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A rapid assessment of herpetofaunal diversity and mortality along a railway track in Northern Western Ghats, India

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ABSTRACT. We conducted a herpetofaunal survey along a 17 km stretch of railway track passing through the Kali Tiger Reserve in Karnataka State. Over a period of 13 days, we documented 48 species, representing around 43% of the known herpetofaunal diversity of the northern Western Ghats. Among the recorded diversity, 21 species are endemic and one additional species has been added to the faunal list as a new record for the state. Vulnerability of the herpetofauna is depicted and discussed in the light of the proposed double lane of the railway track and the need for future ecological research is emphasized.

KEYWORDS. Biodiversity hotspot, herpetofauna, protected area, linear infrastructures, threats

Introduction

The impact of roads on biodiversity has received considerable attention across different countries (Andrews 1990; Fahrig 2003; Benítez López et al. 2010; Barrientos and Borda de Água 2017). In contrast, the impacts of the railways on native wildlife are poorly known (Dorsey et al. 2015), and biased towards large mammals (Van der Grift 1999; Sarma et al. 2006). India, with the fourth largest railway network in the world, is no exception when it comes to railway related mortality of large mammals (Johnsingh et al. 1999; Sarma et al. 2006; Baskaran and Boominathan 2010; Joshi and Dixit 2012; Roy and Sukumar 2017), but herpetofaunal mortality records are largely anecdotal (Sivaraj et al. 2018; Vyas and Vasava 2019; Kumar and Prasad 2020). Railways are known to significantly restrict movement and cause mortality of herpetofauna (Berthoud and Antoniazza 1998; Ray et al. 2002; Budzik and Budzik 2014). Herpetofaunal mortalities on railway tracks often occur in remote locations where detectability and persistence rates of carcasses are poorly known (Barrientos et al. 2018). Such persistent threat may be detrimental to biodiversity hotspot regions such as the Western Ghats, which is known for its herpetofaunal endemism (Bossyut et al. 2004; Dutta et al. 2004; Vijaykumar et al. 2016; Aengles et al. 2018; Dahanukar and Molur 2020; AmphibiaWeb 2020).

With around 112 species of herpetofauna, comprising 47 species of amphibians and 65 species of reptiles, the northern Western Ghats holds almost one-fourth of the Western Ghats herpetofaunal diversity and endemicity (Ramachandra et al. 2012; Patel et al. 2018; Pande et al. 2019; Punjabi et al. 2020). Linear infrastructures such as an extensive road network and almost 345 km of railway lines, even within some protected areas (MoSPI 2019; Punjabi et al. 2020) are potential threats to the biodiversity of this region. With a directive from the Government of India, we conducted a rapid biodiversity assessment for prescribing mitigation measures for the proposed railway track doubling by The Railway Vikas Nigam Limited (RVNL) along a specified section of terrain from Tinaighat railway station to Caranzole railway station in northern Karnataka. The proposed area traverses

Table 1. Annotated checklist of herpetofauna recorded during the present survey.

