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Distribution and conservation status of the caenophidian snake, *Xylophis captaini* Gower & Winkler, 2007 in the Western Ghats, India

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We update the distribution of the little known Captain's Wood Snake (*Xylophis captaini*) in the Western Ghats, based on new observations and collation of the literature. The Maximum Entropy (MaxEnt) algorithm was used to predict the distribution of the species, which showed potential sites south of 10°N and elevations between 50 and 1000 m amsl. *Xylophis captaini* is listed as 'Least Concern' under IUCN criteria, and we suggest the possible elevation of its status to the 'Near-Threatened' category on account of its narrow distributional range and general lack of data on its ecology. The present study highlights the utility of niche models in assessing the distribution of cryptic and little known species in biodiversity-rich areas such as the Western Ghats.

Keywords: Agasthyamalai Biosphere Reserve, Captain's Wood Snake, ecological niche modelling, endemic species.

THE Western Ghats is one of the 34 global biodiversity hotspots[1]. This mountain range has a rich snake fauna with several endemics, but data on their distribution range are mostly scanty. The genus *Xylophis* Beddome, 1878 is endemic to the Western Ghats and currently three species are known. Gower and Winkler described *Xylophis captaini* and provided details on the distribution of this species and its congeners[2] *X. perroteti* and *X. stenorhynchus* based on examination of specimens deposited in various museums. More recently, *X. captaini* has been reported from Ponmudi Hills, Agasthyamalai Biosphere Reserve (ABR) of Kerala and the Ambadi Estate in Tamil Nadu[3,4].

Spatial distributions of species and the factors that regulate them are prerequisites for developing conservation plans. With the support of new algorithms to analyse spatial databases, one can predict the 'ecological niches', or at least the broad-scale spatial aspects of species based on observed occurrences. BIOCLIM[5], DOMAIN[6], Genetic Algorithm for Rule-Set Prediction (GARP)[7], Ecological Niche Factor Analysis (ENFA)[8] and Maximum Entropy (MaxEnt)[9] are a few widely used ecological niche modelling approaches. Each algorithm has its merits and limitations in predicting species distribution[10].

Xylophis captaini was suggested to be categorized as 'Least Concern' under IUCN criteria, assuming that its occurrence in a variety of habitats (agricultural fields, plantations and natural forests)[2], which was also supported by a recent assessment[11]. In this study, we update the distribution of this little known caenophidian snake based on collation from the literature[2–4] and new observations in ABR. Furthermore, notes on the habitat, extent of its distribution across elevation and comments on the conservation status of the species are discussed.

We surveyed along the southwestern slopes of the ABR from March 2012 to December 2013 using time constrained visual encounter survey[12]. Upon locating *X. captaini* (Figure 1), geo-coordinates (using a Garmin 12 Channel GPS), elevation and forest type were recorded. Snout-vent and tail length were measured using flexible twine and a metal scale (accuracy: 1 mm). Colour, number of ventrals and subcaudal scales were noted in the field and snakes were released at the site of encounter. All individuals were identified based on the taxonomic characteristics provided by Gower and Winkler[2].

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Table 1. Distribution of *Xylophis captaini* in the Western Ghats of India; All locations barring *Arukani (Tamil Nadu) are in Kerala state

Place	District	Altitude (m)	Habitat	Source
Vazhakulam	Ernakulam	50	Plantation	Present study
Peralamattayam	Idukki	40	Plantation	ref. 2
Kannam	Kottayam	110	Plantation	ref. 2
Chengalam	Kottayam	120	Plantation	ref. 2
Punalur	Kollam	110	Plantation	ref. 2
Pathanapuram	Kollam	40	Plantation	ref. 2
Mylam	Kollam	30	Plantation	ref. 2
Mottal Mood	Kollam	190	Teak	Present study
Poovanathumoodu	Kollam	170	Evergreen Forest	Present study
Ammayambalam	Kollam	180	Moist Deciduous Forest	Present study
Munnam Chal	Kollam	190	Evergreen Forest	Present study
Pillekode	Kollam	180	Evergreen Forest	Present study
Perum Padappy	Kollam	170	Teak	Present study
Emponge	Kollam	180	Evergreen Forest	Present study
Kambaka Thottam	Kollam	210	Moist Deciduous Forest	Present study
Vilakku Maram	Kollam	190	Moist Deciduous Forest	Present study
Palode	Thiruvananthapuram	80	Plantation	ref. 2
Cheranikara	Thiruvananthapuram	90	Plantation	ref. 2
Mennookonom	Thiruvananthapuram	100	Plantation	ref. 2
Vanchuvam	Thiruvananthapuram	100	Plantation	ref. 2
Potukani	Thiruvananthapuram	320	Plantation	ref. 2
Chathankodu	Thiruvananthapuram	110	Plantation	ref. 2
Vithura	Thiruvananthapuram	110	Plantation	ref. 3
Athirumala	Thiruvananthapuram	980	Evergreen Forest	Present study
Bonacaud	Thiruvananthapuram	810	Semi Evergreen Forest	Present study
Podium	Thiruvananthapuram	200	Agricultural area	Present study
Aamala	Thiruvananthapuram	120	Moist Deciduous Forest	Present study
Peppara	Thiruvananthapuram	150	Moist Deciduous Forest	Present study
Neelikampara	Thiruvananthapuram	120	Plantation	Present study
Chekidi Chal	Thiruvananthapuram	200	Evergreen Forest	Present study
Muppathadi	Thiruvananthapuram	200	Evergreen Forest	Present study
Uthiran Chira	Thiruvananthapuram	210	Moist Deciduous Forest	Present study
Aarukani*	Kanyakumari	200	Plantation	ref. 2

