Gerarda prevostiana (Serpentes: Homalopsidae) in Sri Lanka: Distribution and behaviour

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ABSTRACT - The homalopsid snake *Gerarda prevostiana* is known from parts of southern Asia and lives in coastal brackish-water habitats. For six years we surveyed 50 such habitats around the coastline of Sri Lanka and recorded the distribution and behaviour of this species. We also observed captive *G. prevostiana* to understand microhabitat use and behaviour. During the fieldwork, we recorded three adult male *G. prevostiana* along the west coast within intertidal mangrove swamps and a tidal river. The low rate of encounters suggests that the snake is difficult to detect due to a very secretive nature and possibly a patchy distribution. The localities where *G. prevostiana* was found in Sri Lanka had an abundance of mud crabs (*Scylla* species), and mud lobsters (*Thalassina* species) that make up the snake's diet as well as crab mounds that are used as refugia. Captive *G. prevostiana* remained inactive in underwater refugia during day-time and only become active at night. The snake's ability to remain underwater for prolonged periods and its prehensile tail are noteworthy. Coastal development, destruction of mangrove swamps, and loss of coastal wetlands may pose a significant threat to *G. prevostiana*. To date both in Sri Lanka and India, *G. prevostiana* has only been recorded from west coasts, where it is suggested that habitats are more favourable than the east coasts. Likewise, it appears that *G. prevostiana* is also restricted to the westerly coasts of countries in the Bay of Bengal and Gulf of Thailand.

INTRODUCTION

Gerard's Water Snake, *Gerarda prevostiana* (Eydoux & Gervais, 1837) is a rear-fanged, mildly venomous snake mostly found in mangrove swamps (De Silva, 1980; Porei, 2001). It is restricted to the Indomalayan biogeographic region (Murphy & Voris, 2014; Whitaker & Captain, 2004; Murphy, 2007; Das et al., 2013). In India it is known from scattered populations along only the west coast, including Gujarat, Maharashtra and Kerala (Vyas et al., 2013). At the start of the current study, *G. prevostiana* in Sri Lanka was documented from seven museum specimens also from only the west coast (Ferguson, 1877; Haly, 1886; Gyi, 1970; de Silva & de Silva, 1986–87; de Silva, 1990; Christie & White, 1997; Somaweera, 2005; Somaweera et al., 2006; Murphy & Voris, 2014) or from fishing by-catch trawled from shallow open sea 1 km off the north-west coast (Ukuwela et al., 2017). Although listed "Least Concerned" in the Global IUCN Red List (Murphy, 2010), it is considered "Endangered" in the Red List of threatened fauna and flora of Sri Lanka (MoE, 2012). The snake is predominantly nocturnal (Das et al., 2013) and feeds primarily on freshly-moulted crabs by tearing larger body parts into smaller pieces prior to ingestion via "loop and pull" behaviour (Jayne et al., 2002; Chen, 2010). Given its purported rarity and Red List status of *G. prevostiana* in Sri Lanka, the collection of detailed information on its ecology, natural history, and behaviour is essential for implementing science–based conservation.

In this study of *G. prevostiana* there were three aims, 1) to document the presence of the species in different aquatic habitats on the coastal plains of Sri Lanka, 2) explored

