

Seasons of death: patterns of predation on wild lemurs and other fauna by endemic and introduced predators

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Supplementary material

Text S1. Gross Necropsy Report 1. 4 July 2008. *Lemur catta*, ring-tailed lemur #212. Scott Larsen, Project Veterinarian.

Examined is the body of an adult male ring-tailed lemur, with a black collar and 212 ID tag. A Trovan microchip transponder was located: 00-0663-E82E. The body was found approximately 15 meters to the south of the road that forms the southern border of the Beza Mahafaly Special Reserve. The body was located at 11:45 AM; at that time there was no evidence of rigor mortis, but small fly larvae were evident in the oral cavity and in the exposed thoracic cavity. The head was thrown back in an opisthotonic posture. At 1:20 PM, rigor mortis was evident.

The lemur appears to be in fair body condition; however much of the musculature of the body wall and back are missing and minimal fat is evident in the remaining tissues. There is abundant infraorbital fat. All thoracic and abdominal viscera have been removed and are missing. Some feces containing *Enterospermum* seeds, is present in the caudal abdomen.

There is a large gaping wound on the ventral abdomen and much of the skin, hair, and musculature of the ventral abdomen is missing. Multiple ribs are broken and the caudoventral aspect of the rib cage is removed and missing. The last six ribs on the left and last five ribs on the right are broken, approximately in the region of the costochondral junctions. There is a 7 cm longitudinal full-thickness skin tear on the right aspect of the ventral abdomen with evidence of bruising. There is moderate subcutaneous and muscular hemorrhage that extends from rib 4 to rib 10 on the right side and corresponds to the large skin tear. The gaping abdominal wound extends to the level of the anus and to the left rear leg. The penis, testicles, and all surrounding soft tissue are removed and missing. Ribs 1-5 on both sides were cut and removed in order to examine the cranial thorax and remove the trachea and esophagus. There is a linear longitudinal area of hemorrhage along the right dorsal aspect of the caudal lumbar vertebrae, but this hemorrhage is confined to the superficial fascia and the underlying muscles do not appear to be affected. Although the transponder was detected by a scan, there was no evidence of injury to the dorsal musculoskeletal system in the cervicothoracic region, so this area was not dissected, and the microchip was not retrieved.

There is moderate hemorrhage in the cranial aspect of the thorax, but it cannot be determined if this was antemortem or postmortem pooling of blood. The trachea and esophagus

are transected at the cranial aspect of the thorax. There is nothing within the esophageal lumen and no lesions are found in the trachea. A focal area of hemorrhage is present on the ventral base of the larynx. Dissection of the larynx reveals moderate serosanguinous material in the lumen, but no further evidence of trauma.

There is hemorrhage in the left axillary area congealed in the region of the left axillary lymph node. There is also subcutaneous hemorrhage just cranial to the right shoulder. The musculature of the left rear femur is missing, although the femur itself is intact. The skin and fur are present on the left rear leg below the level of the knee. The right rear leg is intact, but the medioproximal aspect is covered with feces containing *Enterospermum* seeds.

The surface of the tongue is covered with small, rice-grain-size fly larvae. The molariform teeth and incisors show moderate wear. No external wounds are evident on the head, but reflection of the skin reveals hemorrhage in the region of the left cheek. There are two focal areas of hemorrhage on the left cheek – one area in the musculature at the ventral base of the ramus of the mandible and another area 18 mm dorsally, at the juncture of the masseter muscles and the salivary glands. There is associated hemorrhage and bruising on the medial aspect of the skin in this region. The bruising is most intense in two focal areas, 18 mm apart, with a linear connecting area of less intense bruising. These injuries are most consistent with a bite from a carnivore, with puncture by canines and pressure from incisors. There is coagulated blood coming from the left nostril but there is no outward evidence of trauma or fracture of the nose.

