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Finding a Needle in a Haystack: New Methods of Locating and Working with Rhinoceros Vipers (*Bitis rhinoceros*)

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Large snake species are important predators in their ecosystems (Dodd 1987; Greene 1997; Lawson and Klemens 2001). Rhinoceros Vipers (Viperidae: *Bitis rhinoceros*, Schlegel, 1855) are among the biggest and most massive venomous snakes (Phelps 1981). Taxonomically they are closely related to the Gaboon Viper, *Bitis gabonica* (Duméril et al. 1854), and were long considered to be only a subspecies of the latter. A sister species to these two taxa is the Nose-horned Viper, *Bitis nasicornis* (Calvete et al.

2007; Lenk et al. 1999; Lenk et al. 2001). Although there is no ecological study on the Rhinoceros Viper, they are likely to have a very similar ecological niche to the Gaboon Viper. Therefore, we herein compare our data to *B. gabonica*. *Bitis rhinoceros* occurs in Western Africa from Guinea to Togo (e.g., see Chippaux 2001), while *B. gabonica* ranges from Nigeria to central, eastern, and southern Africa (e.g., see Spawls and Branch 1995).

These two vipers can reach 1.80 m (Chippaux 2001; FitzSimons 1962; Pitman 1974; Spawls and Branch 1995) and weigh up to 10 kg (Greene 1997). Their size and strong venom enable them to kill and feed on a wide variety of prey, including medium-sized mammals (Bodbijl 1994; FitzSimons 1962; Luiselli 2006b; Mallow et al. 2003; Marsh and Whaler 1984; Perrin and Bodbijl 2001; Pitman 1974; Spawls and Branch 1995). Both viper species may be very abundant in some habitats (Ionides and Pitman 1965, Luiselli and Akani 1998; Rödel and Mahsberg 2000); for example, Lawson (1993) documented especially high densities of *B. gabonica* in altered habitats like farms and plantations in Cameroon. In Côte d'Ivoire, Doucet (1963) found 282 *B. rhinoceros* on only a few km^2. This indicates that these large forest vipers might play an important functional role in their ecosystems. Unfortunately, knowledge about abundances and ecology of this species is rather anecdotal and stems mostly from extrapolations of *B. gabonica*. In general, there are little data on the ecological role of huge vipers (Greene 1997; Schuett et al. 2002).

Because of their camouflage coloration combined with a sit and wait hunting strategy, it is very time intensive to ascertain the presence of these snakes (even when radio-tracked, Lawson 2006) and almost impossible to estimate exact abundances (see Kéry 2002). There are no studies that investigated the ecology of *B. rhinoceros* and few on *B. gabonica*. Research on *B. gabonica* was conducted in outdoor enclosures (Akester 1979; 1989) and in the wild. The latter was done by applying radio-tracking (Angelici et al. 2000; Bodbijl 1994; Perrin and Bodbijl 2001a; Lawson 2006; Linn et al. 2006) and visual encounter surveys (Luiselli and Akani 1998, 2003; Luiselli et al. 1998; Luiselli 2006a, b; Perrin and Bodbijl 2001b). Numbers of snakes studied varied strongly between studies but were mostly low, ranging from two (Lawson 2006), four (Angelici et al. 2000), six (Linn et al. 2006) to nine (Bodbijl 1994; Luiselli and Akani 1998; Luiselli et al. 1998; Perrin and Bodbijl 2001a) individuals. Numbers increased to 57 (Perrin and Bodbijl 2001a), 81 (Luiselli 2006a), 97 (Perrin and Bodbijl 2001b), 524 (Luiselli and Akani 2003) and 586 (Luiselli 2006b) when i) search effort was strongly elevated (e.g., through high manpower, visiting bush meat markets), ii) secondary habitats were searched, and/or iii) data were pooled over several years, sites, habitats, or supplemented with museum specimens.

