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Kinixys erosa (Schweigger 1812) – Forest Hinge-back Tortoise, Serrated Hinge-back Tortoise, Serrated Hinged Tortoise

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Summary. – The Forest Hinge-back Tortoise, *Kinixys erosa* (Family Testudinidae), is a forest tortoise with considerable range over the continuous Guinea–Congo rainforest region in West and Central Africa. It is a medium-sized to large tortoise, with a carapace length reaching ca. 400 mm, and males larger than females. Tortoises of the genus *Kinixys* can close themselves entirely within their shells through a unique posterior carapacial hinge. *Kinixys erosa* inhabits the lowland evergreen forest, marshy areas, and forest galleries growing along rivers and streams, where it is locally threatened by clearance of forest for cultivation and hunting pressure. It has an omnivorous diet, with mushrooms being predominant. Population sizes are strongly depressed in areas where these tortoises are actively hunted by human populations. The main threats for this species include subsistence hunting by local people in desperately poor economic conditions, agricultural and industrial expansion with deforestation, and trade for the pet industry. There is a strong need for more field research on *K. erosa* ecology, abundance, and status. There are no known conservation actions for this species; however, there is a need to establish protected areas that include viable populations of these tortoises through their natural range.

Distribution.– Angola, Benin, Cameroon, Central African Republic, Congo (Democratic Republic of Congo–DRC), Congo (Republic of Congo–ROC), Equatorial Guinea, Gabon, Ghana, Guinea, Ivory Coast (Côte d'Ivoire), Liberia, Nigeria, Sierra Leone, Togo, Uganda. Widely distributed along coastal forested West Africa from Sierra Leone and Guinea through the Congo Basin of central Africa to northern Angola.

Synonymy.– ***Testudo erosa* Schweigger 1812, *Kinixys erosa*, *Cinixys erosa*, *Kinixys belliana erosa*, *Testudo schoepfii* Fitzinger 1826 (nomen nudum), *Kinixys castanea* Bell 1827, *Cinixys (Cinixys) castanea*, *Cinixys castanea*.**

Subspecies. – None recognized.

Status. – IUCN 2014 Red List: Data Deficient (DD, assessed 1996); TFTSG Draft Red List: Endangered (EN, assessed 2013); CITES: Appendix II, as Testudinidae spp.

Taxonomy. — This species was described as *Testudo erosa* by Schweigger (1812); its type locality is unknown, but Shaw (1802) supposed, by error, that it was a native of North America (Bour 2006). All populations are considered to be homogenous and no subspecies of this taxon are currently considered valid (Bour 2006).

Phylogeny based on both mitochondrial (12S rRNA, 16S rRNA, and cytb) and nuclear (Cmos and Rag2) DNA data, with a total of 3387 aligned characters, suggests that *K. erosa*, as well as all examined *Kinixys* species, belong to a clade including also *Pyxis, Aldabrachelys, Homopus, Chersina, Psammobates,* and *Geochelone* (Le et al. 2006). Studies of three mitochondrial DNA fragments (2273 bp: 12S rRNA, ND4 + adjacent DNA coding for tRNAs, cytb) and three nuclear loci (2569 bp: C-mos, ODC, R35), using both Bayesian and Maximum Likelihood methods suggest that the savannah species of *Kinixys* are paraphyletic with respect to the rainforest species *K. homeana* and *K. erosa*, and that the rainforest species may be derived from a savannah-living ancestor (Kindler et al. 2012).

Description. — Unique among all extant chelonians, the genus *Kinixys* possesses a hinge across the posterior carapace. *Kinixys erosa* is the largest member of the genus, reaching ca. 400 mm in carapace length (CL). It also has the most serrated shell, with very pointed marginal scutes forming a sort of toothed skirt along the posterior shell margin. The anterior marginals are sharply turned upward above the head. The paired gulars are bifid and eventually develop a forked configuration.

Unique among *Kinixys*, male *K. erosa* are significantly larger than females; adult males in Cameroon had a mean plastron length (PL) of 215 mm (range, 149–251 mm, n = 39) and females a mean PL of 185 mm (range, 82–220 mm, n = 73) (Lawson 2001). Allometric relationships of height

Figure 1. Adult female *Kinixys erosa* in Cameroon, central Africa. Photo by Tomas Diagne.

on length, width on length, and width on height showed also significant differences between sexes, with the females being relatively taller than males (Lawson 2001). In the Niger Delta of Nigeria, the range of adult PL was 170–250 mm in males and 150–220 mm in females, and the mass ranged from 800–1700 g in males and 600–1500 g in females (Luiselli, G.C. Akani, and E.A. Eniang, unpubl. data).

Lenglet and Colyn (1989) reported a male specimen of 375 mm CL from Congo (DRC), and Maran (2006) measured a female of 299 mm in Gabon. Laurent Chirio (pers. comm.) collected the shell of a giant *K. erosa* in Cameroon, probably a male, which included two portions of the carapace. The neural bone was missing, but the carapace measured ca. 400 ± 5 mm CL; the total length of the shell, with the projecting anterior lobe, would have been close to 420 mm. This specimen, now in the Paris museum, is considered the largest recorded *K. erosa*.

