

predation of *Ichnocnema ramagii* by spiders. The spiders were collected and deposited in the Coleção of Arachnids and Chilopoda, Instituto Butantan (IBSP122.178 and IBSP122.179) and the anurans in Coleção Herpetológica, Universidade Federal of Sergipe (CHUFS 00200, 00201).

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**LEPTODACTYLUS SAVAGEI** (Smoky Jungle Frog) **ANTIPREDATOR DEFENSE.** Amphibians possess a broad suite of chemical defenses to deter predators (Toledo and Jared 1995. *Comp Biochem Physiol.* 111A:1–29), and this can lead to an evolutionary arms race between predator and prey. Snakes are common predators of amphibians and many amphibians have evolved toxins that deter them (Williams et al. 2003. *Herpetologica* 59:155–163). *Leptodactylus savagei* (Heyer 2005. *Arq. Zool.* 37:269–348) is a large, robust frog with males reaching 177 mm and females reaching 185 mm SVL (Savage 2002. *Amphibians and Reptiles of Costa Rica. A Herpetofauna Between Two Continents, Between Two Seas.* Univ. Chicago Press, Chicago, Illinois. 934 pp). This species ranges from Honduras to central Colombia and is a common inhabitant of SW Costa Rica. It has been reported anecdotally that this species produces noxious compounds in its skin that may cause a skin rash, sneezing, and irritation of mucus membranes in humans (Savage 2002, *op. cit.*; Toledo et al. 2007. *J. Zool.* 271:170–177). These noxious skin compounds may have evolved to deter vertebrate predators, yet Roberts (1997. *Herpetol. Rev.* 28: 84–85.) reported predation of *L. pentadactylus* by the mustelid *Lutra longicaudus* in Brazil.

One of the more commonly encountered snakes in SW Costa Rica is the viper *Bothrops asper*, which can reach lengths of 2.3 m (Solórzano 2004. *The Snakes of Costa Rica.* INBio. 791 pp.). This snake is a generalist predator, and juveniles and subadults consume mostly frogs and lizards and broaden their diets to include birds and mammals when they become adults (Solórzano 2004, *op. cit.*). Solórzano (2004, *op. cit.*) reports that *B. asper* consumes members of Leptodactylidae, and there are no reports of *B. asper* having adverse reactions to noxious prey. Herein we report a predation attempt by *B. asper* (109 cm TL) on an adult *L. savagei* (101 mm male) where the snake experienced severe deleterious effects apparently from skin toxins of *L. savagei*.

Our observations occurred at a small stream at Tres Piedras, Puntarenas Province, Costa Rica (9.325°N, 83.8666667°W; 95 m elev.) on 24 July 2004. We first encountered the predation

event at 2030 h, after the snake had struck the frog and began to consume it. We observed the snake for ca. 10 min. from a distance of 2 m in the streambed. During this time the snake was slowly ingesting the frog headfirst and had reached the frog's forelimbs when we left. The ingesting motions were extremely slow at this time, and we estimate that in 10 min. the snake had consumed ca. 0.5 cm of the frog. We marked the spot of the predation event along the stream and continued our survey. We returned to the location after 45 min. to find the frog dead and regurgitated on the sandy stream bank with two fang marks on its head. The snake was about 1 m downstream of the frog. The snake was lethargic and had difficulty moving when approached. When disturbed, the snake made no attempt to coil and exhibited no defensive actions. We gently turned the snake onto its back using a stick and the snake had difficulty righting itself and made no attempt to strike or escape. We observed the snake for 60 min. after finding it in this state and gently disturbed it every 15 min. to judge possible recovery. After 30 min. the snake still made no defensive or escape movements and when turned on its back it could no longer right itself. After 45 min. the snake began to show signs of recovery, slowly reacting to being touched. We slowly turned the snake on its back a third time and it was able to right itself, but was still moving very slowly. After 60 min. the snake appeared to become more aware and reacted with a quick jerk when touched, and eventually slithered slowly up the stream bank. However, the snake still did not appear to be acting normally at this point as most of its reactions were slow and its movements seemed disoriented. At ca. 105 min. after we discovered it attempting to prey on the *L. savagei*, the snake was finally moved out of the stream bank and it took cover under a log.

We infer that the sluggish behavior of the *B. asper* was due to toxic skin secretions from the *L. savagei* it was attempting to ingest. To our knowledge this is the first report of poisoning of a *B. asper* by *L. savagei*. Although the long-term effects of poisoning on this snake are unknown, it was totally incapacitated and incapable of moving or defending itself for ca. 45 minutes.

One of the skin compounds found in *L. pentadactylus*—sister species to *L. savagei*—is leptoxin, a novel, proteic toxin that is one of the most lethal protein toxins known (Limaverde et al. 2009. *Toxicon* 54:531–538). When ingested by laboratory rats, leptoxin induced cardiorespiratory collapse with abundant



FIG. 1. Adult *Bothrops asper* attempting to swallow an adult *Leptodactylus savagei* in SW Costa Rica. This photo was taken when the event was first observed and the snake was already lethargic. Soon after this photo the snake regurgitated the frog.

tracheal secretion followed by sudden death (Limaverde 2009, *op. cit.*). Leptoxin is not active orally at doses greater than 100 times higher than LD<sub>50</sub> and therefore appears not to be a predator deterrent (Limaverde 2009, *op. cit.*). It is unclear if leptoxin played a role in poisoning the *B. asper*, but it is apparent that *L. savagei* possess a skin compound that can harm a predator. Even though the frog we observed died from the predation attempt, this snake may avoid *L. savagei* as a prey item in the future.