In addition to the difficulty of detecting large forest vipers, they are also dangerous and difficult to handle. They have the longest fangs of all snakes (Pough and Groves 1983) and their large venom glands (Grasset 1946; Pezzano 1986) produce a huge amount of highly haemotoxic venom (Brown 1973; Broadley et al. 2003; Chippaux 2002; Grasset 1946; Phelps 1981; Wildi et al. 2001). Most untreated bites probably are fatal (Chippaux 2002; Mallow et al. 2003; Marsh and Whaler 1984; Marsh et al. 1997, 2007; Spawls and Branch 1995). Though these snakes are considered to be of a docile nature (e.g., Angelici et al. 2000; Broadley et al. 2003; Isenmonger 1962; Lawson 2006; Wildi et al. 2001), handling *Bitis* species poses a severe danger to researchers. This is an important point because medical services in many areas in Africa are generally not well prepared for dealing with snake bite victims (Chippaux 1998; Chippaux 2005; Theakston and Warrell 2000; Theakston et al. 2003; Stock et al. 2007). Additionally, many research areas are too remote to reach proper medical services within an acceptable time span. Hence the personal risk while investigating these snakes has to be minimised.

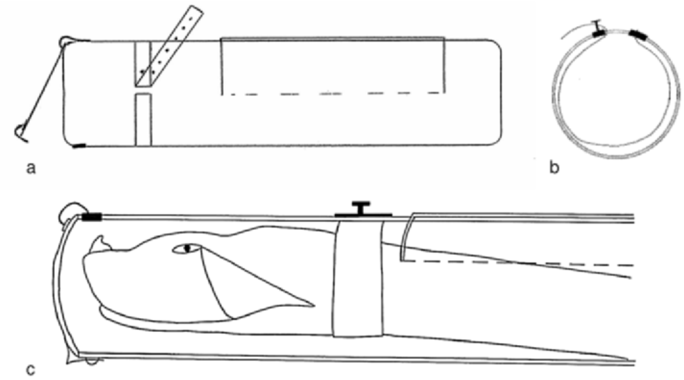

Fig. 1. Transparent Plexiglas tube used for handling Rhinoceros Vipers. a) and c) illustrate how the left side can be closed. The leather belt to fix the snakes' head was attached with a screw on the outside of the tube. a) View of the whole tube, indicating the window that can be opened on the tube's side. b) Cross section of the tube, illustrating the attachment of the belt. c) The belt should be fastened around the neck of the snake.

In order to investigate the role and importance of these large predators in an undisturbed West African rainforest, we tested a new method of finding Rhinoceros vipers and developed a new secure handling method.

Study site.—Our study site was situated in the Taï National Park, which is located in the southwest of Côte d'Ivoire (5°08'–6°07'N, 6°47'–7°25'W), close to the southeastern border of Liberia. It is one of the largest remaining blocks of the Upper Guinean rainforest (Vooren and Sayer 1992). The study area comprised roughly 770 ha of natural forest around the "Station de Recherche en Ecologie Tropicale" (SRET; 5°50'03"N, 7°20'536"W), maintained by the University of Abobo-Adjamé, Abidjan. Rainfall around the SRET is ca. 1800 mm annually, with peaks from March to July and from September to December (Rödel and Mahsberg 2000).

Methods.—Because of their cryptic coloration and secretive lifestyle it is very difficult to record Rhinoceros Vipers with methods like visual encounter surveys on transects, plots, or random searches in particular habitats. Other methods such as cover boards, artificial dens, or different kinds of traps are not applicable for this species, possibly because of their assumed high underground activity, as observed in Nigeria (Angelici et al. 2000) but not confirmed for South Africa (Linn et al 2006; Perrin and Bodbijl 2001a), and presumed low daily movement rates (Alexander and Marais 2007; Linn et al. 2006; Mallow et al. 2003). Previous studies suggest that *B. gabonica* relies rather on its cryptic camouflage than on shelters (Lawson 2006; Linn et al. 2006; Perrin and Bodbijl 2001a; Pitman 1974). Hence these methods could yield few vipers but not in a reliable manner.