Meylan and Auffenberg (1986) described *K. erosa* fossils from the Songhor Hills, Kenya, (near Lake Victoria) from the early Miocene. Lapparent de Broin (2000) mentioned *Kinixys* fossils from Napak, Uganda, also from the early Miocene (19–20 million years ago), as well as many fossils from the same time period in Sudan, Congo, and Chad. Based on all of this fossil evidence, *Kinixys* is considered to be one the oldest genera of tortoises to have appeared and evolved on the African continent.

Contrary to *Kinixys belliana* (sensu lato) and *K. homeana*, *K. erosa* lacks a nuchal scute. The head is elongated, with usually a yellow color, with a projecting snout, and the eyes are placed very high and are separated by a slight depression. The plastron is quite wide, covering most of the underside of the animal, so that when the posterior section of the carapace is lowered, the tortoise is well protected within its bony box.

The plastron is dark, with somewhat lighter seam lines. The limbs are yellow, with heavy scales in the front, and the carapace is orange yellow to gray brown, sometimes with large contrasting markings on the costal scutes. The head is almost uniformly yellow, with darker areas above and at the base of the neck. The dorsal carapacial hinge does not develop until an age of four to six years, and the plastron is already black in young specimens. Juveniles have a red-

Figure 2. Adult *Kinixys erosa* from Kinero Malibé, Gabon. Photo by Laurent Chirio.

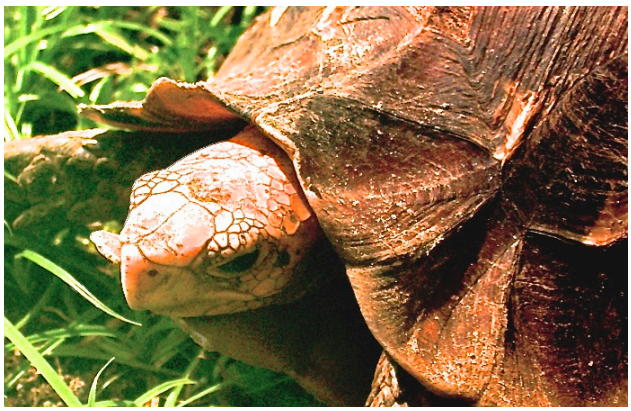

Figure 3. Adult female *Kinixys erosa* from Cameroon. Photo by Tomas Diagne.

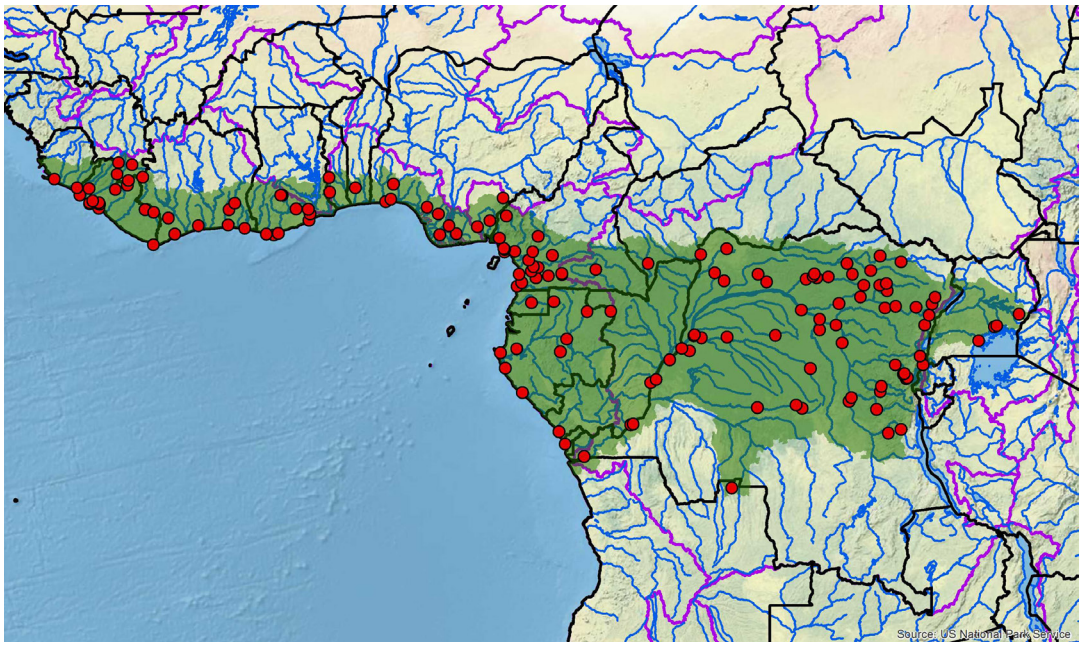

Figure 4. Distribution of *Kinixys erosa* in western and central Africa. Purple lines = boundaries delimiting major watersheds (level 3 hydrologic unit compartments – HUCs); red dots = museum and literature occurrence records of native populations based on Iverson (1992) plus more recent and authors' data; green shading = projected native distribution based on GIS-defined HUCs constructed around verified localities and then adding HUCs that connect known point localities in the same watershed or physiographic region, and similar habitats and elevations as verified HUCs (Buhlmann et al. 2009; TTWG 2014), and adjusted based on authors' subsequent data.

brown color to the carapace, with each scute being circled by light yellow.

This species has a primitive phalangeal formula for land tortoises, i.e., 2–2–2–2–1, the most common pattern found in living testudinid species (Crumly and Sanchez-Villagra 2004).

