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Caption: Painted Stork *Mycteria leucocephala* at Achankulam Lake, Coimbatore by B. Ravichandran, WILD / Zooreach.

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ARTICLE

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Distribution of the threatened Assamese Macaque *Macaca assamensis* (Mammalia: Primates: Cercopithecidae) population in Nepal

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Abstract: Sustainable conservation and management of a species require detailed knowledge of its population status and distribution pattern. The population of the Assamese Macaque *Macaca assamensis* in Nepal, probably a new subspecies endemic to the country, is yet to be studied for documenting its spatial distribution and size. We did extensive surveys across three major river systems of Nepal (Koshi, Gandaki, and Karnali river systems) by modified line transect method covering almost the entire distribution range of the species within the Nepal territory. We counted a total of 829 individuals in 43 groups that accounted for the average group size of 19.29 (±10.40) individuals. The elevation distribution of the species ranged between 130m and 2650m. Further, we assessed the potential distribution areas of the species by ecological niche modeling employing maximum entropy algorithm. The census and ecological niche modeling congruently revealed the mid-hills of eastern and central Nepal outside the protected areas as the major habitats of this nationally endangered and protected primate. Conservation attempts, therefore, should focus on this area.

Keywords: Ecological niche modeling, MaxEnt, primates, spatial distribution.

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Author Contribution: LK, MKC and XJ conceptualized the project. LK and MKC carried out the field work. LK analyzed the data and prepared the manuscript. MKC and XJ supervised the overall research and contributed in manuscript improvement.

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INTRODUCTION

An accurate assessment of population densities in natural habitats is the prerequisite for the determination of priorities for the sustainable conservation and management of a species (Defler & Pintor 1985; Kumara & Radhakrishna 2013). Primate census is useful in the conservation of a species as it provides multiple benefits such as i) population density or total counts that can be the baseline information for future monitoring, ii) evaluation of population changes since a previous census period, if any, iii) an assessment of population tendency with support of frequent censuses, and iv) an evaluation of different habitats for their relative importance in primate conservation. Such assessments can help conservation managers judge the success of the ongoing management activities and decide when, where, and how to mediate for the management of a species (Plumptre & Cox 2006).

Multiple direct and indirect methods are available to understand and monitor species presence and abundance. These include the total count of individuals, strip transects, line transects, capture-mark-recapture methods, and observations of signs like feces, nests, and tracks (Kumara & Radhakrishna 2013). The results from different methods vary and using different census techniques together add unknown errors. Hence, it is necessary to develop uniform methods that can be replicated over time and space to monitor the primate populations for their conservation (Plumptre & Cox 2006). Census by total count is the most reliable method since it is highly informative and accurate if the assumption that all individuals present in the group are counted once and no individual is double-counted is not violated (Kuhl et al. 2008).

Determining the spatial distribution of a species is a multifaceted task (Boubli & de Lima 2009). Species distribution modeling (SDM), also known as ecological niche modeling (ENM), can be coupled with the systematic survey of species presence to identify the potential distribution range of the species (Ortega-Huerta & Peterson 2008) relating the field observations to environment layers of predictor variables (Guisan & Thuiller 2005). SDMs establish relationships of known species occurrences with potential environment covariates and then predict the spatial and temporal distribution of the species. Among the SDM techniques available at present, maximum entropy method or MaxEnt (Phillips et al. 2004) is designed to depict the distribution of individual species using presence-only data (Phillips et al. 2006). It outperforms other existing predictive methods (Elith et al. 2006) and shows exponential growth in its application since its introduction in 2004 (Morales et al. 2017). The tool was used in many taxa including primates for multiple purposes including mapping potential distribution and habitat use (Boubli & de Lima 2009; Norris et al. 2011; Vidal-Garcia & Serio-Silva 2011; Voskamp et al. 2014; Sarma et al. 2015; Sarania et al. 2016), delineating ecological boundaries of multiple taxa (Nag et al. 2014), assessing threats and setting conservation priorities (Thorn et al. 2009; Campos & Jack 2013), paleodistribution reconstruction and phylogeography (Khanal et al. 2018a,b), and range shifts (Elith et al. 2010).

The Assamese Macaque *Macaca assamensis* McClelland, 1840 is one of the members of polytypic *Sinica*-group of macaques that is characterized by the sagittate-shaped glans penis and that has a fragmented distribution in southern and southeastern Asia. Assamese Macaques are medium-sized, arboreal, diurnal, and omnivorous cercopithecine primates that live in multimale-multifemale social groups (Chalise 1999; Molur et al. 2003). It has two known subspecies, Eastern Assamese Macaque *M. a. assamensis* and Western Assamese Macaque *M. a. pelops*, the distribution ranges of which are demarcated by the Brahmaputra River (Roos et al. 2014). The Assamese Macaque population in Nepal differs in pelage and facial color, relative tail length, and elevation distribution range to their nearest conspecific populations (*M. a. pelops*) from the adjacent countries such as India and Bhutan. Thus, the Nepalese population of Assamese Macaque was doubted for a distinct subspecies status and referred to as '*M. assamensis* Nepal population' (Molur et al. 2003; Chalise 2005, 2013; Boonratana et al. 2008).

The Assamese Macaque is categorized as Near Threatened by the IUCN (Boonratana et al. 2008) and its Nepalese population, one of the least studied primates, is nationally listed as Endangered due to its restricted distribution, population threats, and small numbers in fragmented patches of the remaining habitat. Thus, the species is protected by the National Park and Wildlife Protection Act 1973 of Nepal (Boonratana et al. 2008; Chalise 2013; Chalise et al. 2013). It was reported from the mid-hills within Nepal as a sub-tropical habitat specialist, but the details on its socioecology are yet to be documented (Khanal et al. 2018a).

The distribution and conservation status of the Assamese Macaque in Nepal is not well documented. Wada (2005) surveyed the distribution of Assamese Macaque in Nepal and reported it from only the east of

Kaligandaki River. The studies so far in Nepal (Chalise 1999, 2008, 2013; Chalise et al. 2005; Wada 2005) were confined to surveying the fragmented populations of Assamese Macaque at different patches, lacking a systematic study that covers the entire range of the species. Although it is listed as an endangered species and is protected nationally, the species was described as a crop-raider in some parts of Nepal (Chalise 2010; Paudel 2017; Adhikari et al. 2018). Most of the habitats of the species fall outside the protected areas in mid-hills and no detailed documentation of population and distribution was done so far. Therefore, it is crucial to identify the population status, distribution pattern, and conservation status of Assamese Macaque in Nepal.

We aimed to explore the population status, distribution pattern, and the potentially suitable habitats of the Assamese Macaque in Nepal. We did an extensive survey along the tributaries of the three major river systems of Nepal from September 2015 to October 2016 covering almost the entire distribution of the species and performed a population census. We used the census points of the species and bioclimatic variables to determine their potential distribution areas. Here, for the first time, we describe that the westernmost distribution limit of the Assamese Macaque, as described in previous publications (Fooden 1979, 1982; Wada 2005; Timmins & Duckworth 2013), is not the Kaligandaki River of central Nepal. We recorded three groups from far western Nepal and censused them.

MATERIALS AND METHODS

Study Area

Nepal stands on 26.350–30.450^{0}N & 80.067–88.200^{0}E (Sharma 1999). It extends about 800km along the east-west Himalayan axis and its width varies between 150km and 250km, covering a total area of 1,47,181km^2. The Nepal Himalaya forms the central one-third of the entire Himalayan range and includes multiple bioclimate zones. It has geographic diversity ranging from 60m elevation in the tropical Tarai beyond the perpetual snow line to over 7,000m including Earth's highest 8,848m (Mount Everest) (Khanal et al. 2018a). Wide altitude variations and diverse climate conditions resulted in five main physiographic zones within Nepal (Table 1) (Carson et al. 1986) and such extreme altitude gradients created nine bio-climatic zones ranging from tropical to nival (Fig. 1A) (HMGN/MFSC, 2002).

Table 1. Five major physiographic zones of Nepal (Source: Carson et al. 1986).

Physiographic Zone	Area (%)	Elevation (m)	Climate
High Himalaya	23	above 5,000	Tundra-type, Arctic, and Trans-Himalayan
High mountains	20	4,000–5,000 3,000–4,000	Alpine Sub-alpine
Mid-hills	30	2,000–3,000 1,000–2,000	Cool temperate monsoon Warm temperate monsoon
Siwalik Hills	13	300–1,000	Hot monsoon and subtropical
Tarai	14	< 300	Hot monsoon and tropical

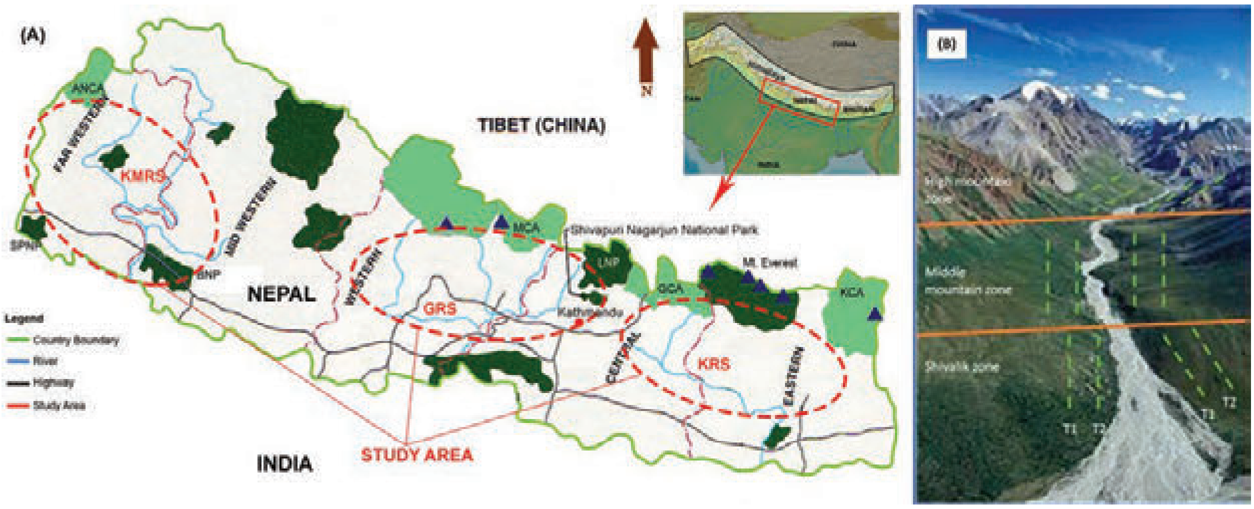

Figure 1. Study area and survey design. A - The three major river systems and survey area in Nepal, B - Transect layout on both the sides of the river axis (not in scale).

Assamese Macaques were reported in Nepal from 300m to 2,350m (Chalise 2013) that includes the Siwalik Hills, lower mid-hills, and upper mid-hills. Surveys were conducted in three physiographic zones (Tarai, mid-hills, and lower Himalaya) across the three major river systems — Nepal-Koshi River system in eastern Nepal, Gandaki River system in central Nepal, and Karnali-Mahakali River system in western Nepal (Fig. 1A).

It included mid-hills and the lower-Himalaya region of eight protected areas of Nepal and non-protected Assam Macaque habitats in the mid-hills. The Tarai and Siwalik zone below 1,000m has tropical forests that can be categorized as *Shorea robusta* forest, *Acacia catechu-Dalbergia sissoo* forest, other riverine forest, and *Terminalia-Anogeissus* deciduous hill forest. The mid-hills bear sub-tropical forest up to 1,700m dominated by *Pinus roxburghii*, *Schima-castanopsis*, and *Alnus nepalensis* and riverine forest with *Toona* and *Albizia* species. The areas from 1,700m to 2,700m bear lower temperate forest dominated by *Quercus leucotricophora*, *Q. lanata*, *Q. floribunda*, *Q. lamellose*, abundant lauraceae, and *Pinus wallichiiana* (Jackson 1994). The lesser Himalaya has temperate forests dominated by the *Quercus*-pine-rhododendron combination (Chalise et al. 2005; Khanal et al. 2018b).

Field Survey Design

The standard method for counting predominantly arboreal monkeys is along the line-transects (Marshall et al. 2008). Spatial distributions of study species in the four physiographic zones across the river systems were surveyed by a modified line-transect method (Buckland et al. 2010). Two line-transects, each of 5km length, were used on either side of the rivers and their tributaries in each physiographic zone (Fig. 1B; 2).

The line-transects were roughly parallel to the river axis. The first transect was within 1km and the second transect was within 4–5 km perpendicular distance from the river center. The Tamor, Arun, and Sunkoshi rivers of Koshi River system, Trishuli-Budhigandaki, Marshyangdi, and Kaligandaki of Gandaki River system, and Bheri, Karnali, and Chamelia rivers of Karnali-Mahakali River system were surveyed. A total of 48 line-transects were surveyed in each river system. In addition to the river systems, surveys were also done in Shivapuri Nagarjun National Park that lies in the mid-hills between Koshi River system and Gandaki River System.

Population Survey

We conducted our field survey between September 2015 and October 2016. Wherever the groups were

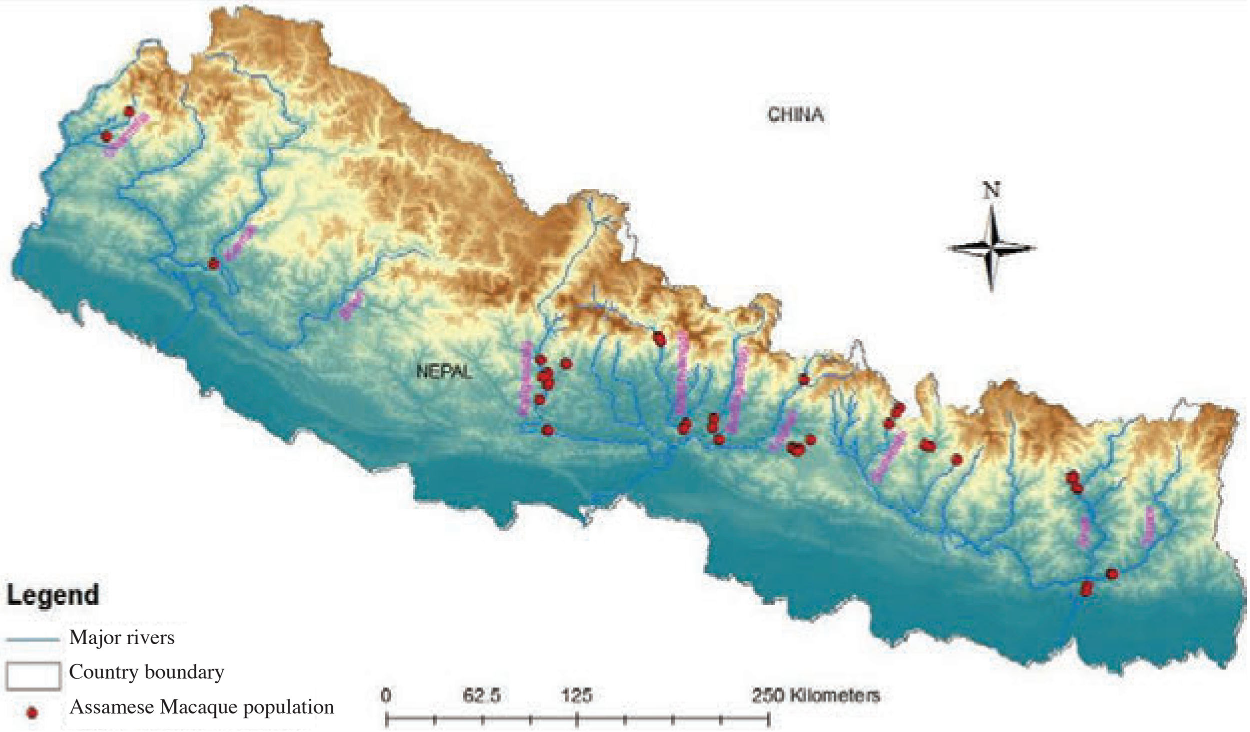

Figure 2. Survey area and Assamese Macaque census points in Nepal.

observed, detailed population censuses were conducted. A closely bonded social assemblage of monkeys sharing resources, at least 200m apart from the nearest assembly, was considered a group (Chalise 2005; Lehmann & Dunbar 2009). The geographic location of the group was noted using GPS and vegetation samplings were done using 20m × 20m quadrates. Distances of group occurrence from the nearest river, human settlement, and crop fields and other relevant measurements were noted. The group size and population composition were observed in detail from a distance varying from about 10m to 100m aided with binoculars whenever necessary. The individuals were divided into four age groups, namely, adults (male and female), sub-adults, juveniles, and infants, following the method of Chalise (2003). The counting was repeated until the concurrent readings were obtained for total count and age groups. On encountering the signs confirmed for Assamese Macaque, even if the group was not observed, the GPS locations were noted and the vegetation survey was done.

Data Analysis

Estimation of Population Parameters

Male to female sex ratios were calculated among the adult and sub-adult age groups separately as the number of males out of 100 females. Infant to female ratio was calculated by dividing the total number of infants by the total number of adult females in the group. The average group size was computed as the mean of the number of individuals among the observed groups.

$$\text{Average group} = \frac{\text{Total number of individuals observed}}{\text{Total number of groups observed}}$$

$$\text{Sex ratio (male: female)} = \frac{\text{Number of males of that age group}}{\text{Number of females of same age group}}$$

$$\text{Infant female ratio} = \frac{\text{Total number of infants}}{\text{Total number of females in reproductive age groups}}$$

The number of individuals varied among the different groups and the group size data was tested for normal distribution by Shapiro-Wilk test. It revealed that the data were not normally distributed (W=0.941, P=0.029), hence, they were normalized first and then the significant difference in group size among the three river systems was tested statistically by One-way ANOVA using Graphpad Prism v.5.01 (Motulsky 1999).

Distribution pattern

The number of groups and individuals observed were categorized based on their presence at different river systems and elevation zones. The statistical significance of the differences in their distribution pattern was tested by one-way ANOVA.

Population distribution in protected and non-protected areas

To assess the conservation status of the Assamese Macaque, the total population observed was subdivided to two groups — population inside protected areas (national parks and buffer zones, conservation areas, wildlife reserves, and hunting reserves) and population outside protected areas. The significant difference in the group size between the two populations was tested by t-test.

Ecological niche modeling

The 19 bioclimatic variables (version 1.4) (Table 2) in a 30 arc second spatial resolution representing the present bioclimatic conditions were retrieved from the WorldClim global climate database portal (WorldClim 2018). For the ecological niche modeling (ENM) of the Assamese Macaque, the geographic coordinates of the 43 groups collected using GPS during the field surveys were used. The Nepalese population of Assamese Macaques are considered endemic to Nepal. Therefore, for modeling their distribution, all bioclimatic variables were clipped to the boundary of Nepal using ArcGIS 10.3.1 and exported in ASCII format. Seven bioclimatic variables (Bio: 1, 3, 5, 11, 12, 15, 18) were selected for the ENM after removing highly correlated ($r \geq |0.8|$) variables on the Pearson correlation test ($P < 0.05$).

MaxEnt v.3.4.1 (Phillips et al. 2006) was used to model and map the current potential distribution of *M. assamensis*. For model evaluation purposes, the species presence data were randomly divided into 75% as the training dataset and 25% as the validation dataset. To account for uncertainty introduced by training and validation set splits, 25 replicated models based on the cross-validation method were generated (Otto-Bliesner et al. 2006). The accuracy of the models was evaluated by using the area under the curve (AUC) of the receiving operating curve (ROC).

The logistic output of habitat suitability was converted to the binary output of unsuitable and suitable habitats using the threshold of maximum training specificity and sensitivity (maxTSS=0.348) as explained for the model generated by presence-only data by Liu et al. (2013). Then, the potential altitude range of suitable

Table 2. Bioclimatic variables used in the construction of ENM for Assamese Macaque

	Abbreviation	Description
1*	**Bio1**	**Annual mean temperature**
2	Bio2	Mean diurnal range [mean of monthly (max temp–min temp)]
3*	**Bio3**	**Isothermality (P2/P7) (×100)**
4	Bio4	Temperature seasonality (standard deviation × 100)
5*	**Bio5**	**Max. temperature of warmest month**
6	Bio6	Min. temperature of coldest month
7	Bio7	Temperature annual range (P5–P6)
8	Bio8	Mean temperature of wettest quarter
9	Bio9	Mean temperature of driest quarter
10	Bio10	Mean temperature of warmest quarter
11*	**Bio11**	**Mean temperature of coldest quarter**
12*	**Bio12**	**Annual precipitation**
13	Bio13	Precipitation of wettest month
14	Bio14	Precipitation of driest month
15*	**Bio15**	**Precipitation seasonality (coefficient of variation)**
16	Bio16	Precipitation of wettest quarter
17	Bio17	Precipitation of driest quarter
18*	**Bio18**	**Precipitation of warmest quarter**
19	Bio19	Precipitation of coldest quarter

* - Bioclimatic variables used in the model development

habitats was evaluated by overlaying the binary output on the SRTM DEM (Jarvis et al. 2008). The elevations of the suitable habitat pixels were extracted and their mean, maximum, and minimum were computed.

RESULTS

Total population and river system-wise distribution of Assamese Macaque in Nepal

A total of 829 individuals of Assamese Macaques from 43 groups were observed during the field survey. The highest number of groups and individuals were observed from Gandaki River system (21 groups and 377 individuals) in central Nepal, followed by the Koshi River system (13 groups and 287 individuals), Shivapuri Nagarjun National Park (six groups, 104 individuals), and Karnali-Mahakali River system (three groups and 61 individuals) (Figs. 2 & 3). The overall average group size was calculated to be 19.29 (±10.40). The groups varied in their sizes and ranged between three to 39 individuals per group; however, variations were not significant among the four study areas (One-way ANOVA, F=0.448; df=(3, 39); *P*=0.692). The highest average group size was computed from Koshi River system (22.07±11.73 individuals per group) and the lowest from Shivapuri Nagarjun National Park (17.33±10.13 individuals per group).

Age-sex composition

The overall adult to young ratio was computed to be 1:1.037, i.e., close to 1:1 ratio. The adult male to female sex ratio was found to be 1:1.91 and the infants to adult female ratio was 0.592:1. The adult to young ratio and adult male to female sex ratio did not vary among the groups of different river systems [One-way ANOVA; adult sex ratio: F=1.050, df= (3,39), *P*= 0.381; adult to young ratio: F= 1.554, df= (3,39), *P*= 0.216].

Elevation-wise distribution

The Assamese Macaque groups were recorded across in the elevation range from 130m at Chatara in eastern Nepal to 2,650m at Langtang National Park in central Nepal. More than one-third of the groups (34.88%) were recorded from the elevation ranges between 1,001m and 1,500m while the highest number of individuals were observed from elevations less than 500m. Population distribution did not vary at different elevation zones of the four study areas (Fig. 4) (F=2.199; df=(3, 16); *P*=0.127).

The average group size was the highest (22.88 individuals per group) for the elevation range of 501–1000 m and the least (15 individuals per group) for the elevation range of 1501–2000 m (Table 3). There, however, was no significant difference in the group size at various elevation ranges (F=0.758; df=(4, 38); *P*=0.558).

Population distribution in protected and non-protected areas

Out of the total 829 individuals counted from 43 groups of Nepal territory (Fig. 3), 22 groups accounting for 407 individuals were observed from protected areas (PAs, national park or conservation area), whereas 422 individuals from 21 groups were observed outside the protected areas. It accounted the average group size of 18.5 ±10.24 and 20.1 ±10.77 individuals per group for inside and outside the PAs, respectively; however, there was no significant difference in group size between the populations inside and outside the protected areas (t= 0.497, df=41, *P*= 0.621).

Ecological Niche of the Assamese Macaque

The MaxEnt model generated for the Assamese

Macaque performed well with a mean AUC value of 0.899 ± 0.064 (Fig. 5B) for 25-fold cross validation indicating the robustness in prediction of distribution of suitable habitat (Fig. 6). The prediction of habitat suitability completely matched with the prevailing distribution records of the Assamese Macaque within Nepal territory. Among the eight predictive bioclimatic variables, precipitation of warmest quarter of the year (bio18, 67.7%) contributed the highest to the model, followed by the isothermality (bio3, 21.2%) and annual mean temperature (bio1, 4.2%).

The Jackknife test of MaxEnt model (Fig. 5A) on variable importance showed that bio18 (precipitation of warmest quarter) has the highest gain when it is used in isolation. It validated that bio18 has the maximum useful information among the variables and contributed most to the model development. Further, omission of bio18 decreased the gain of model indicating that it holds the most information for Assamese Macaque suitable habitat determination among the variables used for the model development. According to the response curve plots, the precipitation of warmest quarter above 1200mm and isothermality around 50 were ideal to define the suitable habitat for Assamese Macaque (Fig. 5C). Such conditions are fulfilled by the mid-hills of central Nepal supporting the broad-leaved vegetations.

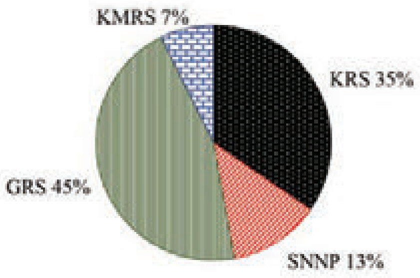

Figure 3. Percentage of Assamese Macaque population in three major river systems and Shivapuri Nagarjun National Park in Nepal.

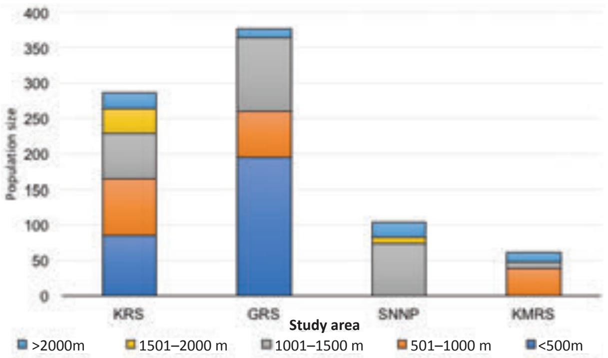

Figure 4. Elevation-wise distribution of Assamese Macaque population in different sampling localities (KRS - Koshi River system, GRS - Gandaki River system, SNNP - Shivapuri Nagarjun National Park, KMRS - Karnali-Mahakali River system) of the Nepal Himalaya.

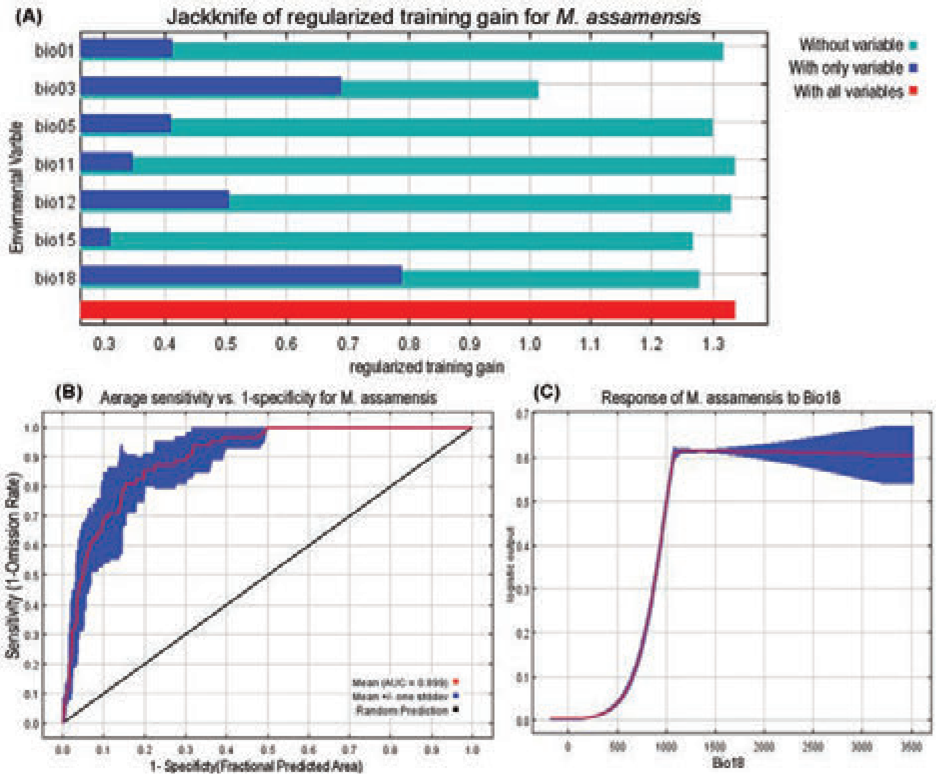

Figure 5. Ecological niche modeling for Assamese macaque by MaxEnt. (A) The variable importance by Jackknife test. (B) The average area under curve (AUC) for 25 replicates of MaxEnt run. The red line represents average value and the blue bar represents ±1 standard deviation. (C) Response curve plot for the variable that has the highest contribution to the model.

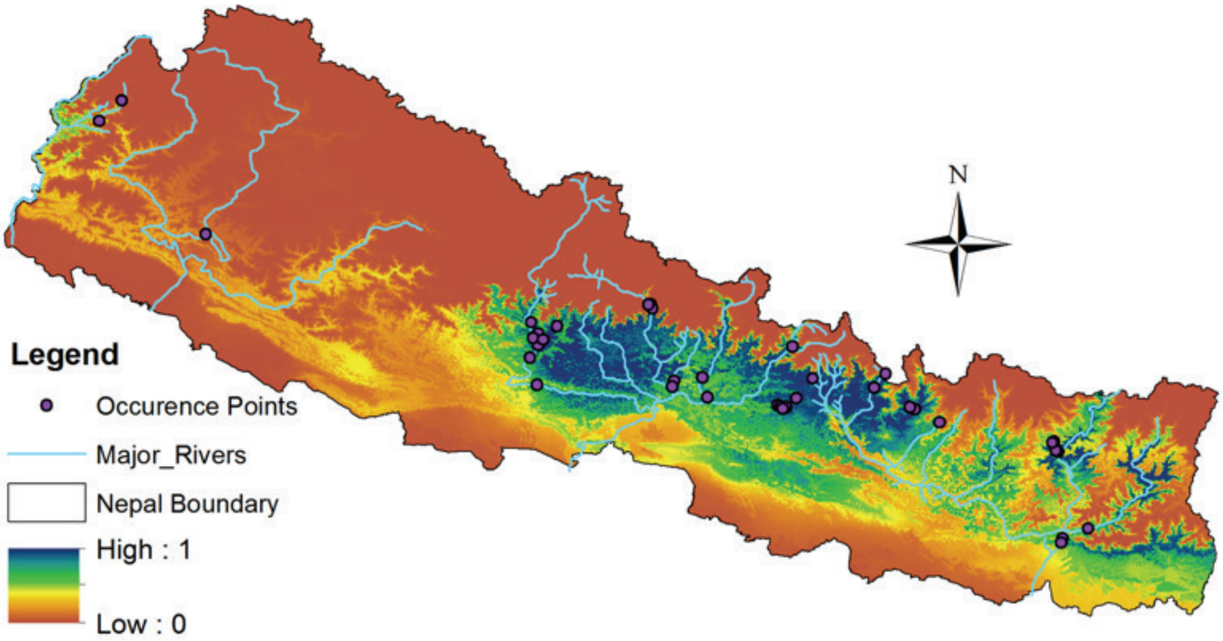

Figure 6. Ecological niche model showing potential distribution of Assamese Macaque in Nepal.

Table 3. Average group size of Assamese Macaque population at different elevation gradients.

	Elevation range	No. of groups	Total population	Average group size (SD)
1	< 500m	13	280	21.54 (±10.62)
2	501–1000 m	8	183	22.88 (±13.57)
3	1001–1500 m	15	250	16.66 (±9.87)
4	1501–2000 m	3	45	15 (±7.99)
5	> 2000m	4	71	17.75 (±4.99)

The MaxEnt model predicted potential habitat of Assamese Macaque within the elevation range between 85m and 2,987m. The mean height of the potential habitat was found to be 1532m, however, maximum number of suitable habitat pixels (55.03%) were predicted from the elevation range between 500m and 1,500m. Currently, 23.49% area of Nepal territory is potential habitat of the Assamese Macaque.

DISCUSSION

Assamese Macaques are the least researched primates in Nepal Himalaya. They are distributed in subtropical and temperate zones (Chalise 2013). Because of the limited and unsystematic studies, population status and distribution patterns of this species is poorly documented. For the successful conservation and management of such primates it is crucial to have basic data on their demographic status and spatial extents of distribution.

Assamese Macaques are sporadically distributed across the fragmented forest patches in Nepal. Wada (2005) recorded a total of 10 groups of Assamese Macaques distributed only east of the Kaligandaki Valley in central Nepal, within the elevation range of 200–1,800 m. In the most recent study, Chalise (2013) recorded a total of 1099 individuals in 51 groups from 380m to 2350m. Both of those studies failed to cover the spatial and temporal facets of demographic research, as the work of Wada (2005) was confined only along six rivers and that of Chalise (2013) was the accumulation of observations at different time periods during last two decades. This study considered both the spatial and temporal aspects and did systematic survey across the entire distribution range of the species within a calendar year. It recorded a total of 829 individuals of Assamese Macaque from 43 groups.

Current average group size of Assamese Macaque (19.29 individuals per group) was consistent with that of Wada (2005), i.e., 19.1; however, it differed with that of Chalise (2013), 21.55 individuals per group, that might be accounted to the temporal variations in their observation as the observations were made at different periods within last two decades. The organisms are restricted to specific altitudinal ranges as a consequence of microclimatic limitations imposed by ambient temperature and humidity on species metabolisms and on their phenological preferences (Sekercioglu et al. 2008). Wada (2005) reported larger average group size of Assamese Macaques on lower elevations than that of mid-hills. In the present study, the population size of Assamese Macaque differed significantly at different elevation ranges, however, no such significant variations on average group size were recorded along the elevation gradients. Wada (2005) reported the distribution range of the species in between 200m and 1,800m, whereas Chalise (2013) explained that of 380m and 2,350m. The present elevation range of distribution (130–2,650 m) also differed with those studies, it was consistently wider both on lower and upper limits. It shows that the species is experiencing the elevational range expansion, especially towards the higher elevation.

This study observed the highest number of groups and individuals from Gandaki River system (21 groups and 377 individuals) in central Nepal followed by the Koshi River system (13 groups and 287 individuals). It revealed the central Nepal to be the glacial refugia for Assamese Macaques which had eastward range expansion after LGM as revealed by the molecular data and ecological niche modeling (Khanal et al. 2018a). Eastern and central Nepal receives higher amount of precipitation from summer monsoon than the western Nepal (Owen et al. 2005), such higher precipitation might facilitate the grow of broadleaf forest in mid-hills which is the most preferred habitat of the species. Additionally, Assamese Macaques entered the Nepal Himalaya from south-east Asian ancestral stock via northeastern India (Khanal et al. 2018a) that may be the principal reason of the higher density of the species in eastern and central Nepal.

The ecological niche modeling results were consistent with the observed distribution pattern of the Assamese Macaque in Nepal Himalaya. It predicted suitable habitats on Siwaliks, mid-hills and lower Himalaya of eastern and central Nepal including the areas of Koshi River and Gandaki River systems, in majority. Using the DNA sequences analyses and niche modeling, Khanal et al. (2018a) reported potential glacial refugia at central Nepal and the expansion of population as well as the species range after the last glacial maximum. Many studies (Wada 2005; Chalise 2013) including the most recent one by Regmi et al. (2018) employing field surveys and ENM reported the westernmost limit of the Assamese Macaque to be the Kaligandaki River at central Nepal, however, during this study some groups of the species were observed from far western Nepal too. The occurrence points employed in the model development are evenly scattered avoiding the sampling bias, and the distributional model developed incorporated all the observed points depicting the robustness of the prediction. The observed elevational range of Assamese Macaque fell within that of the predicted habitat.

A very high percent (~79%) of Asian primate species are threatened with the global extinction (Schipper et al. 2008). Such a high level of threat echoes extreme hunting pressure and habitat depletion impacts (Primack 2006). It may be especially alarming for those species which have small populations and limited geographic ranges (Rovero et al. 2015). Assamese Macaques are considered nationally endangered and are protected by the National Park and Wildlife Protection Act 1973 of Nepal (Khanal et al. 2018a). There are limited protected areas in mid hills of Nepal, so most of the primate habitats lie outside the protected areas and they are under severe anthropogenic influences (Chalise 2013). This study revealed that more than half of the Assamese Macaque population resides outside the protected area system of the country. The mid-hills area with amenable temperature and ample precipitation provide the suitable habitat for Assamese Macaque (Khanal et al. 2018a), but that remains outside the protected area system of the country. Because of this, at many places of the mid-hill districts the species has been described as the notorious crop raiders bringing them into negative interactions with subsistence farmers (Chalise 1999, 2003, 2010, 2013). Extending protected areas benefits to resource-dependent smaller landholders who experience higher losses from human-wildlife conflicts (Karanth & Nepal 2012). Establishment of protected areas in mid hills would conserve the Assamese Macaque habitat together with other plant and animal species.

CONCLUSION

We conclude that Assamese Macaque population in Nepal is distributed within the narrow elevational range especially at the mid-hills. The population is sporadically distributed at fragmented forest patches of the mixed riverine broadleaved forests. More than half of the Assamese Macaque population is resided outside the protected areas of mid-hills within which most of the suitable habitats of the species fall; therefore, conservation efforts should be focused in those areas.

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Redescription of *Leposternon octostegum* (Duméril, 1851), with an identification key for Brazilian *Leposternon* species, remarks on meristic methodology, and a proposal for pholidosis nomenclature (Squamata: Amphisbaenidae)

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Abstract: The amphisbaenian *Leposternon octostegum* (Duméril, 1851) is redescribed based on newly collected material from the state of Bahia, Brazil. Species validity was confirmed, and comparisons made to other *Leposternon* species and to the scarce literature available on *Leposternon octostegum* taxonomy. Aspects of meristic annuli methodology are reviewed, and nomenclatural adjustments for some scales are proposed. To place this information in its taxonomic context, a species identification key for the Brazilian species of the genus *Leposternon* is provided. The present redescription contributes to a better understanding of Amphisbaenia taxonomy, thus also enabling the design of more adequate conservation and management strategies for the species belonging to this group.

Keywords: Amphisbaenia, Bahia, Brazil, *Leposternon octostegum*, meristic methodology, pholidosis nomenclature, taxonomy.

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INTRODUCTION

Amphisbaenia is a group of fossorial reptiles (Gans 1978). Since the last taxonomic checklist by Gans (2005), new species descriptions and more strict taxonomic revisions modified the number of recognized living species from 202 to 194, 72 occurring in Brazil (cf. Uetz & Hošek 2018). South American amphisbaenians include the genus *Leposternon* Wagler, 1824, belonging to the family Amphisbaenidae (Gans 1971a). Except for *L. microcephalum*, recorded from Argentina, Bolivia, Paraguay and Uruguay, and *L. bagual*, endemic in Argentina, the other nine species are known only to occur in Brazil, where they are distributed from the south of the Amazonas River to the extreme meridional State of Rio Grande do Sul (Gans 1967, 1971a, 2005; Ribeiro et al. 2018) in almost all phylogeographic regions (cf. Ribeiro et al. 2008, 2018).

Leposternon, along with the African *Dalophia* and *Monopeltis* and North American *Rhineura* genera, are considered the most specialized burrowing amphisbaenian group, due to their shovel-like head shape, among other characteristics (Gans 1960, 1968, 1974, 1978). The 11 recognized *Leposternon* species are *L. microcephalum* Wagler, 1824, *L. scutigerum* (Hemprich, 1829), *L. octostegum* (Duméril, 1851), *L. polystegum* (Duméril, 1851), *L. infraorbitale* (Berthold, 1859), *L. wuchereri* (Peters, 1879), *L. kisteumacheri* Porto, Soares & Caramaschi, 2000, *L. cerradensis* Ribeiro, Vaz-Silva & Santos-Jr., 2008, *L. maximus* Ribeiro, Nogueira, Cintra, Silva Jr. & Zaher, 2011, *L. bagual* Ribeiro, Santos-Jr. & Zaher, 2015, and *L. mineiro* Ribeiro, Silveira & Santos-Jr., 2018.

The species *L. octostegum* was described from a single specimen (MNHN 7055, holotype) collected in "Brésil" (Duméril 1851). While a few historical records of the species are mentioned in literature, these have been largely plagued with inconsistencies and omissions that greatly reduce their taxonomical value (cf. Barros-Filho et al. 2013). This short literature essentially includes the original description of *L. octostegum* from Duméril (1851), a *Leposternon* revision by Strauch (1881) and the fundamental work of Gans (1971a) on *Leposternon* taxonomy.

During 2003 and 2006, new specimens were collected near Salvador City, in the state of Bahia, northeastern Brazil, allowing for comparisons with the holotype and confirmation of species validity. We can now provide a summary of external morphological variations for the species and detailed shield descriptions, to complete the concise original ones and to offer a more precise understanding of observed sample variations. These were the main objectives of this study, but we also found the need for more precision regarding certain details of the traditional *Leposternon* and amphisbaenian meristic methodology, and also propose a review of some nomenclatural pholidosis terms. Finally, to place this species redescription in its taxonomic context, we also provide a species key for the Brazilian *Leposternon* species (*L. bagual* endemic in Argentina, with osteological diagnostic characters, was not included).

MATERIAL AND METHODS

Specimens were collected (License 0018/2003 – NUFAU/IBAMA/BA) at Aterro Metropolitano Centro (12.858^{0}S & 38.370^{0}W), Salvador City, and at Arembepe County (12.697^{0}S & 38.324^{0}W), in the municipality of Camaçari, state of Bahia, Brazil, in June and November 2003 (Fig. 1). Three specimens were damaged by bulldozers but were useful for most comparisons conducted herein.

Collected specimens were anesthetized with ether, fixed in 4% formalin and preserved in 70% alcohol. The color of the specimens was edited for better exposure of details, except for Image 23, showing the coloration in live and preserved specimens. Drawings were made by Leandro dos Santos Lima Hohl, obtained from photographs, except for Fig. 2A (by José Duarte de Barros-Filho). Images (all the photographs) by José Duarte de Barros-Filho.

Measurements were made with dial calipers to the nearest 0.01mm and taken with a ruler to the nearest millimeter. Sex determination, whenever possible, was achieved by dissection or hemipenial eversion. Specimens were dissected or X-rayed for vertebral (body+caudal) counts (Table 1). The species key is based on both firsthand observations and bibliographic references (Gans 1971a; Porto et al. 2000; Ribeiro et al. 2008, 2011, 2018). *Leposternon octostegum* and *L. scutigerum* specimens examined or cited in this study are housed in the following collections (acronyms follow Sabaj-Pérez 2010 when possible): MCP (Museu de Ciências e Tecnologia, Pontifícia Universidade Católica do Rio Grande do Sul, Brazil), MNHN (Museum National d'Histoire Naturelle, Paris, France), MZUEFS (Museu de Zoologia da Universidade Estadual de Feira de Santana, Bahia, Brazil), MZUSP (Museu de Zoologia, Universidade de São Paulo, Brazil), NMW (Naturhistorisches Museum, Wien, Austria) and ZUFRJ (Departamento de Zoologia, Universidade Federal do Rio de Janeiro, Brazil, now at

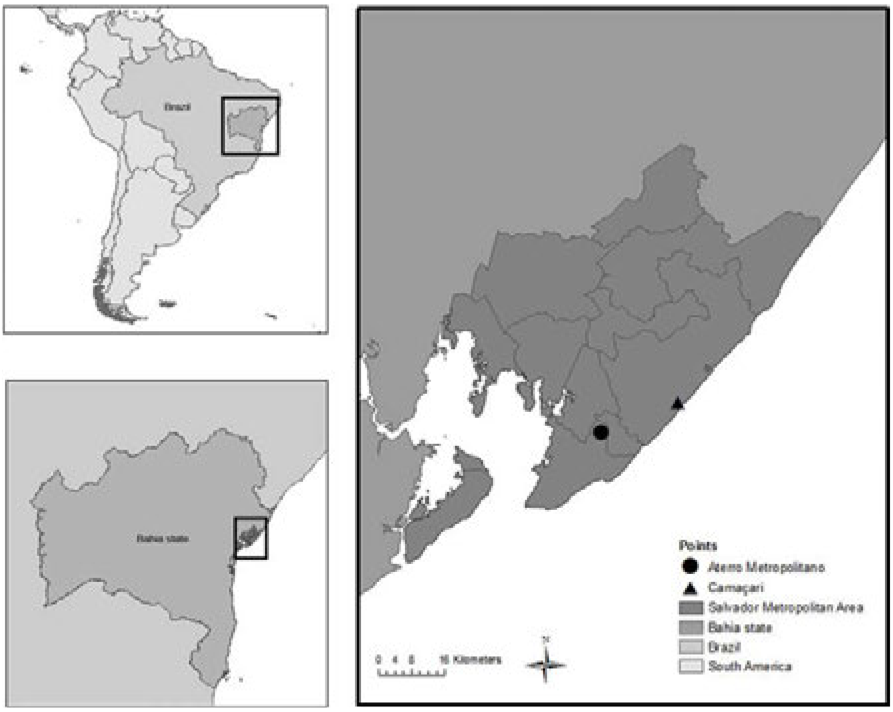

Figure 1. *Leposternon octostegum* collection sites (geographic distribution).

Museu Nacional do Rio de Janeiro). The material used for comparison of counting methodologies and for the analysis of the pholidosis nomenclature are listed in Appendix 1 (*L. microcephalum* and *L. scutigerum* specimens used herein and also by Gans 1971a, Ribeiro et al. 2008, 2011) and Appendix 2 (other amphisbaenians and Lacertilia).

Count methods and pholidosis nomenclature

Gans (1971a: 385) emphasizes that "The segmentation pattern of *Leposternon* differs markedly from that shown in the species of *Amphisbaena*. Consequently, it is necessary to use a slightly different counting and description system from that most recently detailed by Gans (1966)". Indeed, the need for adaptations was verified herein, including for some proposals made by Gans (1971a). Therefore, the methodology of half-annuli counts and some of the pholidosis nomenclature terms used in this study differ to some extent from previous publications. To justify these new proposals, it is important to comment on them before presenting the redescription. The obtained data were compared with appropriate literature and with other *Leposternon*, amphisbaenian and lacertilian species (Table 2, Appendix 1 and 2).

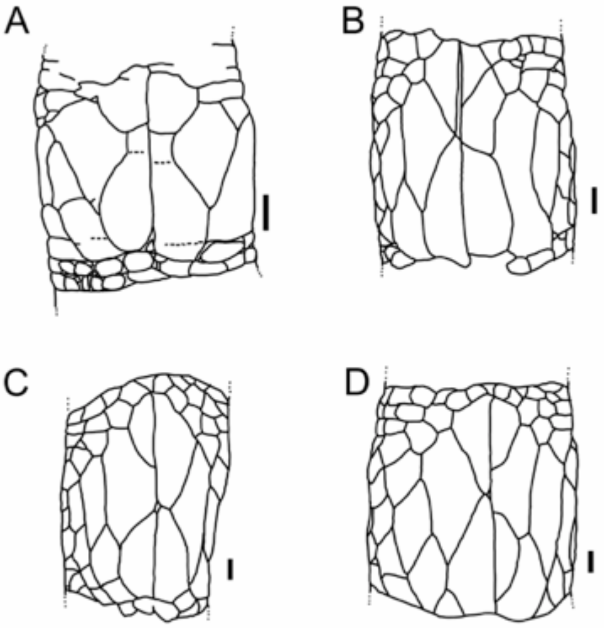

Figure 2. Pectoral shield patterns. *Leposternon scutigerum*, (A) ZUFRJ 1730; *Leposternon octostegum*, (B) ZUFRJ 1749, (C) MZUEFS 653 and (D) MZUEFS 657. Scale bars = 1mm.

Count methodology

The standard methodology for "postpectoral annuli" counts essentially followed herein was established by Vanzolini (1951) and Gans & Alexander (1962), on the amphisbaenian ventral left side. This standardization, used for all genera, has particular importance for *Leposternon*. As Gans (1971a, 1977) points out, the

Table 1. Measurements and meristic data for *Leposternon octostegum*. Abbreviations: AL (anterior lateral annuli, right/left sides), PPVL (postpectoral annuli, ventral and left side), PPVR (postpectoral annuli, ventral and right side), PPDL (postpectoral annuli, dorsal and left side), PPDR (postpectoral annuli, dorsal and right side), L (lateral annuli, right/left sides), C (caudal annuli, counted in the ventral left side from the cloaca to the tip of the tail), PFS (postcloacal flap shields), VAS (ventral annuli scales, counted for five adjacent annuli at midbody), DAS (dorsal annuli scales, counted for five adjacent annuli at midbody), HW (maximum head width, measured at ocular region), BW (body width, measured at half of body length), CW (maximum caudal width, measured at is base), SVL (snout-vent length), CL (caudal length), TL (total length), V (number of vertebrae, body plus caudal), S (sex).

Specimens	AL	PPVL	PPVR	PPDL	PPDR	L	C	PFS	VAS	DAS	HW	BW	CW	SVL	CL	TL	V	S
MNHN 7055	15/16	382	379	376	372	6/6	13	19	23-26	29-32	6.1	8.5	7.8	337	11	348	140+12	-
MNHN 2007.0023	16/16	366	359	370	363	5/6	12	23	26-27	26-29	7.1	8.9	8.5	373	14	387	134+11	male
MNHN 2007.0024	16/15	369	358	367	363	5/5	14	23	24-25	27-28	6.1	7.3	7.5	323	12	335	137+14	female ?
MZUEFS 652*	13/13	15+n +194	15+n +195	n+ 207	n+ 204	4/4	13	21	23-26	28-32	6.3	9.3	8.7	29+n+2-	11	244+n	121+15	female
MZUEFS 653*	16/16	189+ n	190+ n	192+ n	193+ n	-	-	-	25-27***	30-31***	4.8	6.9***	-	126+n	-	126+ n	64+n	-
MZUEFS 654*	15/14	236+ n	245+ n	244+ n	246+ n	-	-	-	25-29***	30-31***	5.6	6.8***	-	150+n-	-	150+ n	79+n	-
MZUEFS 655*	14/14	331+ n	323+ n	327+ n	327+ n	-	-	-	25-26***	28-32***	5.7	6.5***	-	225+n-	-	225+ n	117+n	female
MZUEFS 656	18/17	370	370	381	370	4/4	14	19	24-28	27-31	7.2	7.6	8.3	374	14	388	140+11	male
MZUEFS.657	17/17	369	379	374	367	4/4	12	19	23-24	28-30	5.3	6.1	5.8	238	9	245	100+n	-
MZUEFS.695	16/15	372	374	379	378	6/5	12	21	23-25	28-31	6.4	9.2	8.2	329	11	340	134+12	female ?
MZUEFS.696**	16/16	357	357	361	357	4/5	14	20	26-29	30-33	7.1	9.0	8.5	354	15	369	140+12	male
ZUFRJ.1713**	17/18	363	337	383	367	5/5	14	19	24-25	25-28	3.9	4.3	4.3	150	5	155	42+n	-
ZUFRJ 1714**	15/16	375	374	384	383	5/6	13	18	24-28	25-28	4.5	5.7	4.8	232	9	241	138+9	-
ZUFRJ.1715**	14/14	379	370	397	392	5/5	15	17	24-27	24-28	5.1	6.5	5.4	283	12	295	140+15	female
ZUFRJ.1716**	17/17	381	386	385	384	5/6	14	18	25-28	26-27	4.9	6.9	6.3	320	9	329	114+n	-
ZUFRJ.1748	17/15	359	356	360	358	5/5	13	22	24-25	28-30	6.6	9.3	7.5	368	13	381	142+11	-
ZUFRJ.1749	13/13	353	348	357	354	4/5	14	22	24-26	24-27	6.6	8.6	7.2	344	12	356	113+n	female

* Dissected specimens
** Specimens from Arembepe county, Municipality of Camaçari (all others are from Salvador City)
*** Values taken near half-body length of the damaged specimen

Table 2. Compared counts of post-pectoral ventral half-annuli (PPVLeft or PPVRight body side) for specimens of *Leposternon octostegum*, *L. microcephalum*, and *L. scutiegrum* examined in this paper and in Gans (1971a), Ribeiro et al. (2008, 2011). The cited bibliography do not give individual counts, but the species minimum-maximum counts (min-max), except for the *L. octostegum* holotype (Gans 1971a).

GANS (1971a)	**This paper**
Leposternon microcephalum (N = 19) Rio de Janeiro sample	
(PPVL 181–226)	(PPVL 197–216)
MNRJ 1762	203
MNRJ 1767a	213
MNRJ 1767b	207
MNRJ 1755a	197
MNRJ 1755b	198
MNRJ 1768	200
MNRJ 1774	204
MNRJ 1778a	216
MNRJ 1778f	209
MNRJ 1783	197
MNRJ 3261	204
MNRJ 3262	199
MNRJ 3264	203
MNRJ 3265	208
MNRJ 3266	207
MNRJ 3267	204
MNRJ 3268	208
MNRJ 3269	202
MNRJ 3270	197
Leposternon octostegum (N=1) Brazil	
(PPVL) MHNP 7055 (holotype):378	(PPVL) 382
Ribeiro et al. (2008)	**This paper**
Leposternon microcephalum (N = 30) Brazil sample	
(PPVR 186–254)	(PPVL 193–244)
MNRJ 7469	244
MZUSP 1249*	196
MZUSP 2426*	200
MZUSP 2676*	198
MZUSP 6394*	199
MZUSP 6397*	202
MZUSP 6398*	198
MZUSP 6399*	204
MZUSP 6466*	201
MZUSP 6488*	196
MZUSP 6518*	203
MZUSP 6578*	200
MZUSP 7677*	204
MZUSP 8284*	214
MZUSP 13762*	198
MZUSP 65390*	198
MZUSP 77013*	218
MZUSP 77014*	215
MZUSP 77031*	209
MZUSP 77037*	226
MZUSP 77038	204
MZUSP 77039	205
MZUSP 77040	235
MZUSP 77042*	210
MZUSP 77043	193
MZUSP 77515*	213
MZUSP 77527	204
MZUSP 77532	202
MZUSP 77536*	221
ZUFRJ 1490	203
Leposternon scutigerum (N=3) Rio de Janeiro sample	
(PPVR 250–278)	(PPVL 256–262)
MZUSP 2519*	262
MZUSP 7075*	261
ZUFRJ 289*	256

*Also in Ribeiro et al. (2011).

dorsal counts of *Leposternon* are usually higher and more variable than the ventral counts (Gans 1971a: 386—"…the dorsal counts of certain populations were significantly higher than the ventral counts."; "…the dorsal count is more variable and it is appropriate to discuss the addition of dorsal half-annuli rather than the dropping out of accessory ventral ones."). And some differences between the left and right sides' counts are the normal condition, as the practice of laboratory examination clearly shows (this is implicit in Gans 1971a: 386 - "Left and right counts did not show any **major** differences…"—bold by the authors). Thus, dorsal counts are not a good standard, due to their higher variability, but right or left counts are perfectly comparable and useful; however, besides Papenfuss (1982), only the description papers of Ribeiro and contributors (2008, 2011, 2015, 2018) emphasize the dorsal and the right side counts. It seems that our results using standardized ventral counts are preferable for their stability. At the same time, the data regarding the right counts in Ribeiro et al. (2008, 2011) are, as explained, comparable to our results and other bibliographical data. In fact, the counts on the right side were based on the statement of Gans (1971a) that counts on left or right sides do not make any significant difference to the characterization of the species (Síria Ribeiro, pers. comm. v.2018). So, it is implicit the understanding that data of Ribeiro and contributors are comparable with literature. That is why their data was also used, including in the Key.

Gans (1971a: 387) states that "The postpectoral annuli of *Leposternon* are remarkably irregular and the intercalated half-annuli do not start at the lateral sulci, but often begin either dorsal or ventral to these". These "intercalated half annuli" pose a problem for counts, because they can be represented by variable conditions, as having a total of only one or two segments, instead of having just one or few segments less than a "normal (= complete)" half-annulus. Of course, there are many intermediate situations between these two conditions, and successive counts on a same specimen can show different results (cf. Gans 1971a: 386).

Ribeiro et al. (2008) presented the data of postpectoral counts as "n" complete plus "n" incomplete half-annuli in the species description, but we are of the opinion that a definition of a "complete" or "incomplete" half-annulus is necessary. The complete half-annuli – or, better saying, quarter of annuli, see below – are supposed to have the segments of their extremities touching adjacent sulci, however, since the shape of segments in the extremities of the half-annuli can be somewhat variable, it is not so easy to precise this condition, particularly in twisted specimens. Herein, we also counted as "complete" all half-annuli which, despite having one or few (depending on the proportions) segments less than a "normal" one, are separated from the sulci just by the meeting of the extremities of their two bordering half-annuli.

It is important to highlight that, in practice, we are dealing with counts of a quarter of each annulus: the four longitudinal body sulci (dorsal, ventral and laterals) define four regions. However, as the right and left counts, especially ventrally, are almost the same (cf. Gans 1971a), the literature refers to the counts as ventral or dorsal half-annuli. The standard counts are in the ventral left side – a quarter of annulus – and, ideally, the information about the other quarters must be indicated in descriptions. Table 1 explicits these data.

Gans (1971a: 387) suggests that the anterior lateral counts should be increased by the half-annuli placed between "the *angulus oris* and the first annulus passing back of the enlarged head shields"; however, the anterior laterals, sensu Gans (1971a), are body annuli (i.e., not related to the head), and these half-annuli are clearly in the head region. As such, these half-annuli are treated herein as "temporal", "postemporal", or "occipital".

The first anterior lateral row defined by Gans (1971a: 387) includes the dorsal occipital shields, as understood from the following definition: "Anterior laterals (...) are counted from the first annulus (often reduced to two or three segments flanking the middorsal line) posterior to the last of the highly keratinized dorsal head shields (...)". But ventrally, these "reduced two or three segments" are more related to the gular region than the pectoral region, and the occipital area is a cephalic, not body, region (as is the pectoral area). Thus, these segments are not counted herein together with the anterior laterals, and are referred to simply as the "occipital row". The occipital shields can be poorly expressed or even totally absent in some amphisbaenian forms. In these cases, the most posterior enlarged head shields are the parietals.

Gans (1971a: 387) states that caudal annuli "are counted from the first complete (ventrally not reduced) postcloacal annulus up to and including the last complete annulus showing regular segments"; however, the observed first caudal annulus pattern in *Leposternon* is almost always characterized by a ventral medial concavity shaped by the posterior border of the postcloacal flap. The position of this annulus is definitively caudal, so it is included herein in the tail counts. Also included herein were the annuli towards the caudal tip, since the "last complete annulus showing regular segments" is a dubious definition. For instance, in amphisbaenians the terminal annuli often tends to a spiral (although this is not the common situation for *L. octostegum*), with irregular-shaped but clearly discernible segments. So, they are complete, although not "regular" annuli, and usually occupy a significant area of the tail. In addition, it is not easy to identify the last "regular" annulus and the first "irregular" one, a problem amplified in amphisbaenians by the frequent presence of intercalated incomplete half-annuli (see "dorsal and ventral postpectoral half-annuli" description below).

Thus, it is not justifiable to exclude the terminal annuli from the caudal counts. Even without the spiral pattern, the terminal annuli can generally be traced despite the irregular shape of their segments. Exceptions are natural or artificial damages or a naturally modified caudal tip (e.g., smooth). Hence, some tail counts may vary between the present data and the bibliography, although these differences are minimal and in no case may confuse species identification. For the sake of accuracy, and as the counts obtained with this methodology are perfectly comparable with published data, we propose the present count methodology as a standard.

The number of half-annuli segments (scales) were counted for five adjacent annuli at midbody.

Pholidosis nomenclature

Pholidosis nomenclature largely follows Gans (1971a). Adaptations include new definitions and naming of some scales and scale rows, and an original proposal for the Amphisbaenia nomenclature of "chin shields". The present proposal is naturally focused on *Leposternon* species but it is also applicable for the whole suborder. The reason for these modifications is that the nomenclature (and homology of scales) used for the Amphisbaenian pholidosis is still somewhat unclear, also regarding other Squamata (e.g., Loveridge 1941; Gans 1960). Different approaches have been used, mainly, but not only, for the cephalic shields (e.g. Strauch 1881; Gans & Alexander 1962; Gans 1971a; Vanzolini 1991; Porto et al. 2000; Thomas & Hedges 2006; Ribeiro et al. 2008; Pinna et al. 2010). Unsolved scale homologies between genera and species also add to the confusion (Gans 1971a).

The following points justify the present nomenclatural proposal:

1 - Direct observation that generally used names are not adequate for some scales (do not offer the better/right definition, and/or are historically a source of confusion), thus justifying the need for nomenclatural alterations. In this way Vanzolini (1991: 261) corrected a wrong nomenclature applied by Gans & Alexander (1962): "I do not think that 'malar' (i.e., zygomatic) should be used for a scale on the ventral side of the head". This applies for the naming of groups of associate scales, since associated names eventually tend to be confusing (e.g., "mental"/"genial" and associated scales);

2 - There are relevant classical precedents for the present proposal (e.g., Alexander 1966, Gans 1971a). More recently, scale nomenclatural changes in amphisbaenian literature were accepted and currently adopted (cf. Pinna et al. 2010 adopted by Pinna et al. 2014 & Roberto et al. 2014). These changes, as in the present paper, are understood as an improvement. We are of the opinion that, as the mentioned authors implicitly demonstrated, the terminological stability by itself, if not correctly correlated with the observed anatomy, has no reason to be followed. Consequently, previous dubious interpretations, once detected, must be questioned, and a more desirable terminology, coherent with the anatomical reality of the structures, can be proposed. We consider this as enough evidence, even without a homology analysis, and by no means an artificial resource (this would be a proposal not fit to reality, as were the "malar" scales of Gans & Alexander 1962 and Gans 1971a) or arbitrariness (with no evidence for the need for change, observed in the variety of questionable terms and uses already published on the subject).

3 - Nomenclature criteria: the papers of, for example, Pinna et al. (2010, 2014) and Roberto et al. (2014) explicitly do not base their nomenclatural changes on homology. We understand that homology is the basic criterion for naming morphological structures, and we essentially agree with the statement by Ribeiro et al. (2011): "…we believe that efforts should be invested in the search of more general hypotheses of homology regarding amphisbaenian cephalic shields"; however, there are cases when the homologies are undefined or even inconclusive, but at the same time the structures should be correctly indicated, and other criteria can perfectly be used, in face of evident wrong structure naming and/or persistent confusion of interpreting terms. This is especially significant if the renaming can aid future homological studies.

More importantly in the present case, we agree with the cautious stance adopted by Gans (1971a: 385) regarding *Leposternon* nomenclature and homology: "Any group of species showing fusions of cephalic shields incorporates the seeds of nomenclatural confusion. In 'homologizing' segments one must differentiate between segments that fuse or subdivide, in which case the overall spatial proportions are maintained, and those that shrink or expand, leading to a shift in the regions they occupy. (…) In other instances, such as the prefrontal subdivisions, we are unable to determine by what steps the observed patterns were produced. The present material [over 500 specimens of *Leposternon*] does not permit conclusions regarding presumptive homologies". The same author, on page 386, gives a practical example: "The term prefrontals is retained (…) but it must be recognized that they are only partially homologous to the prefrontals of *Amphisbaena* and similar forms". Thus, strict homologies can be very difficult to understand, and if they are undefined, they cannot be of compulsory use. Meanwhile, there is also no obligation to blindly follow a questionable nomenclature.

Lastly, it is important to mention that our nomenclature, if not focused strictly on homology, does not simply neglect it. One of the propositions brings a stronger base for homology studies in an area of the amphisbaenian head that was never, to the best of our knowledge, considered under this view (the "chin shields"). Regarding most of the other terms, without disregarding those reported in the literature, they act only as guidelines for a better understanding of the head shield pattern disposition, besides bringing a consideration concerning exactly the clearly mistaken approach—also regarding homology—of some nomenclatural terms used for amphisbaenian head pholidosis. Only in one case do we propose a strictly better descriptive usage, but for scales of no critical homology importance.

4 - Following the above considerations, the proposed nomenclature is the best one, as it uses adequate anatomical and semantic criteria for the scales, and takes into consideration morphological characteristics of the peculiar cephalic *Leposternon* features, which are somewhat different from *Amphisbaena,* for example. This last point is important for nomenclature, since particular aspects are typical of *Leposternon* and an explicative nomenclature can, eventually, prevent homology problems, as, for example, Gans (1971a: 386) indicates for the *Leposternon* azygous scale, not present in *Amphisbaena* and most of other amphisbaenian genera: "In order to avoid confusing homologies, the enlarged median shield is hereafter referred to as the azygous". It must be noted that "azygous" was a term elected by its proper condition of not forming a pair, not for any homological criteria, and is a very well established name in amphisbaenian literature (there is also a small azygous median shield in a group of the amphisbaenian genus *Cynisca*, in addition to the prefrontal and frontal scales, cf. Gans 1987). As mentioned above, our proposition is perfectly compatible with other Amphisbaenia; it is important only to emphasize that its application also takes into account *Leposternon* particularities.