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**LIMNONECTES KUHLII** (Kuhl's Creek Frog). **DIET.** *Limnonectes kuhlii* is a medium-sized stocky anuran with a conspicuously broad head in males (Inger 2005. The Systematics and Zoogeography of the Amphibia of Borneo. Natural History Publications [Borneo] Sdn. Bhd. Kota Kinabalu. 402 pp.). This widespread species occurs in northeastern India, southern China, Hong Kong, Taiwan, Myanmar, Laos, Vietnam, Thailand, Peninsular Malaysia, Sumatra, Java, Borneo, and Sulawesi (AmphibiaWeb. <http://amphibiaweb.org/> accessed 25 Sept 2009; Das 2007. A Pocket Guide: Amphibians and Reptiles of Borneo. Natural History Publications [Borneo] Sdn. Bhd. Kota Kinabalu. 200 pp.; Inger 2005, *op. cit.*). *Limnonectes kuhlii* dwells along the banks and in small to medium-sized streams with moderate to weak currents and rocky bottoms, as well as in silty rain puddles in primary and old secondary forests, and in the vicinity of human settlements from near sea level to 1750 m elev (Inger and Stuebing 2005. A Field Guide to the Frogs of Borneo. 2<sup>nd</sup> ed. Natural History Publications [Borneo] Sdn. Bhd. Kota Kinabalu. 201 pp.; Malkmus et al. 2002. Amphibians and Reptiles of Mount Kinabalu [North Borneo]. A.R.G. Gantner Verlag K.G. Ruggell. 424 pp.). To our knowledge, previous publications on the diet of *L. kuhlii* reported that the prey items are ants and insect larvae (Das 2007, *op. cit.*).

On 28 September 2008, between 1900 and 2200 h, an adult *L. kuhlii* (75 mm SVL, 41.3 g) was sampled at Sungai Lidan (5.9767°N, 116.52645°E; 1063 m elev.), Bundu Tuhan, Ranau District, West Coast Division, Sabah, Bornean Malaysia. Within 24 h, the anuran was identified, photographed, euthanized, and dissected, and the stomach contents were extracted. Upon examination, an adult *Tropidophorus beccarii* (71 mm SVL, partial tail length 54 mm) in the early stage of digestion was found in the stomach. The approximate prey/predator SVL ratio was 0.95. *Tropidophorus beccarii* (Scincidae) is a large and slender skink (< 99 mm SVL) endemic to Borneo, which prefers rocky streams in hilly forests up to 1000 m elev (Das 2007, *op. cit.*; Malkmus et al. 2002, *op. cit.*). The anuran (HEP00617) and skink (HEP00956) were deposited in BORNEENSIS, the

Bornean reference collection of the Institute for Tropical Biology and Conservation, Universiti Malaysia Sabah.

Between June and December 2008, another 75 *L. kuhlii* were sampled and dissected as part of research on the biology of anurans at Bundu Tuhan. However, stomach content examination found no vertebrate prey items. Hence, this is the first and only record of *L. kuhlii* preying a reptile as well as a vertebrate.

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**LIMNONECTES KUHLII** (Kuhl's Creek Frog). **MAXIMUM SIZE.** *Limnonectes kuhlii* is commonly found in or around water from in primary forests to the vicinity of human settlements up to 1750 m elev in northeastern India, southern China, Hong Kong, Taiwan, Myanmar, Laos, Vietnam, Thailand, Peninsular Malaysia, Sumatra, Java, Borneo, and Sulawesi (Das 2007. A Pocket Guide: Amphibians and Reptiles of Brunei. Natural History Publications [Borneo] Sdn. Bhd. Kota Kinabalu. 200 pp.; Inger and Tan 1996. The Natural History of Amphibians and Reptiles in Sabah. Natural History Publications [Borneo] Sdn. Bhd. Kota Kinabalu. 101 pp.; Inger and Stuebing 2005. A Field Guide to the Frogs of Borneo. 2<sup>nd</sup> ed. Natural History Publications [Borneo] Sdn. Bhd. Kota Kinabalu. 201 pp.; Malkmus et al. 2002. Amphibians and Reptiles of Mount Kinabalu [North Borneo]. A.R.G. Gantner Verlag K.G. Ruggell. 424 pp.). *Limnonectes kuhlii* is an anuran with a stocky body and short muscular limbs. The broad head is more prominent in males, enabling the males to grow larger than the females (Inger 2005. The Systematics and Zoogeography of the Amphibia of Borneo. Natural History Publications [Borneo] Sdn. Bhd. Kota Kinabalu. 402 pp.). Previous publications report the maximum size for *L. kuhlii* as 75 mm SVL (Das 2007, *op. cit.*; Inger 2005, *op. cit.*). Herein we report a new maximum size for the species.

On 17 Aug 2009, between 1900 and 2200 h, an adult *L. kuhlii* was sampled at Sungai Kepungit (6°N, 116.5439°E; 1394 m elev.), Bundu Tuhan, Ranau District, West Coast Division, Sabah, Bornean Malaysia. Air temperature was 18.6°C, and relative humidity was 84%. The specimen was 88 mm SVL, mass 61.7 g; measurements were taken with a standard metric tape and an electronic balance. The presence of a pair of conspicuous tooth-like projections on the lower jaw, and large size suggest that the anuran was male. The specimen (HEP00959) was deposited in BORNEENSIS, the Bornean reference collection of the Institute