Distribution. — *Kinixys erosa* is a forest tortoise with a considerable range over the continuous Guinea–Congo rainforest region in West and Central Africa. It occurs in the following countries: Guinea, Sierra Leone, Liberia, Ivory Coast (Côte d'Ivoire), Ghana, Togo, Benin, Nigeria, Cameroon, Equatorial Guinea, Gabon, Congo (Republic of Congo–Brazzaville), Congo (Democratic Republic of Congo–Kinshasa), Central African Republic, Angola, and Uganda (see also Trape et al. 2012).

Gambia. — Reported to apparently occur in the Gambia by Andersson (1937), Hakansson (1981) and Iverson (1992). However, Pauwels and Meirte (1996) did not observe any specimens there, nor are we aware of any specimens from either the Gambia or Senegal. Old records from these countries may represent trade specimens, and we consider these records to be unreliable.

Senegal. — No localities presented in Iverson (1992). No current localities are known, but if present, would certainly be limited to the coastal southern regions, close to the Gambia, as other parts of the country are too arid and climatically unsuitable for this species.

Guinea-Bissau. — No localities presented in Iverson (1992), and no current localities known.

Figure 5. Hatchling *Kinixys erosa* from Nigeria (*left*) and Gabon (*right*). Photos by Tomas Diagne (*left*) and Thomas Leuteritz (*right*).

Figure 6. Habitats used by *Kinixys erosa*. A. Mature forest habitat in the surroundings of Badou, Togo. B. Microhabitat near Port Harcourt, Niger Delta, Nigeria. C. Secondary forest habitat near Kpalimé, Togo. D. Swamp forest in Banco National Park, Ivory Coast. Photos by Luca Luiselli.

Guinea. — No localities noted in Iverson (1992). Böhme et al. (2011) and Trape et al. (2012) documented specimens in the forested southeastern part of the country.

Sierra Leone. — Found throughout the southeastern portion of the country, from coastal areas in the south up to approximately Bo and the Loma mountains. Pristine forest (the main habitat of *K. erosa*) has been largely extirpated from Sierra Leone. Fragments of riverine forest survive among vast areas of plantations and forest-derived savannahs, and the suitable habitat remaining for this tortoise is below 10% of the whole country surface.

Liberia. — Found throughout the country; known both from the northwest provinces as well as in the extreme southeast (Iverson 1992; Trape et al. 2012). Several specimens were found by Luiselli et al. (unpubl. data) in the bushmeat markets of Monrovia, Buchanan, and Gbarnga during July 2000. According to the sellers, the tortoises were captured nearby, and *K. erosa* is reported by villagers to be locally common (e.g., around Gbarnga). Pilot surveys in Greenville established an average sighting frequency of 0.50 tortoises/day, which is intermediate between those observed in southern Nigeria in (i) a non-harvest area (0.72 tortoises/day) and (ii) a harvest area (0.22 tortoises/day) (Luiselli 2003a). Based on interviews with local hunters and our preliminary data, we believe that *K. erosa* is still widespread in Liberia, although likely declining due to overexploitation by people. In particular, the civil war which has raged throughout Liberia in recent years has had serious consequences for several populations of this species. *Kinixys erosa*, exactly as for *K. homeana* (see Luiselli et al. 2006), became a common food item for people displaced into forests or bushlands to escape the fighting. Indeed, several interviewees confirmed that tortoises were one of the main protein sources not only for people escaping war but also for soldiers operating in forested zones.

Ivory Coast (Côte d'Ivoire). — Recorded in the forests around Abidjan in the south (Iverson 1992; Maran 2004), and in particular in the provinces of Moyen-Cavally, Bas-Sassandra, Sud-Bandama, Lagunes, Agnebi, and Sud-Comoe (Mifsud and Stapleton 2014). Surveys conducted in 2014 by Sery Gonedele Bi and Luiselli (unpubl. data) provided records of this species from Banco National Park, the surroundings of San Pedro, and Tai Forest in southern and southeastern Ivory Coast. Villagers reported the species to be uncommon or even rare throughout the area.

Ghana. — Reported to be widespread in the southern and central territories (Iverson 1992). *Kinixys erosa* has been found recently in Onyadze and Ony-Winn (two sites at Muni-

Pomadze Lagoon, southern Ghana) in secondary forest and grass/thicket habitats (Raxworthy and Attuquayefio 2000). Luiselli et al. (unpubl. data) captured some specimens in the field in the southern regions (e.g., around Cape Coast), and also observed many specimens traded for food in the local markets, especially around Accra and Koforidua. Diagne (unpubl. data) collected several carapaces from bushmeat consumption in villages near Kumasi. Based on data provided by Raxworthy and Attuquayefio (2000), plus our unpublished surveys (and from comparisons with other geographic regions such as Nigeria and Cameroon), and on interviews with local people, we consider this species to have become increasingly uncommon in Ghana, although possibly still relatively common in the southwestern forests of Ghana near Kakum National Park. Ghana and Togo are known to be the main exporters of tortoises for the pet trade. The numbers of free-ranging tortoises captured for the international pet trade should be monitored, because it is possible that many traded specimens do not come from tortoise farms.

Togo. — Found only in the remnant hilly forests around the towns of Kpalimé and Badou, southwestern Togo (Harris 2001; Segniabeto et al. 2014). It is rare in the few forest sites where it occurs (Luiselli and Segniagbeto, unpubl. data), and is sold in both bushmeat and fetish markets (Segniagbeto et al. 2013).

