m asl). Adult male. SVL 54.5 mm; TaL 65.7 mm, tail original. 12/12 differentiated SL (9/9 until mid-orbit), 11/10 IL. First pair of postmentals broadly in contact with each other. Ca. 14 irregular rows of tubercles at midbody; ca. 35 rows of ventral scales between ventrolateral skin folds at midbody. More than 21 preanofemoral pores (skin

missing above most of the left femur). 9/9 LF4, 8/8 LT4. Subcaudals strongly widened. Spiny tubercles present on each segment of the tail along its whole length.

This anthropophilic gecko is abundant in the village houses and the primary school of the island. This common and widespread species was already recorded from Kisangani, among others by Schwetz (1931a), Kandolo (1983) and Katamba (1988), but not yet from Mbiye Island.

Scincidae

Lepidothyris hinkeli joi Wagner, Böhme, Pauwels and Schmitz, 2009

Vouchers: RBINS 20730, 22 Oct. 2016 (field # MBIYE-305: near 0°27'50.5"N, 25°17'27.9"E, 394 m asl). Juvenile. SVL 76.5 mm; TaL 86.1 mm, tail original. 8/8 SL, 8/7 IL, 4/4 SupO. 38 MSR, dorsal scales with three keels. 68 scales between the mental and the cloaca. 83 SC. 11/12 LF4, 15/15 LT4. Nine irregular black bars on flanks between fore- and hind limb insertions, not framed with white dots. Throat and belly white, SL and IL immaculate. RBINS 20731, 22 Oct. 2016 (field # MBIYE-306: 0°27'50.5"N 25°17'27.9"E, 394 m asl), adult. SVL 151.4 mm; TaL 134.0 mm, tail tip regenerated. 8/8 SL, 7/7 IL, 4/4 SupO. 36 MSR, dorsal scales with three to five keels. 66 scales between the mental and the cloaca. 11/11 LF4, 15/14 LT4. Eight irregular black bars on flanks between fore- and hind limb insertions; mid-dorsum uniformly brown without black bars. Throat and belly white, SL immaculate; IL with each a black dot except the two anteriormost. In both specimens, lower eyelid without transparent disk; ear opening oval, with two pointed lobules on their anterior side; supranasals in contact with each other; and prefrontals separated.

Both individuals were caught in pitfall traps set for a small mammal inventory. No other individual of this colorful but shy species was observed. The island's villagers believe this recently described large skink species to be venomous. It was already recorded from Kisangani, among others by Schwetz (1931a, under *Lygoma* [sic] *fernandi*), but this is the first record for Mbiye Island. *Lepidothyris fernandi* (Burton, 1836) was shown by Wagner, Böhme et al. (2009) to be a more western form, not extending as far east as the DRC.

Panaspis breviceps (Peters, 1873)

Voucher: RBINS 20740, 6 Nov. 2018 (field # MBY-198: near 0°27'50.5"N, 25°17'27.9"E, 394 m asl). SVL 61.3 mm; TaL >49.0 mm, tail tip broken and missing. Nostril opening not in contact with rostral. Lower eyelid with a transparent disk. Tympanic opening well visible, with two lobules on its anterior side. Supranasals widely separated; prefrontals in contact with each other. 7/7 SL, 6/6 IL. Parietals in contact behind interparietal. 38 MSR, dorsals smooth; middorsals not widened. 59 scales between the postmentals and the cloaca. Four discontinued lines of white spots on dorsum; a brown stripe bordered by two light stripes on the flanks. Throat and belly immaculate.

Although it has not been reported to date from Kisangani or Mbiye Island, this forest-dwelling litter skink was documented from several nearby localities in Tshopo Province by Lokasola et al. (2021).



Figure 4. Laterodorsal and ventral views of a freshly preserved adult *Trachylepis maculilabris* (RBINS 20741) from Mbiye Island. Photographs by G. Badjedjea.

Trachylepis maculilabris (Gray, 1845)

Voucher: RBINS 20741 (Figure 4), 26 Oct. 2016 (field # MBIYE-383: near 0°27'50.5"N, 25°17'27.9"E, 394 m asl), adult. SVL 83.4 mm; TaL 125.8 mm, last 62.1 mm regenerated. Lower eyelid with a transparent disk. Tympanic opening well visible, vertically oval. Supranasals in contact with each other; prefrontals in contact with each other. 7/7 SL, 7/7 IL, 4/4 SupO, 5/5 supraciliaries. A pair of large nuchals, in contact medially. 57 scales between the nuchals and a point above the cloaca. 34 MSR, middorsals not widened. Dorsals with six or seven keels. A contrasting light line from below the eye to the tympanum. Throat and belly immaculate.

Several individuals were observed active by day on roofs of village houses. This skink species had already been reported multiple times from Kisangani (among others by Boulenger, 1919; Schwetz, 1931a; Lanza and Vanni, 1976; Punga, 1976; Shalishali, 1976; Mboko, 1986), but not from Mbiye Island. We take this opportunity to mention that, in their revision of the *Trachylepis maculilabris* complex, Ceriaco et al. (2016:314) listed, in their material examined from the DRC, series of specimens from Point [sic] Noire and from Brazzaville, and a specimen from Majumba, all housed in the collections of the *Museum national d'Histoire naturelle* in Paris. Pointe Noire and Brazzaville are actually located in the Republic of Congo, not in the DRC, and Majumba (written Mayumba in modern documents) lies in Nyanga Province, southwestern Gabon.

Varanidae

Varanus ornatus (Daudin, 1803)

Although we did not collect or photograph the Ornate monitor on Mbiye Island, the islanders informed GB and JBA in 2016–2018 that they regularly hunt and eat it. The hunting of this large lizard on Mbiye Island was mentioned by Mbangilwa Mukombe (2009). We examined voucher specimens from other localities in Tshopo Province: RBINS 18802, RBINS 18807 and RBINS 19146 from the area of Bagwase (0°20'07.0"S, 25°37'33.0"E); RBINS 18808 and RBINS 18814 from the area of Uma (0°54'30.0"N, 26°30'20.0"E); and RBINS 19123 from the area of Longala (1°58'10.0"N, 25°30'00.0"E). All show five

transversal bands of yellow ocellae on the dorsum between their anterior and posterior limb insertions, and can thus be identified as *Varanus ornatus* rather than *V. niloticus* (Linnaeus, 1766), the latter showing higher numbers of ocellae rows. This is the monitor species found on Mbiye Island and it is well known from Kisangani (Schmidt, 1919, under *V. niloticus*).

Boidae

Calabaria reinhardtii (Schlegel, 1851)

Voucher: Figure 5, Mbiye Island, 26 October 2016. This individual was found by a villager by day on the forest floor. This harmless and slow snake species is said by Mbiye villagers to be hunted for food consumption. They compare this species to a fish, and give it the name *njombo ya mokili*, a name also locally applied to the fish genus *Protopterus* Owen (Protopteridae).

This fossorial species was already recorded from Kisangani (Schwetz, 1931b), but not from Mbiye Island.

Colubridae

Dasyplectis fasciata Smith, 1849

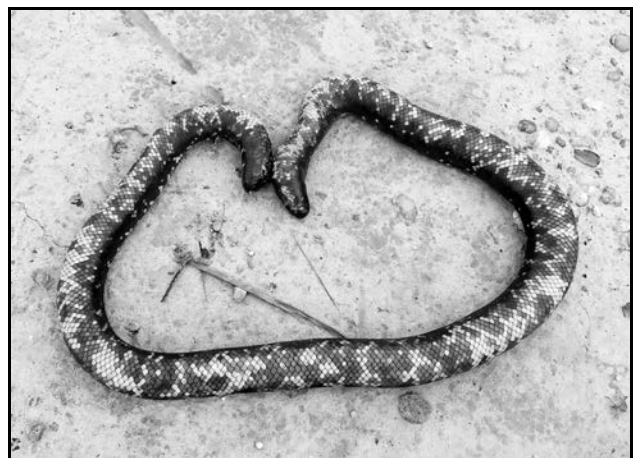


Figure 5. Live *Calabaria reinhardtii* on Mbiye Island. Photograph by G. Badjedjea.



Figure 6. Freshly preserved adult *Dasyplectis fasciata* (CSB 0016) from Mbiye Island. Photograph by J. B. Akuboy.

Voucher: CSB 0016 (Figure 6), Dec. 2016 (0°28'1.1"N, 25°17'43.0"E, 409 m asl).

This individual was found active at night on the ground in secondary forest near a settlement. This egg-eating species is well documented from Kisangani (Gans, 1959). New record for Mbiye Island.

Philothamnus carinatus (Andersson, 1901)

Voucher: CSB 0038 (Figure 7), Dec. 2016 (0°28'1.1"N, 25°17'43.0"E, 409 m asl), adult female. 9(4-6)/8(3-5) SL; 9/9 IL; 1/1 loreal; 1/1 PreO; 2/2 PoO; no suboculars. 1 PV + 161 VEN, keeled; anal single; 77 SC, divided, unkeeled. 13-13-11 DSR.