Conclusions

The injuries sustained appear to be most consistent with an attack by a felid, presumably an ampaha. The wounds on the head are compatible with a felid bite. The longitudinal lacerations on the ventral abdomen may have been a result of injuries from claws, also consistent with a felid. The abdominal and thoracic organs are missing, and there is a large gaping wound with tissues missing on the ventral abdomen, so it is difficult to surmise the extent of internal injuries. The animal may have died from the trauma to the larynx and associated fluid accumulation, but the damage to this area does not appear extensive enough to be the cause of death. The lungs, and half of the trachea, are not present to look for fluid accumulation. There is

minimal trauma of the skeletal system, with only fractures of the ribs. Death may have been a result of abdominal injuries and/or injury to the large vessels of the left leg.

Gross Necropsy Report 2. 21 July 2009. Verreaux's sifaka, *Propithecus verreauxi* 340. Scott Larsen, Project Veterinarian.

The necropsy was started at approximately 14:00 and rigor mortis had begun to set in. The animal was identified with collar #340 as an 11-year-old male. It weighed 2.28 kg and no subcutaneous, visceral, or retro-orbital fat. On reflection of the thoracic skin, the ribs were very prominent with decreased muscle mass. When the skin of the abdomen was reflected, the abdominal musculature was thin, and the tip of the cecum could be seen before making an incision in the abdominal muscles and entering the peritoneum. The diaphragm musculature was also thin.

The hair and skin around the right side of the head, neck and craniodorsal thorax were stained with blood. There is a small amount of blood staining on hair of the right rear leg. There were two large punctures (4×2 mm and 2×2 mm) in the skin at the base of the right mandible on the neck, two smaller punctures (1×1 mm) in the skin, mid-cervical on the right dorsal aspect of the neck, and a large puncture (0.5 mm \times 1.5 mm) slightly left of midline cranial cervical on the dorsum. There was another large puncture (1.5 mm \times 1.5 mm) just to the left of the trachea, mid-cervical. The distance between the two large punctures on the mandible is ~ 4 mm and the distance to the large puncture from these to the puncture left of the trachea is ~ 2.7 cm. Several punctures are found on the right side of the neck and the dorsal aspect of the neck near the base of the skull. When the skin was removed, from the head, neck, and cranial thorax, there was severe hemorrhage around the caudal third of the skull, with severe disruption and hemorrhage of the dorsal and right lateral neck musculature, particularly cranially where the spine connects with the skull. Hemorrhage extended from the caudal third of the skull to the cranial thorax at the point of the scapulae. There was increased laxity to the right of the occipito-atlas junction. No fractures of the skull or spine were found; however dissection of these structures was limited in order to limit artifactual changes for any skeletal preparation. The right jugular vein was severed and macerated as was the right carotid artery. There were focal, ~ 3 cm \times 3 cm areas of

hemorrhage bilateral on the surface of the thoracic cavity. There was a much smaller (~1 cm × 1 cm) focal area of associated hemorrhage on the skin of the right side of the thorax, but no associated skin hemorrhage on the left side of the thorax. There appear to be four pinpoint punctures associated with the skin hemorrhage on the right, but no such punctures on the left side of the thorax. For body lengths: from last rib to caudal pelvis = 15 cm; pelvis = 2.3 cm; caudal pelvis to cranial thorax = 31 cm; and from first rib to last rib = 14 cm.

Several thin white nematodes were found in the peritoneal cavity, most of which were adhering to the abdominal peritoneum or the surface of abdominal organs. It is presumed that these were *Paulianfilaria* nematodes. Several specimens were preserved intact in formalin and in 90% isopropyl alcohol.

