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On the sympatry of three *Trioceros* species in a tropical upland forest in Cameroon

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The Cameroon Volcanic Line is a chain of volcanoes that extends northeast from the island of Annobón (Pagalu) in the Gulf of Guinea through the Western High Plateau of Cameroon (Marzoli et al. 2000). From the island of Bioko through the Western High Plateau, the Cameroon Volcanic Line is home to tropical and subtropical moist broadleaf forests within the Cameroonian Highlands forest, and the Mount Cameroon and Bioko montane forests ecoregions. These ecoregions are rich in diversity and endemism of many floral and faunal groups, including chameleons of the genus *Trioceros* (Klaver & Böhme 1992, Nečas 2004, Gonwouo et al. 2006, Chirio & LeBreton 2007, Barej et al. 2010, Tilbury 2010). Of the 17 [16 if *Chamaeleo quilensis* is treated as a variant of *C. dilepis* (e.g., Tilbury 2010)] species and subspecies of chameleon known to occur in Cameroon (Nečas 2004, Chirio & LeBreton 2007, Barej et al. 2010, Tilbury 2010), eight are montane endemics with restricted ranges (Nečas 2004, Gonwouo et al. 2006, Chirio & LeBreton 2007, Barej et al. 2010, Tilbury 2010). Of the species and subspecies occurring in Cameroon, as many as seven can be found on a single mountain (Gonwouo et al. 2006), and competition resulting from such high diversity has been found to result in niche partitioning (Hofer et al. 2003).

Three *Trioceros* species are known to occur on the western slope of Mount Kupe in the Southwest Region of Cameroon, for instance, with each inhabiting a limited range along an altitudinal gradient. Here, *T. montium* is found up to 1200 m, *T. pfefferi* from 1100 through 1900 m, and *T. q. quadricornis* from 1300 through 2000 m a.s.l. (Hofer et al. 1999, Hofer et al. 2000, Hofer et al. 2003). Tests of the entire herpetofaunal assemblage of Mount Kupe suggest that the distributions of these three species are not the result of different physiological tolerance limits and likely not independent of each other (Hofer et al. 1999, Hofer et al. 2000, Hofer et al. 2003). This is supported by observed differences in snout–vent length (SVL) and dietary niche overlaps between the three species (Hofer et al. 2003). For instance, SVL differences are significant between each of the three species, with the exception of between male *T. q. quadricornis* and *T. montium*, which were found to be not significantly different from each other, but both are significantly larger than *T. pfefferi* (Hofer et al. 2003). Similarly, dietary niche overlaps accounting for prey volumes indicate a niche segregation of *T. pfefferi* from both *T. montium* and *T. q. quadricornis*, with *T. pfefferi* having a predilection for smaller prey items than its congeners, while no such difference was observed between *T. montium* and *T. q. quadricornis* (Hofer et al. 2003). Due to their smaller overall body size and dietary niche segregation, *T. pfefferi* is thus able to occur syntopically with both *T. montium* and *T. q. quadricornis*, while *T. montium* and *T. q. quadricornis* compete more directly with each other, preventing their coexistence (Hofer et al. 2003). These two species are instead allotopic, exhibiting an "ecological contiguity" in elevational distribution, with the upslope boundary of *T. montium* corresponding with the downslope boundary of *T. q. quadricornis* (Hofer et al. 1999, Hofer et al. 2000, Hofer et al. 2003).

During the period from 15 February to 3 March 2011, the authors were able to make additional observations on the sympatric occurrence of *T. montium, T. pfefferi* and *T. q. quadricornis* as they travelled across the Southwest and Northwest Regions of Cameroon as part of the Exo Terra Expedition to investigate the herpetofauna of the region. During this expedition, local habitats were visited with the permission and under the supervision of local land managers. Specimens were located by a combination of spotlight-searching at night with torchlights and intensive searching during the day. The position of each specimen found was

recorded with a GPS device and the specimen was photographed. The SVL of Mount Manengouba *T. montium* specimens were measured. All specimens were then released where they had originally been located.