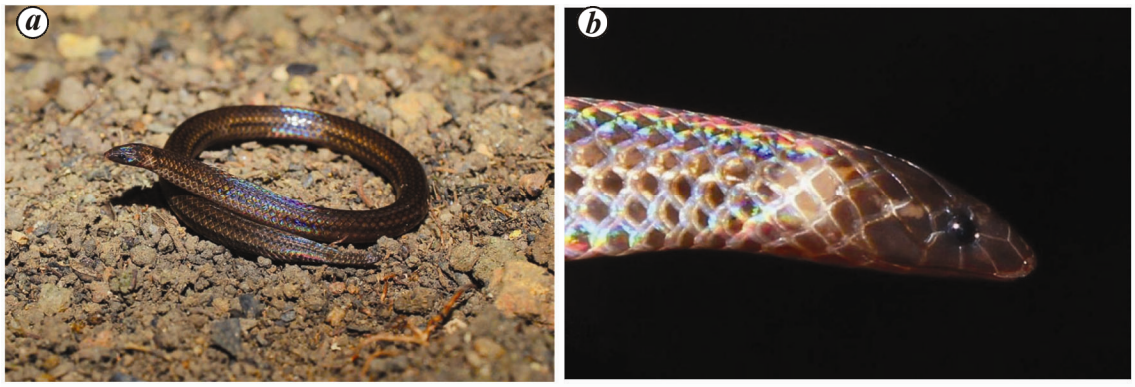

Figure 1. ***a***, Full view of Captain's Wood Snake, *Xylophis captaini*. ***b***, Close-up of head and fore body of the species. (Photos: V. J. Jins.)

Known localities of *X. captaini* from the literature[2–4], observations by one of the authors (J.J.) in a previous study and data obtained during the present study in ABR were considered for analysis. The Maximum Entropy (MaxEnt) algorithm was applied to predict the extent of geographical distribution of the species using presence-only data[9]. Twenty-five environmental variables were considered for analysis including bioclimatic variables (extracted from WorldClim dataset), elevation, slope and aspect (from GIS), and MODIS tree, bare and herb cover[13]. Techniques involved in the interpolation of the climatic data are available elsewhere[14]. Auto-correlated variables were removed, and only eight uncorrelated variables (altitude, slope, MODIS tree cover, isothermality, precipitation seasonality, mean diurnal temperature range, precipitation of wettest month and precipitation of driest quarter)

Table 2. Environmental variables selected for modelling and their contribution to predicting the distribution of *Xylophis captaini* in the Western Ghats

Environmental variables	Percentage of contribution
BIO15 = Precipitation seasonality (coefficient of variation)	26.60
BIO17 = Precipitation of driest quarter	23.50
MODIS Tree cover = percentage of tree cover	18.00
BIO2 = Mean diurnal range (mean of monthly (maximum temperature – minimum temperature))	17.10
Altitude = Elevation from sea level (m)	13.40
Slope = Degree of flow	01.40
BIO13 = Precipitation of wettest month	00.01
BIO3 = Isothermality (P2/P7) (× 100)	00.01

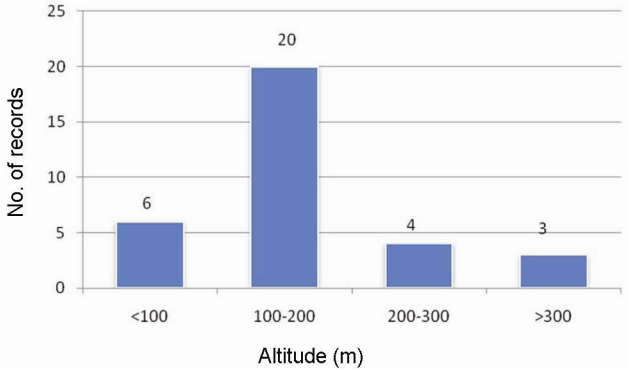

Figure 2. Distributional records for *Xylophis captaini* in various altitudes (in m) of the Western Ghats, India; Number of records = 33; number annotated is number of observations in each altitude category.