Finally, there is another important point to contextualize our proposition. To better explain the guidelines for the present nomenclature, it seems necessary to first consider that the criteria for definition of cranial limits must take into account that, even within Craniata, the shape and disposition of the different parts of the organism can vary, so their identification must refer to their more typical elements and functions. Thus, the disposition of the typical cephalic region must include brain, eyes, nostrils, among others, although in Amphisbaenia the disposition of these elements is different from other organisms, such as humans, for example. That is why, for instance, the amphisbaenian gular area can be recognized as a gular area and not a cephalic area, even if well aligned horizontally and under (not behind) the skull—its gular function is clearly identified. Similarly the posttemporal scales are included in the cephalic area, as well as other head scales mentioned herein—they are elements of the cephalic region, by definition (i.e., anatomical position), and cannot be included in postcephalic annuli counts, independently of the particular interpretations in the literature. This topic is very relevant because the body architecture of amphisbaenians is greatly specialized (cf. Gans 1974, 1978), and has to be correctly understood to undertake homological approaches and other comparisons with different organisms, as well as for the comprehension of the methodological decisions of this paper.

We add that the proposed terminology allows for the clarification of comparisons with previously disputed or inexact approaches of previously published data. For instance, in a seminal paper on Amphisbaenia nomenclatural and meristic standardizations, Gans & Alexander (1962: 78) propose that, for *Amphisbaena,* the first anterior body annulus must include head shields, "Parietal (occipital of some authors)". In the following literature description of Amphisbaenia, this point of view was largely adopted, with variations in shield nomenclature (e.g., Pinna et al. 2010), however, for morphological and homological perspectives, it is not reasonable that scales clearly over the skull (cf. Alexander 1966: 210, relative position of skull and scales; Gans & Montero 2008) should be named as a body structure. Our proposal, in analyzing both dorsal and ventral components of the area between head and body, intends to contribute to also correct these discrepancies.

For the present nomenclatural purposes, the following scales deserve a close analysis:

Temporal and temporal rows

Usually defined as a group of three to five scales aligned in a vertical row immediately behind the ocular line and the last supralabial, and including those above the temporal scale in many amphisbaenian forms. Frequently, the first scales below the temporal, or the temporal itself, are behind the ocular, and the lowest ones behind the supralabial, being usually named "postoculars" and "postsupralabials" (e.g. Ribeiro et al. 2008; 2011; see also Gans 1965, "postocular row" for *Amphisbaena camura*). Vanzolini (1950), however, suggests that "postocular" is not always adequate, an observation followed by Gans (1971a - no reference to "postoculars" or "postsupralabials" scales in *Leposternon*). The reason is that, as mentioned by Gans (1971a: 386), "A variable number of segments is also found in the temporal region. It appears as if the variability of this region is again very large, and it is suggested that the variability results from the overlap of the functional influence extending caudad from the snout and that extending anteriorly from the body (and indeed from the pectoral region)". In other words, variations in scale number and position are frequent in this area, for Amphisbaenia in general (José Barros-Filho pers. comm. v.2001) and certainly for *Leposternon* (e.g., see illustrations in Gans 1971a). Indeed, not always can the scales of this row be identified as postoculars and postsupralabias; many times a particular scale is in a position where it can be indifferently named as one or another, or none, a problem for nomenclature and homologies.

At the same time, there is a clear homogeneity for this row's localization pattern, regarding the amphisbaenian cephalic Bauplan (even if there are not discrete temporal scales, as in *L. scutigerum*). Thus, we herein propose the use of "temporal row" for descriptions, detailing when pertinent which of the scales are in an unmistakable postocular or postsupralabial position. In the descriptions, the "first temporal scale" is defined as the one from top to bottom (and depending on the species will be above, or correspond to, the postocular position), and the others descend as "two", "three", etc.

A similar approach is described in Pinna et al. (2010: 45–46) for *Amphisbaena*: "temporals are scale rows between parietals and supralabials or post-supralabials; numbers of temporals may vary (two in Fig. 1C and D against three in Fig. 1A and B); the postocular (sensu Gans & Alexander 1962) is here considered a temporal". This is certainly of significance, since the use of "temporals" for the scales of this row, adapted to the specific amphisbaenian Bauplan, is a historical procedure also supported by classical amphisbaenian (and descriptive *Leposternon*) papers (e.g., Duméril 1851; Peters 1879; Boulenger 1885; Barbour 1914; Smith 1946; Gans & Alexander 1962; Gans 1971a; Ribeiro et al. 2008, 2011, 2015; Pinna et al. 2010, 2014; Roberto et al. 2014; Teixeira Jr. et al. 2014). The term "temporal" is used not only for Amphisbaenia, since its use in Squamata is very old (e.g., Duméril & Bibron 1839; Peracca 1897 for Serpentes; Barbour 1914), even if, regardless of homological aspects, it must be considered that Squamata do not have temporal bones (Cope 1900; Romer 1956; Höfling et al. 1995), although posterior supratemporal ones can be identified (Romer 1956).

Therefore, "temporal" is a valuable and useful topological reference. In fact, a direct identification of the temporal scale (and region) within the Amphisbaenia skull architecture can lead to difficult problems concerning homology. This occurs because the temporal scale position would have to be related with (at least) one of the following bones: frontal, tabulosphenoid, parietal (cf. Barros-Filho 2000; Gans & Montero 2008) - and even this could vary, due to different adaptations of the Amphisbaenia skull (e.g. Trogonophidae, Gans 1960; *Amphisbaena* = "*Anops*" group, Vanzolini 1999) and head scale arrangements (e.g. the large fusions of *Cynisca* scales, Gans 1987). A homology analysis in this situation can prove not only hard to be understood, but also extremely confusing concerning practical naming of scales.

It is certain that future research will reveal a clearer picture, but considering the lack of trustworthy homological data, the nomenclatural discordances, the stressed adaptive condition for this group of scales and its variability, it seems more sensible and useful to identify them simply as temporal and temporal row, for easier comparisons within Amphisbaenia and to Squamata.

Another convenience of this procedure is that the temporal row (and sometimes the postemporal and occipital ones, see below) incorporates the "postsupral abials"/"postinfralabials", which are defined differently between authors (e.g., Vanzolini 1950; Pinna et al. 2010; Ribeiro et al. 2008). The problem also exists for other genera and species that have scales in this "postlabial" region, which are aligned with the gular area below and one of the head cephalic shields above (temporals, occipitals), i.e., not the first body annulus as standardized by Gans & Alexander (1962) (cf. Alexander 1966 for *Blanus*; Gans 1971b for *Amphisbaena* of "*Aulura*", "*Bronia*" and "*Mesobaena*" groups; Broadley & Gans 1978 for *Chirindia*; Gans & Kraklau 1989 for *Geocalamus* and *Loveridgea*). The first body annulus must be considered, in all amphisbaenians, only after the last recognized head shields, where the skull effectively ends (cf. Alexander 1966).

The importance of this nomenclature also concerns the definition of the postemporal scale row, which includes some scales of disputed interpretation within Amphisbaenia (e.g., in *Leposternon* and *Amphisbaena* spp., see below).

Postemporal row

A vertical row with variable number of segments may be present behind the temporal row and before the occipital row (see below), at least in *Leposternon* species. It has been suggested by Gans (1971a) that these postemporals must be included in the anterior lateral counts, an inaccurate approach. Postemporals are not anterior laterals (which are body scales), as they are located in the cephalic region (laterally) and continue towards the gular region (ventrally). Also, they cannot be considered true temporals, due to their more posterior position and as they are in an area of lateral folding movement of the head, which is not characteristic of the temporal region. The logical way is to name them posttemporals, an unequivocal reference point.

Occipitals and occipital rows

A pair of dorsal medial segments immediately after the azygous (e.g., *L. octostegum*) or the parietals (most other Amphisbaenia), and the scales lateral to this pair, vertically arranged down to the gular region. These shields seem to have been included in the anterior lateral counts by Gans (1971a) however, ventrally they are not related to the pectoral (body) region, but to the gular region. Thus, the annulus that includes them cannot be counted as the first anterior lateral, oriented to the pectoral region. As such, it is referred herein as the occipital row, which is immediately followed by the first "anterior lateral" row. It is assumed herein that they are not merely reduced parietals, which as they are usually bigger shields, but are more likely to have been fused with the other great dorsal head shields to form the azygous (in *L. octostegum*); it is also important to consider that in *L. octostegum* and the other *Leposternon* species the parietals tend to laterally follow the orientation of the temporal/postemporal rows (i.e., the arrangement of the cephalic shields), while the occipital row aligns posteriorly with the gular region. Naturally, the occipital area is posterior to the parietal one (also in other Amphisbaenia). Furthermore, in the original description, Duméril (1851) had already named these shields "occipitals" (see also Steindachner 1867; Boulenger 1885; Gans 1971a).

"Chin region"

For this group of scales we propose not only redefinitions and adaptations as above, but a new nomenclature.

We performed a reevaluation of the nomenclature of the scales of the so called "chin region" of amphisbaenians. This included the scales confined by the genial (= mental), the infralabial scales and the gular region. We found that the terms historically utilized to name these scales are basically derivations of the terms "genial" or "mental". The correct definition of "genys" (Greek; or Latin "mentum" = chin) refers to "The anatomical frontal portion of the mandible, also known as the mentum, that contains the line of fusion of the two separate halves of the mandible (symphysis menti)" (Biology Online 2005). This is a concept shared for both human and animal anatomy (Testut & Jacob 1947; International Committee on Veterinary Gross Anatomical Nomenclature 2012; Medicalency 2014). Informal usages led to the application of this term also for the correspondent external, lower extremity of the face, below the mouth; and, in Zoology, often for the external surface below the lower jaw or between its branches (cf. Vanzolini 1991). In other words, the same name is applied for different regions with different characteristics.

Thus, we propose the name "intermandibular" (Latin "inter" = between and "mandibula" = mandible) for the area confined by the genial (= mental), the infralabial scales and the gular region. The mandible bones encircle this region, being an unequivocal reference for anatomical or homological purposes. The name of the scales restricted to this area will be then related to the term "intermandibular".

Observation

The definitions for intermandibular scales below (Fig. 4) contemplates Amphisbaenia in general, but for the sake of simplicity the observations are mainly for *Leposternon* and *Amphisbaena*.

Lateral intermandibulars are all the scales touching/bordering the infralabials.

Central intermandibulars are the scales immediately behind the postmental (or the mental, in the forms of mental fused with postmental, e.g., *L. octostegum*); these may appear in more than one row (frequently one to three in *Amphisbaena*); laterally limited by the lateral intermandibulars; posteriorly delimited by the posterior intermandibular row.

Medial intermandibulars are the scales that may appear between the central and lateral intermandibulars; these are more frequent in *Leposternon* and usually absent in *Amphisbaena*.

Posterior intermandibular row includes the scales disposed transversally between the last lateral intermadibular scales on each side, and behind the central and medial intermandibular scales. More than one may occur, or it can be absent. It corresponds to the "postmalar row" as cited by Gans & Alexander (1962) except for two lateralmost scales, herein identified as the last lateral intermandibulars (which are frequently larger than the other "postmalar" scales).

Gular row is usually not well identified in *Leposternon*, due to the arrangement of the gular folds and the postintermandibular row, but in *Amphisbaena* corresponds in the majority of the cases to the "first body annulus" of Gans & Alexander (1962), which includes typical dorsal head scales (e.g., occipitals or parietals).

The only reference found to use "intermandibular" with the same term and area was in the report by Komárek (2012: 145–156, Fig. 1-1), in a work conducted on with mice, but of course there is no mention to scales.

For the scales bordering the intermandibular region (e.g., infralabials) there is no need to change the current names, however, adaptations are necessary for the scales touching the gular region ("posterior intermandibular row" and "gular row", see description). For the sake of standardization, we maintain "mental" and "postmental" (e.g., Gans 1971a; Porto et al. 2000; Ribeiro et al. 2008), a very well-established term with a Latin origin (the official anatomical language), and so is preferable to "genial", of Greek origin. The name "symphysal" (Vanzolini 1991) is not adequate, since it refers to the anterior mandibular symphysis, which is not present e.g., in Serpentes, and, thus, hampers homologies.

This standardization also seems advisable since the terms "mental" and "postmental", "genial" and "postgenial" and their derivations (e.g., "lateral genial", among others), in addition to not being correct for some scales, have been repeatedly used with different criteria, which results in great nomenclatural confusion. For instance, Broadley et al. (1976) used "postmental (genial)" for *Monopeltis* and *Dalophia* spp. In a more recent example, Costa et al. (2015), in describing *A. mettalurga*, used "mental", "postmental", "postgenial", "malar" and "postmalar row" simultaneously, following the nomenclature reported by Gans & Alexander (1962) and Teixeira Jr. et al. (2014). This is a historical but incorrect use of "postmental" and "postgenial" simultaneously, both being synonymous and referring to different scales. The same apply to "malars", which presumably was proposed (Gans & Alexander 1962) – inadequately – as the bone structure of reference for these shields.

It is interesting to note that, until now, only the mental/postmental disposition offered a reliable source of homology for the scales of the intermandibular area, due to previous variable/erroneous approaches. The present novel nomenclature for this group of scales is simple to be applied, semantically and anatomically correct, and, thus, facilitates homological analyses for Amphisbaenia and Squamata. In addition, it can be easily compared with published data. We offer the following very brief bibliography (enough as an example) for term and images comparison of scales from the intermandibular region in Squamata (similar words and meaning in English, French, Italian, Latin, Portuguese and Spanish):

Lacertilia – terms: mental, postmental(s), sublabials, gular(s) (sometimes used incorrectly, since the gular region cannot be identified with the region between the more anterior infralabial scales), symphysal, postsymphysal, chin shields and scales between chin shields, chin scales, genials; or they can simply be unnamed and not even mentioned. In: e.g., Boulenger (1885); Vanzolini et al. (1980); Rocha et al. (2000); Avila-Pires (1995); Meneghel et al. (2001); Rodrigues et al. (2001, 2006); Nogueira & Rodrigues (2006); Hoskin (2014); Nicholson & Köhler (2014); Doughty et al. (2015); Troncoso-Palacios et al. (2016).

Amphisbaenia – terms: symphysal, postsympysal, mental, postmental, submental(s), postmental (= "median chin shield of some authors", Gans & Alexander 1962), genial, lateral genial, median genial, postgenial, postmental row, postgenial row, intergenials, malars, postmalar row, chin shields, lateral chin shields, "other shields posterior to the median chin shield", unnamed, sublabials, gulars (inadequately). In: e.g., Strauch (1881); Boulenger (1885); Cope (1900); Barbour (1914); Loveridge (1941); Witte & Laurent (1942); Smith (1946); Vanzolini (1950); Gans (1960); Alexander (1966); Saiff (1970); Broadley et al. (1976); Broadley & Gans (1978); Gans (1987); Gans & Kraklau (1989); Broadley & Broadley (1997); Broadley & Measey (2016).

Serpentes – terms: mental(s), postmentals, symphysal, chin shields, median gular, gular rows, gulars (inadequataly), genials. In: e.g., Peracca (1897); Amaral (1926); Dunger (1966); Downs (1967); Vanzolini et al. (1980); Zaher & Caramaschi (1992); Scrocchi & Cruz (1993); Thomas & Fernandes (1996); Hoogmoed (1997); Ota et al. (1999); Meneghel et al. (2001); Marques et al. (2002); Fernandes et al. (2004); Franco et al. (2006); Shea (2015).

"Anterior and posterior laterals"

These terms were proposed by Gans (1971a) for the group of half-annuli respectively dorsal to the pectoral and cloacal *Leposternon* shields. Effectively, they are partially lateral, but mainly dorsal – the lateral sulci are the parameter for dorsal and ventral half-annuli counts in the same paper. Thus, "lateral" is not the best option. As they are associated to undisputed structures (pectoral and cloacal regions), "anterior" and "posterior" are in this case less descriptive (as is "supra", due to the presence of lateral scales). We propose the standardization of "contrapectoral half-annuli" and "contracloacal half-annuli" for respectively "anterior" and "posterior" "laterals". As Greathouse (2012) explains, the term "contralateral" (Latin *contra* = against; i.e., opposite to) is a strictly relative direction (not defined by a fixed axis), so there is no homology concepts for this term, thus being truly descriptive but also not interfering in homological analysis. In addition, homology is not a critical point in the present case.

RESULTS

Leposternon octostegum (Duméril)

Amphisbaena octostega (Duméril)

Lepidosternon octostegum Duméril, 1851, p. 150–151. *Terra typica*: “Brésil”. Holotype: MNHN 7055.

New material (N = 16): MNHN 2007.0023, MZUEFS 696 (adult males); MZUEFS 652, 655, ZUFRJ 1749 (females); MNHN 2007.0024, MZUEFS 653, 654, 657, 695, ZUFRJ 1748 (unidentified sex) all collected on 05 November 2003 by José Duarte de Barros-Filho, Marco Antônio de Freitas, Danilo Pacheco Cordeiro and Franco Henrique Andrade Leite; and MZUEFS 656 (male), collected on July 2003 by Marco Antônio de Freitas – all specimens are from Aterro Metropolitano Centro (12.858^{0}S & 38.370^{0}W), at sea level), Salvador City, state of Bahia, Brazil. ZUFRJ 1715 (female) and ZUFRJ 1713, 1714, 1716 (unidentified sex) collected on 04 June 2006 by Marco Antônio de Freitas at Arembepe county (12.697^{0}S & 38.324^{0}W), at the Municipality of Camaçari, state of Bahia, Brazil.

Diagnosis

A species of *Leposternon* with an enlarged, polygonal azygous shield atop the head, which, however, does not exclude the discrete prefrontals, oculars and first temporals shields of the dorsal cephalic area posterior to the rostronasal; one large supralabial and one large infralabial shield on each side of mouth; a large mental shield (postmental shield absent, probably fused with the mental shield); 353–382 ventral, postpectoral half-annuli.

Definition

A slender, medium-sized (388mm maximum adult total length) form of *Leposternon*, with an enlarged, polygonal azygous shield atop the head; in dorsal view, the rostronasal, the prefrontals, the oculars, the first temporals and a small pair of occipitals are also clearly discernible; one large supralabial and one large infralabial; mental and postmental shields, probably fused; three pairs of enlarged shields along the midline, with left and right asymmetries: the anterior pair forms a rough stretched pentagon pointing backwards, the second pair has irregular polygons tending to a medial suture in an “X” disposition and the posterior pair showing polygonal transversely elongated shields, larger caudad than rostrad; 353–382 ventral, 357–397 dorsal postpectoral half-annuli; 24–33 dorsal half-annuli scales; 23–29 ventral half-annuli scales; 12–15 caudal annuli; a short, cylindrical and round ending tail; 121–142 precloacal vertebrae; absent precloacal pores and autotomy. Living specimens have a pale grizzled background coloration, with none or inconspicuous sparse, diminute and irregularly distributed dorsal brownish pigments, more concentrated in the second half of the body (Image 23A). Alcohol preserved specimens display a more pale brown (beige) brownish or whitish background coloration, and the pigments are more subtle. The sample from Municipality of Camaçari exhibited a different coloration, with marked brownish blotches or dorsal pigment dots evident along most of the body and in the tail.

Distinguishing features from one another (data in parenthesis) *Leposternon* species

Leposternon octostegum can be distinguished from all congeners by the combination of one supralabial and one infralabial shield, and a large single mental shield. The main evident differences between *L. octostegum* and all other *Leposternon* species, except *L. scutigerum* is the pectoral pattern with three pairs of enlarged unusually-shaped shields along the midline, with left and right asymmetries (see “Other remarks on congeneric comparison” below), and the dorsal shield head pattern with the great azygous shield occupying most (circa 55%) of the total area. Furthermore, *L. octostegum* has three rows of shields atop the head, including rostronasal, prefrontals, azygous, oculars and first temporals (eight main shields, the reason of the specific epithet etimology, cf. Duméril 1851), while *L. scutigerum* has two rows of dorsal head shields, represented by the rostronasal and azygous shields. *Leposternon octostegum* also differs from *L. scutigerum* by having 353–382 ventral postpectoral half-annuli (246–305). In addition to the cephalic and pectoral patterns, *Leposternon octostegum* further differs from other *Leposternon* species by the following combination of characteristics: it differs from *L. wuchereri* by having 353–382 ventral postpectoral half-annuli (233–265), 23–33 dorsal half-annuli scales (16–19) and 23–29 ventral half-annuli scales (16–21), from *L. infraorbitale* by having 353–382 ventral postpectoral half-annuli (201–275), a maximum adult body width of 9.3 mm (30mm or more; usually around 25mm) and live dorsal adult coloration of a pale grizzle background with brownish scale pigments, discrete or not (yellowish or whitish background with dark scale pigments), from *L. microcephalum* by having 353–382 ventral postpectoral half-annuli (186–254) and live dorsal adult coloration of a pale grizzle background with brownish scale pigments, discrete or not (usually a grayish background with dark scale pigments), from *L. polystegum*, *L. kisteumacheri*, *L. cerradensis*, *L. maximus* and *L. mineiro* by having no precloacal pores (two; 2–4 in *L. polystegum* and *L. cerradensis*), from *L. polystegum* by having 353–382 ventral postpectoral half-annuli (244–324), from *L. kisteumacheri* by having 353–382 ventral postpectoral half-annuli (246–264) and live dorsal adult coloration of a pale grizzle background with brownish scale pigments, discrete or not (bright yellow), from *L. cerradensis* by having 353–382 ventral postpectoral half-annuli (302–349), 23–33 dorsal half-annuli scales (32–37), and 23–29 ventral half-annuli scales (30–36), from *L. maximus* by having 353–382 ventral postpectoral half-annuli (408–448) and live dorsal adult coloration of a pale grizzle background with brownish scale pigments, discrete or not (pinkish), from *L. mineiro* by having 353–382 ventral postpectoral half-annuli (270–280).

Other remarks on congeneric comparisons

The pectoral shield pattern is very typical and useful for the identification of *Leposternon* species (cf. Gans 1971a), but seems not to be a diagnostic character for *L. octostegum*, as a similar pattern occurs in *L. scutigerum* (Image 11; Fig. 2A). However, the pairs of main shields are more regular in the latter species, while asymmetries in shape, size and/or position are the natural condition in *L. octostegum*. Nonetheless, *L. scutigerum* ZUFRJ 1730 (Fig. 2A to comparisons) has a close asymmetric situation, so it seems advisable not to use pectorals as a diagnostic character.

Furthermore, the pectoral pattern of *L. octostegum* (three pairs of enlarged, unusually-shaped shields along the midline, with left and right asymmetries, see below) is completely distinct from the ones present in *L. wuchereri* (parallel enlarged shields), *L. infraorbitale* and *L. microcephalum* (general "V" shaped shield arrangement) and *L. polystegum*, *L. kisteumacheri*, *L. cerradensis*, *L. maximus* and *L. mineiro* (diamond shaped shields).

There is a general trend for the elongation of the posterior dorsal half-annuli scales in *Leposternon* (José Barros-Filho pers. comm. v.2001), i.e., the scales tend to be longer instead of larger from near the head to near the tail (compare Images 8 and 18); but this trend, in a more rectangular than "squared" shape, seems relatively more accentuated in *L. octostegum*. In addition, the lateral sulci of *Leposternon* species most commonly do not begin immediately behind the pectoral region as in *L. octostegum*.

Variation in the analyzed samples

Table 1 summarizes the variations among the examined specimens. Additionally, the specimens from the Municipality of Camaçari show some minor morphological differences, such as an eventual suggestion of scale fusions with the azygous, but not enough to characterize a different species. The most evident divergence of the Camaçari sample is the coloration pattern, although this is probably due to an ontogenetic variation (see Discussion).

It was also possible to use the published data regarding four other *L. octostegum* specimens cited by Ribeiro et al. (2008: 20; 2011: 182, Fig. 4B; 2018: 58) in the comparison to *L. cerradensis* and *L. maximus* (MCP 18192, MCP 1893, MZUSP 96349 - Brazil, State of Bahia, Municipality of Camaçari; MZUSP 96350 - Brazil, State of Bahia, Salvador City). The variations of these four specimens from the present *L. octostegum* sample (in parenthesis) are: maximum postpectoral ventral half-annuli 390 (382), minimum postpectoral ventral half-annuli 342 (353), 11 caudal annuli (12–15) and 144 precloacal vertebrae (121–142). The counts of maximum postpectoral dorsal half-annuli 398 (397) and minimum postpectoral dorsal half-annuli 353 (354) are very similar.

In *Leposternon*, the dorsal postpectoral counts are usually greater than the ventral counts (Gans 1971a), as is also true for *L. octostegum*, however, this difference is less striking in some *L. octostegum* specimens (cf. Table 1).

Description

A slender, medium-sized *Leposternon*, with 388mm of maximum adult total length, and maximum body width of 9.3mm at midbody. Body vertebrae 121–142. Measurements and meristic data are summarized in Table 1.

Shields of the dorsal half of the head (Images 1–5)

Rostronasal: Large, roughly semicircular (base: posterior) in dorsal and ventral views. Laterally, its posterior suture forms a triangle of approximately 45^{o} pointing backwards, contacting the prefrontal superiorly and the supralabial inferiorly. Dorsally, at the midline, the transversal suture is deformed by the anterior portion of the azygous, in a triangular or more concave shape; a short middle depression (e.g., Image 1A) or straight sulcus (e.g., Image 1B) usually projects anteriorly from this deformation, but it never reaches the azygous tip. The ventral nares are essentially semicircular, their bases at a near 45^{0} angle from the longitudinal body axis; their medial-anterior rounded portions are protected by a semicircular flap, in a depression (i.e., the flaps are in a plane below the medial-rounded rims plane). A right line of weak suture is variably evident from the posterior extremity of each of the narial bases to the anterior mouth rim, indicating a probable ontogenetic fusion of

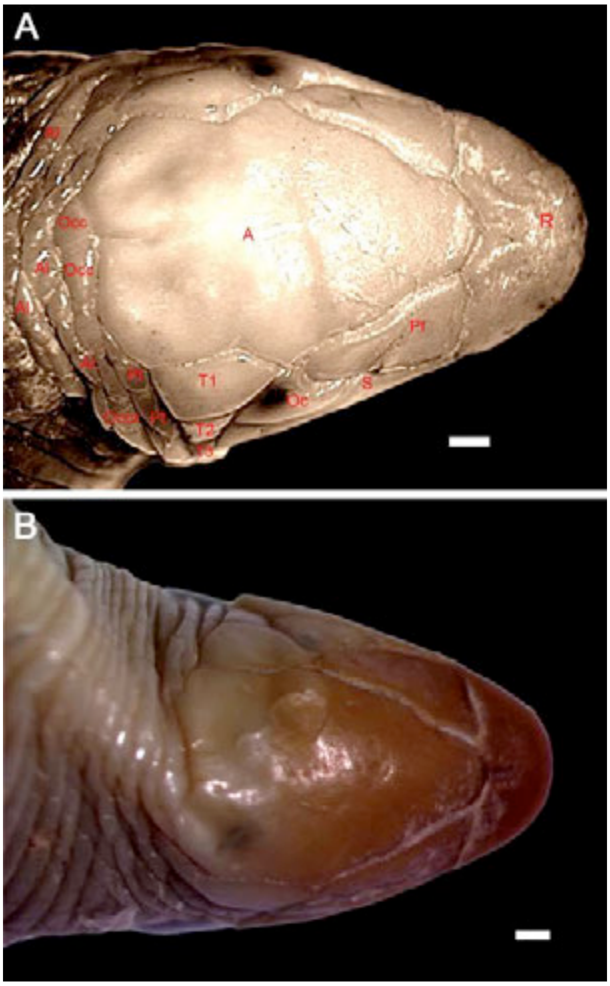

Image 1. *Leposternon octostegum*. Dorsal head shields. (A) MZUEFS 695, (B) MNHN 7055 holotype. Legends: A - azygous; Cp - contrapectorals; Oc - ocular; Occ - occipitals; Occr - occipital row; Pf - prefrontal; Pt - postemporal; R - rostronasal; S - supralabial; T1, T2, T3 - temporal 1, 2, 3 of the temporal row. Scale bars = 1mm.

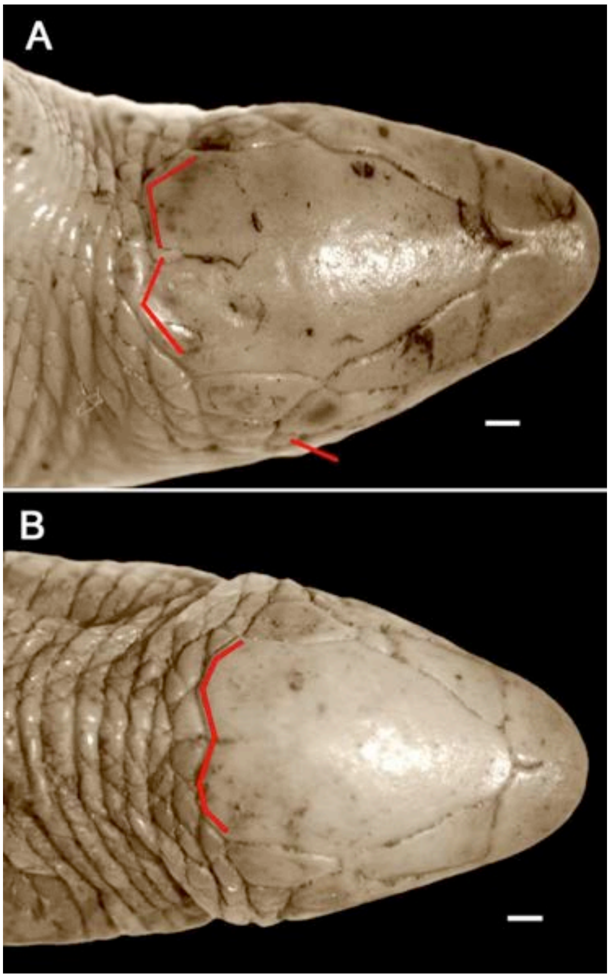

Image 2. *Leposternon octostegum*. Azygous suture variations. (A) ZUFRJ 1716 from Camaçari. Red bars showing the typical posterior "W" azygous suture. The isolated red line points out the extra shield (see *Oculars* description). (B) ZUFRJ 1749. Red bars showing the posterior "W" azygous suture with two more angles. Scale bars = 1mm.

scales involved in the rostronasal shield formation.

Azygous: Very large, occupying most of the dorsal head surface (circa 55% of total area and circa 80% of head length). At first glance, it seems pentagonal in shape, with a near triangular anterior and near squarish posterior contour (a similar impression was registered by Duméril (1851) in the original description). Nonetheless, the pattern is more complex when examined in detail. It anterior portion is actually not triangular; only the most rostral tip, which is inserted in the rostronasal shield, has a more "V" shape (tip not rounded as in the holotype in 13 of 17 specimens; no relation to collecting place or sex). The two "V" lines are anteriorly straight, but run backwards as slight undulated lines (convex and concave successively). They reach the greatest distance between each other at the level of the ocular shields and continue backwards as the posterior lateral sutures. These are almost parallel with each other but can also display undulations or angulations; they dorsally delimit the first temporals on each side. The caudal suture of the azygous is the continuation of these posterior lateral sutures; it is transversely oriented but not as a straight line. Instead, the caudal suture has angulations, with the typical pattern being a stretched "W" (Image 2A).

The azygous's polygon, including the "V" and "W" sutures or other angulations, usually shapes a decagon (N = 8, the most typical conformation). Other patterns can occur, such as, for example, two more angles in "W" forming a dodecagon (Image 2B); or an octagon if instead of the "V" suture there is a rounded one. Other possible polygons include angulations of the posterior lateral sutures (Image 1A).

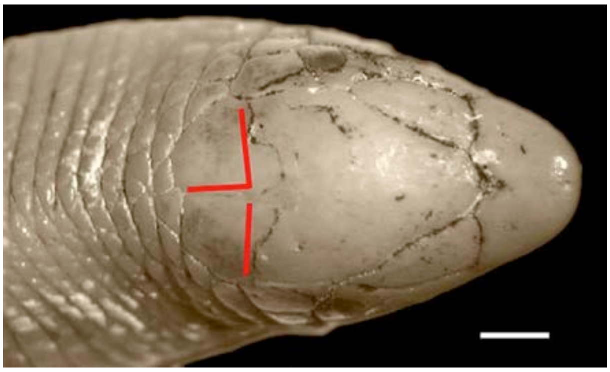

Image 3. *Leposternon octostegum* ZUFRJ 1714 from Camaçari. Red bars indicating that posterior "T" suture remains in the azygous shield. Scale bar = 1mm.

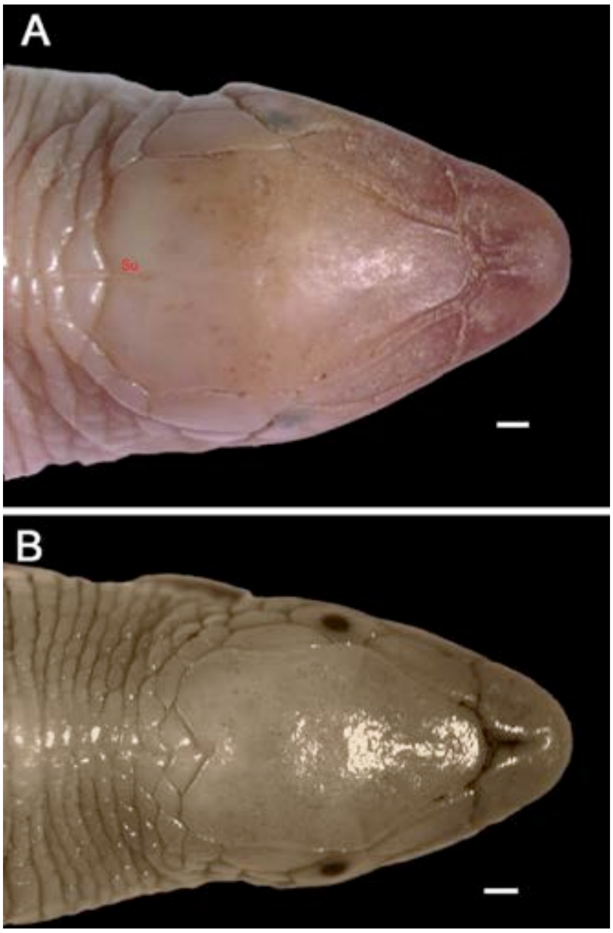

Image 4. *Leposternon octostegum*. (A) MZUEFS 653, posterior azygous sulcus present. (B) ZUFRJ 1713 from Camaçari, posterior azygous sulcus not expressed; note the rounded anterior part of the azygous, the modified"W" suture and small pigmentation. Su – posterior azygous's sulcus. Scale bars = 1mm.

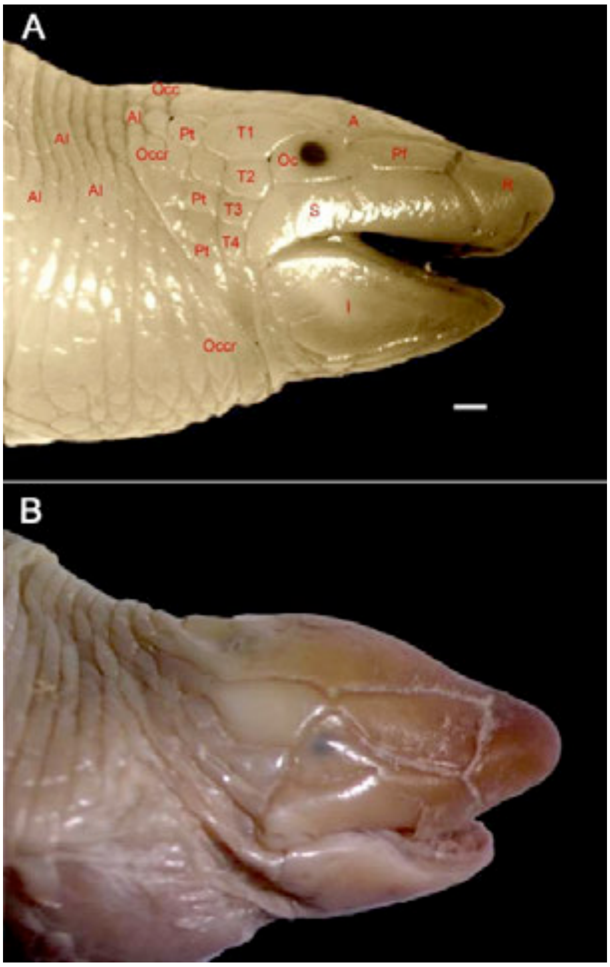

Image 5. *Leposternon octostegum.* Lateral head shields. (A) ZUFRJ 1713 from Camaçari. (B) MNHN 7055 holotype. Legends: A – azygous; Cp – contrapectorals; – infralabial; Oc – ocular; Occ – Occipitals; Occr – occipital row; Pf – prefrontal; Pt – postemporals; R – rostronasal; S – supralabial; T1, 2, 3, 4 – Temporals. Scale bars = 1mm.

In the posterior half of the azygous shield of specimen ZUFRJ 1714, 1716 and 1749 (Image 3), the remains of a pair of elongated rectangular scales, corresponding to the probable fused frontals (with each other and the azygous), can be better noted by a faded "T" (or similar) shaped suture line. In almost all specimens a somewhat elongated sulcus (the posterior portion of the longitudinal "T" trace, touching the "W" caudad suture) is clearly seen in the midst of the posterior portion of the azygous shield (Image 4A). It is aligned with the inter-occipital suture that follows behind the azygous.

Prefrontals: In dorsal view, they are the larger shields on the top of the head after the azygous and rostronasal shields. They form an irregular trapezium with curved corners, despite the general "triangular" appearance, especially in the dorsal view. The base of the "triangle" is relatively short, sutured transversally with the rostronasal shield. The longest, dorsal suture with the azygous shield is undulated, as described above. The ventral suture with the single supralabial is an almost straight line parallel with the mouth line, which then tilts upwards posteriorly, suturing with the ocular and giving it the shape of a trapezium. The prefrontals may contact the first temporal shield above the ocular shield (Image 4A), but usually do not (Image 4B).

Oculars: roughly irregular pentagons, the ventral (and longest) suture to the supralabial is usually slight curved or alternatively being almost straight. The anterior suture, with the prefrontal, is inferiorly concave. The posterior suture, with the two upper temporal shields, is somewhat convex. A point of contact (or very small line) can occur superiorly to the azygous, between the prefrontal and first temporal shields. The Camaçari sample shows oculars shaped almost as trapezia; in ZUFRJ 1713, 1715 and 1716 these "trapezoidal" oculars touch a small extra "infraocular" shield posteriorly and inferiorly, shaped as a trapezium or a triangle, in at least one side of the head (Image 2A). The extra shield is inserted between the ocular, the supralabial and the temporal row.

Supralabials: A single and large supralabial on each side of the head, shaped as a stretched irregular pentagon. Sutures: anteriorly as a backslash ("\") with the rostronasal; superiorly with the prefrontals and oculars, respectively, usually with different angulations with each one, and posteriorly with the temporal row, in an almost convex line. The inferior edge of the supralabial is curved, clearly concave near the angulus oris.

Temporal row: The vertical temporal row on each side of the head lies immediately behind the ocular and last supralabial line, and usually has four scales (rarely three or five). These scales will be here referred as first through fourth temporals, from top to bottom. The first temporal is the largest scale in the row and is longer longitudinally compared to vertically. Its shape varies from a rough trapezium to an irregular polygon with five or six sides. The anterior suture with the ocular is concave; the superior suture with the azygous is slightly undulate; the posterior suture with the postemporal rowscale(s) (see below) is curved or angulated; and the inferior suture with the second temporal is approximately a straight line. The second temporal is usually trapezoidal, almost square-shaped, higher than longer, always with the superior margin being the longest – sometimes appearing as an almost longitudinal rectangle. It is anteriorly sutured with the ocular, or with ocular and supralabial, by curved or straight lines. The inferior and posterior sutures are straight lines, respectively with the third temporal scale and postemporal row. The third and fourth temporals are usually disposed as a rough vertical rectangle, cut by a backslash ("\") that forms the suture between them. They are usually higher than longer, suturing (curved or straight lined) anteriorly with the supralabial (third supralabial rarely in contact with the ocular, see above) and posteriorly with the postemporal row. Minor variations in scale shape, number (up to three small supernumerary scales) and disposition can occur involving the temporal row region, from third temporal down to the angulus oris.

Postemporal row: One to three lateral vertical rows of somewhat irregular shaped scales, confined anteriorly between the temporal row, the dorsal half-annulus that includes the occipitals posteriorly, the azygous superiorly and the gular region inferiorly.

Occipitals and occipital row: A pair of occipital shields is discrete at the midline, sutured with the azygous posterior margin. They are trapezoidal in shape, sometimes almost triangular, usually transversely elongated and of about same area, but a little larger than the immediate lateral and posterior scales. They are sutured medially with each other on a straight line on this side of the trapeziums, which have the narrower vertex laterally oriented. This sagittal suture is aligned posteriorly with the dorsal sulcus and anteriorly with the midst sulcus of the posterior portion of the azygous. The occipitals are in the center of a dorsal half-annulus, composed of somewhat irregular scales (varying in shape, rounded, polygonal or elongated). The occipital row ends inferiorly at the limit of the gular/pectoral region

Shields of the ventral half of head (Images 6–7, Fig. 4)

Mental: This is the biggest ventral head scale, after the infralabials. This shield anteriorly forms the central edge of the mouth. It is about two times longer than wide, with the general appearance of an elongated heptagon. The posterior end is triangular and inserted between the central intermandibulars. Vestiges of up to four sutures can be seen, including what would probably be an individualized postmental shield. The sutures are (probably) the result of ontogenetic development, and are not clearly noticeable in only two of the 17 specimens. The mental scale is laterally sutured, almost straight, from front to rear, with the infralabials, the lateral intermandibulars, and the medial intermandibulars, respectively.

Infralabials: An enormous scale on each side of the mouth, most certainly resulting from the fusion of two shields. The evidence is the presence of a very discrete, but usually not very long sulcus, beginning more or less at the middle of the posterior infralabial shield margin, but ending inside the area of the same shield (Image 7).

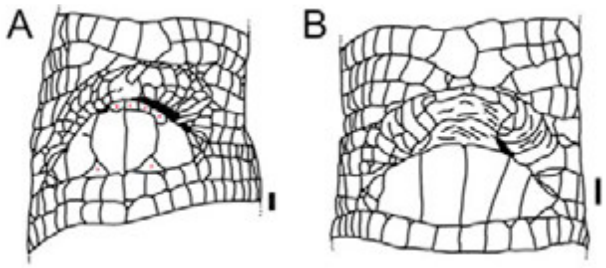

Figure 3. *Leposternon octostegum*. Cloacal flaps. (A) ZUFRJ 1749, with supplementary shields marked in red. (B) ZUFRJ 1715, without any supplementary or extra shields. Scale bars = 1mm.

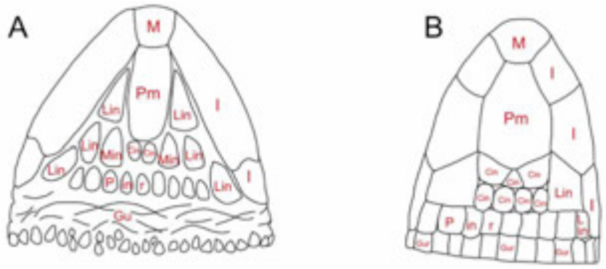

Figure 4. *Leposternon* spp (A) and *Amphisbaena* spp (B). Squematic drawing displaying the ventral head shields. Legends: Cin - central intermandibulars; Gu - Gular region; Gur - Gular row; I - infralabials; Lin - lateral intermandibulars; Min - medial intermandibulars; Pinr - postintermandibular row.

The infralabials have a general triangular appearance, but with undulated sides. They form most of the inferior mouth edge, except for the rostral tip, occupied by the mental scale. They are laterally sutured, from rostrad to caudad, respectively, to the mental and the lateral intermandibulars, in straight or slightly undulated lines; and posteriorly in undulated lines (or, alternatively, straight lines forming angles), with the first of the irregular and narrowed half-annulus that can be present in the gular region.

Lateral intermandibulars: One (usually)**,** two or rarely three (Image 7) on each side; if two, aligned longitudinally. The one, or the anterior of the two, is shaped like an elongated trapezium, with the narrower vertex inserted rostrad between the mental and the infralabial scales. Laterally sutured throughout their length with the infralabial, medially and rostrad with the mentals, medially and caudad with the central intermandibulars, in straight or slightly undulated lines. The second pair of lateral intermandibulars is shorter than the first, not elongated, trapezoidal or almost squared. They are at the level of the central intermandibulars, forming a transversal row with the latter. The lateral intermandibulars suture posteriorly with the postintermandibular row.

Central intermandibulars: One to three discrete scales, each shield triangular or trapezoidal in shape (some deformation can occur). Usually a pair is present, with the narrower vertex inserted rostrad between the mental and lateral intermandibulars, and a median scale slight posterior and between the pair. This median scale is sometimes easily discernible but too far from the mental shield (cf. Fig. 7), being included in the postintermandibular row (see description). The pair is limited laterally by the lateral intermandibulars, and the median scale is limited by the postintermandibular row. Posteriorly, they are sutured to the postintermandibular row.

Medial intermandibulars: In *L. octostegum* these are poorly expressed as very small irregular scales, or absent.

Posterior intermandibular rows: One, two, or rarely three rows of irregulary shaped shields, with a general semicircle arrangement, and the arch of the semicircle rostrad. The shields of the first row are usually enlarged, in a more or less fixed pattern: the median one is larger, almost round or oblong and the lateral ones are oblong, sutured laterally with infralabials, with elongated, almost rectangular, shields between them. The shields of the second/third rows are usually more weakly expressed.

This semicircle arrangement is usual for *Leposternon*, being well expressed or not. This occurs since, in contrast to *Amphisbaena*, the scales of these rows tend to converge anterior and medially in the specific *Leposternon* head *Bauplan* (against the more transversal and organized disposition of *Amphisbaena*). The last row is posteriorly followed by the folds of the gular region, where the definition of the irregular, weakly expressed shields and rows is sometimes vestigial.

Contrapectoral rows and pectoral region (Images 5 and 8–11, Fig. 2)

Contrapectoral rows: These dorsal half-annuli (13 to 18) extend from the first dorsal half-annulus immediately behind the occipital row to the last dorsal half-annulus which touches the modified ventral pectoral shields laterally. They possess two or three rostrad annuli, ventrally, corresponding to a transitional area (due to their postoccipital and gular position), with the shape and pattern of their shields not very distinctive from those of the gular region; they are irregular, polygonal or almost rounded shields, and the largest (or fusion of small shields, frequently triangular) are usually located at the midline.

Dorsally, the contrapectoral rows display rounded or somewhat oval scales (near the head), modified

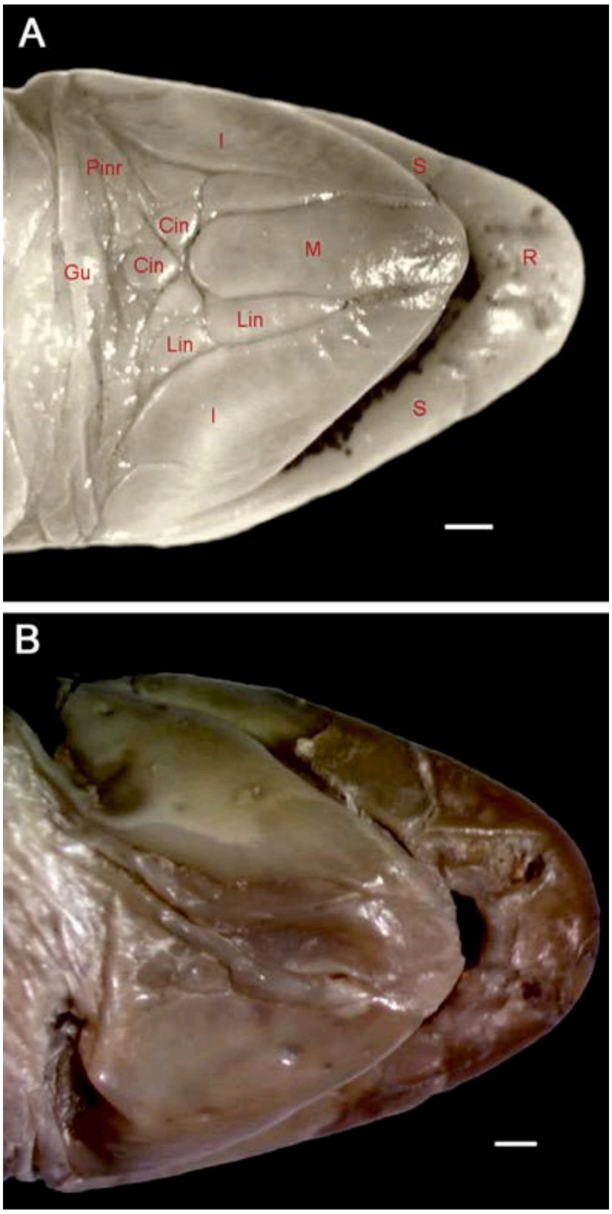

Image 6. *Leposternon octostegum*. Ventral head shields. (A) ZUFRJ 1713 from Camaçari. (B) MNHN 7055 holotype. Legends: M - mental; Gu - gular region; I - infralabials; Lin - lateral intermandibulars; Cin - central intermandibulars; Pinr - postintermandibular row; R - rostronasal; S - supralabials. Scalebars = 1mm.

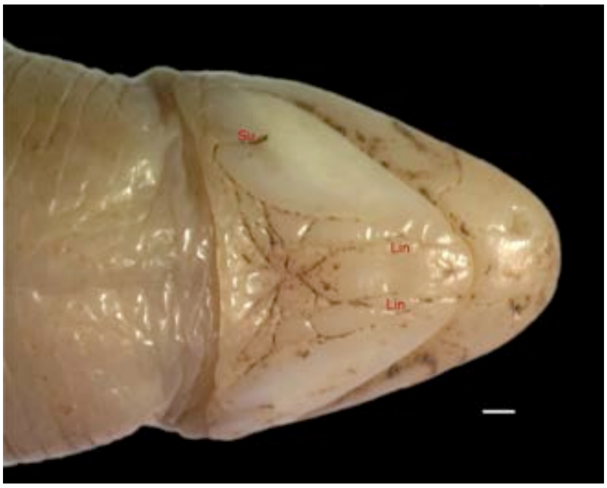

Image 7. *Leposternon octostegum* MZUEFS 654. Legends: Lin - additional anterior pair of lateral intermandibulars; Su - infralabial sulcus. Scale bar = 1mm.

posteriorly into rectangular, squarish scales (Image 8). The medial dorsal sulcus begins in this region, well expressed or only discernible.

Pectoral region: The larger shields of the pectoral region have a very typical disposition pattern (Image 9), but the shape of each individual shield is highly variable. The three mediad pairs are the most characteristic: the anterior pair forms a rough stretched pentagon pointing backwards; the shields of the medial pair may or may not display sagittal contact; they are elongated, irregular polygons, with a marked tendency to suture diagonally both rostrally and caudally with the anterior and posterior pairs respectively, roughly in a "X"-shaped disposition. In addition, as their lateral sutures are elongated and closely parallel to the sagittal plane, the two shields are shaped similarly to a "bowtie". The posterior pair has polygonal elongated shields, usually wider caudad when compared to rostrad. The main variations are the contact of the anterior and posterior pairs, usually separated by the medial pair, the absence of the caudal part of the "bowtie" (i.e., transversal instead of diagonal suture with the posterior pair), and shield asymmetries (shape, size and/or position) (Image 10). Some fusions can occur. Rounded margins and/or shorter length are seen in the posterior pair of specimen MNHN 7055 (holotype), MNHN 2007.0024, and ZUFRJ 1714 (Image 9). Usually, the shields of the anterior pair are trapezoidal, but can display more or less than four sides, or rounded margins; the shields of the medial pair are irregular polygons with - usually - five to seven sides; and the shields of the posterior pair are irregular polygons with - usually - five or six sides. These variations extend to the more laterally located modified pectoral shields, which also display a pattern. Their general disposition is of elongated and concentric rows on both sides of the central pairs. These rows, the more laterally located pectorals, are posteriorly confluent and anteriorly divergent, roughly in a "V" pattern. The more medially placed rows (the first lateral pectoral row), sutured with the three central pairs, usually have three or four main shields. Of these shields, the more elongated and noticeable, sutured mainly with

Image 8. *Leposternon octostegum* ZUFRJ 1716 from Camaçari. Oval scales near the head (left side). Note the anterior dorsal body pigmentation, and squarish tendency of the contrapectoral (middle) and anterior postpectoral scales (right side). Scale bar = 1mm.

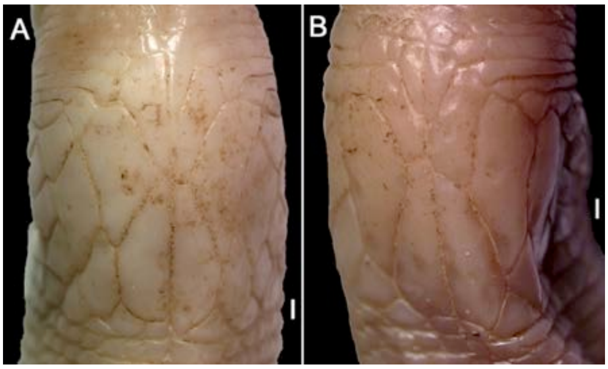

Image 10. *Leposternon octostegum*. Pectoral shield variations. (A) MZUEFS 654, anterior and posterior pectoral main pairs in contact, separating the shields of the medial pair. (B) MZUEFS 653, four instead of three main central shield pairs. Scale bars = 1mm.

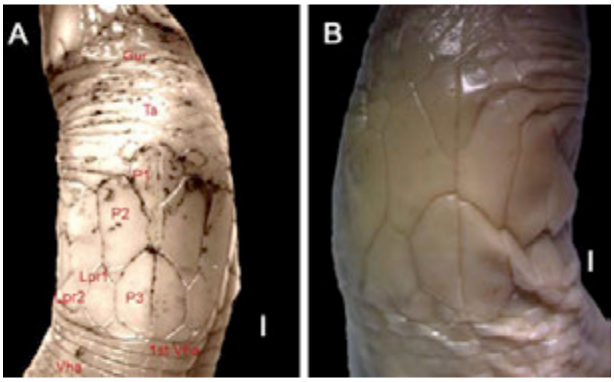

Image 9. *Leposternon octostegum*. Pectoral region shields. (A) ZUFRJ 1714 from Camaçari. (B) MNHN 7055 holotype. Legends: Gur - gular region; Lpr1, 2 - lateral pectoral rows 1, 2; P1, 2, 3 - main pectoral shield pairs 1 (anterior), 2 (medial), 3 (posterior); Ta - transitional area; Vha - ventral postpectoral half-annuli; 1stVha - first ventral postpectoral half-annulus. Scale bars = 1mm.

Image 11. *Leposternon scutigerum*. Pectoral shield pattern, NHMW 12375. Scale bars = 1mm.

the medial ("bowtie") pair, have the general appearance of a typical parallelogram (shorter sides inclined). It is anteriorly preceded by a few smaller typical parallelogram or irregular polygonal shields, and followed posteriorly by one or two smaller and usually irregular polygonal shields. The next (second) lateral row usually has four shorter main shields, with a general typical parallelogram appearance. The next two or three rows on each side are transitional areas to the dorsal contrapectoral half-annuli. They are composed of decreasing smaller shields of typical parallelogram, rectangular or squarish shape, in a regular half-annulus disposition.

Body sulci (Images 12–18)

The four typical amphisbaenian longitudinal sulci (the dorsal, laterals and ventral) usually well expressed in *Leposternon,* are present, although the ventral sulcus may be inconspicuous. They divide the animal's body in roughly four quarters. Three main patterns of sulci formation exist, with minor variations. In the first pattern, the disposition that characterizes the sulcus area, at the extremity of an annulus quarter, has scales inserted as a triangle between two equal extremities of a contacting quarter. This provides a zigzag sulcus appearance and is more typical of the dorsal sulcus (Image 12). A second pattern results from the simple alignment of adjacent scales in the sulcus region, forming a straight line (Image 13). This pattern is eventually undistinguishable from the adjacent longitudinal alignments. The straight-line pattern is more typical for the ventral sulcus. In the third pattern, very small scales of varying shapes fill the sulcus area (Image 14A). In this case, many folding lines are present between the scales. The more regular disposition of this kind comprises of a single scale divided by a pair of diagonal furrow lines that cut it into two more discrete triangles (anterior and posterior, united by one vertex) (Image 14B). The three patterns can occur along the same sulcus (Image 15). The ventral and lateral sulci begin immediately behind the pectoral region, more or less well expressed beginning in the first half-annulus rows. The dorsal sulcus begins immediately behind the occipitals, more or less well expressed already in the first contrapectoral rows. The ventral sulcus ends in the last ventral half-annulus. Except for dorsal or ventral scale alignment, sometimes well expressed, the sulci do not go beyond the cloacal level to the tail.

Dorsal and ventral postpectoral half-annuli (Images 8 and 13–18)

The meristic data are summarized in Table 1. There are 357–382 ventral postpectoral half-annuli, 397–357 dorsal postpectoral half-annuli, 24-33 dorsal half-annulus scales and 23–29 ventral half-annulus scales. Incomplete half-annuli are present, each consisting of a short row of transversal aligned scales that do not reach the normal half-annuli length and are inserted between them. The incomplete half-annuli are not included in the final counts and are few, usually four or less, rarely eight or 10, ventrally, and usually two or less, rarely seven or eight, dorsally (Images 15, 16). The shape of the scales of the half-annuli is always rectangular or squarish (Image 17), except for specializations for the sulci (see above), however, general shape trends within the body region are present: 1 – The dorsal scales tend to be longer instead of wider (Images 14B, 16), and the ventral scales tend to be wider instead of longer, especially the scales delimiting the ventral sulcus (Image 13). A transitional area occurs below the lateral sulci (Image 14A). 2 – Dorsally the first 30 or so postpectoral half-annuli have squarish scales (Image 8). The rectangles stretch backwards in most of the dorsum, and in the posterior body portion they are visibly thinner (Image 18).

Contracloacal rows, cloacal region and tail (Images 19–22, Fig. 3)

Contracloacal rows: Four to six (Table 1). Extra half-annuli may appear, touching the remainder of the lateral sulci. The scales are not differently shaped from the ones of postpectoral and ventral half-annuli (i.e., rectangular), except in the sulci areas (if expressed) and the cloacal base margins, where some kind of minor deformation may occur (e.g., triangle or polygon shapes).

Cloacal region: The cloacal region does not have pores. The precloacal flap is characterized by four main pairs of shields in a transversal row with the addition of small supplementary shields appearing in the same areas. The main eight shields are the large, almost rectangular longitudinal central pair, the large irregular pentagon medial pair, and the two smaller lateral pairs, with triangular or trapezoidal shields (Image 19). Minor variations in these pairs can occur in shape, size or proportions, however, three specimens differ in having one (MNHN 2007.0023, ZUFRJ 1716, on the left side) or two (MZUFES 656, one on each side) extra-large rectangular longitudinal shields between the central shields and the medial ones (Image 20A). The small supplementary shields that normally appear are located as: 1 – a thin row of small usually squarish shields below the central and medial pairs (Image 19); 2 – one or two small but very discrete shields, triangular or trapezoidal, with a vertex inserted between the below suture of a central and a medial shield (Image 20B); 3 – the correspondents of both anterior patterns in the upper side of the precloacal shields (Image 19); 4 – different combinations of all these patterns (Fig. 3A). The summary of these variations is a general trend in only partial manifestations of two additional fragmentally developed rows, both dorsally and ventrally, in the precloacal flap. The only exception is ZUFRJ 1715, without noteworthy supplementary or extra shields (Fig. 3B). The postcloacal flap is composed of short 17–23 longitudinal rows in a semicircular arch, bordering the posterior cloacal opening. The central and more caudad pair of rows is composed of widened scales. The other rows have diminished scales of a generally polygonal shape, the larger usually being the posterior scale in each row (Image 19).

Tail: The tail is short (circa 1/19 body length), cylindrical, with a rounded extremity (Images 20B, 21).

Image 12. *Leposternon octostegum* ZUFRJ 1716 from Camaçari. Zigzag dorsal sulcus formation and coloration. Head to left. Scale bar = 1mm.

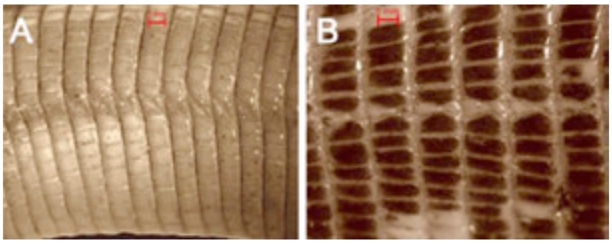

Image 14. *Leposternon octostegum*. Sulci patterns. (A) ZUFRJ 1748. Small scales filling the lateral sulcus region. Below the sulcus, note a transitional scale area, with more rectangular scales turning into lower more squarish ones. Head to right. (B) ZUFRJ 1716 from Camaçari. Dorsal sulcus filled with two main scales. Head to left.

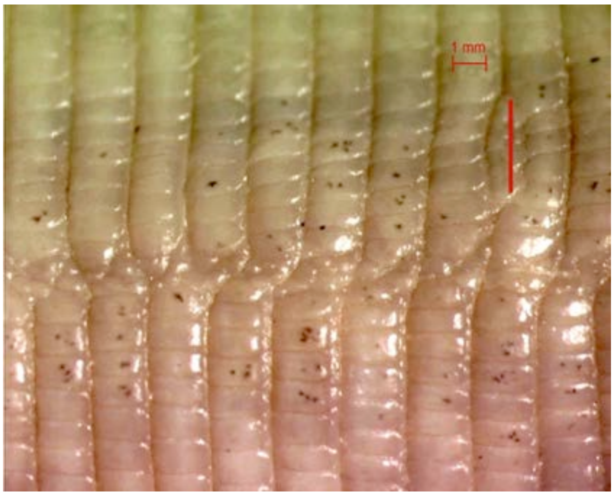

Image 16. *Leposternon octostegum* MZUEFS 654. Red bar showing an incomplete postpectoral scale row near dorsal sulcus. Note pigment disposition. Head to left.

Image 13. *Leposternon octostegum* MZUEFS 654. Ventral sulcus with aligned scales. Head to left.

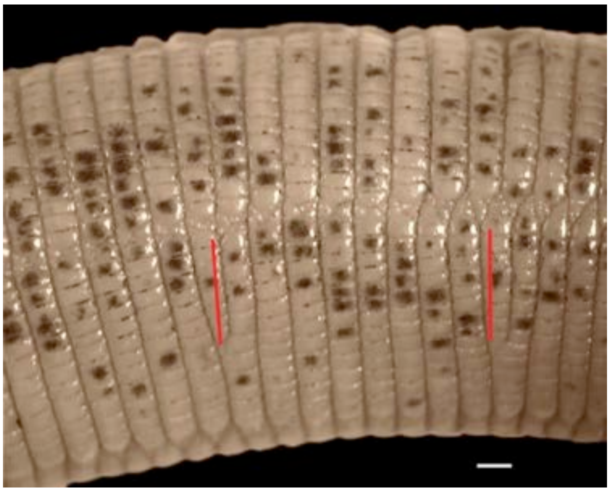

Image 15. *Leposternon octostegum* ZUFRJ 1714 from Camaçari. Dorsal sulcus defined by a zigzag arrangement (right), two main scales (center), and various small scales (left), all occurring simultaneously. The red bars shows examples of incomplete postpectoral scale rows. Head to right. Scale bar = 1mm.

The diameter is usually a little smaller than that of the body (Table 1). There is no autotomy annulus, nor sulci expression, besides the medial scale dorsal and ventral alignment. There is commonly no other regular scale alignment. Extra half-annuli may occur. The annuli count begins at the base of the most posterior margin of the postcloacal flap, even if the first ventral annulus is not complete at the sagittal plane, because its position is postcloacal (there is a tendency for a rostrad enlargement of the mid pair of scales of the second ventral annulus, which interrupts the first annulus by contacting the postcloacal flap). The counts include the tail tip, with

Image 17. *Leposternon octostegum* MNHN 7055 holotype. Dorsal sulcus and squarish or rectangular scales. Head to left. Scale bar = 1mm.