The new method for tracking forest vipers we developed employs following monkeys habituated to humans, Sooty

Mangabeys (*Cercocebus torquatus atys*). During the day, these monkeys forage about 80% of the time on the ground (Berggmüller 1998; Rutte 1998). When encountering a snake, they usually seem to ignore it. However, snakes of the genus *Bitis* are treated differently. The monkeys jump aside and give loud, distinct alarm calls (Range and Fischer 2004), which attracts other monkeys to the site, facing the snake and giving alarm calls as well. In the Taï Monkey Project a habituated mangabey group was followed on a daily basis (Range and Noe 2002). This group consisted of 100–120 individuals of all age classes. Researchers and field assistants followed the monkeys and marked all places with flagging tape where vipers had been indicated. Subsequently, we located the snakes and took the geographic position of these places and photographs of the snake's heads. The latter were used to ascertain individual identification (see Ferner 2007). To assure long-term identification some snakes were additionally marked with a PIT tag (Passive Integrated Transponder; Trovan©) injected subcutaneously, laterally in front of the tail on the right side of the body. For that purpose we had to capture and handle the snakes.

For handling the vipers safely we used custom-made transparent Plexiglas tubes (wall of the tubes 3–4 mm thick) which were open at one end and lockable on the other. Close to the lockable end a loop of leather belt was fed into the pipe. The leather belt was fixed to the outside of the tube in one position and slides through a slot with a locking mechanism in the other (Fig. 1). We had six different sizes of tubes (diameters ranging from 5 to 30 cm; length ranging from 50 to 100 cm), which enabled us to handle various sizes of vipers. If the snake was covered with leaves and/or wood, the cover was first removed. The snake was then gently lifted or pushed into an open area with a long hook (1.80 m) and the head subsequently pinned to the ground using the same hook. The open end of the tube was then placed over the snake's head by a second person. Either the snake started crawling further into the pipe on its own or was still pinned down by the first person, while the second was pushing the tube further ahead. When the head finally passed through the leather belt, the belt was pulled and fixed on the outside of the tube. Due to the triangular head shape, the snake subsequently was not able to move backwards, even when the belt was not too tight. A very tight belt has to be prevented in order to avoid strangulation and because it is suggested that the common procedure of gripping heavy-bodied venomous snakes (e.g., *Lachesis muta*) by their necks can cause serious injuries to the snakes (Ripa 2002). A removable lid on the side of the tube allowed us close examination of the snake's body for detection of ectoparasites, counting scales, inserting PIT tags, etc. (see Fig. 1). After recording data (e.g., pattern, length, weight) the belt was loosened and the tube slowly lifted. The person holding the hook followed the movement of the tube so that the part of the snake outside the tube was always pinned until the head could be reached with the hook. The person holding the tube retreated and the hook was removed afterwards.

Results.—The handling method proved to be effective and safe. No snake under restraint got out of the tube (N = 5). However, the belt had to be fixed at the locking mechanism because some snakes tried to squeeze themselves backwards through the belt. It was also necessary that one person was always holding the hind part of the snake's body in order to prevent the snake from turning around. Both implementations are necessary because due to the large girth, the small neck and the ability of changing the girth dramatically by moving ribs or inflating, no tube will prevent efforts of squeezing around the own axis backwards without injuring the skin. Afterwards these lesions might become entry points for parasites, infections, etc.

Sooty Mangabeys were followed during 429 days (3110 observation hours) from October 2001 to September 2002. We recorded a total of 43 Rhinoceros Vipers (0.01 snake/h). Two snakes were encountered twice. The 41 individuals were registered in an area of 770 ha (1 snake / 18.8 ha). Viper locations were randomly spaced (Nearest Neighbor Analysis R = 0.75, Donnelly Modification for Clark and Evans Test z = -3.44) within the mangabeys' home range (770 ha). Most Rhinoceros Vipers were found between 1000 h and 1400 h (28 snakes). A seasonal peak was registered in October 2001 (12 snakes). During a parallel study on leaf litter anurans (Ernst and Rödel 2005; Rödel and Ernst 2004), we employed 382.5 h of transect walks, thereby carefully investigating the forest floor. During this time, we recorded one Rhinoceros Viper (0.002 snake/h). During additional random visual encounter surveys for litter frogs (without accompanying monkeys, 1999–2002; total time not recorded), we found two more vipers. Unfortunately, we had to interrupt all studies in October 2002 due to the start of a civil war.