This fast, but commonly encountered snake species has already been mentioned from Kisangani, a.o. by Boulenger (1919, under *Chlorophis carinatus*), but not from Mbiye Island.

Rhamnophis aethiopissa ituriensis Schmidt, 1923

Voucher: CSB 001 (Figure 8), Dec. 2016 (0°28'1.1"N, 25°17'43.0"E, 409 m asl).

It shows 15 DSR at midbody. It was found at night in secondary forest, asleep on vegetation overhanging water. This arboreal snake species had not yet been recorded from Mbiye Island.



Figure 8. Freshly preserved *Rhamnophis aethiopissa ituriensis* (CSB 001) from Mbiye Island. Photograph by J. B. Akuboy.

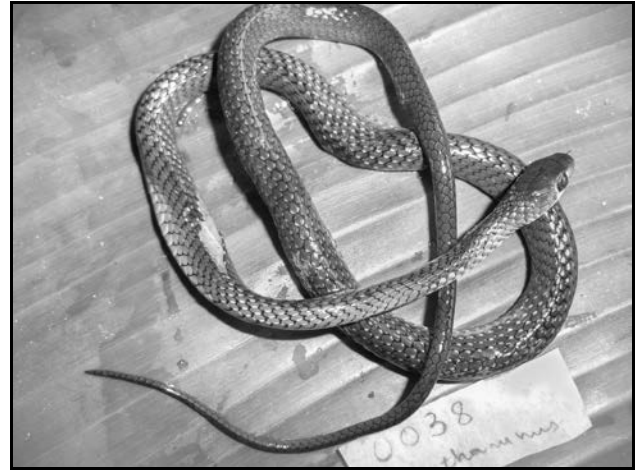


Figure 7. Freshly preserved *Philothamnus carinatus* (CSB 0038) from Mbiye Island. Photograph by J. B. Akuboy.

Thelotornis kirtlandii (Hallowell, 1844)

Vouchers: RBINS 20732 (Figure 9), 27 Oct. 2016 (field # MBIYE-417: near 0°27'50.5"N, 25°17'27.9"E, 394 m asl), adult male (verified by dissection). SVL 725.3 mm; TaL >411.1, extreme tail tip missing. 8(4-5)/8(4-5) SL; 9(5)/10(5) IL; 1/1 loreal; 1/1 PreO; 3/3 PoO (on the left side the upper and lower PoO are not in contact with the anterior temporal, on the right side the lower PoO is not in contact with the anterior temporal, so these could rather be regarded as suboculars; otherwise there are no additional suboculars). 1+(1/(1+1)) temporals on both sides. 1 PV + 178 VEN; anal divided; >146 SC, divided. 19-19-13 DSR, keeled. CSB 0015, Dec. 2017 (0°28'1.1"N, 25°17'43.0"E, 409 m asl), adult.

RBINS 20732 was found asleep at night on vegetation above a path used by villagers to go to a spring. CSB 0015 was encountered in secondary forest. New species record for Mbiye Island. This venomous arboreal snake species has already been mentioned from Kisangani, among others by Schwetz (1931b).

Toxicodryas adamantea Greenbaum, Allen, Vaughan, Pauwels, Wallach, Kusamba, Muninga, Mwenebatu, Mali, Badjedjea, Penner, Rödel, Rivera, Sterkhova, Johnson, Taponjou and Brown, 2021



Figure 9. Freshly preserved adult male *Thelotornis kirtlandii* (RBINS 20732) from Mbiye Island. Photograph by J. B. Akuboy.



Figure 10. Freshly preserved *Toxicodryas adamantea* (CSB 0024) from Mbiye Island. Photograph by J. B. Akuboy.

Voucher: CSB 0024 (Figure 10), Dec. 2016 (0°28'1.1"N, 25°17'43.0"E, 409 m asl).

This arboreal snake was found active at night on a tree five m above the ground. This recently described species had already been recorded from the area of Kisangani, a.o. by Boulenger (1919, under *Dipsadomorphus pulverulentus*). A recent revision of the genus *Toxicodryas* by Greenbaum et al. (2021) showed that *T. pulverulenta* is actually limited to West Africa, west of the Niger Delta. We expect that the larger, congeneric snake, *Toxicodryas vexator*, more common in the Kisangani area than *T. adamantea*, will soon be found on the island.

Elapidae

Naja melanoleuca Hallowell, 1857

Voucher: CSB 0032 (Figure 11), Dec. 2016, (0°28'1.1"N, 25°17'43.0"E, 409 m asl).

This individual was found by day on a palm tree eight m above the ground. This large and deadly venomous cobra is hunted for food by Mbiye villagers. This snake species had already been recorded from Kisangani (Schwetz, 1931b), but not from Mbiye Island.



Figure 11. Freshly preserved *Naja melanoleuca* (CSB 0032) from Mbiye Island. Photograph by J. B. Akuboy.

Lamprophiidae

Hormonotus modestus (Duméril, Bibron and Duméril, 1854)

Voucher: CSB 0022 (Figure 12), Dec. 2016 (0°28'1.1"N, 25°17'43.0"E, 409 m asl).

This individual was found by day in secondary forest, and represents the first and only record for Mbiye Island. This widespread but rarely encountered species was already recorded from Kisangani (Schmidt, 1923).

Typhlopidae

Afrotyphlops congestus (Duméril and Bibron, 1844)

Voucher: RBINS 20745 (Figure 13), 21 Oct. 2016 (field # MBIYE-272; (0°27'57.6"N, 25°17'41.5"E, 397 m asl). SVL 198.5 mm, TaL 4.1 mm. Maximum body width 10.1 mm. Snout rounded in dorsal view, not sharply angular in profile, lacking a keratinized edge. Eye well developed with pupil visible through the ocular. Nostril pierced ventrally. Dorsal rostral broad (4.5 mm), nearly as wide as interocular distance (5.4 mm). Inferior nasal suture arising from near the rostral/1st SL junction. Preocular not in contact with 1st SL. Origin of the ocular above 3rd SL. Ocular shield overlaps 3rd SL. Supraocular transverse, its lateral apex between preocular and ocular. 347 middorsal between the interparietal and a point above the cloaca. 32-28-



Figure 12. Freshly preserved *Hormonotus modestus* (CSB 0022) from Mbiye Island (the field label erroneously states that it is a *Gonionotophis*). Photograph by J. B. Akuboy.



Figure 13. Freshly preserved *Afrotyphlops congestus* (RBINS 20745) from Mbiye Island. Photograph by G. Badjedjea.

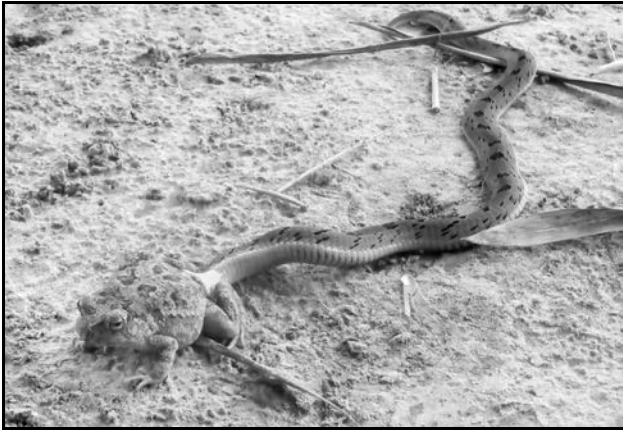


Figure 14. Live adult *Causus maculatus* preying on a *Sclerophrys pusillus* toad on Mbiye Island. Screenshot from a video made by A. P. Tezuni.

23 scale rows. 11 SC, not widened. Dorsal pattern marbled, black and white; venter immaculate.

It was found by day by a villager on the forest floor. This is the first record of this fossorial snake from Mbiye Island.

Viperidae

Causus maculatus (Hallowell, 1842)

Voucher: Figure 14, 2018 (0°27'57.6"N, 25°17'41.5"E, 397 m asl).

This adult individual was filmed by day while it was preying on an adult *Sclerophrys pusilla* (Mertens, 1937) (Anura: Bufonidae). Long known from Kisangani (see Boulenger, 1919, under *C. rhombeatus*), this mildly venomous terrestrial viper had not yet been recorded from Mbiye Island.

New material from Kungulu Island

Testudines

Testudinidae

Kinixys erosa (Schweigger, 1812)

Although no voucher was collected, in 1981–1982 MC observed numerous individuals of this tortoise species in the forest of Kungulu Island in the course of a morphological study on this tortoise (Lenglet and Colyn, 1989; unpublished data).