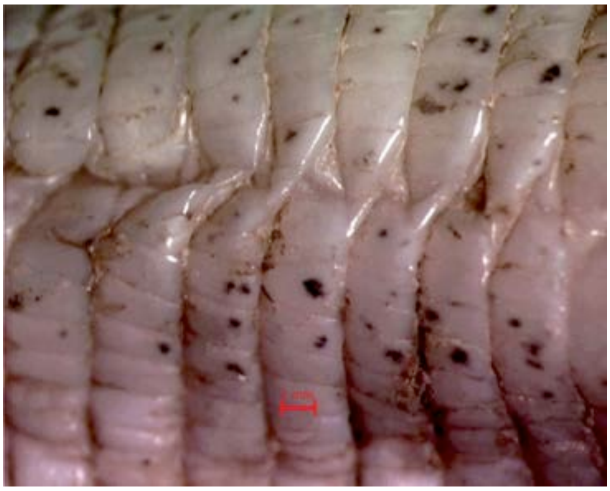

Image 18. *Leposternon octostegum* MZUEFS 652. Dorsal sulcus and thinner rectangular scales. Head to left.

the always recognizable, even if irregular, annulus. There are 12–15 caudal annuli present. The shape of the scales varies; dorsally and laterally they are more regular, longitudinal rectangles (Image 21A). The dorsal medial pair is usually larger than the rest. Approaching the tail tip, the scales tend to be squarish. Ventrally, the medial pairs are usually a little wider or more squarish than the lateral pairs, except for the first two or so. These tend to be trapezoidal or irregular pentagons (Images 20B, 21B). The last (i.e., posterior) five or so annuli display more scale shape variation. They can be irregular hexagons or pentagons (especially dorsally), with elongations, or shortening, and/or irregular polygonal forms in the extreme tip (Image 22). There are no scale fusions, but eventually the extreme scales show slightly attenuated limits.

Coloration (Images 2, 8, 12, 14–16, 18, 20–21 and 23)

Living specimens from Salvador City have a pale grizzled background coloration (cf. Image 23A), including head, pectoral region and tail. The head of the holotype is brownish (Images 1B, 5B, 6B, 23B), perhaps due to preservative artifacts. There is no marked head pigmentation, although diminute dots can be present (cf. Images 2, 4B). Body scale pigments are absent (MNHN 2007.0034 and MZUEFS 657; also MZUEFS 563, 654, however, these are mutilated specimens) or usually inconspicuous, represented by sparse, diminute and irregularly-distributed dorsal brownish dots, normally several dots per scale, also observed in the preserved specimens (cf. Images 14A, 16, 18). These are usually more concentrated in the second half of the body. The alcohol-preserved specimens show a more pale brown (beige) or whitish background coloration, and the pigments are faded (Images 23B, C), however, even the holotype (MNHN 7055, from 1851) still retains some pigment blotches dorsally, at the corresponding cloacal area. Tails are depigmented, except for very few small sparse dots in MZUEFS 652, 696.

Three of four specimens from the Camaçari sample (ZUFRJ 1714, 1715, 1716) have a marked different coloration. In the preservative (they were not seen alive to obtain a color description), the background color is beige from head to tail and the pigmentation is more pronounced compared to all other specimens (Images 23D-F). There is no ventral coloration except for the tail of specimens ZUFRJ 1715 and 1716. Very few dorsal brownish dots may occur on the head (Image 2A). Immediately after the head, in the first 1/10 of the body, the dorsal brownish dots are less intense and scarcely distributed (Image 8). The rest of the dorsal body has an evident brownish pigmentation (Images 12, 14B, 15), that eventually reaches the lateral sulci, although not all scales are pigmented, nor are the spaces between annuli or scales (they seem to be in e.g. Image 12, however see comment on edited photographs in the Material and Methods section). The pigments can occupy the entire scale (e.g., Image 14B) or not (e.g. Image 15). The tail can display a ventral pigmentation of discrete blotches (Image 20B) or small dots (Image 21B), or none at all (ZUFRJ 1714). Dorsally, the tail has few pigmented scales, concentrated medially and rostrad, but some dots can appear near the tip (Image 21A). Specimen ZUFRJ 1713 is smaller than the others from Camaçari (and Salvador) and does not show any discernible pigmentation.

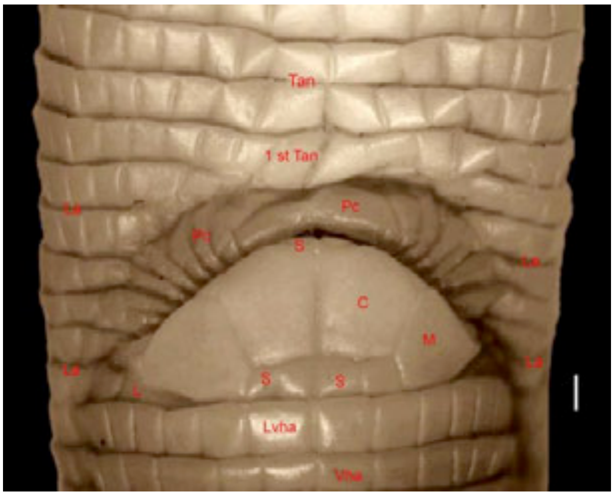

Image 19. *Leposternon octostegum* MNHN 7055 holotype. Cloacal region. Legends: C - shield of the central pair in the cloacal flap; Cc - contrapectoral rows; L - lateral shield of the cloacal flap; Lvha - last ventral postpectoral half-annulus; M - shield of the medial pair in the cloacal flap; Pc - postcloacal rows; S - supplementary shields; Tan - tail annuli; Vha - ventral postpectoral half-annulus; 1st Tan - first tail annulus. Scale bar = 1mm.

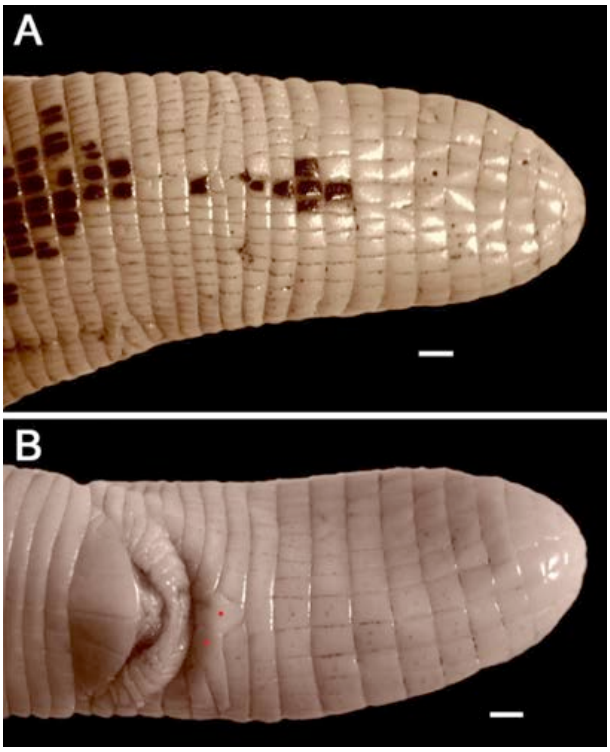

Image 21. *Leposternon octostegum*. Tail scales and pigmentation pattern of Camaçari specimens. (A) ZUFRJ 1716, dorsal view. (B) ZUFRJ 1715, ventral view; irregularly shaped scales marked in red. Scale bars = 1mm.

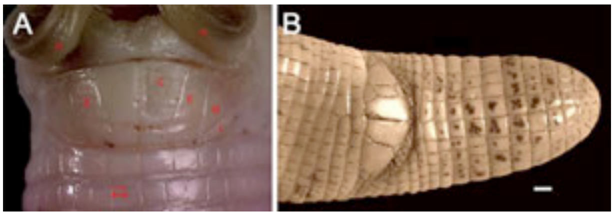

Image 20. *Leposternonoctostegum*. Cloacal region. (A) MZUEFS 656. Legends: C - shield of the central pair in the cloacal flap; E - extra shields; H - hemipenis; L - shield of the lateral pair in the cloacal flap; M - shield of the medial pair in the cloacal flap. (B) ZUFRJ 1716 from Camaçari. Tail shape and cloacal flap shield disposition. Note pigmentation pattern. Scale bar = 1mm.

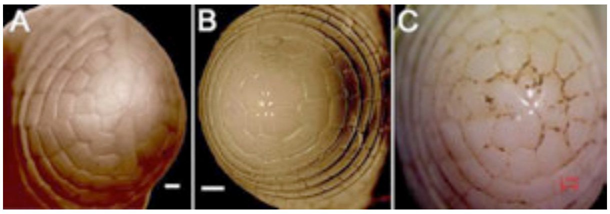

Image 22. *Leposternon octostegum*. Tail extremities. (A) MNHN 7055 holotype, with discrete, yet irregular, rows and scales. (B) MZUEFS 695, showing more attenuated scale sutures. (C) MZUEFS 652, showing regular scale rows until the very tip. Scale bars = 1mm.

Geographic distribution and habitat

Detailed data of *Leposternon octostegum* distribution and habitat are provided by Barros-Filho et al. (2013). The species is known only to occur in the state of Bahia, Brazil (Fig. 1).

DISCUSSION

The analysis conducted by Gans (1971a) retained the validity of *L. octostegum*, although the point of view of this author was based on a single specimen. The new data presented herein confirm that author's conclusions and provide detail on intraspecific variation.

Except for some nomenclatural changes and minor different counts or measurements, the original data (Duméril 1851) and posterior references (Peters 1879; Boulenger 1885; Gans 1971a) are well in general accordance with the holotype; however, Duméril (1851) was wrong in describing "straight lines" for lateral and posterior azygous sutures, and Boulenger (1885) in referring to a "small mental", "followed by a single rather small chin-shield" (there is only one big mental); Gans (1971a), with knowledge only of the holotype, mentioned the pectorals as "regular shields", but these display great individual variations (but there is a shield

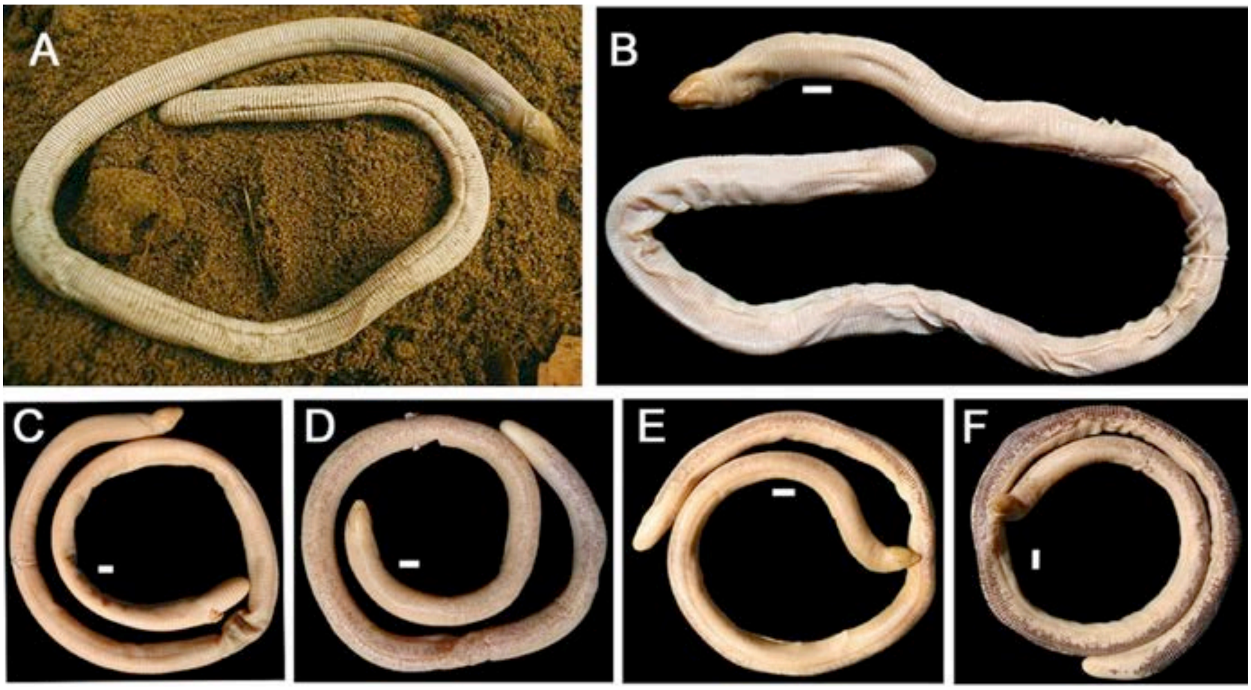

Image 23. *Leposternon octostegum*. Coloration. (A) Live coloration of newly captured specimen from Aterro Metropolitano Centro, near Salvador City, State of Bahia, Brazil; without scale; (B) MNHN 7055 holotype and (C) MNHN 2007.0023, color in preservative. (D) ZUFRJ 1714, (E) ZUFRJ 1715 and (F) ZUFRJ 1716 from Municipality of Camaçari, Arembepe County, color in preservative. Scale bars = 5mm.

arrangement pattern). Great discrepancy is found in the count by Gans (1971a), of 106 "body vertebrae" against the 121–142 counted herein. Even different X-rays or other methodological approaches cannot explain the problem (cf. Hoffstetter & Gasc 1969 : 174–175, "post-axial" plus "precloacal" vertebrae, the same as "body vertebrae" in the present study).

The annuli count methodologies used herein preserve the logic of the standards proposed by Gans (1971a) and improve them (e.g. desirable counts until the tip of the tail) by considering the particular morphology of amphisbaenian specimens. The reliability of this procedure was tested by comparing the counts reported by Gans (1971a) for the *L. octostegum* holotype (378 postpectoral annuli) with the count herein (379 ventral right postpectoral annuli) for the same specimen.

In addition, it is important to remember that the species do not display unique and exact counts, but indeed, variations - i.e., *L. octostegum* postpectoral ventral left annuli vary from 353 to 382. The same idea is expressed in Table 2, comparing counts of specimens analyzed in more than one paper. Gans (1971a) and Ribeiro et al. (2008, 2011) show only the range of these counts, but this range comfortably agree with the data presented herein for each specimen, highlighting that, even if there is some slight individual discrepancy with literature data, they are insignificant for the purpose of comparisons.

A note regarding Table 2: In the study performed by Ribeiro et al. (2011) there is no mention of ventral postpectoral counts for other *Leposternon* species save *L. maximus*, which was being described in the paper; in this aspect, the authors only listed the material examined for comparison. The explanation is that, as stated by the *L. maximus* species diagnosis, "*Leposternon maximus* sp. nov. differs from all amphisbaenians by presenting 404–448 dorsal postpectoral half-annuli and 408–448 ventral postpectoral half-annuli". One species that reaches near counts is *L. octostegum* (Fig. 4: 182), with less than 400 left ventral postpectoral half-annuli. Again, the counts reported herein, despite the methodological differences, agree adequately with these observations.

Moreover, not only the sample used in this study, but also the large series of *Leposternon* spp. and Amphisbaenia of different genera and species have been analyzed, counted and identified by the present count methodology, for more than 30 years (Barros-Filho unpublished data) without any mistake or problem. In all pertinent cases, minimal count differences are far from causing confusion regarding species identification or description.

Therefore, we conclude that the count methodology adopted herein absolutely does not damage or prevent comparisons with bibliographical data. Instead, it offers increased accuracy in this regard, with desirable adjustments for the methodology proposed by Gans (1971a) and Gans & Alexander (1962), thus allowing for more exact observations and being fully valid for comparative analyses with Amphisbaenia literature. That is why the new methodology is proposed herein, as well as the suggested modifications in pholidosis nomenclature, to be applied as new standards.

The pholidosis nomenclature proposed herein aims to contribute to an improvement of this still disputed subject in amphisbaenian studies. The authors are of the opinion that the propositions are fully justifiable and a necessity, due to the repetitive confusing usage of inadequate or simply mistaken terms. This applies especially for the terminology of the so called "chin shields", historically laden with synonymic terms for different scales.

With this aim, the specificities of the *Leposternon* and amphisbaenian Bauplan were considered, particularly concerning the cephalic region. The adopted names are more consistent with the location area of the respective shields. In fact, we identified very significant nomenclatural inconsistencies in this aspect. For instance, Gans & Alexander (1962) named the first body annulus one that dorsally includes typical head shields; this is also incompatible with the cranial elements that are supposed to support homological structure relations (cf. Gans & Montero 2008).

We recognize that the ideal approach for nomenclatural changes (connected to the definition of scales and scale rows and, consequently, with their counts) is the identification of homology between structures. Even if no homological analysis were available, there are solid reasons for the proposed modifications. As detailed in Material and Methods section, there are cases when homologies can be hard to determine (e.g., the amphisbaenian temporal region) but on the other hand, some applied historical terms are so wrong that there is really no sense in using them, just because they are in the literature. In these cases, other criteria, such as more consistent topological references, are improvements not only regarding description clarity, but also in facilitating the understanding of future homological studies.

To be effective and useful in this sense, however, we are of the opinion that new nomenclatural propositions should take into account the entire study group. For example the nomenclature suggested by Pinna et al. (2010), although certainly an improvement in some cases, restricted the analysis essentially to South American *Amphisbaena* species. This can make future comparisons within Amphisbaenia harder. The present proposals deal with morphological aspects that contemplate comparison bases for the entire suborder.

The proposed modifications are also easy to compare with published descriptions and illustrations (e.g., Castro-Mello 2003; Hoogmoed & Mott 2003; Thomas & Hedges 2006; Mott et al. 2008; Ribeiro et al. 2008, 2009, 2011, 2015, 2016, 2018; Strüssmann & Mott 2009; Pinna et al. 2010, 2014; Gomes & Maciel 2012; Roberto et al. 2014; Sindaco et al. 2014; Teixeira Jr. et al. 2014; Costa & Bérnils 2015; Costa et al. 2015; Broadley & Measey 2016), despite the variability of adaptations in amphisbaenians, and are a solid resource for the better understanding of nomenclatural and homological issues in this group.

The pigmentation differences observed in the Camaçari sample (coupled with smaller total length) suggests an ontogenetic color variation. The smaller specimen (ZUFRJ 1713, 150mm total length) shows no pigmentation, while the others (ZUFRJ 1714 – 232 mm, ZUFRJ 1715 – 283mm, ZUFRJ 1716 – 320mm total length) show increasing pigment intensity associated with total length. The larger specimens (and thus, supposedly older) from Salvador also tend to show more intense pigmentation than the smaller specimens (MZUEFS 657 with 245mm total length is not pigmented). Future collection of specimens will be needed to clarify issues regarding color variation by site and ontogeny.

An important aspect of correctly identifying species is the consequent support for their conservational status. *Leposternon octostegum* is a species with a relatively restricted geographical distribution and few known ecological data (cf. Barros-Filho et al. 2013). And, till recently, the species was based only on the holotype. Since much remains to be discovered with regards to the taxonomy and distribution of reptiles from Bahia and Brazil (e.g., Freitas et al. 2011, 2012a,b), and new shovel-headed Brazilian species are under present investigation (Ribeiro 2010), we understand that the redescription of *L. octostegum* will add to the clarification of the taxonomy of Brazilian amphisbaenians, and also contribute to its conservation and management strategies, largely overlooked in the country because (within other factors) taxonomic issues in this group remain unclear.

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Key to Brazilian *Leposternon* species*

1 A pair (rarely two) of very small precloacal pores, at the precloacal flap sides 2
– Precloacal pores absent 6
2 Azygous smaller than frontals, which are almost rectangular and in longitudinal arrangement; preocular present .... *L. polystegum*
Azygous somewhat or discretely larger than frontals; preocular absent 3
3 Three infralabials; less than 300 ventral postpectoral half-annuli 4
– Two infralabials; more than 300 ventral postpectoral half-annuli 5
4 246-264 ventral postpectoral half annuli .... *L. kisteumacheri*
– 270-280 ventral postpectoral half annuli .... *L. mineiro*
5 Supraoculars present; 408-448 ventral postpectoral half-annuli .... *L. maximus*
– Supraoculars absent; 302-349 ventral postpectoral half-annuli .... *L. cerradensis*
6 Azygous by far the largest shield atop the head, covering nearly the entire head dorsum 7
– Azygous variably enlarged, but never covering almost the entire head dorsum 8
7 Rostronasal and azygous are the only two main large shields in dorsal view; postmental shield present; 246-305 ventral postpectoral half-annuli .... *L. scutigerum*
– Rostronasal, azygous, prefrontals, oculars and first temporals clearly discrete in dorsal view; postmental shield absent; 353-382 ventral postpectoral half-annuli .... *L. octostegum*
8 Azygous very large (circa 25% of total head area), usually touching the rostronasal; the contact of the azygous with the rostronasal is always a point contact of the anterior “V” shape of the azygous, never a broad contact of the anterior azygous margin; a pair of very large rectangular, almost squarish frontals (together, occupying near the same head area of the azygous); parietals usually absent; four to six longitudinal, almost rectangular, main pectoral shields, in general in a parallel pattern ...... *L. wuchereri*
– Azygous variably large (but less than 25% of total head area), usually separated from the rostronasal by the prefrontals; parietals present, but may be partially (rarely totally) fused with the frontals; pectoral shields fused or not, disposed in a more or less discrete general “V” pattern, except for the medial ones 9
9 Adults very large, reaching more than 3 cm in mid-body diameter; yellow dorsal background coloration may be present in alive individuals; three supralabials at each side; usually one infraocular; pectoral shields may be large, but not fused or elongated; body scales small and squarish .... *L. infraorbitale*
– Adults sometimes large, but never reaching 3 cm in mid-body diameter (usually 1 to 2 cm); grayish dorsal background coloration in alive individuals; two supralabials at each side; infraocular absent; the pectoral large shields are usually fused and elongated, especially a medial pair; body scales rectangular .... *L. microcephalum*

* *Leposternon bagual* endemic from Argentina (cf. Ribeiro et al. 2015) is not included here. In addition, its diagnostic features are osteological, and the type-series (four exemplars) shows obvious external morphological variations.

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Appendix 1. *L. microcephalum* and *L. scutiegrum* specimens examined in this paper (1) and in the studies performed by Gans (1971a) (2), Ribeiro et al. (2008) (3), (2011) (3).

Leposternon microcephalum (N = 49)
BRAZIL: MINAS GERAIS: Nova Ponte: MNRJ 7469[1,3]; *Sacramento*: MZUSP 77040[1,3]. *MATO GROSSO DO SUL: Anaurilândia*: ZUFRJ 1490[1,3]; *Porto Taboado*: MZUSP 77532[1,3]. *RIO DE JANEIRO: Angra dos Reis*: MNRJ 1762[1,2]; *Barro Branco*: MNRJ 1767a[1,2]; MNRJ 1767b[1,2]; *Duque de Caxias*: MNRJ 1774[1,2]; MZUSP 6394[1,3]; MZUSP 6397[1,3]; MZUSP 6398[1,3]; MZUSP 6399[1,3]; MZUSP 65390[1,3]; *Floriano*: MZUSP 578[1,3]; *Manguinhos*: MZUSP 7677[1,3]; MZUSP 8284[1,3]; *Miguel Pereira*: MZUSP 6539O[1,3]; *Parati*: MNRJ 1755a[1,2]; MNRJ 1755b[1,2]; *Petrópolis*: MNRJ 1778a[1,2]; MNRJ 1778f[1,2]; *Rio de Janeiro*: MNRJ 1768[1,2]; MNRJ 1783[1,2]; MNRJ 3261[1,2]; MNRJ 3262[1,2]; MNRJ 3264[1,2]; MNRJ 3265[1,2]; MNRJ 3266[1,2]; MNRJ 3267[1,2]; MNRJ 3268[1,2]; MNRJ 3269[1,2]; MNRJ 3270[1,2]; *Rio de Janeiro*: MZUSP 2426[1,3]; MZUSP 2676[1,3]; MZUSP 13762[1,3]. *SANTA CATARINA: Corupá*: MZUSP 1249[1,3]; MZUSP 6466[1,3]; MZUSP 6488[1,3]; MZUSP 6518[1,3]. *SÃO PAULO: Assis*: MZUSP 77038[1,3]; MZUSP 77039[1,3]; *Ilha da Queimada*: MZUSP 77031[1,3]; *Passa Quatro*: MZUSP 77527[1,3]. *São Carlos*: MZUSP 77536[1,3]. *São Paulo*: MZUSP 77013[1,3]; MZUSP 77014[1,3]; MZUSP 77037[1,3]; MZUSP 77042[1,3]; MZUSP 77515[1,3]. *Tupã*: MZUSP 77043[1,3].

Leposternon scutigerum (N=3)
BRAZIL: RIO DE JANEIRO: Rio de Janeiro: MZUSP 2519[1,3]; MZUSP 7075[1,3]; ZUFRJ 289[1,3].

Appendix 2. Amphisbaenia and Lacertilia specimens examined for comparisons of counts and/or shield nomenclature with *Leposternon octostegum*. Acronyms follow Sabaj-Pérez 2010 when possible: UnB (Universidade de Brasília, Brazil; UNESP-Rio Claro (Universidade Estadual Paulista, Campus de Rio Claro, Brazil); UERJ (Universidades Estadual do Rio de Janeiro, Brazil; UFC (Universidade Federal do Ceará, Brazil); MHNCI (Museu de História Natural Capão da Imbuia, Curitiba, Brazil; MNRJ (Museu Nacional do Rio de Janeiro, Brazil); MPEG (Museu Paraense Emílio Goeldi, Brazil); MZUSP (Museu de Zoologia, Universidade de São Paulo, Brazil); ZUFES (Departamento de Zoologia, Universidade Federal do Espírito Santo, Brazil); ZUFRJ (Departamento de Zoologia, Universidade Federal do Rio de Janeiro, Brazil, now at Museu Nacional do Rio de Janeiro).

AMPHISBAENIA (N = 213)
Amphisbaena dubia (N = 2): MZUSP 77054, ZUFRJ 996.
Amphisbaena mertensi (N = 13): UNESP-Rio Claro A51, A52, A54, A56-A58, 115, 126, 513, 530, 540; ZUFRJ 993-995.
Amphisbaena mitchelli (N = 2):MZUSP 828, 829.
Amphisbaena neglecta (N = 1):ZUFRJ 990.
Amphisbaena pretrei (n = 7):ZUFRJ520-526.
Amphisbaena roberti (n = 13): UNESP-Rio Claro A23 a A25, A53, A55, 70, 80, 356, 533, 541, 561; MZUSP 77072; ZUFRJ 992.
Amphisbaena vermicularis (N = 2):MZUSP 77067, 77077.
Amphisbaena vanzolinii (N =1):ZUFRJ 70.
Anops kingi (N =1): ZUFRJ 817.
Aulura anomala (N =1): ZUFRJ 826.
Leposternon infraorbitale (N = 6): MNRJ 4035, 4456; ZUFRJ 504, 538-539; UnB 3663.
Leposternon microcephalum(N = 107): UERJ 29, 59, 108, 219, 144, 220, 234, 274-275, 296, 359, 359.1, 419, 424, 435, 595, 597; MHNCI 1398, 2780, 2941, 3034, 3538, 4223; MNRJ 1773, 4020-4033, 4264, 4487-4489, 4501; MZUSP 3345-3350, 3472, 6392-6393, 6395-6396, 6406, 6537, 6579, 6601, 6650, 7020, 7051, 7300, 7753-7755, 8282-8283, 8346, 13760-13761, 13763; ZUFRJ 29, 59, 240, 249, 280-281, 284-288, 299, 457, 462, 467-469, 483, 540-544, 639-640, 764, 797, 1001-1009.
Leposternon polystegum (N = 16): MPEG 6559, 6671, 7588 7602, 7597; UFC 204, 219, 298, 1467, 1646, 1802, 1839; ZUFRJ527-528, 938-939.
Leposternon scutigerum (N = 16): MNRJ 4036-4040, 4458, 4490-4492; ZUFRJ 289, 381, 530, 550, 798, 997, 1000.
Leposternon sp. (N = 6): MNRJ 4041-4046.
Leposternon wuchereri (N = 8): MNRJ 3892, 3893; MZUSP 8812; ZUFES 15/126, 15/181, 15/203, 15/208-15/209.
Loveridgea ionidesi (N = 3): MZUSP 2004-2006.
Monopeltis capensis capensis (N =1): MZUSP 58124.
Rhineura floridana (N =4): MNRJ 3188; MZUSP 3062, 3305-3307.
Trogonophis wiegmanni (N = 3): MZUSP 3199, 3200, 72807.

LACERTILIA (N = 6)
Bachia bresslaui (N =4): ZUFRJ 650-653.
Dibamus novaeguineae (N =1): MZUSP 68753.
Mabuya sp. (N =1): ZUFRJ 15.

Portuguese abstract: O anfisbênio Leposternon octostegum (Duméril 1851) é redescrito com base em novos exemplares coletados no Estado da Bahia, Brasil. É confirmada a validade da espécie e são feitas comparações com outras espécies de Leposternon e com a parca literatura relativa à espécie. Foram analisados aspectos merísticos e são propostos ajustes nomenclaturais para a folidose. Uma chave de identificação para as espécies de Leposternon é fornecida, de forma a melhor contextualizar estas informações taxonômicas. A conservação dos Amphisbaenia tem sido grandemente negligenciada, pois mesmo questões taxonômicas básicas para este clado permanecem indefinidas. A presente redescrição, contribuindo para o esclarecimento da taxonomia deste grupo, auxiliará no desenvolvimento de estratégias de conservação e manejo mais sólidas, tanto para L. octostegum quanto para todo o grupo dos Amphisbaenia.

Palavras-chave: Amphisbaenia, Bahia, Brasil, Leposternon octostegum, metodologia merística, nomenclatura de folidose, taxonomia.

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COMMUNICATION

Annotated checklist and conservation status of mammals of Fars Province, southern Iran

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Abstract: Our purpose in this study was to gather all previously published data and our own data of extensive field expeditions and camera trapping to present a general view of the Fars mammals. The mammals of Fars Province, southern Iran, comprise of 72 species in 53 genera, 28 families and seven orders. The most diverse order is Chiroptera with 23 species or 31.9% of the mammalian fauna, followed by Carnivora and Rodentia (each with 18 species, 25%). The most diverse family is Vespertilionidae with nine species or 12.5% of the mammalian fauna, followed by Rhinopomatidae and Muridae, each with eight species or 11.1% of the mammalian fauna, Felidae and Canidae (each with five species, 6.9%), respectively. Sixteen families have only one species each. The Fars Province is the type locality of *Triaenops persicus* Dobson, 1871, *Eptesicus serotinus shiraziensis* (Dobson, 1871), *Microtus irani* Thomas, 1921, and *Apodemus witherbyi* (Thomas, 1902). Five species are listed in the Appendix I, eight species in the Appendix II, and eight species in the Appendix III of the Convention on International Trade in Endangered Species (CITES). In addition, three species are considered as endangered and nine species as protected species based on the rules and regulations/laws of the Iranian Department of the Environment (DOE). The Asiatic Lion *Panthera leo persica* Meyer, 1826 is extirpated in Iran. Among the reported species, 60 species (83.3%) are considered as Least Concern (LC), two species as Not Evaluated (2.7%), one species as Data Deficient (1.4%), six species (8.3%) as Vulnerable (VU), and three species (4.2%) as Near Threatened (NT) in the IUCN Red List of Threatened Species. The current checklist shows that the mammalian fauna of Fars Province is rich and taxonomically diverse, and the provided information will be necessary for the development of competent and pragmatic management plans and effective conservation policies.

Keywords: Conservation, distribution, Iran, mammalian fauna, taxonomy.

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Author Contribution: SK collected the specimens and prepared the photos; FZ, HRE, and SK prepared, reviewed, analyzed, and approved the manuscript.

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INTRODUCTION

The information provided in checklists is necessary for the development of competent and pragmatic management plans and effective conservation policies (Esmaeili et al. 2017). Biodiversity conservation, biogeography, and evolutionary history influence faunal composition. This is also true when postulating inter-realms communication routes and dispersal barriers (Lomolino et al. 2006). Faunal composition data, when coupled with geographical, physiographic, and climatological information, can inform hypotheses on the processes of diversification and endemism (Darvish et al. 2014). Faunal documentation is also relevant to public health management (Stenseth et al. 2003), especially in the case of mammals which are considered as pests (Schiller et al. 1999) and reservoirs of zoonotic diseases (Nateghpour et al. 2013).

Zoogeographically, Iran is an interesting country, as much of its area is located in the Western Palearctic, but southern parts are affected by the Indomalayan and Afrotropical elements. Thus, diversity in the mammalian fauna of Iran is such that it can be considered as a collection of European, African, Asian, and Iranian species (Ziaie 1996).

Situated in southern Iran, the Fars Province is the fourth largest province of the country. Besides its idiosyncratic zoogeographic position, a wide range of geographic and physiographic conditions, coupled with climatologically diverse environments in this province, have provided enormous diversity (Esmaeili & Teimori 2017). Among vertebrates, the herpetofauna (Gholamifard et al. 2012) and ichthyofauna (Esmaeili & Teimori 2017) of Fars Province have been well-studied and received more attention. So far, no comprehensive faunistic study has been published on the mammalian fauna of Fars Province. Herein, we present an up-to-date checklist of its mammalian species with notes on their taxonomy and conservation status.

MATERIALS AND METHODS

Study Area: This checklist focuses on the mammals of Fars Province which lies between 27^0N and 31^0N and 50^0E and 55^0E in southern Iran and covers a total area of about 1,22,608km² (7.4% of the total area of Iran). The map of the study area (Fig. 1) has been created using Global Mapper 18 (Global Mapper Software, LLC, Olathe, Kansas) and Surfer 11 (Golden Software, LLC). The elevation of Fars Province ranges from 450m in the south to about 4,050m in the north, with a mean of 1,491m. The mean annual precipitation ranges from 150mm to 1,200mm (Gholamifard et al. 2012).

Fars Province possesses three national parks (Bamou, Bakhtegan, and Qatruiyeh), one wildlife refuge (Bakhtegan), eight protected areas (Arzhan and Parishan, Mianjangal, Hormood, Bahram-e Goor, Meleh Galeh, Tang-e Bostanak, Margoon, and Baghe Shadi), minor parts of two other protected areas (Dena and Tarom) and 17 non-hunting areas (Fig. 1). Recommended areas for promotion to protected status are also the Dareh Bagh, Barm-e Firouz, and Gorm Mountains. Thus, the total area of the listed protected areas (both declared and recommended) in this province is about 12,80,386ha (31.1% of the total area).

Fars Province possesses three main terrestrial ecoregions, including the central Persian desert basins in the north and northeast, the Zagros Mountains forest steppe extending from northwest to the southeast, and the Nubo-Sindian desert and semi-desert ecoregion in the south, as well as numerous aquatic ecoregions including at least 10 lakes and 29 rivers (Olson et al. 2001). A wide range of geographic and geologic conditions coupled with the climatologically diverse environments and consequent habitat types have provided enormous diversity in this part of Iran.

Study Method: The data presented in this checklist come from the published scientific reports (e.g., Lay 1967; De Blase 1971, 1972, 1980; De Blase et al. 1973; Etemad 1978, 1985; De Roguin 1988; Harrison & Bates 1991; Ziaie 1996; Firouz 1999; Gutleb & Ziaie 1999; Benda et al. 2006, 2012a; Esmaeili et al. 2008a,b; Ghoddousi et al. 2008a; Karami et al. 2008; Zareian et al. 2012; Karami et al. 2016) and our extensive field expeditions as well as camera-trapping during recent years. Mammals were identified based on morphologic characteristics and descriptions using various field guides (e.g., Etemad 1978, 1985; Ziaie 1996; Karami et al. 2016). Information regarding the type locality follows Karami et al. (2008). Geographic distribution for each species was provided according to available references and provincial divisions map of the country (Fig. 2).

RESULTS

The total confirmed mammals of Fars Province comprises 72 species in 53 genera, 28 families, and seven orders (Table 1), living in different habitats (Image 1). The most diverse order is Chiroptera (23 species, 31.9%), followed by Carnivora and Rodentia

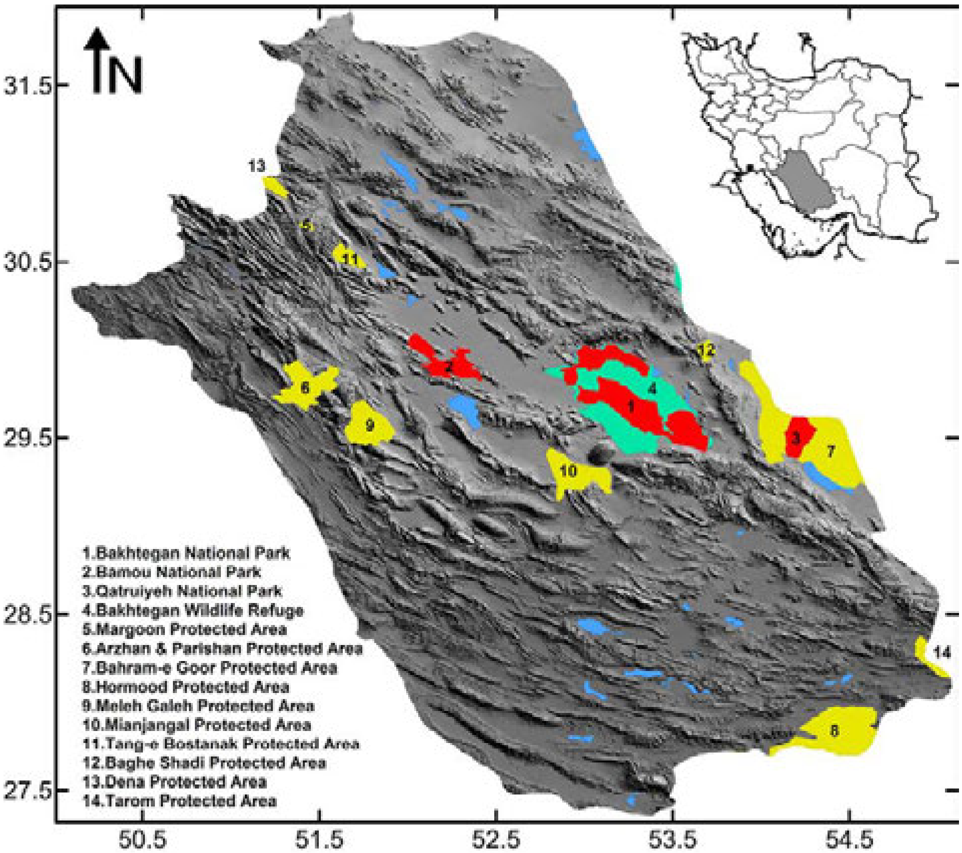

Figure 1. Fars Province, southern Iran showing the area and distribution of the protected areas.

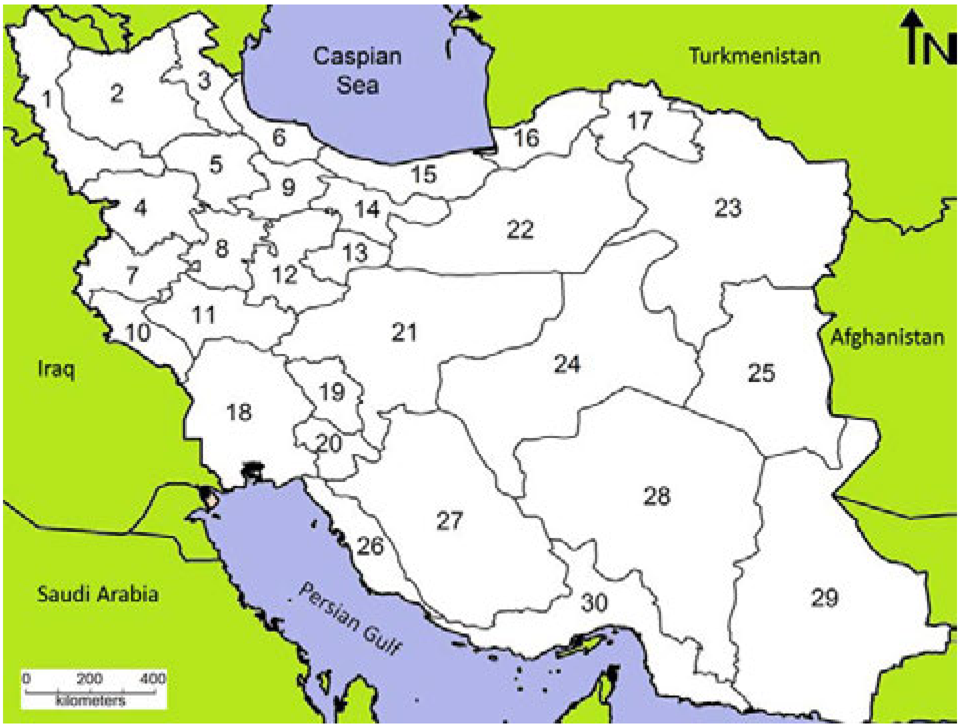

Figure 2. Provinces of Iran. 1 - West Azerbaijan; 2 - East Azerbaijan; 3 - Ardabil; 4 - Kurdistan; 5 - Zanjan; 6 - Gilan; 7 - Kermanshah; 8 - Hamadan; 9 - Qazvin; 10 - Ilam; 11 - Lorestan; 12 - Markazi; 13 - Qom; 14 - Tehran and Alborz; 15 - Mazandaran; 16 - Golestan; 17 - North Khorasan; 18 - Khuzestan; 19 - Chaharmahal and Bakhtiari; 20 - Kohgiluyeh and Boyer-Ahmad; 21 - Isfahan; 22 - Semnan; 23 - Razavi Khorasan; 24 - Yazd; 25 - South Khorasan; 26 - Bushehr; 27 - Fars; 28, Kerman; 29 - Sistan and Baluchestan; 30 - Hormozgan.

Table 1. Species diversity of mammalian families in Fars Province, southern Iran.

Order	Family	Genera	Species
Eulipotyphla	Erinaceidae	1	1
	Soricidae	3	3
Chiroptera	Pteropodidae	1	1
	Rhinopomatidae	2	8
	Emballonuridae	1	1
	Hipposideridae	2	2
	Vespertilionidae	5	9
	Miniopteridae	1	1
	Molossidae	1	1
Carnivora	Canidae	2	5
	Felidae	3	5
	Herpestidae	1	2
	Hyaenidae	1	1
	Mustelidae	3	4
	Ursidae	1	1
Perissodactyla	Equidae	1	1
Artiodactyla	Suidae	1	1
	Cervidae	1	1
	Bovidae	3	4
Rodentia	Sciuridae	1	1
	Dipodidae	2	2
	Calomyscidae	1	1
	Cricetidae	4	4
	Muridae	7	8
	Gliridae	1	1
	Hystricidae	1	1
	Ochotonidae	1	1
	Leporidae	1	1

(each with 18 species, 25%). The most diverse family is Vespertilionidae (nine species or 12.5%), followed by Rhinopomatidae and Muridae (each with eight species, 11.1%), Felidae and Canidae (each with five species, 6.9%), respectively. Sixteen families have only one species each. Fars Province is the type locality of *Triaenops persicus* Dobson, 1871, *Eptesicus serotinus shiraziensis* (Dobson, 1871), *Microtus irani* Thomas, 1921, and *Apodemus witherbyi* (Thomas, 1902). Among the reported species, 60 species (83.3%) are considered as Least Concern (LC), two species as Not Evaluated (2.7%), one species as Data Deficient (1.4%), six species (8.3%) as Vulnerable (VU), and three species (4.2%) as Near Threatened (NT) in the IUCN Red List of Threatened Species. Five species are listed in Appendix I, eight

Image 1. Examples of habitat types in Fars Province. A & B - Arzhan & Parishan Protected Area; C & D - Bamou National Park. © S. Kafaei.

species in Appendix II and eight species in Appendix III of the Convention on International Trade in Endangered Species (CITES). In addition, three species are considered as endangered and nine species as protected based on the rules and regulations/laws of the Iranian Department of the Environment (DOE). The Asiatic Lion *Panthera leo persica* Meyer, 1826 is extirpated in Iran.

TAXONOMIC ACCOUNT

Order Eulipotyphla Waddell, Okada & Hasegawa, 1999

Family Erinaceidae Fischer, 1814

Genus *Paraechinus* Trouessart, 1879

***Paraechinus hypomelas* (Brandt, 1836)** - Brandt's Hedgehog

Type locality: South Kazakhstan.

Diagnosis: HB 140–270 mm, T 10–40 mm, HF 33–38 mm, S 38mm and W 400–700 g; ears triangular and longer than the dorsal spines; a bare triangular area between spines on the forehead; body black, with tawny and white forms; face and under parts hairs black in the black forms, spines with black and yellow stripes, but the whole body looks black; ventral area whitish-yellow, and spines tawny with no black coloration in the lighter forms.

Comments: The nominate subspecies is distributed in mainland Iran, but those from the Larak Island, southern Iran, belong to a distinct cluster (Yusefi et al. 2016).

Distribution: Fig. 2 (9, 10, 12, 16, 20, 21, 23, 24, 26, 27, 28, 29, 30).

Conservation status: IUCN: Least Concern; CITES: not listed; DOE: unsupported.

Family Soricidae Fischer, 1814

Genus *Crocidura* Wagler, 1832

***Crocidura suaveolens* (Pallas, 1811)** - Lesser White-toothed Shrew

Type Locality: Russia, Crimea, Khersones, near Sevastopol.

Diagnosis: HB 56-88 mm, T 35–56 mm, HF 10–14 mm and W 4.5–15 g. Tail longer than half of head-body length, relatively thick and gradually tapers off, ending with a tuft of short hairs; eyes small; pinna enlarged; body covered with dense, soft and delicate hairs; dorsal fur variable from light gray to grayish brown; ventral fur orange-yellow.

Comments: The southernmost records in Iran are from localities in Fars (Esmaeili et al. 2008b, Hutterer & Harrison 1988) and Kerman provinces (Dubey et al. 2007). A gene tree revealed two main clades in Iran, northern vs. central and northwestern (Hadadian-Shad et al. 2017).

Distribution: Fig. 2 (1, 16, 17, 19, 20, 21, 27, 28).

Conservation status: Conservation status: IUCN: Least Concern; CITES: not listed; DOE: unsupported.

Genus *Suncus* Ehrenberg, 1832

***Suncus etruscus* (Savi, 1822)** - Etruscan Shrew

Type Locality: Italy, Pisa.

Diagnosis: HB 35-48 mm, T 25–30 mm, HF 7–8 mm, and W 1.5–2.5 g. Body small and delicate; snout long, pointed and projects beyond the lower lip, long whiskers observed around it; eyes small; ears long; tail thick at the base and longer than half the head-body length, covered with short hairs with a few long hairs between them; tail end with a tuft of large hairs; fur soft and short, grayish-brown on dorsal and light gray on ventral; feet short.

Comments: One record from the Gorm Mountain, Jahrom, Fars Province, by Esmaeili et al. (2008b) extended its known distribution range in Iran further to the south.

Distribution: Fig. 2 (3, 16, 18, 19, 23, 27, 30).

Conservation status: IUCN: Least Concern; CITES: not listed; DOE: unsupported.

Genus *Neomys* Kaup, 1829

***Neomys anomalus* Cabrera, 1907** - Mediterranean Water Shrew (Figs. 4A-B)

Type Locality: Spain, Madrid Province, Jarama River, San Martin de la Vega.

Diagnosis: HB 72–90 mm, T 45–60 mm, HF 1,418mm and W 7–20 g. Hair smooth, black on dorsal and gray on the ventral, with a visible demarcation between the two; eyes small; pinna short; tail length medium, covered with coarse hairs; tail underside with white hairs, gradually becoming longer and denser towards the tip, forming a white tuft at the end; fore and hind limbs with five fingers, end with sharp claws; long hairs between hard pads and soles of fore and hind limbs; teeth tips reddish-brown.

Comments: Records from Fars Province by Esmaeili et al. (2008a) extended its known distribution range in Iran further to the south.

Distribution: Fig. 2 (16, 27).

Conservation status: IUCN: Least Concern; CITES: not listed; DOE: unsupported.

Order Chiroptera Blumenbach, 1779
Family Pteropodidae Gray, 1821
Genus *Rousettus* Gray, 1821

***Rousettus aegyptiacus* (Geoffroy, 1810)** - Egyptian Rousette

Type Locality: Egypt, Giza.

Diagnosis: HB 118-148 mm, FA 84–99 mm, T 8–19 mm and W 100–170 g. Face fox-like; tail very short; interfemoral membrane reduced; second finger clawed; tragus absent; ear margin complete; dorsal fur grey to brown, slightly paler ventrally; males larger, with scent glands in the throat; eyes large.

Comments: Southern populations in Iran assigned to *R. a. arabicus* Anderson, 1902 (Karami et al. 2008), but Benda et al. (2012b) suggested that all Palearctic populations belong to the nominate subspecies, which is uniform in genetics but plastic in morphometric traits.

Distribution: Fig. 2 (20, 26, 27, 28, 29, 30).

Conservation status: IUCN: Least Concern; CITES: not listed; DOE: unsupported.

Family Rhinopomatidae Bonaparte, 1838
Genus *Rhinopoma* Geoffroy, 1818

***Rhinopoma hardwickii* Gray, 1831** - Lesser Mouse-tailed Bat (Image 2C)

Type Locality: India, West Bengal.

Diagnosis: HB 51–71 mm, FA 47–60 mm, T 55–76 mm and W 11–14 g. Size intermediate between greater and small mouse-tailed bats; tail longer than forearm; calcar absent; dermal ridge on muzzle trigonid and more pronounced than in *R. muscatellum* Thomas, 1903; hairs pale grey brown on back, paler on the chest and belly; teeth 28; color similar to *R. muscatellum*, paler than *R. microphyllum* (Brünnich, 1782); nasal inflations not as developed as in *R. muscatellum*.

Distribution: Fig. 2 (10, 11, 18, 27, 30).

Conservation status: IUCN: Least Concern; CITES: not listed; DOE: unsupported.

***Rhinopoma microphyllum* (Brünnich, 1782)** - Greater Mouse-tailed Bat

Type Locality: Egypt, Giza.

Diagnosis: HB 61–102 mm, FA 59–70 mm, T 30–63 mm and W 14–37 g. The largest mouse-tailed bat; tail shorter than forearm; calcar absent; tragus long and bluntly sickle-shaped; feet slender, but larger than those of other two species of *Rhinopoma*; interfemoral membrane small, posterior border slightly concave and inserted on each tibia distally at about three-quarters of its length; face, lips and upper throat nearly naked; lower back and extreme lower abdomen also naked; back hair pale greyish-brown, slightly paler below; sagittal crest much more developed than that of *R. hardwickii*; teeth 28.

Comments: Akmali et al. (2011) concluded that the Iranian specimens belong to *R. m. harrisoni* Schlitter & DeBlase, 1974.

Distribution: Fig. 2 (7, 10, 18, 26, 27, 29, 30).

Conservation status: IUCN: Least Concern; CITES: not listed; DOE: unsupported.

***Rhinopoma muscatellum* Thomas, 1903** - Small Mouse-tailed Bat

Type Locality: Oman, Muscat, Wadi Bani Ruha.

Diagnosis: HB 47–69 mm, FA 42–54 mm, T 43–70 mm and W 8–15 g. The smallest mouse-tailed bat of Iran, some overlap in size with the smaller specimens of *R. hardwickii*; tail longer than forearm; calcar absent; muzzle dermal ridge low, may be flat-topped or with a slight median depression; feet slender and small; teeth 28; pelage fine and silky; back hairs pale grey brown, paler on abdomen and chest; tympanic bullae relatively larger than in other two mouse-tailed bats of Iran.

Distribution: Fig. 2 (10, 18, 26, 27, 29, 30).

Conservation status: IUCN: Least Concern; CITES: not listed; DOE: unsupported.

Genus *Rhinolophus* Lacépède, 1799

***Rhinolophus blasii* Peters, 1867** - Blasius's Hoseshoe Bat

Type Locality: Italy, Milan and Triest.

Diagnosis: HB 46–54 mm, FA 40–51 mm, T 25–30 mm and W 12–15 g. Size medium; upper connecting process straight and pointed, not bent down; lower connecting process shorter, narrow and rounded; horizontal fold slightly indented in centre; ears and membranes light grey; dorsal fur grey brown, sometimes with lilac tinge; ventral fur lighter; second phalanx of the fourth finger not more than twice as long as the first phalanx.

Distribution: Fig. 2 (1, 2, 5, 10, 12, 17, 19, 21, 22, 23, 24, 25, 27, 28, 29).

Conservation status: IUCN: Least Concern; CITES: not listed; DOE: unsupported.

***Rhinolophus euryale* Blasius, 1853** - Mediterranean Horseshoe Bat (Image 2D)

Type Locality: Italy, Milan.

Diagnosis: HB 43–58 mm, FA 43–51 mm, T 22–30 mm and W 8–17.5 g. Size medium; upper connecting process pointed, bent slightly downwards; lower connecting process shorter; ears and membranes light grey; fur grey-brown with reddish or lilac tinge above, grey white

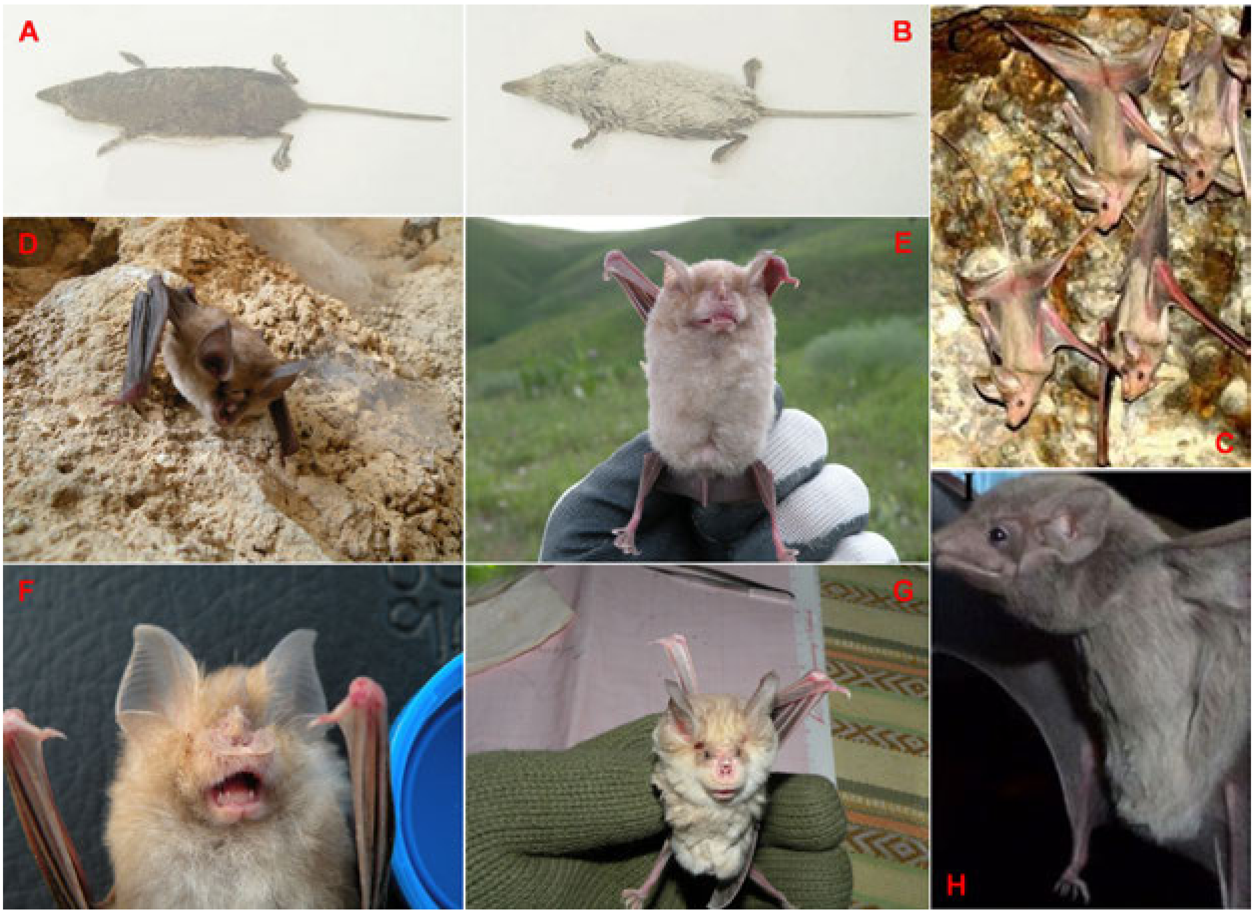

Image 2. A & B - *Neomys anomalus* (dorsal and ventral views); C - *Rhinopoma hardwickii*; D - *Rhinolophus euryale*; E - *Rhinolophus ferrumequinum*; F - *Rhinolophus hipposideros*; G - *Rhinolophus mehelyi*; H - *Taphozous perforatus*. © H.R. Esmaeili & V. Akmali.

below; second phalanx of the fourth finger more than twice as long as the first phalanx; may hibernate with open wings.

Distribution: Fig. 2 (1, 4, 7, 8, 11, 16, 19, 20, 21, 23, 27).

Conservation status: IUCN: Near Threatened; CITES: not listed; DOE: unsupported.

***Rhinolophus ferrumequinum* (Schreber, 1774)** - Greater Horseshoe Bat (Image 2E)

Type Locality: France.

Diagnosis: HB 54–71 mm, FA 51–61 mm, T 31–44 mm and W 13–34 g. Largest horseshoe bat; horseshoe relatively narrow and does not cover the whole muzzle; sella relatively small, constricted in the middle, widened below and narrowed above; lower connecting process pointed; upper connecting process short, bluntly rounded; lancet hastate, tip long and slender; third metacarpal short; in the nominate subspecies, ears and membranes light grey-brown, juveniles distinctly greyer; *Rhinolophus ferrumequinum irani* paler; pale fawn above, the hair bases pale drab darkening to pale fawn at the tip; underparts pale drab; wraps itself completely in wing membranes when torpid.

Comments: Shahabi et al. (2017) concluded that two subspecies are found in Iran, *R. f. irani* (Type locality: Iran, Fars Province, Shiraz) in southern Iran and *R. f. proximus* in northern Iran.

Distribution: Fig. 2 (1, 2, 3, 4, 5, 6, 7, 11, 12, 15, 17, 19, 21, 23, 26, 27, 28).

Conservation status: IUCN: Least Concern; CITES: not listed; DOE: unsupported.

***Rhinolophus hipposideros* (Bechstein, 1800)** - Lesser Horseshoe Bat (Image 2F)

Type Locality: France.

Diagnosis: HB 37–45 mm, FA 34–42 mm, T 23–33 mm and W 59g. Smallest horseshoe bat; upper connecting process rounded; lower connecting process longer and pointed; fur soft and fluffy, grey-brown on dorsal surface and lighter underneath; all fur on youngsters body gray; wraps its wings completely around the body when torpid.

Distribution: Fig. 2 (1, 3, 4, 5, 6, 7, 10, 11, 12, 15, 19, 23, 27, 30).

Conservation status: IUCN: Least Concern; CITES: not listed; DOE: unsupported.

Rhinolophus mehelyi **Matschie, 1901** - Mehely's Horseshoe Bat (Image 2G)

Type Locality: Romania, Bucharest.

Diagnosis: HB 42–64 mm, FA 48–56 mm, T 21–37 mm and W 10–23 g. Slightly larger than *R. blasii* and *R. euryale*; upper connecting process relatively blunt, slightly longer than the lower; lower connecting process wide and rounded from front view; lancet tapers rapidly in upper half; fur grey-brown above, almost white below; ears and membranes light grey; second phalanx of fourth finger more than twice as long as first phalanx.

Distribution: Fig. 2 (1, 4, 7, 19, 27).

Conservation status: IUCN: Vulnerable; CITES: not listed; DOE: unsupported.

Family Emballonuridae Gervais, 1855

Genus *Taphozous* Geoffroy, 1818

Taphozous perforatus **Geoffroy, 1818** - Egyptian Tomb Bat (Image 2H)

Type Locality: Egypt, Kom Ombo.

Diagnosis: HB 56–73 mm, FA 58–66 mm, T 14–28 mm and W 20–30 g. Morphologically similar to *Taphozous nudiventris* but distinctly smaller and fully covered with soft and silky fur on both dorsal and ventral surfaces, down to the root of the tail; dorsal hairs bicoloured with white bases and sepia brown tips; ventral side grey or greyish-brown; gular sac abscent; the ears tall and narrow with about 10 transverse ridges; tragus club-shaped; the tail protrudes through the donsal surface of the interfemoral membrane at the mid-point; less-developed calcar than *T. nudiventris*; the wings are long and narrow and the membranes are brownish; a well-developed pouch of skin on the ventral side of the carpus, between the base of fifth finger and the forearm; the braincase smooth, lacking the powerful sagittal crest of *T. nudiventris*; the upper incisor minute; the second upper premolar attains the height of the canine.

Comments: The Jahrom record (Fars Province) represents one of the northernmost sites of *T. perforatus* in the Asian part of the species range (Benda et al. 2012a).

Distribution: Fig. 2 (27, 30).

Conservation status: IUCN: Least Concern; CITES: not listed; DOE: unsupported.

Family Hipposideridae Lydekker, 1891

Genus *Asellia* Gray, 1838

Asellia tridens **(Geoffroy, 1813)** - Geoffroy's Trident Leaf-nosed Bat

Type Locality: Egypt, Thebes.

Diagnosis: HB 50–62 mm, FA 44–54 mm, T 21–30 mm and W 6–13 g. Size small; the nose leaf with three distinctive vertical processes above the horseshoe; central process pointed, outer two blunt, tail protruding 3–5 mm beyond the interfemural membrane; ears fairly large, with a very convex outer margin; fur soft, fluffy and dense, variable from reddish or bright orange to pale brownish-grey or pale yellow on the back, paler whitish buff on the belly; small upper premolar absent.

Distribution: Fig. 2 (10, 18, 26, 27, 28, 29, 30).

Conservation status: IUCN: Least Concern; CITES: not listed; DOE: unsupported.

Genus *Triaenops* Dobson, 1871

Triaenops persicus **Dobson, 1871** - Persian Leaf-nosed Bat

Type locality: Iran, Fars Province, Shiraz.

Diagnosis: HB 51–64 mm, FA 49–55 mm, T 31–39 mm and W 8–15 g. Slightly larger than *Asellia tridens*; tail tip does not protrude from the interfemoral membrane; pinna with a conspicuous notch on the inner margin; color light grey brown on the back and pale buff on the belly; some individuals tinted with orange-red; noseleaf with three long vertical projections, fourth one projects from the centre; second phalanx of the fourth digit with a spicule of bone projecting transversely into the wing membrane; a small first upper premolar present.

Distribution: Fig. 2 (26, 27, 29).

Conservation status: IUCN: Least Concern; CITES: not listed; DOE: unsupported.

Family Vespertilionidae Gray, 1821

Genus *Eptesicus* Rafinesque, 1820

Eptesicus serotinus **(Schreber, 1774)** - Common Serotine

Type Locality: France.

Diagnosis: HB 66–92 mm, FA 46–58 mm, T 47–56 mm and W 18–35 g. Size large; snout broad; face and ears black-brown; ears moderately tall (14–22 mm), with broad tragus less than half the height of the ear; dorsal fur long (11mm) and silky; hairs dark brown at base, with shiny lighter tips, golden brown in some populations; ventral fur lighter, yellow-brown or grey-brown, with no distinct demarcation along the neck; tail tip protrudes from interfemoral membrane by 5–6 mm; calcar half-length of tail membrane; narrow postcalcarial lobe present; wings broad (5th finger longer than 59mm); upper tooth-row (CM^3) more than 72mm; southwestern form of the country larger than northern forms, northwestern form darker than southwestern and northeastern forms.

Comments: Except an isolate from Fars Province (*E. s. shiraziensis*.

Type locality: Shiraz, Fars Province, Iran), DeBlase (1980) assigned most of the records from Iran to the nominate subspecies.

Distribution: Fig. 2 (1, 3, 5, 6, 9, 14, 15, 16, 17, 24, 27).

Conservation status: IUCN: Least Concern; CITES: not listed; DOE: unsupported.

***Eptesicus anatolicus* Felten, 1971** - Anatolian Serotine

Type Locality: Turkey, Alanya.

Diagnosis: HB 61–77 mm, FA 43–52 mm, T 42–59 mm and W 14–21 g. A medium-sized serotine, smaller than *E. serotinus* (Schreber, 1774) but larger than *E. bottae* (Peters, 1869); snout shorter and tragus narrower than in *E. serotinus*; face, ears and flight membranes deep black and in contrast with the paler fur; dorsal hairs shorter (8.5mm) than in *E. serotinus*, bicolored with brown base and honey to blond tips; ventral fur whitish-grey; youngsters darker with more grey shades and a less strongly contrasting ventral side; penis broader at the tip; skull wider, braincase higher than that of *E. bottae*; upper tooth-row (CM^3) less than 7mm; second upper incisors small, barely taller than the cingulum on the first incisors.