Sl. No.	Family	Species Name	No. of Individuals recorded (VES)	IUCN status
		AMPHIBIANS		
ANURANS (Toads & Frogs)				
	Bufonidae	*Duttaphrynus melanostictus*	3	LC
	Dicroglossidae	*Euphlyctis* cf. *cyanophlyctis*	359	LC
		Hoplobatrachus tigerinus	1	LC
		Minervarya cf. *gomantaki* +	4	NE
		Minervarya cf. *mysorensis* +	20	DD
		Minervarya sp.	2	
		Minervarya syhadrensis +	64	LC
	Micrixalidae	*Micrixalus* aff. *uttarghati* +	16	NE
	Microhylidae	*Microhyla* aff. *ornata*	1	LC
		Uperodon mormorata +	2	EN
	Nyctibatrachidae	*Nyctibatrachus petraeus* ◦ +	50	LC
	Ranidae	*Clinotarsus curtipes*	21	NT
		Hydrophylax aff. *malabaricus*	7	LC
		Indosylvirana caesari +	85	NE
		Indosylvirana sp. +	10	VU
	Ranixalidae	*Indirana* cf. *salelkari* +	94	NE
		Indirana chiravasi +	6	NE
	Rhacophoridae	*Polypedates maculatus*	6	LC
		Pseudophilautus amboli +	10	CR
		*Raorchestes bombayensis** + ◦	65	VU
		Raorchestes sp.	_	
		Rhacophorus malabaricus +	1	LC
GYMNOPHIONA(Caecilians)				
	Grandisoniidae	*Gegeneophis danieli* + *	_	DD
	Ichthyophiidae	*Ichthyophis* sp.	_	
		REPTILES		
LIZARDS				
	Agamidae	*Calotes versicolor*	2	LC
		Monilesaurus rouxii +	1	LC
	Gekkonidae	*Cnemaspis flaviventralis* +	3	NE
		Hemidactylus cf. *murrayi*	4	NE
		Hemidactylus frenatus	1	LC
		Hemidactylus prashadi +	5	LC
		Hemidactylus whitakeri	1	NE
	Scincidae	*Eutropis carinata*	2	LC
		Eutropis macularia	2	NE
	Varanidae	*Varanus bengalensis*	_	VU

SNAKES			
Colubridae	*Ahaetulla borealis* [+◦]	16	NE
	Boiga thackerayi [+]	1	NE
	Dendrelaphis tristis	_	LC
	Fowlea piscator	3	NE
	Hebius beddomei	_	LC
	Lycodon aulicus	1	LC
	Lycodon travancoricus	_	LC
	Oligodon taeniolatus	1	LC
	Ptyas mucosa	1	
	Rhabdops aquaticus	2	LC
Elapidae	*Bungarus caeruleus*	1	
Viperidae	*Craspedocephalus*(=*Trimeresurus*) *malabaricus* [+]	5	LC
	Hypnale hypnale [+◦]	_	
TURTLE			
Geoemydidae	*Melanochelys trijuga*	1	LC

+ Western Ghats endemics; ◦ Castlerock as type locality; *New state record; LC = Least concern, CR = Critically endangered, EN = Endangered, VU = Vulnerable; NT = Near threatened, NE = Not evaluated.

through a heterogeneous habitat of the northern Western Ghats, which also falls under the protected area of Kali Tiger Reserve in Karnataka.

Materials and methods

Our field survey between 18th November and 3rd December 2020 coincided with the drier season in the Western Ghats (Kunte 1997; Balasubramanian et al. 2019). The temperature range during the study period was 19–29 °C and the average humidity was 70% (Source: World Weather Online, 2020). The vegetation type of the study area is composed of moist deciduous to semi-evergreen forests (Champion and Seth 1968). The survey was conducted along a 17 km railway section between the Tinaighat (15.4489º N, 74.3983º E, 658 m a.s.l.) and Caranzole (15.3731º N, 74.3114º E; 621 m a.s.l.) railway stations in Karnataka (Figure 1). We used time-constrained Visual Encounter Survey (VES) (Crump and Scott 1994) at 13 sites, investing a total of 39 person hours (three person/h). These one-hour surveys were conducted between 19:00 h. and 21:30 h. The survey sites were randomly selected within a buffer zone of 5–250 m from the railway track, maintaining a gap of at least 50–100 m between two consecutive sites. Within the selected buffer zone, night surveys (VES) were stratified across all potential herpetofaunal habitats around the railway track such as perennial streams, riparian zones, dry streambeds, and seasonal streams with lentic pools, based on accessibility. We also surveyed modified sites around the railway track sections where modifications, such as forest cutting, newly built cemented culverts, cemented constructions for newly proposed railway tracks, etc., had already taken place or were ongoing as a part of the proposed doubling. The sampling points along the track are shown in the map (Figure 1). We presume that our single, site-specific survey at a time of limited herpetofaunal activity helped avoid pseudo-replication. We have also included opportunistic observations to obtain the maximum record of the diversity.