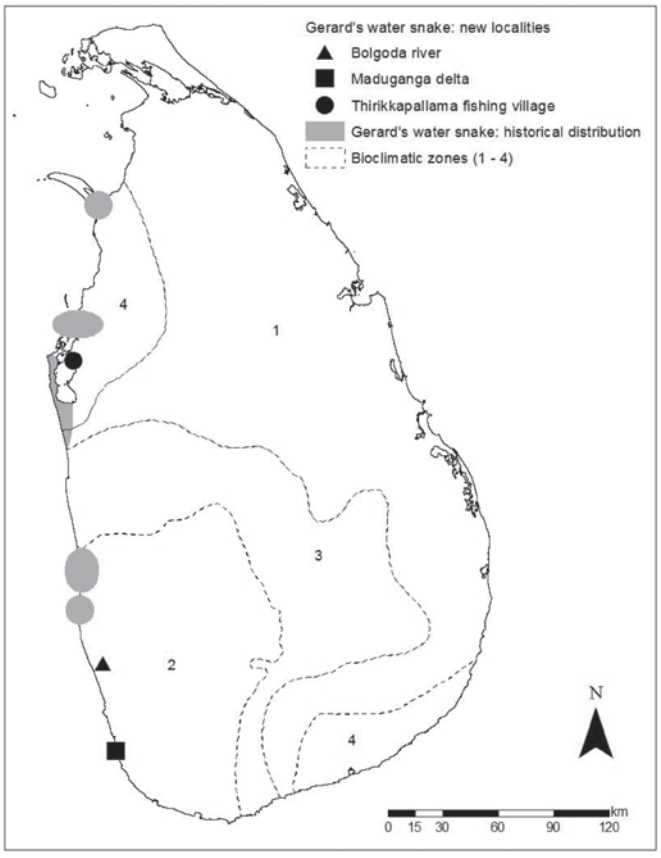

Figure 1. Previous and new records of *G. prevostiana* in Sri Lanka (1, dry zone; 2, wet zone; 3, intermediate zone; 4, arid zone)

Table 1. Morphometric and meristic data of *G. prevostiana* specimens in Sri Lanka; [(1)] ZPM/W14A/047, University of Peradeniya; [(2)] NMSL 2013.18.01 and [(3)] NMSL 2013.19.01, National Museum, Colombo, Sri Lanka

Character/Measurement	Source/references of the specimen					
	Somaweera et al. (2006)[1]	Ukuwela et al. (2017)[2]	Ukuwela et al. (2017)[3]	Current study		
Locality Name	Kalaoya	Vankale	Vankale	Thirikkapallama	Maduganga	Bolgoda
Head length (mm)	18.1	15.3	14.7	15.8	16.7	16.2
Snout vent length (mm)	348	168.6	151.5	187.2	216.3	198.1
Tail length (mm)	64	27.2	24.7	28.3	28.9	28.6
Preoculars (L/R)	2	1/1	1/1	1/1	1/1	1/1
Postoculars (L/R)	2	2/2	2/2	2/2	2/2	2/2
Supralabials (L/R)	7	8/8	8/8	7/7	8/8	7/7
Infralabials(L/R)	7	7/7	8/8	7/7	8/8	8/8
Anterior temporals (L/R)	1	1/1	1/1	1/1	1/1	1/1
Posterior temporals (L/R)	2	2/2	2/2	2/2	2/2	2/2
Loreal (L/R)	1/1	1/1	1/1	1/1	1/1	1/1
Internasal	1	1	1	1	1	1
Dorsal scale rows (anterior)	17	17	17	17	17	17
Dorsal scale rows (mid-body)	17	17	17	17	17	17
Dorsal scale rows (posterior)	15	15	15	15	13	15
Ventral scales	153	154	159	151	163	156
Subcaudals (divided)	33	37	33	37	35	37
Anal	divided	divided	divided	divided	divided	divided
Pre Anal	entire	entire	entire	entire	entire	entire

various aspects of its natural history such as habitat associations and behaviour, and 3) investigate threats to provide some insights into better conservation.

MATERIALS AND METHODS

Fieldwork and data collection

We conducted an opportunistic (non-systematic) six-year field survey (2010–2015) targeting *G. prevostiana* at 52 distinct locations (3000 man–hours in total) in brackish water habitats around the entire coastal plain that encircles Sri Lanka (Fig. 1). We sampled 29 locations on the west coast and 21 elsewhere - north (7), south (8) and east (6). We made repeated visits to 20 west coast locations. Our survey of the coastal plain included the four recognised bioclimatic zones of Sri Lanka (Fig. 1), nearshore aquatic environments and inland tidal rivers. To document the focal species activities, surveys were undertaken in the morning (08.00–11.00h) and after sunset (19.00–22.00h). At each site, we surveyed a total area (both aquatic habitat and the adjacent uplands, including the entire tidal zone) of 2 ha for ~4 hours by visually scanning for surface–active snakes and turning all cover objects for hidden snakes. At each survey location, we measured the average water depth at low tide, average day-time and night–time temperature (using a Digitech QM 1594, 6 in 1 multifunction environment meter, Digitek Instruments Co., Ltd, Hong Kong, China), and recorded the locality and the dominant vegetation types.