Benin. — Although no records are available in Iverson (1992), the species is certainly present in the southern part of Benin Republic (Trape et al. 2012), where it is heavily exploited (Luiselli et al., unpubl. data).

Nigeria. — The current distribution is well known, as the species has been studied intensively during the last 15 years (e.g., Luiselli et al. 2000, 2003; Luiselli, 2003a,b,c, 2005). This species has been observed in several Nigerian States (Akani, Eniang, and Luiselli, unpubl. data), as follows:

Lagos: Presumably rare; a few specimens were found in the forest fragments and bush around the coastal lagoons.

Oyo: Very rare according to several interviewees; we found it in forest patches around Ibadan, where it is actively hunted. Butler and Shitu (1985) also reported its presence and cultural utilization in this area. Currently, the areas inhabited by this species are also inhabited by *K. nogueyi*, which is here the dominant species (Segniagbeto et al. 2015b). Diagne (unpubl. data) found a live adult male kept in a village compound at Makoli.

Edo: Found only in a few forest fragments, but presumably extirpated from the many recently deforested areas. Based on random surveys throughout 19 potential sites of occurrence in 1999–2005, we verified its presence in only three sites (15.8%).

Delta: Very endangered due to severe habitat loss (potential habitat for tortoises covers approximately only 0.1% of the state area) and hunting for subsistence.

Bayelsa and Rivers: Found in some swamp-forest patches of both these states (e.g., Luiselli et al. 2000) and is locally common in a few areas where it is worshipped by indigenous communities (Luiselli 2003a). However, it is actively persecuted for both subsistence and traditional medicine (*ju-ju*) in most areas, where it is very likely to be declining (see Luiselli 2003a). In addition, it is severely threatened by habitat loss (deforestation) due to expanding petrochemical development.

Anambra: Extremely rare, it is found only in a few riverine forest patches in the southernmost part of this state and surrounding Oguta (in AGIP oil-field forest site). Most of the state landscape is characterized by plantations and cultivations that are not suitable habitat for this tortoise.

Abia: Recorded up to now only in the gallery forest of Imo River, where it is apparently uncommon, but traded as a bushmeat source in local markets (Akani and Luiselli, unpubl. data).

Akwa-Ibom: Severely fragmented populations are found in a few riverine forests (e.g., along the banks of the River Kwa-Ibo) and in the Stubbs Creek Forest Reserve; many specimens are traded for *ju-ju* and food in Uyo market, but it seems that a good proportion of them may have come from the adjacent Cross River State (see also Luiselli et al. 2006, for similar data on *K. homeana*). In addition, the species is severely threatened by habitat loss (deforestation) due to petrochemical expansion in coastal areas. It is more common at the border with Cross River State (around Itu), where there are some sacred forests that, although dedicated to the cultural protection of a guenon species (*Cercopithecus sclateri*), still provide indirect benefit to tortoises species as well (E.A. Eniang, pers. comm.).

Cross River: Rare in lowland forests (e.g., in the Ikpan Forest block; see Eniang and Luiselli 2002) where *K. homeana* is more abundant instead. *Kinixys erosa* is more common, and even locally abundant, in hilly and mountainous forests. In the Cross River National Park, for instance, it is more common than *K. homeana*, both in the Akamkpa and in the Okwangwo Divisions of the Park (Eniang, Ebin, and Luiselli, unpubl. data).

Cameroon. — Found throughout the coastal regions and also in the Southern Province (Iverson 1992; Chirio and LeBreton 2007); its presence has also been well documented in the Southwest Province in recent years (e.g., Lawson 1993, 2000, 2001, 2006). In general, it has a wider distribution than *K. homeana* as far as this country is concerned (Chirio and LeBreton 2007). Lawson (2000) reported very strong hunting pressure on this species in the Western and Southwest Provinces, with local decline in numbers around Nfainchang (Lawson 1993). LeBreton (1999) reported its consumption for food in the Dja River area. According to published authorities (summarized in LeBreton 1999), the following localities of presence can be cited: Bipindi, mouth of the Doumé River,

Campo, Efulen, Lolodorf, Metet, Sakpabayémé, Sangmelima, Yaoundé, Kribi, Ngam, Foulassi, Nkoétyé, Djomedio, and Dja River Faunal Reserve. Additional known localities are in the Takamanda forest (LeBreton et al. 2003). This species also appears to be locally common in the Mount Cameroon area (Gonwouo et al. 2007). According to LeBreton et al. (2003), these tortoises are hunted actively in Takamanda forest, where it is possible to see many dried shells in the local villages; the authors urged the need for assessing the impact of this traditional hunting activity on the local tortoise populations.

Equatorial Guinea. — Found in Rio Muni (Iverson 1992). The species is regularly found in bushmeat markets (e.g., Fa et al. 2000; Fa and Garcia Yuste 2001).

Gabon. — Found throughout the country. Maran (2006) observed this species in 86 localities, covering all the dense forest domains, and noted it to be the most common chelonian species in the country. Laurent Chirio (pers. comm.) also considered this species to be locally still abundant in many forests of Gabon. Probably, Gabon is the country where there is the least concern for the conservation status of this species.

Congo (ROC–Brazzaville). — Found throughout the country (see also Jackson and Blackburn 2007). No data available concerning its local abundance.