The muscles of the jaw were in rigor mortis and the mouth was not opened so as not to damage the skull or the teeth. From limited evaluation, the dental wear appeared to be moderate, with no broken canines and an intact tooth comb. At the end of the necropsy (~16:00) fly larvae were evident in the oral cavity. The esophagus was empty, and no lesions were found. The stomach was very full of homogenous green chewed plant material and weighed >250 g (maximum of gram scale); no lesions on the luminal surface of the stomach were found; however, the lining of the stomach was separating from the stomach wall postmortem. The small intestine (245 cm) had liquid ingesta with gas; no intestinal lesions were found. The large intestine was 320 cm and had no visible abnormalities on the visceral or luminal surface. There was voluminous stool in the large intestine and cecum, with abundant fecal pellets in the ascending and descending colon. On cut section, the luminal surface of the cecum, large intestine, and colon appeared normal. The liver (66.4 g) appeared normal, and no abnormalities were found on cut-section. The gall bladder appeared normal. The spleen was 100 × 6 mm. It had three large, smooth, purple nodules on the lateral surface (12 × 6 mm, 10 × 5 mm, and 8 × 4 mm).

There was a small amount of ingesta in the glottis, but no food material was found in the trachea, bronchi, or on cut-section of the lungs. The right lungs were very firm and congested throughout while the left lungs were only congested in the medial third. No distinct lesions were found in the pulmonary parenchyma or on cut surface of the trachea or bronchi. No abnormalities

were found in the heart or greater vessels. The inguinal lymph nodes appeared normal. The urinary bladder was empty and small; no abnormalities were found on the peritoneal or luminal bladder surface. Two tubular structures were observed on either side of the bladder and are presumed to be accessory sex glands. The kidneys appeared normal, with no abnormalities on cut surface. The left kidney weighed 5.6 g (3.2 cm long) and the right kidney weighed 5.3 g.

To preserve the skeleton, the brain was not removed and examined. The skeleton was left as intact as possible and returned to Jacky.

Samples in formalin included inguinal lymph nodes, thymus, tongue, trachea, esophagus, eye, liver, gall bladder, skeletal muscle (semitendinosus/semimembranosus mm), testicle, both kidneys, urinary bladder, ureter, bulbourethral glands, spleen, pancreas, stomach, cecum, colon, jejunum, ileum, duodenum, both lungs, and heart.

Complete histopathologic evaluation of these tissues by a veterinary pathologist with experience with non-human primates, particularly prosimians, is highly recommended.

Preliminary conclusions

The sifaka was in lean body condition at the time of its death. Other than this, there was no gross evidence of underlying pathology that would have contributed to its death by predation. The animal likely died from severe blood loss from the severed right jugular vein and carotid artery but may have also died from trauma to the back of the head and base of neck, with both brain and spinal damage possible. The pattern of the punctures on the neck suggest that the maxillary canines and incisors of the cat punctured the more dorsal aspects of the sifaka's neck, while the mandibular canines and incisors punctured the more ventral aspects of the neck.

Figure S1. (A) juvenile *Lemur catta* with broken lower jaw resulting from a dog attack (see table 2 and supplementary table S1, predation attempt #3). Photo by James B. Millette. (B) Adult *Lemur catta*. Skull (arrow) and body intact with intestines removed from body and thigh muscles also missing (arrow) (see table 2, predation #1). (C) Adult *Propithecus verreauxi*, individual #367. Intestines have been pulled outside of the body; internal organs and thigh muscles also removed (see table 2 and supplementary table S1, predation #5). (D) Young adult female *Lemur catta*, individual #271. Massive trauma to the face and jaw (white arrows) (see table 2 and supplementary table S1, predation #6). E. Only the rib cage, skull, mandible, hair, and small bone remnants of this individual remains).

Figure S2. Predated remains of adult male *Lemur catta* animal #212, July 4, 2008 (see table 2 and supplementary table S1, predation #8). (A) Muscles have been stripped from left thighs, body cavity opened, the abdominal and thoracic organs are missing, and the intestines are intact and have been removed from the body. (B) A large (12 cm long) buried scat sample is found near the remains that is subsequently identified as *Felis catus*, based on DNA analysis. (C) Injuries around the neck, esophagus and trachea analyzed by Dr. Scott Larsen, the research project veterinarian is consistent with a bite from a carnivore, with puncture by canines and pressure from incisors (arrows). (D) Skull of forest cat fit puncture wounds at the neck, but as noted in the text, this does not by itself rule out fosa predation by a younger individual. Photos by Michelle Sauther.