Discussion.—To our knowledge our capture protocol is the safest method for the human observer and large vipers alike. The tubes prevent snakes from breaking free through violent and sudden head jerking as has been observed in other vipers, e.g., *Bitis arietans* (Visser and Chapman 1980). The tubes are easily fabricated and can be customized to any size and modified for specific needs, such as the removable window on the side of the tube which we employed for the insertion of PIT tags (Lang 1992).

Although the monkeys clearly showed fear of big vipers, the respective reasons remained unclear and were not addressed in our study. It is long known that various species of monkeys react with specific alarm calls ("conceptual semantics") towards snakes (Coss et al. 2007; Crockford and Boesch 2003; Fichtel et al. 2005; Range and Fischer 2004; Struhsaker 1967; Seyfarth et al. 1980a, b), especially if the snakes are moving. However, we observed that they react towards stationary snakes and that reactions towards Rhinoceros Vipers (and Nose-Horned vipers, *Bitis nasicornis*) differ from those toward other snakes such as Forest Cobras (*Naja melanoleuca*). This is contrary to observations on Vervet Monkeys (*Chlorocebus aethiops*), where monkeys reacted with specific alarm calls towards Puff Adders (*Bitis arietans*) and Egyptian Cobras (*Naja haje*) (Struhsaker 1967). We hypothesize that large vipers are capable of killing and subsequently devouring such large prey (Angelici et al. 2000). Large prey items are rare (Luiselli and Akani 2003; Luiselli 2006b; Perrin and Bodbijl 2001b), but a Royal Antelope (*Neotragus pygmaeus*) has been recorded for *B. rhinoceros* (Cansdale 1965). A Large Spotted Genet (*Genetta tigrina*) (Perrin and Bodbijl 2001b) and monkeys (Broadley and Cock 1975; *Chlorocebus pygerythrus,* J. Newby quoted in Broadley et al. 2003) have been noted for *B. gabonica*. We never observed any encounters with Rock Pythons (*Python sebae*), which do occur in the area and elicit alarm calls in three other monkey species (Starin and Burghardt 1992) and are easily capable of feeding on Sooty Mangabeys (e.g., see Cowlishaw

1994; Starin and Burghardt 1992; Struhsaker 1967). Other snakes, although capable of killing monkeys with their venom (*Naja* spp.), are smaller and their gape limitation does not allow them to feed on monkeys. An additional hypothesis assumes that the monkeys warn other members of their group when encountering vipers (Cheney and Seyfarth 1992; Struhsaker 1967) to not accidentally step on the snake, thereby avoiding a defensive bite. Neither of the two viper species will flee immediately when detected by a group of mangabeys, allowing the behavior of habituated mangabeys to be exploited to locate large forest vipers.

The peaks of snake records between 1000 h and 1400 h were most likely due to peaks in foraging activity of the monkeys during that same time period. Similarly, a seasonal peak of snake records was coincidental with fruiting (October–December and May–June) of one major fruit tree used by the mangabeys (*Saccoglottis* sp.). During these periods the monkeys covered a larger foraging area than during other periods, therefore increasing the chance to encounter more snakes. The observed density of 0.053 snakes per hectare is at the lower limit known for comparable sized species (see review by Parker and Plummer 1987) and lower than modelled densities of the sister species *B. gabonica* in southern Nigeria (mean: 0.22/ha; min.: 0.014/ha; max.: 0.372/ha; Luiselli 2006a). However, we would have needed a much higher recapture rate to calculate real densities. The monkeys did not equally use all parts of their home range and although a Nearest Neighbor Analysis of the Rhinoceros Viper records revealed a random distribution in the forest, we cannot exclude the possibility that the snakes could be much more abundant in parts were monkeys forage rarely.

Our results showed that, by using the monkey's specific warning system, we have identified a highly valuable method to detect large vipers in West Africa. Data from our study revealed more vipers per unit time compared to visual encounter surveys. Our refined method of tubing snakes is highly recommended for safe handling of large vipers.

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