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Sex ratio, size structure and morphometrics of turtle populations from Togo, West Africa
(Testudines: Testudinidae, Pelomedusidae)

Geschlechterverhältnis, Größenverteilung und morphometrische Merkmale in Schildkrötenpopulationen aus Togo, Westafrika
(Testudines: Testudinidae, Pelomedusidae)

GABRIEL H. SEGNIAGBETO & KOMAL AFIADEMAGNO & GODFREY C. AKANI & FABIO PETROZZI & LUCA LUISELLI

KURZFASSUNG

Studien grundlegender populationsbiologischer Aspekte wie Geschlechterverhältnis und Größen- bzw. Altersaufbau sind wesentliche Voraussetzung bei der Erarbeitung von Schutzprogrammen gefährdeter Arten. Allerdings sind nur wenige derartige Arbeiten verfügbar, was afrikanische Land- und Süßwasserschildkröten betrifft. Die Autoren untersuchten das Geschlechterverhältnis, und den Größen- bzw. Altersaufbau bei Populationen von *Kinixys homeana* BELL, 1827, *Pelomedusa* cf. *subrufa* (BONNATERRE, 1789) [wahrscheinlich *P. variabilis* PETZOLD et al., 2014 oder *P. olivacea* (SCHWEIGGER, 1812)] und *Pelusios castaneus* (SCHWEIGGER, 1812) und berichten zugehörige morphometrische Daten (Panzermaße, Körpermasse). Die untersuchten Populationen waren untereinander ähnlich, was das Geschlechterverhältnis (nahe 1:1) und den geschlechtsbedingten Größenunterschied (nicht signifikant) betrifft, unterschieden sich aber auffällig in ihrem Größen- bzw. Altersaufbau. In den Populationen von *K. homeana* waren weder Jungtiere noch Erwachsene von voller Größe festzustellen. Im Gegensatz dazu wiesen die Populationen der beiden aquatischen Schildkrötenarten beträchtliche Anteile an Jungtieren und Subadulten auf. Diese Größenverteilungen werden als zahlenmäßiger Rückgang in den Populationen von *K. homeana* und als arterhaltende Vermehrungsrate bei den zwei Pelomedusenarten interpretiert.

ABSTRACT

Studies on the basic aspects of population biology, including, e.g., sex ratio and size or age structure, are important for designating management programs for threatened species. Nonetheless, very few studies of this type are available as for the African tortoises and turtles. The authors studied sex ratio and size structure of Togolese populations of *Kinixys homeana* BELL, 1827, *Pelomedusa* cf. *subrufa* (BONNATERRE, 1789) [probably *P. variabilis* PETZOLD et al., 2014, or *P. olivacea* (SCHWEIGGER, 1812)], and *Pelusios castaneus* (SCHWEIGGER, 1812), and report corresponding morphometric data (shell measurements, body mass). All the studied populations were similar in terms of both sex ratio (close to 1:1) and sexual size dimorphism (not significant), but differed remarkably as for their overall size structure. *Kinixys homeana* showed a population profile in which neither juveniles nor full-grown adults were observed. In contrast, the population profiles of the two aquatic species revealed a considerable proportion of juveniles and subadults. These patterns are interpreted as a signal of decline for the population of *K. homeana* and sustaining populations as for the two aquatic Pelomedusidae.

KEY WORDS

Reptilia: Testudines: Testudinidae: *Kinixys homeana*, *Kinixys erosa*, *Kinixys nogueyi*; Pelomedusidae: *Pelomedusa* cf. *subrufa*, *Pelomedusa olivacea*, *Pelomedusa variabilis*, *Pelusios castaneus*, *Cyclanorbis senegalensis*; sex ratio, body size, shell morphology, population biology, ecology, pet trade, conservation; Togo, West Africa

INTRODUCTION

Documenting basic aspects of population biology may be important for understanding population trajectories and even designing accurate management plans for the conservation of target species (e.g., BJORNDAL 1982; STUBBS et al. 1985). In chelonians, the presence of numerous juveniles along with few very old individuals has been interpreted as a signal of increasing population size or of a population that has not suffered any recent catastrophes (FILIPPI et al. 2010), whereas the opposite is not correct due to methodological problems of detecting juveniles (see e.g., PIKE et al.