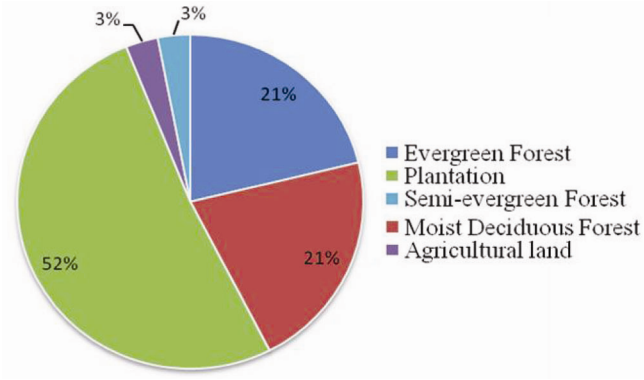

Figure 3. Distribution of *Xylophis captaini* in various habitats of the Western Ghats region, India; Number of records = 33.

were retained for further analysis. A buffer with a radius of 2 km was generated around each occurrence locality. One occurrence location was chosen when there was an overlap with the buffer of another occurrence location. Only points without overlap at 2 km radius were used for model building. MaxEnt has been applied to predict and quantify the extent of suitable habitats available for the species and to estimate the probable distribution of a species across the area of interest, especially the areas not covered during the survey[9]. Elevation of each locality record of the species was derived using a Digital Elevation Model (SRTM) and broad habitat type was identified on the basis of available vegetation maps.

Based on the literature and recent surveys, *X. captaini* has been reported from about 50 locations in the Western Ghats and among them, 33 were more than 2 km away from each other. All these distributional records lie within five districts of Kerala and one from the Kanyakumari district of Tamil Nadu (Table 1). Among them, 16 (50%) were from the Thiruvananthapuram district alone, and all of them were from the windward side of the hill range. The known elevation range of the species is 50–1000 m amsl, and a few specimens have been found on the plains, i.e. away from hills. From the available data, it appears that this species is predominantly distributed in low altitude (<200 m), i.e. 20 (61%) of 33 records (Figure 2). *Xylophis captaini* has been reported from various habitats; agricultural fields and plantations to natural forests. In natural forests, the species was observed in moist deciduous, semi evergreen and evergreen forests (Figure 3). It was found in loose soils, under boulders, fallen trees and in leaf litter[2].

The distribution of *X. captaini* was predicted with eight environmental variables (two topographic, one vegetation type and five bio-climatic variables). The area under the receiver operating characteristic (ROC) curve value was higher (mean = 0.991), indicating that the model distribution was not random. The precipitation seasonality has the highest predictive gain when used in isolation and it appears to be the most important variable for the predicted model. The model also strongly associated with the precipitation of driest quarter and MODIS tree cover. Climatic and topographic variables such as altitude and mean diurnal temperature range have also contributed to the predicted model (Table 2).

The MaxEnt model showed the predicted distribution of *X. captaini* to be south of Thodupuzha (09°58′N, 76°38′E Vazhakulam, Ernakulam district) of Kerala (Figure 4). There is a high probability of its occurrence at unsampled locations in the Kanyakumari and Tirunelveli districts in Tamil Nadu, especially in Kalakad–Mundanthurai Tiger Reserve and east of Aryankavu Pass. The