Dead herpetofauna observed within five meters of railway ballast with signs of injury (such as lacerations on the skin, limbs, amputated body parts, crushed head etc.) and desiccation were considered to be rail kills. All findings of dead amphibians and reptiles were photographed and geo-referenced. Species identity was determined using Smith (1935, 1943); Das

Table 2. Diversity Index (DI) of herpetofauna from all survey sites from Tinaighat-Castlerock-Caranzol section.

Site	Species Richness	Total Individual counts	Species Encounter Rate	Individuals Encounter Rate	Shannon's Index	Simpson's Index	Habitat Types
1	9	45	3.00	15.00	1.46	0.65	**Perennial stream**
2	10	58	3.33	19.33	1.94	0.83	Perennial stream
3	5	14	1.67	4.67	1.53	0.77	Modified area
4	9	66	3.00	22.00	1.67	0.76	Stream riparian
5	8	198	2.67	66.00	0.95	0.52	Seasonal stream with lentic pools
6	8	24	2.67	8.00	1.89	0.82	Dry streambed
7	9	185	3.00	61.67	1.02	0.44	Seasonal stream with lentic pools
8	11	29	3.67	9.67	2.08	0.84	Stream riparian
9	12	72	4.00	24.00	1.22	0.47	Perennial stream
10	11	114	3.67	38.00	1.35	0.62	Stream riparian
11	13	19	4.33	6.33	2.35	0.88	Perennial stream
12	5	15	1.67	5.00	1.2	0.6	Seasonal stream with lentic pools
13	6	22	2.00	7.33	1.48	0.71	Modified area

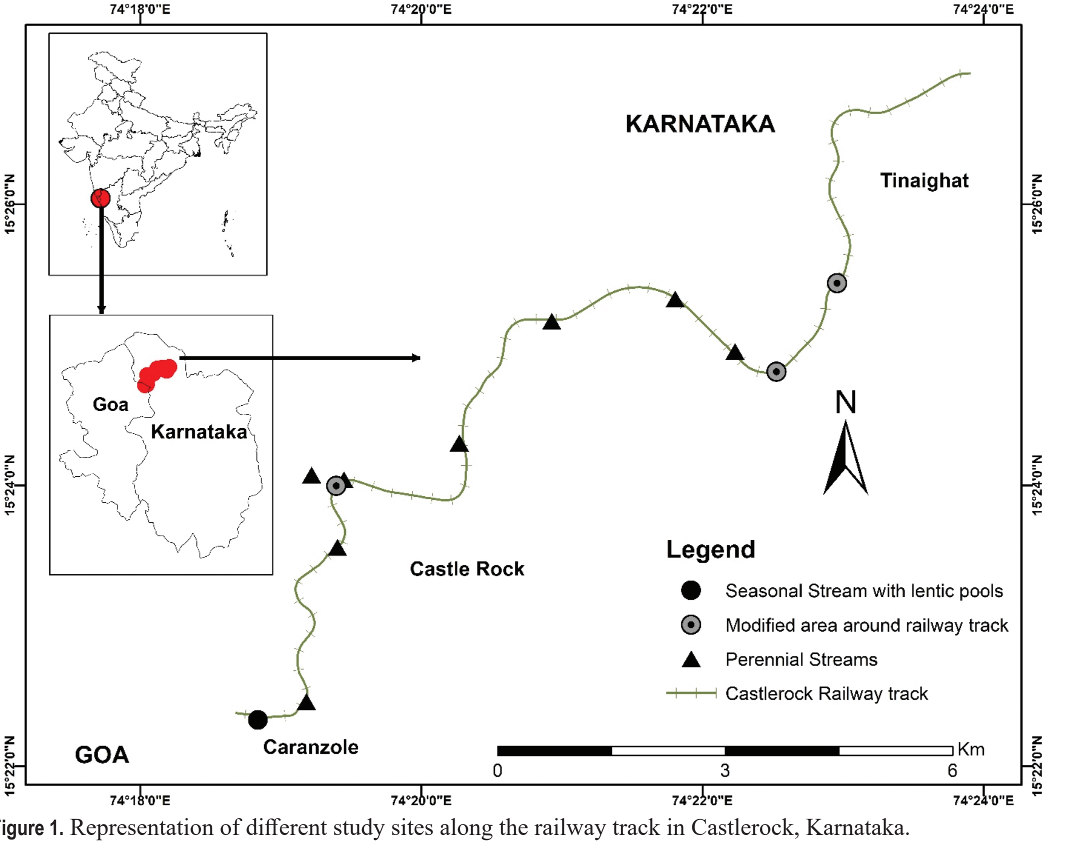

Figure 1. Representation of different study sites along the railway track in Castlerock, Karnataka.