2008). Moreover, Stubbs et al. (1985) and Hailey (2000) showed that catastrophic events (such as fires) negatively affected juveniles much more than adults.

Concerning African tropical chelonian species, there are just very few studies documenting even basic aspects of population biology of single populations, and this scarcity of data may be detrimental to conservation actions, especially if we take into account that African turtles and tortoises are seriously threatened at a continental-wide scale (Luiselli 2009; Bombi et al. 2012, 2013).

In this paper, the authors present field data on some aspects of the population biology of a few chelonian species from two major vegetation zones of the Guinean forest-savannah mosaic, of Togo (West Africa). Although data on five species belonging to the genera *Kinixys* (Testudinindae), *Pelusios*, *Pelomedusa* (Pelomedusidae) and *Cyclanorbis* (Trionychidae) were collected, focus was put on three species from which the most data was recorded, i.e., *Kinixys homeana* Bell, 1827, *Pelomedusa* cf. *subrufa* (Bonnaterre, 1789) [probably *Pelomedusa variabilis* Petzold, Vargas-Ramirez, Kehlmaier, Vamberger, Branch, Du Preez, Hofmeyr, Schleicher, Široký & Fritz, 2014, or *Pelomedusa olivacea* (Schweigger, 1812)], and *Pelusios castaneus* (Schweigger, 1812). The taxonomic status of Togolese *Pelomedusa* is still uncertain. *Pelomedusa variabilis* was described on the basis of specimens from neighboring Ghana and Ivory Coast and *Pelomedusa* "lineage III" [*olivacea*] *sensu* Petzold et al. (2014) from adjacent Benin and Burkina Faso. The authors refrain from assigning the reported *Pelomedusa* turtles to one of those species and will use the name *Pelomedusa* cf. *subrufa*. However, the short linear distance of the south Togolese (Badon Akapé) specimens to *P. variabilis* from Ghana as well as that both share the same ecoregion speaks in favor of the latter species.

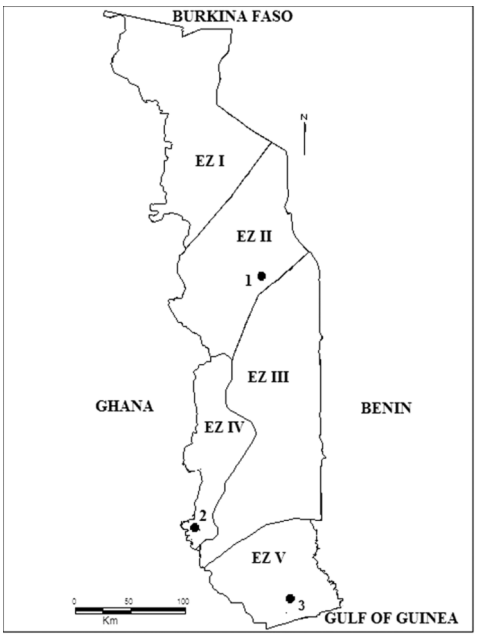

Fig. 1: Map of Togo, showing the position of the study areas. EZ I - EZ V - Ecozones I-V (Ern 1979). 1 - Sokodé, 2 - Badou, 3 - Togoville.

Abb. 1: Karte von Togo mit der Lage der Untersuchungsgebiete. EZ I - EZ V - Ökozonen I-V (Ern 1979). 1 - Sokodé, 2 - Badou, 3 - Togoville.

MATERIALS AND METHODS

Study areas and species.- Chelonian populations from the following localities were studied: Badou (Atakpamé) for the *Kinixys* species *homeana*, *erosa* (Schweigger, 1812), *nogueyi* (Lataste, 1886), and *Pelomedusa* cf. *subrufa*; Togoville for *Pelusios castaneus*; and Sokodé for *Cyclanorbis senegalensis* (Duméril & Bibron, 1835) (Fig. 1).