Comments: DeBlase (1980) reported one site, Darab, Fars Province; Benda et al. (2012a) added further records from Jahrom, Fars Province, southern Iran.

Distribution: Fig. 2 (7, 11, 18, 20, 27, 28).

Conservation status: IUCN: Not Evaluated; CITES: not listed; DOE: unsupported.

Genus *Nyctalus* Bowdich, 1825

***Nyctalus leisleri* (Kuhl, 1817)** - Leisler's Noctule

Type Locality: Germany, Hessen, Hanau.

Diagnosis: HB 48–72 mm, FA 47mm, T 35–48 mm and W 8–20 g. Size medium; similar to *N. noctula* (Schreber, 1774), but smaller and darker with a more pointed nose; tragus short, broad, and mushroom shaped, distally; long fur dark rufous brown on the back, lighter yellowish brown on the ventral; dorsal fur bicolored, hairs with a darker base; ears, nose and membranes dark brown to black; underside of the wing membranes covered with hairs along the body and up along the arms to the fifth finger; tail membrane extends to the ankles with well-developed calcars; tail short and barely protrudes beyond the membrane.

Distribution: Fig. 2 (2, 15, 16, 23, 27).

Conservation status: IUCN: Least Concern; CITES: not listed; DOE: unsupported.

Genus *Pipistrellus* Kaup, 1829

***Pipistrellus kuhlii* (Kuhl, 1817)** - Kuhl's Pipistrelle

Type Locality: Italy, Triest.

Diagnosis: HB 39–55 mm, FA 30–36 mm, T 30–45 mm and W 5–10 g. Size small, larger than *P. pipistrellus* (Schreber, 1774); dorsal fur bicolored, dark at base and lighter yellowish-brown at tips; free edge of the wing and tail membrane, particularly between the fifth digit and foot, with a white edge of variable width; ears small, with five transverse folds; tragus rounded, but not wider at the tip; first upper incisors with single cusp, second upper incisors very small; first upper premolars (p^3) very small, displaced inside tooth row.

Distribution: Fig. 2 (1, 2, 3, 5, 6, 7, 10, 11, 14, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30).

Conservation status: IUCN: Least Concern; CITES: not listed; DOE: unsupported.

***Pipistrellus pipistrellus* (Schreber, 1774)** - Common Pipistrelle

Type Locality: France, Normandy, Beauvais Cathedral.

Diagnosis: HB 36–51 mm, FA 28–34 mm, T 23–36 mm and W 4–8 g. Size small; face and ears dark brown to black, contrasting with the fur, chestnut to dark brown on the back and grey-brown on ventral side; internarial ridge absent; tragus half-length of ear, smoothly curved with round tip; tail membrane with no hair; fifth digit less than 42mm; calcar one third of interfemoral membrane; postcalcarial lobe obvious; penis gray; glans penis with a pale median stripe; first upper incisors bicuspid; second upper incisors as high as the secondary cusp of first incisors; first upper premolars (p^3) small and partially concealed by canine, when viewed from the side.

Comments: Iranian specimens assigned to two subspecies, *P. p. pipistrellus* (Schreber, 1774) in north and *P. p. aladdin* Thomas, 1905 in west, southwest and northeast (DeBlase 1980). A molecular study failed to support this taxonomic division (Hulva et al. 2004).

Distribution: Fig. 2 (1, 2, 3, 5, 6, 7, 10, 11, 15, 16, 17, 19, 21, 23, 24, 27, 28, 30).

Conservation status: IUCN: Least Concern; CITES: not listed; DOE: unsupported.

Genus *Hypsugo* Kolenati, 1856

***Hypsugo savii* (Bonaparte, 1837)** - Savi's Pipistrelle

Type Locality: Italy, Pisa.

Diagnosis: HB 40–54 mm, FA 32–38 mm, T 31–43 mm and W 5–10 g. Size small; dorsal fur long and silky; hairs bicolored, dark bases and tips may vary between pale and dark buff; ventral fur lighter, greyish-brown bases and yellowish-white to silver tips; no distinct line of demarcation along the neck; membranes, face and ears very dark; calcar poorly developed; postcalcarial lobe narrow; tip of tail projects about 3mm beyond interfemoral membrane; first upper incisor bicuspid, with secondary cusp about three-quarters the height of the principal one; first upper premolar (p^3) small, or even absent, and hidden by the canine and large upper premolar.

Distribution: Fig. 2 (1, 2, 3, 4, 6, 14, 15, 17, 19, 23, 24, 27, 29).

Conservation status: IUCN: Least Concern; CITES: not listed; DOE: unsupported.

Genus *Myotis* Kaup, 1829

***Myotis blythii* (Tomes, 1857)** - Lesser Mouse-eared Myotis

Type Locality: India, Rajasthan, Nasirabad.

Diagnosis: HB 68–81 mm, FA 54–68 mm, T 49–71 mm and W 18–30 g. Largest myotis in Iran, distinguishable from other members based on forearm length; size cline in cranial measurements, culminating in west Iran; ears slightly shorter (22–29 mm) and narrower than in *M. myotis* (Borkhausen, 1797), with five to six folds along the outer edge; nose narrower and more pointed; feet smaller; thumb long measuring 11.5mm with the claw; tail relatively long; skull shorter but broader; cheek teeth smaller in breadth; color paler than *M. oxygnathus* Monticelli, 1885; dorsal fur uniform pale wood brown to dull grey; ventral fur lighter and broadly washed with cream buff.

Comments: For its parasites in Iran, see Sharifi et al. (2008), Vatandoost et al. (2010), and Hemmati et al. (2013).

Distribution: Fig. 2 (1, 2, 3, 4, 5, 6, 7, 10, 11, 12, 14, 15, 16, 18, 19, 21, 23, 27, 27, 30).

Conservation status: IUCN: Least Concern; CITES: not listed; DOE: unsupported.

***Myotis capaccinii* (Bonaparte, 1837)** - Long-fingered Myotis

Type Locality: Italy, Sicily.

Diagnosis: HB 42–57 mm, FA 38–44 mm, T 35–47 mm and W 7–10 g. A medium-sized myotis with large and strong feet with long bristles; nostrils markedly protrude forward; dorsal fur and wing membrane grey; ventral fur light grey or white; youngsters inconspicuously grey; face reddish-brown; ears and membranes grey; ears length medium (14–17 mm); tragus lanceolate, slightly S-shaped, reaching about half the height of the ear; wing membrane attached to tibia above ankle; dorsal and ventral sides of interfemoral membrane covered with downy hair to about centre; calcar straight, extending to one third of the interfemoral membrane.

Diagnosis: Fig. 2 (5, 7, 18, 27).

Conservation status: IUCN: Vulnerable; CITES: not listed; DOE: unsupported.

***Myotis emarginatus* (Geoffroy, 1806)** - Geoffroy's Myotis

Type Locality: France, Ardennes, Charlemont.

Diagnosis: HB 41–56 mm, PA 36–44 mm, T 38–52 mm and W 7–15 g. Size medium; ear length medium (17–20 mm), with a distinct notch at about two-thirds height; tragus pointed and more than half the length of the ear; fur dense and wooly; dorsal hairs tricolored, with a grey base, buff centre section and orange-brown tips; ventral fur yellow-grey; face, ears and membranes reddish-brown; calcar about half length of interfemoral membrane, fringed with short and soft hairs; individuals from southeast of Iran slightly larger and lighter.

Comments: Iranian populations assigned to *M. e. desertorum* (Benda et al. 2006).

Distribution: Fig. 2 (1, 7, 9, 12, 14, 15, 16, 23, 26, 27, 29, 30).

Conservation status: IUCN: Least Concern; CITES: not listed; DOE: unsupported.

Family Miniopteridae Dobson, 1875

Genus *Miniopterus* Bonaparte, 1837

***Miniopterus pallidus* Thomas, 1907**– Pale Bent-winged Bat

Type Locality: Iran, Golestan Province, near Bandar-i-Gaz.

Diagnosis: HB 58–67 mm, FA 43–48 mm, T 56–66 mm, W 10–19 g. Size medium; snout short (CM^3 less than 6.2mm); forehead high domed; baculum absent; ears short (9–12 mm) and triangular, widely separated and not projecting above the top of the head; tragus short and curved, with a round tip; head and dorsal fur greyish-brown, paler and greyer than *M. schreibersii* (Kuhl, 1817); ventral side greyish-white; no demarcation line along the sides of the neck; wings long and narrow, with the second phalanx of the third finger about three times as long as the first phalanx; at rest, the third and fourth fingers fold inwards at the joint between the first and second phalanx; tail very long; calcar reaches less than half the length of the interfemoral membrane; postcalcarial lobe absent; teeth 38; vestigial anterior premolar typical of the family.

Comments: The elevation of traditional subspecies *M. s. pallidus* Thomas, 1907 to full separate species status is confirmed by recent genetic and biogeographic studies and all Iranian populations affiliate taxonomically to it (Furman et al. 2010; Karami et al. 2016).

Distribution: Fig. 2 (1, 2, 3, 4, 5, 7, 8, 10, 11, 12, 16, 19, 23, 25, 27).

Conservation status: IUCN: Not Evaluated; CITES: not listed; DOE: unsupported.

Family Molossidae Gervais in de Castelnau, 1855

Genus *Tadarida* Rafinesque, 1814

***Tadarida teniotis* (Rafinesque, 1814)** - European Free-tailed Bat

Type Locality: Italy, Sicily.

Diagnosis: HB 81–92 mm, FA 57–64 mm, T 37–57 mm and W 22–54 g. Size large; ears long broad (25–32 mm), extend forward over the muzzle; tragus small rounded; antitragus large, rectangular; muzzle with five folds each side of the upper lip; half the tail projects beyond the free edge of the interfemoral membrane; fur short, soft and velvety; hairs dark grey on the back and lighter underneath.

Distribution: Fig. 2 (3, 6, 7, 11, 14, 15, 16, 18, 23, 26, 27, 28, 30).

Conservation status: IUCN: Least Concern; CITES: not listed; DOE: unsupported.

Order Carnivora Bowdich, 1821

Family Canidae Fischer de Waldheim, 1817

Genus *Canis* Linnaeus, 1758

***Canis aureus* Linnaeus, 1758** - Golden Jackal (Image 3A)

Type Locality: Iran, Lorestan Province, Benna Mountains.

Diagnosis: HB 75–105 cm, T 20–26 cm, SH 40–50 cm and W 7–15 kg. Larger than the Common Fox (*Vulpes vulpes* (Linnaeus, 1758)); muzzle narrow; ears big; tail bushy and short with a dark tip; tail and dorsal brownish-gray with black stripes, flanks tawny and ventral buff and white; areas around the lips, cheeks and throat white; five toes on the forefeet with the first inner finger being above the others; four toes on the hind feet.

Comments: Iranian specimens belong to the nominate subspecies (Ellerman & Morrison-Scott 1951).

Distribution: Fig. 2 (all provinces).

Conservation status: IUCN: Least Concern; CITES: Appendix III; DOE: unsupported.

***Canis lupus* Linnaeus, 1758** - Gray Wolf

Type Locality: Sweden.

Diagnosis: HB 90–130 cm, T 30–50 cm, SH 65–80 cm and W 20–80 kg. Largest wild canid in Iran; head large and wider; eyes oblique; neck heavily muscled, and held level with the spine; contrary to domestic dog does not raise its tail; muzzle long and powerful; fur composed of a thick undercoat and long coarse guard hairs; fur usually grey but sometimes whitish, buff, fawn or dark grey; tail bushy, black tipped with black hairs.

Comments: *Canis lupus pallipes* Sykes, 1831 is the suggested Iranian subspecies (Ellerman & Morrison-Scott 1951). Iranian populations are uniform in the size and shape of skull (Khosravi et al. 2012). Khosravi et al. (2013) and Aghbolaghi et al. (2014) concluded that hybridization between *C. l. pallipes* and *C. familiaris* (Linnaeus, 1758) is sporadic in the country and can be a threat to wolf populations.

Distribution: Fig. 2 (all provinces).

Conservation status: IUCN: Least Concern; CITES: Appendix II; DOE: unsupported.

Genus *Vulpes* Frisch, 1775

***Vulpes cana* Blanford, 1877** - Blanford's Fox

Type Locality: Pakistan, Gwadar.

Diagnosis: HB 34–47 cm, T 26–36 cm, SH 26–28 cm and W 0.7–1.6 kg. Distinguished from other foxes by its dark fur, large and bushy tail (as big as the animal itself) which is not white-tipped; ears wide and elongated; muzzle short; dorsal fur thick and brown-gray, interspersed with long black guard hairs; ventral dark yellow; head and neck gray; black tear lines run from the internal corner of the eye to the muzzle.

Comments: Lay (1967) reported specimens from Fars Province.

Distribution: Fig. 2 (10, 12, 21, 22, 24, 25, 27, 29).

Conservation status: IUCN: Least Concern; CITES: Appendix II; DOE: Endangered.

***Vulpes rueppellii* (Schinz, 1825)** - Rüppell's Fox

Type Locality: Sudan, Dongola.

Diagnosis: HB 35–56 cm, T 25–39 cm, SH 25–30 cm and W 1.1–2.3 kg. Head, body and tail shorter than those of the common fox, but ears larger and wider; digitigrade; soles of the feet fully covered with hair; fore and hind feet relatively short; fur soft and dense, sandy or yellowish light orange, becoming grayish dark brown on the upper side and turning to white on the lower parts; tail slightly darker than the body and is white-tipped; sides of the face and cheeks white; a dark tear-line runs from the corner of the eye to the mouth.

Comments: Iranian subspecies is *V. r. zarudnyi* Birula, 1912 (Ellerman & Morrison-Scott 1951).

Distribution: Fig. 2 (13, 21, 22, 23, 24, 26, 29, 30).

Conservation status: IUCN: Least Concern; CITES: not listed; DOE: Protected.

Vulpes vulpes **(Linnaeus, 1758)** - Red Fox

Type Locality: Sweden, Uppsala.

Diagnosis: HB 50–90 cm, T 30–50 cm, SH 35–45 cm and W 2.5–10 kg. Body medium sized; muzzle slender; ears long and pointed; tail long, bushy and white-tipped; coat varies from brownish-gray or reddish-brown to light cream; ventral lighter than the dorsal and creamy; backs of the ears black or brown; lips, face sides and cheek white; a black tear-line runs from the eyes to the mouth.

Comments: Iranian specimens assigned to three subspecies, *V. v. pusilla* Blyth, 1854, *V. v. flavescens* Gray, 1843 and *V. v. splendens* Thomas, 1902 (Witt & Deblase 1983).

Distribution: Fig. 2 (all provinces).

Conservation status: IUCN: Least Concern; CITES: Appendix III; DOE: unsupported.

Family Felidae Fischer von Waldheim, 1817

Genus *Caracal* Gray, 1843

Caracal caracal **(Schreber, 1776)** – Caracal (Image 3B)

Type Locality: South Africa, Table Mountain near Cape Town.

Diagnosis: HB 55–90 cm, T 22–34 cm, SH 40–50 cm and W 18kg. Female relatively smaller; slender, yet muscular with long, triangular ears with highly developed apical black tufts (almost 6cm); limbs long and slender; tail medium without a black tip; footpads wide; pelage uniform light sandy brown to a darker red-brown on the back; ventral and areas around the eyes and under the chin white; no pattern or spots on the body.

Comments: Suggested subspecies in Iran are *C. c. schmitzi* (Matschie, 1912) and *C. c. michaelis* (Heptner, 1945). *Caracal c. michaelis* is restricted to the northeast of Iran (Ellerman & Morrison-Scott 1951; Witt & Deblase 1983; Etemad 1985; Nowell & Jackson 1996; Farhadinia et al. 2007; Karami et al. 2008).

Distribution: Fig. 2 (7, 10, 11, 14, 17, 18, 21, 22, 23, 24, 27, 28, 29).

Conservation status: IUCN: Least Concern; CITES: Appendix I; DOE: Protected.

Genus *Felis* Linnaeus, 1758

Felis chaus **Schreber, 1777** - Jungle Cat

Type Locality: Russia, NE Caucasus, Dagestan, Terek River.

Diagnosis: HB 55–94 cm, T 20–31 cm, SH 35–40 cm and W 5–12 kg. Larger than the wildcat; pelage grey to brownish-red with no distinctive marking on the body, except for occasional dark bands or spots on the limbs; tail tip with 2–3 black rings.

Comments: *Felis chaus chaus* Schreber, 1777 occurs in Iran (Ellerman & Morrison-Scott 1951).

Distribution: Fig. 2 (1, 2, 3, 4, 6, 7, 8, 9, 10, 15, 16, 17, 18, 23, 24, 26, 27, 28, 29, 30).

Conservation status: IUCN: Least Concern; CITES: Appendix II; DOE: Protected.

Felis margarita **Loche, 1858** - Sand Cat

Type Locality: Algeria.

Diagnosis: HB 39–57 cm, T 28–35 cm, SH 24–30 cm and W 1.3–3.4 kg. Fur pale sandy to yellow over most of the body, with pallid bars, and white on the chin and ventral; black tipped tail with 2–3 black bands; two reddish lines run across the cheeks from the outer corners of the eyes; long hairs growing between toes that create a cushion of fur under the footpads; ears large and widely spaced.

Comments: Suggested subspecies in Iran is *F. m. thinobius* (Ognev, 1926).

Distribution: Fig. 2 (21, 22, 23, 24, 25, 27, 29).

Conservation status: IUCN: Least Concern; CITES: Appendix II; DOE: Endangered.

Felis silvestris **Schreber, 1777** - Wild Cat

Type Locality: Germany.

Diagnosis: HB 50–80 cm, T 25–35 cm, SH 30–40 cm and W 3–6 kg. Tail long and bushy with widened black tip; muzzle short; eyes large; ears large and triangular shaped; fore and hind feet long and slender; body brown to grey; well-pronounced spots present on the body; body larger than that of a domestic cat, with more spots.

Distribution: Fig. 2 (all provinces).

Conservation status: IUCN: Least Concern; CITES: Appendix II; DOE: unsupported.

Genus *Panthera* Oken, 1816

Panthera pardus **(Linnaeus, 1758)** – Leopard (Image 3C)

Type Locality: Egypt.

Diagnosis: HB 110–180 cm, T 60–100 cm, SH 45–78 cm and W 35–90 kg. Body large and muscular; head wide; legs short with strong paws; fur soft and short,

Image 3. A - *Canis aureus*; B - *Caracal caracal*; C - *Panthera pardus saxicolor*; D - *Hyaena hyaena*; E - *Ursus arctos*; F - *Equus hemionus onager* photographed in the Qatruiyeh National Park east of Fars Province. © S. Kafaei.

light buff, become lighter under the belly and covered with spots, or rosettes.

Comments: Iranian subspecies is *P. p. saxicolor* Pocock, 1927. Iranian lineage is a monophyletic group that diverged from a group of the Asian leopards in the second half of the Pleistocene (Farhadinia et al. 2015).

Distribution: Fig. 2 (all provinces). Although the species has a wide distribution in Iran, it has a low abundance. In Bamu National Park, seven adult leopards were identified and a density of 1.9 leopards/ 100km^2 was estimated (Khorozyan 2008).

Conservation status: IUCN: Vulnerable; CITES: Appendix I; DOE: Protected.

Family Herpestidae Bonaparte, 1845

Genus *Herpestes* Illiger, 1811

***Herpestes edwardsii* (Geoffroy, 1818)** - Indian Gray Mongoose (Image 4A)

Type Locality: India, Madras.

Diagnosis: HB 32–48 cm, T 30–45 cm, HF 6.5–8 cm, E 1.5–2.5 cm and W 1.4–2 kg. Males larger; body long and slender; tail long covered with coarse hairs; ears

Image 4. A - *Herpestes javanicus*; B - *Sciurus anomalus*. © S. Kafaei.

round and small; fore and hind limbs short with long non-retractable and strong claws; snout elongated and pointed; eyes small; body covered with long and dense hairs which are light brown to red fawn on the back and lighter on the belly; tail color similar to that of the body with a dark reddish tip.

Comments: Khoobdel et al. (2016) documented the negative impacts of introduced *H. edwardsii* on biodiversity in the Abu-Musa Island, southern Iran.

Distribution: Fig. 2 (21, 27, 28, 29, 30).

Conservation status: IUCN: Least Concern; CITES: Appendix III; DOE: unsupported.

***Herpestes javanicus* (Geoffroy, 1818)** - Small Asian Mongoose

Type Locality: Indonesia, Java.

Diagnosis: HB 22–46 cm, T 22–29 cm, HF 4.4–5.2 cm, E 2–2.5 cm and W 0.3–1 kg. Male somewhat bigger with a wider head; distinguished from *H. Edwardsii* by its smaller size and less dense hair; head elongated; ears short; body slender; legs short; plantigrade with five toes on both front and hind legs; the soles of the front and hind feet naked and dark; body and tail grayish-brown spotted with small golden or olive dots; fur under the chin and throat creamy-buff; eyes relatively small with a brown ocular ring.

Distribution: Fig. 2 (18, 27).

Conservation status: IUCN: Least Concern; CITES: Appendix III; DOE: unsupported.

Family Hyaenidae Gray, 1821

Genus *Hyaena* Brisson, 1762

***Hyaena hyaena* (Linnaeus, 1758)** - Striped Hyena (Image 3D)

Type Locality: Iran, Lorestan Province, Benna Mountains.

Diagnosis: HB 112–184 cm, T 25–47 cm, SH 60–94 cm, and W 25–55 kg. Head and jaws large; ears long and narrow with bluntly pointed tips; neck bent downwards; forelimbs longer and stronger than the hind limbs; tail length medium, covered with long hair; a dense, tall mane extends from the back of the head to the beginning of the tail; pelage creamy white to gray with black or dark brown stripes; snout and around the eyes black; a black patch present on the throat; dorsal hair long, dense and gray in winter; digitigrade with four toes on the front and hind legs; moves the front and hind limb of each side of the body simultaneously while walking.

Distribution: Fig. 2 (5, 6, 7, 9, 10, 14, 16, 17, 18, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30).

Conservation status: IUCN: Near Threatened; CITES: Appendix III; DOE: unsupported.

Image 5. Roadkill *Lutra lutra:* A - lateral side of the head; B - ventral side of the head; C & D - foot; E - drop; F - habitat. © H.R. Esmaeili.

Family Mustelidae Fischer de Waldheim, 1817

Genus *Lutra* Brünnich, 1771

***Lutra lutra* (Linnaeus, 1758)** - European Otter (Image 5)

Type Locality: Sweden, Uppsala.

Diagnosis: HB 60–90 cm, T 35–55 cm, HF 9–13 cm, E 2–3 cm, SH 30cm, and W 5–17 kg. Males larger; body long, slender and sinuous; head flattened with a short, blunt muzzle; neck ill-defined; vibrissae long and sensitive; eyes small; ears low and inconspicuous, scarcely projecting above the fur; tail thickened and muscular at the base, tapering sharply to the tip; limbs very short with broad feet and extensive interdigital webs that together with the tail; hair soft and dense, brown to grayish brown on the body and white under the chin and throat.

Distribution: Fig. 2 (1, 2, 3, 4, 6, 7, 8, 9, 10, 11, 14, 15, 16, 18, 19, 20, 26, 27).

Conservation status: IUCN: Near Threatened; CITES: Appendix I; DOE: unsupported.

Genus *Martes* Pinel, 1792

***Martes foina* (Erxleben, 1777)** - Beech Marten, Stone Marten

Type Locality: Germany.

Diagnosis: HB 40–54 cm, T 22–30 cm, HF 8–9 cm, E 3–5 cm, and W 1.1–2.3 kg. A cat-size mustelid; fur dark brown to pale grayish-brown; a wide white patch starts from the chin and continues under the neck to the throat and then forks down and continues towards the forelimbs; dorsal fur in youngsters covered with grey hairs; body slender with a long and bushy tail and naked feet; tail longer and the pelt coarser than *Martes martes* (Linnaeus, 1758).

Distribution: Fig. 2 (1, 9, 10, 14, 15, 16, 17, 19, 20, 26, 27, 28, 29, 30).

Conservation status: IUCN: Least Concern; CITES: Appendix III; DOE: unsupported.

Genus *Meles* Brisson, 1762

***Meles meles* (Linnaeus, 1758)** - Eurasian Badger

Type Locality: Sweden, Uppsala.

Diagnosis: HB 56–90 cm, T 15–20 cm, HF 9–11 cm, E 3–5.5 cm, SH 30cm and W 10–16 kg. Head small; tail short and thick, snout narrow; ears small but quite visible; neck short; limbs short and strong; feet bottoms covered with soft hairs; claws on the forelimbs strong, elongated with an obtuse end; back and flanks fur long and coarse, generally silvery-gray; belly and legs black; two black bands pass along the head, starting from the upper lip and passing upwards to the base of the ears; a wide white band extends between the two dark bands, from the nose tip through the forehead and crown.

Distribution: Fig. 2 (2, 3, 4, 5, 6, 9, 11, 14, 15, 16, 19, 21, 23, 27).

Conservation status: IUCN: Least Concern; CITES: not listed; DOE: unsupported.

Genus *Mellivora* Storr, 1780

***Mellivora capensis* (Schreber, 1776)** - Honey Badger

Type Locality: South Africa, Western Cape Province, Cape of Good Hope.

Diagnosis: HB 55–80 cm, T 16–23 cm, SH 23–28 cm, and W 5.5–14 kg. Males larger; upper side of the body lighter than lower; body black except for a large white band that covers the upper body, beginning at the top of the heads and extending to the base of the tails; upper band becomes darker with age; hair coarse and longer on hind legs and tail; the fore claws length may reach 40mm.

Comments: Three subspecies occur in Iran, *M. c. wilsoni* Cheesman, 1920, *M. c. indica* (Kerr, 1792) and *M. c. buechneri* Baryshnikov, 2000 (Baryshnikov 2000; Etemad 1985).

Distribution: Fig. 2 (16, 18, 24, 27, 28).

Conservation status: IUCN: Least Concern; CITES: Appendix III; DOE: unsupported.

Family Ursidae Fischer de Waldheim, 1817

Genus *Ursus* Linnaeus, 1758

***Ursus arctos* Linnaeus, 1758** - Brown Bear (Image 3E)

Type Locality: Northern Sweden.

Diagnosis: HB 140–250 cm, T 6–14 cm, SH 90–110 cm, and W 100–250 kg. Male larger; head large; ears small and round; eyes small; tail very short; body covered with a dense, brown and sometimes darker or lighten fur; cubs dark brown with a lighter spot on the chest; plantigrade with five toes, with long and strong nails on fore and hind feet.

Comments: Etemad (1985) listed two subspecies, *U. a. syriacus* Hemprich & Ehrenberg, 1828 and *U. a. caucasicus* Smirnov, 1919, but Wozencraft (2005) synonymized them. Genetic analyses revealed a major clade within the Iranian Brown Bears, comprising 2–3 subclades, northern Iran, western Iran, and Fars Province subclade (Ashrafzadeh et al. 2016).

Distribution: Fig. 2 (1, 2, 3, 4, 5, 6, 7, 8, 10, 11, 14, 15, 16, 17, 18, 19, 20, 21, 27).

Conservation status: IUCN: Least Concern; CITES: Appendix II; DOE: Protected.

Order Perissodactyla Owen, 1848

Family Equidae Gray, 1821

Genus *Equus* Linnaeus, 1758

***Equus hemionus* Pallas, 1775** - Onager (Image 3F)

Type Locality: Russia, Transbaikalia, Dauria, Tarei-Nor.

Diagnosis: HB 200–250 cm, T 30–55 cm, SH 110–142 cm, E 17–20 cm and W 150–260 kg. Similar to the donkey, having long, narrow and pointed ears; dorsal yellowish-brown or orange and sides and the rumps, flanks, and venter white; males darker; moults in the spring; a short and black mane present on the neck; a distinctive dark brown stripe runs along the neck and backbone reaching the tail; a small dark patch present on the inner side of the femurs.

Comments: Suggested Iranian subspecies is *E. h. onager* Pallas, 1775; remaining populations occur in the Touran Protected Complex (Semnan) and Bahram-e-Goor Protected Area and Qatruiyeh National Park (Fars Province) (Hemami & Momeni 2013).

Distribution: Fig. 2 (22, 23, 24, 27, 28).

Conservation status: IUCN: Near Threatened; CITES: Appendix II; DOE: Endangered.

Order Artiodactyla Owen, 1848

Family Suidae Gray, 1821

Genus *Sus* Linnaeus, 1758

***Sus scrofa* Linnaeus, 1758** - Wild Boar (Image 6A)

Type Locality: Germany.

Diagnosis: HB 100–185 cm, T 16–30 cm, SH 60–110 cm and W 50–300 kg. Body big; head large; neck short and thick; hand and feet with four digits extended to hoofs, but only middle toes reach to the ground; eyes small; muzzle long and cylindrical with nostrils on its flat tip; hair shaggy long, brown to grey in color but sometimes creamy yellow; youngsters with yellow and brown stripes; canines present in both upper and lower jaws; males with more developed canine teeth, visible as half-circle shaped tusks emerging from the mouth.

Comments: Suggested Iranian subspecies is *S. s. attila* Thomas, 1912 (Etemad 1985).

Distribution: Fig. 2 (all provinces).

Conservation status: IUCN: Least Concern; CITES: not listed; DOE: unsupported.

Family Cervidae Goldfuss, 1820

Genus *Dama* Frisch, 1775

***Dama dama* (Linnaeus, 1758)** - Fallow Deer (Image 6B)

Type Locality: Sweden.

Diagnosis: HB 130–200 cm, T 16–20 cm, SH 85–100 cm and W 45–110 kg. Male's antlers broad and branched; numbers of points correlated with age; antlers shed in the winter and start growing in spring; length of antlers and their branches 50–70 cm and 7–20 cm, respectively; antlers in old males shorter and sometimes with no branches; body covered with reddish orange short hairs on the back and flanks in summer; white spots present on the back and flanks which turns to the white line on the latter; body hair longer in winter and grey in color.

Comments: Suggested Iranian subspecies is *D. d. mesopotamica* (Brooke, 1875). The original habitats of Persian Fallow Deer in Iran were open landscapes with scattered trees and shrubs in Zagros Mountains in western Iran and woodlands in southwestern province of Khuzestan, however, habitat destruction and extensive hunting wiped out or severely reduced their populations. Now the small free remaining herds are scattered in woodlands along Karkheh and, perhaps, Dez rivers. Presently, the majority of Persian Fallow Deer in Iran live on Ashk Island in Urmia Lake and several enclosures throughout the country, including the Miankotal, Arzhan, and Parishan protected areas in Fars Province (Karami et al. 2016).

Distribution: Fig. 2 (2, 4, 7, 15, 18, 20, 24, 27).

Conservation status: IUCN: Least Concern; CITES: Appendix I; DOE: Protected.

Family Bovidae Gray, 1821

Genus *Gazella* Blainville, 1816

***Gazella bennettii* (Sykes, 1831)** - Indian Gazelle

Type Locality: India, Deccan.

Diagnosis: HB 90–110 cm, T 15–20 cm, SH 55–65 cm, HL 32cm and W 15–25 kg. Smaller and darker than *G. subgutturosa* (Gueldenstaedt, 1780); winter fur in eastern populations dark grayish sandy, often with a distinct brown band edging the white underparts; summer fur reddish-brown; western populations larger, lighter, and lack the dark mid-facial region of the eastern populations; horns rather parallel with tips, sometimes turning in; horns longer in males; tail black, conspicuous against the white buttocks when raise in scape.

Comments: Iranian specimens are assigned to three subspecies, *G. b. fuscifrons* Blanford, 1873, *G. b. karamii* Groves, 1993, and *G. b. shikarii* Groves, 1993 (Groves 1993). There are four captive breeding centers in the country. For population status in Iran see Akbari et al. (2014).

Distribution: Fig. 2 (21, 22, 23, 24, 27, 28, 29, 30). In Iran, the current population is estimated at 2,818 individuals in 32 reserves (including Bahram-e Goor, Tarom and Hormood protected areas in Fars Province) and additionally at least 500 individuals outside protected areas (Akbari et al. 2014).

Conservation status: IUCN: Least Concern; CITES: Appendix III; DOE: Protected.

***Gazella subgutturosa* (Gueldenstaedt, 1780)** - Persian Gazelle (Image 6C,D)

Type Locality: Azarbaijan, Steppes of East Transcaucasica.

Diagnosis: HB 90–115 cm, T 16–20 cm, SH 70–80 cm and W 20–45 kg. Males horns reach 25–45 cm in length, black and sharply diverging, and form an S-shaped, bending up backward and turning in at the tips; females lack horns, but in western Iran females with short horns observed; males with a goiter-like bulge on the throat during the mating season; legs long; tail quite short; fur short and sandy during the warm season, replaced by thick and brownish fur in winter, and becomes lighter with increasing age.

Comments: Two subspecies are listed for Iran, *G. s. subgutturosa* (Gueldenstaedt, 1780) and *G. s. seistanica* Lydekker, 1910 (Etemad 1985), but a genetic analysis is required to verify them. *Gazella subgutturosa marica* is a distinct lineage, currently regarded as *G. marica* (Wacher et al. 2010).

Distribution: Fig. 2 (5, 9, 11, 12, 14, 17, 18, 21, 22, 23, 24, 25, 26, 27, 30). The current population of Persian Gazelle in Iran is estimated less than 20,000 individuals (Karami et al. 2016). The remaining population in Fars Province is limited to Bamau National Park and Basiran hunting prohibited region in north of Fars Province.

Conservation status: IUCN: Vulnerable; CITES: not listed; DOE: Protected.

Genus *Capra* Linnaeus, 1758

***Capra aegagrus* Erxleben, 1777** - Wild Goat (Image 6E)

Type Locality: Russia, NE Caucasus, Dagestan.

Diagnosis: HB 120–160 cm, T 15–20 cm, SH 70–100 cm and W 25–120 kg. Males with long scimitar shaped horns marked with annual growth rings that could reach 152cm in length; females with short horns (few centimeters); body stocky and muscular; fur brownish or yellowish gray; males darker; adult males with a beard and a black stripe running from the withers down the front of the shoulders merging with the black chest; become pale with increasing age, and cream-white on the sides and flanks in an advanced age; front of their feet with black hairs; fur paler in winter; males with special sebaceous glands under the tail.

Comments: Iranian subspecies are the nominate one and *C. a. blythi* Hume, 1875.

Distribution: Fig. 2 (all provinces of Iran).

Conservation status: IUCN: Vulnerable; CITES: Appendix I; DOE: unsupported.

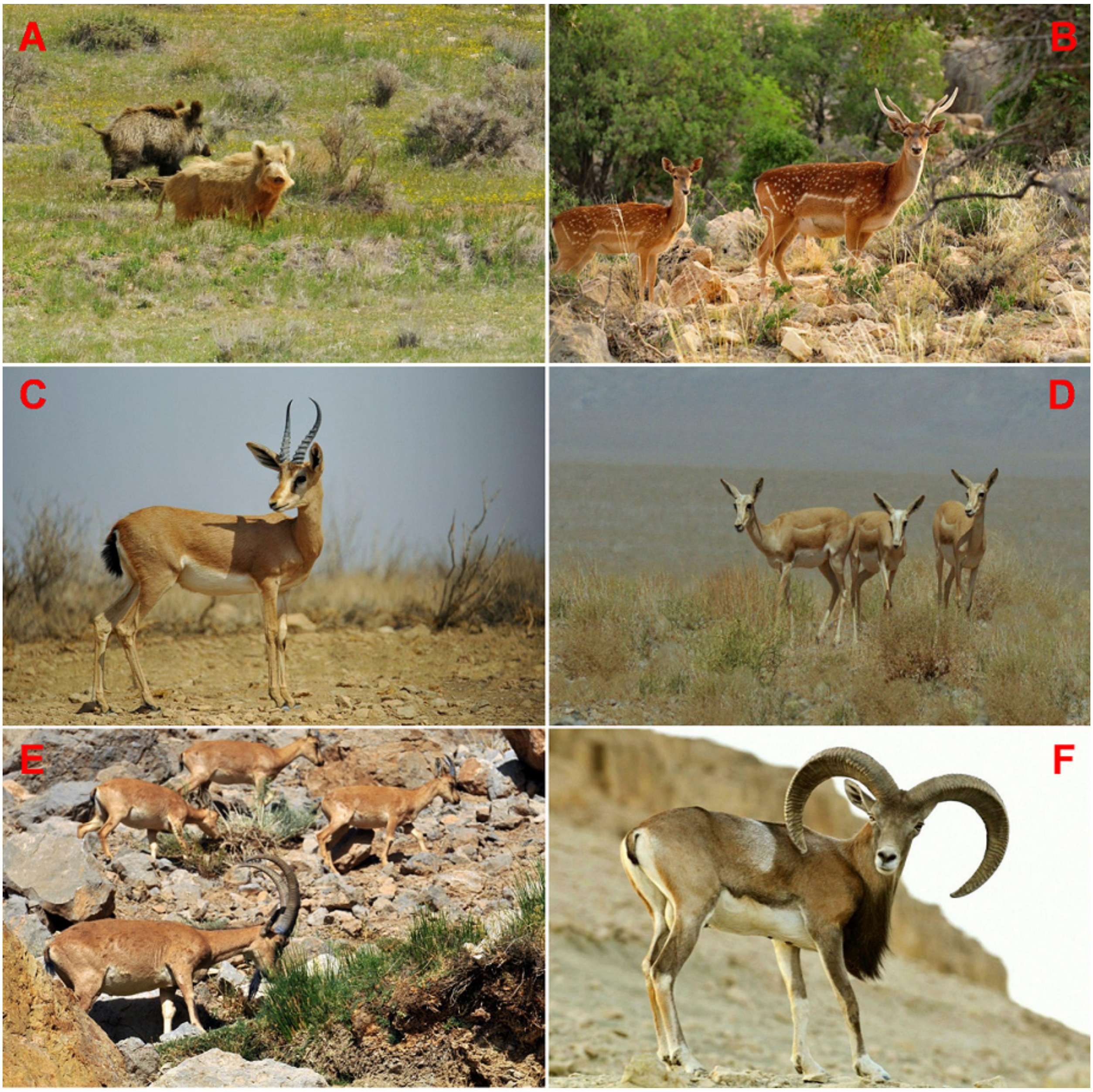

Image 6. A - *Sus scrofa*; B - *Dama dama mesopotamica*; C - male *Gazella subgutturosa*; D - female *Gazella subgutturosa*; E - *Capra aegagrus*; F - *Ovis orientalis*. © S. Kafaei.

Genus *Ovis* Linnaeus, 1758

***Ovis orientalis* Gmelin, 1774** - Mouflon (Image 6F)

Type Locality: Iran, Eastern Alborz Mountains.

Diagnosis: HB 140cm, SH 80cm, and W 20–65 kg. Males larger, with horns shorter than the horns of male Urial Wild Sheep and with somewhat elliptical cross sections; horns curve in the same plane towards the neck; chest and throat hairs rough, short and range from brown to black; females lack horns or with short and slightly curved horns; males with a white or gray saddle patch in winter.

Comments: Four subspecies are recognized in Iran, *O. o. laristanica* Nasonov, 1909, *O. o. isphahanica* Nasonov, 1910, *O. o. gmelinii* Blyth, 1841 and *O. o. arkal* Eversmann, 1850 (Ziaie 1996). Distribution of Laristan sheep *O. o. laristanica* is limited to southern and western parts of Fars and Hormozgan provinces. Hormood and Geno protected areas are well-known habitats for this population. Laristan rams are the smallest rams in the world with adult males weighing less than 35kg. Shiraz ram is a hybrid between Armenian (*O. o. gmelinii*) and Larestan (*O. o. laristanica*) populations. Horns are similar to Laristan rams but with a large body size. Distribution is limited to areas surrounding Shiraz, especially Bamou National Park (Karami et al. 2016). Based on a molecular study, Rezaei et al. (2010) concluded that wild sheeps in Iran form two monophyletic groups (*O. orientalis* in western parts and *O. vignei* in eastern parts of the country) and other populations throughout Iran are hybrids of these two species.

Distribution: Fig. 2 (1, 2, 4, 5, 7, 8, 9, 10, 11, 12, 13, 18, 19, 21, 27, 28, 30).

Conservation status: IUCN: Vulnerable; CITES: Appendix II; DOE: Protected.

Order Rodentia Bowdich, 1821

Family Sciuridae Fischer de Waldheim, 1817

Genus *Sciurus* Linnaeus, 1758

***Sciurus anomalus* Gmelin, 1778** - Caucasian Squirrel (Image 4B)

Type Locality: Georgia, Sabeka, 25km southwest of Kutaisi.

Diagnosis: HB 190–210 mm, T 128–143 mm, HF 50–60 mm, E 27–29 mm and W 330–430 g. Body size medium; tail long and bushy; upper parts brown with a tint of russet red; under parts yellow; tail shorter than the head-body length; top of the tail russet red and lighter on the bottom; claws delicate and long, with a dark base becoming lighter towards the tips; eyes large; ears relatively long.

Distribution: Fig. 2 (1, 4, 7, 10, 11, 19, 20, 21, 27).

Conservation status: IUCN: Least Concern; CITES: not listed; DOE: unsupported.

Family Dipodidae Fischer de Waldheim, 1817

Genus *Allactaga* Cuvier, 1836

Comments: For a molecular phylogeny of the genus *Allactaga* in Iran, see Dianat et al. (2013).

***Allactaga elater* (Lichtenstein, 1828)** - Small Five-toed Jerboa

Type Locality: Western Kazakhstan, Kirgiz Steppe.

Diagnosis: HB 90–128 mm, T 148–185 mm, HF 46–58 mm, E 25–38 mm and W 32–73 g. Smallest jerboa in Iran; muzzle short and wide; ears long, when folded forward, extend beyond the muzzle; pelage dark grey on the back with buff tipped hairs; flanks lighter and venter white; a white bar on the thigh, which unites with the white color on the venter; tail tuft with three colors of hair, short off-white hairs, followed by 3cm black hairs and 2cm long white hairs at the tip; hind feet with five fingers; feet soles naked; a pair of small premolars on the upper jaw; small incisors with no grooves.

Comments: Occurrence of five subspecies is likely in Iran, *A. e. elater* (Lichtenstein, 1828), *A. e. caucasicus* Nehring, 1900, *A. e. indica* Gray, 1824, *A. e. aralychensis* (Satunin, 1901) and *A. e. turkmeni* Goodwin, 1940 (Shenbrot et al. 2008). Mohammadi et al. (2016) suggested the existence of two additional mitochondrial lineages.

Distribution: Fig. 2 (1, 3, 8, 9, 12, 14, 16, 17, 18, 22, 23, 25, 27, 28, 29).

Conservation status: IUCN: Least Concern; CITES: not listed; DOE: unsupported.

Genus *Jaculus* Erxleben, 1777

Comments: For an integrative taxonomic study in Iran, see Darvish et al. (2016).

***Jaculus blanfordi* (Murray, 1884)** - Blanford's Jerboa

Type Locality: Iran, Bushehr.

Diagnosis: HB 108–136 mm, T 170–218 mm, HF 60–67 mm, E 18–23 mm and W 77–93 g. Largest *Jaculus* in Iran; eyes large; ears small; hind limbs long; front limbs short; fur on the dorsum creamy yellow, and pure white on the venter; tail tuft 5cm long, dark brown at the base with a 3cm white tip; hind feet with three toes, with vestigial lateral ones; feet soles covered with long hairs; premolars absent.

Comments: There is an intraspecific geographic variation in second lower molar shape in *J. blanfordi* so that northern and southern populations are determinable, which strengthen the idea of occurrence of two subspecies in northeast and southeast of Iran (Darvish et al. 2016). Results of genetic analysis by Melnikova & Naderi (2017) uncovered two distinct lineages, thus supporting the presence of two subspecies, *J. b. blanfordi* (Murray, 1884) and *J. b. turcmenicus* Vinogradov & Bondar, 1949.

Distribution: Fig. 2 (13, 14, 17, 21, 23, 25, 27, 28, 29).

Conservation status: IUCN: Least Concern; CITES: not listed; DOE: unsupported.

Family Calomyscidae Vorontsov & Potapova, 1979

Genus *Calomyscus* Thomas, 1905

Comments: For an integrative taxonomy of the genus *Calomyscus* in Iran, see Sahebjam et al. (2010), Shahabi et al. (2012), Shahabi (2013), Shahabi et al. (2013), and Zarei et al. (2013b).

***Calomyscus bailwardi* Thomas, 1905** - Zagros Mountains Calomyscus

Type Locality: Iran, Khuzestan Province, southeast of Ahwaz, Izeh.

Diagnosis: HB 70–92 mm, T 82–100 mm, HF 20–23 mm, E 19–26 mm and W 10–24 g. Body small; ears long and tail bushy; snout rounded; eyes large; hind feet delicate with five toes; part of the feet soles covered with white hair, while the rest naked; body orange brown on top and white underneath; flanks dark; ears long, bare, light and covered with scattered hairs; the frontal base of the ears with a small white patch; upper parts of the fore and hind limbs white; lower part of the tail pure white.

Comments: Akbarirad et al. (2016) revealed the existence of four groups in Iran and concluded that the Zagros Mountains has promoted geographic isolation in the genus *Calomyscus*. Group B includes the samples from the southeastern part of the Zagros including Fars Province.

Distribution: Fig. 2 (4, 10, 11, 18, 19, 20, 21, 27, 28, 30).

Conservation status: IUCN: Least Concern; CITES: not listed; DOE: unsupported.

Family Cricetidae Fischer, 1817

Genus *Arvicola* Lacépède, 1799

***Arvicola amphibius* (Linnaeus, 1758)** - Eurasian Water Vole

Type Locality: England.

Diagnosis: HB 146–186 mm, T 100–136 mm, HF 30–33 mm, E 15–17mm and W 80–200 g. Largest vole in Iran; head large; muzzle wide and short; eyes small; ears short and hide among hairs; dorsal hairs dark brown mixed with orange and grey; flank darker, turning to black; ventral grey, sometimes tinted with orange yellow; tail long and almost half of the head-body length, covered with short hairs; cartilaginous scales visible; soles of fore and hind limbs bare; incisors yellow-orange; molar teeth grow continuously as incisors.

Distribution: Fig. 2 (1, 2, 4, 5, 7, 8, 11, 12, 14, 15, 21, 27).

Conservation status: IUCN: Least Concern; CITES: not listed; DOE: unsupported.

Genus *Chionomys* Miller, 1908

***Chionomys nivalis* (Martins, 1842)** - European Snow Vole

Type Locality: Switzerland, Berner Oberland, Faulhorn.

Diagnosis: HB 110–140 mm, T 50–70 mm, HF 18–22 mm, E 16–18 mm and W 38–50 g. Tail long yellow, almost half the head-body length; fur long and dense, which is light brown mixed with gray, gradually gives away to gray on the sides; ventral fur white gray; soles of fore and hind limbs naked; claws white and pointed; pinna small.

Comments: Mahmoudi et al. (2017) concluded that *C. layi* Zykov, 2004 is synonymous with *C. nivalis*.

Distribution: Fig. 2 (5, 15, 19, 23, 27).

Conservation status: IUCN: Least Concern; CITES: not listed; DOE: unsupported.

Genus *Microtus* Schrank, 1798

***Microtus irani* Thomas, 1921** - Iranian Vole

Type Locality: Iran, Fars Province, Shiraz, Bagh-i-Rezi.

Diagnosis: HB 100–107 mm, T 34–39 mm, HF 18–19 mm and W about 300g. Similar to Social Vole; pelage olive-buff above; flanks paler; ventral off-white.

Comments: To date, five different cytotypes were reported for this species that made it a notorious example of an unstable taxonomy (Zima et al. 2013).

Distribution: Fig. 2 (27). The first report was from an orchard near Shiraz at 1,700m. It was described by Thomas, 1921 from the southern border of *Microtus* species range (Shiraz-Iran) (Karami et al. 2016). A recent study on chromosomal data of *Microtus* species from Iran have revealed two different cytotypes (2n=48, 64) from the type locality (Mahmoudi et al. 2014). Mahmoudi et al. (2014) also confirmed the limited scope of *M. irani irani* just to the type locality (Shiraz), and showed more extended range of *M. i. karamani* between Iran, Lebanon and Turkey.

Conservation status: IUCN: Data Deficient; CITES: not listed; DOE: unsupported.

Genus *Cricetulus* Milne-Edwards, 1867

***Cricetulus migratorius* (Pallas, 1773)** - Gray Dwarf Hamster

Type Locality: Western Kazakhstan, lower Ural River.

Diagnosis: HB 85–115 mm, T 20–35 mm, HF 14–19 mm, E 15–20 mm and W 35g. Body small; face wide; muzzle pointed; fur gray on the back and white underneath; between upper and lower fur marked; tail creamy and very short, about quarter of body length; tail terminates with a tuft; ears long and if folded forward would reach the eyes; pinna gray and ellipsoid, with short and thin hairs on the outer surface.

Distribution: Fig. 2 (all provinces except 12, 13, 18, 26 and 30).

Conservation status: IUCN: Least Concern; CITES: not listed; DOE: unsupported.

Family Muridae Illiger, 1811

Genus *Gerbillus* Desmarest, 1804

***Gerbillus nanus* Blanford, 1875** - Baluchestan Gerbil

Type Locality: Pakistan, Gedrosia.

Diagnosis: HB 70–90 mm, T 108–125 mm, HF 19–22 mm, E 11–13 mm and W 10–15 g. Size small; tail long (1.5 times of the head-body length) and covered with hair throughout its length, ends with a small tuft; fur long, soft and dense; eyes large; muzzle narrow; moustaches well grown and black and white; each foot with five toes and naked soles; body upper parts light brown with a shadow of gray; face covered with lighter fur; a white crescent area present above the eye and the base of the ear; under parts fur, from cheeks to tail, pure white; between upper and lower parts on the flanks quite demarcated.

Comments: Sympatric occurrence of long-tailed and short-tailed morphotypes has been reported in the country (Siahsarvie & Darvish 2007).

Distribution: Fig. 2 (17, 18, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30).

Conservation status: IUCN: Least Concern; CITES: not listed; DOE: unsupported.

Genus *Merione*s Illiger, 1811

Comment: For a morphometric study of the genus in Asia and northern Africa see Darvish (2009).

***Meriones hurrianae* Jerdon, 1867** - Indian Desert Jird

Type Locality: India, Delhi, Hurriana District.

Diagnosis: HB 125–142 mm, T 138–145 mm, HF 30–34 mm, E 12–13 mm and W 50–70 g. Size medium; hairs short and rough; fur on upper part sandy grayish-buff, on fore and hind feet lighter and on ventral side grayish or creamy; no demarcation line between fur color on back and lower side; tail as long as head-body length; color of the upper part of the tail same as upper part of the body, and lower side lighter; fore- and hind feet thick with long black claws; ears short and somewhat triangular; eyes relatively small.

Distribution: Fig. 2 (27, 29, 30).

Conservation status: IUCN: Least Concern; CITES: not listed; DOE: unsupported.

***Meriones persicus* (Blanford, 1875)** - Persian Jird

Type Locality: Iran, Kohrud Mountains, north of Esfahan.

Diagnosis: HB 120–198 mm, T 150–195 mm, HF 35–42 mm, E 20–25 mm and W 55–100 g. Tail longer than head-body length; back color yellowish brown with a brown or black shade; ventral side white from chick to tail; hairs gradually become taller in the final third part of the tail which terminates with a tuft at the end; tail upper side with the same color as the back of the body, lower side white and wheat brown; ears large and triangular; pinna covered with short hairs on outer surface, but inner surface bare; hind limbs tall; the soles of the hind feet bare, only on the fringes of heals and near toes covered with white hairs; hind limbs claws white; a white patch obvious above the eyes.

Comments: Subspecies in Fars Province is *M. p. ambrosius* Thomas, 1919; Dianat et al. (2016) concluded that it is close to the nominate subspecies, thus additional analyses are needed to validate its status.

Distribution: Fig. 2 (throughout the country with the exception of deserts, northern and southern coastal areas).

Conservation status: IUCN: Least Concern; CITES: not listed; DOE: unsupported.

Genus *Tatera* Lataste, 1882

***Tatera indica* (Hardwicke, 1807)** - Indian Gerbil

Type Locality: India, United Province, between Benares and Hardwar.

Diagnosis: HB 125–190 mm, T 145–205 mm, HF 20–38 mm, E 20–36 mm and W 100–225 g. Size relatively big and rat-like; tail thick, bushy and longer than head-body length; hairs become longer at the tip of the tail, establishing a small terminal tuft; upper part of the body light brown with a black shadow; under part white; boundary between upper and lower part obvious; tail dark above and below, and pale along the sides; fore and hind feet long; the soles of the feet naked; ears long with rounded pinnae.

Comments: Two main phenetic groups occur in the Iranian populations, northern vs. southern (Mirshamsi et al. 2007).

Distribution: Fig. 2 (7, 18, 20, 23, 25, 26, 27, 28, 29, 30).

Conservation status: IUCN: Least Concern; CITES: not listed; DOE: unsupported.

Genus *Acomys* Geoffroy, 1838

***Acomys dimidiatus* (Cretzschmar, 1826)** - Eastern Spiny Mouse

Type Locality: Egypt, Sinai.

Diagnosis: HB 85–110 mm, T95–120 mm, HF 17–20 mm, E 15–19 mm and W 30–60 g. Similar to house mouse, but somewhat larger; tall and rough hairs (spines) cover soft hairs of the back; tail bare, scaled and longer than head-body length; eyes and ears relatively large; pinna grey and its upper edge covered with soft, short hairs; the soles of the feet and hands bare; the hairs on the back and lower parts yellowish-brown and white, respectively; a white spot present under eye and ear.

Distribution: Fig. 2 (26, 27, 29, 30).

Conservation status: IUCN: Least Concern; CITES: not listed; DOE: unsupported.

Genus *Apodemus* Kaup, 1829

Comments: Radiation and distribution of *Apodemus* in the eastern Mediterranean is probably influenced largely by vicariance events during the Neogene including the uplifting of the Zagros Mountains and the Anatolian Plateau, climate oscillations, and formation of the Hyrcanian forests (Darvish et al. 2015).

***Apodemus witherbyi* (Thomas, 1902)** - Steppe Field Mouse

Type Locality: Southern Iran, Fars Province, Shul.

Diagnosis: HB 93–104 mm, T 93–110 mm, HF 20–23 mm, E 15–17 mm and W 15–30 g. Body size and morphology similar to the house mouse, but hind feet longer and slender, eyes and ears larger, and upper incisors without cusps; fur light brown with a tint of russet; fur on abdominal side and limbs white; demarcation line along flanks very distinct; scales on tail easily visible; short, thin hairs cover tail sides and the terminal part of the tail; tail brown on upper part and white on abdominal side, with a clear demarcation line between them.

Distribution: Fig. 2 (1, 7, 10, 11, 15, 17, 19, 20, 22, 23, 27).

Conservation status: IUCN: Least Concern; CITES: not listed; DOE: unsupported.

Genus *Mus* Linnaeus, 1758

***Mus musculus* Linnaeus, 1758** - House Mouse

Type Locality: Sweden, Uppsala.

Diagnosis: HB 65–100 mm, T 60–105 mm, HF 15–18 mm, E 11–15 mm and W 12–30 g. Tail long and thin; tail length exceeds head-body length; fur short, thin, soft and grey-brown above; a shadow of the golden yellow present above the body in some specimens; under parts of the body white; between darker back and lighter below demarcated; pinna well-developed and round above, covered with thin hairs; eyes small; snout relatively sharp; tail covered with short and thin hairs, but rings conspicuous; the soles of the feet, with the exception of lateral part, bare.

Comments: Iranian subspecies is *M. m. domesticus* Schwarz et Schwarz, 1943. Two additional subspecies have been recognized more recently from northeast of Iran: *M. m. bactrianus* Blyth, 1846 from South Khorasan Province and *M. m. musculus* Linnaeus, 1758 from North Khorasan Province (Darvish 1995).

Distribution: Fig. 2 (all provinces).

Conservation status: IUCN: Least Concern; CITES: not listed; DOE: unsupported.

Genus *Nesokia* Gray, 1842

***Nesokia indica* (Gray, 1830)** - Short-tailed Nesokia

Type Locality: India [uncertain].

Diagnosis: HB 150–215 mm, T 90–130 mm, HF 30–45 mm, E 15–20 mm and W 130–180 g. Size large; muzzle short and round; hairs short, dense and soft with long black hairs visible among them; tail shorter than head-body length, covered with scales and scantly haired; hands and feet broad and short, with fingers and toes that end with long clear nails; pelage brownish yellow or grayish-brown with a red shade on upper parts that gradually merges with the light grayish under parts; incisors wide and strong.

Comments: Five subspecies have been reported for Iran (Ellerman 1961). Zarei et al. (2013a) conducted a geometric morphometric analysis of some populations in Iran.

Distribution: Fig. 2 (1, 7, 9, 14, 15, 16, 17, 18, 20, 22, 23, 25, 26, 27, 28, 29, 30).

Conservation status: IUCN: Least Concern; CITES: not listed; DOE: unsupported.

Family Gliridae Muirhead, 1819

Genus *Dryomys* Thomas, 1905

***Dryomys nitedula* (Pallas, 1778)** - Forest Dormouse

Type Locality: Russia, Lower Volga River.

Diagnosis: HB 80–113 mm, T 80–111 mm, HF 19–24 mm, E 10–17 mm and W 30–60 g. Body smaller than dormouse; two black stripes, encircling the eyes, visible on the face; eyes large; ears small and the upper part round without hairs; whiskers well developed, in 3–4 cm long; upper parts of the body in forested areas, olive brown and under parts light yellow, but in open areas back side yellowish gray and underside white; tail long, bushy; forelimb with four and hind limb with five fingers; soles of fore and hind limbs, except feet heels, naked.

Distribution: Fig. 2 (2, 3, 4, 14, 15, 17, 19, 21, 23, 24, 27, 28).

Conservation status: IUCN: Least Concern; CITES: not listed; DOE: unsupported.

Family Hystricidae Fischer de Waldheim, 1817
Genus *Hystrix* Linnaeus, 1758

Hystrix indica **Kerr, 1792** - Indian Crested Porcupine

Type Locality: India.

Diagnosis: HB 70–90 cm, T 8–10 cm, S 18–35 cm, and W 11–25 kg. The largest rodent in Iran; spines long and cover the body; tail quite short; muzzle broad and covered with rough hairs; vibrissae very long and sometimes reach 20cm on upper lip; body covered with rough hairs which partly change to spines on the back and flanks; short and bristle-like hairs present under and among spines; spines are slender and long on the neck and shoulders, thick and short on the back, marked with black and white bands; spines on the tail short and white.

Distribution: Fig. 2 (all provinces).

Conservation status: IUCN: Least Concern; CITES: not listed; DOE: unsupported.

Order Lagomorpha Brandt, 1855
Family Ochotonidae Thomas, 1897
Genus *Ochotona* Link, 1795

Ochotona rufescens **(Gray, 1842)** - Afghan Pika

Type Locality: Afghanistan, Baber's Tomb, Kabul.

Diagnosis: HB 160–180 mm, T 15mm, HF 29–33 mm, 17–21 mm and W 150g. Resembles large rats; tail very small, only small part remains that hidden in the fur; feet not long as in hares and similar to hands; muzzle short and black, and white whiskers present around it; color could range from gray mixed with brown to gray mixed with reddish-brown; flanks gradually become lighter and blend with the color of the under parts which is a mixture of grayish-yellow; no visible boundary presents between upper and lower parts.

Distribution: Fig. 2 (1, 4, 7, 8, 11, 12, 14, 15, 16, 17, 19, 21, 22, 23, 24, 25, 27, 28, 29, 30).

Conservation status: IUCN: Least Concern; CITES: not listed; DOE: unsupported.

Family Leporidae Fischer de Waldheim, 1817
Genus *Lepus* Linnaeus, 1758

Lepus europaeus **Pallas, 1778** - European Hare

Type Locality: Poland, Silesia.

Diagnosis: HB 40–70 cm, T 7–13 cm, HF 11–17 cm, E 8–12 cm and W 2–7 kg. Fore feet short, while the hind feet elongated; tail short; ears long; five digits on fore-foot and four in the hind foot, terminating with strong toes; dorsal coloration grayish clay-brown, becomes lighter on the flanks; chin, throat and belly white; tail bi-colored, with light under part and darker dorsal surface; ears grey, with a small black triangular patch at the tip; soles of fore and hind feet covered with coarse, yellowish-brown long hairs.

Distribution: Fig. 2 (all provinces).

Conservation status: IUCN: Least Concern; CITES: not listed; DOE: unsupported.

DISCUSSION

Our purpose in this study was to gather all previously published data and our own data of extensive field expeditions and camera trapping to present a general view of the mammals of Fars. The current checklist shows that the mammalian fauna of Fars Province is rich and taxonomically diverse. Based on this checklist, mammalian fauna of Fars comprises 72 species in 53 genera, 28 families, and seven orders, a number which is equivalent to about 38.9% of all terrestrial mammal species recorded throughout the country (i.e., 185 species, Karami et al. 2016) and approximately 32.9% of all terrestrial mammal species recorded in Europe (i.e., 219 species, Temple & Terry 2007). Asiatic Lion *P. l. persica* Meyer, 1826 is extirpated in Iran with no decisive records in more than 70 years. It was widespread in Iran in the far remote past, covered a very significant part of the country throughout the western half, reaching Tehran in the north and Makran in southeast; however, in the last two centuries they were confined to southwest provinces of Khuzestan, Fars and Bushehr (Karami et al. 2016). In the late 1800s, the valley of Dasht-e Arzhan and Miankotal area in Fars Province were famous for their lions (Blanford 1876, Nowell & Jackson 1996). Main causes of extinction were habitat loss, poaching, and persecution. A reintroduction program was in place in mid-1970s in order to establish a sustainable population of *P. l. persica* in Arzhan and Parishan protected area, west of Shiraz, but abandoned afterward (Karami et al. 2016).

Iran is the confluence point of major zoogeographic realms (Coad 2017). It has been infiltrated by many mammal species coming from different zoogeographic regions, which have advanced to a greater or lesser depth within the country. The result is thus a composite mammalian fauna, in which native species are mixed with Palearctic elements, as well as with others of Oriental and Ethiopian origin. From the biogeographic perspective, southern Iran has acted as a bridge between Oriental and Ethiopian realms (Frey & Probst 1986; Coad & Vhlenkin 2004; Madjnoonian et al. 2005). The mammals of Fars must in general be regarded as Palearctic, however, genera such as *Acomys* Geoffroy, 1838, *Meriones* Illiger, 1811, and *Gerbillus* Desmarest, 1804, are equally prevalent in the Sahara and must therefore be regarded as only marginally Palearctic. Many non-Palearctic species have made their way into southern Iran by different routes. Indian fauna entered the country mainly from Balochestan region, southeastern Iran. The introduction of African elements was probably in the region of Bandar Abbas (Hormozgan Province), south of Fars (Fig. 2), and the penetration must have occurred during the Quaternary, when the mainland was still continuous across the present Strait of Hormuz, which is now 34 miles wide. The African species did not infiltrate very far into the country, settling mainly in Baluchestan region (e.g., *Acomys dimidiatus*) (De Misonne 1968). *Acomys dimidiatus* entered southern Iran from the west passing northern edge of Persian Gulf reaching south of Pakistan (Etemad 1978, Firouz 1999, Frynta et al. 2010). Connection was made between India and Iraq through southern Iran by some elements (e.g. *Tatera indica*), originally belonging to hot regions, and the degree of their infiltration northward depended on their capacity for adapting to the cold (De Misonne 1968).

Besides its large area (i.e., 1,22,608km² or 7.4% of the total area of Iran, making it the fourth largest province in the country) and special biogeographic position which we discussed above, biodiversity in Fars Province also has an ecologic background (Esmaeili & Teimori 2017). Fars Province possess three main terrestrial ecoregions, including the central Persian desert basins in the north and northeast, the Zagros Mountains forest steppe extended from northwest to the southeast, and the Nubo-Sindian desert and semi-desert ecoregion in the south, as well as numerous aquatic ecoregions including at least 10 lakes and 29 rivers (Olson et al. 2001). A wide range of geographic and physiographic conditions, coupled with climatologically diverse environments in this province, have provided enormous habitat diversity for many mammalian species with different physiologic adaptations.