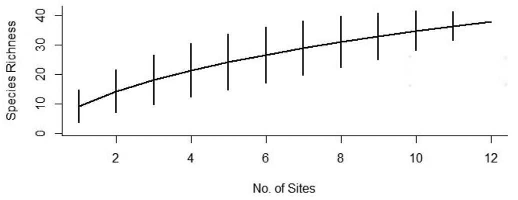

Figure 2. Species accumulation curve of all survey sites between Tinaighat-Castlerock-Caranzol section.

and Kunte (2005); Whitaker and Captain (2004, 2008); Gururaja (2012); Biju et al. (2014) and discussions with regional experts. No specimens were collected during the present study.

VES data were used to estimate the richness and encounter rates of herpetofaunal species. Shannon's diversity index, Simpson's diversity index, and species accumulation curve for all the species were also calculated. All data were analyzed in R studio (version 3.4.1). The study site map was prepared using ArcGIS 10.1 version.

Results

Species diversity and encounter rate. A total of 880 individuals belonging to 24 species of amphibians (19 genera and 10 families) and 24 species of reptiles (19 genera, eight families) were recorded (Table 1). The species accumulation curve was calculated, and it did not reach asymptote (Figure 2). A total of 14 species of herpetofauna were recorded from perennial streams followed by 10 species from seasonal streams, and seven species from arboreal habitats. Stream habitats also accounted for the maximum number of herpetofaunal counts with 361 individuals (six spp.) followed by the riparian zone with 233 individuals (eight spp.). Site 11 showed maximum species diversity and richness, followed by site 9 and site 5, which were the least diverse according to Shannon and Simpson's indices (Table 2). The distribution of species richness and individual count with respect to the distance from the railway track has also been shown in Figure 3 and Figure 4, respectively.

Euphlyctis cf. *cyanophlyctis* was found to be the most frequently encountered species (9.2/person-hour) among amphibians, and *Ahaetulla borealis* was the most frequently encountered reptile with 0.4/person-hour, followed by *Hemidactylus prashadi*, *Monilesaurus rouxii*, and *Hemidactylus frenatus*. Species such as *Hemidactylus whitakeri*, *Ptyas mucosa*, *Bungarus caeruleus*, *Duttaphrynus melanostictus*, and *Rhacophorus malabaricus* were recorded only once (Table 2).

Sightings of amphibians such as *Uperodon mormorata*, *Microhyla* aff. *ornata*, *Hoplobatrachus tigerinus*, and reptiles such as *Boiga thackerayi*, *Ptyas mucosa*, *Bungarus caeruleus*, *Hypnale hypnale*, etc., were based on opportunistic encounters.

Herpetofaunal mortality on railway tracks. We recorded 20 individuals belonging to 11 species as rail kills, comprising six species of reptiles and five species of amphibians. Of the recorded herpetofaunal mortality, there were three aquatic, two arboreal, one fossorial, and five terrestrial species. *Indosylvirana* sp. (n = 6) and *Ahaetulla borealis* (n = 3) were relatively more frequent as rail kills. Among others, reptiles such as *Hebius beddomei*, *Fowlea piscator*, *Lycodon travancoricus*, *Bungarus caeruleus*, *Dendrelaphis* sp. and amphibians such as *Duttaphrynus melanos-*

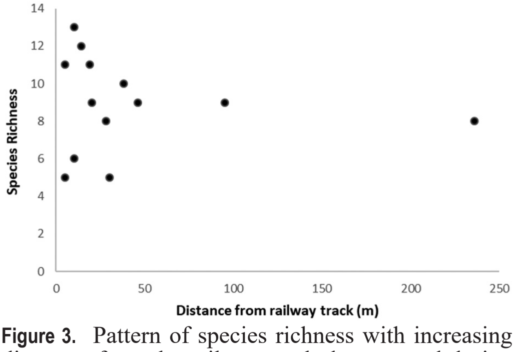

Figure 3. Pattern of species richness with increasing distances from the railway track documented during our survey period.