Squamata

Colubridae

Hapsidophrys smaragdinus (Schlegel, 1837)

Voucher: RBINS 19711, 30 June 1984 (field # R205: 0°33'38.6"N, 25°04'23.1"E, 390 m asl, adult female (sex verified by dissection). SVL 651.4 mm; TaL >371.2, extreme tail tip missing. 9(5-6)/9(5-6) SL; 9(5)/9(5) IL; 1/1 loreal; 1/1 PreO; 2/2 PoO; no suboculars. 1+1+2 temporals on both sides. 1 PV + 160 VEN, keeled; anal divided; >128 SC, divided and keeled. 15-15-11 DSR, keeled.

Although long known from Kisangani (Schwetz, 1931b, under *Gastropyxis smaragdina*), this common and widespread agile diurnal snake had not been recorded so far from Kungulu Island.

Philothamnus carinatus (Andersson, 1901)

Voucher: RBINS 19680, 5 Jan. 1984 (field # R30: 0°33'38.6"N, 25°04'23.1"E, 390 m asl), juvenile male (sex verified by dissection). SVL 260.4 mm; TaL 101.2 mm, tail complete. 9(4-6)/9(4-6) SL; 10(5)/10(5) IL; 1/1 loreal; 1/1 PreO; 2/3 PoO; no suboculars. 2+2+2 / 3+2+2 temporals. 1 PV + 144 VEN, keeled; anal single; 89 SC, divided, unkeeled. 13-13-11 DSR.

This other common and widespread diurnal snake had also not been recorded so far from Kungulu Island.

Thelotornis kirtlandii (Hallowell, 1844)

Vouchers: Field # R 206, 30 June 1984, 0°33'38.6"N, 25°04'23.1"E, 390 m asl), adult female (sex verified by dissection). SVL 722 mm; TaL 472 mm. 8(4-5)/8(4-5) SL; 10(4)/11(5) IL; 1/1 loreal; 1/1 PreO; 3/3 PoO (contacts with temporal not examined; see remark under RBINS 20732); one anterior temporal. 1 PV + 178 VEN; anal divided; 163 SC, divided. 19-19-13 DSR, keeled. Field # R 208, same locality and date as R206. Juvenile. 8(4-5)/8(4-5) SL; 9(4)/9(4) IL; 1/1 loreal; 1/1 PreO; 3/3 PoO (contacts with temporal not examined; see remark under RBINS 20732); one anterior temporal. 1 PV + 176 VEN; anal divided; 145 SC, divided. 19-19-13 DSR, keeled.

Morphological data on these *Thelotornis* specimens were taken in the field by one of us (MC) in 1984. They were then integrated in the reference collections of the University of Kisangani, but the herpetological material deposited in the 1970s and 1980s at the university no longer exists (pers. comm. from Asumani Bin Isiaka, technician at the University of Kisangani, December 2022).

Elapidae

Naja melanoleuca Hallowell, 1857

Voucher: Field # R 209, 30 June 1984 (0°33'38.6"N, 25°04'23.1"E, 390 m asl). female (sex verified by dissection). 7(3-4)/7(3-4) SL; 8(4)/8(4) IL; 0/0 loreal; 1/1 PreO; 3/3 PoO (contacts with anterior temporal not examined; the lower one probably rather corresponds to a subocular). 1+2 temporals on both sides. 1 PV + 214 VEN; anal single; 66 SC, divided. 27-19-13 DSR.

Similarly to the two preceding specimens and the next one, deposited by MC in 1985 at the University of Kisangani, this voucher is lost.

Natricidae

Natriciteres olivacea (Peters, 1854)

Voucher: Field # R 207, 30 June 1984, (0°33'38.6"N, 25°04'23.1"E, 390 m asl). juvenile male. 8(4-5)/8(4-5) SL; 10(5)/10(5) IL; 1/1 loreal; 1/1 PreO; 3/3 PoO. 1+2 temporals on both sides. 138 PV+VEN; anal divided; 68 SC, divided. 19-19-17 DSR.

It is to be noted that no reptile material from Kungulu and Mbiye islands is present in the collections of the Royal Museum for Central Africa in Tervuren, Belgium (G. Cael, pers. comm. to OSGP, Nov. 2022).

Discussion

According to discussions with local villagers in 2016–2018 (field data of GB and JBA), the aquatic cobra *Naja annulata* Peters, 1876 (Elapidae) and the vipers *Bitis gabonica* (Duméril, Bibron and Duméril, 1854) and *B. nasicornis* (Shaw, 1802) (Viperidae) also inhabit Mbiye Island, as well as several other snake species whose identity is not yet confirmed. For his un-

published Master thesis on the biology of *Kinixys erosa* in Kisangani area, Mugangu-Trinto (1976) collected not less than 20 distinct, live individuals (12 males and eight females) in the forest of Mbiye Island.

In another unpublished Master thesis on the snakes of north-eastern DRC, Kakolo (1979) mentioned having eaten on Kungulu Island three *Bitis* vipers (one *B. gabonica* and two *B.*

Table 1. Comparison of the herpetofaunas of Mbiye and Kungulu Islands, Congo River, Tshopo Province, DRC.

| Taxa | Mbiye Island | Kungulu Island | References |
|--|--------------|----------------|--|
| Testudines | | | |
| Pelomedusidae | | | |
| <i>Pelusios gabonensis</i> | X | | This work |
| Testudinidae | | | |
| <i>Kinixys erosa</i> | X | X | Mugangu-Trinto (1976) ; this work |
| Squamata | | | |
| Agamidae | | | |
| <i>Agama agama</i> | X | | This work |
| Gekkonidae | | | |
| <i>Hemidactylus ituriensis</i> | X | | This work |
| <i>Hemidactylus mabouia</i> | X | | This work |
| Scincidae | | | |
| <i>Lepidothyris hinkeli joi</i> | X | X | Okangola (1981, under <i>Riopa fernandi</i>); Devos et al. (1989, under <i>R. fernandi</i>); this work |
| <i>Panaspis breviceps</i> | X | | This work |
| <i>Trachylepis maculilabris</i> | X | X | Okangola (1981, under <i>Mabuya maculilabris</i>); Devos et al. (1989, under <i>M. maculilabris</i>); this work |
| <i>Trachylepis</i> sp. | | X | Okangola (1981, under <i>Mabuya varia varia</i>); Devos et al. (1989, under <i>M. varia</i>) |
| Varanidae | | | |
| <i>Varanus ornatus</i> | X | X | Okangola (1981, under <i>V. niloticus</i>); Devos et al. (1989, under <i>V. niloticus</i>); Mbangilwa Mukombe (2009:92, under “varan du Nil”); this work |
| Boidae | | | |
| <i>Calabaria reinhardtii</i> | X | X | Kakolo (1979); this work |
| Colubridae | | | |
| <i>Dasypeltis fasciata</i> | X | | This work |
| <i>Hapsidophrys smaragdinus</i> | | X | This work |
| <i>Philothamnus carinatus</i> | X | X | This work |
| <i>Rhamnophis aethiopissa ituriensis</i> | X | | This work |
| <i>Thelotornis kirtlandii</i> | X | X | Kakolo (1979); Devos et al. (1989); this work |
| <i>Toxicodryas adamantea</i> | X | | This work |
| Elapidae | | | |
| <i>Naja melanoleuca</i> | X | X | Kakolo (1979); Devos et al. (1989); this work |
| Lamprophiidae | | | |
| <i>Hormonotus modestus</i> | X | | This work |
| Natricidae | | | |
| <i>Natriciteres olivacea</i> | | X | Devos et al. (1989); this work |
| Typhlopidae | | | |
| <i>Afrotyphlops congestus</i> | X | | This work |
| Viperidae | | | |
| <i>Bitis gabonica</i> | | X | Kakolo (1979, under <i>B. gabonica gabonica</i>) |
| <i>Bitis nasicornis</i> | | X | Kakolo (1979); Devos et al. (1989) |
| <i>Causus maculatus</i> | X | | This work |