Badou (village of Atakpamé) (2 in Fig. 1) is situated in the south-western portion of Togo, in the ecological zone IV (forest) situated in the southern section of the Togo hills. In the south (Ecological Zone IV, Kloto area i.e., Kuma Tomegbe, Kpadape, Kametonou, Hanyigba), several forest ecosystems are distinguished. There are *Celtis* and *Terminalia superba* forest ecosystems at the mountain flanks and the Meliaceae and Moraceae forest ecosystems with *Parinaria excelsa*, *P. glabra* and *Polyscias fulva* in the top regions. At present, the underbrush of these semi-deciduous

forests is often replaced by coffee and cocoa farms. The forest islets and the underbrush are dominated by *Piper umbellatum*, *Dicranolepis grandiflora*, *Lea guineensis*, *Rothmania longiflora*, *Pteris togoensis*, etc. Under human pressure (i.e., expansion of farmland due to increasing population size), these forests are currently being transformed into a continuous grassland savannah-like vegetation type that is easily consumed by bush fire.

Togoville (3 in Fig. 1) is characterized by an extended marshy area situated around Lake Togo. The habitats surrounding the wetlands are mostly degraded and comprise coastal forest on coastal sand and alluvial deposits.

The Sokodé area (1 in Fig. 1) includes the northern part of the Mono River and extends between the towns of Sokodé and Tchamba, in the Central region of the country. *Cyclanorbis senegalensis* lives in the Alibi local community forest and in the Abdoulye Reserve from which the specimens of this study were captured. The habitat is chiefly constituted by gallery forest, with *Cola gigantea*, *Uapaca togoensis*, and *Mellittia thonningii* as principal species.

Protocol.- Terrestrial, tortoises (*K. nogueyi*, *K. homeana* and *K. erosa*) were captured by hand during random visual encounter surveys (VES) and using pitfall traps. Local guides (who were hunters in some cases) escorted the authors when walking along random transects in the forest, took the authors to good sites for finding turtles and helped in collecting the animals. In the forest, leaves under the trees and deadwood trunks were moved to enhance the probability of finding these elusive tortoises. Turtles caught were weighed, sexed and measured. To avoid multiple data logging, animals were marked by notching marginals of their carapaces. More specimens were provided by hunters working for different reptile farms in Lomé. The field surveys of forested areas were conducted in March, July and October, 2013, and also included the localities of Gbowle and Atchankeli, in Togodo North National Park.

The aquatic turtle species were collected opportunistically by the authors and through the help of local fishermen and the advice of Jean Apedo, a very experienced

Table 1: Descriptive statistics of the ratios 'carapace length to plastron length' (CL/PL) and 'carapace length to width' (CL/CW) (measurements in cm) for males (M) and females (F) of the turtle species *Kinixys homeana* Bell, 1827, *Pelomedusa* cf. *subrufa* (Bonnaterre, 1789) and *Pelusios castaneus* (Schweigger, 1812), studied in the present paper. Values of two-tailed Student t-test on the intersexual differences in the above-mentioned ratios are presented. $\bar{x}$ - Mean value, (SD) – Standard deviation.

Tab. 1: Beschreibende Statistiken der Verhältnisse von Karapaxlänge zu Plastronlänge (CL/PL) und Karapaxlänge zu –breite (CL/CW) (Angaben in cm) für Männchen (M) und Weibchen (F) der in der vorliegenden Arbeit untersuchten Schildkrötenarten *Kinixys homeana* Bell, 1827, *Pelomedusa* cf. *subrufa* (Bonnaterre, 1789) and *Pelusios castaneus* (Schweigger, 1812). Die Ergebnisse zweiseitiger Student t-Tests auf Geschlechtsunterschiede in den beschriebenen Verhältnissen sind angegeben. $\bar{x}$ - Mittelwert, (SD) – Standardabweichung.