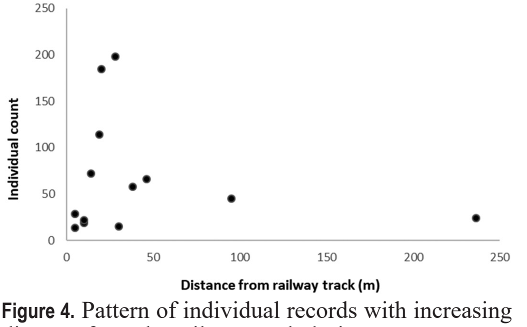

Figure 4. Pattern of individual records with increasing distance from the railway track during our survey period

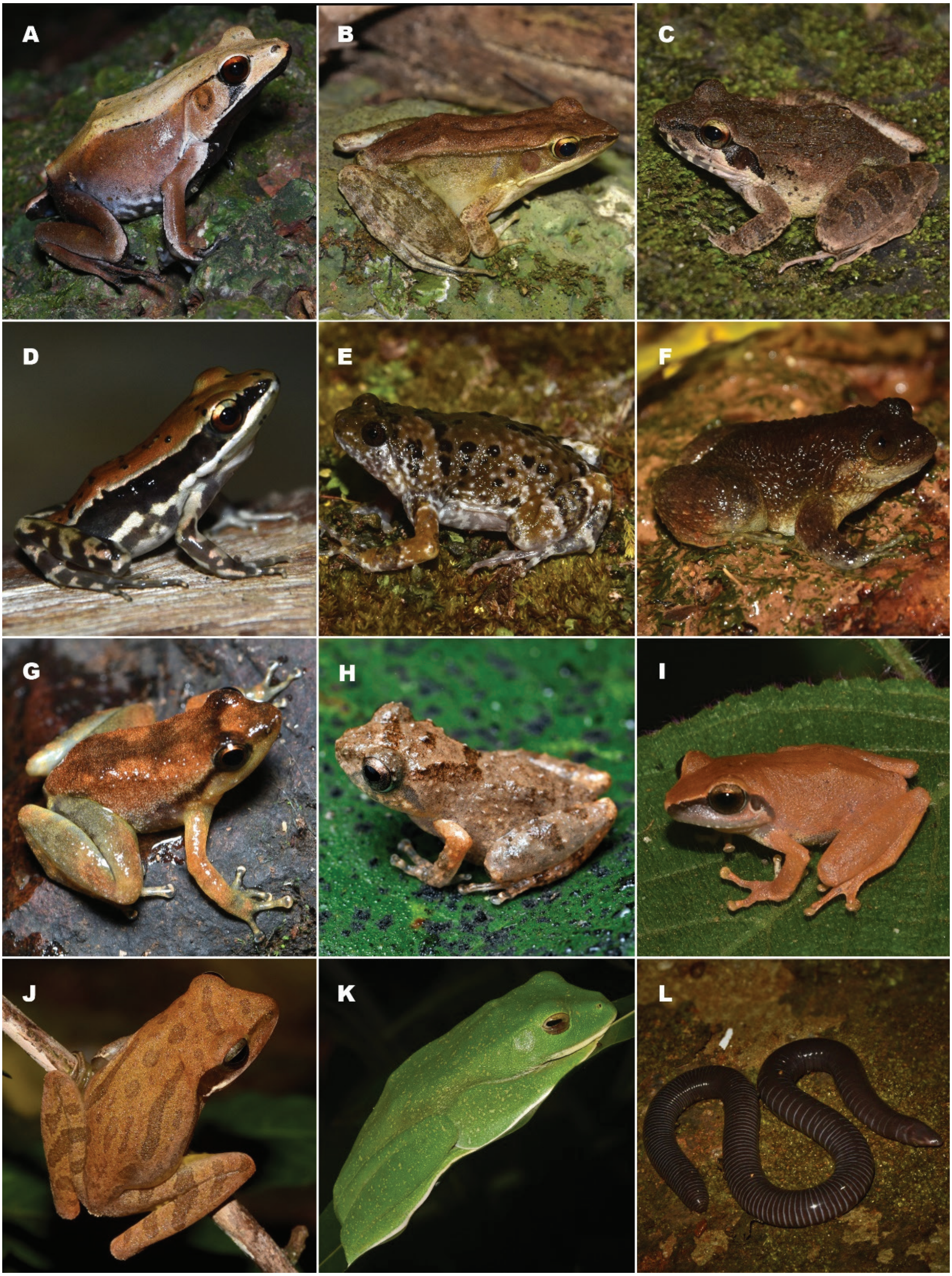

Figure 5. Amphibians of Castlerock: **A.** *Clinotarsus curtipes*, **B.** *Indosylvirana* cf. *caesari*, **C.** *Indirana* cf. *chiravasi*, **D.** *Hydrophylax malabaricus*, **E.** *Uperodon mormorata*, **F.** *Nyctibatrachus petraeus*◦, **G.** *Micrixalus* aff. *uttaraghati*, **H.** *Raorchestes bombayensis*◦, **I.** *Pseudophilautus amboli*, **J.** *Polypedates* cf. *maculatus*, **K.** *Rhacophorus malabaricus*, **L.** *Gegeneophis danieli** [*New state record, ◦Species with castle rock as type locality]