We used standard field guides to verify species identification (Whitaker et al., 2004; Somaweera, 2006). For each *G. prevostiana* captured, we recorded the 18 morphometric and meristic features listed in Table 1, we recorded the same for two preserved specimens from the National Museum of Sri Lanka (NMSL). For any measurements, a digital Vernier calliper or tape measure was used. We sexed captured snakes by everting hemipenes and photographing them.

Mesocosm study

To investigate the behaviour and habitat use of *G. prevostiana* each of the three male snakes captured during the survey was placed in a small (120 cm long × 70 cm wide× 50 cm high) glass tank. To make the enclosure resemble some aspects of the natural environment of this species, it contained fine sand, silt, leaf litter, small rocks (20–40 mm), two medium–sized logs (48.5 cm in length, 12.5 cm in diameter) as bottom substrates, and brackish water filled up to a depth of 20 cm. After a two-day acclimatisation period, we documented the position of the snake (microhabitat and substrate used) for a total of 8 h per day (03.00–07.00h and 18.00–22.00h) for five continuous days. In each day of the experiment, we offered the snake the following food items: *Awaous melanocephalus* (large–snout Gobies, average body length: 30 mm); *Oreochromis niloticus* (Nile tilapia, average body length: 40 mm); freshwater shrimps of genus *Machrobrachium* (average body length: 30 mm); and, freshwater crabs of the genus *Perbrinckia* (average body length: 22.5 mm) collected from coastal lagoons. At the end of this test the snakes were released back to the site of capture.

Table 2. Distribution of *G. prevostiana* in Sri Lanka: previous records and those contributed by the current study

Location and Reference	Date	Coordinates	Closest Town	Distance from shore	Bioclimatic zone	Floral community	Water Temperature ˚C	
							Day	Night
Sri Lanka (Ferguson 1877)	1877	-	–	–	–	–	–	–
Kelani River (Haly 1886)	1886	-	Ja–Ela	–	Wet zone	–	–	–
Sri Lanka Gyi (1970)	1970	-	–	–	–	–	–	–
Kala–oya Somaweera et al. (2006)	1985	-	Eluwankulam	–	Dry zone	Mangrove	–	–
Dandugan–oya Porej (2001)	1997	-	Muthurajawela	–	Wet zone	Marsh	–	–
Doowa Somaweera (2005)	1999	-	Negombo	–	Wet zone	Mangrove	–	–
Vankale (Ukuwela et al. 2017)	2011	08.893550 N 79.928656 E	Mannar	–	Dry zone	Mangrove	–	–
Thirikkapallama (Current study)	12 Dec 2011	08.182692 N 79.823861 E	Eluwankulam	3 km	Dry zone	Mangrove	29.2	27.3
Bolgoda (Current study)	03 Aug 2014	06.699522 N 79.972239 E	Bandaragama	6 km	Wet zone	Mangrove	28.8	26.5
Maduganga (Current study)	24 May 2015	06.273294 N 80.037844 E	Balapitiya	50 m	Wet zone	Mangrove	28.6	27.2

Figure 2. A live specimen of *G. prevostiana* from Maduganga River

RESULTS

During the survey we found only three specimens of *G. prevostiana* (Fig. 2, Fig. 4 a–d) and these were at distant sites along Sri Lanka's western coastal plains (mean elevation 3 m above sea level) (Table 2, Fig. 1). All specimens were male and were captured after sunset (18.00–20.00h) in new moon conditions at low–tide. All three snakes were of similar length (mean 229 mm) and resembled previous records in terms of both morphometric and meristic features (Table 1).