	CL/PL (M) $\bar{x}$ (SD)	CL/CW (M) $\bar{x}$ (SD)	N	CL/PL (F) $\bar{x}$ (SD)	CL/CW (F) $\bar{x}$ (SD)	N	Intersexual differences / Geschlechtsunterschiede t-test (CL/PL)	t-test (CL/CW)
Kinixys homeana	1.39 (0.08)	1.40 (0.09)	10	1.42 (0.07)	1.40 (0.054)	10	t = 0.857, *p* = 0.403	t = 0.058, *p* = 0.954
Pelomedusa cf. *subrufa*	1.17 (0.52)	1.14 (0.069)	28	1.17 (0.057)	1.13 (0.066)	43	t = 0.179, *p* = 0.858	t = 0.329, *p* = 0.743
Pelusios castaneus	1.12 (0.050)	1.09 (0.04)	34	1.32 (1.38)	1.07 (0.05)	46	t = 0.827, *p* = 0.410	t = 1.061, *p* = 0.291

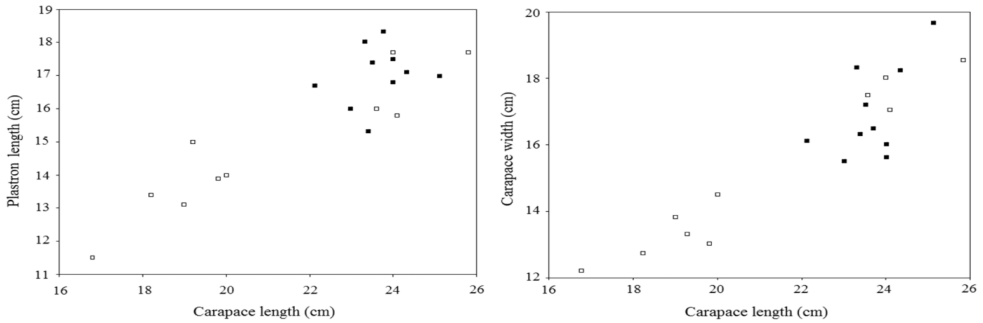

Fig. 2: Relationships between carapace length and plastron length (left) and between carapace length and carapace width (right) in Togolese *Kinixys homeana* Bell, 1827 (*n* = 20).
Full symbols - males, empty symbols - females.

Abb. 2: Die Beziehung von Karapaxlänge und Plastronlänge (links) sowie Karapaxlänge und Plastronbreite (rechts) bei *Kinixys homeana* Bell, 1827 aus Togo (*n* = 20).
Volle Symbole - Männchen, leere Symbole - Weibchen.

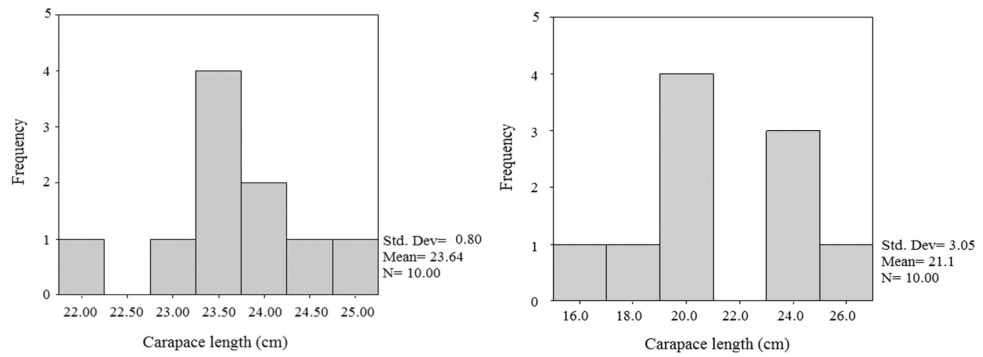

Fig. 3: Frequency distribution of the carapace lengths in 10 male (left) and 10 female (right) Togolese *Kinixys homeana* Bell, 1827.

Abb. 3: Häufigkeitsverteilung der Karapaxlängen bei 10 Männchen (links) und 10 Weibchen (rechts) von *Kinixys homeana* Bell, 1827 aus Togo.