Congo (DRC–Kinshasa). — Found throughout most of the country (Iverson 1992). Diagne et al. (2013) found 22 live specimens in two bushmeat markets plus empty shells in villages near Goma. No data available concerning its local abundance.

Figure 7. Adult (*top*) and juvenile (*bottom*) *Kinixys erosa* with intricate carapacial markings from the Democratic Republic of Congo. Photos by Konrad Mebert.

Figure 8. Adult *Kinixys erosa* caught by BaAka children near Bayanga, Mossapoula district, Central African Republic. Photo by Andy Noss.

Angola. — A few localities are presented by Anonymous (2005); these include Posto de Lóvua, Perto de Rio Camualua (Dundo), North Lunda, and Cabinda. We have a photographic record of a specimen traded in a market in Cambulo, ca. 70 km from the border with Congo (DRC–Kinshasa). The species is limited to the extreme northern regions of this country.

Central African Republic. — Found only in the extreme southwest of the country, at the border with the two Congo nations (Chirio and Ineich 2006). No data available concerning its local abundance.

Uganda. — Found widely in the country, but is probably uncommon, given that it seems to be absent from very well-preserved forest areas; for instance, it has not been found in Kibale National Park (Vonesh 2001).

Fossil records of *Kinixys erosa* are known from Songhor Hill, Kenya (Meylan and Auffenberg 1986).

According to calculations based on the map published here, the entire range of *K. erosa* has a potential extent of occurrence of about 3,083,452 km^2 (= sum of areas of all 4828 selected level 8 HUC's). The country comprising the highest percentage of the projected range is Congo–DRC, followed by Gabon; other important countries are Congo–ROC and Nigeria.

Habitat and Ecology. — Most of the data available on the habitat preferences of *K. erosa* populations are based on anecdotal observations. It is generally reported that this species occurs in forests throughout its range, generally of a wetter type than the forests inhabited by *K. homeana*, according to Ernst and Barbour (1989), but of a drier type than *K. homeana* in Cameroon (Chirio and LeBreton 2007) and Nigeria (Luiselli and Diagne 2013). According to Broadley

(1989) it inhabits lowland evergreen forest, marshy areas, and forest galleries growing along rivers and streams, where it is locally threatened by clearance of forest for cultivation, e.g., around Nfainchang (Lawson 1993). In Nigeria, its abundance tends to increase in hilly forests, whereas the relative abundance of *K. homeana* tends to decrease with altitude (Luiselli and Diagne 2013), so that *K. homeana* tends to be more abundant in the Niger Delta forests and *K. erosa* more abundant in Cross River National Park. All authorities agree in considering this species a typical inhabitant of dense forests. However, it is reported to occasionally cross savannah habitat to reach new forest zones (e.g., in Gabon; see Maran 2006).

In the River Niger Delta (southern Nigeria), at a landscape scale, the populations of *K. erosa* are habitat specialists, being linked to zones of mature or secondary swamp forest (Luiselli et al. 2000). Considering that these habitat types have declined from 2% of the Delta state area in 1976–78 to only 0.2% in 1993–95 (Geomatics 1996), it can be inferred that habitat loss, due primarily to the expansion of the petrochemical industry, may represent a very serious cause of decline for *K. erosa*.

At a local scale, Luiselli (2003a) demonstrated that the type of attitude that human communities have towards tortoises may have very serious consequences on the habitat preferences of these animals, so that any generalization can be difficult. Luiselli (2003a) studied tortoise population ecology at six study areas with similar habitat characteristics in the eastern axis of the Niger Delta. In three of these areas the tortoises were worshipped by local communities as holy animals bringing happiness. In the other three areas these tortoises were actively hunted for subsistence.

The habitat use by tortoises was very different depending on the type of "management" (hunting versus veneration) of each study area: in the veneration areas the tortoises were frequently found in such disparate habitats as dense dry bush, sparse dry bush, riparian vegetation, swamps and even plantations (Luiselli 2003a, 2006a). On the other hand, in the hunting areas the tortoises were found almost exclusively inside dense bush, and strongly avoided plantations. It seems likely that these different habitat uses reflect avoidance behavior (Luiselli 2003a).

This study may have crucial implications for the global scale of this species' range. It suggests that where the tortoises are hunted for subsistence (which is a common occurrence in West and Central Africa, e.g., Fa et al. 2000; Lawson 2000; Fa and Garcia Juste 2001; Luiselli et al. 2003), the true habitat for these tortoises is just a fraction of the whole potential habitat (i.e., those portions of the forests characterized by very dense vegetation structure where access for human hunters is problematic). Considering that forest habitat loss is an enormous problem in West Africa, with a dramatically rapid rate of destruction (Oates 1999), it is obvious that the long-term sustainability of these tortoises cannot be maintained with such concomitant threatening factors as hunting activity, human overpopulation, and habitat loss (e.g., Luiselli 2003a,c; Luiselli et al. 2003).

Home range patterns are still poorly known. Lawson (2000, 2006) documented that, in western Cameroon, male home range may exceed 0.5 km^2; his data were very similar to data recorded in Nigeria, despite the different study regions and environmental conditions. Radiotracked *K. erosa* home ranges varied from 5.5 ha to 45.37 ha in Cameroon (Lawson 2006). There was considerable variability in home range sizes; some animals had larger dry season home range estimates than rainy season estimates, whereas a resident male had considerably larger rainy season home range estimates than dry season estimates (Lawson 2006).