Table 1. Lemur successful and attempted predations at Bezà Mahafaly in 2006, 2008 and 2009.

1. <i>Lemur catta</i> adult, unknown individual, and sex. July 14 th , 2004. Yellow West, below Blue I. Primarily intact with remnant intestines separate from body and muscles of both femurs missing. Remains indicate fosa or forest cat predation.
2. <i>Lemur catta</i> adult female. March 2006. Killed by a dog (IAJY, pers. comm.).
3. <i>Lemur catta</i> , juvenile. June 23, 2006 (supplementary fig. S1A). Red West, Blue II. JM comes upon the event due to hearing alarm calls. Going to the area of the calls, he finds a dog has pinned a young individual (probably best described as a young juvenile since this would have occurred during the dry season) to the ground. He chases the dog away. Once the dog left, the juvenile then climbs back into the tree where it then attempts to approach an individual who JM assumes is its mother. This is when it becomes apparent that the individual has serious damage to its jaw, which was broken and bent down vertically. The other individual seems a hesitant to approach the injured juvenile. She does not run down to pick it up or comfort it like one often sees when an infant falls from tree. Most of the other animals in the group have left during or immediately after the attack. The infant survives for almost a week after the attack and then disappears.
4. <i>Propithecus verreauxi</i> #94, adult male. July 27 th , 2006 (fig. 5D). Green East, Pink 3. This individual is found alive by members of the BMSR monitoring team. The sifaka had severe injuries indicative of a dog attack that include massive bites and muscle damage to the lower right leg and the upper right thigh as well as back of the upper left arm. Project veterinarian's attempt to close numerous wounds and after several days the individual is released, where it is able to climb into a tree. It is not clear if this individual survived as it was not seen by our team again in 2006.
5. <i>Propithecus verreauxi</i> , adult #367. Found June 25, 2008 (supplementary fig. S1C). Near Green East North of Pink

3. Muscles have been stripped from both thighs, body cavity has been opened, stomach and intestines are present but have been removed from the body cavity. Remains indicate fosa or forest cat predation.
<p>6. <i>Lemur catta</i>, young adult female #271, 2.8 years old.</p> <p>Found July 2, 2008 (supplementary fig. S1D-E). Outside eastern part of reserve, southeast of camp. This individual had previously survived a perforated bowel with a diverticulum in 2007 (Moresco <i>et al.</i>, 2012). Massive trauma to the face, missing left orbit and maxilla, and appear crushed, disarticulated lower jaw. Only the rib cage, skull, mandible, hair, and small bone remnants remain. Feeding style suggests a canid but it is unclear whether a dog was the predator or subsequent scavenger of the remains.</p>
<p>7. <i>Propithecus verreauxi</i>, adult uncollared.</p> <p>Found July 2, 2008 (supplementary fig. 1B). Outside western part of reserve, south of road. Muscles have been stripped from both thighs and the body cavity has been opened. All the phalanges on the individual's left foot have been consumed. Remains indicate fosa or forest cat predation.</p>
<p>8. <i>Lemur catta</i>, adult male # 212.</p> <p>Found July 4, 2008 (fig. 5C, supplementary fig. S2A-D). Outside eastern part of reserve, northwest of camp. Orange troop is giving click-click and yap alarm call (Sauther, 1989), which attracts the research team. ML finds the lemur's body. Remains are fresh with no evidence of rigor mortis. Muscles have been stripped from the left thigh, body cavity opened, the abdominal and thoracic organs are missing, and the stomach and intestines are intact and have been removed from the body. Injuries around the neck, esophagus and trachea analyzed by SL, the research project veterinarian are consistent with a bite from a carnivore, with puncture by canines and pressure from incisors. Enafa, a member of the Ecological Monitoring Team, notes a dirt mound near the body and from this a large, fresh (12 cm long) buried scat sample is found (fig. 7B). Subsequent DNA analysis indicates it is likely from a cat (Tkach and Ness, 99-100% match, unpubl. data). See necropsy report, supplementary text S1.</p>
9. <i>Lemur catta</i> , adult female #232.