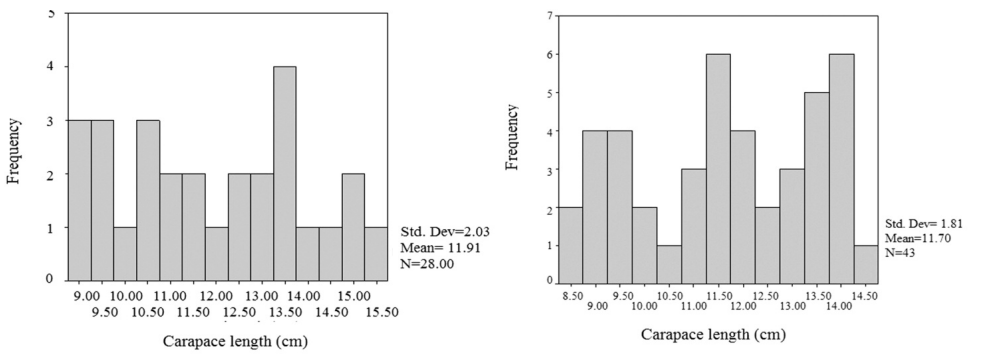

Fig. 4: Frequency distribution of the carapace lengths in 28 male (left) and 43 female (right) Togolese *Pelomedusa* cf. *subrufa* (Bonnaterre, 1789) .

Abb. 4: Häufigkeitsverteilung der Karapaxlängen bei 28 Männchen (links) und 43 Weibchen (rechts) von *Pelomedusa* cf. *subrufa* (Bonnaterre, 1789) aus Togo.

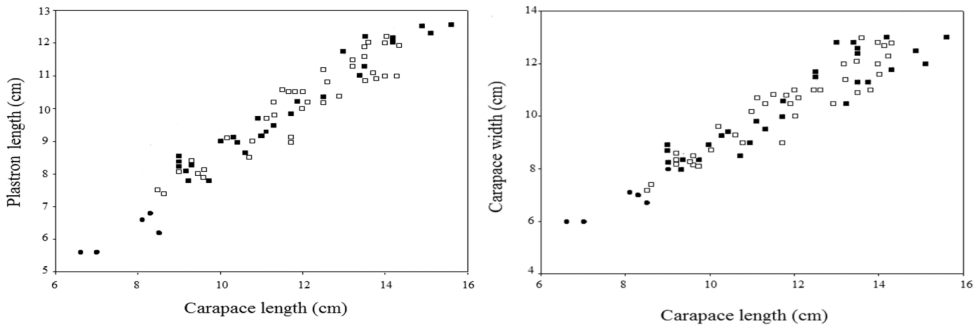

Fig. 5: Relationships between carapace length and plastron length (left) and between carapace length and carapace width (right) in a Togolese population of *Pelomedusa* cf. *subrufa* (Bonnaterre, 1789) (*n* = 77). Full squares - males, empty squares - females, full circles - unsexed juveniles.

Abb. 5: Die Beziehungen von Karapaxlänge und Plastronlänge (links) sowie Karapaxlänge und Plastronbreite (rechts) bei *Pelomedusa* cf. *subrufa* (Bonnaterre, 1789) aus Togo (*n* = 77). Volle Quadrate - Männchen, leere Quadrate - Weibchen, volle Kreise - Jungtiere ohne Geschlechtsangabe.

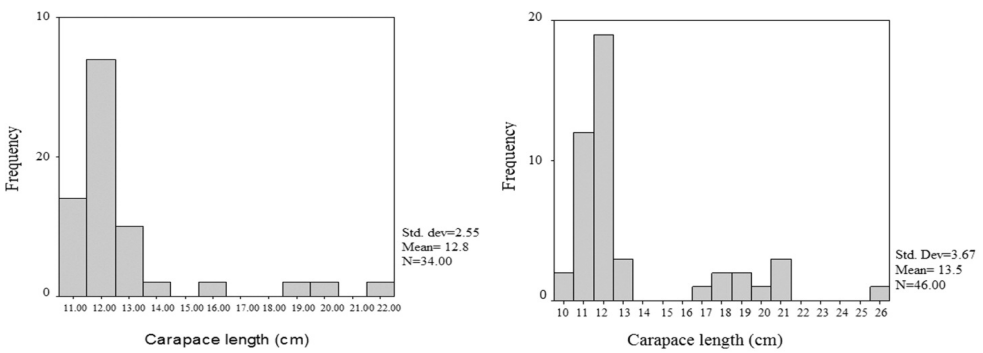

Fig. 6: Frequency distribution of the carapace lengths in 34 male (left) and 46 female (right) Togolese *Pelusios castaneus* (Schweigger, 1812).