In the Niger Delta (southern Nigeria), Luiselli et al. (unpubl. data) radiotracked 39 adults (20 males and 19 females) for 40 continuous days, and measured mean home activity areas (quantified via minimum convex polygon) of 0.46 km^2 for males and 0.33 km^2 for females, with some specimens (especially males) exhibiting areas as large as 0.63 km^2. Moreover, both in Nigeria (Luiselli et al., unpubl. data) and in Cameroon (Lawson 2000, 2006), male tortoises are highly territorial, and usually drive other males away from their core home ranges. Thus, the density of these tortoises is low in most places, even in highly suitable environments.

Kinixys erosa is most active during the wet season, whereas during the dry months it may spend prolonged time (and even several consecutive days) without leaving its refuges (Luiselli 2003b). The species is very elusive, and often hides inside tree roots or under leaf litter (Maran 2006). It basks occasionally, and it usually prefers darker microhabitats (Luiselli 2005). Both opportunistic observations and radiotelemetry data reveal that this species is mainly active by night or by day during prolonged periods of rain (Naulleau 1988).

Kinixys erosa has an omnivorous diet. Although it may feed on earthworms, snails, arthropods, carrion, plants, seeds, and fruits that drop on the ground, its main food is mushrooms (Luiselli 2006b).

The species is potentially in interspecific competition with *K. homeana*, which shares a similar diet composition, habitat requirements, and geographic range. Overall, interspecific competition at the local scale between these two species produces dominance of one species over the other, albeit without extirpation of the locally disfavored species (Luiselli 2006c; Luiselli et al. 2008). The dietary niche overlap values between *K. erosa* and *K. homeana* were much higher within heavily altered forest habitats than within mature forest habitats. Thus, the potential for interspecific competition for food is much higher in degraded forests (Luiselli 2006b). The implications of this study are that, in altered habitats, the reduced niche differentiation might

result in the over-exploitation of certain prey types if both tortoise species now include these items in their diets. If the above scenario is correct, one would predict that in one, or both, of the species, population numbers would be reduced with forest habitat loss (Luiselli 2006b). However, the spatial niche is likely the dimension most clearly partitioned by these tortoise species (Luiselli 2006c), and further research is needed to understand exactly how spatial niche partitioning occurs in these two forest species.

Interestingly, in the hilly forests of southwestern Togo, that are ongoing progressive deforestation, the habitat niche of *K. erosa* and *K. homeana* is being exploited also by the Guinea savannah species *K. nogueyi* (Segniagbeto et al. 2015a). This species also shares a similarly omnivorous diet and is, at least locally, now well-adapted to high forest habitats (Segniagbeto et al. 2015b). Thus, it is possible that the three sympatric species may become competitors for the available resources, and field studies are currently ongoing (by G.H. Segniagbeto, F. Petrozzi, and Luiselli).

The reproductive biology of this species in the wild is poorly known. In Gabon, nesting occurs throughout the year, and females carrying shelled eggs were observed in August, November, December, February, and March, with a peak in February (Maran 2006). The eggs are slightly flat, hard-shelled, and whitish in color, and measured 38.0–45.1 mm in length, 34.1–39.0 mm in width, 31.0–34.0 mm in height, and 27.0–30.5 g in mass (Maran 2006). Female *K. erosa* from Niger Delta populations in Nigeria oviposit 1–5 eggs per clutch once per year, generally between December and January, i.e., in the dry season (Akani et al. 2004). Average size of egg-laying females, in southern Nigeria, was 200–220 mm PL (Luiselli, G.C. Akani, E.A. Eniang, unpubl. data).

Many wild individuals are heavily parasitized, and leeches are often found on these tortoises (Maran 2006). For instance, some new species of heterakids (e.g., the nematodes *Africana kinixysae* and *A. congoensis*) were described from Congolese populations of *K. erosa* (Bouamer and Morand 2007).

High predation rates are likely important regulators of the population dynamics of *K. erosa*, as for *K. spekii* (Coulson and Hailey 2001). However, very little is known about the natural predators of these tortoises; snakes may eat hatchling and small tortoises, and adults may be eaten by genets, mongooses, leopards and other cats (Hart et al. 1996), and birds of prey.

Population Status. — There are no comprehensive data available on the global population size and density of *K. erosa* at the continental scale, but it is highly likely that populations are declining in most areas. Luiselli (2003a) presented some data on population structure and abundance of *K. erosa* that can be useful for calculating a rough density of these tortoises under natural conditions. During 20 consecutive field days of research in southern Nigeria (10 days in the wet season and 10 days in the dry season, from February 2001 to January 2002) ten people independently searching a 20 ha area found an average density of 0.47 tortoises/ha at six localities. The density ranged from 0 to 0.35 tortoises/ha in harvest areas, and from 0.40 to 1.10 tortoises/ha in veneration areas (Luiselli 2003a).

Lawson (2000) studied the harvest rates of *K. erosa* in three protected areas of Cameroon (Korup National Park, Banyang-Mbo Sanctuary, and Nta-Ali Reserve), and estimated an overall mean annual harvest rate of 0.7–0.8 animals/km^2 in these areas with good habitat conditions and relatively low human density.

Using a different approach (DISTANCE analysis on transect data), Luiselli et al. (2008) determined a mean density of 0.63 individuals/ha along three transecs in Ghana, 0.25 individuals/ha along six transects in Benin, 0.20 individuals/ha along nine transects in southwestern Nigeria, and 1.24 individuals/ha along four transects in southeastern Nigeria.