nasicornis) and having preserved their head and skin. He also recorded a *Calabaria reinhardtii*, two individuals of *Thelotornis kirtlandii* (including one “avalant un Lézard mabuya,” i.e., “swallowing a mabuya lizard,” probably a *Trachylepis*) and a *Naja melanoleuca* from the island. Kakolo (1979) provided diagnostic characters allowing an unambiguous confirmation of the specific identity of each of the snakes he recorded from Kungulu Island. In his unpublished Master’s thesis about the lizards of the area of Kisangani, Okangola (1981) reported four species from Kungulu Island: *Lepidothyris hinkeli joei*, *Trachylepis maculilabris*, *Trachylepis* sp. (under *Mabuya varia varia*) (Scincidae) and *Varanus ornatus*. Okangola explained that he did not find *Agama agama* nor *Hemidactylus mabouia* on the island because these anthropophilic species did not find there the environment they need. Devos et al. (1989) recorded ten reptile species from Kungulu Island, although they indicated one record (*Kinixys erosa*) as doubtful, without justification, and one identification (*Philothamnus heterodermus*) as uncertain (these two records are hence not included in Table 1). The remaining species listed by Devos et al. were *Lepidothyris hinkeli joei*, *Trachylepis maculilabris*, *Trachylepis* sp. (under *Mabuya varia*) (Scincidae), *Varanus ornatus* (Varanidae), *Thelotornis kirtlandii* (Colubridae), *Naja melanoleuca* (Elapidae), *Natriciteres olivacea* (Peters, 1854) (Natricidae) and *Bitis nasicornis* (Viperidae). The identity of the species listed by Okangola (1981) and Devos et al. (1989) under *Mabuya varia* from Kungulu Island should be re-evaluated with voucher material. Devos et al. (1989) mentioned an unpublished report by Heymans (1980) listing several species besides their own list, but they regarded Heymans’s undocumented records (“*Boulengerina annulata*, *Calabaria reinhardtii*, *Boiga pulverulenta*, *Hapsidophrys lineatus*, *Mehelya poensis*, *Dendroaspis jamesoni*, *Bitis gabonica*, *Causus maculatus*, *Philothamnus irregularis irregularis*, *Philothamnus semivariiegatus nitidus* et *Dispholidus typus viridis*”) as doubtful. Two of these latter species (*Calabaria reinhardtii* and *Bitis gabonica*) had however already been documented by Kakolo (1979); although the occurrence of several of the remaining species cited by Heymans from Kungulu Island is very likely, we do not include them in Table 1,

as they should still be confirmed with voucher material.

At least eight species recorded from Kungulu Island are hence shared with Mbiye Island (Table 1): *Kinixys erosa*, *Lepidothyris hinkeli joei*, *Trachylepis maculilabris*, *Varanus ornatus*, *Calabaria reinhardtii*, *Philothamnus carinatus*, *Thelotornis kirtlandii* and *Naja melanoleuca*.

Housing dense secondary forest, swamp forest, agricultural fields and human settlements, Mbiye Island, more diverse and much larger than Kungulu Island, is probably home to many reptile species in addition to the ones we document here, including those already listed from Kungulu Island, and a number of the species already recorded from Kisangani.

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The Role of Sex Chromosomes in the Evolution of a Few Frog Lineages

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Abstract

An autosome is any chromosome that is not a sex chromosome. Sex chromosomes have a unique origin story that starts with a simple autosome mutation, but they possess an extraordinarily complex suite of characteristics: a high level of recombination in only one sex, rapid evolution, and a tendency to accumulate loci that generate incompatibility. Sex chromosomes are thus thought to promote divergence and maintain reproductive isolation between lineages. However, predictions about the role of sex chromosomes in species divergence have been made for organisms with differentiated sex chromosomes (where one of the chromosomes is decayed). In contrast to warm-blooded vertebrates with conserved, differentiated sex chromosomes, amphibians have sex chromosomes ranging from extremely differentiated to almost identical. Frogs in particular present a diverse array of unstably evolving sex determination systems and sex chromosomes. For this reason, these slimy vertebrates provide excellent systems for comparative studies. I synthesize work from several lineages of current research focus. I explore the role of sex chromosomes in the evolution of a genus of treefrogs (*Hyla*) and a species of true frogs (*Rana temporaria*). Sex chromosomes in these groups are intricately patterned with signs of turnover and recombination that reflect phylogeographic and climatic histories. I end with a discussion of another true frog species, *Glandirana rugosa*, which, amazingly, varies in sex determination systems among populations.

Sex chromosomes create barriers and promote divergence

That sex chromosomes arise from autosomes is an accepted view. According to the theory, new sex chromosomes evolve via mutations on an autosomal gene. The result is that homozygotes develop into one sex (XX females or ZZ males) and heterozygotes, the other (XY males and ZW females) (Ohno, 1967; Rice, 1996; Charlesworth and Charlesworth, 2000). Sexually antagonistic (SA) mutations are favored around a sex-determining (SD) gene on the Y or W (the heterogametologs). SA mutations resolve sexually antagonistic effects of sexual selection, because the heterogametic sex is likely to inherit alleles detrimental to fitness only in the opposite sex. Recombination between SA alleles and the SD gene is thereby suppressed on the heterogametolog (Bull, 1983; Rice, 1987).

Linkage disequilibrium—the phenomenon where genes in close physical proximity are more likely to be inherited together

because these genes are less likely to be broken up by recombination during meiosis—favors SA mutations at the border of the non-recombining region. Meanwhile, phenomena like background selection (loss of genetic diversity in non-deleterious genes because of negative selection against linked deleterious genes); selective sweeps (loss of genetic diversity in non-deleterious genes due to positive selection for linked beneficial genes); and genetic drift (random mutations being becoming fixed in a population stochastically, because the population harbors fewer copy numbers of the heterogametolog) cause genes in the non-recombining region to accrue deleterious mutations. All but a few genes vital for the sexual development of the heterogametic sex are lost. Gene loss then causes the W or Y to degenerate, which explains heteromorphic sex chromosomes (a gene-rich X or Z, and a decayed Y or W) (Charlesworth and Charlesworth, 2000).

Sex chromosomes compete for segregation between the two

sexes (i.e., which sex chromosome ends up in which offspring sex). These chromosomes are therefore hypothesized to be a battlefield where sexual and genomic conflict are resolved. Classical theory in evolution thus predicts a central role for sex chromosomes in speciation. In fact, linkage between traits involved in pre-mating (sexual traits and preferences) and post-mating isolation (hybrid incompatibilities, or pairings of parental genes that make the hybrid offspring less fit than their parents) on sex chromosomes likely contributes to the assortative mating (i.e., members of a lineage choosing to mate only with members of the same lineage) we observe in many organisms (Seehausen et al., 2014).

The tightly linked genes of sex chromosomes are predicted to act as supergenes of speciation. Supergenes on sex chromosomes can display signatures of adaptive introgression (where gene flow from one lineage into another [introgression] improves fitness [is adaptive] in the recipient lineage) after a hybridization event, which likely facilitates adaptive evolution (Seehausen et al., 2014). An example are the large, low-diversity, supergene-like regions on the human X chromosomes, which show evidence of strong selective sweeps since divergence from chimpanzees. These regions are devoid of signatures of Neanderthal introgression. Hence, X-linked regions that undergo selective sweeps are likely among the first to form reproductive barriers between diverging species (Dutheil et al., 2015).

It is predicted that the characteristics of differentiated sex chromosomes—exposure of large-effect, accumulated, recessive incompatibility factors in hybrids, fast evolution, and recombination exclusive to the homogametic sex—can drive isolation at any stage of the speciation continuum. Empirical data support the importance of sex chromosomes in the speciation of several groups, e.g., mammals, birds, and most insects (Dufresnes and Crochet, 2022). These animals have conserved, heteromorphic sex chromosomes (e.g., the ZZ/ZW system of birds and XX/XY of mammals), with ancient, decayed heterogametologs. However, examples of sex chromosome pairs that lack a degenerated chromosome are continually unearthed in poikilothermic vertebrates (most fish, reptiles and amphibians). For example, 96% of amphibians have apparently homomorphic, or undifferentiated, sex chromosomes (Eggert, 2004)—a parenthetical comment, however, is that these characterizations were made mostly with antiquated light microscopy techniques, and thus ostensibly homomorphic chromosomes may diverge at the levels of DNA sequence or gene expression and thus not recombine (Kratovichil et al., 2021).

Also in contrast to groups like mammals and birds, frogs have diverse SD systems that are evolutionarily and ontogenetically unstable. Some lineages are XX/XY and others ZZ/ZW (in one case both systems are observed in the same ranid species, *Glandirana rugosa*, to be discussed later). A phylogenetic reconstruction suggested at least seven transitions from a ZZ/ZW to XX/XY system in frogs, but the reverse has been observed too (the most notable case being *G. rugosa*) (Hillis and Green, 1990; Miura et al., 1998).

Authors frequently state that genetic sex determination is under genetic control in frogs, qualifying that environmentally mediated sex reversal is common. However, a recent study failed to locate a sex-determining locus in the Chinese edible frog

Hoplobatrachus rugulosus and insisted that sex is likely controlled by temperature (Panthum et al., 2021; see Perrin et al. [2009], however, for a discussion of why frogs are unlikely to encounter the requisite temperatures in nature). Furthermore, environmental sex determination (the particular cause not yet pinpointed) seems likely in a population of *Rana temporaria* discussed later (Rodrigues et al., 2014; Rodrigues et al., 2017). Sex reversal is common in wild populations of frogs and sex chromosome turnovers are common, though turnover rates vary widely among taxa. Interestingly though, the same five chromosomes are repeatedly recruited as sex chromosomes during evolution, likely because they contain genes important in the sex-determining cascade. Frogs also present neo-sex chromosomes (i.e., recently formed sex chromosomes), translocations, B chromosomes recruited into sex chromosomes, and multiple sex chromosomes (Ma and Veltsos, 2021).