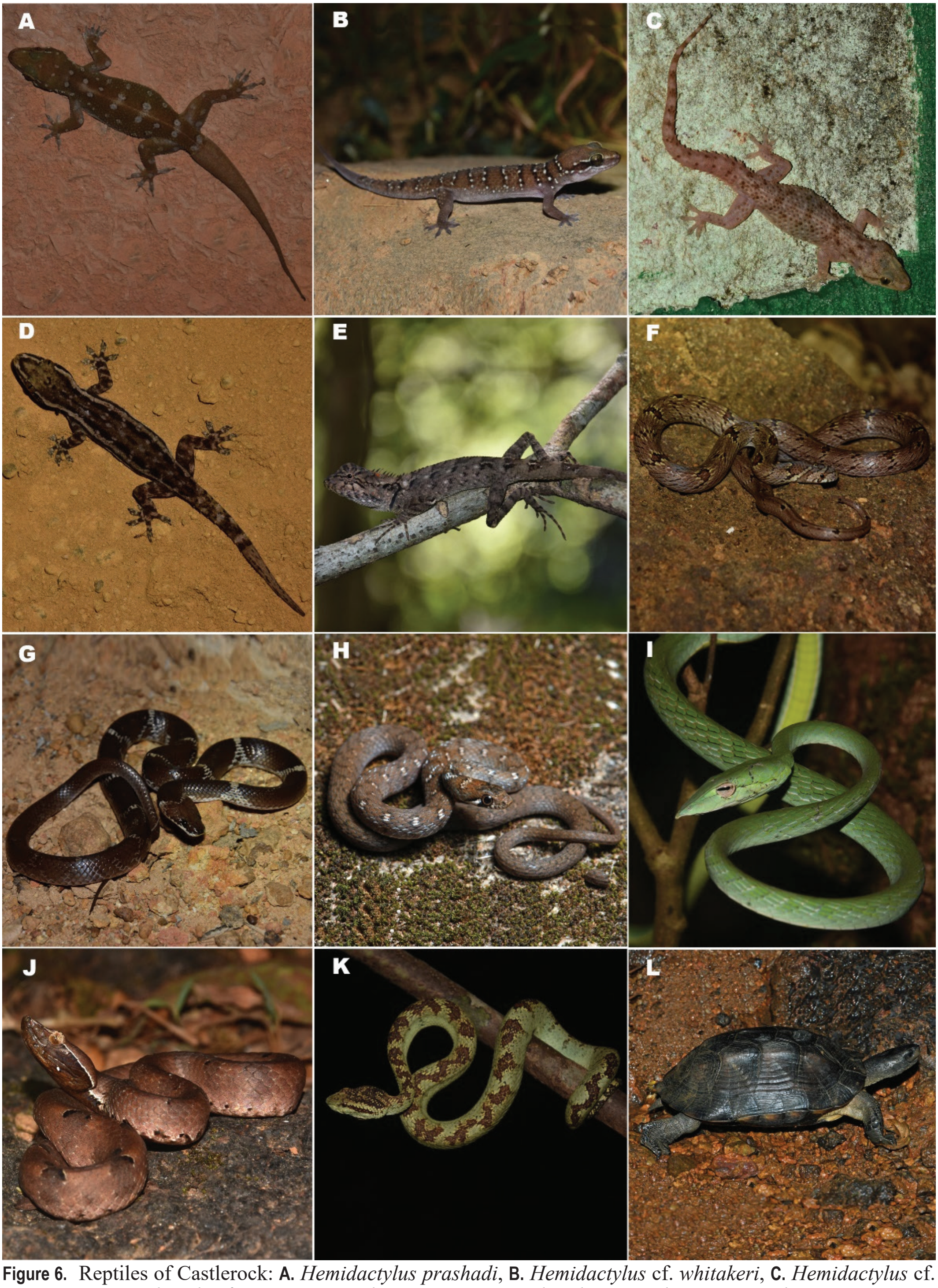

Figure 6. Reptiles of Castlerock: **A.** *Hemidactylus prashadi*, **B.** *Hemidactylus* cf. *whitakeri*, **C.** *Hemidactylus* cf. *murrayi*, **D.** *Hemidactylus frenatus*, **E.** *Monilesaurus rouxii*, **F.** *Oligodon taeniolatus*, **G.** *Lycodon travancoricus*, **H.** *Hebius beddomei*, **I.** *Ahaetulla borealis*◦, **J.** *Hypnale hypnale*◦, **K.** *Craspedocephalus*(= *Trimeresurus*) *malabaricus*, **L.** *Melanochelys trijuga*. [◦Species with castle rock as type locality]

Figure 7. Herpetofauna killed on the railway track: **A.** *Dendrelaphis* sp., **B.** *Bungarus caeruleus*, **C.** *Lycodon* sp., **D.** *Ahaetulla borealis*, **E.** *Indosylvirana* sp., **F.** *Ichthyophis* sp. (desiccated), **G.** *Hydrophylax* aff. *malabaricus*, **H.** *Hoplobatrachus tigerinus*.

tictus, *Hydrophylax* aff. *malabaricus*, *Raorchestes* sp., and *Ichthyophis* sp. were found as rail kills only once each.

We also recorded live individuals of *Monilesaurus rouxii*, *Duttaphrynus melanostictus*, *Pseudophilautus amboli*, *Indirana* sp., and *Hydrophylax* aff. *malabaricus* on the railway track.

Discussion

The survey was a part of the biodiversity assessment designed for a detailed study for prescribing preliminary mitigation measures for all taxa, keeping in view the expansion (doubling) of the 17 km stretch of railway track in the proposed study area. Our survey was planned to get an overview of the species that might be impacted due to the proposed doubling within the stipulated period of time given by the sanctioning authority (Railway Vikas Nigam Limited, GoI). However, our short rapid survey is just representative and not exhaustive in the context of the herpetofaunal diversity of northern Western Ghats. The study span was limited to approximately two weeks and also constrained by dry season effects. Sukumar and Sitharam (2017) reported 51 species from the study area with additional records of *Pedostibes tuberculosus*, *Phrynoderma aloysii*, *Uropeltis ellioti*, and *Python molurus*, which were not documented in the present study.