On the western slope of Mount Kupe, nine *T. montium*, one *T. pfefferi* and three *T. q. quadricornis* were located over a period of two days and two nights. All *T. montium* specimens were located between 900 and 1100 m a.s.l. at heights of 1.5 to 3.5 m above the ground (Fig. 1A). The single *T. pfefferi* specimen was found at 1425 m at a height of approximately 7 m above the ground (Fig. 1B). Finally, the three *T. q. quadricornis* were located between 2.5 to 5 m above

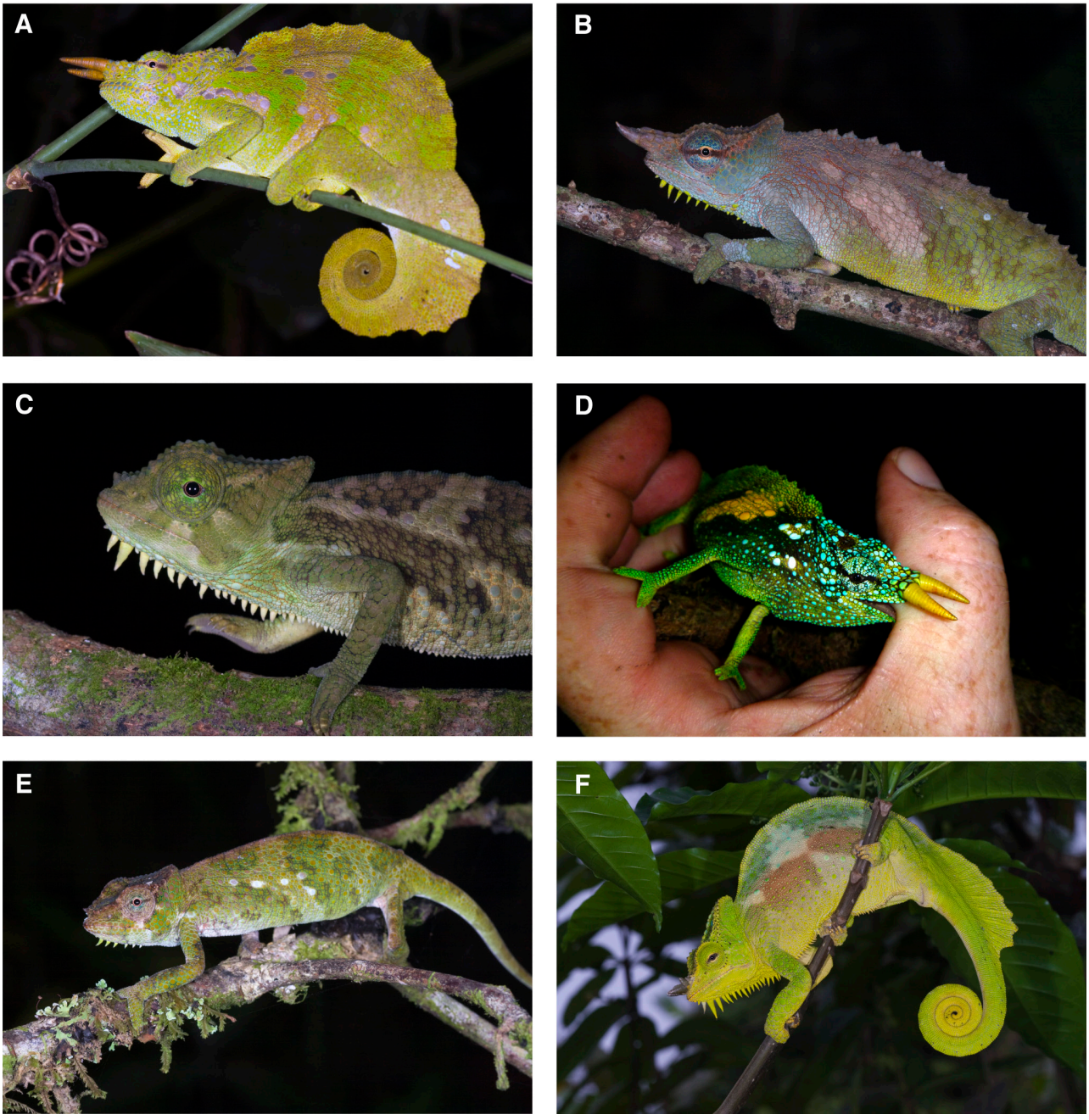

Figure 1. Examples of *Trioceros* species encountered during surveys on Mounts Kupe and Manengouba. (A) Male *Trioceros montium* (900 m, western slope of Mt. Kupe); (B) Male *Trioceros pfefferi* (1425 m, western slope of Mt. Kupe); (C) Juvenile male *Trioceros q. quadricornis* (1500 m, western slope of Mt. Kupe); (D) Male *Trioceros montium* (1500 m, southwestern slope of Mt. Manengouba); (E) Female *Trioceros pfefferi* (1500 m, southwestern slope of Mt. Manengouba); (F) Male *Trioceros q. quadricornis* (1500 m, southwestern slope of Mt. Manengouba). Photos A-C, E, F: C. Anderson; Photo D: E. Van Heygen.

the ground at an elevation of 1450-1600 m (Fig. 1C) and included a juvenile with a healed injury that had resulted in the complete loss of its left front limb.