Although the reasons for evolutionary instability of frog sex chromosomes remain unclear, occasional X-Y recombination and high turnover rates are often proposed to explain the prevalence of sex chromosome homomorphy in amphibians. In cases where sex chromosomes are undifferentiated, recombination is thought to be facilitated; the location of master SD genes should turn over easily between chromosomes; and sex chromosomes are not expected to accumulate more incompatibilities than autosomes (Dufresnes and Crochet, 2022).

Due to their diversity in degrees of differentiation, the sex chromosomes of frogs likely vary in the extent to which they adhere to predictions about speciation. For example, recent evidence suggests that frogs vary in how prone they are to accumulation of incompatibilities at sex chromosomes. Single nucleotide polymorphism—or SNP—data (genetic marker data based on single nucleotide sites across the genome that vary among species or populations), linkage maps (genetic maps of the chromosomes), and cline models (differences correlated with geographic distance) were used to examine patterns of introgression in 41 pairs of frogs and toads. Species represented *Hyla* (Hylidae), *Rana* (Ranidae), and *Bufo* (Bufonidae) from Europe and northern Africa. As divergence increases between lineages, phylogeographic transitions become narrower, and larger parts of the genome resist introgression. Thus, speciation in many frogs likely occurs as small-effect loci accumulate genome-wide, followed by behavioral isolation. Moreover, small-effect loci are disproportionately sex-linked in *Hyla*, but not in *Rana* and *Bufo*. Thus, major incompatibilities on sex chromosomes may be drivers of speciation in the sex chromosomes of some, but not other, species. The importance of large-effect incompatibilities may depend on the degree of differentiation of the sex chromosomes (Dufresnes, Brelsford, Jeffries, et al., 2021).

In this paper, I focus on the part sex chromosomes have played in a few actively studied frog lineages. Like other amphibians, most frogs have homomorphic sex chromosomes, but there is variation. Frogs display intricate patterns of recombination, rapid turnover that sometimes changes of heterogametic sex during a homomorphic state, and heteromorphic transitions during which the heterogametolog decays. These phenomena can both inform and be affected by historical patterns of speciation (Dufresnes and Crochet, 2022). Furthermore, frog sex

chromosomes contain clues about histories of phylogeography and hybridization. Here, I explore the intricate evolutionary dynamics of sex chromosomes in lineages with complex SD and in secondary contact at varying stages of divergence—namely, treefrogs of the Hylidae family (genus *Hyla*) and the European common frog *Rana temporaria* in the true frog family Ranidae. I conclude with a discussion of another ranid species that has proven to be a treasure trove of information on diverse sex chromosome dynamics—the Japanese soil frog *Glandirana rugosa* (Dufresnes and Crochet, 2022).

Sex chromosomes in the evolution of *Hyla*

Studies of sister species of frogs with ancestral, undifferentiated sex chromosomes might allow estimates of the extent to which X-Y recombination explains the ubiquity of sex-chromosome homomorphy in cold-blooded vertebrates. Treefrogs of the genus *Hyla* are outstanding candidates for studies of speciation dynamics that maintain sex chromosome homomorphy (Stöck et al., 2011). Most *Hyla* treefrogs have homomorphic sex chromosomes, but both the autosomes and sex chromosomes of *Hyla* males (including those in the two *Hyla* where ZZ/ZW SD systems are documented [Dufresnes, Brelsfjord, Baier and Perrin, 2021]) have lower recombination rates than those of females. Reduced male recombination genome-wide is the norm in frogs and may relate to unique aspects of male meiosis (Jeffries et al., 2018).

Hyla XY males have reduced recombination of a known sex linkage group, even in species in which it is autosomal. In fact, from a monophyletic radiation of XX/XY *Hyla*—*H. arborea*, *H. orientalis*, *H. intermedia*, and *H. molleri*—X-Y recombination has not been directly documented. Recombination was not reported from genotypes of thousands of laboratory-crossed offspring nor from microsatellite assays (microsatellites are neutral markers of the genome with repetitive sequence—scientists consider the different numbers of repeats to be alleles) of *H. arborea*, *H. intermedia*, and *H. molleri* (Stöck et al., 2011). The fountain-of-youth hypothesis (Perrin, 2009) and the hot-potato model (Blaser et al., 2014), are often proposed to explain homomorphy. The fountain-of-youth model posits that the occurrence of recombination in sex-reversed females every few generations is sufficient to maintain undifferentiated sex chromosomes. The hot-potato model suggests that selection will favor a mutation that converts an autosome into a new sex chromosome, due to the accumulation of deleterious mutations on a non-recombining chromosome. Recent evidence for occasional recombination, possibly in sex reversed females, is indirect but compelling in *Hyla*. Conversely, there is a lack of evidence for mutation-load driven turnovers in this genus (Dufresnes et al., 2015).

Indeed, *Hyla* sex chromosomes cluster by species rather than gametolog, a pattern expected for genes involved in SD under recombination models (Stöck et al., 2011). In addition, a genotyping-by-sequencing genome scan approach showed that *H. arborea*, *H. orientalis*, *H. intermedia*, and *H. molleri* share a small, ancestral SD region (Brelsfjord, Dufresnes and Perrin, 2016). Phylogenetic trees of DNA sequences along the known sex linkage group of these four species are consistent with occasional X-Y recombination (Dufresnes et al., 2015). Sex-

linked markers of XX/XY *Hyla* also display large-scale X-Y similarity, more than could be explained, for example, by the occasional gene conversion seen in mammals (Stöck et al., 2011). Finally, a non-zero rate of recombination in *Hyla* has been empirically estimated, likely substantial enough to render the patterns of homomorphy we observe (Guerrero et al., 2012).

With respect to the fountain-of-youth model, empirical estimates in frogs suggest rare recombination events in females are sufficient to rejuvenate the Y chromosome (Grossen et al., 2012), and a single sex reversal event is expected to generate a diversity of novel Y haplotypes (Stöck et al., 2011). Also, high rates of female recombination have been calculated in *Hyla*, e.g., in *H. arborea* (Dufresnes, Bertholet, et al., 2014).

It should be noted that the fountain-of-youth hypothesis and turnover are nonexclusive. For example, a temperature shift that results from a range expansion may favor phenotypic sex reversal and thus create more opportunity for recombination in females. However, an initial abundance of females may generate turnover events via sex-ratio selection, when there is selection for the number of males to increase (Stöck et al., 2011).

Despite signs of low male recombination in all *Hyla*, one species, *H. arborea*, shows enormous variation in both X-Y differentiation and overlap of allele frequencies across its range. *Hyla arborea* recently expanded through Europe from a glacial refugium. Results of microsatellite assays that included a gene known to be sex-linked in *Hyla* (*Med15*) showed that southern refugial populations have low levels of X-Y differentiation, geographically and historically intermediate moderate levels, and northern postglacial populations no X-Y recombination and strong differentiation (Dufresnes, Stöck, et al., 2014). The variation in this species lends itself to future phylogeographic investigations of Y haplotypes and examination of coalescence times of neutral markers in the vicinity of SD and SA loci over the range of *H. arborea*. These studies will be essential to uncover the spatial and temporal dynamics of recombination (Stöck et al., 2011).

Geographic and historical patterns that have driven suppression of Y recombination in postglacial *H. arborea* populations remain obscure. One possibility is a selective sweep on introduced Y haplotypes favoring male-beneficial alleles during range expansion (Dufresnes, Bertholet, et al., 2014). On the other hand, possibilities for a lack of differentiation in refugial populations include lower genetic drift (fewer bottlenecks during population expansion and larger local population sizes), rare recombination, or influx of Y haplotypes from other populations. Analyses of highly differentiated populations of *Hyla* will be useful to disentangle the relative contributions of drift and recombination in speciation (Stöck et al., 2011).

Sex chromosomes in the evolution of *Rana temporaria*

Selection is expected to favor transitions that preserve the heterogametic sex (e.g., an XY to XY transition) over ones that switch the heterogametic sex (e.g., an XY to ZW transition) in cases where deleterious mutations have accumulated. In the former case, the decayed heterogametolog is discarded, but in the latter case, a degenerated heterogametolog is fixed as an

autosome. This logic has been used to explain the ubiquity of mutation-induced turnovers that preserve male heterogamety in Ranidae (true in all cases except for *G. rugosa*). An explanation is that because male ranids (like other frogs) have reduced recombination, chromosome differentiation is faster than in warm-blooded vertebrates, favoring more turnovers (Jeffries et al., 2018). However, why turnovers and not occasional recombination (e.g., in sex-reversed females) are the recurrent responses to mutation-load selection in this family is unclear. Turnovers converge nonrandomly on the same few chromosomes that likely harbor important SD genes—though an alternative possibility is that the SD gene translocates to new chromosomes (Jeffries et al., 2018).