Out of 48 species recorded, the specific identity of a few cryptic herpetofaunal species could not be ascertained, conferred, or affined to any genus or species group (Table 1; Figures 5 and 6). The identity of a few rail-killed individuals could not be confirmed till the species level (viz. *Indosylvirana* sp., *Dendrelaphis* sp., and *Ichthyophis* sp.) due to their desiccated and mutilated status (Figure 7). Nonetheless, the recorded diversity includes 21 Western Ghat endemics with four species that were originally described from Castlerock (Table 1). Significantly, the record of *Micrixalus* aff. *uttaraghati* (K.V Gururaja, *pers. Comm.* January 2021) marks a noteworthy documentation as its range now extends to ca. 73 km south in Karnataka state (Figure 5G), and it was previously only known from its type locality in Amboli, Sindhudurg, Maharashtra (Biju et al. 2014), the Kulem region (Sukumar and Sitharam 2017), and from the state of Goa (Punjabi et al. 2020). Record of *Gegeneophis danieli* (Varad Giri *pers. comm.* May 2021) is also a new addition to the faunal list for the state of Karnataka (Figure 5L). This species was described from a single specimen in Amboli, Sindhudurg district, Maharashtra (Giri et al. 2003). Additionally, a record of the recently described *Boiga thackerayi* (Giri et al. 2019) from the study area also shows the vulnerability of the species from the expansion plan of the railway track.

Species associated with seasonal and perennial streams contribute to 43% of all recorded species, including the obligate stream breeding *Nyctibatrachus petraeus* (Willaert et al. 2016) and *Micrixalus* aff. *uttaraghati* (Biju et al. 2014). Record of single individuals of *Rhacophorus malabaricus* and *Gegeneophis danieli* perhaps indicate lower detectability of species that are known to be highly seasonal in breeding activities and movement (Bhatta 1998; Biju et al. 2013). Among reptiles, Gekkonids such as *H. prashadi* and *C. flaviventralis* were frequently observed under railway culverts, while *H.* cf. *murrayi* was recorded among dumped construction materials along the railway tracks. The distribution of species richness and individual numbers showed a clustered pattern within 50 m from the tracks (Figures 3 and 4). Such a pattern might be an outcome of seasonal constraints in recording “forest species” and increased records of “edge species”. Nonetheless, such distribution strongly indicates the relative vulnerability of such fauna.

Mortality of nocturnal snakes such as *Bungarus* and *Lycodon* on the tracks may be attributed to their thigmothermic behaviour (Rodriguez et al. 1996; Lenders 2001; Gratison 2006). On the contrary, the high number of arboreal snakes appearing as rail kill either indicate their habitat preference, as members of the genus *Ahaetulla* are known to be present along forest fringes (Mohapatra et al. 2017; Deepak et al. 2019), or their sheer relative abundance in the study area (e.g., *Ahaetulla borealis*). Mortality for some amphibian species is probably related to their prolonged breeding activity (*Indosylvirana* sp.). Although limited to a single observation, less vagile animals like the caecilian (*Ichthyophis* sp.) might have faced desiccation while crossing the track (Figure 9F). Besides direct mortality, increased railway traffic might also lead to auditory masking in amphibians (Bee et al. 2007).

All these encounters were purely observational and the present study had no provisions or facilities to collect samples and conduct necropsy, which is a long procedure and demands a larger number of samples. The aim of the present study was primarily to assess the presence of animal signs and the abundance of species around the study area that can indicate any direct present or future impacts of railway traffic, and not to analyse the cause and time of death or injury assessments of herpetofauna. Also, there was no presence of other possible ways viz. human conflict, road traffic, etc., which could have otherwise caused the observed mortalities.

The study specifically highlights the importance of stream and riparian habitats as one of the critical refuges for several species of amphibians and reptiles. Additionally, the study portrays unforeseen threats that the herpetofauna of the present study site might face if the expansion of the railway line takes place. Henceforth, in case of any future development in terms of railway doubling or expansion, tunnel extension, culvert or underpass construction, fencing and barrier installation, etc., proper mitigation measures are of paramount importance as delineated in the Wildlife Institute of India reports (2016 and 2020). This also sets the platform for forthcoming explorations and calls for the need for thorough surveys in areas with linear infrastructures, specifically railway lines, which have remained fairly understudied to date.

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