During a single afternoon and night near the village of Nkack on the southwestern slope of Mount Manengouba, twelve *T. montium*, three *T. pfefferi* and one *T. q. quadricornis* were found. These individuals were located within a stretch of 50 m in a flat section of forest at 1500 m a.s.l., with specimens of all three species being found within 20 m of each other. The *T. montium* specimens were found at heights of 1.5 to 3 m above the ground (Fig. 1D), the *T. pfefferi* between 3.5 and 5 m (Fig. 1E), and the single *T. q. quadricornis* was found at 2 m above the ground (Fig. 1F). The *T. montium* specimens found at this location comprised one juvenile, six sexually mature males, and five mature females. The eleven sexually mature individuals appeared noticeably smaller and of different colouration than those located on either Mount Kupe or Mount Cameroon, and their lengths were measured as a result. These specimens exhibited more yellow than specimens from either Mount Kupe (Fig. 1A) or Mount Cameroon (Fig. 2), with yellow scales surrounding blue tubercles on the flanks and head in the display colouration of both sexes, and the males had bright yellow horns and yellow to orange bands on the flanks (Fig. 1D). Males measured 83–108 mm in SVL [92.67 ± 9.07 mm SVL (mean ± standard deviation), n = 6], whereas females measured 75–83 mm SVL (79.60 ± 2.97 mm SVL, n = 5). Based on our sample, 95% confidence limits around the mean fail to reject the null hypothesis of male *T. montium* from Mount Manengouba being equal in size to the male *T. montium* measured by Hofer et al. (2003) from Mount Kupe (99 ± 8.7 mm SVL, n = 10). Among females, however, 95% confidence limits around the mean revealed that female *T. montium* from Mount Manengouba are smaller on average than those measured by Hofer et al. (2003) from Mount Kupe (89 ± 9.3 mm SVL, n = 10).

Our observations of *T. montium, T. pfefferi* and *T. q. quadricornis* distributions on the western slope of Mount Kupe are consistent with previously described patterns (Hofer et al. 1999, Euskirchen et al. 2000, Hofer et al. 2000, Hofer et al. 2003). Observations from the adjacent southwestern slope of Mount Manengouba, however, revealed that all three of these species occur syntopically, at least at 1500 m a.s.l., in this area. This location could represent an overlap of the upslope boundary of *T. montium* and the downslope boundary of *T. q. quadricornis*, which may not yet have been located on Mount Kupe since previous transects were performed at elevational intervals of 100 m (Hofer et al. 1999, Hofer et al. 2000, Hofer et al. 2003). Alternatively, while male *T. montium* from Mount Manengouba were not statistically smaller than males

Figure 2. Male *Trioceros montium* (1000 m, Mount Cameroon). Photo: C. Anderson.

from Mount Kupe, it is possible that *T. montium* on Mount Manengouba are in general either smaller than *T. montium* on Mount Kupe or, more relevantly, are significantly smaller than *T. q. quadricornis*. *Trioceros montium* on Mount Manengouba would thus not compete as strongly with *T. q. quadricornis*, allowing them to exist syntopically. Finally, the presence of a lone male *T. q. quadricornis* at this location could be indicative of an isolated individual that roamed beyond typical *T. q. quadricornis* territory. Additional sampling is needed to explicitly test these hypotheses on the elevational distributions of these three species relative to each other.

Interestingly, similar observations of syntopic *T. montium, T. pfefferi* and *T. q. quadricornis* have been made in the Bakossi Highlands near the village of Kodmin in the Mwendelengo Mountains at 1440 m a.s.l. (Euskirchen et al. 2000). This suggests that our observation on Mount Manengouba might not be one of an isolated *T. q. quadricornis* individual roaming beyond the species' typical territory, but rather that these three taxa can indeed exist syntopically in certain areas. When compared to the elevational distributions observed on Mount Kupe (Hofer et al. 1999, Euskirchen et al. 2000, Hofer et al. 2000, Hofer et al. 2003), our observations on Mount Manengouba coupled with those of Euskirchen et al. (2000) in the Mwendelengo Mountains indicate that the dynamics between these three taxa may warrant additional investigation. It remains to be seen if these dynamics vary between different localities and habitat structures, or if previous sampling intervals have simply failed to locate range overlaps of these species. Additional comparative studies between localities may help elucidate the complex interactions between these species more completely.

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