Despite a greater importance of turnover in ranids, levels of sex chromosome differentiation can vary enormously within a ranid species, just as in *Hyla*. Microsatellite assays of sex-linked genes in *R. temporaria* of the Swiss Alps and Sweden have revealed that males in some populations are fixed for male-specific alleles across Y markers (differentiated Ys), in others only at the sex-linked gene *Dmrt1* (“proto-” Y chromosomes), and in the rest, sex chromosomes are indistinguishable (undifferentiated Xs) (Rodrigues et al., 2014; Rodrigues et al., 2017). Haplotypes of *Dmrt1* vary in their probability of association with a differentiated Y chromosome in a Swiss population. This phenomenon may relate to variation in the masculinizing effect of alleles. Populations of *R. temporaria* with more differentiated sex chromosomes might produce a genotypic sex factor on the Y that is strongly masculinizing, whereas the sex factor would be extremely weak in undifferentiated populations. It is possible then, that homomorphic *R. temporaria* populations have epigenetic control of SD (i.e., how sex determination is regulated genetically depends on environmental factors), whereas heteromorphic populations have completely genetic control (Rodrigues et al., 2017).

Indeed, genetic control has been demonstrated in heteromorphic populations. Important SD genes on the Y of heteromorphic populations from northern Sweden co-segregate and likely reflect a reciprocal translocation between an original Y chromosome and an autosome. This neo-sex chromosome may be the youngest thus far described and could act as a supergene of speciation in the future (Rodrigues et al., 2016).

Epigenetic control of SD, on the other hand, has not been demonstrated directly but would explain the following findings in homomorphic populations: (1) the higher number of sex-reversed females in *R. temporaria* in the Swiss Alps (Rodrigues et al., 2017), (2) the lack of a correlation between parental haplotypes and sex of progeny at a known sex linkage group of *R. temporaria* in the Swiss lowlands, based on a high-power SNP analysis (Brelsford, Rodrigues and Perrin, 2016), and (3) the variance in phenotypic sex of a southern Swedish population not accounted for by genetic factors in a microsatellite study (Rodrigues et al., 2016). Importantly, model-based, hypothesis-driven approaches have been devised to disentangle the effects of climate and phylogeography in terms of expected correlations

between parental linkage group haplotypes and phenotypic sex, across populations whose sex chromosomes vary in levels of differentiation. A description is beyond the scope of this paper, but see Rodrigues et al. (2014).

Concluding remarks on a true frog from Japan

The *Hyla* and *Rana temporaria* systems will clearly be instructive for an understanding of population-level variation in sex chromosome differentiation. Nonetheless, I move beyond these two systems, concluding with a discussion of a frog species whose sex chromosome evolution may be the most extraordinary known to amphibians: the true frog *Glandirana rugosa* of Japan. Like *Hyla* and *Rana temporaria*, *G. rugosa* varies in sex chromosome differentiation. However, unlike other systems studied to date, this species also displays population-level variation in SD systems, with multiple transitions from male to female heterogamety. Variation in SD systems within a single species is astounding, because SD was formerly thought to evolve only at deep evolutionary timescales. Research on *G. rugosa* promises to bring to light how profound sex chromosome variation can evolve rapidly. One heteromorphic XX/XY and two heteromorphic ZZ/ZW geographic groups of *G. rugosa* exist. Mitochondrial phylogenetics revealed that the ZZ/ZW evolved twice independently from an XY ancestor. The younger ZZ/ZW group is called the Neo-ZW (Ogata et al., 2008). According to analyses using sex-linked markers, hybridization between homomorphic populations of *G. rugosa* from western and eastern Japan—which occurred shortly after the origin of the species—spurred the evolution of heteromorphic XX/XY and ZZ/ZW (Miura et al., 1998).

Exciting new analyses of sex-linked SNP genotypes suggest at least four independent decays and resurrections of the X chromosome into W chromosomes between heteromorphic groups of *G. rugosa* (Ogata et al., 2022). A phylogenetic analysis recovered three older populations of ZW, with deep introgression of XY in one, and two populations of what is called the Neo-ZW geographic form, Neo-ZW1 and Neo-ZW2. The Neo-ZW1 and Neo-ZW2 populations both recently originated from an XY group. SNP analyses suggest that the newer Neo-ZW population (Neo-ZW2) formed from hybridization between Neo-ZW1 and the heteromorphic XY group (Ogata et al. 2022). Results demonstrated that admixture of opposite SD systems can recycle X chromosomes into new W chromosomes, and more broadly, that hybridization can generate *de novo* SD systems (Ogata et al. 2018). Future research in *G. rugosa* using genome scans to search for major incompatibility loci in heteromorphic populations and measure hybrid viability will be useful. Moreover, the construction of evolutionary trees for individual genes on non-recombining regions of the sex chromosomes would help us to identify more granular patterns of introgression. The aforementioned methods will reveal exactly how hybridization can cause transitions of heterogametic sex and evolution from homomorphy to heteromorphy.

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Herpetology 2023

In this column the editorial staff presents short abstracts of herpetological articles we have found of interest. This is not an attempt to summarize all of the research papers being published; it is an attempt to increase the reader's awareness of what herpetologists have been doing and publishing. The editor assumes full responsibility for any errors or misleading statements.

STUDYING SALAMANDER BEHAVIOR

T. A. Clay and M. E. Gifford [2022, *Herpetologica* 78(2):86-92] note that how organisms respond to abiotic conditions is paramount for predicting their response to climate change. Mechanistic models have been used extensively to predict the distribution and abundance of many organisms based on their physiology and behaviors. To provide further support for, and inform, mechanistic model predictions, relatively realistic laboratory experiments can be created to replicate natural climatic scenarios. The authors designed enclosures for terrestrial salamanders that allowed for manipulation of abiotic conditions in a relatively realistic way and for observation of both surface and subsurface behaviors. During a trial, enclosures provided realistic conditions that were an accurate reflection of the field conditions that the study species would be exposed to during their active season. Salamanders behaviorally responded to changing abiotic conditions in the enclosures in a similar fashion to what has been observed through long-term field studies. The study also documented differences in subsurface behavior, with younger and smaller salamanders occupying shallower depths in response to days since feeding. Given the strong correlation between laboratory and field behaviors under current climatic scenarios, as well as the potentially unknown outcomes between abiotic and biotic conditions, the authors recommend using realistic laboratory enclosures to replicate future climatic conditions to further refine the predictive power of mechanistic models.

THE USE OF PIT TAGS

S. C. Sterrett et al. [2022, *Journal of Herpetology* 56(2):146-152] note that studying the movements of organisms that live underground for at least a portion of their life history is challenging, given the state of current technology. Passive integrated transponders (PIT tags) provide a way to individually identify and, more recently, study the movement of smaller animals, including those that make subterranean movements. However, there are widespread assumptions of the use of PIT tags that remain problematic. The authors tested the effects of PIT-tag implantation on growth and survival, along with the effects of electromagnetic fields for reading PIT tags on behavior, of the smallest salamander that has been PIT-tagged: the red-backed salamander. They found no effect of PIT tags on growth or survival. Using a mesocosm experiment, they also found that electromagnetic effects associated with reading PIT tags had no effect on salamander behavior. They describe a novel PIT antenna and soil mesocosm experimental arena for studying belowground movements of woodland salamanders. Collectively, these studies suggest that the use of PIT tags do not influence the growth, survival, or behavior of red-backed salamanders. Given the challenges of studying salamanders that live underground and the impending changes in climate and landscapes, this research suggests that PIT tags remain a viable tool for studying the movement ecology of salamanders under global change.

HOMING BEHAVIOR OF FOWLER'S TOADS

N. Jreidini and D. M. Green [2022, *Herpetologica* 78(3):154-160] note that homing abilities have been widely documented in amphibians, but it remains unclear whether individuals have homing tendencies in the absence of motivational cues related to breeding and site fidelity. The authors tested whether artificial displacement would affect the movement behavior of a non-philopatric terrestrial amphibian, the Fowler's toad (*Anaxyrus fowleri*), within its home range and after its breeding season had ended. They translocated 65 male and female Fowler's toads from their initial points of capture a total of 104 times over one of three different distances (100 m, 250 m, and 500 m) and compared these toads' subsequent 24-h movements with those of a control group of 43 untranslocated toads. To shield the translocated toads from auditory, visual, and olfactory cues en route, they translocated them in opaque enclosed boxes and performed the experiment in the uniformly unobstructed landscape of the Lake Erie shoreline of Long Point, Ontario, Canada. They mainly investigated directionality bias as the orientation between control and translocated groups, homing tendency as the correlation between movements after translocation and translocation distance, and homing accuracy as the variation in distance between final and initial capture points. Results provide clear evidence that translocation changes the movement behavior of these toads and that they possess homing tendencies outside of their breeding season. Toads had a strong directional bias to move in the opposite direction to the one in which they were artificially displaced, in contrast with the control group, which showed no directional bias among 61 recorded 24-h movements. This tendency for amphibians to home after artificial displacement might be a significant confounding factor in any procedure involving their relocation.