Abb. 6: Häufigkeitsverteilung der Karapaxlängen bei 34 Männchen (links) und 46 Weibchen (rechts) von *Pelusios castaneus* (Schweigger, 1812) aus Togo.

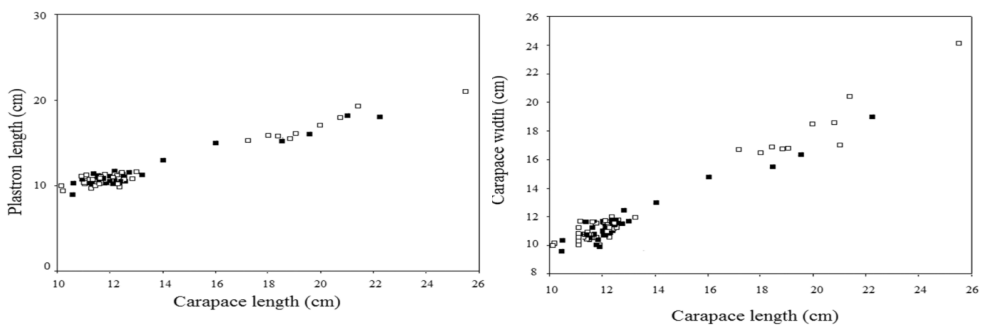

Fig. 7: Relationships between carapace length and plastron length (left) and between carapace length and carapace width (right) in a Togolese population of *Pelusios castaneus* (Schweigger, 1812) (*n* = 80). Full symbols - males, empty symbols - females.

Abb. 7: Die Beziehung von Karapaxlänge und Plastronlänge (links) sowie Karapaxlänge und Plastronbreite (rechts) bei *Pelusios castaneus* (Schweigger, 1812) aus Togo (*n* = 80). Volle Symbole - Männchen, leere Symbole - Weibchen.

reptile catcher. Many *Cyclanorbis senegalensis* were examined during field surveys along the rivers Oti and Mono in May, 2010, and from February to June, 2013. Fishermen in Mango, Komongou and Naboulgou provided several specimens as well.

Turtle and tortoise individuals were measured with regard to curved carapace length, width, and plastron length, with a tape measure (precision to 1 mm).

Statistical analyses.- All tests were two-tailed, with alpha set at 0.05 and performed using SPSS version 11.0 software. Sex ratio within populations was analyzed with the help of χ^2 tests; mean body size differences between males and females by Student t-test, and the linear relationship between two morphometric variables by Pearson's correlation coefficient.

RESULTS

Kinixys homeana Bell, 1827.- The small sample of this rare tortoise consisted of 20 individuals, 10 males and 10 females (balanced sex ratio 1:1). No newborn or very young individuals were observed, only two individuals (females) were classified subadult (carapace lengths 16.8 cm and 18.1 cm). Males and females did not differ in terms of the ratios carapace length to plastron length and carapace length to width (Table 1, Fig. 2). Mean carapace length was 22.32 cm (SD = 2.54), with the males being longer than females (Fig. 3). However, this difference in mean size was due to two subadult females, whereas no subadult males were observed. Males and females attained similar body size (largest male: 25.1 cm, and largest female: 25.8 cm). The body mass averaged 756.2 g (SD 203.1 g, range 400 g -1000 g, median 800 g).

Fig. 8: *Pelomedusa* cf. *subrufa* (Bonnaterre, 1789) of the study area in Togo.

Abb. 8: *Pelomedusa* cf. *subrufa* (Bonnaterre, 1789) des Untersuchungsgebietes in Togo.