<p>Found July 14, 2008. Outside western part of reserve, south of road. Muscles have been stripped from left hind thigh and lower leg and body cavity opened and internal organs are missing. In addition, phalanges of this individual's right foot been consumed. Remains indicate fosa or forest cat predation.</p>
<p>10. <i>Propithecus verreauxi</i>, adult #153.</p> <p>Found July 19, 2008. Yellow East above Pink 2. Remains include intact skull and articulated mandible, hair, and long bones. Unknown predator.</p>
<p>11. <i>Lemur catta</i>, adult male, uncollared.</p> <p>January 14, 2009. Individual killed by two unidentified men. Back of skull crushed, left tibia and fibula chopped at midsection, splinters of bone of tibia. Located at Fihamy Be, outside of the reserve, East of Sakamena River, 800 m east of camp, outside Parcel 1.</p>
<p>12. <i>Lemur catta</i>, juvenile, uncollared.</p> <p>June 26th, 2009 observed by TO. The juvenile (sex unknown) ring-tailed lemur was a member of an uncollared group (UG125) that resides north of Blue-III and Green (East) in Parcel I of the Beza Mahafaly Special Reserve. The observation was made at Green (East) 20 meters south of Pink1 (S23.65219 E044.63289 \pm 2.9 m) on 26 June 2009 at 11:25 am while following a study group (Green) that was foraging on the ground (eating termite soil) approximately 30 meters from the uncollared group. The UG125 group members (approximately 7) were spread throughout the understory trees and along the ground. Ground cover was not dense and very little foliage was present in the herb layer of the forest floor. At least one subadult animal (approximately 21 months of age) was sitting on the ground on the trail and several other adult individuals were foraging on the ground. The juvenile was observed to descend a large tamarind tree to its base where 3 adult lemurs were foraging on fallen tamarind fruits. While surveying the group's composition a loud squealing was heard and the foraging animals fled the ground into nearby trees. We then observed a medium-sized cat (estimated at 3 kg based on the size of female wildcats measured by Luke Dollar) holding the juvenile to ground by the back of the neck until it stopped struggling (approximately 5</p>

seconds). The cat then saw us and quickly carried the dead lemur by the back of the neck (like a kitten) to the trail (2 meters away) and moved away rapidly north along Green (East) for 10 meters and then ran west into the underbrush. Only once the cat was 20 meters away did the lemurs begin to alarm call (the whap – whap – whap vocalization with growling/croaking) and move high into the trees. Until this moment the rest of the group members were silent and immobile. After the predation event was over, we inspected the kill site and found small amounts of blood, but not enough to indicate exsanguination as a primary cause of death.

13. *Propithecus verreauxi*, adult male #340, 11 years old.

July 21, 2009 (fig. 8). Blue I between Black and Center Trail. At 11:30 AM MLS hears sifaka alarm calling in Parcel 1. She approaches the group and observes a forest cat running into the bushes in the Bezà Mahafaly Special Reserve near the Blue I trail, between the Black trail and the Center trail. A group of sifaka in the area are alarm calling and a dead sifaka is found ~2 meters south of the Blue I trail. The body is warm with no evidence of rigor mortis and there is a large amount of blood staining around the head and neck. With the permission of Youssouf Jacky, the Beza representative of the University of Antananarivo, the sifaka cadaver is moved to camp for a gross postmortem examination by SL, the project veterinarian. The sifaka is in lean body condition at the time of its death. Other than this, there is no gross evidence of underlying pathology that would have contributed to its death by predation. The animal likely died from severe blood loss from the severed right jugular vein and carotid artery but may have also died from trauma to the back of the head and base of neck, with both brain and spinal damage possible. The pattern of the punctures on the neck suggest that the maxillary canines and incisors of the cat punctured the more dorsal aspects of the sifaka's neck, while the mandibular canines and incisors punctured the more ventral aspects of the neck. See necropsy report, supplementary text S1.