Threats to Survival. — The species is threatened by subsistence hunting by local people living in desperately poor economic conditions (Noss 1998; Lawson 2000, Luiselli 2003c), agricultural and industrial expansion and deforestation (Akani et al. 1998; Segniagbeto et al. 2015a), and trade for the pet industry (Harris 2001; Ineich 2011). These threats are particularly strong in southern Nigeria (Luiselli and Diagne 2013), where heavy deforestation occurs due to oil and natural gas industry development, this region being the most important oil-producing zone in all of Africa (Akani et al. 1998; Akani and Luiselli 2010).

There is clear evidence of massive population declines for *K. erosa* in this oil-producing region, with the numbers of this species traded in bushmeat markets having collapsed over the last 10 years, despite no change in demand by people (Luiselli et al. 2013). The same collapse in traded amounts was also confirmed by Ohimain et al. (2014) in the central Niger Delta, who found *K. erosa* and *K. homeana* to be less than 1% of 1512 total turtles displayed for sale. There is no reason to predict that this negative trend may change in due time, and populations and numbers of traded specimens are likely to continue to decrease. Reptile dealers in Lomé (interviewed in July 2014 by G.H. Segniagbeto and Luiselli) concurrently agreed in reporting that the species is clearly less frequently encountered now than 10 years ago or more, in their usual collection areas.

This species is also subjected to traditional use for local *ju-ju* medicine. For instance, in southwestern Nigeria it is considered to be an efficient treatment against infertility in women (Dedeke et al. 2006).

Conservation Measures Taken. — Apart from generic habitat management in protected forest areas (where, however, illegal hunting often still occurs), there have been no specific conservation measures undertaken in favor of this species. CITES includes the species under Appendix

II as a member of the family Testudinidae. The IUCN Red List (www.iucnredlist.org) assessed the species as Data Deficient in 1996, but re-assessment by the IUCN/SSC Tortoise and Freshwater Turtle Specialist Group in 2013 provisionally assessed the survival status of the species as Endangered.

The species has been recorded from at least the following protected areas: Parc National Iles Ehotile, Parc National d'Assagny, Parc National de Banco, and Parc National Tai in Ivory Coast; Kakum National Park in Ghana; Okomu National Park, Taylor Creek Forest Reserve, Edumanon Forest Reserve (Akani et al. 2014a), Upper Orashi Forest Reserve (Akani et al. 2014b), Stubbs Creek Forest Reserve, Taylor Creek Forest Reserve, Nun River Forest Reserve, and Cross River National Park in Nigeria; Dja River Faunal Reserve (LeBreton 1999), Korup National Park, Banyang-Mbo Sanctuary, and Nta-Ali Reserve in Cameroon (Lawson 1993); Gamba complex of protected areas in Gabon (Pauwels et al. 2006); and Nouabale-Ndoki National Park in Congo–ROC (Jackson and Blackburn 2007).

Conservation Measures Proposed. — Since several of the wild populations of this species are declining precipitously, it is mandatory to start immediate conservation measures to help prevent any further declines or population collapses. It is important to plan the management of this species by collecting as much information as possible on the cultural interactions between local human communities and tortoises, because it may be possible to create a mosaic of protected areas linking all the forested zones in which people traditionally venerate tortoises. This strategy is certainly possible in some areas of southern Nigeria, such as around the towns of Sagbama and Brass in Bayelsa State. The same needs to be urgently explored in Congo (DRC) and Gabon.

Although *K. erosa* is on CITES Appendix II (included among all Testudinidae spp.), thus banning the import of wild individuals into Europe (EC regulation number 338/97), and requiring that trade be non-detrimental to wild populations, it nevertheless seems necessary to develop further conservation legislation in favor of this species both at the international and national levels (Ineich 2011). At the international level (IUCN Red List), it seems reasonable, based on emerging data, to list this species as Endangered instead of Data Deficient. At national and subnational levels it is necessary to include this species among the protected fauna in all jurisdictions of occurrence.

This species is legally protected in Togo under Article 62, Section 2, Chapter II of the law N° 2008-005, regulating environmental protection and wildlife conservation. In Nigeria, exports of this species are not allowed. However, at present there is virtually no country that can reliably preserve this species, and we have seen several specimens traded for food or traditional medicine even inside protected areas (e.g., Upper Orashi Forest Reserve in Rivers State, southeastern Nigeria) (Eniang and Ijeomah 2011). Another serious problem is represented by the high rates of export of these tortoises to western markets from such countries as Ghana, Benin, and Togo (e.g., see Lawson 2000). The exports of these specimens should be more closely monitored and controlled to prevent free-ranging specimens from being taken, especially considering that it is often unclear how these specimens are obtained, as tortoise farms are very underdeveloped in these countries (see also Harris 2001; Ineich 2011).

The field ecology of *K. erosa* has been studied intensively only in southern Nigeria and in western Cameroon. These studies should be continued in these two countries to achieve a very detailed dataset, with special respect to protected areas, in order to verify whether habitat protection (albeit non-perfect) may suffice for the conservation of this species. Field studies should also be urgently expanded into other countries of this species' range for comparative purposes (especially Congo–DRC, Congo–ROC, and Gabon). The same is true also for the studies on the relationship between humans and tortoises.