PREVALENCE OF SNAKE FUNGAL DISEASE

M. Gramhofer et al. [2022, *Journal of Herpetology* 56(3):274-277] note that ophidiomycosis (snake fungal disease; SFD) is a disease of conservation concern caused by the fungus *Ophidiomyces ophidiicola* that threatens the health of snake populations worldwide. Gaps exist in our knowledge about the prevalence of this disease across landscapes. The authors compared the prevalence of ophidiomycosis between a low-impacted forest site (n = 93) and a highly disturbed remediated landfill (n = 53) in Anderson County, Tennessee, USA. Free-ranging snakes were examined for the presence of skin lesions that are consistent with ophidiomycosis and were swabbed to detect *O. ophidiicola* DNA using quantitative PCR (qPCR). Apparent ophidiomycosis (qPCR-positive and skin lesions present) was diagnosed at both sites, but there was no significant difference in prevalence between the two sites (24.7% at the forest site; 22.6% at the landfill site). Apparent ophidiomycosis was most prevalent in racers (38%; *Coluber constrictor*) and ring-necked snakes (26%; *Diadophis punctatus*). There was no difference in ophidiomycosis status between sites for the most-sampled species: racers, black rat snakes (*Pantherophis obsoletus*), and ring-necked snakes (*Diadophis punctatus*). The study represents the first report of ophidiomycosis at focal sites in Tennessee. The findings suggest that *O. ophidiicola* may be ubiquitous across the landscape and point to the need for further study of diverse habitat types for the prevalence of *O. ophidiicola*.

FIRE ANT PREDATION ON SNAKE EGGS

M. C. Swartwout and J. D. Willson [2022, *Herpetologica* 78(2): 139-144] note that invasion and spread of Red Imported Fire Ants (RIFA; *Solenopsis invicta*) is cited as a possible cause for enigmatic reptile declines in the southeastern United States. Reptiles are negatively affected by RIFA through predation of eggs, hatchlings, and adults. The authors used short-term (12-h) field trials early in incubation to evaluate whether RIFA could successfully depredate intact eggs from six species of native terrestrial oviparous snakes: North American racer (*Coluber constrictor*), speckled kingsnake (*Lampropeltis holbrooki*), prairie kingsnake (*L. calligaster*), rough greensnake (*Opheodrys aestivus*), black ratsnake (*Pantherophis obsoletus*) and Great Plains ratsnake (*P. emoryi*). Then they used an artificial nest field experiment at the end of incubation to test whether RIFA predation differed between a species that has apparently declined in areas of its range where RIFA has invaded (*L. holbrooki*) and a species that has apparently not declined (*C. constrictor*). They measured pip-hatch and incubation time for each species in the laboratory to determine whether differences in time between pipping and hatching (pip-hatch time) could account for interspecific differences in RIFA predation on eggs. Overall, RIFA predation rates on snake eggs were high for all species (25–67% during early trials, 50–100% at end of incubation), although *P. obsoletus* was only depredated after hatching in the field. *Coluber constrictor* had significantly shorter pip-hatch times than other species, but probability of predation by RIFA did not differ for *C. constrictor* and *L. holbrooki*. This study provides novel observations of RIFA predation and suggests that time spent in nest, eggshell characteristics, and nest microhabitat may be more important than pip-hatch time in mediating vulnerability of snake eggs to RIFA predation.

WIND FARMS AND AMPHIBIANS

C. M. Trowbridge and J. D. Litzgus [2022, *Herpetologica* 78(2): 75-85] note that anurans exhibit altered chorusing behaviors in response to anthropogenic noise, yet no studies have considered the effects of wind farm presence on anuran chorusing behaviors. They studied amphibian communities in a wind farm situated in a landscape that includes relatively pristine wetlands and forests. They measured amphibian diversity in habitats adjacent to wetlands using transect surveys, and quantified anuran chorus and call characteristics (diversity, frequency, and duration) using nightly audio recordings in replicated turbine sites (<0.5 km from turbines) and control sites (>1.5 km from turbines). If wind farms present a source of disturbance, then they expected wetlands near turbines to have lower species diversity, lower chorus intensity, and altered call characteristics. They found significantly lower chorus diversity in turbine-site recordings, but no differences in biodiversity between turbine and control sites based on animals captured during transect surveys. Call characteristics did not differ between control and turbine sites; however, frogs calling in the wind farm displayed call characteristics similar to those of frogs calling near noisy roads within control sites, and some anuran species were notably absent from turbine sites. Identification of new threats, including those resulting from putatively green energy alternatives, is essential to mitigating global amphibian decline.

LOGGERHEADS AT TORTUGUERO

J. Restrepo et al. [2022, *Journal of Herpetology* 56(3):336-340] note that Costa Rica is considered a hot spot for biodiversity and wildlife conservation in Central America, and sea turtles are a good example of this. Largely distributed along both the Caribbean and Pacific coast, adult females of five of the seven extant sea turtle species select beaches on both coasts as their breeding sites. Although green sea turtles (*Chelonia mydas*), leatherback sea turtles (*Dermochelys coriacea*), hawksbill sea turtles (*Eretmochelys imbricata*), and olive ridley sea turtles (*Lepidochelys olivacea*) have been extensively studied in Costa Rica, little information regarding loggerhead sea turtles (*Caretta caretta*) is available. The authors present an exhaustive data record of every loggerhead encountered at Tortuguero beach (northeastern Caribbean coast of Costa Rica) over the past 60 yr. They collected loggerhead nesting data between 1957 and 2021 through daytime and nocturnal monitoring activities. They documented 14 loggerhead sea turtle nesting attempts between 1957 and 2021 at Tortuguero. Among them, seven nested successfully, four did not lay eggs, and one's fate is unknown. Additionally, two turtles were killed by jaguars. Mean minimum curve carapace length for loggerheads was 98.2 ± 3.7 cm (range, 90.0–101.4 cm). Finally, they found that every encounter occurred between April and July, which coincides with the loggerhead nesting season in the Northwest Atlantic. This study is the first assessment of loggerhead sea turtles nesting in Costa Rica, bringing to light new records for this species in the Caribbean Sea.

INTERMEDIATE HOSTS FOR AN INVASIVE PARASITE

J. N. Palmisano et al. [2022, *Journal of Herpetology* 56(3):355-361] note that *Raillietiella orientalis*, an invasive pentastome parasite, inhabits the lungs of snakes as adults and is rapidly spreading in Florida and Australia. The species that serve as intermediate hosts are currently unknown. They conducted laboratory infection experiments with insects (*Blaberus discoidalis*), lizards (*Anolis sagrei*), and anurans (*Anaxyrus terrestris*, *Lithobates sphenoccephalus*, *Osteopilus septentrionalis*) to develop an understanding of which species may serve as intermediate hosts and to determine the fitness consequences of infection by *R. orientalis*. Lizards and insects, but not anurans, were readily infected by consuming food that was contaminated with pentastome eggs. *Anolis sagrei* and *L. sphenoccephalus* were both infected after eating a single roach that was infected with *R. orientalis* larvae. Comparison with uninfected control animals revealed that pentastome infection did not significantly affect survival or growth in roaches, lizards, or anurans. The life cycle of *R. orientalis* in Florida is likely to involve a sequence of three hosts, with eggs hatching in coprophagous insects that infect lizards and anurans that infect the definitive host (snakes) after they are consumed. The results indicate that the native species that serve as intermediate hosts are unlikely to experience major negative consequences from *R. orientalis*, unlike the native snake species that serve as the definitive hosts. The diversity of species that can serve as intermediate hosts and the potential for vehicular rafting by infected roaches and anoles indicate that the rapid geographic range expansion of *R. orientalis* will probably continue.

BEHAVIOR OF KAROO DWARF TORTOISES

V. J. T. Loehr et al. [2021, *Herpetologica* 77(3):232-238] note that in arid regions with summer rainfall, herbivorous reptiles are able to acquire water and fresh food in the presence of high environmental temperatures that can promote ectotherm activity. However, extremely high temperatures and below average rainfall may also limit foraging opportunities due to risks of overheating and predation while gathering scarce food. Karoo dwarf tortoises, *Chersobius boulengeri*, inhabit an arid region in South Africa where most rains fall around austral summer (October–May). The authors used focal-animal observations and instantaneous recording to assess their behavioral patterns. Despite relatively high rainfall and available plant growth, Karoo dwarf tortoises spent approximately 80–90% of their time in retreats. Whereas activity (behavior outside retreats) in the spring was unrelated to time of the day, possibly due to moderate ambient temperatures, activity in the summer was restricted to the afternoon and evening, when tortoises walked and scanned for food and retreats, and fed only 11 min/d on average. In summer, body temperature of tortoises within retreats was positively associated with retreat temperatures, but tortoises appeared to thermoregulate using bodily postures and possibly other means. The authors suggest that Karoo dwarf tortoises mitigate predation risks by maintaining a low level of activity and thermoregulating within retreats. The short feeding time of Karoo dwarf tortoises compared to other tortoise taxa may result in slow growth and reproductive rates, which might in turn affect population resilience and conservation needs of this endangered species.