Unlike high species diversity, population trend for most mammalian species in Iran is declining. Among 72 reported species here, 60 species (83.3%) are considered as Least Concern (LC) in the IUCN Red List. The reason for this large number of species categorized as LC is the scanty of data about the species at national level. This shows the necessity of reconsideration of global categories and application of the IUCN Red List criteria at the national level (Esmaeili et al. 2017). It seems that habitat destruction, illegal hunting, road accident, restricted habitats and severe drought, especially in the recent years due to climate changes are the main anthropogenic and natural factors affecting mammals of Fars Province (e.g., Tatin et al. 2003; Hamadanian 2005; Ghoddousi et al. 2008b, 2009, 2016; Ashayeri & Newing 2012; Zareian et al. 2012; Ghadirian et al. 2016).

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Functional sperm assessments of African Lion *Panthera leo* (Mammalia: Carnivora: Felidae) in field conditions

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Abstract*:* Wild African Lion *Panthera leo* populations are decreasing due to inbreeding and reduced genetic variability. Thus, the use of assisted reproduction in the species could one day become essential. Before this is possible, however, studies need to be conducted on the basic reproductive traits of the species, especially those regarding sperm cells. This study aimed to analyze the semen of African Lions in field conditions. We included seven captive African Lions in our study. The animals were chemically restrained and electro-ejaculated. Twenty sperm samples were selected and analyzed for sperm motility and progressive motility, sperm motility index, and sperm morphology. In addition, the samples were analyzed for membrane and acrosome integrity (hypoosmotic swelling test and fast green/rose Bengal dyes, respectively) and assessed for cytochemical activity of the mitochondria. We found that sperm motility rate was 75.25%±2.03, progressive motility rate was 3.25%±0.10, and sperm motility index was 70.12%±1.71. We found morphologic abnormalities roughly at the expected rate with 34.61%±7.22 of the sperm cells having an intact plasma membrane and acrosome integrity of 92.27%±2.73; high mitochondrial activity was 54.26±4.88% and absence of mitochondrial activity was 2.72±0.68% in the sperm cells. These findings show that conventional tests for sperm motility and sperm morphology bring about the expected results for lions according scientific literature. Though a hypoosmotic swelling test may be performed using different concentrations, it might lead to a higher number of sperm cells with membrane damage. Fast green/rose Bengal stain and 3’3 diaminobenzidine assay, however, can be used in sperm analysis of lions in field conditions.

Keywords*:* Mitochondrial activity, plasma membrane, acrosome, sperm analysis.

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INTRODUCTION

African Lion *Panthera leo* is considered a prolific species and may be used as an experimental model for other endangered large felids (Gilmore et al. 1998; Borrego & Dowling 2016). Large successfully reproducing captive populations provide a satisfactory number of animals for experimental studies aimed at being replicated in wild populations. Lion populations are decreasing in their native countries leading to increased inbreeding and reduced genetic variability (Wildt et al. 1995; McDermid et al. 2017). Other endangered felids such as Jaguar *Panthera onca*, Tiger *P. tigris*, and Snow Leopard *P. uncia* also face similar problems (Caso et al. 2008; Jackson et al. 2008; Chundawat et al. 2011).

The study of the reproductive parameters in lions is fundamental for the successful application of reproductive technologies such as artificial insemination (Goeritz et al. 2012) and cryopreservation (Luther et al. 2017). Although techniques of assisted reproduction in humans and livestock species are well-established, it is important to recognize that these cannot be applied universally without species-specific studies (Howard et al. 1986). Consequently, the knowledge of sperm features in lions is important for the successful application of such techniques in wild felids.

Previous studies demonstrated the possibility to predict sperm fertility after semen analysis in humans (Nosrati et al. 2016), bovines (Utt 2016), and dogs (Hesser et al. 2017). To our knowledge, however, there is so far no study of this relationship in lions. Moreover, the combination of conventional sperm analysis and sperm functional tests allows a more adequate prediction of the fertility of semen samples (Shen & Ong 2000; Aitken 2006). Today, there are several possibilities to evaluate sperm functionality such as fluorescent probes (Singh et al. 2016), computer sperm analysis (Barranco et al. 2017), and the estimation of lipid peroxidation rates (Nichi et al. 2017).

The evaluation of sperm samples from wild felids should be focused on field conditions since there are limitations in transporting the samples of some of the endangered species to research centres that have the facilities to handle the sperm cells (Hermes et al. 2013). Therefore, the establishment of sperm function rates for lions in field conditions can simplify future fieldwork and help develop reproductive technologies applicable under field conditions.

The aim of this study was to establish the standard rates of sperm evaluation by conventional and functional assessments (i.e., mitochondrial activity, the integrity of acrosome, and sperm plasma membrane) for African Lions under field conditions.

MATERIALS AND METHODS

Animals

We used seven captive adult lions between the ages of four and seven years, which were housed individually at the Fundação Parque Zoológico de São Paulo (São Paulo, Brazil). According to the reproductive records provided by the zoo, all males in this study were proven to be breeders.

Semen collection

Semen collections were made after electro-ejaculation under anaesthesia. The animals were anaesthetized with a combination of Tiletamine and Zolazepam (Zoletil 50, VirbacTM do Brasil, 10mg/kg, IM). Electro-ejaculation was performed using the protocol described by Howard (1993). Semen was collected in sterile plastic tubes (15mL) and immediately evaluated. Each animal was submitted to semen collection at least four times at intervals of five weeks between the handling events. In total, 28 collections were performed, out of which six were interrupted due to problems during the procedure (e.g., anaesthesia or urine contamination) and two samples did not reach the minimum standards.

Conventional sperm analysis

Immediately after semen collection, the motility (0–100%) and progressive motility (0–5) were measured, sperm morphology was examined, and sperm motility index (SMI) was calculated. Motility and progressive motility were assessed using 10µL of semen sample placed on a clean and pre-warmed glass slide at 37°C, covered with a coverslip, and evaluated under a microscope equipped with a hot stage to keep the slides at 37°C (100x and 400x magnification, Nikon® E200, Japan). The sperm motility index was calculated using the formula described by Howard (1993) (motility + 20 x progressive motility). Morphologic alterations were evaluated fixing sperm samples in a 10% formalin buffer solution (V/V) in wet mounts, which were observed under a phase contrast microscope (1000x magnification, Nikon® E200, Japan). Abnormalities were classified according to their locations in the sperm cell (Barth & Oko 1989).

Hypoosmotic swelling test

To evaluate sperm membrane integrity, we used a hypoosmotic swelling assay. To perform this technique, two media of different osmolarities were prepared, one isoosmotic (300mOsm) and one hypoosmotic (50mOsm). The isoosmotic medium was prepared by mixing sodium citrate (50%) and fructose (50%) in 500ml of distilled water in accordance with the technique described by Jeyendran et al. (1984). One aliquot of 200µl of semen was added to the same volume of isoosmotic and hypoosmotic media. The mixture was homogenized and incubated in a water bath at 37^0C for 30min. The reactions were stopped by adding 10µL of 10% formalin solution (V/V). In the hyposomotic mixture, cells were swelling aiming to establish equilibrium between the intra and extracellular environment. Samples were evaluated in wet mounts under an interference phase microscope (400x magnification, Leitz Dialux 20) by counting the swollen sperm cells showing coiled tails (200 sperm in each medium), which indicate biochemically active cells. As a control group, the isoosmotic medium was used aiming to evaluate tails that were abnormally coiled in the ejaculate. The percentage of sperm cells with intact membranes was calculated by subtracting the percent of cells with coiled tails in the hypoosmotic medium from the percent found in the isoosmotic medium. The results were expressed as percentages (%).

Acrosome integrity analysis

Acrosome integrity was analyzed using a single-stain solution containing 1% (w/v) rose Bengal, 1% (w/v) fast green FCF, and 40% ethanol in McIlvaine's citrate phosphate buffer (Pope et al. 1991). A mixture of 5µL of stain solution and 5µL of semen was transferred on a pre-warmed slide (37°C) and, a smear was made using a different slide after 60s. The smears were air-dried and at least 200 cells were counted under a light microscope (Nikon Eclipse E200, Japan) at a 1000× magnification. The results were expressed as percentages (%). The acrosome was considered damaged if the acrosome region remained unstained or brighter than the post-acrosome area. The acrosome was considered intact if the sperm acrosome region was stained in purple or darker than the post-acrosome area.

Evaluation of mitochondrial activity

Semen samples were analyzed for mitochondrial activity using a 3'3 diaminobenzidine (DAB) assay (Hrudka 1987; Angrimani et al. 2017a). Therefore, the semen was diluted (1:1) in 1mg/ml solution of DAB in PBS (Phosphate-buffered saline) and incubated in a water bath at 37°C for one hour in the dark. Smears were then prepared on glass slides and fixated in 10% formalin for 15min. These were evaluated under the light microscope with oil immersion objective (Nikon Eclipse E200, Japan) at 1000× magnification; 200 sperm cells were evaluated. The results were expressed in percentage (%). Sperm cells were classified into four categories: high mitochondrial activity (100% of the mid-piece stained – DAB Class I), medium mitochondrial activity (more than 50% of the mid-piece stained – DAB Class II), low mitochondrial activity (less than 50% of the mid-piece stained – DAB Class III), and absence of mitochondrial activity (absence of staining in the mid-piece – DAB Class IV).

Statistical analysis

In total, 20 ejaculates exhibiting at least 60% of motility and progressive motility greater than three (scale of 0–5) could be analyzed. All data were analyzed using the SAS system for Windows (SAS Institute Inc., Cary, NC, USA). Descriptive analysis was performed using the PROC MEANS. Results are reported as untransformed means ± S.E.M. Spearman correlation was used to calculate the relationship between the variables studied. A probability value of $p < 0.05$ was considered statistically significant.

RESULTS

Sperm motility rates were 75.25±2.03%. Progressive motility was 3.25±0.10 and sperm motility index averaged 70.12±1.71% (Fig. 1). Mean values of the percentage of morphologic abnormalities observed in the acrosome, head, mid-piece, and tail found in the unstained fixed samples were 2.42±0.95%, 3.89±0.70%, 9.5±2.58%, and 43.07±6.39%, respectively (Table 1).

The percentage of sperm cells with intact membrane evaluated by HOST was 34.61±7.22% and the acrosome integrity rate was 92.27±2.73% in the sperm cells (Fig. 2). High mitochondrial activity (DAB – Class I) was shown by 54.26±4.88% of the sperm cells. Medium mitochondrial activity (DAB – Class II) was shown by 36.7±3.92% and low mitochondrial activity by 6.25±0.88% of the sperm cells. No mitochondrial activity was shown by 2.72±0.68% of the sperm cells (Fig. 3).

Positive correlations were found between the percentage of high mitochondrial activity (DAB – Class I), intact plasma membrane (r=0.60, p=0.049), and acrosome integrity (r=0.69, p=0.0041). No other correlations were found in the variables evaluated.

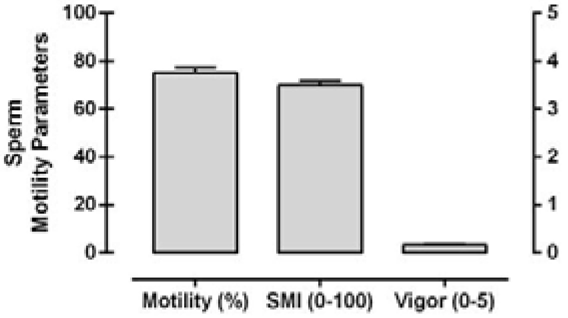

Figure 1. Mean and standard error of the mean (SEM) of motility (Motility in %), sperm motility index (SMI: 0–100), and progressive motility (Vigor, 0–5) in sperm samples from adult African Lions

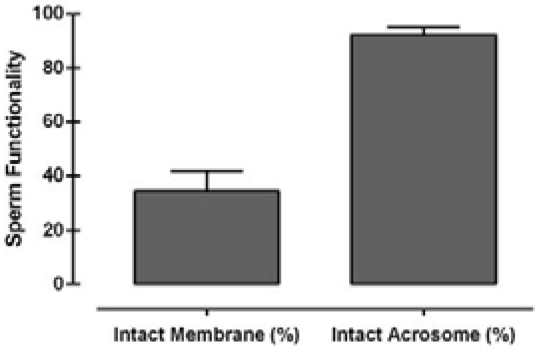

Figure 2. Mean and standard error of the mean (SEM) of plasma membrane integrity (in %) and acrosome integrity (in %) in sperm samples from adult African Lions

Table 1. Mean, standard error of the mean (SEM), and minimum (Min) and maximum values (Max) of sperm morphologic abnormalities according to location in adult African Lion *Panthera leo* sperm samples

Sperm morphologic abnormalities (%)	Mean	SEM	Min	Max
Sperm head abnormalities	3.89	0.70	1.0	11.0
Sperm mid-piece abnormalities	9.5	2.58	0	46.0
Sperm tail abnormalities	43.07	6.39	8.0	90.0
Sperm acrosome abnormalities	2.42	0.95	0	17.0

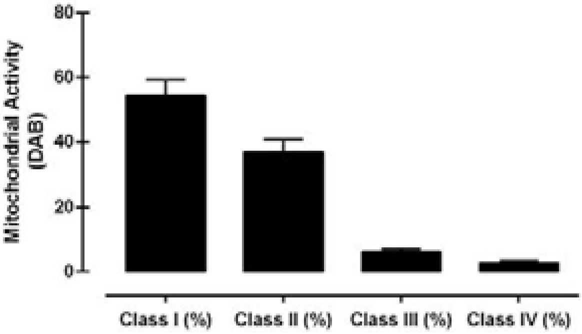

Figure 3. Mean and standard error of the mean (SEM) of mitochondrial activity (A - DAB-Class I: high activity, B - DAB-Class II: medium activity, C - DAB-Class III: low activity, D - DAB-Class IV: absence of activity) in sperm samples from adult African Lions

DISCUSSION

In this study, we evaluated the spermatic features of African Lions by conventional (i.e., motility and morphologic abnormalities) and functional (i.e., mitochondrial activity and plasma membrane and acrosome integrity) tests.

We observed a high motility rate, progressive motility, and SMI values assessed by conventional microscopy. Other authors previously reported similar results (Gilmore et al. 1998; Luther et al. 2017). Our values for sperm morphologic abnormalities were also in accordance with previous studies of lions (Lueders et al. 2012). This shows that sperm parameters were within the expected range for the species in the conventional evaluation. It is important to verify that the sperm is of high quality for the subsequent functional tests. Moreover, it is noteworthy that with this motility and normal morphology rates, the collected semen could be used in cryopreservation protocols (Luther et al. 2017).

Our values for cells with intact membranes (34.61±7.22%), however, were low when compared to other felines such as Tigrina *Leopardus tigrinus* (Angrimani et al. 2017a), Domestic Cat *Felis catus* (Zambelli et al. 2010), and Clouded Leopard *Neofelis nebulosa* (Tipkantha et al. 2017). To our knowledge, this is a pioneer study of the sperm cell membrane integrity in lions using hypoosmotic swelling tests. Lueders et al. (2012) observed 66.3±10.1% of sperm membrane integrity using vitality staining in lions. Thus, we believe that our result is underestimated.

However the sperm cells in this study showed a high motility; if this high percentage of damaged membranes would be correct the efficient transduction of ATP through the cell would be compromised, causing immobility or low motility rates (Amaral et al. 2013; Angrimani et al. 2017b). The relation between a normal mitochondrial function and membrane integrity was demonstrated in this study, when we observed the positive correlation between high mitochondrial activity and plasma membrane and acrosome integrity. In this scenario, we hypothesize that may the hypoosmotic swelling test in the used concentration of fructose and sodium citrate was deleterious for the sperm cells In fact, Comercio et al. (2013) observed modifications in sperm response after different concentrations of fructose and sodium citrate in the hypoosmotic test in domestic cats. Therefore, further studies with lions are recommended using different concentrations of solutes for the hypoosmotic test, or another method of plasma membrane integrity evaluation, such as eosin/nigrosin stain which can be certainly used in field conditions (Daub et al. 2016).

In contrast to the results on plasma membrane integrity, in the acrosome analysis we found a higher number of cells with intact acrosomes. This membrane endurance is pivotal for the sperm to tolerate post-ejaculation injuries and to be able to bind to the oocyte (Bucci et al. 2017). Thus, this result shows that fast green/rose bengal stain could be an option to field evaluation of semen of African lions or even other wild felids.

Finally the mitochondrial activity test that a high number of sperm cells had the maximum mitochondrial functionality (high and medium activity – DAB Class I and II), which is essential for the production of ATP and consequently for the motility kinetics (Vicente-Carrillo et al. 2015). This was expected in our study since the samples are fresh from animals in reproductive age and with high motility rates (i.e. conventional tests). Besides, the low percentage of DAB Class III and IV (low and absence of mitochondrial activity), was also a predictable result, as high rates of this parameters are associated with mitochondrial dysfunctions due to lesion in axonemal proteins or decreased energy production (de Lamirande and Gagnon 1992a; de Lamirande and Gagnon 1992b; Rui et al. 2017), which were both not found in this study.

In conclusion, the results from conventional tests were as expected for the species. Regarding the functional assessments, the hypoosmotic swelling test did not show to be a good option to analyze plasma membrane integrity in lion. On the other hand, fast green/rose bengal stain and 3’3 diaminobenzidine (DAB) assays appear to be a good optiosn for analyze the sperm from African Lions *P. leo* in filed conditions.

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DESCRIPTION OF A NEW SPECIES OF *PSEUDOPHILAUTUS* (AMPHIBIA: RHACOPHORIDAE) FROM SOUTHERN SRI LANKA

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Abstract: We describe a new *Pseudophilautus* species, *P. conniffae* sp. nov. from southern Sri Lanka. It was previously confused with *Pseudophilautus rus* (Manamendra-Arachchi & Pethiyagoda). The new species differs from the latter by the combination of the following characters: fourth toe webbing to penultimate subarticular tubercle on inner and outer sides (vs. fourth toe webbing in between penultimate and anetpenultimate subarticular tubercles on inner and outer sides), presence of conical median lingual process (vs. absent), and black patches on the posterior flank, anterior and posterior edges of the thigh (vs. black patches on the anterior surface of the thigh). *Pseudophilautus conniffae* sp. nov. may be sympatric with *P. limbus* (Manamendra-Arachchi & Pethiyagoda), which shares certain characters with the new species. The new species is, however, distinguished from *P. limbus* by the following characters: having supernumerary tubercles on manus (vs. lacking), absence of frontoparietal ridges (vs. presence), fourth toe webbing to penultimate subarticular tubercle on both sides (vs. fourth toe webbing between penultimate and anetpenultimate subarticular tubercle on both sides), third toe webbing to distal subarticular tubercle on both sides (vs. distal subarticular tubercle on outer side and below penultimate subarticular tubercle on inner side), and having the dorsum light brown with dark brown patches (vs. black and yellow variegated pattern on dorsum). The new species may be restricted to the southwestern wet zone of Sri Lanka. It is compared with all known *Pseudophilautus* species and also provided with a field key to identify it from those species that are sympatric with it or inhabit the southwestern wet zone.

Keywords: Dediyagala, lowland rainforest, *Pseudophilautus rus, Pseudophilautus limbus*.

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Author Contribution: SB, MDS & SU - designed the research, did the field work and wrote the manuscript.

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INTRODUCTION

Sri Lanka possesses highly diverse endemic fauna and flora and is a reservoir of a unique evolutionary history (Myers et al. 2000; Bossuyt et al. 2004). It is also included in the revised hotspots of the world along with the Western Ghats of India (Mittermeier et al. 1998). It was estimated that India's Western Ghats along with Sri Lanka lost more than 70% of its original habitat due to the rapid growth of human population (Myers et al. 2000). In Sri Lanka, the most sensitive and unique amphibian biodiversity is found to be confined to the southwestern wet zone stretching up to the southwestern side of the central massif covering the Peak Wilderness and the Horton Plains (Manamendra-Arachchi & Pethiyagoda 2005; Meegaskumbura & Manamendra-Arachchi 2005, 2011; Meegaskumbura et al. 2007, 2009, 2012; Wickramasinghe et al. 2013, 2015).

South Asian Shrub Frog genus *Pseudophilautus* is restricted to India and Sri Lanka (Biju & Bossuyt 2009; Manamendra-Arachchi & Pethiyagoda 2006; Dinesh et al. 2017). Seventy-nine valid species are known from this genus of which 76 occur in Sri Lanka (Manamendra-Arachchi & Pethiyagoda 2005; Meegaskumbura & Manamendra-Arachchi 2005, 2011; Meegaskumbura et al. 2007, 2009, 2012; Wickramasinghe et al. 2013a,b,c, 2015; Biju & Bossuyt 2009; Dinesh et al. 2017), all of which are endemic to the island and all but one is restricted to the wet zone (annual rainfall > 2,000mm) (Meegaskumbura et al. 2012). Interestingly, about 60% of the Sri Lankan members of the genus were described in the recent past (Manamendra-Arachchi & Pethiyagoda 2005; Meegaskumbura & Manamendra-Arachchi 2005 , 2011; Meegaskumbura et al. 2007, 2009; Wickramasinghe et al. 2013a, 2015). Major forest reserves includes in the southwestern wet zone are Haycock, Sinharaja, and Kanneliya-Dediyagala-Nakiyadeniya forest reserves (KDN complex). Highest altitude is around < ~600m in this region. These forests are evergreen with no significant seasonal change. A total of 44 species of amphibians were recorded from the lowland wet zone in the southwestern Sri Lanka, of which 34 (77.3%) are endemic to Sri Lanka (Manamendra-Arachchi & Pethiyagoda 2006; Meegaskumbura & Manamendra-Arachchi 2005, 2011; Meegaskumbura et al. 2009; Wickramasinghe et al. 2012). Sixteen species of *Pseudophilautus* were hitherto recorded from the lowland rain forests of the island's southwestern wet zone (Manamendra-Arachchi & Pethiyagoda 2005; Meegaskumbura & Manamendra-Arachchi 2005, 2011; Meegaskumbura et al. 2009).

The new species described herein was first observed during a biodiversity survey of the Dediyagala Forest Reserve by the Wildlife Conservation Society-Galle (WCSG).

MATERIALS AND METHODS

Materials used for this study are deposited in the collection of WCSG and will be deposited in the collection of the National Museum Colombo (NMSL). Measurements were taken with KWB dial vernier calipers to the nearest 0.1mm under a stereoscope. The methodology of measurements and anatomical nomenclature follow Manamendra-Arachchi & Pethiyagoda (2005), except for the lingual papillae. For lingual papillae, we follow the terminology introduced by Grant et al. (1997), the median lingual process. Images were taken using Canon IXUS 50 and Nikon D700 digital cameras. Specimens were fixed in 10% formalin bath and were subsequently stored in 70% ethanol. Comparisons were made with the materials preserved in the collections of the NMSL, the Wildlife Heritage Trust of Sri Lanka (WHT, now in NMSL), Zoologisches Museum Berlin (ZMB), and also with published descriptions of Bossuyt & Dubois (2001), Manamendra-Arachchi & Pethiyagoda (2005), Meegaskumbura & Manamendra-Arachchi (2005), Biju & Bossuyt (2009), and Meegaskumbura et al. (2009).

Bioacoustics data were recorded in the field using a Marantz PMD660 recorder with a Sennheiser MKH20 microphone mounted on to a parabola. Ambient relative humidity and temperature were noted during the recordings. Calls were analyzed using Raven Lite software, Raven Pro: Interactive Sound Analysis Software, Version 1.0 (The Cornell Lab of Ornithology, Ithaca, NY). The calls of the new species (*n*= 5) were recorded at 76% relative humidity and 27.5^{0}C air temperature (during 2000–2300 hr), while the calls of *P. rus* (*n*= 4) were recorded at 80% relative humidity and 26^{0}C (during 1800–2300 hr). For call character terminology, we followed Cocroft & Ryan (1995).

RESULTS

Pseudophilautus conniffae sp. nov.

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Conniff's Shrub Frog (Images 1, 2A–E; Figs. 1A, 2)

Material examined: Holotype: NMSL WCSG 0005, male, 20.v.2012, 23.5mm SVL, Dediyagala Forest Reserve, Matara District, Southern Province, Sri Lanka, 6.166^{o}N, 80.433^{o}E, 80m, coll. S. Batuwita & S. Udugampala. Paratypes (all from type locality): NMSL WCSG 0001, male, 25.6mm SVL, 14.v.2012, coll. S. Batuwita & S. Udugampala; NMSL WCSG 0003 & NMSL WCSG 0004, 29.3mm SVL & 24.1mm SVL, female & male, 10.vi.2012, coll. S. Batuwita, S. Udugampala & V. Pushpamal; NMSL WCSG 0002, female, 30.7mm SVL, 11.vi.2012, coll. S. Batuwita, M. de Silva & S. Darshana; NMSL WCSG 0006, male, 22.9mm SVL, 11.vi.2012, coll. S. Batuwita & S. Udugampala.

Diagnosis: Mature male holotype 23.5mm in SVL. Tympanum discernible. Dorsal surface of body glandular, with prominent warts. Supratympanic fold prominent. Canthal edges more or less straight. Skin on head co-ossified with cranium. Nuptial pads absent. Median lingual process present, small and conical. Tarsal tubercle present. Supernumerary tubercles present on manus and pes. Toes medially webbed. Chest and belly heavily granular. Large, dark brown more or less square-shaped blotch on middorsum between forelimbs. Anterior and posterior surfaces of thigh and posterior flank region with black and white patches (Image 1D).

Description of holotype: (see Table 1 for mensural data). Snout rounded in lateral aspect (Image 1C), obtuse in dorsal aspect (Image 1A), angle of snout in dorsal view ~90^{0}. Canthal edges more or less straight (Image 1A), canthus rostralis moderate (Image 1A). Loreal region concave (Image 1A). Interorbital region flat. Snout, interorbital region, sides of head, and dorsum with isolated glandular warts. Internarial region slightly convex, nostril closer to snout tip than eye (Image 1C). Eyes prominent, large, laterally oriented (Image 1C). Pineal ocellus absent. Tympanum distinct, oval, oblique (Image 1C); supratympanic fold prominent (Image 1C). Skin on head co-ossified with cranium. Tongue ovoid, distal end deeply divided; a median lingual process present, conical and small. Vomerine ridge present, bearing a few small teeth, angled at about 45^{0} relative to body axis, shorter than the distance between ridges.

Skin of ventral surface of throat with isolated granules; chest, belly, and underside of thigh heavily granular (Image

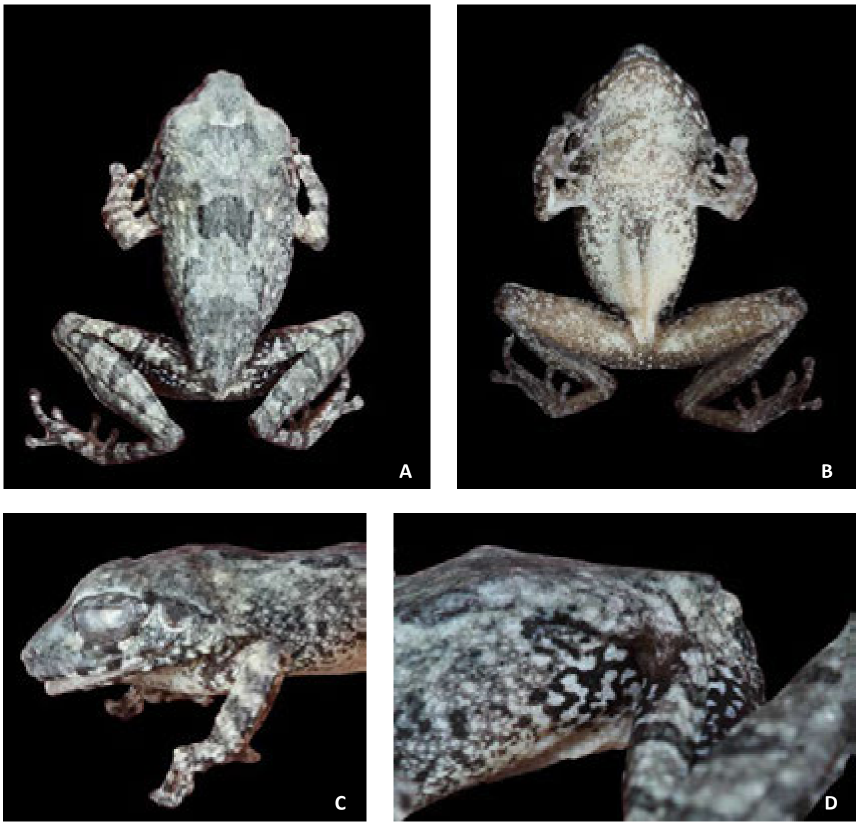

Image 1. Holotype of *Pseudophilautus conniffae* sp. nov., male, NMSL WCSG 0005, 23.5mm SVL from Dediyagala Forest Reserve. A - dorsal view of body, B - ventral view of body, C - lateral view of head, D - left lateral view of posterior flank region (showing black and white markings).

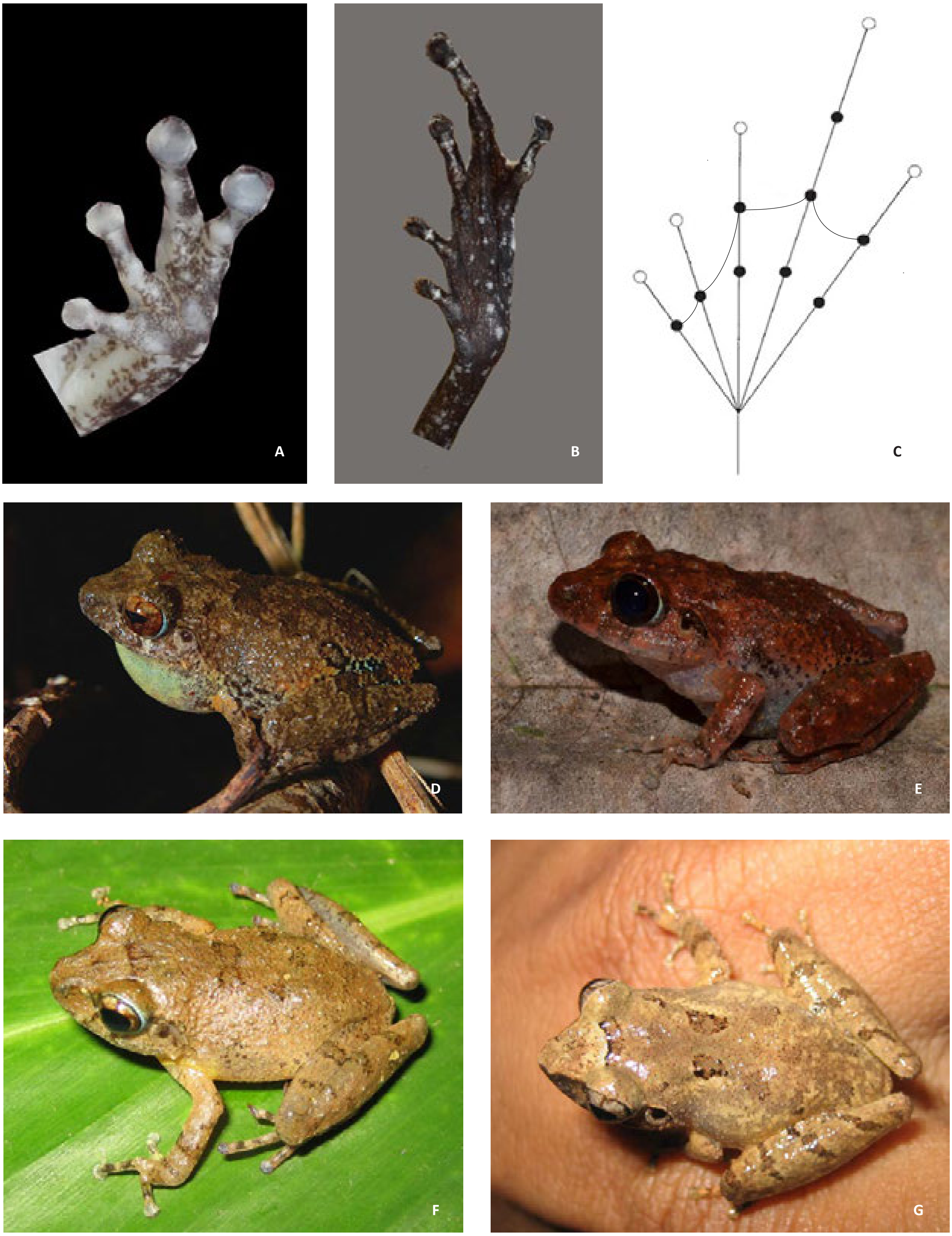

Image 2. A–E - *Pseudophilautus conniffae* sp. nov.: A - ventral view of left manus, B - ventral view of left pes, C - semi-diagrammatic representation of the left pes, showing webbing pattern of holotype male, D - live coloration of male from Hiyare forest Reserve (not preserved), E - live coloration of female paratype, NMSL WCSG 0002, 30.7mm SVL from Dediyagala Forest Reserve, F - live coloration of adult male *Pseudophilautus rus* from Hantane Range Kandy, 22.5mm SVL (not preserved), G - live coloration of adult male *Pseudophilautus silvaticus* from Morningside Forest Reserve, 31.1mm SVL (not preserved).

Table 1. Mensural data of *Pseudophilautus conniffae* sp. nov. (in mm)

	Holotype	Paratypes				
	NMSL WCSG 0005	NMSL WCSG 0001	NMSL WCSG 0003	NMSL WCSG 0004	NMSL WCSG 0002	NMSL WCSG 0006
Sex	Male	Male	Female	Male	Female	Male
DBE	8.8	8.5	9.7	9.3	10.2	8.1
DFE	4.7	4.9	5.6	4.9	5.5	4.4
DL	1.2	1.2	1.7	1.3	1.4	1.4
DW	0.9	1.0	1.5	1.2	1.4	1.1
ED	3.4	3.4	4.1	3.6	5.2	3.7
EN	2.5	2.5	2.7	2.6	3.0	2.7
ES	4.2	4.7	5.3	4.4	5.5	4.4
FEL	12.7	14.3	16.3	12.7	17.3	12.1
FL	1.7	2.0	2.7	2.5	2.3	1.7
FOL	16.9	17.9	22.3	17.5	22.1	16.7
HL	11.0	11.4	13.2	11.6	14.2	11.2
HW	10.6	11.0	13.1	11.2	12.9	10.3
IML	1.0	1.0	1.4	1.1	1.3	1.1
IN	2.4	2.2	2.5	2.5	2.6	2.5
IO	2.7	3.1	3.2	2.7	3.0	2.7
LAL	5.5	6.3	7.6	6.2	7.8	6.2
MBE	4.8	4.2	5.6	4.7	4.5	4.3
MFE	7.3	7.3	8.5	7.1	8.9	6.8
MN	9.6	9.5	11	9.8	12.0	9.6
NS	1.7	1.2	1.6	1.5	2.1	1.7
PAL	6.3	6.8	8.4	7.0	8.4	5.6
SVL	23.5	25.6	29.3	24.1	30.7	22.9
TAD	1.1	1.7	1.4	1.2	1.7	0.8
TBL	13.5	14.4	17.3	14.1	17.5	12.7
TL	2.0	2.0	2.8	2.3	2.4	1.9
TND	6.8	7.4	8.8	7.3	8.8	7.4
TPD	4.7	4.7	5.5	4.9	5.3	4.6
TYE	2.2	2.3	2.8	2.0	2.5	1.8
UAW	4.6	4.6	6.5	4.7	6.5	5.2
UEW	3.2	2.7	3.6	2.7	3.5	2.7

1B); flank with isolated, indistinct granules. Dorsolateral fold absent. Cloacal opening directed posteriorly at the ventral level of thighs, unornamentated (Image1A).

Forelimbs moderately slender (Image 1A), their dorsal and ventral surfaces smooth. Relative length of fingers: III>IV>II>I (Image 2A); tips of fingers rounded, lateral dermal fringe absent; circum-marginal groove present. Subarticular tubercles rounded to ovoid, distributed on fingers as follows: one on fingers I, II, and IV, two on finger III (Images 2B); inner palmar tubercle ovoid (Image 2B); outer almost granular, minute; supernumerary palmar tubercles absent. Nuptial pads absent (Image 2A).

Hind limbs slender (Image 1A,B); tarsal fold absent; tarsal tubercle present. Dorsal areas of thigh, shank, and pes with a few scattered granules. Toes long, slender, their relative length: IV>III~V>II>I (Image 2C); toes medially webbed (Image 2C), their tips rounded; inner metatarsal tubercle elongate, no external tubercle (Image 2B). Subarticular tubercles rounded, small, distributed on toes as follows: one on toes I and II, two on toes III and V, three on toe IV (Image 2B,C).

Colour in life: (See Images 2D,E). Dorsum light brown

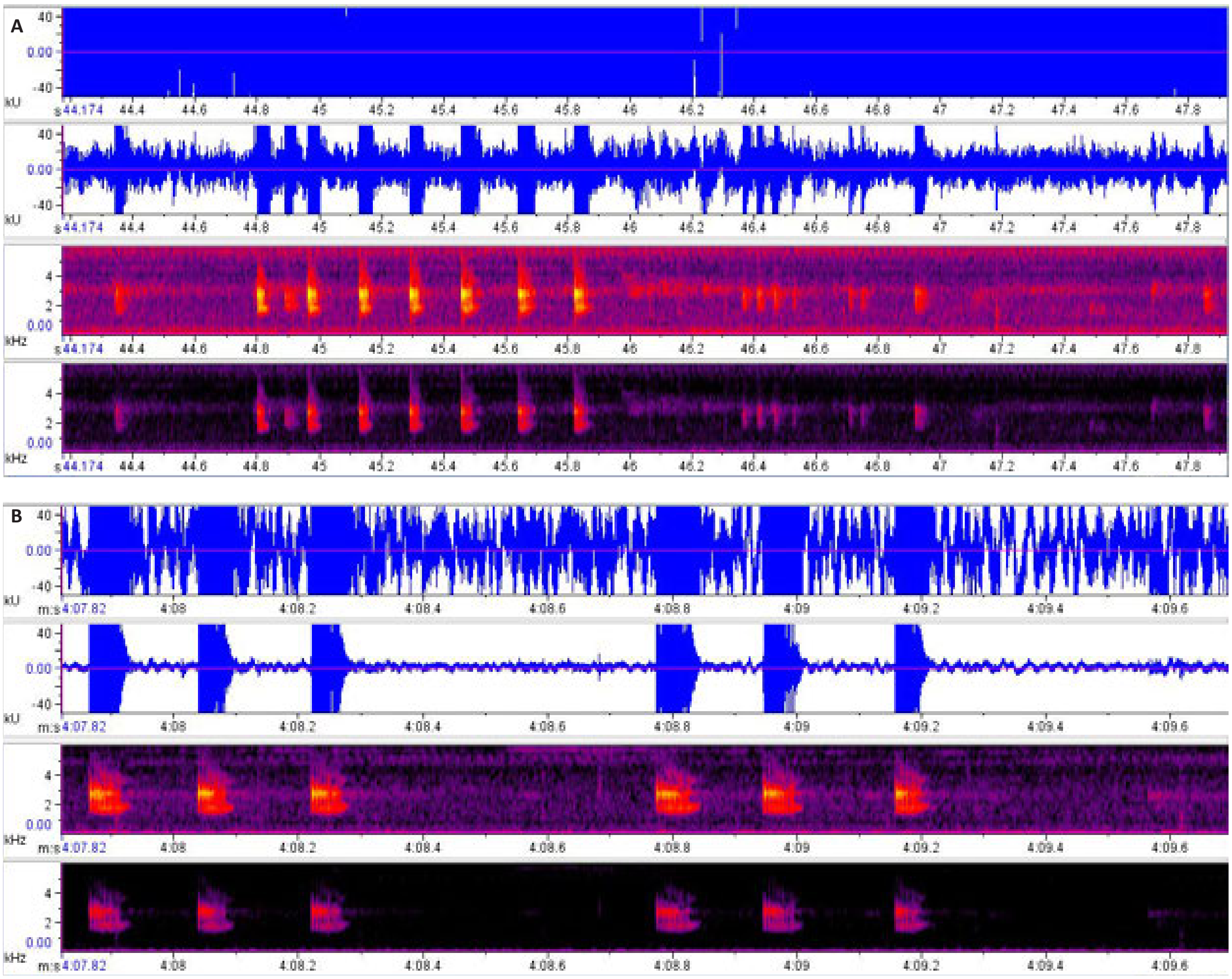

Figure 1. Oscillogram (above) and sonagram (below) of advertisement calls of *Pseudophilautus* species. A - *P. conniffae* sp. nov., B - *P. rus*.

with dark brown patches. Middle of tympanum dark brown, border lighter. Upper lip dark brown with pale and ashy brown patches. Loreal region dark brown. Anterior mid dorsal region of the body with a large, dark brown, square-shaped patch. Upper flank light brown to chestnut; lower flank spotted in females. Dorsal and lateral regions of forelimb and dorsal region of thigh, shank, and pes brown with dark brown crossbars. Throat, chest, belly, and underside of thigh light yellow with small dusky spots, throat light yellow in males. Webbing dark brown.

Colour in preservative: (based on holotype, NMSL WCSG 0005, see Image 2A,B). Dorsum greyish with dark grey-brown patches. Anterior mid-region of the body with a large, dusky, square-shaped patch. The region below supratympanic fold dusky brown than that above, tympanum dusky brown than the area surrounding it, lower margin of tympanum whitish. Loreal region greyish. Anterior flank greyish; posterior flank, anterior, and posterior thigh marbled in black and white. Dorsal and lateral sides of forelimb, dorsal side of thigh, dorsal side of shank, and dorsal side of pes brown with dark brown crossbars. Throat pale white with dark brown pigments; margins of lower jaw, anterior chest, belly, and underside of thigh pale white with dark brown pigments. Webbing black with small grayish patches.

Vocalization: *Pseudophilautus conniffae* sp. nov. is able to emit two different call types, of which one consists of a long series of unpulsed click-like notes repeated at regular intervals. The other call type consists of a shorter series of very short whistling notes repeated in fast succession (Fig. 1A). The latter call appears to be the advertisement call of *P. conniffae* sp. nov. The advertisement call of the species may be distinguished from that of *P. rus* by the greater call length (0.693–1.052 s vs. 0.408–0.427 s in *P. rus*), higher frequency (4593–5111 Hz vs. 4222–4444 Hz), greater pulse length (0.161–0.189 s vs. 0.046–0.047 s), and greater number of pulses

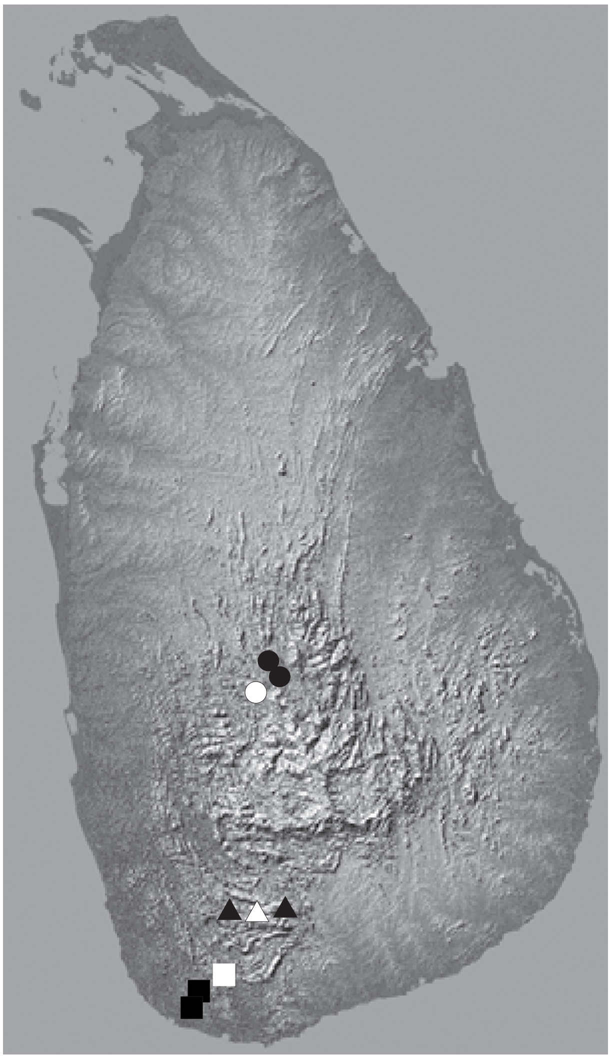

Figure 2. Distribution of *Pseudophilautus conniffae* sp. nov. in Sri Lanka (squares), *P. rus* (circles), and *P. silvaticus* (triangles) (type localities are in white).

per call (6–7 vs. 2–3) (Fig. 1A vs 1B).

Variation: Single specimen had less prominent warts on dorsum (NMSL WCSG 0003): snout, interorbital region, sides of head, and dorsum had isolated glandules. The angle of snout in dorsal view was approximately 80^0 in females and ~90^0 in males.

Etymology: The species name is an eponym honoring Karen Iynn Conniff for her generous support for the establishment of the WCSG and for her efforts to document the Odonata of Sri Lanka.

Distribution: *Pseudophilautus conniffae* sp. nov. was recorded from Galle and Matara districts (~80–300 m elevation; Fig. 2). It is confined to the rainforest areas in both districts. *Pseudophilautus conniffae* sp. nov. appears to be a habitat specialist as it was often observed in bamboo *Davidsea attenuata* vegetation (on dry bamboo leafs). It was observed calling from leaves and bamboo branches less than 1m above the ground.

Conservation status: Extent of occurrence: about 200km^2, Dediyagala, Kottawa-Kombala, and Hiyare forest reserves. Outcome: Near Threatened.

Remarks

Pseudophilautus conniffae sp. nov. keys out as *P. limbus* according to the key of Manamendra-Arachchi & Pethiyagoda (2005). It may be distinguished from *P. limbus*, however, in having less prominent throat granules (vs. heavily granular in *P. limbus*; see Manamendra-Arachchi & Pethiyagoda 2005: Fig. 95c vs. Image 1B), having supernumerary tubercles on manus (vs. lacking), having the dorsum light brown with dark brown patches (vs. black and yellow variegated pattern on dorsum; see Manamendra-Arachchi & Pethiyagoda 2005: Fig. 93 vs. Image 2D,E), lacking frontoparietal ridges (vs. having), fourth toe webbing to penultimate subarticular tubercle on both sides (vs. below the penultimate subarticular tubercle on both sides), and third toe webbing to distal subarticular tubercle on both sides (vs. distal subarticular tubercle on outer side and below penultimate subarticualr tubercle on inner side; see Manamendra-Arachchi & Pethiyagoda 2005: Fig. 95f vs. Image 2B,C).

We note in passing that although Manamendra-Arachchi & Pethiyagoda (2005) stated that nuptial pads were absent in males of *P. silvaticus*, we observed these to be present in all male specimens of its type series. While examining the type specimens of the species described recently by Wickramasinghe et al. (2013), we observed a few discrepancies: the authors mentioned that the tympanum of *P. newtonjayawardanei* is wanting, but we observed the presence of tympanum in the holotype and its upper one-third is covered by supratympanic fold. Wickramasinghe et al. (2013) stated that *P. dayawansai* lacks vomerine teeth, whereas we observed the same in the holotype.

Comparisons: The new species is immediately distinguished from the following species that are sympatric in the type locality (only opposing suites of characters are mentioned): *P. abundus* (Manamendra-Arachchi & Pethiyagoda, 2005): throat heavily granular and presence of a distinct suborbital white marking; *P. auratus* (Manamendra-Arachchi & Pethiyagoda, 2005): median lingual process absent and vomerine teeth absent; *P. cavirostris* (Günther, 1869)*:* presence of tuberculated fringe on posterior margin of lower arm and tarsus, and cloaca ornamented with spine-like tubercles; *P. folicola* (Manamendra-Arachchi & Pethiyagoda, 2005): a dark lateral stripe from nostrils to base of upper arm and two fronto-parietal ridges present; *P. hoipolloi*

(Manamendra-Arachchi & Pethiyagoda, 2005): vomerine teeth absent and head skin not co-ossified with cranium; *P. limbus* (Manamendra-Arachchi & Pethiyagoda, 2005): supernumerary tubercles absent on manus and throat heavily granular; *P. mittermeieri* (Meegaskumbura & Manamendra-Arachchi, 2005): presence of tuberculated fringe on posterior margin of lower arm and tarsus and absence of vomerine teeth; *P. nemus* (Manamendra-Arachchi & Pethiyagoda, 2005): vomerine teeth absent and median lingual process absent; *P. reticulatus* (Günther, 1864): presence of calcar and head skin not co-ossified with cranium; *P. schneideri* Meegaskumbura & Manamendra-Arachchi, 2011: absence of median lingual process, head skin not co-ossified with cranium and presence of nuptial pads; *P. singu* (Meegaskumbura, Manamendra-Arachchi & Pethiyagoda, 2009): vomerine teeth absent and head skin not co-ossified with cranium *P. sordidus* (Manamendra-Arachchi & Pethiyagoda, 2005): throat and chest smooth; *P. stictomerus* (Günther, 1876): median lingual process absent, and nuptial pads present in males; *P. tanu* (Meegaskumbura, Manamendra-Arachchi & Pethiyagoda, 2009): absence of vomerine teeth, no median lingual process and head skin not co-ossified with cranium.

The new species is also distinguished from the following non-sympatric species (only opposing suites of characters are mentioned): *P. alto* (Manamendra-Arachchi & Pethiyagoda, 2005): vomerine teeth absent and calcar present; *P. asankai* (Manamendra-Arachchi & Pethiyagoda, 2005): vomerine teeth absent and tympanum not discernible; *P. bambaradeniyai* Wickramasinghe et al., 2013: absence of supernumerary tubercles on manus and pes, absence of vomerine teeth, presence of nuptial pads and absence of median lingual process; *P. caeruleus* (Manamendra-Arachchi & Pethiyagoda, 2005): supratympanic fold not prominent and absence of vomerine teeth; *P. cuspis* (Manamendra-Arachchi & Pethiyagoda, 2005): vomerine teeth absent and calcar present; *P. dayawansai* Wickramasinghe et al., 2013: presence of nuptial pads and absence of median lingual process; *P. decoris* (Manamendra-Arachchi & Pethiyagoda, 2005): vomerine teeth absent and calcar present; *P. dilmah* Wickramasinghe et al., 2015: calcar present and vomerine teeth absent; *P. femoralis* (Günther, 1864): vomerine teeth absent and supernumerary tubercles absent on pes; *P. fergusonianus* (Ahl, 1927): presence of nuptial pads and absence of a median lingual process; *P. frankenbergi* (Meegaskumbura & Manamendra-Arachchi, 2005): supernumerary tubercles absent on pes and vomerine teeth absent; *P. fulvus* (Manamendra-Arachchi & Pethiyagoda, 2005): calcar present and nuptial pads present in males; *P. hallidayi* (Meegaskumbura & Manamendra-Arachchi, 2005): vomerine teeth absent and nuptial pads present in males; *P. hankeni* Meegaskumbura & Manamendra-Arachchi, 2011: presence of dermal fringe on tarsal and absence of vomerine teeth; *P. hoffmanni* (Meegaskumbura & Manamendra-Arachchi, 2005): skin on head not co-ossified with cranium and vomerine teeth absent; *P. hypomelas* (Günther, 1876): supernumerary tubercles absent on pes and vomerine teeth absent; *P. jagathgunawardanai* Wickramasinghe et al., 2013: absence of vomerine teeth, presence of nuptial pads and absence of median lingual process; *P. karunarathnai* Wickramasinghe et al., 2013: absence of supernumerary tubercles on manus and pes, presence of nuptial pads and absence of median lingual process; *P. lunatus* (Manamendra-Arachchi & Pethiyagoda, 2005): calcar present and skin on head not co-ossified with cranium; *P. macropus* (Günther, 1869): skin on head not co-ossified with cranuim and toes fully webbed*; P. microtympanum* (Günther, 1859): skin on head not co-ossified with cranium and nuptial pads present in males; *P. mooreorum* (Meegaskumbura & Manamendra-Arachchi, 2005): absence of vomerine teeth and absence of supratympanic fold; *P. newtonjayawardanei* Wickramasinghe et al., 2013: nuptial pads present, absence of both vomerine teeth and median lingual process; *P. ocularis* (Manamendra-Arachchi & Pethiyagoda, 2005): throat heavily granular and skin on head not co-ossified with cranium. *P. papillosus* (Manamendra-Arachchi & Pethiyagoda, 2005): calcar and nuptial pads present; *P. pleurotaenia* (Boulenger, 1904): vomerine teeth absent and toes fully webbed; *P. poppiae* (Meegaskumbura & Manamendra-Arachchi, 2005): vomerine teeth and supernumarary tubercles absent on pes; *P. popularis* (Manamendra-Arachchi & Pethiyagoda, 2005): nuptial pads present in males and vomerine teeth absent; *P. procax* (Manamendra-Arachchi & Pethiyagoda, 2005): supernumerary tubercles absent on pes and a suborbital pale blotch present; *P. puranappu* Wickramasinghe et al., 2013: presence of nuptial pads and supernumarary tubercles absent on pes; *P. regius* (Manamendra-Arachchi & Pethiyagoda, 2005): throat heavily granular and nuptial pads present in males; *P. rus* (Manamendra-Arachchi & Pethiyagoda, 2005): absence of conical median lingual process and anterior surface of thigh with black patches; *P. samarakoon* Wickramasinghe et al, 2013: nuptial pads present, absence of both median lingual process and vomerine teeth; *P. sarasinorum* (Müller, 1887): skin on head not co-ossified with cranium and vomerine teeth absent; *P. schmarda* (Kelaart, 1854): prominent lateral dermal finge on lower arm and tarsus and vomerine teeth absent; *P. semiruber* (Annandale, 1913): vomerine teeth absent and supratympanic fold feebly developed; *P. silus* (Manamendra-Arachchi & Pethiyagoda, 2005): throat heavily granular and skin on head not co-ossified with cranium; *P. silvaticus* (Manamendra-Arachchi & Pethiyagoda, 2005): skin on head not co-ossified with cranium and presence of a V-shaped tubercular pattern starting behind eyes extending towards midline of dorsum; *P. simba* (Manamendra-Arachchi & Pethiyagoda, 2005): skin on head not co-ossified with cranium and no vomerine teeth; *P. sirilwijesundarai* Wickramasinghe et al., 2013: absence of vomerine teeth, presence of nuptial pads and absence of median lingual process; *P. steineri* (Meegaskumbura & Manamendra-Arachchi, 2005): skin on head not co-ossified with cranium and nuptial pads present in males; *P. stellatus* (Kelaart, 1853): supratympanic fold indistinct and spotted dorsal colouraton; *P. stuarti* (Meegaskumbura & Manamendra-Arachchi, 2005): vomerine teeth absent and skin on head not co-ossified with cranium; *P. viridis* (Manamendra-Arachchi & Pethiyagoda, 2005): vomerine teeth absent and skin on head not co-ossified with cranium; *P. zorro* (Manamendra-Arachchi & Pethiyagoda, 2005): calcar present and vomerine teeth absent.

Pseudophilautus conniffae sp. nov. differs from following putative extinct species (only opposing suite of characters are mentioned): *P. adspersus* (Günther, 1872): vomerine teeth absent, median lingual process absent and throat heavily granular; *P. dimbullae* (Shreve, 1940): median lingual process absent and skin on head not co-ossified with cranium; *P. eximius* (Shreve, 1940): throat smooth and vomerine teeth absent; *P. extirpo* (Manamendra-Arachchi & Pethiyagoda, 2005): throat heavily granular and vomerine teeth absent; *P. halyi* (Boulenger, 1904): vomerine teeth absent, median lingual process absent and skin on head not co-ossified with cranium; *P. leucorhinus* (Lichtenstein, Weinland & Von Martens, 1856): vomerine teeth absent and median lingual process absent; *P. maia* (Meegaskumbura, Manamendra-Arachchi, Schneider & Pethiyagoda, 2007): absence of both tarsal tubercle and median lingual process; *P. malcolmsmithi* (Ahl, 1927): median lingual papilla absent; *P. nasutus* (Günther, 1869): calcar present, median lingual process absent and vomerine teeth absent; *P. oxyrhynchus* (Günther, 1872): calcar present and vomerine teeth absent; *P. pardus* (Meegaskumbura, Manamendra-Arachchi, Schneider & Pethiyagoda, 2007): absence of both vomerine teeth and median lingual process; *P. rugatus* (Ahl, 1927): median lingual process absent, vomerine teeth absent and throat heavily granular; *P. temporalis* (Günther, 1864): median lingual process absent and skin on head not co-ossified with cranium; *P. nanus* (Günther, 1869): median lingual process absent, nuptial pads present and throat heavily granular; *P. variabilis* (Günther, 1859): median lingual process absent, vomerine teeth absent and throat heavily granular; *P. zal* (Manamendra-Arachchi & Pethiyagoda, 2005): vomerine teeth absent and median lingual process absent; *P. zimmeri* (Ahl, 1927): nuptial pads present in males, median lingual process absent and W-shaped tubercle pattern on head.

The new species can also compared with three Indian species of *Pseudophilautus* (Dinesh et al. 2017) (only opposing characters are mentioned): *P. amboli* (Biju & Bossuyt, 2009): presence of nuptial pads in males and absence of median lingual process; *P. kani* (Biju & Bossuyt, 2009): absence of nuptial pads in males and median lingual process; *P. wynadensis* (Jerdon, 1853): absence of both vomerine teeth and median lingual process.

DISCUSSION

Pseudophilautus comprises a highly diverse amphibian species assemblage in Sri Lanka (Manamendra-Arachchi & Pethiyagoda 2006). Currently, about 79 species are recognized from India and Sri Lanka (Manamendra-Arachchi & Pethiyagoda 2005; Meegaskumbura & Manamendra-Arachchi 2005, 2011; Meegaskumbura et al. 2007, 2009, 2012; Wickramasinghe et al. 2013a,b,c, 2015; Dinesh et al. 2017). The discovery of *P. conniffae* sp. nov. increases the assemblage of frog fauna of the lowland wet zone of Sri Lanka to 17.

Among its Sri Lankan congeners, *P. conniffae* sp. nov. superficially resembles *P. rus, P. fergusonianus*, and *P. silvaticus*. *Pseudophilautus conniffae* sp. nov. is distinguished clearly from *P. rus* based on morphometric data (Table 1 vs. Table 2). *Pseudophilautus conniffae* sp. nov. is also distinguished from *P. silvaticus* in having a relatively acute snout (~80^0–90^0 in dorsal view vs. 95^0–100^0 in *P. silvaticus*), presence (vs. absence) of skin on head co-ossified with cranium, and absence (vs. presence; Image 2F) of a V-shaped tubercular pattern on dorsum.

Based on their morphological and mensural data (Table 1 vs. Table 2), *Pseudophilautus conniffae* sp. nov. is easily distinguished from *P. rus*. To support our conclusion, however, we here analyzed the call structure of both species. The two species are easily distinguished by their call length, frequency, pulse length, and the pulse per call (Fig. 1A vs. 1B). In addition, the type series of

Table 2. Mensural data of *Pseudophilautus rus* and *P. silvaticus* (in mm)

	Pseudophilautus rus (paratypes)					*P. silvaticus* (type series)				
	WHT 5438	**WHT 5434**	**WHT 5436**	**WHT 5440**	**WHT 5432**	**WHT 3295, holotype**	**WHT 3279**	**WHT 3310**	**WHT 3378**	**WHT 3462**
Sex	Male	Male	Male	Male	Male	Male	Male	Male	Male	Male
DBE	6.4	7.3	7.5	7.4	7.5	9.3	8.8	10.2	9.2	7.6
DFE	4.5	3.8	4.4	4.1	3.8	4.6	4.9	5.6	4.8	4.1
DL	0.9	1.0	1.0	1.0	0.8	0.9	1.5	1.2	1.5	1.4
DW	0.9	1.0	1.1	1.1	1.0	0.7	1.4	1.2	1.3	1.0
ED	3.6	3.6	3.5	3.4	3.5	4.5	4.1	3.8	4.4	3.8
EN	2.1	2.2	2.7	2.4	2.6	2.5	3.0	3.0	2.9	2.3
ES	3.8	3.6	3.9	3.9	4.0	4.0	4.6	5.2	5.0	4.1
FEL	12.5	12.9	12.9	12.7	13.0	16.1	17.0	16.0	17.3	14.1
FL	2.4	2.4	3.1	3.0	2.3	2.3	1.8	2.6	2.7	1.9
FOL	17.3	17.2	18.2	16.2	17.5	20.6	21.0	22.9	21.5	17.8
HL	9.7	9.4	9.9	9.4	9.9	11.9	12.1	13.0	12.7	10.3
HW	8.8	8.6	8.9	8.5	8.4	11.0	11.3	12.7	12.0	9.3
IML	1.0	0.8	1.1	1.0	1.0	0.9	1.2	1.2	1.2	0.9
IN	1.8	1.6	1.7	1.6	1.6	2.3	2.2	1.9	2.4	1.5
IO	2.3	2.2	2.2	2.3	2.2	2.9	3.0	2.9	3.3	2.5
LAL	4.8	5.0	5.3	4.8	4.6	6.8	6.7	7.0	7.5	6.4
LPH	–	–	–	–	–	0.5	0.2	0.3	–	0.1
LPW	–	–	–	–	–	0.5	0.4	0.3	–	0.4
MBE	2.9	2.8	3.0	3.3	3.0	4.1	4.7	4.4	4.1	3.5
MFE	6.0	6.0	6.3	6.1	6.5	7.6	8.1	7.9	8.2	6.9
MN	8.1	8.1	8.5	7.8	8.2	9.8	10.3	11	10.7	8.6
NS	0.7	1.0	0.9	1.0	1.1	1.1	1.4	1.2	1.7	1.0
PAL	6.6	6.3	6.7	7.0	7.1	8.1	7.7	8.5	7.3	6.8
SVL	21.8	20.5	21.8	22.8	22.8	27.4	27.1	31.4	28.3	24.8
TAD	0.2	0.5	0.4	0.4	0.5	0.3	0.6	0.6	0.6	0.4
TBL	13.3	12.3	13.3	12.7	13.1	16.7	17.7	17.4	18.0	14.3
TL	1.5	1.6	2.0	1.8	2.2	2.4	1.8	2.6	2.0	1.7
TND	5.8	5.5	6.3	6.2	6.5	7.3	7.4	7.6	7.6	6.6
TPD	3.5	3.6	5.7	3.8	4.0	4.9	4.6	4.8	4.8	4.0
TYE	1.4	1.4	1.5	1.6	1.6	1.8	2.1	1.9	2.2	1.8
UAW	4.1	3.5	4.5	4.1	4.8	5.8	6.5	6.2	6.1	4.4
UEW	1.9	2.1	2.4	2.6	2.3	2.1	2.9	2.3	2.8	2.5

Pseudophilautus rus were collected from Kandy (7.283°N & 80.583°E, ~500m) in the Kandy District, whereas the type locality of *P. conniffae* sp. nov. is Dediyagala (6.166°N & 80.433°E, 80m) in Matara District. The two localities are at a ~200km straight-line distance and also in different zoogeographic zones (Central Hills and lowland wet zone, respectively). We confirmed that *P. conniffae* sp. nov. is restricted to lowland wet zone rain forests (in Galle and Matara districts), while *P. rus* is confined to forests and forest buffer zones of the Central Hills around Kandy District (see Fig. 2) and to Morningside in the Rakwana Hills (Meegaskumbura et al. 2012). We, however, did not observe *P. rus* from Sinharaja, Millawa, Diyadawa, and the surrounding forests. Thus, *P. rus* and *P. conniffae* sp. nov. are two discrete species based on the geography as well. In addition, *P. rus* is a habitat generalist, common in anthropogenic habitats (e.g., buffer zones of Gannoruwa and Hantana mountains and home gardens), whereas *P. conniffae* sp. nov. is a habitat specialist, distributed

Key to the species of *Pseudophilautus* that are or may be sympatric with the new species

1	A. Presence of a distinct suborbital white marking/s	2
	B. Absence of suborbital marking/s	3
2	A. Absence of vomerine teeth/ ridge	*P. hoipolloi*
	B. Presence of vomerine teeth/ ridge	4
3	A. Presence of tuberculated fringe on posterior margin of lower arm and tarsus	5
	B. Absence of tuberculated fringe on posterior margin of lower arm and tarsus	6
4	A. Dorsum light brown color with scattered dark brown blotches	*P. sordidus*
	B. Dorsum dark green color with scattered dusky green blotches	*P. abundus*
5	A. Presence of vomerine teeth	*P. cavirostris*
	B. Absence of vomerine teeth	*P. mittermeieri*
6	A. Absence of vomerine teeth	7
	B. Presence of vomerine teeth	8
7	A. Longitudinal dermal ridges on dorsum	*P. nemus*
	B. No longitudinal dermal ridges on dorsum	9
8	A. Presence of calcar or tarsal tubercle	10
	B. Absence of calcar or tarsal tubercle	11
9	A. Prominent tubercle on upper eyelid	*P. singu*
	B. No prominent tubercle on upper eyelid	12
10	A. Presence of calcar	*P. reticulatus*
	B. Presence of tarsal tubercle	13
11	A. Skin on head not co-ossified with cranium	14
	B. Skin on head co-ossified with cranium	15
12	A. Skin on head co-ossified with cranium	*P. tanu*
	B. Skin on head not co-ossified with cranium	16
13	A. Supernumarary tubercles absent on manus, two frontoparietal ridges present; fourth toe webbing to below the penultimate subarticular tubercle on both sides; third toe webbing to distal subarticular tubercle on outer side and below penultimate subarticualr tubercle on inner side	*P. limbus*
	B. Supernumerary tubercles present on manus, no frontoparietal ridges; fourth toe webbing to penultimate subarticular tubercle on both sides; third toe webbing to distal subarticular tubercle on both sides	*P. conniffae* sp. nov.
14	A. Nuptial pads absent in males; dorsum light brown color with scattered dark brown blotches or spots	*P. sordidus*
	B. Nuptial pads present in males; no spots or blotches on dorsum	*P. stictomerus*
15	A. Nuptial pads present in males	*P. schneideri*
	B. Nuptial pads absent in males	*P. folicola*
16	A. Median lingual process present	*P. hoipolloi*
	B. Median lingual process absent	*P. auratus*

in lowland wet zone forests such as Kottwa-Kombala, Kanneliya, and Dediyagala.