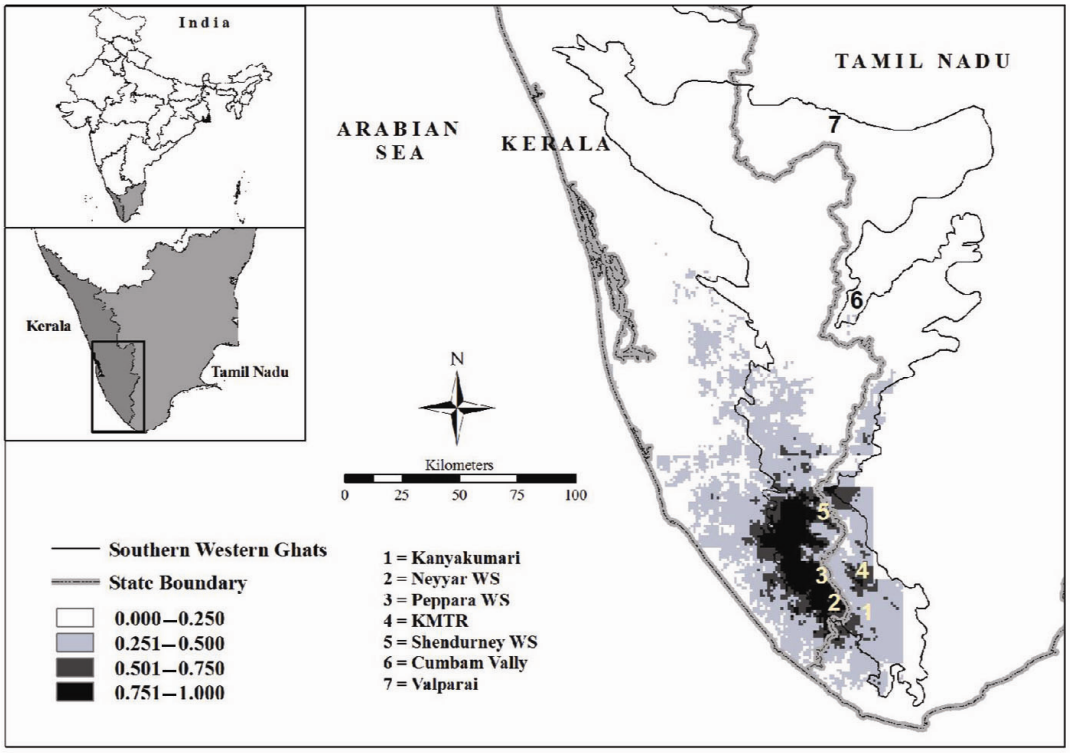

Figure 4. Distribution of *Xylophis captaini* as predicted by Ecological Niche Modeling (Maximum Entropy algorithm); 1, Kanyakumari Wildlife Sanctuary; 2, Neyyar Wildlife Sanctuary; 3, Peppara Wildlife Sanctuary; 4, Kalakad–Mundanthurai Tiger Reserve; 5, Shendurney Wildlife Sanctuary; 6, Cumbam Valley; 7, Valparai.

estimated potential area of the species distribution (10 percentile training presence – 0.181) is about 3900 sq. km. Even though the predicted area of distribution of this species is narrow, it is reported to be locally common[2].

The higher contribution of variables such as precipitation seasonality (26.60%) and precipitation of driest quarter (23.50%) shows that, rainfall might be the major regulating factor for the distribution of the species (Table 2). From the available data, the high sighting frequency of the species is recorded from lowlands (<300 m) and human modified habitats, which is probably due to higher sampling intensity and focused survey techniques. However, the present analysis showed that the major proportion of high probability sites is within the protected area network. Hence, the species may have pristine areas in its distribution range. Further studies covering protected area network in the southern Western Ghats would provide more insights into the status and distribution of this species in its predicted range.

It is reported that *X. stenorhynchus* is similar to *X. captaini*[2]. Including a museum record of *X. indicus* (BMNH 78.8.2.1), a junior synonym of *X. stenorhynchus*[15,16], is represented by only a few precise and authentic locality records, i.e. forests of Cumbam Valley (~1200 m), in Theni district and Paralai, Valparai (1200 m amsl, Coimbatore district) of Tamil Nadu. The report of *X. stenorhynchus* from Nedumangad near Thiruvananthapuram during 1888–95 (ref. 17) needs to be examined, which is likely to be *Xylophis captaini*. The distribution range of *X. stenorhynchus* (Cumbam Valley and Valparai) is disjunct from the predicted range of *X. captaini* (Figure 4). From the available data[2,15,16,18], it appears that the three species of *Xylophis* of the Western Ghats are spatially segregated; *X. perroteti* (higher elevation >1500 m, plateau, largely north of Palghat gap), *X. stenorhynchus* (1200–1500 m, possibly on the eastern slopes of the mountains from south of Palghat Gap) and *X. captaini* (50–1000 m, western slope, south of Idukki district, Kerala).

The data with respect to population status and extent of distribution of *X. captaini* are scanty. About 900 person hours of searching in 20 months in ABR yielded eight sightings (about one snake per 110 person hours of search). *Xylophis captaini* is listed as 'Least Concern' under IUCN criteria[11]. Currently, *X. captaini* is known only from three protected areas in Kerala (Neyyar, Peppara and Shendurney Wildlife Sanctuaries) and potentially in Kanyakumari Wildlife Sanctuary and Kalakad-Mundanthurai Tiger Reserve in Tamil Nadu. The extent of occurrence of the species is estimated to be 3153 sq. km, which qualifies 'criteria-B1' of the 'Vulnerable category' under IUCN Red List of Threatened Species (criteria: B1 – extent of occurrence less than 20,000 sq. km + B2 – area of occupancy less than 2000 sq. km). The area of

occupancy of the species is not quantified due to the poor survey effort across its distribution range. However, considering the low extent of predicted suitable sites (3900 sq. km), pending data on sub-criteria such as fragmentation and, decline in the area of its occurrence and occupancy, we propose its placement in 'Near-Threatened' category.

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