All our new records were made in mangrove swamps with muddy substrates in the coastal intertidal zone (Table 2, Fig. 3a–c). One record was in the dry zone of Sri Lanka while the rest were in the wet zone. In the same habitats, we observed small–sized (15–25 mm) mud crabs (*Scylla* species) and medium–sized (50–85 mm) mud lobsters (*Thalassina* species) as well as mud–lobster mounds. Details of the three new record localities are shown in Table 2. The first record, in Thirikkapallama fishing village (Fig. 3a), was in the north-western coastal arid zone (annual average precipitation <2,000 mm). The locality was a mangrove swamp (low–tide depth: 0.4 m, muddy–bottom substrate) where *Avicenia marina*, *Bruguieria cylindrica*, *Rhizophora mucronata*, *Scyphiphora hydrophyllaceae*, and *Sonneratia alba* were the dominant flora. The second record was at the Bolgoda River (Fig. 3b), 6 km inland from the seashore in the south-western coastal wet zone lowlands. Among the new localities, this was the most inland locality, and located furthest from the shoreline. This locality comprised mostly mangrove vegetation (low–tide water depth: 1.3 m, muddy bottom) dominated by *Sonneratia caseolaria*, *Excoecaria agallocha*, *Rhizophora apiculata*, and *Xylocarpus granatum*. The third record was from the Maduganga River in the southern coastal wet zone lowlands (Fig. 3c). The locality was a mangrove swamp (average mid–tidal water depth: 0.8 m) dominated by *Rhizophora apiculata*, *Bruguiera gymnorrhiza*, *Sonneratia caseolaria*, *Xylocarpus granatum*, *Lumnitzera littorea*, and *Excoecaria agallocha*.

Observations from the mesocosm study

During the early morning (03.00–07.00h), the snakes remained relatively inactive, and mostly submerged. They retreated under the logs, remained in a coiled position, and resurfaced to breath at various time intervals with individuals resurfacing after only 7.2 mins or after as long as 1.4 h. For breathing, the snakes lifted their nostrils immediately above the water surface, and retreated back after 1-2 secs of inhalation. In contrast, during night-time (18.00–22.00h), the snakes spent much less time underwater (an average of 3.8 mins, range: 1.67– 7.42 mins) and emerged from refugia under the logs and remained active by continuously swimming, and even moved onto the log above the water level. All snakes refused the food we provided. We observed tongue–flicking behaviour both above and below water. Above–water tongue–flicking was limited to night-time where the snakes emerged onto the logs. The snakes also performed tongue–flicking when they were active underwater particularly during the night-time.

Figure 3. Mangrove habitats of *G. prevostiana* in Sri Lanka: **(a)** Thirikkapallama, **(b)** Bolgoda River, **(c)** Maduganga RAMSAR wetland