COVER OBJECTS IN SOUTHERN CALIFORNIA

J. M. Lemm and M. W. Tobler [2021, *Herpetologica* 77(4):307-319] note that artificial cover objects (ACOs) are known to attract small terrestrial vertebrates, but the actual parameters that attract species to ACOs can vary across geographic regions and climates. For this study ACOs were placed in coastal sage scrub and grassland habitats in southern California and surveyed weekly for small terrestrial vertebrates over a 4-yr period. The authors observed 1643 individuals of 34 taxa during 143 survey sessions totaling 16,312 ACO days. Overall species richness and abundances under ACOs were highest from February to April. Results showed that the probability of encountering a reptile under an ACO was highest in February and March under large wooden ACOs containing moist soil, when temperatures under the ACO were relatively mild, and when minimum air temperatures were low. At the community level, encounter probabilities for small mammals were highest for large wooden ACOs and ACOs with low soil moisture, with several species differences. Amphibians of three species were only captured in low numbers, primarily under wooden ACOs, from November to March. Use of ACOs in research and monitoring is an inexpensive and simple way to document and capture a wide variety of small terrestrial vertebrates. Species richness and abundance can be maximized over short periods using ACOs and can be equally important for long-term monitoring, particularly once the factors that make ACO use effective for small terrestrial vertebrates of a certain region have been investigated.

Minutes of the CHS Board Meeting, December 13, 2022

A meeting of the CHS board of directors was called to order via Zoom at 7:38 P.M. Board members Stephanie Dochterman Kyle Houlihan, Tom Mikosz and Amelia Pollock were absent. Gabrielle Evans also attended. Minutes of the November 15 board meeting were read and accepted.

Officers' reports

Treasurer: Rich Crowley presented the November financial report.

Media secretary: Gabrielle Evans agreed to serve as media secretary for the coming year. She still needs access information for a few more of our sites. She will see if we can get members to send in photos for us to post online, and hopes to post at least every other day to keep up our social media presence.

Membership secretary: Mike Dloogatch reported that our ability to accept online dues payments has been restored. There was a net increase in membership this month.

Sergeant-at-arms: There were 20 attendees in person at the November 20 meeting.

Old business

Membership survey: Rachel Bladow reported that the survey is complete. Results will appear in the *Bulletin*.

John Archer is still searching for someone to run the library.

The meeting adjourned at 8:33 P.M.

Respectfully submitted by recording secretary Gail Oomens

NEW CHS MEMBERS THIS MONTH

Caitlin David
Eric Fishman

Rowan McGaffey
James P. Rowan

Lucy and John Webb

Advertisements

For sale: **highest quality frozen rodents**. I have been raising rodents for over 30 years and can supply you with the highest quality mice available in the U.S. These are always exceptionally clean and healthy with no urine odor or mixed in bedding. I feed these to my own reptile collection exclusively and so make sure they are the best available. All rodents are produced from my personal breeding colony and are fed exceptional high protein, low fat rodent diets; no dog food is ever used. Additionally, all mice are flash frozen and are separate in the bag, not frozen together. I also have ultra low shipping prices to most areas of the U.S. and can beat others shipping prices considerably. I specialize in the smaller mice sizes and currently have the following four sizes available: Small pink mice (1 day old—1 gm), \$25 /100; Large pink mice (4 to 5 days old—2 to 3 gm), \$27.50 /100; Small fuzzy mice (7 to 8 days old—5 to 6 gm), \$30/100; Large fuzzy mice / hoppers (10 to 12 days old—8 to 10 gm), \$35/100 Contact Kelly Haller at 785-224-7291 or by e-mail at kelhal56@hotmail.com

Line ads in this publication are run free for CHS members — \$2 per line for nonmembers. Any ad may be refused at the discretion of the Editor. Submit ads to mdloogatch@chicagoherp.org.

Snakenanigans

Jonathan Montgomery Pollock took this photograph of a reticulated python at the Peggy Notebaert Nature Museum.

Entitled “Snakenanigans,” it was voted best snake photograph at the June 29 CHS meeting.



Chicago Herpetological Society
Income Statement: January 1 – December 31, 2022

| Income | | Expense | |
|---------------------|--------------------|-----------------------------|--------------------|
| Membership dues | \$ 7,611.20 | Bulletin printing / mailing | 10,556.91 |
| Donations | 9,353.67 | Rent (storage) | 2,763.00 |
| AmazonSmile | 31.73 | Bank / PayPal / Square fees | 276.24 |
| Interest | 1.14 | Liability insurance | 1,261.00 |
| Raffle | 138.00 | Dues, licenses and permits | 490.35 |
| | | Miscellaneous supplies | 49.64 |
| | | Postage | 1,908.43 |
| | | General meeting expense | 599.39 |
| Total Income | \$17,135.74 | Total Expense | \$17,904.96 |

Net Income (Loss) (\$769.22)

Chicago Herpetological Society
Balance Sheet: December 31, 2022

Assets

| | |
|-----------------------|-------------|
| Checking | \$ 2,882.27 |
| Money market | 11,478.22 |
| Petty cash— show fund | 350.00 |
| PayPal | 1,229.61 |
| Postage on deposit | 461.06 |

Total Assets \$16,401.16

Liabilities

| | |
|--------------|---------------|
| Credit cards | <u>238.00</u> |
|--------------|---------------|

Equity

| | |
|-------------------|-----------------|
| Retained earnings | 16,932.38 |
| Net income (loss) | <u>(769.22)</u> |

Total Equity \$16,163.16

Total Liabilities & Equity \$16,401.16

UPCOMING MEETINGS

From now on the monthly meetings of the CHS will be held in the afternoon on the third Sunday of each month. The meetings will begin at 2:00 P.M. The next meeting will take place on January 15. The program has not yet been confirmed. Please try to join us online or *in person* at the Notebaert Nature Museum, 2430 N. Cannon Drive, Chicago.

The February meeting will take place on Sunday, February 15. The program has not been confirmed.

Please check the CHS website or Facebook page each month for information on the program. Information about attending a Zoom webinar can be found here:

<<https://support.zoom.us/hc/en-us/articles/115004954946-Joining-and-participating-in-a-webinar-attendee->>

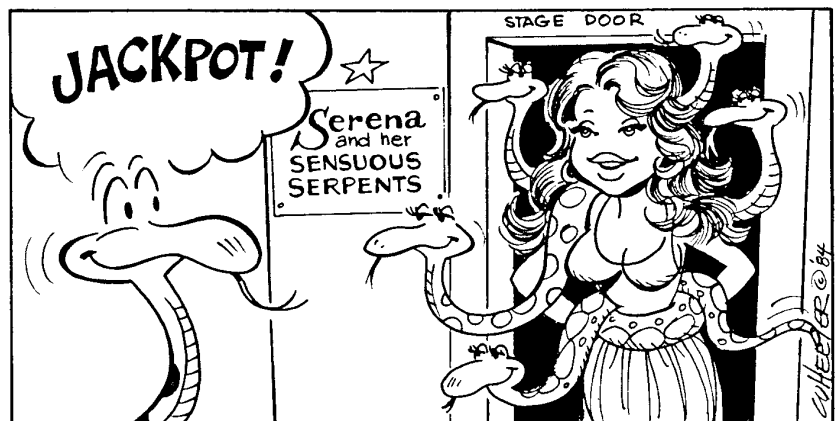
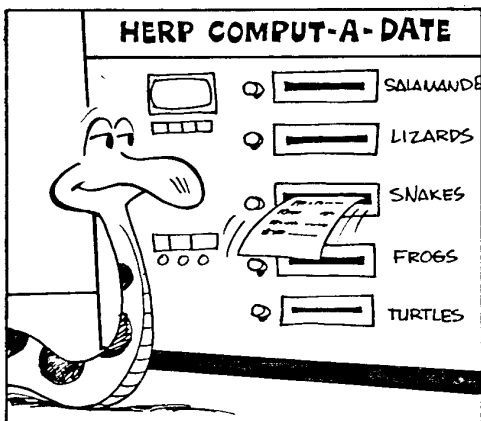
Board of Directors Meeting

Are you interested in how the decisions are made that determine how the Chicago Herpetological Society runs? And would you like to have input into those decisions? The next board meeting will be held online. If you wish to take part, please email: jarcher@chicagoherp.org.

REMINDER

When you shop AmazonSmile and select the Chicago Herpetological Society as your charity, Amazon will make a donation to the CHS. <<https://smile.amazon.com/>>

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