Evaluation of the genetics of individuals in captive breeding colonies and maintaining sufficient gene diversity will be an important part of establishing viable long term assurance colonies. Because *K. erosa* occurs over a large range, evaluation of genetic clades within the species will help best determine which specimens should be bred together. A management strategy and breeding transfer plan should be developed in coordination with taxon managers and *Kinixys* advisory groups (Mifsud and Stapleton 2014). Genetic work is warranted to assess population-level and range-wide genetic phylogeography. Collection of genetic samples during research activities will help better verify the number of species within the genus while defining geographic distribution and relatedness among species. The establishment of assurance colonies will also benefit from the collection of genetic data. Genetics can be used to determine the influences of inbreeding and outbreeding depression in colonies with limited numbers of founder individuals. This information will also establish reference blood ranges for future veterinary and health analyses as well as gaining a better understanding of disease pathology (Mifsud and Stapleton 2014).

There is a strong need to establish protected areas that include populations of these tortoises, and perhaps a very promising initiative would be to create protected corridors by linking areas where local people traditionally protect tortoises.

Preliminary attempts at trade management have been undertaken (Ineich 2011); however, these should be developed more to reduce the impact of export trade on wild-caught animals.

Captive Husbandry. — Mifsud and Stapleton (2014) provided detailed information on how to keep these tortoises captive, also for establishing eventual assurance colonies. Enclosures should be spacious with at least three square feet per inch of shell. If kept in groups, sufficient area must be provided. Cypress mulch or hardwood mulch are generally readily available products that are good bases for substrate. In addition, peat or coconut fiber are beneficial as additives that provide more natural texture and moisture retention when mixed with other base substrates.

Kinixys erosa is most active and healthiest when maintained at 60–90% humidity, though grassland species can be maintained on the lower end of this range. This can be achieved by misting several times daily or use of a fogging system. In addition, partially covering the enclosure with a plastic tarp and/or incorporating nontoxic live plants can help maintain higher humidity levels. As a general rule, temperatures should be kept between 70–85°F (21–29ºC) for day temperatures and 60–70°F (15–21ºC) at night.

These tortoises are omnivorous and should be provided with a varied diet, including high-calcium green leafy plant matter, fungi, vegetables, high fiber fruits, and animal protein. *Kinixys erosa* relishes earthworms, is known to consume snails, and will often aggressively take thawed feeder mice. The species also eats a large amount of mushrooms, and Mifsud and Stapleton (2014) reported that its growth in captivity increases considerably on a mushroom-based diet. Young individuals can also be given a variety of invertebrates, such as crickets, mealworms, and waxworms for protein and enrichment. Leafy weeds and greens like kale, chicory, clover, endive, dandelion, escarole, mustard greens, and red leaf lettuces are occasionally eaten.

Kinixys erosa, as well *K. homeana*, is notoriously difficult to keep in captivity because individuals are usually heavily parasitized and in bad general conditions when they arrive in the Western world. However, health conditions are often treatable and can be prevented by proper husbandry and early detection (Mifsud and Stapleton 2014). It is imperative that all new tortoise arrivals be quarantined from existing populations to prevent cross contamination. Different species should also never be housed together.

Wild caught *Kinixys* are particularly prone to heavy parasite loads of worms and protozoa, although a proper diet can maintain healthy gut flora and decrease the severity of parasites. It is important to note that small numbers of worms and protozoa may be normal gut residents potentially providing some benefits to the animal. In stressed or immune-compromised animals this balance can become disrupted. Though both are problematic and can result in the decline or death of an animal, protozoans have likely historically been the major killer of imported *Kinixys*. Diet can be key in minimizing and controlling these organisms. Evaluation of the need for treatment for parasites should be done on a case-by-case basis and under the supervision of a qualified veterinarian with demonstrated experience working with tortoises. Excessive or unnecessary treatment of *Kinixys* for parasites may damage gut health and efficiency. Coccidia can be particularly problematic and lethal with this genus and detection of this pathogen prior to any treatment for other parasites is important. Examining the stool is a good indication of how balanced the tortoise's diet is. Scat should be firm and contain little undigested food. Diarrhea and loose stool indicates a diet that is possibly too low in fiber, too high in fruit or water content, overfeeding, or illness.

Current Research. — Population demography and ecology of this species has been studied in southern Nigeria for 15 years by Luiselli and associates, particularly Godfrey C. Akani and Edem A. Eniang. In addition, Gabriel H. Segniagbeto, Fabio Petrozzi, and Luiselli have started a population study of these tortoises in Togo (2012), and Petrozzi, Sery Gonedele Bi, and Luiselli have started work in Ivory Coast (2014). In Ghana, a population ecology study with capture-mark-recapture protocols has been undertaken by Phil Allman and colleagues. Diagne, in conjunction with Nature Tropicale ONG, has started a community-based project in Benin (Oueme region near the border with Nigeria) to protect a remaining critical habitat where *K. erosa* and *K. homeana* occur sympatrically.

Ex-situ conservation programs on the various species of the genus *Kinixys* have been initiated recently in the USA, led by David Mifsud. A captive breeding assurance colony has been established by Diagne at the African Chelonian Institute (ACI) facility in Ngaparou, Senegal, from confiscated animals from Nigeria. A population genetics study of *K. erosa* has been initiated by ACI in collaboration with Nathanael Stanek at Cornell University.

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