Grant et al. (1997) stated no intraspecific variation in the median lingual process in frogs and also mentioned that both sexes and all sizes of frogs had this character. Interestingly, we observed a paratype of *P. silvaticus* (WHT 3378, an adult male) wanting this character (see also Manamendra-Arachchi & Pethiyagoda 2005; e.g., *P. folicola* and *P. viridis*). Thus, the individual variation of such characters, including the median lingual process, in Sri Lankan *Pseudophilautus* needs to be studied in the future.

Based on its present distribution data, *Pseudophilautus conniffae* sp. nov. can be a Near Threatened species. The species has a restricted distribution and is highly vulnerable due to habitat fragmentation (Manamendra-Arachchi & Pethiyagoda 2005). Hence, conservation assessment of the species needs to be initiated in the future.

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Appendix 1. Comparative material examined

Pseudophilautus abundus (Manamendra-Arachchi & Pethiyagoda, 2005): holotype, WHT 3006; Labugama Forest Reserve, Labugama.

Pseudophilautus auratus (Manamendra-Arachchi & Pethiyagoda, 2005): holotype, WHT 2356; Morningside Forest Reserve (near Rakwana).

Pseudophilautus cavirostris (Günther, 1869): topotypes, WHT 1294, Haycock (Hiniduma, Galle); WHT 2318; Kosmulla near Neluwa, 450m.

Pseudophilautus cuspis (Manamendra-Arachchi & Pethiyagoda, 2005): holotype: WHT 1177(e); paratypes: WHT 1177(a), 1177(b); Koskulana (near Panapola).

Pseudophilautus decoris (Manamendra-Arachchi & Pethiyagoda, 2005): paratypes: WHT 3194, WHT 3257, WHT 3258; Morningside Forest Reserve (near Rakwana).

Pseudophilautus fergusonianus (Ahl, 1927): topotypes, WHT 731, WHT 2233; Kumaradola, Monaragala; WHT 3178, WHT 3179; Puwakpitiya, Knuckles Range.

Pseudophilautus folicola (Manamendra-Arachchi & Pethiyagoda, 2005): holotype: WHT 2645; paratypes: WHT 2646, 2647; Kottawa (Galle).

Pseudophilautus hoipolloi (Manamendra-Arachchi & Pethiyagoda, 2005): holotype: WHT 2673; paratypes, WHT 2674, 2675, Haycock (Hiniduma).

Pseudophilautus limbus (Manamendra-Arachchi & Pethiyagoda, 2005): holotype, WHT 2700; Haycock.

Pseudophilautus lunatus (Manamendra-Arachchi & Pethiyagoda, 2005): holotype, WHT 3283; Handapan Ella Plains.

Pseudophilautus microtympanum (Günther, 1859): topotypes, WHT 2710, WHT 3446; Horton Plains National Park.

Pseudophilautus mittermeieri (Meegaskumbura & Manamendra-Arachchi, 2005): holotype: WHT 3522; paratype: WHT 3526; Kottawa, Galle.

Pseudophilautus nemus (Manamendra-Arachchi & Pethiyagoda, 2005): holotype: WHT 1319; Haycock (Hiniduma).

Pseudophilautus ocularis (Manamendra-Arachchi & Pethiyagoda, 2005): holotype: WHT 2360; Morningside Forest Reserve (near Rakwana).

Pseudophilautus papillosus (Manamendra-Arachchi & Pethiyagoda, 2005): holotype: WHT 3284; Handapan Ella Plains (near Rakwana).

Pseudophilautus procax (Manamendra-Arachchi & Pethiyagoda, 2005): paratypes: WHT 2786, 2787, WHT 3277, 3278; Morningside Forest Reserve (near Rakwana).

Pseudophilautus reticulatus (Günther, 1864): topotypes, WHT 2288, 2289; Dediyagala Forest reserve, Akuressa; WHT 3366, Haycock (Hiniduma).

Pseudophilautus rus (Manamendra-Arachchi & Pethiyagoda, 2005): paratypes, WHT 5432, WHT 5434, WHT5436, WHT 5438, WHT 5440; Pilimatalawa (near Peradeniya).

Pseudophilautus silvaticus (Manamendra-Arachchi & Pethiyagoda, 2005): holotype, WHT 3295; paratypes: WHT 3378, 3379, 3462; Handapan Ella Plains (near Suriyakanda); WHT 3310, Sinharaja World Heritage Site (near Kudawa).

Pseudophilautus stictomerus (Günther, 1876): topotypes: WHT 1173, WHT 2402; Kottawa (Galle).

Pseudophilautus zimmeri (Ahl, 1927): holotype: ZMB 6111; Point de Galle.

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Marine snakes of Indian coasts: historical resume, systematic checklist, toxinology, status, and identification key

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Abstract: We compile an up-to-date checklist of 26 species of marine snakes known from the Indian coastlines. We furnish information on the original orthography, authorship, date of publication, current binominal representation, synonymy and chresonymy lists for each recognized taxon. In addition, we provide details of name-bearing types, repository and type locality (both original and subsequent restrictions where applicable) of the prevailing nomen for all recognized species. We summarise the history of research on Indian marine snakes from Linnaeus to the present day, including taxonomic and regional treatises, and highlight the taxonomic flux. We also provide a revised key for this group to facilitate easier identification and support effective conservation.

Keywords: Achrochrodide, annotated checklist, Homalopsidae, Hydophiinae, India, literature review, synonymy.

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The authors are part of the Coastal and Marine Biodiversity Conservation Network (CoMBINe) Database team involved in updating Species checklists and documenting recorded Species information in Indian waters. This updated checklist is part of the ongoing initiative to list out and update marine biodiversity of India.

Author Contribution: SRG and VDS conceived the study, with inputs from RP and RR. TN, CRS, KRA were involved in literature survey. SRG led the writing with inputs from TN and VDS. All authors eqaually participated in refining the manuscript, addressing editorial comments and approving the final text.

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INTRODUCTION

Snakes which live completely or occasionally in marine and estuarine environments comprise about 90% of living marine reptile species (Wallach et al. 2014; Uetz & Hosek 2017). Marine snakes are mainly found in warm tropical and subtropical coastal waters (Dunson 1975; Tu 1988; Heatwole 1999; Rasmussen et al. 2011; Wallach et al. 2014), and are broadly classified as brackish water snakes, sea kraits and true sea snakes. Occasionally sea snakes venture into tidal river creeks far from the tide line, and similarly brackish water snakes can swim into the sea (Rasmussen et al. 2011; Murphy 2012). Brackish water snakes comprise of wart snakes (Acrochordidae) and mangrove water snakes (some species belonging to family Homalopsidae), which are either non-venomous (Acrochordidae) or mildly venomous (Homalopsidae) and have a cylindrical tapering tail (Whitaker & Captain 2004; Murphy 2007; Alfaro et al. 2008). The true sea snakes (Elapidae: Hydrophiinae) are all venomous with front fangs, and are distinguished by their laterally compressed paddle-like or oar-shaped tail (Heatwole 1999). Two tribes, Hydrophiini (true sea snakes) and Laticaudini (sea kraits) which are also highly venomous and have paddle-shaped tail (Heatwole et al. 2012, 2016; Sanders et al. 2012), are present. Marine snakes live in a variety of habitats like mangrove swamps, coral reefs and lagoons, mud flats and estuaries (Voris & Murphy 2012). Water salinity has been reported to greatly influence the distribution of marine snakes globally (Gasperetti 1988; Brischoux et al. 2012).

As a group of thoroughly aquatic and stenohaline taxa, true sea snakes (Hydrophiinae) have several special adaptations (Brischoux & Shine 2011). Like all reptiles these snakes undergo pulmonary respiration and have an elongated cylindrical lung on the left side of their body for adequate gas exchange. They have nostril valves that regulate air entering the lung so that they can remain under water for 0.5 to 2 hours during a dive. True sea snakes have specialized head-heart distance and lung morphology (Lillywhite et al. 2012b), and like most marine snakes they have a salt-excretion gland under their tongue sheath (Dunson & Dunson 1973). Sea snakes have a paddle-shaped tail for efficient swimming (Aubert & Shine 2008) and specialized visual systems to facilitate underwater habitat selection, foraging and mating (Hart et al. 2012). Sea kraits are known to possess a unique skin that is partially permeable to water exchange (Dunson & Robinson 1976; Lillywhite et al. 2009). A recent study on true sea snakes has revealed the existence of unique sense organs on the scales called sensilla which are sensitive to light variations in the environment (Zimmermann & Heatwole 1990; Crowe-Riddell et al. 2016). True sea snakes have also been reported to be influenced by water loss and dehydration even at mid-sea (Lillywhite et al. 2008, 2012a, 2014, 2015).

True sea snakes shed their skins more frequently (every 2–6 weeks) than land snakes (3–4 months), mainly to remove fouling marine organisms like algae, barnacles and bryozoans (Mays & Nickerson 1968; Key et al. 1995). They are mainly ovoviviparous except for the egg-laying sea kraits (Shetty & Shine 2002). They usually copulate for a long duration lasting up to over 3 hours on the water surface (Heatwole 1999; Chanhome et al. 2011). The reproduction period ranges from 4–11 months and most species reproduce annually (Rasmussen 1989, 1992, 1994; Shine 1988, 2005). Juvenile sea snakes swim up to the water surface to breathe immediately after birth. In many species, juveniles are brightly banded while the adults are unpatterned (Heatwole 1999). Unlike snakes of the tribe Hydrophinii, which are typically adapted to warm coastal waters (Heatwole & Cogger 1993), the sea kraits (genus *Laticauda* Laurenti, 1768) are semi-aquatic and can move well on land, as they often do for thermoregulation, oviposition, skin shedding, prey digestion and assimilation (Heatwole & Guinea 1993; Shine & Shetty 2001).

In India, snakes have religious (Vogel 1926), medical (Whitaker & Andrews 1995) and socio-economic significance (Whitaker 1978). Scientific studies of Indian snakes by the academic community started in the late 18th Century (Vijayaraghavan 2005), and currently a total of 26 marine snake species are recognized (Whitaker & Captain 2004; Adimallaiah 2014): one species of file snake, five species of brackish water snakes and 20 species of venomous sea snakes, including two species of sea kraits (Aengals et al. 2018; Adimallaiah 2014). The file snake is restricted mainly to mangrove areas and occasionally ventures into the sea along India's west coast, the Bengal coast and the Bay Islands' coasts (Whitaker & Captain 2004). The remaining snakes are homalopsids, a family of rear-fanged aquatic snakes comprising of smooth water snakes, mud snakes and mangrove snakes. Of the five species of the homalopsid brackish water snakes, only one (*Cerberus rynchops*) is widespread and common, whereas the other four (*Cantoria violacea*, *Dieurostus dussumierii*, *Fordonia leucobalia* & *Gerarda prevostiana*) are rather rare or range-restricted (Whitaker & Captain 2004; Chandramouli et al. 2012; Kumar et al. 2012; Adimallaiah 2014). The following section presents an in-depth description of Indian marine snakes.

HISTORY OF RESEARCH ON INDIAN MARINE SNAKES

In the 18th Century Linnaeus described a few species of Indian marine snakes, including *Coluber laticaudatus* (now *Laticauda laticaudata* (Linnaeus, 1758)) and *Anguis platura* (now *Hydrophis platurus* (Linnaeus, 1766)). Later the Scottish naturalist Patrick Russell described a few more species using vernacular names that were later given scientifical names by others, including Bokadam: *Cerberus rynchops* (Schneider, 1799); Kerril patti: *Hydrophis nigrocinctus* Daudin, 1803; Shootur sun and / or Kalla Shootur sun: *Hydrophis obscurus* Daudin, 1803; Chittul: *Hydrophis cyanocinctus* Daudin, 1803; Hoogli pattee and /or Valakadyen: *Hydrophis schistosus* Daudin, 1803; Shiddil: *Hydrophis jerdoni* (Gray, 1849) and Kadel Nagam: *Microcephalophis gracilis* (Shaw, 1802) (Russell 1796, 1801). In the same century Schneider (1779) described *Hydrus granulatus* (now *Acrochordus granulatus* (Schneider, 1799)), *Hydrus rynchops* (now *Cerberus rynchops* (Schneider, 1799), *Hydrus Colubrinus* (now *Laticauda colubrina* (Schneider, 1799)) and *Hydrus fasciatus* (now *Hydrophis fasciatus* (Schneider, 1799)).

In the early 19th Century, Shaw (1802) described *Hydrus spiralis* (now *Hydrophis spiralis* (Shaw, 1802)), *Hydrus caerulescens* (now *Polyodontognathus caerulescens* Shaw, 1802), *Hydrus curtus* (now *Hydrophis curtus*) and *Hydrus gracilis* (now *Microcephalophis gracilis* (Shaw, 1802). Daudin (1803) described *Hydrophis schistosus* Daudin, 1803, *H. cyanocinctus* Daudin, 1803, *H. nigrocinctus* Daudin, 1803, *H. obscurus* Daudin, 1803 and *Anguis mamillaris* (now *Hydrophis mamillaris* (Daudin, 1803) (also see Bour 2011). Schlegel (1837) described the brackish water snakes *Homalopsis leucobalia* (now *Fordonia leucobalia* (Schlegel, 1837)). Eydoux & Gervais (1837) described *Coluber* (*Homalopsis*) *prevostianus* (now *Gerarda prevostiana* (Eydoux & Gervais, 1837)). Gray (1842, 1846, 1849) described the sea snakes *Aturia ornata* (now *Hydrophis ornatus* (Gray, 1842)), *Hydrus stokesii* (now *Hydrophis stokesii* (Gray, 1846)), *Aturia lapemoides* (now *Hydrophis lapemoides* (Gray, 1849)) and *Kerilia jerdonii* (now *Hydrophis jerdonii* (Gray, 1849)). André Marie Constant Duméril (1774–1860), Gabriel Bibron (1805–1848) and Auguste Henri André Duméril (1812–1870), zoologists associated with the Museum National d'histoire Naturelle in Paris, France also studied sea snakes. Duméril et al. (1854) described *Eurostus dussumierii* (now *Dieurostus dussumierii* Duméril, Bibron & Duméril, 1854). Later, a German-born zoologist working with the Natural History Museum, London, Albert Karl Ludwig Gotthilf Günther described two species, *Hydrophis stricticollis* Günther, 1864 and *Microcephalophis cantoris* Günther, 1864 (see Günther 1864).

By the late 19th Century no new species of Indian marine snakes were being described (see Whitaker & Captain 2004). The first regional treatise on Indian herpetology was prepared by the British physician Thomas Caverhill Jerdon (1811–1872) (see Jerdon 1854), followed by a treatise by Günther (1864). Museum-based stock-takings and catalogues were also produced, including a description of the holdings of the Indian Museum in Calcutta by William Theobald (Theobald 1868, 1876) and an expanded herpetological catalogue from the same institution by museum director William Lutley Sclater (Sclater 1891). George Albert Boulenger (1858-1937), a Belgian-British zoologist, expanded and revised his early work on Indian herpetology (Boulenger 1890) based on the collections of the London Museum (Boulenger 1896).

In the early 20th Century, Frank Wall, a British physician and herpetologist who lived in South Asia wrote extensively about Indian snakes (Campden-Main 1968, 1969). He published a descriptive list of sea snake specimens preserved in the Indian Museum, Calcutta (Wall 1906), and then what is perhaps the first monograph exclusively dealing with sea snakes (Wall 1909). Like Russell and Jerdon, Wall's experience included studies of museum specimens and a considerable amount of field observation. He worked with the holdings of the Bombay Natural History Society Museum, the British Museum, the Madras Museum and the Indian Museum in Calcutta (Wall 1906, 1909). In a more regional context, Prater (1924) recorded snake species from the Islands of Bombay and Salsette and the surrounding seas, and reported 11 species of sea snakes. Following Wall, Malcolm Arthur Smith (1875-1958) expanded and refined the sea snake monograph (1926) and also the work on Indian ophiology (1943), mainly based on collections in the London and Indian museums.

In modern times studies of Indian marine snakes have primarily consisted of regional reviews (Table 1). Gyi (1970) revised the Homalopsid snakes that also covered the Indian taxa. Ahmed (1975) studied the sea snakes of the Indian Ocean based on the collection of Zoological survey of India (ZSI), dealing with systematics, ecology and distribution of sea snakes, recognizing 29 species. McCarthy (1986) elaborated on the relationships of sea kraits, that also included Indian species. Das (2003) made an extensive overview of the systematics, taxonomy and nomenclature of Indian reptiles, listing 23 species of marine snakes including true sea snakes, sea kraits, file snakes and brackish water snakes. Whitaker

Table 1. Records of sea snakes from Indian waters from 1796 to 2004. Number in entries denote the numbers of nominal representations (i.e., synonyms) for each species as currently recognized. Abbreviations: Rus: Russell (1796-1809), Jerd: Jerdon (1854), Gthr: Günther (1864), Blgr: Boulenger (1890), Scltr: Sclater (1891), Wall: Wall (1909), Smt: Smith (1943), Ahm: Ahmed (1975), WC: Whitaker & Captain (2004), NA: not applicable. * indicates usage of vernacular names.

Species	Rus*	Jerd	Gthr	Blgr	Scltr	Wall	Smt	Ahm	WC
Acrochordus granulatus		1	1	1	1	NA	1	NA	1
Dieurostus dussumierii						NA	1	NA	1
Cerberus rynchops	1	1	1	1	1	NA	1	NA	1
Fordonia leucobalia			1	1	1	NA	1	NA	1
Gerarda prevostiana				1	1	NA	1	NA	1
Cantoria violacea			1	1	1	NA	1	NA	1
Laticauda colubrina		1		1	1	1	1	1	1
L. laticaudata			1	1	1	1	1	1	1
Hydrophis caerulescens			1	1	1	1	1	1	1
H. curtus		1	1	1	1	1	1	1	1
H. cyanocinctus	1	1	1	3	2	1	1	1	1
H. fasciatus			1	1	1	1	1	1	1
H. jerdoni	1		1	1	1	1	1	1	1
H. lapemoides			1	1	1	1	1	1	1
H. mamillaris				1		1	1	1	1
H. nigrocinctus	1	1	1	2	1	1	1	1	1
H. obscurus	2		1	3	3	2	1	1	1
H. ornatus			1	1		1	1	1	1
H. platurus		1	1	1	1	1	1	1	1
H. schistosus	2	1		2	1	1	1	1	1
H. spiralis			1	2	1	1	1	1	1
H. stokesi			1	1		1	1		1
H. stricticollis			1				1	1	1
H. viperinus				2	1	1	1	1	1
Microcephalophis cantoris			1	1	1	1	1	1	1
M. gracilis	1	1	1	1	1	1	1	1	1

& Captain (2004) published a field guide to the snakes of India that illustrated and described 157 of over 270 species of Indian snakes, including 23 species of marine snakes. They provided photographs of several marine snakes providing a useful tool for species identification by non-experts. Smith (1926) who considers *H. hardwickii* to not be part of the Indian sea snake fauna, quotes Günther's (1864) remark that though its type specimen is believed to be from India, several circumstances lead one to suppose that it is from Penang [in Malaysia]. Subsequently, *H. hardwickii* is treated as a synonym of *H. curtus* (see Gritis & Voris 1990).

More recently, several reviews on Indian taxa have appeared (Voris 1972, 2017; Rasmussen 1989, 1992, 1994, 1997; Heatwole et al. 2005, 2012, 2017; Kharin 2005; Kharin & Czeblukov 2006; Somaweera et al. 2006; Somaweera & Somaweera 2009; de Silva et al. 2011; Murphy et al. 2012; Sanders et al. 2013; Wallach et al. 2014; Ukuwela et al. 2017). Other aspects studied include marine snake ecology and conservation, and the distribution and diversity of marine snakes along the coasts of India (Murthy 1977 a,b; Lobo et al. 2005; Lobo 2006; Murthy 2007; Kannan & Rajagopalan 2008; Palot & Radhakrishnan 2010; Adimallaiah 2014). Adimallaiah (2014) reported the poorly-known mud snake *Dieurostus dussumierii* from Kochi beach in the Malabar Coast (also see Chadramouli et al. 2012; Kumar et al. 2012). In Homalopsid snakes, some poorly-known Indian species were researched (Alfaro et al. 2004; Somaweera et al. 2006; Chandramouli et al. 2012; Kumar et al. 2012; Das et al. 2013; Vyas et al. 2013; Adimallaiah 2014; Murphy & Voris 2014; Ukuwela et al. 2017). Lastly, Aengals et al.

(2018) worked on an updated checklist of Indian reptiles, featuring a total of 26 marine snakes.

This summary shows that there has been a considerable amount of work published documenting Indian marine snakes since the 18th Century. Taxonomic inconsistency is evident, with different authors having described the same species using different names or synonyms. Major works from 1796 to 2004 are listed in Table 1, followed by a synopsis for each species mainly sourced from Smith (1943), Golay et al. (1993), Somawera & Somaweera (2009), Wallach et al. (2014) and Uetz & Hosek (2017). An updated chreso-synonymy (sensu Smith & Smith 1973; Dubois 2000), information of type specimen(s), type locality and other pertinent data have also been updated to current taxonomy.

SPECIES SYNOPSIS

Acrochordidae Bonaparte, 1831

File Snake *Acrochordus granulatus* (Schneider, 1799)

Hydrus granulatus Schneider, 1799 (sic)

Anguis granulatus acrochordus Schneider, 1801

Acrochordus fasciatus Shaw, 1802

Pelamis granulatus — Daudin, 1803 (sic, for *Pelamis granulata*)

Chersydrus [fasciatus] — Cuvier, 1817

Chersydrus granulatus — Merrem, 1820

Acrochordus fasciatus — Raffles, 1822

Hydrus granulatus — Raffles, 1822

Acrochordus granulatus — Cantor, 1847

Chersydrus annulatus Gray, 1849

Chersydrus granulatus luzonensis Loverdige, 1938

Type locality: “Madras, India” (fide Sang et al. 2009).

Type specimen: unknown or lost (fide Sang et al. 2009; Wallach et al. 2014).

Homalopsidae Jan, 1863

Dussumier’s Mud Snake *Dieurostus dussumierii* (Duméril, Bibron & Duméril, 1854)

Eurostus dussumierii Duméril, Bibron & Duméril, 1854

Hypsirhina dussumieri — Jan, 1863 (nomen incorrectum)

Dieurostus dussumieri —Berg, 1901

Hypsirhina malabarica Werner, 1913

Enhydris dussumieri — Smith, 1943

Enhydris dussumieri — Murphy, 2007

Enhydris dussumieri — Kumar & Captain, 2011 (nomen incorrectum)

Enhydris dussumierii — Chandramouli et al., 2012

Dieurostus dussumieri — Kumar et al., 2012 (nomen incorrectum)

Dieurostus dussumieri — Murphy & Voris, 2014

Dieurostus dussumierii — Wallach et al., 2014

Type locality: Malabar Coast, India / ‘Bengal’.

Type specimen: Lectotype, Muséum National d’Histoire Naturelle, Paris, France, MNHN 3751 (after Wallach et al. 2014; *contra* Kumar et al. 2012).

Type species: *Eurostus dussumierii* Duméril, Bibron & Duméril, 1854 is the type species of the genus *Dieurostus* Berg, 1901.

Dog-faced Water Snake *Cerberus rynchops* (Schneider, 1799)

Hydrus rynchops Schneider, 1799

Boa moluroides Schneider, 1801

Hydrus cinereus Shaw, 1802

Coluber cerberus Daudin, 1803

Hurria bilineata Daudin, 1803

Python rhynchops — Merrem, 1820

Homalopsis cerberus — Fitzinger, 1826

Homalopsis molurus H. Boie, 1826

Coluber decipiens Oppel in Boie, 1826

Homalopsis rhynchops — Boie, 1827

Cerberus cerberus — Cuvier, 1829

Homalopsis rufotaeniatus Wagler, 1833

Cerberus grantii Cantor, 1836

Cerberus cinereus — Cantor, 1839

Cerebrus russellii — Fitzinger, 1843

Homalopsis rhinchops (*sic*) — Cantor, 1847; Mason, 1852

Cerberus unicolor Gray, 1849

Cerberus rhynchops — Günther, 1864

Cerberus rhynchops — Anderson, 1871

Hurria rynchops — Stejneger, 1907

Type locality: “Ganjam” (Orissa State, E India).

Type specimen: Lectotype; specimen illustrated in Russell (1796), after Wallach et al. (2014).

Type species: *Hydrus rynchops* Schneider, 1799 is the type species of the genus *Cerberus* Cuvier, 1829.

Crab-eating Water Snake *Fordonia leucobalia* (Schlegel, 1837)

Homalopsis leucobalia Schlegel, 1837

Fordonia leucobalia — Gray, 1842

Fordonia unicolor Gray, 1849

Hemiodontus leucobalia — Duméril, Bibron & Duméril, 1854

Hemiodontus chalybaeus Jan, 1863

Fordonia bicolor Theobald, 1868

Fordonia papuensis Macleay, 1877
Fordonia variabilis Macleay, 1878
Fordonia leucobalia — Smith, 1943

Type locality: Timor (Indonesia) by lectotype designation

Type specimen: Lectotype, Rijksmuseum van Natuurlijke Historie, Leiden, The Netherlands RMNH 1161 (see Wallach et al. 2014).

Type species: *Homalopsis leucobalia* Schlegel, 1837 is the type species of the genus *Fordonia* Gray, 1842.

Glossy Marsh Snake *Gerarda prevostiana* (Eydoux & Grevias, 1837)

Coluber (Homalopsis) prevostianus Eydoux & Gervais, 1837
Gerarda bicolor Gray, 1849
Campylodon prevostianum — Duméril, Bibron & Duméril, 1854
Gerarda prevostiana — Cope, 1862
Heleophis flavescens Müller, 1884 (fide Smith, 1943)
Helipophis flavescens Müller, 1884 (fide Murphy & Voris, 2014, in error)
Gerardia prevostiana — Wall, 1905

Type locality: "Manille" (= Manila in Luzon, Philippines)

Type specimens: Syntypes: Muséum national d'Histoire naturelle Paris, France, MNHN 3758 and MNHN 7593 (Wallach et al. 2014).

Remarks: Type specimen details was stated to be unknown by Das et al. (2013).

Type species: *Coluber prevostianus* Eydoux & Grevias, 1837 is the type species of the genus *Gerarda* Gray, 1849.

Mangrove Snake *Cantoria violacea* Girard, 1858

Cantoria violacea Girard, 1858
Hydrodipsas elapiformis Peters, 1859
Hemiodontus elapiformis – Jan, 1863
Cantoria elongata Günther, 1864 (nom. nov. pro *Cantoria violacea* Girard) – nomen nudum Wallach et al., 2014
Cantoria elapiformis – Günther, 1869
Cantoria dayana Stoliczka, 1870
Cantoria dayana — Anderson, 1871
Cantoria violacea — Grandison, 1978

Type locality: "Singapore".

Type specimen: Holotype; United States National Museum, Chicago, USA USNM 5523.

Type species: *Cantoria violacea* Girard, 1858 is the type species of the genus *Cantoria* Girard, 1858.

Remarks: Precise Indian records of this species are from the Andaman Islands (Ghodke & Andrews 2002).

Elapidae Boie, 1827

Common Sea Krait *Laticauda laticaudata* (Linnaeus, 1758)

Coluber laticaudatus Linnaeus, 1758 (part)
Laticauda scutata Laurenti, 1768
Platurus fasciatus Latreille, 1801
Platurus laurenti Rafinesque, 1817 (non *Platurus laurenti* Daudin, 1803)
Aspisurus laticaudatus — Gray in Grey, 1841 (nomen incorrectum) – Wallach et al. 2014
Platurus laticaudatus — Girard, 1858
Platurus fischeri Jan, 1859
Platurus fasciatus Jan, 1859
Platurus affnisi Anderson, 1871
Platurus fischeri — Anderson, 1871
Platurus muelleri Boulenger, 1896
Platurus laticaudatus — Wall, 1906
Laticauda laticaudata — Stejneger, 1907
Laticaudata laticaudata — Oshima, 1910
Laticauda laticauda — Brehm, 1913
Laticauda laticoudata — Khole, 1991

Type locality: "Indiis"; by lectotype designation (see Wallach et al. 2014).

Type specimen: Lectotype; Naturhistoriska Riksmuseet, Stockholm, Sweden NRM (NHRM Lin-87).

Type species : *Coluber laticaudatus* Linnaeus, 1758 is the type species of the genus *Laticauda* Laurenti, 1768.

Yellow-lipped Sea Krait *Laticauda colubrina* (Schneider, 1799)

Hydrus colubrinus Schneider, 1799
Coluber laticaudatus Linnaeus, 1758 (part)
Platurus colubrinus — Wagler, 1830
Coluber platycaudatus Oken, 1836 (nomen substitutum)
Hydrophis colubrina — Schlegel, 1837
Hydrus colubrinus — Begbie, 1846
Laticauda scutata (non Laurenti, 1768) Cantor, 1847
Platurus fasciatus var. *colubrina* — Fischer, 1856
Platurus laticaudatus var. B. — Günther, 1858 (part)
Platurus colubrinus — Fischer, 1884
Platurus colubrinus — Boulenger, 1896 (part)
Laticauda colubrina — Stejneger, 1907
Laticauda celubrina — Deraniyagala, 1977 (nomen incorrectum)

Type locality: "East Indian Ocean" (Bauer 1998)

Type specimen: Holotype; Zoologische Museum, Berlin, Germany, ZMB 9078

Malacca Sea Snake *Hydrophis caerulescens* (Shaw, 1802)

Hydrus caerulescens Shaw, 1802 (sic)
Polyodontus annulatus Lesson, 1834
Hydrophis caerulescens — Gray, 1842
Hydrophis hybrida Schlegel, 1844
? *Hydrophis colubrinus* Jerdon, 1854
Hydrophis protervus Jan, 1859
Hydrophis wertmani Jan, 1859
Hydrophis frontalis Jan, 1863
Hydrophis polydonta Jan, 1863
Hydrophis polyodontus Jan, 1872 in Jan & Sordelli, 1870-1881
Hydrophis caerulescens thai Smith, 1920
Polyodontognathus caerulescens — Wall, 1921
Hydrophis coerulescens — Bouquet, 1964 (nomen incorrectum)
Hyhdrophis caerulscens — Deraniyagala, 1977 (nomen incorrrectum)
Hydrophis coerelescens — Lin, 1975 (nomen incorrectum)
Aturia caerulescens — Welch, 1994
Hydrophis caerulescens — Sanders et al., 2013
Polyodontognathus caerulescens — Wallach et al., 2014

Type specimen: Holotype; The Natural History Museum London, UK, BMNH 1946.1.3.90, from "East-Indian" (= Indian Ocean).

Type locality: Indian Ocean (as East-Indian); however, label on type cites type locality as "Indian Ocean: Vizagapatam" (see Smith 1926).

Short Sea Snake *Hydrophis curtus* (Shaw, 1802)

Hydrus curtus Shaw, 1802
Hydrophis flaviventris Siebold, 1827
Hydrophis pelamidoides Schlegel, 1837
Lapemis curtus — Gray, 1842
Lapemis loreatus Gray, 1843
Hydrus pelamoides Hallowel, 1845 (nomen emendatum)
Hydrophis pelamiodes Duméril, 1853 (nomen incorrectum)
Hydrophis pelamidoides — Duméril, Bibron & Duméril, 1854
Hijdrophis pelamidioides Bleeker, 1856 (nomen emendatum)
Hydrophis (*Pelamis*) *pelamidoides* var. *annulata* Fischer, 1856
Hydrophis (*Pelamis*) *pelamidoides* — Fischer, 1856
Hydrophis problematicus Jan, 1859
Hydrophis propinquus Jan, 1859
Hydrophis abbreviatus Jan, 1863
Hydrophis brevis Jan, 1863
Hydrophis loreata — Günther, 1864
Hydrophis fayreriana Anderson, 1871
Hydrophis fayeri Fayer, 1871 (nomen emendatum)
Hydrophis pelamidoides unimaculatus Peters *in* Martens, 1876
Hydrophis pelamoides Hilgendorf, 1876 (in error)
Hydrophis hardwickei — Boettger, 1888 (emendation)
Hydrophis abreviatus — Casto de Elera, 1895 (nomen incorrectum)
Enhydris curtus — Werner, 1895
Hydrophis pelmoides — Khan, 1982 (nomen incorrectum)
Hydrophis abbreviataus — Culotta & Pickwell, 1993 (nomen incorrectum)
Hydrophis curtus — Sanders et al., 2013
Lapemis curtus — Wallach et al., 2014

Type specimen: Holotype; The Natural History Museum London, UK, BMNH 1946.1.17.59.

Type locality: "East-India", none stated more precisely.

Annulated Sea Snake *Hydrophis cyanocinctus* Daudin, 1803

Hydrophis cyanocinctus Daudin, 1803
Leioselasma striata Lacépède, 1804
Hydrophis chittul Rafinesque-Schmaltz, 1817
Hydrophis striata — Schlegel, 1837
Hydrophis sublaevis Gray, 1842 (in part)
Hydrophis subannulata Gray, 1849
Hydrophis aspera Gray, 1849
? Hydrophis striatus — Duméril, Bibron & Duméril, 1854
Hydrophis striata — Fischer, 1856
Hydrophis westermani Jan, 1859
Hydrophis westermanni — Jan, 1863 (emendation)
Hydrophis trachyceps Theobald, 1868
Hydrophis crassicollis Anderson, 1871
Hydrophis tuberculatus Anderson, 1871
Hydrophis dayanus Stoliczka, 1872
Hydrophis tenuicollis Peters, 1872
Hydrophis asperrimus Murray, 1886
Hydrophis taprobanica Haly, 1887
Hydrophis phipsoni Murray, 1887
Hydrophis cyanocincta — Boulenger, 1887
Distira cyanocincta — Werner, 1895
Distira cyanocincta — Boulenger, 1896
Distira saravacensis Boulenger, 1900
Distira sarawacensis — Shelford, 1901 (nomen

emendatum)

Hydrophis cyanocyneta — Anonymous, 1902 (nomen incorrectum)

Distira longissima Rosén, 1905

Distina cyanocincta — Aiyar, 1906 (nomen incorrectum)

Disteira cyanocincta — Stejneger, 1907

Distra cyanocincta — Castellani & Chalmers, 1913 (nomen incorrectum)

Leioselasma [sic] *cyanocincta* — Wall, 1921

Leioselasma cyanocincta — Prater, 1924

Hydrophis cyanocinctus — Smith, 1943

Hydrophis asperriums — Meyers, 1947 (nomen incorrectum)

Hydrophys cyanocinctus — Anthony, 1955 (nomen incorrectum)

Disteira saravaciensis — Culotta & Pickwell, 1993 (nomen incorrectum)

Hydrophis asperiums — Culotta & Pickwell, 1993 (nomen incorrectum)

Hydrophis cyanocinctus — Sanders et al., 2013

Leioselasma cyanocincta — Wallach et al., 2014

Type specimen: Holotype; The Natural History Museum, London, UK, BMNH 1946.1.9.23 (see Wallach et al. 2014).

Type locality: "Coromandel" Coast of eastern peninsular India, precisely the Sunderban in Bengal.

Remarks: Type material was misreported to be lost by Sang et al. (2009). The nomen *Hydrophis dayanus* Stoliczka, 1872 has varying been considered as a synonym of *H. cyanocinctus* Daudin, 1803 and *H. lapemoides* (Gray, 1849) (see Das et al. 1998).

Banded Sea Snake *Hydrophis fasciatus* (Schneider, 1799)

Hydrus fasciatus Schneider, 1799 (sic)

Hydrophis laticauda Latreille in Sonnini & Latreille, 1801

Anguis xiphura Hermann, 1804

Hydrophis lanceolatus Oken, 1817

Hydrus chlorus Merrem, 1820

Disteira fasciata — Fitzinger, 1826

Hydrus chloris Gray in Griffith & Pidgeon, 1831 (nomen emendatum)

Pelamis Lindsayi Gray in Griffith & Pidgeon, 1831

Hydrophis gracilis (not of Shaw 1802) Schlegel, 1837 (part)

Aturia Lindsayi — Gray, 1842

Colubrinus hydrus Duméril, Bibron & Duméril, 1854

Hydrophis fasciatus — Duméril, Bibron & Duméril, 1854

Hydrophis chloris Günther 1864 (non *H. cloris* Daudin, 1803)

Hydrophis Lindsayi — Anderson, 1871

Hydrophis fasciatus — Peters, 1872

Hydrophis leptodira Boulenger, 1896

Hydrophis fasciatus — Boulenger, 1896

Hydrophis rhombifer Boulenger, 1900

Hydrophis lindsays — Mocquard, 1904 (nomen incorrectum)

Disteira fasciata — Stejneger, 1907 (part)

Hydrophis lindsaya — Wall, 1921 (nomen incorrectum)

Micromastophis fasciatus — Prater, 1924

Aturia fasciata — Wall, 1921

Hydrophis fasciatus — Smith, 1943

Hydrophis fasciatus faciatus — Lin, 1975 (nomen incorrectum)

Pelamis fasciataus — Culotta & Pickwel, 1993 (nomen incorrectum)

Type specimens: Lectotype; Zoologisches Museum Berlin, Germany, ZMB 2836.

Type locality: None given. Smith (1926, 96) stated that the type of *Hydrophis fasciatus* was labelled "East Indies."

Type species: *Hydrus fasciatus* Schneider, 1799 is the type species of the genus *Hydrophis* Latreille *in* Sonnini & Latreille, 1801.

Jerdon's Sea Snake *Hydrophis jerdonii* (Gray, 1849)

Eryx shiddil Wagler, 1825 (nomen ineditum)

Hydrus shiddil Boie, 1827 (nomen nudum)

Kerilia jerdonii Gray, 1849 (sic)

Hydrus cantori Jerdon, 1854

Hydrophis jerdonii — Anderson, 1871

Distira jerdonii Boulenger, 1896

Hydrophis jerdonii — Boulenger, 1912

Kerilia jerdonii — Wall, 1921

Kerilia jerdoni siamensis Smith, 1926

Hydrophis jerdone — Culotta & Pickwell, 1993 (nomen incorrectum)

Hydrophis jerdonii — Sanders et al., 2013

Type specimen: Holotype; The Natural History Museum London, UK, BMNH 1946.1.10.11.

Type locality: Madras, India.

Type species: *Kerilia jerdoni* Gray, 1849 is the type species of the genus *Kerilia* Gray, 1849. The validity of the subspecies has been questioned before (see Rasmussen & Anderson 1990).

Persian Gulf Sea Snake *Hydrophis lapemoides* (Gray, 1849)

Aturia lapemoides Gray, 1849

Hydrophis lapemoides — Günther, 1864

Hydrophis holdsworthii Günther, 1872

Hydrophis stewartii Anderson, 1872

Distira lapemioides — Boulenger, 1890 (nomen emendatum)

Distira lapemoides — Werner, 1895

Distira lapemoides — Wall, 1909

Lioselasma [sic] *lapemidoides* [sic] — Wall, 1921

Distira lapimoides — Phisalix, 1922 (nomen incorrectum)

Disteira lapemoides — Werner, 1924

Hydrophis lapemoides — Smith, 1926

Lioselasma lapemoides — Culotta and Pickwell, 1993

Chitulia lapemoides — Kharin, 2005

Hydrophis lapemoides — Sanders et al., 2013

Type specimen: Lectotype; The Natural History Museum London, UK, BMNH 1946.1.7.2 (after Wallach et al. 2014).

Type locality: Ceylon, now Sri Lanka.

Bombay Gulf Sea Snake *Hydrophis mamillaris* (Daudin, 1803)

Anguis mamillaris Daudin, 1803

Hydrophis tesselatus — Murray, 1886

Hydrophis mammillaris — Wall, 1906 (nomen emendatum)

Lioselasma mamillaris — Wall, 1921 (*sic*)

Leioselasma mamillaris — Smith, 1926

Hydrophis mamillaris — Smith, 1943

Aturia mamillaris — Welch, 1994

Hydrophis mamillaris — Das, 1996

Hydrophis mammillaris [sic] — Khan, 2002 (incorrect spelling)

Chitulia mamillaris — Kharin, 2005

Hydrophis mamillaris — Sanders et al., 2013 (by implication)

Chitulia (Dolichodira) mamillaris — Kharin, 2012

Chitulia mamillaris — Wallach et al., 2014

Type specimen: Neotype; The Natural History Museum London, UK, BMNH 1861.12.30.38 (Wallach et al. 2014).

Type locality: “Vizagapatam” (=Vishakhapatnam), in northeastern Andhra Pradesh, India.

Black-banded Sea Snake *Hydrophis nigrocinctus* Daudin, 1803

Hydrophis nigrocinctus Daudin, 1803

Hydrophis nigro-cinctus — Duméril, Bibron & Duméril, 1854

Hydrophis nigrocincta — Fischer, 1856

Hydrophis nigro-cincta — Viaud-Grant-Marias, 1880 (nomen illegitimum)

Hydrophis nigrocyneta — Anonymous, 1902 (nomen incorrectum)

Melanomystax nigrocinctus — Wall, 1921

Hydrophis nigrocinctus — Smith, 1943

Disteira walli Kharin, 1989

Disteira nigrocincta — Welch, 1994

Disteira nigrocinctus — Rasmussen, 1997

Disteira nigrocincta — Wallach et al., 2014

Type specimen: Holotype; The Natural History Museum London, UK, BMNH 1946.1.10.13, depicted in Russell, 1801, p. 7, pl. 6.

Type locality: salted waters of a river near Calcutta, Sundarban, West Bengal, India.

Estuarine Sea Snake *Hydrophis obscurus* Daudin, 1803

Hydrophis obscura Daudin, 1803

Hydrophis cloris Daudin, 1803

Hydrophis shooter Rafinesque-Schmaltz, 1817

Pelamis chloris — Merrem, 1820 (nomen emendatum)

Leioselasma obscura — Fitzinger, 1827

Hydrophis subcinctus Gray, 1842

Hydrophis coronata Günther, 1864

Hydrophis latifasciata Günther, 1864

Hydrophis subcincta — Günther, 1864

Hydrophis coronata — Anderson, 1871

Porrecticollis obscurus — Wall, 1921

Hydrophis obscurus — Smith, 1943

Porreticollis obscurus — Culotta & Pickwell, 1993 (nomen incorrectum)

Type specimen: Holotype; The Natural History Museum London, UK, BMNH 1946.1.9.27 (specimen depicted in Russell, 1801, pl. 8).

Type locality: Sandbarbans, now Sunderban, West Bengal, India.

Cochin Banded Sea Snake *Hydrophis ornatus* (Gray, 1842)

Aturia ornata Gray, 1842

Hydrophis laevis Lütken, 1863 (nomen praeoccupatum)

Hydrophis ellioti Günther, 1864

Hydrophis ornata — Günther, 1864

Hydrophis godeffroyi Peters, 1879

Hydrophis ellioti — Boulenger, 1887

Distira andamanica Annandale, 1905

Distira mjobergi Lönnberg & Andersson, 1913

Distira godeflovi — Phisalix, 1922 (nomen incorrectum)

Disteira ornata — Taylor, 1922

Hydrophis inornatus — Smith, 1926

Distira ornata godeffroi — Takahashi, 1935 (nomen incorrectum)

Hydrophis ornatus — Smith, 1943

Hydrophis ornatus maresinensis Mittleman, 1947

Hydrophis ornata godeffrayi — Wang & Wang, 1956 (nomen incorrectum)

Hydrophis maresianus Kelmmer, 1963 (nomen emendatum)

Hydrophis ernata— Deraniyagala, 1974 (nomen incorrectum)

Hydrophis oranatus — Tamiya & Puffer, 1974 (nomen incorrectum)

Hydrophis elliotti — Culotta & Pickwell, 1993 (nomen incorrectum)

Chitulia ornata — Wallach et al., 2014

Type specimen: Holotype; The Natural History Museum London, UK, BMNH 1946.1.23.72.

Type locality: none given; later restricted to Indian Ocean by Günther (1864).

Black and Yellow Sea Snake *Hydrophis platurus* (Linnaeus, 1766)

Anguis platura Linné, 1766

Anguis platuros — Gmelin, 1789 (nomen incorrectum)

Hydrus bicolor Schneider, 1799

Pelamis bicolor — Schneider, 1799

Pelamis platuros [sic] Daudin, 1803

Pelamis bicolor — Daudin, 1803

Natrix dorsalis Rafinesque-Schmaltz, 1817

Ophinectes lutens Rafinesque-Schmaltz, 1817

Pelamis schneideri Rafinesque-Schmaltz, 1817 (nomen substitutum)

Hydrophis pelamis Schlegel, 1837 (nomen substitutum)

Pelamis ornata Gray, 1842 (non *Aturia ornata* Gray, 1842)

Pelamis bicolor var. *maculata* Duméril, Bibron & Duméril, 1854 (nomen nudum)

Pelamis bicolor var. *variegata* Duméril, Bibron & Duméril, 1854

Pelamis bicolor var. *sinuata* Duméril, Bibron & Duméril, 1854

Hydrophis (Pelamis) bicolor var. *alternans* Fischer, 1855

Hydrophis (Pelamis) bicolor var. *sinuata* — Fischer, 1855

Pelamijs bicolor — Bleeker, 1856 (nomen emendatum)

Hydrophis (Pelamis) bicolor var. *alternans* Fischer, 1856 (nomen substitutum pro *P. variegata*).

Hydrophis (Pelamis) bicolor — Fischer, 1856

Hydrophis (Pelamis) bicolor var. *sinuata* — Fischer, 1856

Hydrophis bicolor chinensis Jan, 1859

Pelamis tricolor Bennett, 1862

Pelamides platurus — Blyth, 1863 (nomen incorrectum)

Hydrophis bicolor maculata Jan, 1863 (nomen nudum)

Hydrophis bicolor maculata Jan, 1872 in Jan & Sordelli, 1870-1881

Pelamis platurus — Stoliczka, 1872

Hydrus platurus — Boulenger, 1896

Hydrus platyurus — Lydekker, 1901 (nomen incorrectum)

Hydrus platurus linnaeus — Castellani & Chalmers, 1910 (nomen incorrectum)

Pelamydrus platurus — Stejneger, 1910

Hydrus platurus pallidus Wall, 1921

Hydrus platurus subobscurus Wall, 1921

Pelamydrus platalus — Nagai, 1928 (nomen incorrectum)

Pelamas platurus — Deam, 1938 (nomen incorrectum)

Pelamiris platurus — Daniel, 1949 (nomen incorrectum)

Pelamis platura brunnea Deraniyagala, 1955

Pelamis platura fasciata Deraniyagala, 1955

Pelamis platura leucostriata Deraniyagala, 1955

Pelamis platura neuricatenata Deraniyagala, 1955

Pelamis platura neurileucura Deraniyagala, 1955

Pelamis platura tricolor Deraniyagala, 1955

Pelamis platyura — Deraniyagala, 1977 (nomen incorrectum)

Palemis platurus — Felger & Moser, 1985 (nomen incorrectum)

Pelamydrus platarus — Culotta & Pickwell, 1993 (nomen incorrectum)

Hydrophis platurus — Sanders et al., 2013

Type specimen(s): Cabinet of Natural Wonders of F. Ziervogel, pharmacist to the Royal Court in Stockholm, fide E. Thorsell (in litt.) ; but stated to be in Department of Vertebrate Zoology, Stockholm, Stockholm, Sweden, NHR fide Wall (1921) (see Wallach et al. 2014).

Type locality: Unknown, erroneously cited as Suriname (Wallach et al. 2014)

Remarks: Holotype was stated to be unknown by Sang et al. (2009).

Type species: *Hydrus bicolor* Schneider, 1799 is the type species of the genus *Pelamis* Daudin, 1803.

Hook-nosed Sea Snake *Hydrophis schistosus* Daudin, 1803

Hydrophis schistosus Daudin, 1803

Enhydris valakadin Rafinesque-Schmaltz, 1817

Hydrophis cianura Rafinesque-Schmaltz, 1817

Hydrophis hoglin Rafinesque-Schmaltz, 1817

Hydrus valakadjen — Boie in Schlegel, 1826 (nomen incorrectum)

Hydrophis flaviventris Siebold, 1827

Hydrus valakadyn — Boie, 1827 (nomen incorrectum)

Disteira russelii Fitzinger, 1827 (based on Russell 1801)

Polyodontes annulatus Lesson, 1832 in Bélanger, 1831-1834

Hydrophis schistosa (not of Daudin, 1803) Schlegel, 1837

Hydrophis bengalensis Gray, 1842

Hydrophis subfasciata Gray, 1842

Enhydrina valakadyen — Gray, 1849 (nomen emendatum)

Thalassophis werneri Schmidt, 1852

Thalassophis werneria Duméril, Bibron & Duméril, 1854 (nomen emendatum)

Hydrophis schistosus — Duméril & Bibron & Duméril, 1854

Hydrophis schistosa — Fischer, 1856

Enhydrina schistosa — Stoliczka, 1870

Enhydrina valakadyen — Stoliczka, 1870

Enhydrina valacadyen — Anderson, 1872 (nomen incorrectum)

Hydrophis fasciatus (not of Schneider, 1799) — Jan, 1872

Hydrophis schistosus — Jan, 1872

Entrydrina bangaensis — Phipson, 1887 (nomen incorrectum)

Enhydrina valakadien — Boulenger, 1890 (nomen emendatum)

Enhydrina vikadien — Boettger, 1892 (nomen incorrectum)

Enhydrina schistosa — Van Denburgh, 1895

Enhydrina velakadien — Flower, 1899 (nomen incorrectum)

Enhydrina valacadjen — Kathariner, 1900 (nomen incorrectum)

Enhydrina schistoza — Codoceo, 1956 (nomen incorrectum)

Enhydrina schitosa — Bouquet, 1964 (nomen incorrectum)

Enhydrena schistose — Chippaux & Goyffon, 1983 (nomen incorrectum)

Enhydria schistose — Murthy, 1986 (nomen incorrectum)

Enhydrina valacadien — Culotta & Pickwell, 1993 (nomen incorrectum)

Disteira schistosa — McDowell, 1972

Hydrophis schistosus — Sanders et al., 2013

Type specimen: Holotype; The Natural History Museum London, UK, BMNH 1946.1.10.7.

Type locality: Tranquebar (now Tarangampadi), Tamil Nadu, India.

Type species: *Hydrophis schistosus* Daudin, 1803 is the type species of the genus *Enhydrina* Gray, 1849.

Yellow Sea Snake *Hydrophis spiralis* (Shaw, 1802)

Hydrus spiralis Shaw, 1802

Hydrus brugmannii Boie in Schlegel, 1826 (nomen nudum)

Hydrophis brugmansii Boie, 1827 (nomen emendatum)

Hydrophis melanurus Wagler, 1828

Hydrophis sublaevis Gray, 1842 (in part)

Hydrophis spiralis — Duméril, Bibron & Duméril, 1854

Hydrophis rappi Jan, 1863 (nomen nudum)

Hydrophis robusta Günther, 1864

Hydrophis robsustus — Theobald, 1868

Hydrophis rappii Jan, 1872 in Jan & Sordelli, 1870-1881

Hydrophis temporalis Blanford, 1881

Hydrophis bishopii Murray, 1884

Hydrophis aurifasciata Murray, 1886

Hydrophis melanocinctus Wall, 1906

Hydrophis brugmansii — Boulenger, 1912

Distira brugmansi — Stone, 1913

Lioselasma [sic] *spiralis* — Wall, 1921

Distira spiralis typica Raj, 1926

Hydrophis spiralis — Smith, 1943

Leioselasma spiralis — Prater, 1924

Hydrophis rapii — Culotta & Pickwell, 1993 (nomen incorrectum)

Leiocephalus spiralis — Das, 1996

Leioselasma spiralis — Wallach et al., 2014

Type specimen: Holotype; The Natural History Museum London, UK, BMNH 1946.1.6.94.

Type locality: Indian Ocean.

Remarks: Perhaps the largest of true sea snakes, at least among those found in Indian waters (Wall 1909; Smith 1926, 1943; Whitaker & Captain 2004).

Stoke's Sea Snake *Hydrophis stokesii* (Gray, 1846)

Hydrus stokesii Gray, 1846
Hydrus major Shaw, 1802 (part)
Hydrophis schizopholis Schmidt, 1846
Hydrus annulatus Gray, 1849
Hydrophis schizopholis — Duméril, Bibron & Duméril, 1854
Astrotia schizopholis — Fischer, 1856
Hydrophis güntheri Theobald, 1868 (nomen praeoccupatum)
Hydrophis granosa Anderson, 1871
Hydrophis guttata Murray, 1887
Disteira stokesii— Boulenger, 1896
Astrotia stokesi — Wall, 1909
Astrossii stokesii — Lowe, 1932 (nomen incorrectum)
Astrokia stokesi — Ruiter, 1958 (nomen incorrectum)
Astoria stokesi — Sawai, 1976 (nomen incorrectum)
Astroria stokesi — deSilva, 1976 (nomen incorrectum)
Astrocia stokessi — Khole, 1991 (nomen incorrectum)
Hydrophois guentheri — Cogger, 1983 (nomen corrigendum)
Hydrophis stokesii — Sanders et al., 2013
Astrotia stokesii — Wallach et al., 2014

Type specimen: Holotype; The Natural History Museum London, UK, BMNH 1946. 1. 17. 12.

Type locality: Australian Seas.

Type species: *Hydrus stokesii* Gray *in* Stokes, 1846 is the type species of the genus *Astrotia* Fischer, 1855.

Narrow-collared Sea Snake *Hydrophis stricticollis* Günther, 1864

Hydrophis stricticollis Günther, 1864
Hydrophis neglectus Wall, 1906
Distira neglecta — Wall, 1909
Aturia stricticollis — Welch, 1994
Chitulia stricticollis — Kharin, 2005
Chitulia (*Dolichodira*) *stricticollis* — Kharin, 2012
Hydrophis stricticollis — Sanders et al., 2013
Chitulia stricticollis — Wallach et al., 2014

Type specimen: Holotype; The Natural History Museum London, UK, BMNH 1946.1.6.90.

Type locality: Bay of Bengal, India.

Viperine Sea Snake *Hydrophis viperinus* (Schmidt, 1852)

Thalassophis viperina Schmidt, 1852
Diseira praescutata Duméril, 1853 (nomen nudum)
Diseira praescutata Duméril, Bibron & Duméril, 1854
Hydrophis doliata (not of Lacépède, 1804) Fischer, 1856
Hydrophis obscurus (not of Daudin, 1803) Jan, 1859 (nomen praeoccupatum)
Hydrophis nigra Anderson, 1872
Hydrophis jayakari Boulenger, 1887
Hydrophis plumbea Murray, 1887
Hydrophis viperinus — Boettger, 1888
Distira viperina — Boulenger, 1896
Disteira viperina — Stejneger, 1907
Praescutata viperina — Wall, 1921
Thalassophina viperina — Smith, 1926
Thallassophina viperina — Corkil, 1932 (nomen incorrectum)
Thalassophinae viperina — Maegraith, 1958 (nomen incorrectum)
Praescutata viperine — Sayed, 1972 (nomen incorrectum)
Paraescutata viperina — Khan, 1982 (nomen incorrectum)
Enhydrus plumbea — Culotta & Pickwell, 1993 (lapsus calami)
Thalassophina veperina — Culotta & Pickwell, 1993 (nomen incorrectum)
Hydrophis viperinus — Sanders et al., 2013
Thalassophina viperina — Wallach et al., 2014

Type specimen: Holotype; Zoologisches Museum Hamburg, Germany, ZMH 404, destroyed in World War II (see Wallach et al. 2014).

Type locality: coast of Java.

Type species: *Thalassophis viperina* Schmidt, 1852 is the type species of the genera *Praescutata* Wall, 1921 and *Thalassophina* Smith, 1926.

Remarks: Smith (1926) whilst erecting the genus *Thalassophina*, overlooked the existing senior nomen *Praescutata* Wall, 1921, a stance that he corrected later (Smith 1943). *Praescutata* Wall, 1921 is also regarded by some authorities as a nomen ineditum (see Wallach et al. 2014).

Cantor's Small-headed Sea Snake *Microcephalophis cantoris* (Günther, 1864)

Hydrophis cantoris Günther, 1864
Distira gillespiae Boulenger, 1899
Microcephalophis cantoris — Wall, 1921

Microcephalophis cantori Lin, 1975 (nomen incorrectum)

Hydrophis (Microcephalophis) cantoris — Kharin, 2004

Microcephalophis cantoris — Sanders et al., 2013; Wallach et al., 2014

Type specimen: Holotype; The Natural History Museum London, UK, BMNH 1946.1.18.30.

Type locality: Penang, Malaysia.

Common Small-headed Sea Snake *Microcephalophis gracilis* (Shaw, 1802)

Hydrus gracilis Shaw, 1802 (sic)

Disteira gracilis — Fitzinger, 1826

Microcephalophis gracilis — Lesson, 1834

Hydrus kadell-nagam Boie, 1827 (based on Russell, 1801) (nomen incorrigendum)

Hydrus garcilis — Mason, 1852 (nomen emendatum)

Thalassophis microcephala Schmidt, 1852

Hydrophis microcephalus — Duméril, Bibron & Duméril, 1854

Hydrophis gracilis — Duméril, Bibron & Duméril, 1854

Hydrophis microcephala — Fischer, 1856

Hydrophis gracilis — Fischer, 1856

Hydrophis leprogaster Duméril, 1853 (nomen nudum)

Hydrophis leprogaster Duméril & Bibron in Fischer, 1856

Hydrophis guentheri Theobald, 1868

Hydrophis guntherii — Murray, 1884 (nomen emendatum)

Distira gracilis — Wall, 1909

Hydrophis rostralis Smith, 1917

Microcephalophis gracilis gracilis Smith, 1926

Microcephaloides gracilis — Barret, 1950 (nomen incorrectum)

Distevia gracilis — Okada, 1953 (nomen incorrectum)

Microcephalus graculis — Saint-Girons, 1967 (nomen incorrectum)

Microcephalophus gracilis — Vitt, 1987 (nomen incorrectum)

Microcephalophus gracilis microcephalophis — Culotta & Pickwell, 1993 (nomen incorrectum)

Microcephalophis gracilis — Culotta & Pickwell, 1993 (nomen incorrectum)

Hydrophis (*Microcephalophis*) *gracilis* — Kharin, 2004

Microcephalophis gracilis microcephalus — Kharin, 2005

Microcephalophis gracilis — Sanders et al., 2013

Microcephalophis gracilis — Wallach et al., 2014

Type specimen: Holotype; The Natural History Museum London, UK, BMNH 1946.1.17.37.

Type locality: none given.

Type species: *Hydrus gracilis* Shaw, 1802 is the type species of genus *Microcephalophis* Lesson, 1832.

Remarks: One of the few sampled genera of true sea snakes found in Indian waters that was not nested within *Hydrophis* group taxa (Sanders et al. 2013).

THREATS AND CONSERVATION STRATEGIES

The major threat to the survival of marine snakes in India is not known precisely but their primary or direct threat is considered to be death by entangling in fishing nets when caught as bycatch by the trawlers, in fact those which survive are killed by the fishermen. The indirect threat is due to the degradation of their ecosystems like coral reef and destruction of mangrove forest habitat. Sea snakes are caught as the bycatch in trawls, and it is assessed that roughly 50% of mortality is by suffocating or being smashed by the heaviness of the catch in the trawls (Ward 2000; Wassenberg et al. 2001; Milton et al. 2009). Mass bycatch mortality of sea snake (*Hydrophis schistosus*) was reported in Goa (Padate et al. 2009). In 2015 another such instance was noted, resulting in a mass mortality in two consecutive days where around 60–80 dead sea snakes lay scattered over 20–30 meter stretch on shore. This occurred because of the operation of shore seines pulled down to the shore and the catch landed by the fishermen. Sea snakes when encountered get killed intentionally as their presence is perceived as a threat by the local community (Jamalabad 2015). Prawn trawling and boat seine nets are also among the top threats for sea snakes. In a study reported from Puducherry coast, nearly 234 *Hydrophis schistosus* were found trapped in 316 trawling nets. In 63 boat seine nets around 103 sea snakes were found entangled (Muthukumaran et al. 2015). Though some southeastern Asian countries exploit sea snakes for their meat for food and animal food purpose, in India they are not exploited for food industries, but yet many other threats doom the marine snakes in India (Das 2012; Sarker 2013; Cao et al. 2014).

A legal management plan for the conservation of marine snake species in India is the Indian Wildlife (Protection) Act, 1972 wherein the species are protected under Schedule IV. Status of the world's sea snakes according to IUCN category has been enumerated by Livingstone (2009) and several threatened species find place in that list. Lukoschek et al. (2013) reported on inexplicable declines in sea snake populations in Great Barrier Reef of Australia. Although marine snakes are designated as scheduled species in India to prevent exploitation, there is a need for better understanding on the impacts and vulnerability assessments of marine snakes. There is no major study on the environmental impacts and direct human threats to marine snakes are practically unknown, therefore we require a multidisciplinary effort (Elfes et al. 2013). Implementation of long-term bycatch monitoring programme to obtain baseline evidence on the abundance of the sea snake species. The most fundamental aspect of conservation effort is to analyze the areas of high biodiversity and the distribution of threatened species (Brooks et al. 2006; Hoffman et al. 2008).

BITES AND TOXINOLOGY

Bites and toxinology of sea snakes, particularly with reference to Indian scenario have been briefly reviewed by Vijayaraghavan & Ganesh (2015) and Whitaker & Martin (2015). This is sumamrised in the following: "Sea snake bites are consensually accepted as being potentially lethal to human beings and produce symptoms such as are postsynaptic neurotoxic activity, attenuated twitch blockade, degenerative changes in the central nervous system, petechiae and ecchymoses throughout the viscera, distal tubular necrosis in the kidney, lung emphysema and patchy edema, slight endocardial fibrosis, coronary sclerosis, centrilobular degeneration and necrosis in the liver, porter round-cell infiltration in the liver, and myoglobinuria". Toxinology of sea snake envenomations have been compiled by Reid (1979), Pickwell (1994) and Takasaki (1998). Ali et al. (2000) reported the bite management of an India species *Hydrophis cyanocinctus*, based on Malyan case studies. Lomonte et al. (2014) reported the envenomation and treatment of the bites of *Hydrophis platurus* based on a study from Central America. Tan et al. (2015a) reported on envenomation management in Malaysia, for one of India's widespread and fairly defensive species of sea snake – *Hydrophis schistosus*. Tan et al. (2015b, 2016) reported on cross-neutralisation by Malayan anti-cobra antivenom, of sea snake envenomations in two species – *H. schistosus* and *H. curtus*, both of which occur in India. Cases of fatality from sea snake (*Hydrophis schistosus*) bites were documented in Sri Lanka (Vithanage & Thirumavalavan 2013; Kularatne et al. 2014). The portion on snake envenomations by McGoldrick & Marx (1991) and Fenner (1998) may also be referred.

CONCLUSION

Indian marine snakes have been scientifically known and described as early as the late 18th Century, yet, there are many radical changes in their classification at species-level, genus-level and even family-level up to this day. Conflicting consensus on the taxonomy and nomenclature is far higher for this group than other snakes in India.

Many are widespread along the coast of the country, but still newer observations and records turn up. Some are so rare that they have been sporadically sighted and not adequately documented by researchers.