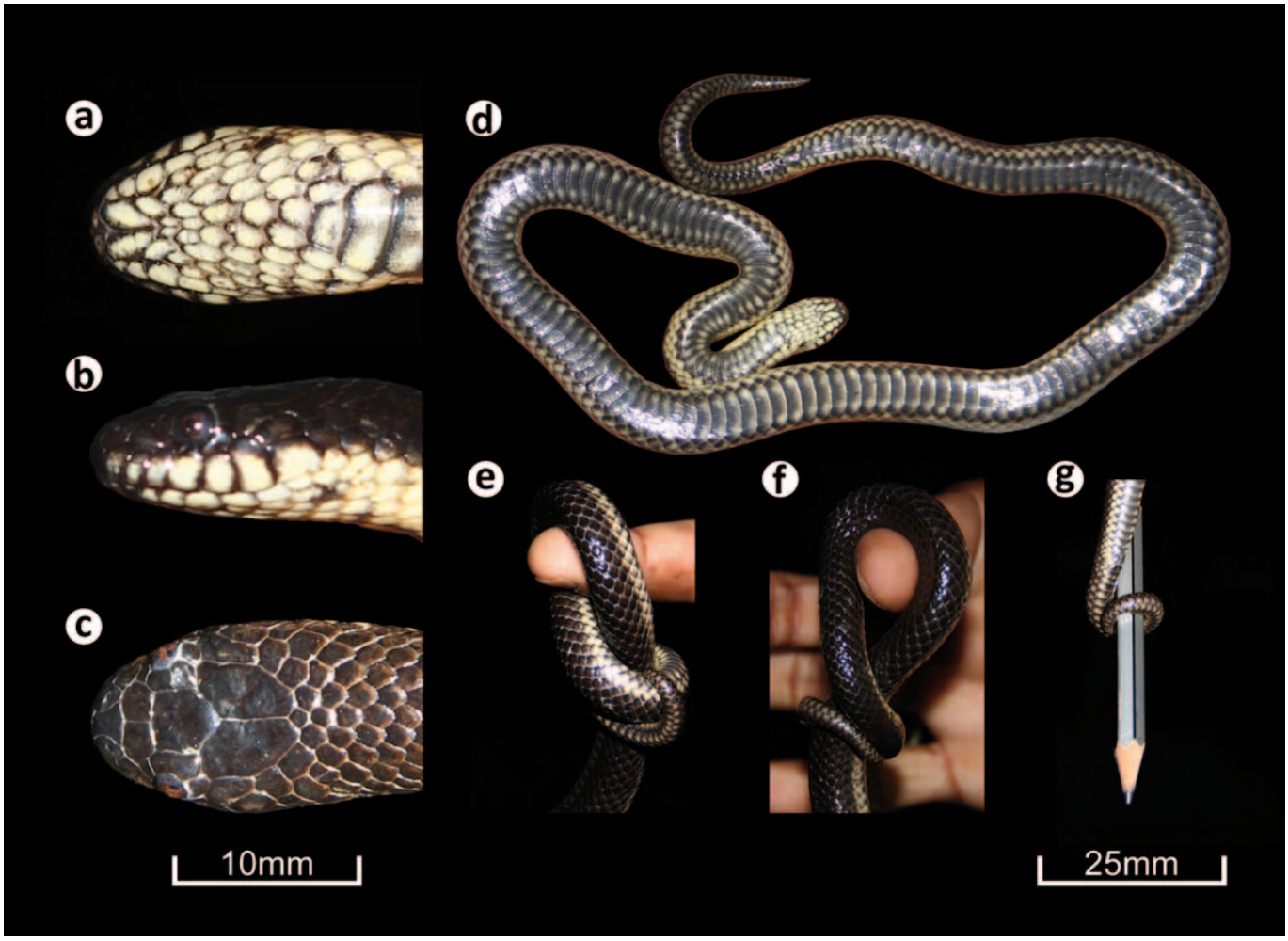

Figure 4. Close–ups of *G. prevostiana*: **(a)** ventral side of the head; **(b)** lateral side of the head; **(c)** dorsal side of the head; **(d)** ventral side of the body; **(e)** prehensile tail with the knot; **(f)** prehensile tail; **(g)** tail locking

Natural history and behaviour

Our observations suggested that the snake's surface activity was exclusively nocturnal. When handled, none of the captured snakes bit nor were aggressive regardless of the time of the day. Their terrestrial locomotion was quite weak, but they were excellent swimmers in both open water and in the heavily–vegetated littoral zone. When disturbed on land, the snakes coiled–up, hid their head within their coils, and remained motionless. We also noted that their tail was robust and prehensile. They can constrict their tail firmly around objects and suspend themselves from their tails (Fig. 4e-g). Moreover, they even dragged objects (12–47 g in weight) using their tails (Fig. 4g). Our observations indicated that our focal species is sympatric with other native aquatic snakes– *Xenochrophis piscator* (checkered keelback), *Atretium schistosum* (olive keelback), *Cerberus rynchops* (dog–faced water snake), *Hydrophis schistosus* (beaked sea snake), and *Hydrophis viperinus* (viperine sea snake).

DISCUSSION

Gerarda prevostiana is a poorly studied snake in both Sri Lanka and India. In Sri Lanka this species was previously known from seven records (Table 2). Three new records have been added by the current study, two of which are from