Pelomedusa cf. *subrufa* (Bonnaterre, 1789) (Fig. 8).- The sample consisted of 77 adult and juvenile individuals, including 28 males, 43 females, and 6 unsexed juveniles. Sex ratio (0.65:1) was not significantly skewed from equality (χ^2= 3.17, df = 1, p = 0.075). Males and females did not differ significantly in terms of carapace length (t = 0.459, df = 69, p = 0.647); their body size distributions are presented in Fig. 4. Maximum body size was slightly larger in males (15.6 cm carapace length) than in females (14.3 cm). There was a large number of juveniles in the sample studied, with 29.9 % of the individuals measuring less than 10 cm in carapace length. Males and females did not differ in terms of the ratios carapace length to plastron length and carapace length to width (Table 1, Fig. 5).

Pelusios castaneus (Schweigger, 1812).- Eighty adult and juvenile individuals were analyzed, including 34 males and 46 females. Sex ratio (0.74:1) was close to equality (χ^2= 1.80, df = 1, p = 0.179). Males and females did not differ significantly in terms of carapace length (t = -1.028, df = 78, p = 0.307); their body size distributions are presented in Fig. 6. Despite that the two sexes averaged similar carapace length, the observed maximum size was clearly larger in females (25.5 cm cara-

pace length) than in males (22.2 cm). As in the case of *Pelomedusa* cf. *subrufa*, there was a large number of juveniles in the sample studied, with 30.0 % of the individuals of less than 11.5 cm in carapace length. Males and females did not differ in terms of the ratios carapace length to plastron length and carapace length to width (Table 1, Fig. 7).

Other chelonian species recorded and measured during the present study were excluded from the analysis due to small sample size of one (*K. erosa*), two (*K. nogueyi*) and six (*C. senegalensis*) individuals. However, it should be noted that the two *K. nogueyi* and the only recorded *K. erosa* were syntopic to several *K. homeana*, with no apparent differences in microhabitat. Concerning *C. senegalensis*, these individuals were observed in syntopy with *P.* cf. *subrufa*.

DISCUSSION

The present study allowed the analysis of sex ratio and size structure for wild populations of three chelonian species in Togo. This data is important because there is no study available on size structure and morphometrics of turtles and tortoises in a West African country, outside Nigeria (Luiselli et al. 2003).

The populations of all the three species studied were similar in terms of sex ratio (close to 1:1) and sexual size dimorphism (not significant), but differed remarkably as for their size (and thus, age) structure. The population profile of *Kinixys homeana* was characterized by the absence of juveniles as well as large, full-grown adults (given that, at least in remote forest sites in southern Nigeria, adults larger than 24 cm carapace length can be found, i.e., considerably larger than those observed here; Akani, Eniang, Luiselli & Petrozzi, unpublished data). On the other hand, the population profiles of the two aquatic species revealed a considerable proportion of juveniles and subadults, although large individuals (i.e., larger than 15 cm for *Pelomedusa* cf. *subrufa* and 20 cm in case of *Pelusios castaneus*) were rare in the samples.

It is suggested by the authors, that these distinct population profiles in size (or age) structure reveal the general status of the wild populations of these species in Togo, and hence are worthy to be included in conservation considerations. In analogy to observations previously made in European tortoise populations (Stubbs et al. 1985; Hailey 2000), the particular size structure of the *K. homeana* population studied (no juveniles) is considered a clear indication of its declining status. Indeed, this population has been heavily exploited for the international pet trade during the last 30 years, with Togo being one of the main exporters of this species in the whole of Africa (CITES 1980), and thus a declining population status seems to be likely, also because the tortoise hunters, who supply the trade exporters in Lomé, witnessed a negative trend during the last decade (authors' unpublished interviews). The absence of full-grown specimens may be linked to both pet trade (i.e., live individuals do not have time to grow till the maximum size because they are collected for exportation before that time) and harvesting for local consumption (people catch them for food, especially the larger individuals; see Luiselli et al. 2003). Thus, this data confirms the serious status of threat for *K. homeana* in Togo where it has a very narrow distribution range (Segniagbeto et al. 2014), and that its populations are globally collapsing in the wild due to domestic consumption and the international pet trade (Luiselli et al. 2006a, 2006b, 2013). Thus, the red list status of "Critically Endangered" (CR) was proposed for this species by the IUCN/SSC Tortoise and Freshwater Turtle Specialist Group in the Red listing Workshop held in Lomé (Togo), on August 2013.