Many are potentially venomous and known to cause life-threatening envenomations in adult humans. As of date, specific anti-venom is unavailable for the bites and their venoms are poorly researched in India.

Some species are encountered by fishermen while entangled in the fishing gears, especially the bottom trawling nets. Often, a sharp hook-shaped pole is used to peg and throw them back into the sea. Snakes brought ashore are usually discarded on the shores or at the landing sites.

Despite being so, the biology and natural history for many species still remain obscure with no proper field observations and scientific studies.

Marine species are well-protected statutorily in most areas, both inside and outside marine protected areas (MPAs). Marine snakes often get prejudiced and killed / harmed directly by people when encountered.

India with many zoos and serpentaria has a poor history of captive stock and studies on marine snakes in such captive care facilities.

Fraught with so many paradoxes and challenges, it is hoped that this overview will stimulate further research interest and attract conservation attention towards this group of snakes.

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Image 1. Some Indian marine snakes: a - *Dieurostus dussumierii*; b - *Cerberus rynchops*; c - *Acrochordus granulatus*; d - *Laticauda colubrina*; e - *Hydrophis platurus*; f - *Hydrophis fasciatus*; g - *Hydrophis cyanocinctus*; h - *Hydrophis caerulescens*; i - *Hydrophis ornatus*; j - *Hydrophis schistosus*; k - *Hydrophis spiralis*; l - *Hydrophis curtus*.

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Key to Indian marine snakes

"*The classification of sea snakes has proved to all observers a most difficult task, in fact has given more trouble than that of any other Ophidian family*" - Wall, 1906

"*This group [i.e. sea snakes] is admittedly a difficult one, and has lead to considerable diversity of opinion among herpetologists …*" - Smith, 1926

The following key has been, to certain extent, modified from Smith (1943); however, in certain cases the arrangement has been newly devised for certain groups, based on customized set of character-states largely due to the change in generic allocation and the number of species in each group.

A. No enlarged teeth, skin very coarse and loosely attached .... *Acrochordus granulatus*
B. Enlarged maxillary fangs at the rear of jaw; grooved
I. Nasal scales touch one another; parietals broken up; scales keeled .... *Cerberus rynchops*
II. Nasal scales separated by internasal; parietals entire; scales usually smooth
a. Midbody scalerows 25–27, loreal present .... *Dieurostus dussumierii*
b. Midbody scalerows 25–27, loreal absent .... *Fordonia leucobalia*
c. Midbody scalerows 17, nasal scale smaller than internasal .... *Gerarda prevostiana*
d. Midbody scalerows 19, nasal scale larger than internasal .... *Cantoria violacea*
C. Enlarged maxillary fangs at the front of jaw; not grooved but hollow
I. Ventral scales very wide, extending to the full belly width .... *Laticauda*
a. Midbody scalerows 19; prefrontals 2; no azygous extra scale .... *L. laticaudata*
b. Midbody scalerows 21–25; prefrontals 3, often with an extra azygous scale .... *L. colubrina*
II. Ventrals scales much reduced in width, without any median groove
i. Head scales not normal; parietals scales often broken–up .... *Hydrophis curtus*
ii. Head scales normal, neck slightly narrower than trunk; two (or three) anterior temporals
a. Midbody scalerows 39–45; ventrals 296–330 .... *H. nigrocinctus*
b. Midbody scalerows 37–47; ventrals 300–390 .... *H. cyanocinctus*
c. Midbody scalerows 45–55; ventrals 374–452 .... *H. stricticollis*
d. Midbody scalerows 33–55; ventrals 209–312 .... *H. ornatus*
e. Midbody scalerows 43–51; ventrals 314–372 .... *H. lapemoides*
f. Midbody scalerows 35–43; ventrals 302–390 .... *H. mamillaris*
g. Midbody scalerows 38–54; ventrals 253–334 .... *H. caerulescens*
h. Midbody scalerows 47–59; ventrals grooved, paired, 226–286 .... *H. stokesii*
i. No distinct mental groove; black and yellow colouration .... *H. platurus*
iii. Head normal; neck as wide as other parts of trunk; usually one anterior temporal
a. Midbody scalerows 19–21; snout declivous .... *H. jerdoni*
b. Midbody scalerows 39–55; mental elongate, hidden in a groove .... *H. schistosus*
iv. Head and neck very thin and much narrower than rest of the trunk
a. One anterior temporal; midbody scalerows 47–58 .... *H. fasciatus*
b. two or three anterior temporals; midbody scalerows 29–37; ventrals 300–338 .... *H. obscurus*
v. Ventral scales posteriorly with median furrow, partly or fully divided, spiny and tuberculate
a. Prefrontal not touching 3rd supralabial; ventrals 220–287.................... *Microcephalophis gracilis*
b. Prefrontal touching 3rd supralabial; ventrals 404–468 .... *M. cantoris*

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SHORT COMMUNICATION

FEEDING TRAILS OF DUGONG *DUGONG DUGON* (MÜLLER, 1776) (MAMMALIA: SIRENIA: DUGONGIDAE) IN THE GULF OF KACHCHH, WESTERN COAST OF INDIA

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Abstract: Dugong *Dugong dugon* (Müller, 1776) is the only herbivorous marine mammal distributed along the tropical and subtropical oceans of the Indo-Pacific regions. The record of the species in India is mainly from the east coast including Andaman and Gulf of Mannar. In this note the authors have recorded feeding trails of Dugong on the *Halodule uninervis* meadow in the Gulf of Kachchh, i.e., northwestern part of India. Most of the records of this species from this area are stranding records. This is the second record of the trail from this region.

Keywords: Dugong, ecology, *Halodule uninervis*, seagrass, trail.

The Dugong *Dugong dugon* (Müller, 1776) occurs in the tropical and subtropical sea areas of the Indo-Pacific region (Nishiwaki & Marsh 1985), and is classified as Vulnerable in the IUCN Red List (Thornback & Jenkins 1982). In the Indian subcontinent, this protected species occurs in the Gulf of Mannar, Palk Bay, Gulf of Kachchh (GoK), and Andaman & Nicobar islands.

Sivakumar & Nair (2013) gave comprehensive details on the potential regions for Dugong in all the three regions of India. Tuticorin-Tharuvaikulam and Roachamanagar Dhanushkodi stretches, including the offshore islands, were identified as critical for Dugong in the Gulf of Mannar (Sivakumar & Nair 2013). Areas in Palk Bay include waters off Dhanushkodi, Rameshwaram, Devipattinam, Thiruppalaikudi, Morepannai, Mullimunnai, Pudupattinam, Thondi, Mimisal, Kottaippattanam, Manamelkudi and Manora. The critical Dugong habitat identified in the Andaman Islands includes the waters off Landfall Island, Reef Island, White-Cliff Island, Smith Island, North Reef Island, Interview Island, Sound Island, Mayabunder, Karmatang, Long Island, North Passage, Ritchie's Archipelago, M.G. Marine National Park, Sister Islands and Brother Islands, as well as parts of Jarawa Reserve and the eastern and southern coast of Little Andaman (Sivakumar & Nair 2013).

The population of Dugong and its habitats are continuously declining in India with about only 200 surviving individuals (Sivakumar & Nair 2013). Several reasons have been attributed to the decline in the Dugong population, including sea grass habitat loss, gill netting, disease, water pollutants, indigenous use and poaching (Sivakumar & Nair 2013). Reviews of Dugong in Indian waters have consistently treated Gulf of Kachchh as an area of little significance (Frazier & Mundkur 1990). Dugong were noted by different researches at different locality in Gulf of Kachchh (Moses 1942; Mani 1960; Silas 1961; Mohan 1963; Frazier & Mundkur 1990; and Singh 2003). Frazier & Mundkur (1990) compiled the dugong

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observation with the help of fishermen interview and reported 18 animals from the Gulf of Kachchh, particularly in Bet Dwarka, Poshitra and their neighbouring areas. Singh (2003) noted four dead Dugong from this region that includes one skull on Bhaidar Island, two dead animals in Bharana and one dead animal on Poshitra coast.

OBSERVATION

On 27 May 2017, during the marine invertebrate study, the authors visited Narara reef area in the central region of the Gulf of Kachchh. The area is also a part of Marine National Park and Sanctuary – Jamnagar. The area significantly harbors 7.5ha of *Halodule uninervis* Meadow (22.479^{0}N & 69.718^{0}E to 22.483^{0}N & 69.718^{0}E) (Fig. 1). Peculiar grazing pattern was observed in the meadow, and was considered to be a Dugong feeding trail. The grass was completely uprooted and grazed, and the width of the trail varied from 20–28 cm and length varied from 100–520 cm. The trail was recorded at the low tide where during the high-tide the water rises to 4.5m. Photographs and measurements of all the trails were taken (Image 1). International experts were consulted for confirming the trails, which were confirmed as feeding trails of Dugong.

DISCUSSION

Most of the records of the species are from the western parts of the gulf and majority of the records are stranded, washed off dead animals questioning the status of the population within the GoK (Table 1). Most observations of the species in GoK are stranding records towards Okha, Poshitra and Bhaider, i.e., opening of the gulf, indicating the population as vagrant or non-resident to GoK. Pandey et al. (2010) recorded the first feeding trail for GoK from the seagrass meadows of Pirotan Island. This is the second record of the feeding trail from the central part of the GoK. Narara is an important Dugong habitat in GoK (Sivakumar & Nair 2013). The observation of Dugong feeding trail in this area is an important but indirect evidence of the presence of the species and is of considerable importance as it indicates the presence of live animals in the central areas of the GoK indicating the presence of the species in this area further more towards the east in GoK. Kamboj (2014) provided status of the seagrass in the Marine National Park and Sanctuary, however, the seagrass beds of Narara are not included in the same. All the stranding records are in proximity to the existing seagrass beds (Table 2; Fig 2).

The Dugong population in the Arabian Gulf is believed to be the second largest in the world after Australia. Akab Island (Umm al Qaywayn, UAE) is the oldest site (6000 years) where Dugong remains have been discovered (Jousse 1999). The Arabian Gulf is considered to contain the most important Dugong habitat in the western half of the Dugong's range (Preen 1989). The population estimate of Dugong in the Arabian Gulf was estimated

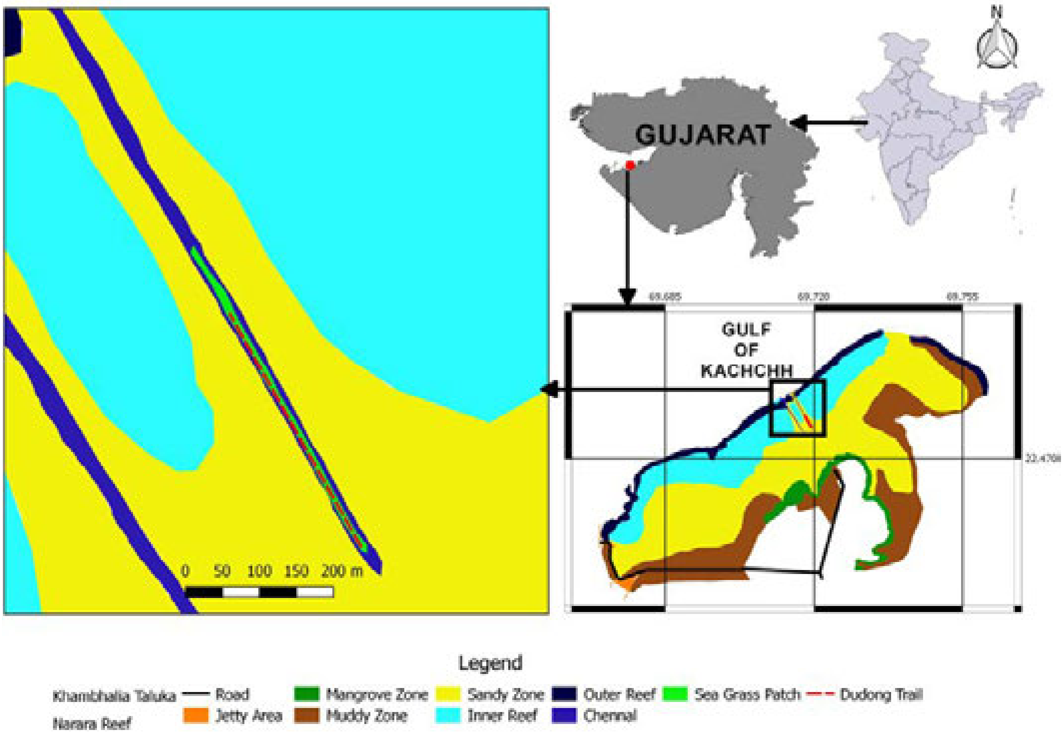

Figure 1. Study area

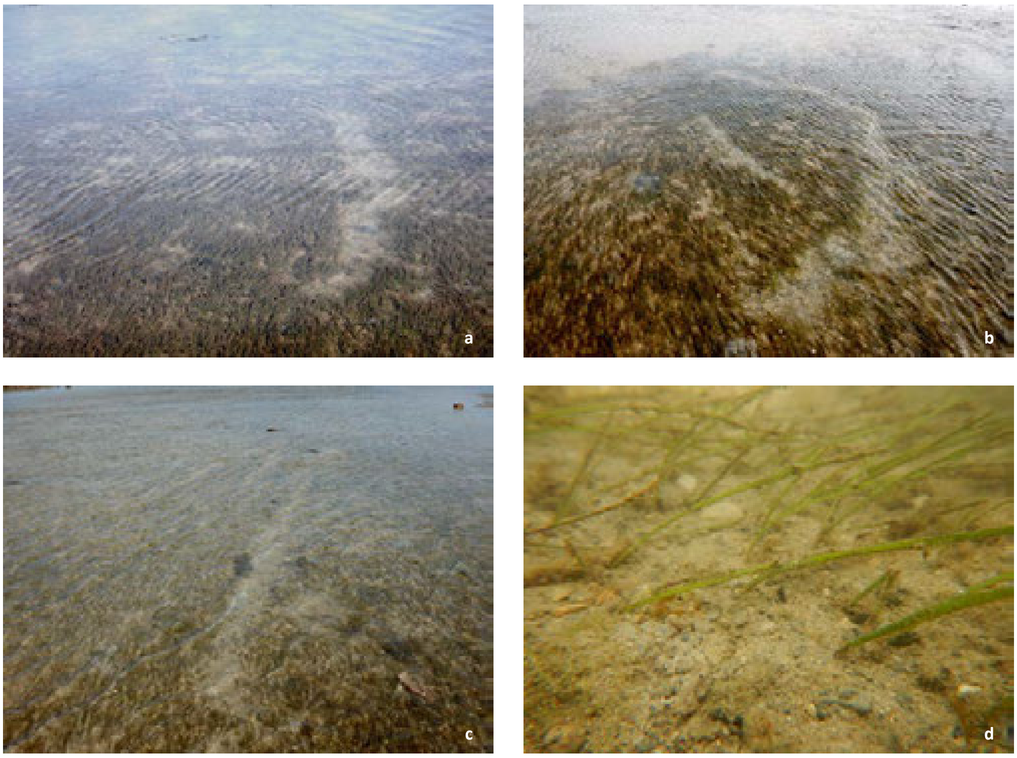

Image 1. a–c - Feeding trails recorded during the study; d - Seagrass *Halodule uninervis* recorded during the study.
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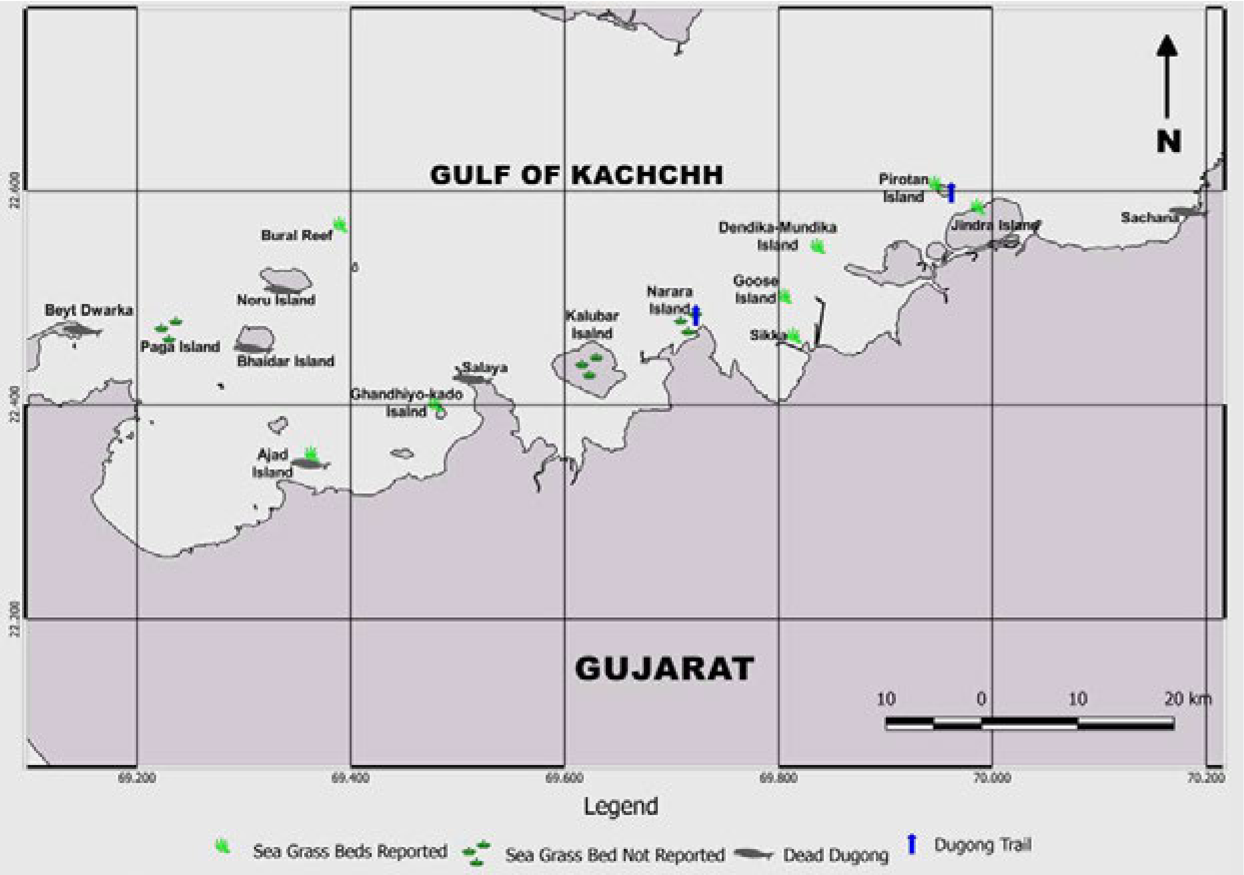

Figure 2. Dugong occurrences and Seagrass beds in the Gulf of Kachchh

Table 1. Dugong stranding records from Gulf of Kachchh

	Year	Location	No. of Dugong	Source
1	1877	Sachana	1	Frazier & Mundkur 1990
2	1893	Mandvi	1	Thurston 1895
3	1959	Kalyan Light House	1	Mani, 1960; Silas 1961
4	1962	Pirotan Island	2	Mohan 1963
5	1962	Salaya	1	Mohan 1963
6	1978	Bhaider island	1	Frazier & Mundkur 1990
7	1983	Bet Dwarka	2	Ved 1983
8	1984	Poshitra	1	Singh 1994
9	1987	Bet Dwarka	3	Frazier & Mundkur 1990
10	1987	Poshitra	1	Frazier & Mundkur 1990
11	1987	Poshitra point	1	Frazier & Mundkur 1990
12	2000	Bhaider island	1	Singh et. al. 2004
13	2000	Noru-Bhaider	2	Singh et. al. 2004
14	2002	Poshitra (Shaan)	1	Singh et. al. 2004
15	2003	Poshitra	1	Singh et. al. 2004
16	2004	Poshitra	1	Asari (pers. Comm.)
17	2007	Bet Dwarka	1	Pandey et al. 2010
18	2010	Bet Dwarka	1	Forest Department
19	2013	Mithapur	1	Yogeshkumar et al. 2013

Table 2. Seagrass meadows in the Marine National Park and Sanctuary (Source: Kamboj 2014)

	Location	Area (ha)
1	Bhural reef	1321.72
2	Ajad Island	8.94
3	Gandhio Kado Island	3.01
4	Goose reef	15.65
5	Sikka reef	198.81
6	Dedeka Mundeka	354.62
7	Pirotan	504.18
8	Jindra and Chhad islands	25.38
9	Narara (current study)	7.5

to be 1861 individuals in summer and 2185 in winter (Al-Ghais & Das 2001). The phenomenon of winter congregation and dispersed population in summer was also reported by Preen (1989). The feeding trail reported by Anand et al. (2012) was in the month of May and the present study also reports the feeding trail in month of May, i.e., in northwestern Asia including Arabian Gulf and Gulf of Kachchh. The presence of the species in summer gives rise to two different possibilities: (a) the species is present in the area in very low number so that it is not recorded live, or (b) the occurrence is accidental and result of population dispersal from the Arabian Gulf during summer. The distance between these two sites, however, is more than 1,500km and this hypothesis needs to be assessed by satellite tagging few animals in the Arabian Gulf.

Observations and frequent monitoring of these seagrass meadows may help in understanding the presence and movements of the Dugong population in the area. This information will be valuable for the better management practice of the species in the region.

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Population status and floral biology of *Trichopus zeylanicus* ssp. *travancoricus* Burkill ex K. Narayanan (Dioscoreaceae), an important ethnomedicinal plant of the southern Western Ghats, India

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Abstract: *Trichopus zeylanicus* ssp. *travancoricus* is locally known in Tamil Nadu as Arogyapachai, meaning a plant that provides good health and vitality. The unripe fruits of the plant are highly rejuvenating and are used by the Kani Tribe to ameliorate fatigue. This subspecies is also known for its pharmacological and medicinal utility and possesses choleretic, aphrodisiac, hepatoprotective, mast cell stabilizing, adaptogenic, and cardioprotective properties. A study was attempted to understand the population status and floral biology of *T. zeylanicus* ssp. *travancoricus* in its natural habitat. The population of this herb was found to be severely fragmented and settled in shaded banks of streams and rivulets in Agasthyamalai Hills. Being a rhizomatous herb, its flowers are concealed by its broad leaves, thus preventing exposure to pollinators. The number of pollinating agents in the flowers was reported as meager. The fruits are capsules with two to six seeds, each having a hard seed coat with a projected endosperm. Therefore, the conventional propagation of the subspecies is not so successful due to its poor seed set and prolonged maturation time. In addition, the fruits are damaged by rodents, livestock, and collection for medicinal usage, which severely affect the population status of the plant. Sustainable use of this wonder herb is important for its conservation in its natural habitat.

Keywords: Kani Tribe, *Trichopus sempervirens*, Indian Ginseng, Agasthyamalai Hills, pollination, conservation.

A number of scientists worked on the genus *Trichopus* Gaertn. and transferred its position from one family to another. The genus was treated under Aristolochiaceae by Lindley (1832) and Thwaites (1861), under Dioscoreales by Bentham & Hooker (1883), and under the monogeneric Trichopodaceae by Hutchinson (1934) and Dahlgren et al. (1985). Takhtajan (1980) conceded the status of a subfamily to Trichopodaceae under Dioscoreaceae but later accepted the view of Hutchinson (1934). In the recent past, Rao (1955), Ayensu (1966), Ramachandran (1968), and Kale & Pai (1979) studied the different botanical aspects of *Trichopus* with respect to its systematic position and supported its separation from Dioscoreaceae. The genus, however, is believed to be a connecting link between Dioscoreaceae and Taccaceae, combining the characters of both as well as those of Stemonaceae and Trilliaceae of the order Dioscoreales (Dahlgren

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et al. 1985). The members of Dioscoreaceae are usually rhizomatous climbing lianas or vines with small vascular bundles arranged in two circles with larger cauline bundles alternating with seeds. *Trichopus* are climbing or prostrate herbs with the vascular bundles arranged in an arc. The detailed systematic account provided by Caddick et al. (2002) on the relationship between *Stenomeris* and *Trichopus* remained unclear. After several confirmative studies conducted by the Angiosperm Phylogenetic Group (APG), *Trichopus* was placed under the individual family Trichopodaceae under the order Dioscoreals (Angiosperm Phylogeny Group 1998). In APG II, however, Trichopodaceae was merged with Dioscoreaceae (Angiosperm Phylogeny Group 2003), which was followed in APG III (Angiosperm Phylogeny Group 2009) and APG IV (Angiosperm Phylogeny Group 2016).

The genus *Trichopus* was reported with two herbaceous species, namely *T. sempervirens* (H.Perrier) Caddick & Wilkin and *T. zeylanicus* Gaertn. Both the species show restricted distribution — *T. sempervirens* is reported as endemic to Madagascar whereas *T. zeylanicus* is distributed in peninsular India, Sri Lanka, the Malay Peninsula, Singapore, and Thailand. *Trichopus zeylanicus* usually grows in lowland sandy areas of streams but in low-lying forests in the Malay Peninsula. In these habitats, it is vulnerable to flooding but similar conditions (sandy areas of streams) rule where it grows in the higher altitudes of the southern Western Ghats. *Trichopus zeylanicus* was reported with three subspecies, namely *T. zeylanicus* ssp. *angustifolius*, *T. zeylanicus* ssp. *Travancoricus*, and *T.* ssp. *zeylanicus*.

After several periodical field visits conducted in different forest areas of Agasthyamalai and observations of herbarium specimens in different repositories, it was confirmed that *T. zeylanicus* ssp. *travancoricus* can be considered as a valid subspecies. All the three subspecies were distinguished based on the number of nerves in their leaves. *Trichopus zeylanicus* ssp. *travancoricus*, with five to seven nerves in its leaves, is distributed in southern India and the Malay Peninsula. Both the triple-nerved subspecies, *T. zeylanicus* ssp. *angustifolius* and *T. zeylanicus* ssp. *zeylanicus*, are reported as endemic to Sri Lanka. The specimens collected in Sri Lanka were undoubtedly distinguished from those in peninsular India by their deltoid or linear-lanceolate erect leaves with 3mm long tepals. According to Burkill (1951), consent has to be given with distinguishing name to the Indian species as *T. zeylanicus* ssp. *travancoricus* and Indo-Malaysian specimens. The specimen from Sri Lanka possesses great variation, which is absent in the Indo-Malaysian subspecies.

Trichopus zeylanicus Gaertn ssp. *travancoricus* Burkill ex K. Narayanan is locally known in Tamil Nadu and Kerala as Arogyapacha or Arogyapachai, meaning leaves that give health and vitality. It is reported as one of the important ethnomedicinal plants that grows near wet banks of streams and rivulets in dense forests. The Kani Tribe contributed in bringing the multifarious uses of this wild plant to today's medicinal world. The tribe also claims that to remain healthy, agile, young, and resistant to various infectious diseases, one should consume the fresh fruits of the plant regularly (Pushpangandan et al. 1988). Its seeds are reported to be rich in saponins and a preparation from its leaves, stems, and seeds is used as health tonic (Sharma et al. 1989). The plant is treated as Indian Ginseng because of its similarity to *Panax ginseng* in pharmacological properties (Anilkumar et al. 2002). *Trichopus zeylanicus* also possesses choleretic, aphrodisiac, hepatoprotective, mast cell stabilizing (Subramoniam et al. 1997, 1998, 1999), adaptogenic (Singh et al. 2005), and cardioprotective (Velavan et al. 2009) properties. The whole plant has the potential for anxiolytic and antidepressant, hepatoprotective, immunomodulatory, and anti-ulcer activities (; Rishikesh & Sambathkumar 2016).

In India, this subspecies was reported as endemic to the southern Western Ghats with a restricted distribution in Agasthyamalai Biosphere Reserve, one of the five important centres of plant diversity in India. The area is also one of the 24 microcenters of endemism and a super hotspot of biodiversity (Ramasubbu et al. 2016). Eleven forest types were recognized from this area with 448 endemic species of angiosperms (TNFD 2016). The reserve harbours about 2,000 species of flowering plants, including about 150 strict endemics. It is also unique in having a genetic reservoir of cultivated plants.

MATERIALS AND METHODS

The distribution status of *T. zeylanicus* ssp. *travancoricus* was analysed during extensive field trips conducted to forest areas of Kalakkad-Mundanthurai Tiger Reserve (KMTR) of Tamil Nadu and Rosemala and Sornagiri of Kerala. The extent of occurrence, the area of occupancy, and the number of mature individuals were recorded based on IUCN guidelines (IUCN 2012). The information gathered from the field visits was compared with that in published literature. To assess the population status of the subspecies, about 2x2 m^2 plots were laid down in the distribution areas. The number of individuals per square metre was calculated randomly in different parts of the three study sites. The periodical assessment of the number of individuals per square kilometre was calculated for about three years (2014–2016).

Phenology is the study of the functional rhythm of plants in relation to seasonal and climatic factors. Phenological studies are important for understanding the responses of plants to various biotic and abiotic factors. In the present study, the selected individuals of *T. zeylanicus* ssp. *travancoricus* was marked in the natural habitat of the different study sites and observed during regular field visits. The flowering phenology was observed on a day-to-day basis, which included flower initiation, development and maturation, anthesis, anther dehiscence, and flowering and fruiting period. The phenophase events were recorded as per the method suggested by Dafni et al. (2005). The percentage of natural fruit set and flower-fruit ratio, if any, was also calculated for all the study sites.

Trichopus zeylanicus ssp. *travancoricus* Burkill ex K. Narayanan

Nair, Kew Bull. 48:127–128, 1993; Mohanan & Sivadasan, Fl. Agasthyamala 2002; Nayar et al. Fl. Pl. Kerala – A Handbook 2006; Nair et al. Fl. Pl. Western Ghats India 2014. *Trichopus zeylanicus* ssp. *travancoricus* (Bedd.) Burkill Sivarajan et al. Kew Bull. 45: 353–359; Nair, Kew Bull. 48:127–128, 1993; Mohanan & Henry, Fl Thiruvananthapuram 1994. *Trichopus zeylanicus* Gaertn. Rama Rao, Fl. Pl. Travancore 1914; Gamble, Fl. Pres. Madras 1928–1936; Sivarajan et al. Kew Bull. 45: 353–359; *Trichopodium travancoricum* Bedd. Sivarajan et al. Kew Bull. 45: 353–359.

Small, rhizomatous, glabrous, perennial herbs; rhizome 1–4 cm long, with slightly ascending tips, covered with scales, older parts loose scales and dying off progressively; scales closely set, chaffy, lanceolate, acute or acuminate, 5–8 mm long; roots many, fibrous, stem wiry, 3–10 from the axils of scales, petiole-like, each terminating in a solitary, petioled leaf, terete, longitudinally striate or faintly ribbed, 7–8 cm long, purplish; dorsally grooved, 4–20 cm long; lamina highly variable in size, shape and venation, broadly ovate, deeply cordate, truncate or cuneate at base, wavy at margin, acute at apex, 5–7 nerved from base with another pair of nerves running along the whole leaf margin; fertile branch terminal on the stem, but pushed towards one side by the petiole which usurps the line of the stem, short, sessile, densely clothed with scaly, lanceolate bracts similar to the scales on the rhizome; leaves and flowers of this plant shine like grey-black stone; flowers 1–11 on each plant, hermaphrodite; pedicel filiform, 2–8 cm long; perianth of six subequal lobes in two series, campanulate, 3–10 mm long, constricted above the gynostemium, lobes lanceolate, apiculate, broader and saccate at base, keeled on the back; stamens six, filaments short, flat, united with the top of the ovary and base of style, anthers two-celled, connective broad, projecting and meeting by their edges making a roof over a chamber; ovary inferior, three-loculed with two superposed ovules in each chamber; style short, stout; stigma three, each two-lobed, lobes fleshy, erect at first and reflexed later, always included in the staminal chamber; fruit capsular, three-lobed, three-winged, ellipsoid or trapezoid, 1–5cm length x 1 cm width, opening by irregular rupture of the fruit wall; seeds 2–6, oblong or ellipsoid, covered with dense brownish tomentum, ventrally flat and ruminate, 4x2 mm.

Vernacular name: Tamil: Arochyappachai, Nilakottai; Malayalam: Arogyappacha.

Materials examined

***Trichopus zeylanicus* ssp. *travancoricus*:** MH 166487, 10.x.1992, Ingikuzhi, coll. R. Gopalan; MH 166488, 10.x.1992, Ingikuzhi, coll. R. Gopalan; MH 166089, 28.iii.1991, Kannikatti Rain Forest, coll. R. Gopalan; MH 166090, 28.iii.1991, Kannikatti Rain Forest, coll. R. Gopalan; MH 107169, 23.iii.1979, Vallachithodu, Lower Kodayar, coll. A.H. Henry; MH 107170, 23.iii.1979, Vallachithodu, Lower Kodayar, coll. A.H. Henry; MH 51676, 1901, Kannikatti; MH 51677, 1901 , Kannikatti; MH 51678, 1901 , Kannikatti; 1873, Tirunelvelli hills, coll. R.A. Beddome; GUH 152, 22.viii.2015, Rosemala, coll. G. Manikandan & R. Ramasubbu; GUH 298, 19.ii.2016, Sornagiri, coll. F. Irudhyaraj & R. Ramasubbu; GUH 322, 16.ix.2016, Kannikatti, coll. N. Sasi Kala & R. Ramasubbu.

Trichopus zeylanicus: K00029181, 14.xi.1891, Flauggi, coll. H.N. Ridley; K001140902, 20.i.1928; K001140903, 00.xi.1893; K001140904, 16.i.2003, Induruwa Forest, coll. M.W. Chase & M. Fay; K001140905, 28.i.1972, Hallawakellae Forest, coll. K. Balakrishnan; K001140910, 12.i.1972, Badagama Forest Reserve, coll. M. Jayasurya & S. Balasubramanium; K001140912, 00 .vi.1901, Kannikatti; K001140913, 1974 , Sungel Kolok, Nikom Waeng, coll. K. Larsen & S.S. Larsen.

Trichopodium cordatum: K001140906, 1867, Ceylon, coll. Walher; K001140907, 1867, Ceylon; K001140908, 1867, Ceylon, coll. Walher; K001140909, 1867, Mountale Falls, coll. Hooker.

***Trichopodium angustifolium*:** K001140911, 1867, Ceylon, coll. Wehler.

Avetra sempervirens: K001140922, 19.xii.1997, 500m beyond a tomb on the path to Vatovavy, coll. P. Wilkin, G. Rafamananatsoa, C. Foster & L. Caddick; K001140935, 13.ii.2003, Madagascar, coll. J. Rabenantoandro et al.

Distribution and ecology

Trichopus zeylanicus ssp. *travancoricus* grows near the wet banks of streams and rivulets in the dense forests of Agasthyamalai Hills of southern Western Ghats, India.

Population studies

The distribution of the subspecies is known to be restricted to Agasthyamalai Biosphere Reserve, which was also confirmed by various field explorations conducted in different forest areas. According to the literature (Sivarajan et al. 1990), the herb is largely distributed in Thiruvananthapuram District of Kerala and its adjoining forest areas of KMTR in Tamil Nadu; This has also been seen in Kanyakumari District. The present study confirmed that the population of *T. zeylanicus* ssp. *travancoricus* is largely fragmented and eradicated in most of the forests of Kerala and Tamil Nadu due to illegal collection and over exploitation. Populations with small to medium number of individuals were observed near streams and shady areas and were seen to prefer a warm humid climate and heavy litter.

Since the species is known to have a wide range, it is not possible to analyse its global distribution status. During the study period, however, the extent of occurrence of *T. zeylanicus* ssp. *travancoricus* was analysed within the Agasthyamalai Biosphere Reserve. The subspecies has extended to about 46±11 km^2 of the forest area. The area of occupancy of the subspecies in the forest areas of KMTR is comparatively larger than that in the forest areas of Rosemala and Sornagiri. Other distribution areas of the subspecies, like lower Kodayar, were not explored in the current study. The area of occupancy of *T. zeylanicus* ssp. *travancoricus* is about 25–34 km^2 within the distribution area of the Agasthyamalai Biosphere Reserve. The number of individuals recorded per population was about 4–13 and the number of individuals per square kilometre was recorded as 77.4±15.67 in Kannikatti and Ingikuzhi forest areas. The populations of *T. zeylanicus* ssp. *travancoricus* at Sornagiri and Rosemala areas were not as healthy and the numbers of individuals recorded per square kilometre were 56.2±16.55 and 49.55±23.88, respectively. A major part of this forest reserve is occupied by commercial plantations like rubber and coffee estates, vegetable cultivation, and other agriculture. Of the three study sites analysed, KMTR has comparatively healthy populations with more number of individuals (Fig. 1).

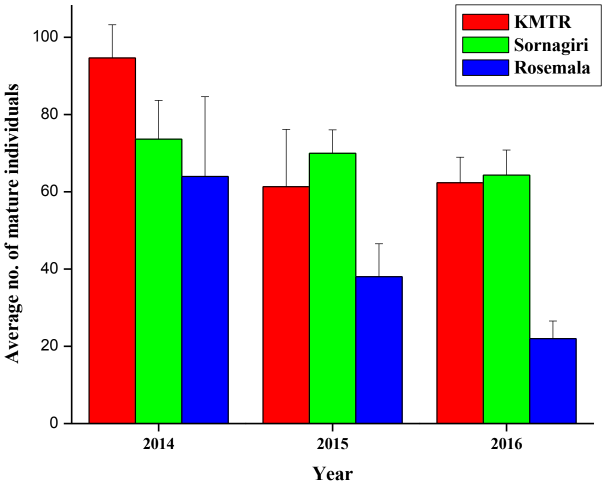

Figure 1. Average number of mature individuals of *Trichopus zeylanicus* ssp. *travancoricus* recorded from various study sites in the southern Western Ghats, India

The rhizomatous herb grows prostrate along with a meagre number of associated species, namely *Cinnamomum* sp., *Pellionia heyneana*, *Ochlandra travancorica*, *Dioscorea* sp., *Anaphyllum wightii*, and *Calamus* sp. The subspecies also prefers to grow in the shaded areas of river banks. The mature individuals of *T. zeylanicus* ssp. *travancoricus* showed major difference in growth performance across the three study sites. The size of the leaves of the specimens collected from Sornagiri was larger (13.74±0.87 cm) when compared to that of Rosemala (12.34±1.6 cm) and KMTR (6.12±1.4 cm). Also, it had a greater variation in the average number of caulescant leaves per plant. The individuals collected from the populations of Ingikuzhi had more number of leaves (18–22) than those of Sornagiri (12–14) and Rosemala (11–13).

This subspecies is commercially collected for several medicinal drug formulations. Therefore, illegal collection from the forest areas must be banned while encouraging cultivation for commercial purposes. Moreover, due to the failure of intermittent rainfall, a major percentage of the seeds failed to germinate. The failures of the reproductive ability of the herb may considerably reduce its number of individuals per population.

Image 1. *Trichopus zeylanicus* ssp. *travancoricus*: a - adult mature individual; b - leaf flushing; c - closer view of flower; d - closer view of Gynostemium; e - SEM view of Gynostemium; f - SEM view of anther; g - closer view of fertilized ovary; h - mature fruits; i - infected fruit.

Floral biology

The phenological events of the subspecies were observed during periodical field visits conducted at the different study sites. At leaf flushing, two-folded tender leaves developed with pale yellowish green colour before opening to its normal form. During the initiation of a fresh leaf, the size of the petiole was 4–6 cm, which then extended upto 22–30 cm as the leaf attained maturity. In most of the cases, the plant was completely dried off and the leaf flushing started in July and extended upto November, even though the plant emerged after the monsoon. The leaf flushing was followed by flowering in the middle of August. The peak flowering period was observed from September to

October and sometimes extended upto December. At the same time, the fruiting also started in November and extended upto March. In Rosemala and Sornagiri, however, flowering and fruiting were observed in most parts of the year due to occasional rainfall.

The flowers emerged from the pulvinus part of the petiole-like stem and the pedicel pushed towards one side by the petiole that usurps line of the stem. The flowers are solitary and highly attractive with a pedicel of approximately 16cm and are actinomorphic. The anthesis of the flower was recorded between 09.00h and 11.00h. The tepals are highly attractive and arranged in two rows, polypetalous, lanceolate in shape, apiculate at the tip, dark brownish with maroon colour at the center, and sandal with white at the tip (Image 1). The androecium comprising of six stamens are arranged in two whorls that alternate, opposite to the trifid stigma. Stamens have short filaments with two-celled anther, monosulcate, orange in colour that attached with the gynoecium and the anther dehisced on the day of anthesis. Fleshy, wet, two-lobed trifid stigma is reported at the centre of the flower. The development stages of the flower to fruit were observed and the ratio was calculated as 1:1. The fruit has three locules, each containing two seeds and the seeds located at the superposed position. The seeds are covered with dense brownish tomentum and the surface of the seeds are deeply furrowed and cerebriform are distinctive. Since,the seeds have a strong seed coat, they take more time to imbibe water. Majority of the fruits were foraged and damaged in its natural habitat. The seedlings were not observed in the natural habitat and preliminary studies on seed propagation did not yield good results. *Trichopus zeylanicus* ssp. *travancoricus* mostly propagated through the rhizome part of the subspecies.

In general, Agasthyamalai and its environments are already affected due to the conversion of the reserve forests into plantations, reservoirs, and roads. The present population studies of *T. zeylanicus* ssp. *travancoricus* revealed that the subspecies is facing a high risk of extinction in the distribution areas. Based on the field data on the extent of occurrence, area of occupancy, and numbers of populations and mature individuals, this subspecies can be included under the Endangered category of IUCN. Little observation only made on distribution, we have plan to observe detailed distribution of the herb in future. Effective conservation protocol and propagation techniques have to be developed for the sustainable utilization of this wonder herb.

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Taxonomic notes on *Grosourdya muriculata* (Orchidaceae: Epidendroideae: Vandeae: Aeridinae), a little known endemic orchid from the Andaman & Nicobar Islands, India

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Abstract: *Grosourdya muriculata* (Rchb.f.) R. Rice (Orchidaceae) is a little known epiphytic, endemic orchid from the Andaman & Nicobar Islands in India. The present article provides the detailed taxonomy, ecology, distribution, conservation status, and photographic account of the species. The data collected from field surveys indicates that the status of the species needs to be downgraded to Near Threatened as per the criteria of IUCN (2018).

Keywords: Epiphytes orchid, ecology, distribution, conservation status, photographic account, status updation, threatened taxa.

The epiphytic genus *Grosourdya* was established by H.G. Reichenbach in 1864 to commemorate R. de Grosourdy, a renowned botanist who specialised in the medicinal plants of the Antilles and tropical southern America. It belongs to the subtribe Aeridinae, tribe Vandeae, and subfamily Epidendroideae of the family Orchidaceae. Preliminary molecular studies (Pridgeon et al. 2014) led to the broadening of the circumscription of the genus and more than 20 species from the genera *Ascochilus* Ridl., *Ascochilopsis* Carr, and *Biermannia* King & Pantl. were placed under it. More recently, Rice (2018) transferred eight species of the genus *Pteroceras* to *Grosourdya* on the basis of supporting evidence from his own work and the preliminary phylogenetic study of Pridgeon et al. (2014). The recently expanded genus now includes species with pollinia having notched or cleft aperture without auricles to the stipe. Therefore, small short-stemmed *Pteroceras* species with characters more consistent with the genus *Grosourdya*, such as densely muricate to speculate surface of the inflorescence rachis and short-lived flowers generated singly in succession with gently curved column and a large conspicuous stigma are, placed under it. This brought up the total number of species in the genus to 28, distributed from China and the Indian subcontinent to southeastern Asia.

Before the revision by Rice (2018), five species of the *Pteroceras*, namely *P. muriculatum* (Rich.f.) P.F. Hunt, *P. monsooniae* Sasidh. & Sujanapal*, P. leopardinum* (E.C. Parish & Rchb.f.) Seidenf. & Smitin, *P. teres* (Blume) Holttum, and *P. unguiculatum* (Lindl.) H.A. Pedersen, were reported from India. With the recent species transfer, two species, namely *P. monsooniae* Sasidh. & Sujanapal and *P. muriculatum* (Rich.f.) P.F. Hunt, were transferred to the *Grosourdya.* Additionally, based

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on molecular studies, Kocyan & Schuiteman (2013) transferred *P. unguiculatum* (Lindl.) H.A. Pedersen to the genus *Brachypeza*. After these recent taxonomic modifications, the *Pteroceras* in India include only two species, namely *P. leopardinum* (E.C. Parish & Rchb.f.) Seidenf. & Smitin and *P. teres* (Blume) Holttum (Table 1).

The updated taxonomy led to an increase in the number of species of *Grosourdya* in the Andaman & Nicobar Islands to three, namely, *G. appendiculata* (Blume) Rchb. f., *G. muriculata* (Rchb.f.) R. Rice, and *G. muscosa* (Rolfe) Garay. *Pteroceras*, earlier represented by three species (*P. muriculatum* (Rich.f.) P.F. Hunt, *P. teres* (Blume) Holttum, and *P. unguiculatum* (Lindl.) H.A. Pederson), now consists of only one species, namely *P. teres* (Blume) Holttum.

Table 1. Status of *Pteroceras* species found in India after modifications by (Rice 2018)

Earlier name	Current name
Pteroceras monsooniae Sasidh. & Sujanapa.	*Grosourdya monsoonia* (Sasidh. & Sujanapa.) R. Rice
P. leopardinum (E.C. Parish & Rchb.f.) Seidenf. & Smitin	*Pteroceras leopardinum* (E.C. Parish & Rchb.f.) Seidenf. & Smitin
P. muriculatum (Rich. f.) P.F. Hunt	*Grosourdya muriculata* (Rchb.f.) R. Rice
P. teres (Blume) Holttum	*P. teres* (Blume) Holttum
P. unguiculatum (Lindl.) H.A. Pederson	*Brachypeza unguiculatum* (Lindl.) Kocyan & Schuit.

Grosourdya muriculata (Rchb.f.) R. Rice is an endemic species of the Andaman & Nicobar Islands and was recorded as Endangered by Karthigeyan et al. (2014). Moreover, it was described as one of the vanishing orchid species of the island (Mathew et al. 2005). The present authors studied the species for its detailed taxonomy, ecology, and distribution and evaluated its conservation status as per the recent IUCN criteria (IUCN 2018). The results are summarized below along with images for ease of identification.

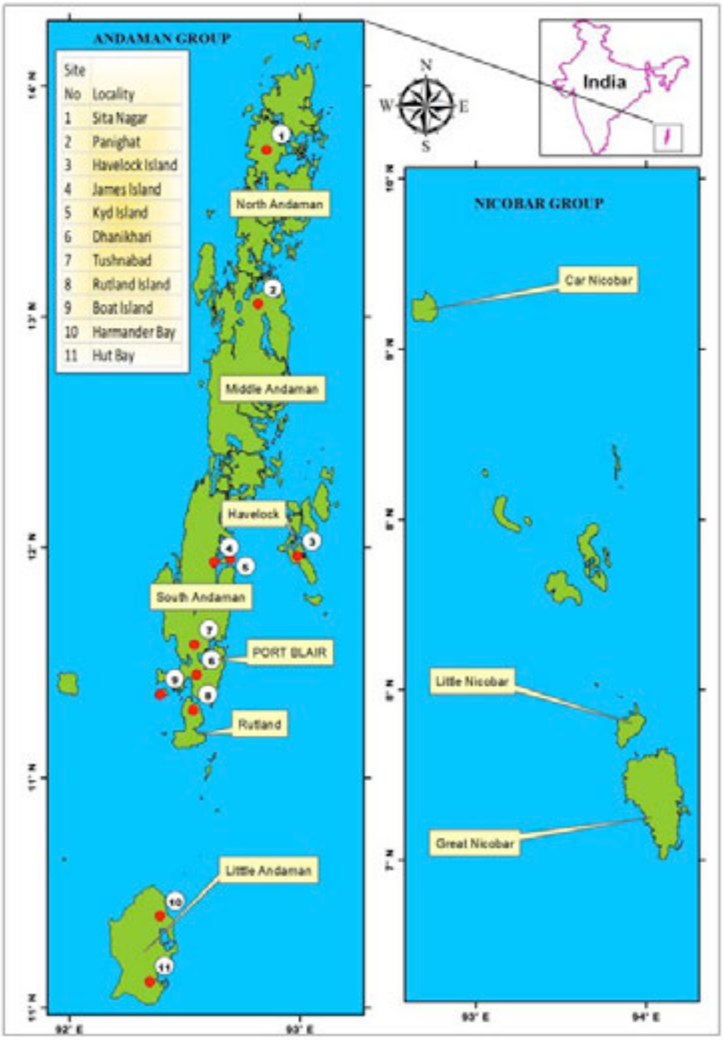

Figure 1. Map showing the distribution of *Grosourdya muriculata* in the Andaman & Nicobar Islands (Mapped by Dr. Shivashankar, Department of Disaster Management, Pondicherry University, Port Blair)

TAXONOMY

Grosourdya muriculata (Rchb.f.) R.Rice

Photo Intro to: Vandoid Orchid Genera in Asia. 160. 2018; *Sarcochilus muriculatus* Rchb.f., Gard. Chron., n.s., 15: 198. 1881.

Synonyms: *Thrixspermum muriculatum* (Rchb.f.) Rchb.f., Gard. Chron., n.s., 16: 198. 1881; *Pteroceras muriculatum* (Hort. ex Rchb. f.) P.F.Hunt in Kew Bull. 24: 96. 1970.

Type: *Bull s. n.* (anno1881)/Herb, Rchb.f. 31588, “India orientalis”-Andaman Islands (Holotype W).

Epiphytic herb, stem terete, glabrous, erect to pendent, unbranched, 4–8 cm long. Leaves sessile, distichously arranged, spreading, elliptic-oblong to lanceolate, c. 18.0×2.5 cm, obliquely botched or bilobed at apex, leaf base clasping the stem, coriaceous; leaf sheaths imbricate, glabrous, covering the internodes. Inflorescences many, perforating the leaf sheaths, racemose, pendulous, 5–15 cm long, peduncle glabrous, c. 5cm long, rachis c. 10cm, 10–20 flowers, floral bracts triangular and concave. Flowers spirally arranged, pedicellate, light yellow, c. 1.5cm across, sweet-scented. Sepals and petals with two to four purple bars. Sepals sub-equal; median sepal obovate to elliptic, c. 7.5x4.0 mm, obtuse at apex, base 1.2–2.4 mm wide; lateral sepals spreading, c. 7x4 mm, pointed at apex, base 1.4–3.1 mm wide. Labellum 3.5–5.1 mm long, sessile, erect side lobes pointing upwards, white with a brick red blotch, 3.5–5.0 x 1.1–2.0 mm, triangular; apex mostly obtuse, finely serrate, front edges connected by high apically bilobed wall. Mid lobe in form of white crest like callus with raised, somewhat erose violet margins (Image 2D), 0.1–2.1 mm long, 1.3–2.5 mm wide, 0.7–1.1 mm high. Spur somewhat conical, 2.4–3.7 mm in outer diameter, glabrous, white, often spotted purple in front; apex shortly prolonged, rounded, glabrous, white to light yellow. Columns sub-terete or slightly clavate; 3.0–4.4 mm high, 1.2–1.7 mm in diameter, brick red. Column foot 2.6–4.1 mm long glabrous and smooth. Anther terminal, triangular with a caudate apex, strongly

Image 1. *Grosourdya muriculata*. A - habit, B - flowers having sepals and petals with two spiral bands, C - flowers having sepals and petals with three to four spiral bands, D - capsules. © Sanjay Mishra

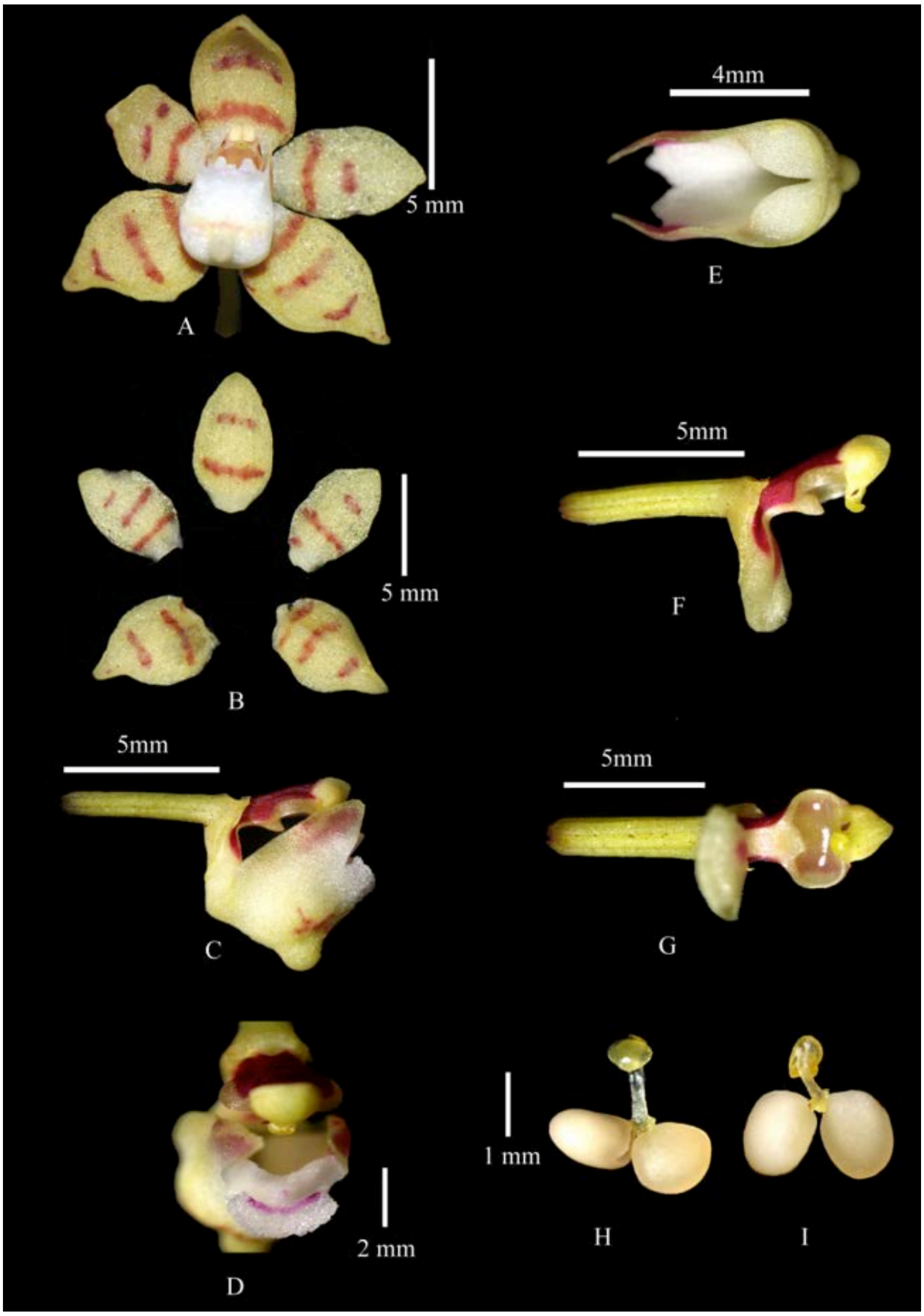

Image 2. *Grosourdya muriculata*. A - flower, B - sepals and petals, C - side view of lip (shortly clawed and saccate), D - front view of lip, E - inner view of lip showing lip sac, F - side view of column, G - nectar in the cavity of the column, H - front view of pollinia, I - back view of pollinia. © Sanjay Mishra

incumbent. Pollinia two, obovoid, with deep cleft, with stipe 0.9mm long. Capsules c. 75×4 mm wide (Figs. 1 & 2).

Flowers and fruits: March–November (flowers more than once a year).

Distribution and ecology: Endemic to Andaman & Nicobar Islands. This species prefers to grow in dense shade. Usually, it is found on plants near small rainwater streams running inside forests. Sometimes it is observed in mangrove swamps and rocky sea shores. They are extremely sensitive to exposure to direct sunlight and heat and, therefore, are found always in the shade. They are found growing scattered or in small populations of 75–100 mature individuals at a locality.

Note: Hooker (1885) treated this species as *Sarcochilus muriculatus* Rchb.f., where he mentioned sepals and petals with two purple bars. The authors, however, observed the flowers with two to four purple bars on sepals and petals. Mathew et al. (2005) recorded the flowering period of the species in Andaman to be exclusively in the rainy season during the southwest monsoon in May to June. Karthigeyan et al. (2014) mentioned the flowering period to be April–November. Careful observation of the phenology of the species in different seasons and herbarium data of previous collections from the island reveal that it has several flowering periods during March–November, both in the wild and in the individuals conserved in the Dhanikhari Experimental Garden cum Arboretum, Nayasahar, Port Blair.

DISCUSSION

According to Mathew et al. (2005), *Grosourdya muriculata* was not collected since its original description, until their own collection in 2005 from the semi-evergreen forests at Chidiyatapu, South Andaman Islands. It was considered one of the vanishing, endemic orchid species from the Andaman Islands. Afterwards, Karthigeyan et al. (2014) assessed the orchid diversity of the Andaman & Nicobar Islands and recorded the species from South Andaman, North Andaman, and Little Andaman as one of the rare orchids.

In the present assessment, the authors located and collected *Grosourdya muriculata* from Kyd and James Islands in South Andaman, Long Island in Middle Andaman, Ramnagar in North Andaman, and on the way to Harmander Bay at Krishnanagar Nallaha in Little Andaman. These collections were successfully conserved in the Dhanikhari Experimental Garden cum Arboretum of the Botanical Survey of India at Nayashahar, Port Blair. The authors also consulted 12 specimens placed at the herbarium of the Botanical Survey of India, Andaman & Nicobar Regional Center (PBL), collected by different workers from Andaman Islands.

South Andaman: 32589 (PBL), 08.viii.2016, Kyd Island, ±5m (11^{0}56.715'N & 092^{0}44.744'E), coll. S. Mishra, C.P. Vivek & G.A. Ekka; 32680 (PBL), 12.viii.2016, James Island, ±5m (11^{0}58.706'N & 092^{0}44.251'E), coll. S. Mishra, C.P. Vivek & G.A. Ekka; 21409 (PBL), 15.v.2004, Boat Island, coll. K. Karthigeyan; 7937 (PBL), 27.iii.1980, Camp No. 03, Havelock Island, ±25m, coll. T.A. Rao & R.K. Premanath; 874 (PBL), 06.ii.1974, Dhanikhari, ±50m, coll. N.G. Nair; 3684 (PBL), 12.v.1976, Herbatabad, Tushnabad, Sea level, coll. N.G. Nair; 6909 (PBL), 07.iv.1978, towards Jetty, Rutland Island, ±25m, coll. N.G. Nair.

Middle Andaman: 1332 (PBL), 04.v.1974, Panighat, Mayabunder, ±25m, coll. N.P. Balakrishanan.

North Andaman: 9021 (PBL), 15.v.1982, Sita Nagar Forest, coll. M.K. Vasudeva Rao.

Little Andaman: 8313(PBL), 27.i.1981, 4km from HutBay, coll. R.K. Premanath; 2346 (PBL), 30.iv.1975, 24km north from Hutbay, ±10m, coll. N. Bhargava; 2414 (PBL), 08.v.1975, near forest nursery, Hutbay, Sea level, coll. N. Bhargava; 4191 (PBL), 28.viii.1976, Hutbay, Sea level, coll. N. Bhargava; 6552 (PBL), 23.xi.1977, way to Harmander Bay, Sea level, coll. N. Bhargava.

CONCLUSION

Based on the present study and field observations, the authors are of the opinion that *Grosourdya muriculata* is distributed throughout the Andaman Islands, namely North, Middle, South, and Little Andaman. It is also present in small islands such as Long Island, Kyd Island, James Island, Havelock Island, and Rutland Island. We could locate two specimens from Nicobar Islands identified as *Grosourdya muriculata* (PBL572, 14.iii.2015, Katchal Island, Japan Tikari, coll. S. Prabhu & R. Sathiyaseelan; PBL415, 18.x.2011, Nancowry Island, Nallah Basthi, coll. S. Prabhu & R. Sathiyaseelan) placed at PBL. These specimens did not have flowers and, therefore, their identity could not be ascertained by the authors because of its similarity with *Pomatocalpa spicatum* Breda, Kuhl & Hasselt in the vegetative stage. Therefore, further investigation is needed to ascertain its occurrence in the Nicobar Islands.

Grosourdya muriculata was assessed as Endangered [EN B1ab (i,ii)] by Karthigeyan et al. (2014). Although the area of occupancy of the species is less than 5,000km^2, the authors were able to locate its population at 11 localities (Fig. 1) during field observations in the present study. At each locality, about 50–75 clumps were seen with each comprising one to five mature individuals. At five locations, multiple sub-populations were also observed. Therefore, on the basis of IUCN (2018), the authors suggest changing the status of the species to Near Threatened as the species does not qualify for a threatened status at present but is likely to do so in the near future. As most of these localities fall under protected areas, There is no immediate grave threat to the existence of the species. Further field surveys and regular monitoring, however, are recommended as these localities are scattered and some of them are facing threats due to anthropogenic and natural coastal activities, which may lead to the disappearance of the species from the habitats situated at the periphery of open forests.

Image 3. Herbarium sheet of *Grosourdya muriculata*

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THE IMPORTANCE OF TRANS-BOUNDARY CONSERVATION OF THE ASIATIC ELEPHANT *ELEPHAS MAXIMUS* IN PATHARIA HILLS RESERVE FOREST, NORTHEASTERN INDIA

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The 4,156km international border (IB) with Bangladesh spreads across five different states of India (West Bengal, 2217km; Meghalaya, 443km; Assam 262km; Mizoram 443km; and Tripura, 180km). The Karimganj District of Assam has 92km IB with Bangladesh of which 41km is riverine (Jamwal 2004). The remaining 51km lies in the western part of the district and a good portion shares the border through the Patharia Hills Reserve Forest (RF). The Patharia Hills RF (24.6231^{0}N & 92.250^{0}E) occupies an area of 76.47km^2 and is situated on the western side of Karimganj District of Assam and the eastern side of Sylhet District of Bangladesh. The headquarters of Karimganj District is located on the north of the RF and Tripura State on the south. The topography of the RF is very diverse, ranging from hilly areas to plain lands and water bodies. Average annual rainfall (>3,000mm) and a moderate climate support enormous flora and fauna in the area. Important plant species found in the RF are *Albizia* sp., *Artocarpus* sp., *Bombax ceiba, Canarium bengalense, Caryotaurens, Cassia fistula, Cinnamomum tamala, Erythrina variegata, Ficus bengalensis, Gmelina arborea, Maniltoa polyandra, Neolamarckia cadamba, Sapium* sp., *Streblus asper, Tectona grandis, Terminalia chebula, Terminalia arjuna, Toona ciliata, Vitex* sp., and *Zanthoxylum rhetsa*. Important wild fauna include eight primate species, viz., *Macaca mulatta, M. assamensis, M. arctoides, M. leonina, Nycticebus bengalensis, Trachypithecus phayrei, Trachypithecus pileatus, Hoolock hoolock,* and *Elephas maximus*, besides many carnivores and rodents (Talukdar & Choudhury 2017a).

The RF is the last resort of the wild elephants of the region along with Katakal RF. Currently, six female wild elephants are surviving in the RF and they face many anthropogenic threats (Talukdar & Choudhury 2017b). Besides, in the absence of a male elephant in the herd, their survival in the area in future is at stake (Talukdar & Choudhury 2017a). It was observed that after the death of one female elephant through electrocution in August 2017 in Medli Tea Estate (Karimganj, Assam), they are now divided into two small herds, three in each group. Though the original herd has now been segregated into two, it has been observed that one herd always follows the other. The sudden behavioral changes may be due to accidental shock and an act of defense mechanism.