more southerly sections of the west coast than previously (Bolgoda River and Maduganaga River delta) and suggest that the species may occur along much of the west coast (Fig. 1). Since we documented *G. prevostiana* across multiple bioclimatic zones, it is unlikely that this snake's distribution is restricted to any of the four recognised bioclimatic zones of Sri Lanka. Instead, prey availability (crustaceans) and mangrove habitats seemed to be the primary determinants of this species. To date all records of *G. prevostiana* have been from the west coast, despite the presence of significant mangrove habitats along the other coastlines. The more intensive survey effort on the west coast could have biased the result and further surveys are required in other coastal areas where there are mangrove habitats with high densities of crustaceans. However, the fact that in India *G. prevostiana* is also apparently restricted to the west coast (Murphy, 2010) suggests that our observations do not result from under sampling. The west and east coasts of the two countries are almost contiguous, separated only by the narrow Gulf of Mannar and Palk Strait, giving a distribution of *G. prevostiana* along the west coast adjacent to the Arabian Sea, from the Gulf of Kutch southwards. In India, the west coast distribution of the species is attributed to more favourable geological, hydrological and climatic conditions. The western coastlines of both Sri Lanka and India are climatically more stable (fewer tornados), receive a greater volume of precipitation year around, and are rich in backwater systems, lagoons, and estuaries, which are ideal physical environments for mangroves (Mag & Sengupta, 1992). Further, the west coast of Sri Lanka has more river deltas, thus sustains a greater freshwater influx, including nutrients and sediments (Survey Department of Sri Lanka, 2007). It may not be a coincidence that the apparent bias for a west coast distribution for *G. provostiana* is noticeable for the countries bordering the Bay of Bengal and Gulf of Thailand. In the Bay of Bengal, the species has been recorded from the south-east coast of Bangladesh (Rahman et al., 2014), coastal Myanmar (Murphy, 2014) and the west coast of peninsula Malaysia (Tweedie, 1983) to the north coast of Singapore (Karns et al., 2002). Likewise in the Gulf of Thailand, there are no records from the east coast of peninsular Malaysia (Tweedie, 1983) or Thailand until further north in the inner Gulf of Thailand (Chan-ard et al., 2015) and then coastal Cambodia (Murphy, 2014). It may well be that the apparently more favourable conditions of the west coast adjacent to the Arabian Sea are similarly more suitable to *G. provostiana* in the more westerly coasts adjacent to the Bay of Bengal and Gulf of Thailand.

In general, homalopsids are very secretive and sedentary, which accounts for their low detectability (Karns et al., 2002; Voris & Murphy, 2012). We failed to document *G. prevostiana* in 94% of the locations surveyed and this suggests that the species is rare along the Sri Lankan coastal plains and/or like other homalopsids is difficult to detect. *Gerarda prevostiana* is known to retreat into tidal burrows (Vyas et al., 2013) and although such habitats were searched in our survey, this behaviour would have contributed to low detectability. Nevertheless, this species has been recorded in high abundance at a coastal urban park in Singapore (Karns et al., 2002).

Most previous specimens were documented in coastal habitats with ample mangrove vegetation, such as lagoons, estuaries, and coastal marshes (Voris & Murphy, 2012). These observations are consistent with the natural history of other homalopsids which are associated with muddy substrates and also occupy nearshore coastal wetlands. A specimen documented by Gyi (1970) was the most inland location known for *G. prevostiana* indicating that our focal species can roam inland along aquatic habitats. The specimen we documented in Bolgoda River confirms that *G. prevostiana* could inhabit inland aquatic habitats that are influenced by tidal currents.

During our survey, we failed to make any observations on the foraging ecology of the focal species. However, it is considered to be a crustacean specialists, feeding selectively on recently–moulted crabs (Voris & Murphy, 2002; Rahman et al., 2014). While these snakes swallow small prey whole, with the aid of their prehensile tail, they rip apart larger prey into smaller ingestible pieces by "loop and pull" behaviour, which enables these snakes to ingest prey items that are substantially larger than their gape size (Jayne et al., 2002; Chen, 2010). The prehensile tail could also help them anchor onto coastal vegetation and other substrates to avoid being drifted by tidal currents and coastal waves.

According to Sri Lanka's Red List, *G. prevostiana* is "endangered" (MoE, 2012). Being a specialist of coastal habitats, *G. prevostiana* is likely to be negatively impacted by a multitude of anthropogenic disturbances affecting the Sri Lankan coastline and mangrove ecosystems, such as urban development, commercial-scale aquaculture, drainage of coastal wetlands, amenity–based development, and recreational activities (Christie & White, 1997; Srinivasan et al., 2012). Sri Lankan brackish–water ecosystems are also heavily impacted by pollution (solid–waste discharge, industrial effluvia, urban runoff, siltation, and nutrient loading) (Dayaratne et al., 1995; Dahanayaka & Wijeyaratne, 2010; Karunarathna et al., 2011). Given the dependency of *G. prevostiana* on mangrove ecosystems, anthropogenic threats encountered in mangrove ecosystems, and food specialisation, we strongly recommend that the conservation status of *G. prevostiana* in Sri Lanka be retained as "Endangered". Moreover, Ukuwela et al. (2017) indicated that the Sri Lankan populations of *G. prevostiana* was genetically distinct from the South-east Asian populations, therefore, we recommend separate assessments of conservation status for those two populations.

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