On the other hand, the two freshwater species studied seem to be abundant and their populations did not show any declining trend; instead, the high proportion of subadults seems to indicate current stable conditions. This pattern is consistent with

Fig. 9: The hillside forest in south-western Togo is habitat to three *Kinixys* species. Note the anthropogenic clearings (highlighted by the ovals) and the exploitation level of the landscape. It is here suggested that the co-occurrence of two forest species (*K. erosa* and *K. homeana*) and a savannah species (*K. nogueyi*) may be due to the high deforestation rates, causing the latter species to colonize the area.

Abb. 9: Der Wald in den Hügeln Südwest-Togos ist Lebensraum von drei *Kinixys*-Arten. Man beachte den anthropogenen Einschlag (durch ovale Umrandung gekennzeichnet) und den Erschließungsgrad der Landschaft. Das gemeinsame Vorkommen zweier Waldbewohner (*K. erosa* und *K. homeana*) und einer Savannenart (*K. nogueyi*) ist vermutlich auf die starke Entwaldung zurückzuführen, die letzterer Art erlaubt, das Gebiet zu besiedeln.

general observations on the distribution and abundance of *Pelomedusa* cf. *subrufa* and *Pelusios castaneus*, which are considered the two most abundant chelonian species in Togo (Segniagbeto et al. 2014). It is noteworthy that Badou for *Pelomedusa* and Togoville for *Pelusios* are among the most exploited sites for the international pet trade, suggesting that the current exportation numbers are sustainable in the medium term, considering that the local reptile farms exploit these populations for over 30 years and their population size structure seems to be consistent with that of flourishing populations. In this regard, it should be mentioned that, apart from the above mentioned case of collapsing *Kinixys homeana* populations, Togolese reptile farms seem to have exploited reptilian species in a relatively sustainable way for the last 30 years, especially with regard to *Python regius* (Shaw, 1802) (Luiselli et al. 2012). Nonetheless, they just ranch the various species without real attempts at captive breeding (Ineich 2011), and this fact merits continued monitoring by competent authorities.

Concerning species poorly represented in the present study, the authors would like to stress the occurrence in the same forest zone (the Badou forest) of three species of *Kinixys*, including not only the typical forest species *K. homeana* and *K. erosa*, but also the mainly savannah species *K. nogueyi*. Sympatric occurrence of these three species is rarely reported in the literature, despite a few sites of their co-occurrence are known from the Niger Delta in southern

Nigeria (Luiselli et al. 2000). This unusual co-occurrence may be due to the fact that both the hillside forests of Togo and the moist forests of the Niger Delta are presently over-exploited by human development practices, resulting in high deforestation rates that facilitate the colonization by the savannah species *K. nogueyi* (Fig. 9).

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AUTHORS: Gabriel H. Segniagbeto < h_segniagbeto@yahoo.fr >, Komal Afiademagno < afiade@gmail.com > - Département de Zoologie et Biologie animale, Faculté des Sciences, Université de Lomé, BP 1515, Lomé, Togo; Godfrey C. Akani < gakanina2000@yahoo.com > - Department of Applied and Environmental Biology, Rivers State University of Science and Technology, Port Harcourt, Rivers State, Nigeria; Fabio Petrozzi < fapetrozzi@gmail.com > - Ecologia Applicata Italia s.r.l., via E. Jenner 70, 00151 Roma, Italy - Department of Applied and Environmental Biology, Rivers State University of Science and Technology, Port Harcourt, Rivers State, Nigeria; Luca Luiselli (Corresponding author, < lucamlu@tin.it >) - Centre of Environmental Studies Demetra, Rome, Italy - Department of Applied and Environmental Biology, Rivers State University of Science and Technology, Port Harcourt, Rivers State, Nigeria.