They stay on both sides of the forest (i.e., Indian as well as Bangladesh portion) and cross the border frequently. The elephants have broken border fences on their corridor and use the routes as their migratory

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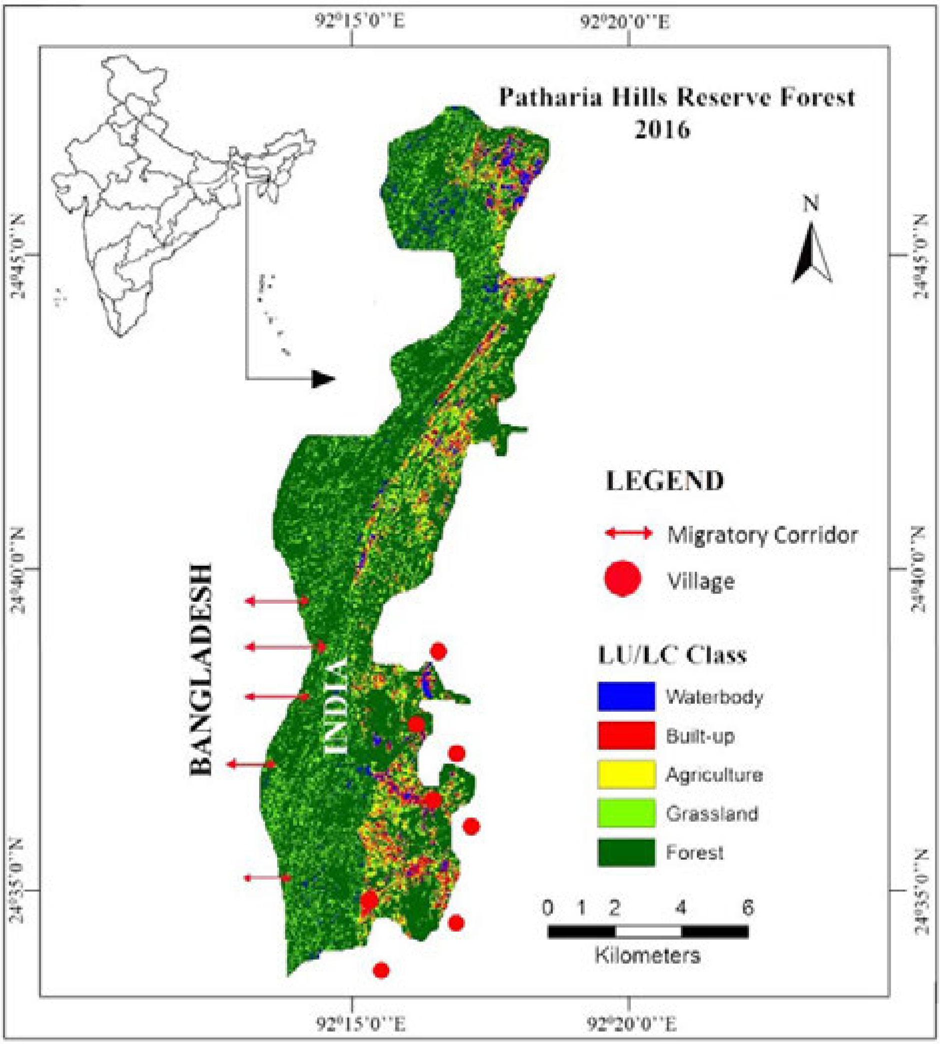

Figure 1. Migratory corridor and villages adjoining the Patharia Hills Reserve Forest.

corridor. They are limited to the southern part of the RF (Fig. 1) as habitats in other parts have been degraded due to human encroachment. Villagers often observe the wild elephants (Image 1) in winter but in summer their presence is seldom witnessed. During summer (April-July), they mostly stay within the Bangladesh territory of the RF, however, recently it has been observed that also during summer they use the corridor for a sojourn in Bangladesh territory and then come back. The shifting pattern of migration may be due to the food shortage on both sides as anthropogenic activities have increased (Talukdar & Choudhury 2017a). In the winter season (November and December), they prefer to stay on the Indian side in the forest patches of neighboring tea estates (Medli TE, Putni TE, Tirmiti TE, and Sephinjuri TE) at dusk and visit the paddy fields in Kurti and Putni at dawn. Villages like Mongool, Lathitilla, Dumabaroi, Adamtila, Bhubrighat, Chambarbri, Putni are located adjacent to the southern part of the RF and hence all these villages are in human-elephant interaction prone areas during the summer season (Fig. 1). While discussing the issue with the present BSF commandant of Sonatola, we were told that they now try their best to ensure safe movement of the elephants across the border and they have no plans to repair the areas that were previously damaged by elephants, as these pachyderms are not creating any problem. It is our suggestion to equip the BSF staff with the tranquilizer gun for use in incidences of retaliation.

Though the elephants do not affect the local people directly, yet the villagers are scared of them. Crop raiding is the major issue that has led to the formation of a negative attitude towards conservation of the species among victims. After interviewing the local people, it was found that they have no problem improving the reserve forest but need protection from crop raiding and other damaging activities by the elephants. It has been our observation that the majority of the people


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Image 1. Elephants in Patharia Hills Reserve Forest

have a positive attitude on the conservation of the elephant. Some of them also suggested that low voltage electric fences might be helpful in minimizing negative interactions. The villagers also sought strong action against illegal activities within the forest (Talukdar & Choudhury in press). They strongly believe that if stern action is not taken up by the government and the forest department, someday or other the forest may lose its identity.

Local people have to be made more aware of co-existing, alternative livelihood and value-added services outside the forest. Training and capacity building of local youth on precautionary measures for reducing elephant incidents is of utmost importance. It is the need of the hour that the reserve forest is elevated as a wildlife sanctuary, the activities within the RF be stopped, eviction of forest dwellers and rehabilitation into other government lands may be done. Wildlife Trust of India and other organizations working in the field of conservation may take initiatives to conserve the wild fauna of the area as taken up in other conservation priority areas. A large portion of the Patharia Hills RF has been subsumed under the territory of the neighboring country, (i.e., Bangladesh). Thus, initiating any conservation action for the area is comparatively difficult, as this deserves joint initiatives of both the countries. So, in order to better protect the wildlife and their habitats, the two countries can join hands as has been done for biodiversity conservation in Sundarban ('the MOU', Governments of India and Bangladesh 2011a,b). It is time if conservation action is not taken up right now, the RF will be a dense human settlement area without any trace of wildlife in the near future.

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Breeding record of Common Hoopoe *Upupa epops* (Aves: Upupidae) at Satchari National Park in northeastern Bangladesh

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Bangladesh has a rich biological heritage owing to its location in the subtropical belt at the confluence of two major biotic subregions (Indo-Himalaya and Indo-Chinese) of the Oriental region (Khan 2008; Feeroz 2014). A total of 1,619 species were recorded were recorded from the country. With 566 evaluated species, birds constitute the most species-rich group in Bangladesh (IUCN Bangladesh 2015). Of this group, 383 are residents, 218 winter visitors, 11 summer visitors, and 94 vagrants. Common Hoopoe *Upupa epops* of Upupidae family is thought to be a local breeding resident having been recorded throughout the year (Harvey 1990) but without any confirmation of breeding in the country. The species is distributed widely in Europe, Asia, northern Africa, Sub-Saharan Africa, and Madagascar (Kristin 2001). Here we document the first nesting of Common Hoopoe in Bangladesh.

On 6 May 2016 at 10:00hr, during habitat data collection of Bengal Slow Loris *Nycticebus bengalensis* at Satchari National Park (SNP) (24.122^{0}N & 91.443^{0}E) in northeastern Bangladesh, we found a Common Hoopoe carrying a food item (Image 1). Another individual too was seen carrying food in the same direction. Following that direction for approximately 45min, we discovered their probable destination. After a further 40min of observation, a nest was found with at least one chick (Image 2). We tried to determine the number of chicks through binoculars but failed due to the height of the nest cavity. The chick(s) seen was thought to be 20–30 days old and stuck its head out of the nest and called continuously. Parents visited separately with food (Image 3). Most food items appeared to be small invertebrates but could not be identified to the species level, although a few seemed to be spiders and also some sort of larva.

The Common Hoopoe pair has built its nest in a large *Terminalia chebula* tree at the top of a hillock of 51m elevation. The nest was in a partly hidden cavity with a narrow entrance and was about 30m above the ground, hidden by dense undergrowth. The nest location high in the canopy in a less disturbed patch of forest appeared a good choice for potential breeding success.

The nest was typical – Hoopoes nest in trees having cavities with narrow entrances (Perrins & Harrison 1979; Cramp 1985) but do not excavate their own nest cavities (Perrins & Harrison 1979). We presume that this nest was in an old woodpecker hole. The nesting area is comparatively less logged and disturbed by visitors, although in the last few years the area was converted to

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Image 1. Food collection by Common Hoopoe for its chick

lemon gardens by the local communities. Many of the large trees used by birds such as Oriental Pied Hornbill for nesting were cut down illegally. Habitat destruction is a threat for birds and other threatened animals in SNP. As far as the authors' knowledge, this is the first description of the Common Hoopoe nesting in Bangladesh that confirms its status as a breeding resident. We, however, found no other Hoopoe nests in SNP in our two years of faunal surveys in the forest.

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Image 2. Common Hoopoe chick in the nest waiting for its parents


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Image 3. Common Hoopoe feeding its chick

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ADDITIONAL RECORD OF THE POORLY KNOWN ARGUS *PARALASA NEPALICA* (PAULUS, 1983) (INSECTA: LEPIDOPTERA: NYMPHALIDAE) IN NEPAL

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The genus *Paralasa* (Moore, 1891) belongs to the family Nymphalidae which is also linked to the genus *Callerebia*. The recent molecular phylogeny support Miller (1968) who proposed the placement of *Paralasa* within the *Callerebia* series of Ypthimina (Peña et al. 2006), however, the life history and karyotype study by Sauracov & Emmel (2008) showed no new evidence supporting its affinity with Ypthimina. It is usually distributed in the higher mountains of central Asia (NW-Himalaya, Szechwan, East Tibet, Karakorum, Pamir, Tien Shan, Hindukush (Vis & Coene 1987).

This genus is easily identifiable by the presence of a distinct row of 5–7 white points on the underside of the hindwing in the female and reduced white in the male. The underside of females is bicolor since forewing apex and the whole hindwing are covered with a dense layer of whitish-grey scales. The apex of the forewing is sharpened, the eye-spot is round with a single white pupil (Churkin & Tuzov 1998). The female is somewhat bigger than the male.

There are 30 species of *Paralasa* recorded globally (NHM 2018) and Nepal is home to a single species, *Paralasa nepalica*. In 1973, *Paralasa* material was collected from northwestern Nepal by Martens. The material was studied by Paulus (1982), who realized that the species was new and described it as *P. nepalica,* representing the easternmost species of the genus *Paralasa* (Vis & Coene 1987). The species is considered endemic to Nepal (Smith 1994).

After the first collection by Martens in 1973 (Vis & Coene 1987), there have been only two additional records till date, one from Chya lekh, Mahakali, northwestern Nepal, at an elevation of 3,740m (Morishita & Innomata 1998) and another above Phoksumdo Village, Dolpa, at 3,500m (Sourakov & Emmel 2008). This is the fourth observation record of this species in Nepal, obtained about 166km north-west from Dolpa and 68.7km north-east from Chya lekh, Darchula, Nepal. Also, no photograph of this species is known to have been taken yet in its natural habitat. The photograph presented here is most likely to be the first for this species in its natural habitat.

We observed the butterfly in Talung Valley (30.203^{0}N & 81.700^{0}E, 4,400m) of upper Humla, Province - 6, on 27 July 2017 at 1:30hr. The butterfly was basking by the roadside along with two other butterflies—Indian Tortoiseshell *Aglais cashmirensis* and Lofty Bath White *Pontia callidice*.

Like most *Paralasa* species, *P. nepalica* is mentioned

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Image 1. Female Nepal Argus *Paralasa nepalica*, Humla, Nepal, 27 July 2017.

Image 2. Talung Valley, Humla, Nepal, where Nepal Argus *Paralasa nepalica* was photographed on 27 July 2017.

to prefer pine forest belt (Vis & Coene 1987), however, the observation presented in this paper is very different as the habitat is characterized by a wide valley interspersed by big boulders and rocky hills with steep trails that are mostly covered with lichens, grasses, forbs, sedges, and shrubs. The anomaly in the observation calls for further research to better understand the habitat and ecology of the species.

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FIRST REPORT OF THE CATFISH NILGIRI MYSTUS *HEMIBAGRUS PUNCTATUS* (JERDON, 1849) (BAGRIDAE) FROM STANLEY RESERVOIR, TAMIL NADU, INDIA

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The catfish genus *Hemibagrus* is represented by three species in the Indian subcontinent, namely, *H. menoda* (Hamilton, 1822), *H. maydelli* (Rössel, 1964), and *H. punctatus* (Jerdon, 1849). *Hemibagrus menoda* is reported from the Brahmaputra, Ganges, Mahanadi, and Godavari river drainages in India, Nepal, and Bangladesh (Ng & Ferraris 2000; Ng 2010) and *H. maydelli* is known to be restricted to the Krishna River system in peninsular India (Dahanukar et al. 2011). The Nilgiri Mystus *H. punctatus* is endemic to the Cauvery River system in the Western Ghats of India (Dahanukar et al. 2004; Ng & Kottelat 2013), where it faces severe threats including pollution, habitat alteration due to construction of dams and indiscriminate fishing resulting in drastic population declines close to 100% and the species being listed as Critically Endangered on the IUCN Red List (Raghavan & Ali 2011).

Jerdon (1849) described *Bagrus punctatus* (=*Hemibagrus* Bleeker, 1862) from the Cauvery River and its tributaries in southern India. Subsequent records of the species are available from the main stem of the Cauvery (Rao & Seshachar 1927; Hora 1937; Ali et al. 2013) and its various tributaries including Bhavani (Day 1867, 1877, 1878; Mukerji 1931; Rajan 1955), Moyar (Rajan 1955; Rajan 1963; Manimekalan 1998), Hemavathy (Jayaram 1977; Madhyastha & Murugan 1993), Kabini (Easa & Shaji 1997), and Bhavani (Athikadavu) (Ali et al. 2013). Recent ichthyofaunal surveys (March 2018) in the Stanley Reservoir (Image 1; Fig. 1) resulted in the collection of 10 specimens of *H. punctatus,* which constituting a new distribution record for the species. The collected specimens were identified following Jerdon (1849) and Ng & Kottelat (2013) and subsequently preserved in 10% formalin and deposited in the freshwater fish collections of the Zoological Survey of India, Kolkata (ZSI FF7653-7654), and in the personal collection of J. Praveenraj (JPC-1-8) (Table 1).

Materials collected: ZSI FF 7653-7654, 2ex., 16.iii.2018, 138.84–162.82 mm SL, India, Tamil Nadu, Cauvery River, Stanley Reservoir, 11.9^{0}N & 77.77^{0}E, 221.50m, coll. N. Moulitharan; JPC-1-8, 8 ex., 16.iii.2018, 132.97–179.8 mm SL, India, Tamil Nadu, Cauvery River, Stanley Reservoir, 11.9^{0}N & 77.77^{0}E, coll. N. Moulitharan.

Hemibagrus punctatus was not recorded specifically from the Stanley Reservoir in the scientific literature despite being known to be consistently harvested in gill net (mesh size 24–45 mm) fisheries. Locally known as ‘Kallu Keluthi’ in Tamil (Kallu: stone, Keluthi: catfish), this species, however, represents only a negligible part

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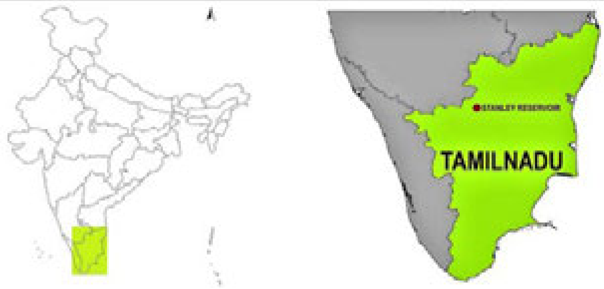

Figure 1. Location of Stanley Reservoir in Tamil Nadu, India

Image 1. Collection site of *Hemibagrus punctatus*: a pool cut off from the Stanley Reservoir in Tamil Nadu, India

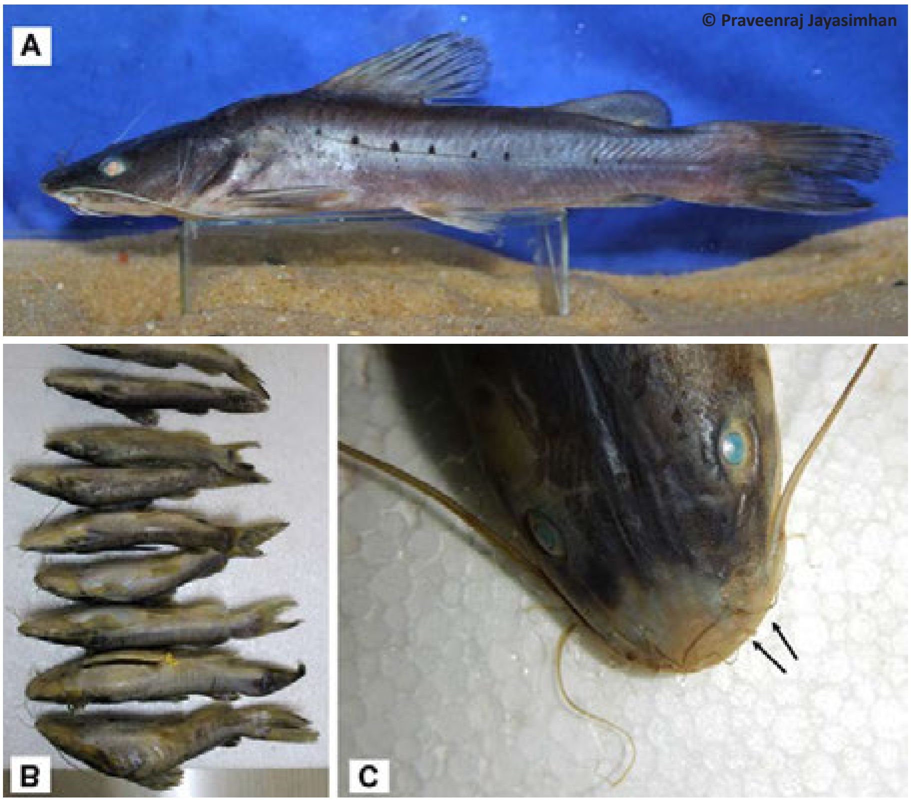

Image 2. *Hemibagrus punctatus*. A - live specimen, 139.06mm SL, B - preserved specimens (n=10), C - black arrows indicating forked maxillary barbel.

of the capture fisheries of the reservoir and is generally consumed in the dry form.

Hemibagrus punctatus is widely considered to be a rare species as most previous records are based only on a single specimen (e.g., Mukerji 1931; Hora 1937; Rajan 1955). This species was also considered extinct from its native range until its rediscovery (based on four specimens) after a gap of 14 years from the tributaries of Cauvery in Tamil Nadu and Karnataka (Ali et al. 2013).

A number of factors pose threat to the continued survival of *H. punctatus* in and around the Stanley Reservoir, including ghost fishing, use of pesticides for agriculture along the shores of the reservoir (Image 3), and increasing occurrence of invasive alien species, namely, *Oreochromis* spp. and *Clarias gariepinus* (Image 4).

One specimen of *H. punctatus* (JPC-8, 179.8mm SL) was dissected for examining the gut content, which revealed traces of fish and terrestrial grass. In the specimens examined, we also noted the presence of forked maxillary barbel (Image 2C), an aberration that was also recorded in *Mystus vittatus* (Bloch, 1794) (Rao 1984).

Although *H.punctatus* is assessed as Critically Endangered (Raghavan & Ali 2013), Ali et al. (2013) suggested reassigning it to the Vulnerable category

Table 1. Morphometric characters of *Hemibagrus punctatus* (n=10) from Stanley Reservoir in Tamil Nadu, India. All proportional measurements are expressed as percents of standard length and head length.

Characters	Mean (Mean ± S.E.)
Standard Length (SL)	**155.77±5.55mm**
In % SL	In mm
Head length	27.77
Head depth	14.40
Maximum head width	20.44
Pre-dorsal length	39.75
Pre-pectoral length	26.71
Pre-pelvic length	52.63
Pre-anal length	70.47
Pre-anus length	59.29
Least depth of caudal peduncle	10.04
Caudal-peduncle length	17.53
Dorsal-fin length	19.67
Dorsal-fin base length	15.44
Pectoral-fin length	18.49
Pectoral-fin base length	4.80
Pelvic-fin length	14.94
Anal-fin length	14.04
Anal-fin base length	12.23
Dorsal to adipose distance	17.82
Adipose-fin height	4.60
Adipose-fin base length	12.97
Post adipose distance	15.58
Maxillary barbel length	58.94
Nasal barbel length	11.16
Mandibular barbel length	23.51
Inner mandibular barbel length	12.47
Eye diameter	3.69
Snout length	11.42
Inter-orbital length	9.91
Dorsal spine length	13.15
Caudal-fin length	22.50
Post-orbital length	12.69
Body depth at anus	15.65
Pectoral-spine length	16.75
Head length (HL)	**43.26±1.81mm**
In % HL	
Head depth	51.86
Maximum head width	70.29
Eye diameter	13.29
Snout length	41.13
Inter-orbital length	35.69
Post-orbital length	45.69
Maxillary barbel length	212.24
Nasal barbel length	40.20
Mandibular barbel length	84.67
Inner mandibular barbel length	44.90

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Image 3. Around Stanley Reservoir in Tamil Nadu, India. A - abandoned net on exposed rocks, B - burning of old nets at the banks, C - evidence of use of pesticides for agriculture carried out along the banks.

Image 4. Catch from the *H. punctatus* collection site. A - *Oreochromis* spp., B - *Clarias gariepinus*.

considering that its average population decline was more than or equal to 30%. This species, however, continues to face a decline in its native range (Ali et al. 2013), and ecological and community-based conservation measures need to be implemented to ensure healthy populations of this threatened species.

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THE EASTERNMOST DISTRIBUTION AND HIGHEST ELEVATION RECORD OF THE RARE DESERT CAT SNAKE *TELESCOPUS RHINOPOMA* (REPTILIA: COLUBRIDAE) IN PAKISTAN

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One of the most enigmatic reptile species in the Western Palearctic, the Desert Cat Snake *Telescopus rhinopoma* (Blanford, 1874) is currently known from only a few records from the Middle East (southeastern Iran, with the type locality of the species in Kerman Province), central Asia (southern Turkmenistan), and southern Asia (central Afghanistan and western and northwestern Pakistan). It is a monotypic species biogeographically classified as an Iranian chorotype (Blanford 1876; Wall 1914; Minton 1966; Böhme 1977; Rai 1978; Sindaco et al. 2013).

As is the case for the other members of its genus (currently comprised of 15 species; Mazuch et al. 2018), this species has a triangular head, distinct from the neck with a flat and broad snout. It is the largest species of the genus. The body is cylindrical, moderately slender with a total length of about 160cm (Latifi 1991; Mazuch et al. 2018). It is pale greyish dorsally with a series of large dark brown squarish blotches that fade away from mid-body onward. There is a lateral colour pattern consisting of alternating series of smaller poorly defined spots. The ventral surface is dark brown (Minton 1966; Khan 2006). Due to overlapping morphologic characteristics with *T. fallax* and *T. tessellatus*, *T. rhinopoma* was ranked as a member of the *T. fallax* complex (Böhme 1977; Sindaco et al. 2013).

Telescopus rhinopoma is a nocturnal, oviparous species that was recorded from arid, rocky hills of up to 2,000m in elevation in Iran (Moradi et al. 2013). The record from Afghanistan comes from a locality with an elevation of approximately 1,050m (Böhme 1977; see Wagner et al. 2016 for the corrected geographic position of the locality). All previously recorded Pakistani localities of the species range up to 1,600m in elevation (Mertens 1969; Table 1), though Khan (2006) documented the species only up to 700m. In summary, we have very little knowledge about the distribution and ecology of *T. rhinopoma* within its known distribution range. Due to the rarity of this species, each new record is important and should be documented in detail to assess the threat status and to determine conservation priorities of the species. The current category for the species according to the IUCN is Data Deficient (Papenfuss et al. 2017).

More than three decades ago, *T. rhinopoma* was known in Pakistan from only five exact localities and one unknown locality situated in Sindh Province (Ingoldby & Procter 1923; Minton 1966; Mertens 1969; Böhme 1977). The easternmost records of this species were from Pakistani Waziristan's federally administered tribal areas

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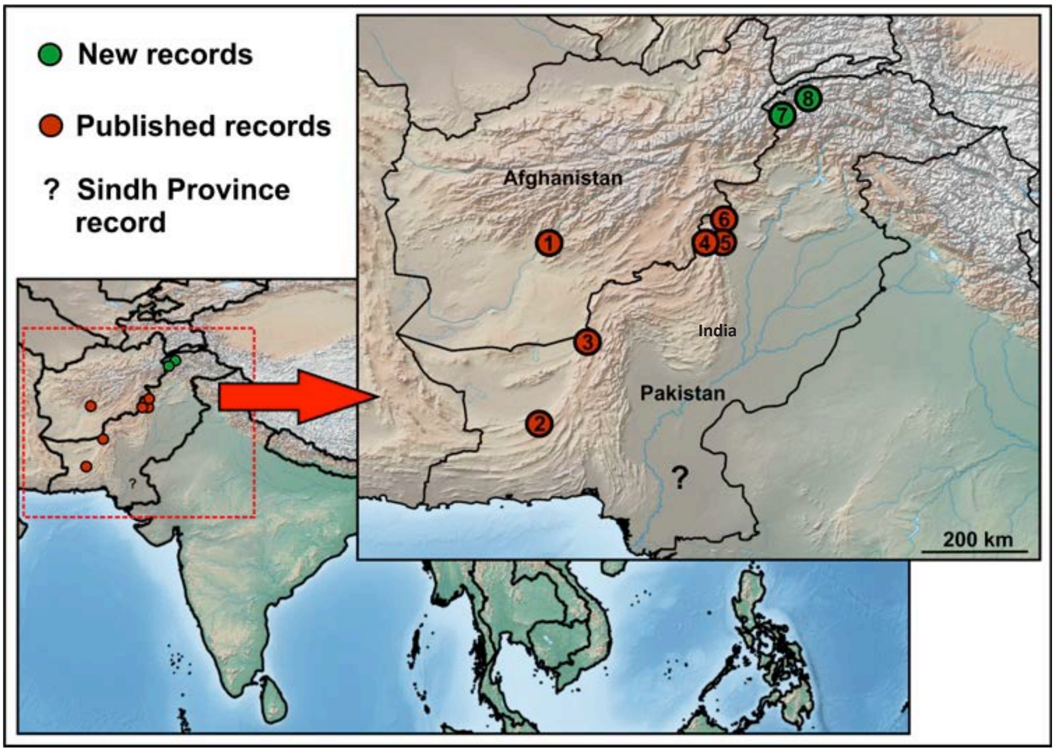

Figure 1. The current distribution records of Telescopus rhinopoma from southern Asia (Afghanistan & Pakistan). 1 - Band-e-Kajaki, 2 - Kacha Daman, 3 - Galangur, 4 - Kirgi Bridge, 5 - Jandola, 6 - Miran Shah, 7 - Gahtak, 8 - Kroi Deri, Mastuj. The question mark indicate questionable record of the species from Sindh Province.

Table 1. A summary of distribution records of *Telescopus rhinopoma* from Afghanistan and Pakistan

	Country	Locality	⁰N	⁰E	Elevation (m)	Sources
1	Afghanistan	Band-e-Kajaki	32.32	65.24	1,050	Böhme 1977; Wagner et al. 2016
2	Pakistan	Kacha Daman (Thana)	27.36	64.94	1,315	Wall 1914
3	Pakistan	Galangur	29.64	66.34	1,570	Mertens 1969
4	Pakistan	Kirgi Bridge	32.30	69.63	1,320	Ingoldby & Procter 1923; Minton 1966
5	Pakistan	Jandola	32.32	70.13	680	Ingoldby & Procter 1923; Minton 1966
6	Pakistan	Miran Shah (Tochi Valley)	32.97	70.17	754	Smith 1943
7	Pakistan	Gahtak	35.86	71.80	1,823	This study
8	Pakistan	Kroi Deri, Mastuj	36.28	72.47	2,269	This study

(Fig. 1). Here we provide two new records of the species from Chitral District in Khyber Pakhtunkhwa Province, Kunar River Valley, Hindu Kush range, Pakistan. The first record originates from Kroi Deri Village near Mastuj (36.28^{0}N & 72.47^{0}E, 2,269m), where an adult specimen was observed in October 2012. The snake was found injured lying on the main road towards Mastuj, possibly struck by a vehicle (Image 1). The second observation was recorded near the village of Gahtak in November 2016 (35.86^{0}N & 71.80^{0}E, 1,823m). This individual was also an adult but was not photographed. Both records are from semi-arid, rocky areas (Image 1). These observations were made by a local naturalist, without exact measurements or other recorded data. Both individuals were released and not collected. We compared our new records with the published geo-referenced records of this species from Afghanistan and Pakistan using Google Earth (WGS84). These records expand the known distribution range of the species to more than 400km northeastwards. Moreover, the elevation limit of the occurrence of the species increased overall by 269m, particularly by 699m in the territory of Pakistan.

Image 1. An adult individual of *Telescopus rhinopoma* observed from Kroi Deri, Mastuj, with an overview of its locality. © Khurshid Shah & Daniel Jablonski

These new records represent an important new range and elevation extension for *T. rhinopoma* in Pakistan and the Hindu Kush range. The new localities are located 350km (Gahtak) and 415km northeast (by air), respectively, from the nearest known locality of Miran Shah in Pakistani Waziristan (Smith 1943). Both new localities are characterised by dry, semi-evergreen deciduous scrub, evergreen oak deodar forests, or subtropical pine forests, habitats that are suitable for the occurrence of *T. rhinopoma* (Khan 2006). From a biogeographical point of view, the presence of *Platyceps rhodorachis* (Jan, 1865), *Ptyas mucosa* (Linnaeus, 1758), *Spalerosophis diadema* (Schlegel, 1837), or *Naja oxiana* (Eichwald, 1831) in the region suggests a common migration route (the so-called Hindu Kush corridor; Khan 2006) along the Kunar River system from Chitral Valley to Mastuj. These mostly Irano-Turanian species have similar habitat requirements, although not ecologically compatible. The deep valleys of the Hindu Kush, with an arid and rocky character, allow the eastward penetration of reptiles from lower semi-desert foothill regions to the mountain areas. The Kunar River system was also hypothesized as a potential migration route for *Natrix tessellata* (Laurenti, 1768) in Pakistan (Mebert & Masroor 2013). Further field research is needed to understand whether the lack of data from areas between these localities is due to poor sampling or rather reflects a fragmentary distribution of the species in isolated populations. Genetic analyses that show affiliations of this and other populations of *T. rhinopoma* are also needed.

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NOTE

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A CHECKLIST OF SPIDER FAUNA OF RAJASTHAN, INDIA

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Proper documentation of biodiversity is essential for its sustainable management and conservation by the timely monitoring of the rate of species loss. Checklists form a vital part of systematic documentation. Species identified from various parts of the world are added to global databases and catalogues, which form a mainstay of taxonomy and indirectly contribute to the conservation of biodiversity. Considering the escalating level of anthropogenic threats to biodiversity, an inventory and proper documentation of biodiversity, especially on neglected groups like arachnids, is needed urgently. The World Spider Catalog (2018) documented a total of 47,829 species belonging to 4,112 genera and 118 families.

Despite being the key invertebrate predators of almost all terrestrial ecosystems, spiders are a comparatively neglected group of animals. So far, very few attempts were made to study the spider fauna of Rajasthan in India. Notable works on spiders were initiated by Tikader (1961). Gajbe & Bhadra (1978), Bhanotar et al. (1980), and Roonwal (1982) also contributed to the field of arachnology of Rajasthan. Tikader (1961), Tikader & Gajbe (1977), Tikader & Malhotra (1982), and Gajbe (1993) reported new species from Rajasthan and named them after their places of discovery (*Gnaphosa kailana, Scotophaeus rajasthanus, Callilepis rajasthanica, G. jodhpurensis, Megamyrmaekion jodhpurense*, and *Evippa banarensis*). After a gap of a decade, further attempts to study the spider fauna of the state was made by Sivaperuman & Rathore (2004), who documented 13 families of 21 genera consisting of 28 species from Desert National Park, which falls under Jaisalmer and Barmer districts of Rajasthan. Later studies were reported from Ranthambhore National Park, Sawai Madhopur (Sen et al. 2009; Saha et al. 2015), Shekhawati Aravalian region (Saini et al. 2012), and Deeg Town in Bharatpur (Lawania et al. 2013). Recently, two new species of jumping spiders *Epocilla sirohi* and *Mogrus rajasthanensis* were recorded from Sirohi District of Rajasthan (Caleb et al. 2017).

The present paper lists 71 species of spiders belonging to 47 genera and 15 families reported so far from various parts of the state of Rajasthan (Table 1). It is a checklist based on previous publications. Classification follows World Spider Catalog (2018). The most species-rich family reported so far is Araneidae and Gnaphosidae (14 species each), followed by Lycosidae (12 species).

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Table 1. Spider fauna of Rajasthan State, India

	Family/species	Distribution (districts)	References
I	**Araneidae** Clerck, 1757		
1	*Araneus diadematus* Clerck, 1757	Sikar, Jhunjhunu	Tikader 1982
2	*Argiope aemula* (Walckenaer, 1841)	Bharatpur	Lawania et al. 2013; Kaur et al. 2014
3	*A. anasuja* Thorell, 1887	Bharatpur	Lawania et al. 2013
4	*A. lobata* (Pallas, 1772)	Bikaner	Tikader 1961
5	*Cyrtophora cicatrosa* (Stoliczka, 1869)	Bharatpur	Lawania et al. 2013
6	*C. citricola* (Forsskål, 1775)	Nagaur, Bharatpur	Tikader 1961; Lawania et al. 2013
7	*C. exanthematica* (Doleschall, 1859)	Sawai Madhopur	Saha et al. 2015
8	*Gibbaranea bituberculata* (Walckenaer, 1802)	Sikar, Jhunjhunu	Saini et al. 2012
9	*Herennia multipuncta* (Doleschall, 1859)	Jaisalmer	Sivaperuman & Rathore 2004
10	*Larinioides sclopetarius* (Clerck, 1757)	Sikar, Jhunjhunu	Tikader 1982
11	*Neoscona nautica* (L. Koch, 1875)	Jodhpur, Sikar, Jhunjhunu	Tikader 1961
12	*Nephila kuhlii* (Doleschall, 1859)	Bharatpur	Lawania et al. 2013
13	*N. pilipes* (Fabricius, 1793)	Pratapgarh, Udaipur	Lawania et al. 2013
14	*Zilla diodia* (Walckenaer, 1802)	Sikar, Jhunjhunu	Tikader 1982
II	**Cheiracanthiidae** Wagner, 1887		
15	*Cheiracanthium melanostomum* (Thorell, 1895)	Sawai Madhopur	Saha et al. 2015
III	**Eresidae** C.L. Koch, 1845		
16	*Stegodyphus pacificus* Pocock, 1900	Jodhpur	Tikader 1961
17	*S. sarasinorum* Karsch, 1892	Jaisalmer, Jaipur, Sawai Madhopur	Sivaperuman & Rathore 2004; Saha et al. 2015
IV	**Gnaphosidae** Pocock, 1898		
18	*Callilepis rajasthanica* Tikader & Gajbe, 1977	Jodhpur	Tikader & Gajbe 1977
19	*Drassodes lapidosus* (Walckenaer, 1802)	Barmer	Tikader 1982
20	*D. luridus* (O. Pickard-Cambridge, 1874)	Jaisalmer, Barmer	Sivaperuman & Rathore 2004
21	*D. parvidens* Caporiacco, 1934	Jaisalmer, Barmer	Sivaperuman & Rathore 2004
22	*Gnaphosa jodhpurensis* Tikader & Gajbe, 1977	Jodhpur	Tikader & Gajbe 1977
23	*G. kailana* Tikader, 1966	Jodhpur, Nagaur, Bikaner	Tikader 1961
24	*G. poonaensis* Tikader, 1973	Jodhpur	Tikader 1982
25	*Megamyrmaekion jodhpurense* Gajbe, 1993	Jodhpur	Gajbe 1992
26	*Poecilochroa sedula* (Simon, 1897)	Jaisalmer, Barmer	Sivaperuman & Rathore 2004
27	*Scotophaeus rajasthanus* Tikader, 1966	Nagaur	Tikader 1961
28	*Trachyzelotes jaxartensis* (Kroneberg, 1875)	Jodhpur	Tikader 1982
29	*Zelotes ashae* Tikader & Gajbe, 1976	Jodhpur	Tikader 1982
30	*Z. desioi* Caporiacco, 1934	Jaisalmer	Sivaperuman & Rathore 2004
31	*Z. nasikensis* Tikader & Gajbe, 1976	Jaisalmer, Barmer	Sivaperuman & Rathore 2004
V	**Hersiliidae** Thorell, 1870		
32	*Hersilia savignyi* Lucas, 1836	Bharatpur, Jaipur	Saini et al. 2012; Lawania et al. 2013
VI	**Lycosidae** Sundevall, 1833		
33	*Evippa banarensis* Tikader & Malhotra, 1980	Jodhpur	Tikader 1982
34	*E. rajasthanea* Tikader & Malhotra, 1980	Jodhpur	Tikader 1982
35	*Hippasa madhuae* Tikader & Malhotra, 1980	Bharatpur, Sawai Madhopur	Saha et al. 2015
36	*H. pisaurina* Pocock, 1900	Bikaner, Sikar, Jhunjhunu	Tikader 1961
37	*Lycosa madani* Pocock, 1901	Jaisalmer, Barmer	Sivaperuman & Rathore 2004
38	*L. pictula* Pocock, 1901	Bharatpur	Lawania et al. 2013

	Family/species	Distribution (districts)	References
39	*Pardosa birmanica* Simon, 1884	Jodhpur, Udaipur, Bharatpur	Tikader 1961; Lawania et al. 2013
40	*P. heterophthalma* (Simon, 1898)	Jaisalmer, Barmer	Sivaperuman & Rathore 2004
41	*P. pusiola* (Thorell, 1891)	Barmer, Jaisalmer	Sivaperuman & Rathore 2004
42	*P. sumatrana* (Thorell, 1890)	Jaisalmer, Jodhpur, Barmer, Sikar, Jhunjhunu	Sivaperuman & Rathore 2004; Saini et al. 2012
43	*Trochosa punctipes* (Gravely, 1924)	Nagaur	Tikader 1961
44	*T. urbana* O. Pickard-Cambridge, 1876	Bharatpur	Lawania et al. 2013
VII	**Oecobiidae** Blackwall, 1862		
45	*Uroctea indica* Pocock, 1900	Jaisalmer, Barmer	Sivaperuman & Rathore 2004
VIII	**Oxyopidae** Thorell, 1870		
46	*Oxyopes birmanicus* Thorell, 1887	Bharatpur, Sikar, Jhunjhunu	Lawania et al. 2013
47	*O. javanus* Thorell, 1887	Bharatpur	Lawania et al. 2013
48	*O. shweta* Tikader, 1970	Jaipur, Sawai Madhopur, Sikar, Jhunjhunu	Saini et al. 2012; Saha et al. 2015
49	*O. sitae* Tikader, 1970	Sawai Madhopur	Saha et al. 2015
IX	**Philodromidae** Thorell, 1870		
50	*Thanatus lanceoletus* Tikader, 1966	Bikaner	Tikader 1961
X	**Pholcidae** C.L. Koch, 1850		
51	*Artema atlanta* Walckenaer, 1837	Nagaur, Bikaner, Jodhpur, Bharatpur	Tikader 1961; Lawania et al. 2013
52	*Crossopriza lyoni* (Blackwall, 1867)	Jodhpur	Tikader 1961
53	*Pholcus phalangioides* (Fuesslin, 1775)	Bharatpur	Lawania et al. 2013
XI	**Salticidae** Blackwall, 1841		
54	*Epocilla sirohi* Caleb, Chatterjee, Tyagi, Kundu & Kumar, 2017	Sirohi	Caleb et al. 2017
55	*Hyllus semicupreus* (Simon, 1885)	Bharatpur	Lawania et al. 2013
56	*Mogrus rajasthanensis* Caleb, Chatterjee, Tyagi, Kundu & Kumar, 2017	Sirohi	Caleb et al. 2017
57	*Phintella vittata* (C. L. Koch, 1846)	Bharatpur	Saini et al. 2012
58	*Plexippus paykulli* (Audouin, 1826)	Bharatpur, Sikar, Jhunjhunu	Saini et al. 2012; Lawania et al. 2013
59	*Portia assamensis* Wanless, 1978	Bharatpur	Lawania et al. 2013
60	*Rhene albigera* (C. L. Koch, 1846)	Sawai Madhopur	Saha et al. 2015
61	*Telamonia dimidiata* (Simon, 1899)	Bharatpur, Sawai Madhopur	Lawania et al. 2013; Saha et al. 2015
XII	**Sparassidae** Bertkau, 1872		
62	*Heteropoda fabrei* Simon, 1885	Jaisalmer	Sivaperuman & Rathore 2004
63	*Olios tener* (Thorell, 1891)	Sawai Madhopur	Saha et al. 2015
XIII	**Tetragnathidae** Menge, 1866		
64	*Tetragnatha mandibulata* Walckenaer, 1841	Jodhpur, Jaipur	Tikader 1961
XIV	**Theridiidae** Sundevall, 1833		
65	*Argyrodes gazedes* Tikader, 1970	Sawai Madhopur	Saha et al. 2015
66	*Theridion varians* Hahn, 1833	Sikar, Jhunjhunu	Tikader 1982
XV	**Thomisidae** Sundevall, 1833		
67	*Indoxysticus minutus* (Tikader, 1960)	Jaipur, Sikar, Jhunjhunu	Saini et al. 2012
68	*Ozyptila chandosiensis* Tikader, 1980	Barmer, Jaisalmer	Sivaperuman & Rathore 2004
69	*Thomisus andamanensis* Tikader, 1980	Sawai Madhopur	Saha et al. 2015
70	*T. italongus* Barrion & Litsinger, 1995	Sawai Madhopur	Saha et al. 2015
71	*T. projectus* Tikader, 1960	Bharatpur	Lawania et al. 2013

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NOTE

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NEW RECORDS OF *CHRYSOMYA PUTORIA* AND *C. THANOMTHINI* (DIPTERA: CALLIPHORIDAE) FROM INDIA, WITH A REVISED KEY TO THE KNOWN INDIAN SPECIES

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The cosmopolitan genus *Chrysomya* Robineau-Desvoidy, 1830 comprises 36 species across the globe. The members of this necrophagous group are associated with carrion, garbage, ordure, and other fermenting substances. Due to their feeding habits, the *Chrysomya*, or blow flies, provide an excellent spatio-temporal indicator for forensic entomologists. Furthermore, blowflies are incriminated as agents of disease or vectors in medicine, public health, and veterinary (Lutz et. al. 2017).

To date, nine species are known from the Indian region (excluding *Chrysomya defixa*, which is of a dubious record from India) (Senior-White et al. 1940; Bharti 2011). *Chrysomya putoria* (Wiedmann, 1830) and *C. thanomthini* Kurahashi & Tumrasvin, 1977 are the new additions to the group. Both species were collected from Himachal Pradesh. An updated key to the known Indian species is provided herewith.

The specimens were collected with sweeping nets from apple orchards in the state of Himachal Pradesh. The material was examined under a Nikon SMZ 1500 stereozoom microscope. Digital images of *C. putoia* and *C. thanomthini* were captured using MP Evolution Digital camera (with auto-montage software, Syncroscopy, Division of Synoptics Ltd.) mounted on the microscope. The images were then processed with Adobe Photoshop CS5. The specimens are housed at Punjabi University, Patiala (PUPDC: Punjabi University Patiala Diptera collection).

Chrysomya putoria (Wiedemann, 1830)
(Images 1, 2)

Material examined: #101 PUPDC, 2 ex., 24.vi.2018, female, Jubbal, Himachal Pradesh, India, 31.109^{0}N, 77.662^{0}E, 2,000m, coll. M. Bharti.

Distribution: India (new record), Saudi Arabia, Iran, all over Africa south of Sahara (including western Africa, northwest to Senegal and Gambia, northeast to Sudan, Eritrea and Ethiopia, and south to South Africa), and the Neotropical region.

Remarks: The species differs from other closely related species like *C. chloropyga* in having conspicuous dusting in the dorsal part of its thorax, black marginal bands on abdominal segment III broad, even up to one-half of tergite length, and posterior edge of tergite V of the female entire, without incisions.

Ecology: The species was collected from a heap of rotten apples in the apple orchards in the town of Jubbal, Shimla District, Himachal Pradesh. The region is famous for its apple orchards and generally remains cool throughout the year with summers ranging from 15˚C to 30˚C. The temperature falls below zero degrees in the winter season.

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Image 1. Head and frontal view of *Chrysomya putoria*

Image 3. Head and frontal view of *Chrysomya thanomthini*

Image 2. Profile view of *Chrysomya putoria*

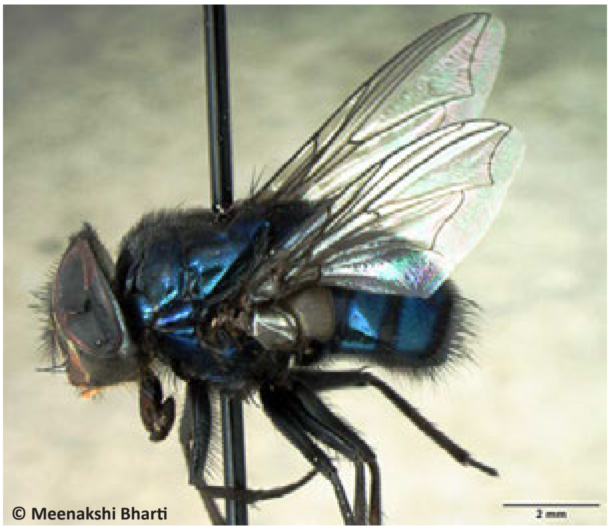

Image 4. Profile view of *Chrysomya thanomthini*

Chrysomya thanomthini Kurahashi & Tumrasvin, 1977 (Images 3, 4)

Material examined: #102 PUPDC, 10 ex., 26.vi.2018, females, Jubbal, Himachal Pradesh, India, 31.109^{0}N, 77.662^{0}E, 2,000m, coll. M. Bharti.

Distribution: India (new record), Nepal, Myanmar, Thailand, Malaysia (peninsular and Borneo), and southern China (Yunnan).

Remarks: *Chrysomya thanomthini* could be differentiated from closely related species like *C. megacephala* (Fabricius) and *C. pinguis* (Walker) on the basis of its purple colour and absence of presutular intra-alar bristles. The post-humeral bristle does not occur in the male but is weakly developed in females.

Ecology: The species was collected from the forests near the town of Jubbal, Shimla District, Himachal Pradesh.

Key to the Indian species of the genus *Chrysomya* Robineau-Desvoidy, 1830

1	Anterior spiracle white/yellow 2
-	Anterior spiracle black to dark brown 5
2	Only one katepisternal setae developed (0+1), all hairs on the surface of tergite V black .... *C. nigripes* Aubertin
-	Two katepisternal setae developed (1+1), at least some hairs on the surface of tergite V white 3
3	Dorsal part of thorax with conspicuous dusting; black transverse marginal abdominal bands on abdominal segment III broad, even up to one-half of tergite length, posterior edge of tergite V of the female entire, without incision .... *C. putoria* (Wiedemann)
-	Dorsal part of thorax shiny, with little dusting, black transverse marginal abdominal segments III and IV very narrow, up to about a quarter on segment III and usually not more than about 1/6th in segment IV, posterior edge of tergite V of female with incision...4
4	Third antennal segment wholly dark, blackish brown; proepimeral seta absent .... *C. albiceps* Wiedmann
-	Third antennal segment pale brown-reddish on the inner surface; proepimeral seta present .... *C. rufifacies* (Macquart)
5	Femora swollen in male and female, but more noticeably so in male, eyes dichoptic in both the sexes; outer-verticals (*ov*) well developed in male, female tergite V with median incision, facial ridge well-developed, high .... *C. villeneuvi* Patton
-	Femora normal 6
6	Eyes dichoptic in both sexes, facets small and uniform, outer verticals well developed in male; female tergite V with median cleft/incision .... *C. phaonis* (Seguy)
-	Eyes holoptic in the male, anterior facets enlarged; dichoptic in the female; outer verticals absent in male; female tergite V without median incision 7
7	Both upper and lower calypter entirely fuscous black, parafacialia and genae fuscous 8
-	At least base of upper calypter white 9
8	Post humeral bristle usually developed, medium-sized dark blue or green species, body length less than 11mm .... *C. pinguis* (Wiedmann)
-	Post humeral bristle absent, sometimes weakly developed in the female, large dark purple flies, body length more than 11mm .... *C. thanomthini* Kurahashi
9	Parafacialia and genae fuscous to black; setulae and hairs on parafacialia and facialia blackish; venter of tergite V with black hairs only; basal part of upper calypter opaque white, bare ventrally except for fringe .... *C. chani* Kurahashi
-	Parafacialia and genae entirely orange; setulae and hairs on the parafacialia and facialia yellowish; venter of tergite V intermixed with yellow hairs; opaque white basal part of upper calypter haired ventrally 10
10	Upper and lower calypter white; facets of male eye somewhat enlarged above, but not sharply demarcated from the area of smaller facets below; frontal stripe of female parallel-sided .... *C. bezziana* Villeneuve
-	Upper and lower calypters largely brown except for the pale base; facets of male eye much enlarged above, sharply demarcated from the area of the smaller facets below; frontal stripe of female broader at the middle of frons, not parallel-sided .... *C. megacephala* (Fabricius)

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NOTE

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Lectotypifiction of *Impatiens duclouxii* Hook.f., a new addition to the flora of India from Arunachal Pradesh

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The floristic diversity of the northeastern region of India is not well-documented due to its inaccessibility and difficult terrain. *Impatiens* is one such floristic genus that is not well-documented from the state of Arunachal Pradesh, a part of the eastern Himalaya. The genus is represented in India by more than 210 species (Bhaskar 2012), of which 137 are endemic (Vivekananthan et al. 1997; Swaminathan et al. 2001). In the recent past, however, many new species of *Impatiens* were discovered (Gogoi & Borah 2013a, 2014, 2015a,b,c,d,e, 2017a,b; Gogoi et al. 2017a,b; Hareesh et al. 2016a,b, 2017a,b; Hareesh & Sabu 2017; Liden & Bharali 2017), rediscovered (Gogoi et al. 2013b), and extended in range (Gogoi & Borah 2013b; Borah et al. 2015; Gogoi et al. 2015a,b, 2016; Tiwari et al. 2018) in the region.

During two expeditions to the West and East Kameng districts of Arunachal Pradesh in 2014 and 2017, respectively, one specimen of *Impatiens* with red-spotted yellow-coloured flowers was collected. After critical examination of the specimen and of the detailed literature dealing with *Impatiens* of the Indian subcontinent and adjacent areas (Hooker 1875, 1908a,b, 1910; Toppin 1920; Grey-Wilson 1989, 1991; Vivekananthan et al. 1997; Swaminathan et al. 2001; Huang et al. 2003; Huang 2006; Chen et al. 2008, 2012; Pusalkar & Singh 2010; Dessai & Janarthanam 2011; Bhaskar 2012; Gogoi & Borah 2013a,b, 2014, 2015a,b,c,d,e; Gogoi et al. 2013, 2015; Ruchisansakun et al. 2014; Borah et al. 2015), the species was identified to be *Impatiens duclouxii* Hook.f. (Balsaminaceae). A perusal of literature revealed that the species was not reported from India so far. Hence, it is reported here for the first time with descriptions and colour illustrations for easy identification in the field.

Impatiens duclouxii Hook.f.

Nouv. Arch. Mus. Hist. Nat., sér. 4, 10: 245 1908; Chen et al., Fl. China, 12: 64. 2007.

Lectotype (designated here): China, Yunnan, 5,000ft, 1900, A. Henry 12559 K (K000694008), image!; isolectotype: China, Yunnan, 5,000ft, 1900, A. Henry 12559 E (E00313630) (Images 1 & 2).

Perennial, sparsely branched, up to 100cm tall. Stem terete, slightly ridged, hairy. Leaves confined to the upper part of the stem, alternate, petiole up to 5.5cm long, with glands, stipule absent; lamina elliptic to ovate, 8.5–13.5 x 4–5 cm, ventrally pubescent along nerves, dorsally glabrous, base cuneate to obtuse, apex acute to acuminate, margin serrate, setose between teeth, lateral veins to 11 pairs, subopposite. Inflorescence axillary, 3–5 flowered, peduncle up to 2.5cm long,

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glabrous, bud yellowish-green with red spots, pedicel to 1.5cm long, green, bracts at the base, triangular, persistent, apex acute, mid-vein indistinct, glabrous. Lateral sepals two, obovate to orbicular, greenish-white, sometimes with red spots, to 1.3 x 1.5 cm, apex minutely mucronate, margins entire. Lower sepal bucciniform, pale yellow, up to 2.5cm long, spur coiled, up to 1.2cm long, yellow. Upper petal obovate, pale yellow with red spots, to 2 x 1.7 cm, apex emarginated, dorsally with a prominent horn, horn pale green. Lateral united petals pale yellow with red spots in basal lobe, bilobed, subequal, up to 3cm long (whole), basal lobe obovate, apex slightly emarginate, up to 1.5cm long, 1cm wide, clawed, distal lobe dolabriform, apex obtuse, 2cm long, 1.3cm wide, basal auricle orange, triangular, 2mm long. Stamens five, united, upright, 8mm long, anther lobes acute. Capsule not seen.

Flowering & fruiting: July–November

Habitat: The species was found growing in a moist habitat at 30–45 ^{0}C in a gentle slope along a small stream in Jamiri area in West Kameng District. It was later collected from Richikurung of East Kameng District, where the area is dominated by *Terminalia myriocarpa*, *Ficus semicordata*, *Bauhinia purpurea*, *Saurauia*

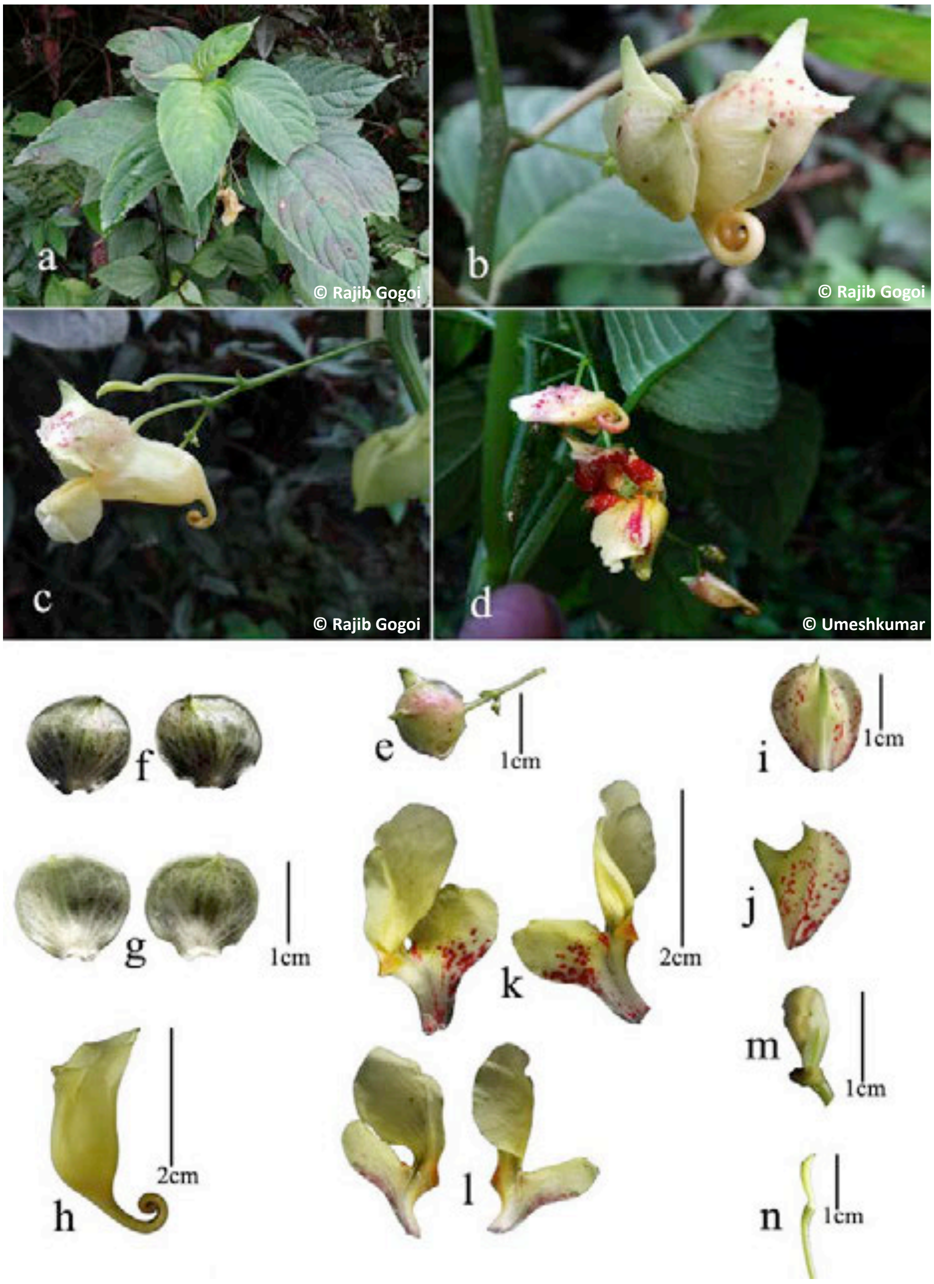

Image 1. *Impatiens duclouxii*. a - individual in its habitat, b - flower bud, c - lateral view of the flower, d - inflorescence, e - bud, f - dorsal view of lateral sepals, g - ventral view of lateral sepals, h - lower sepal, i - upper view of dorsal petal, j - lateral view of dorsal petal, k - ventral view of lateral united petals, l - dorsal view of lateral united petals, m - androecium, n - gynoecium.

roxburghii, Kydia calycina; the associated shrubs were *Melastoma normale, Alpinia nigra, Musa acuminata, Trevesia palmata, Bambusa pallida*, and *Strobilanthes paniculata.*

Distribution: China and India (West Kameng District in Jamiri, Arunachal Pradesh).

Conservation status: Chen et al. 2008 mentioned neither the distribution of the species in Yunnan in China nor its population. Herbarium records show that this species is represented by ca. 120-year-old collections. Therefore, it could have an extended distribution and new species record in India. Based on the distribution records, the authors would like to assess the species as Indeterminate (I) due to insufficient information on its distribution. Intensive explorations are required in similar habitats in adjacent areas for the possible location of the species. During the present survey, only 12 mature individuals were located, which were growing as undergrowth in a semi-evergreen forest along a stream.

Lectotypification: While describing this species, Hooker (1908) referred to three herbarium sheets of *I. duclouxii* as held at P, E & K (P - Herbarium,Muséum National d'Histoire Naturelle, Paris France; E - Herbarium, Royal Botanic Gardens, Edinburgh, EH3 5LR,. Scotland, UK; K - Herbarium, Royal Botanic Gardens, Kew, Richmond Surrey. TW9 3AE, England. UK. LWG). Among these, one sheet, A. Henry 12559 (K000694008) (Image 2), was selected as the lectotype. This sheet was examined by Hooker and found to closely match the protologue. Since the other sheets with the same collection number by A. Henry 12559 (E00313630) are regarded as part of the original gathering and match the protologue, it is here designated as an isolectotype.

Other specimens examined: 21969 (CAL), 27.x.2014, India, Arunachal Pradesh, West Kameng District, Jamiri, 1,200m, coll. R. Gogoi & B.B.T. Tham; 47947 (ARUN), 08.x.2017, East Kameng District, Palejee (Sube) on the way to Richikurung, 27.353^{0}N & 92.770^{0}E, 1,103m, coll. U.K. Tiwari.

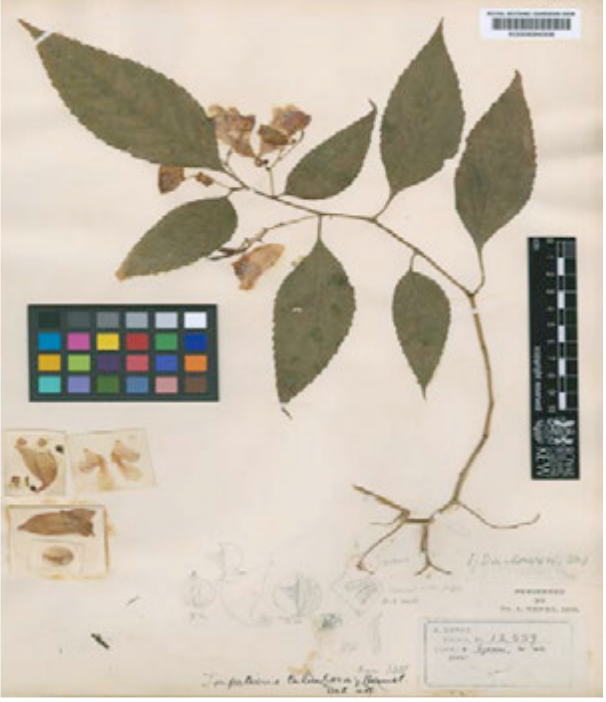

Image 2. Lectotype of *Impatiens duclouxii* (designated here). Source: http://apps.kew.org/herbcat/getImage.do?imageBarcode=K000694008

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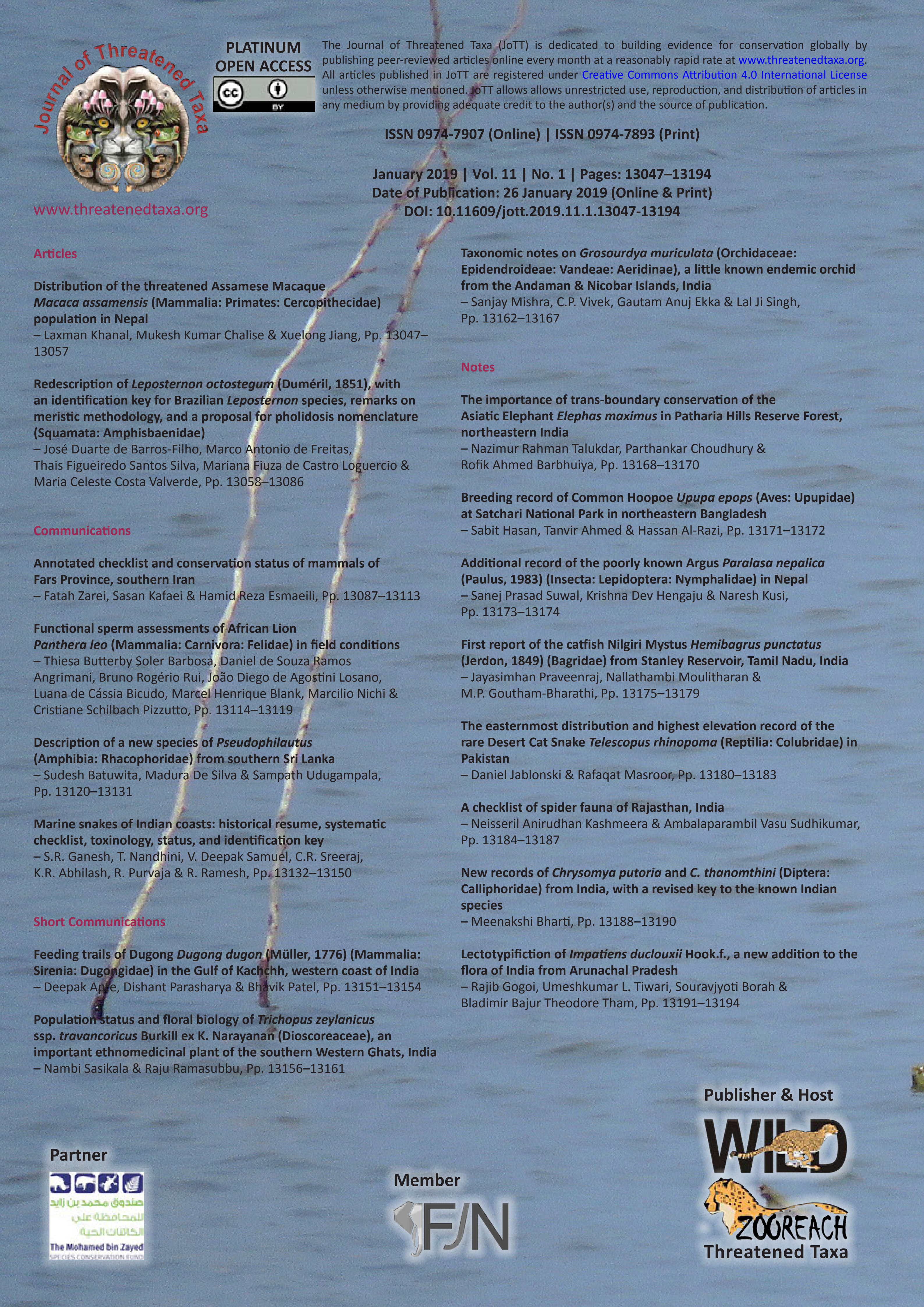

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