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Ecology of Lizards in an Ecologically Significant Semi-Arid Grassland Patch near Solapur, Maharashtra, India

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Abstract: Eighteen species of lizards (Reptilia: Sauria) have been documented in a yearlong study undertaken to investigate the diversity and ecology of lizards in 15 km^2 altered semi-arid grassland habitat patch adjacent to a proposed airport near Boramani village, Solapur, Maharashtra, India. However, the intensive ecological investigation was restricted to a 7 km^2 typical semi-arid grassland patch. This study resulted in the documentation of 888 individuals belonging to 14 species, eight genera and five families. With reference to spatial pattern of microhabitat preference, 82.77% of individuals (n=735) favored rocks on plateau as their preferred microhabitat, 10.59% (n=94) chose rock mound along the road as their microhabitat and 3.94% (n=35) showed preference for termite mound. Only 2.70% (n=24) individuals showed association with crevices, rocks along gentle slope and rodent holes. With regard to temporal variation, the activity of the lizards increased with the onset of summer in March and stabilized in the monsoon (June and July) and then it showed a declining trend from August with least number of individuals represented in the month of February. Furthermore, it has been recorded that, this remnant patch of semi-arid grassland is home to grassland indicator species like Indian grey wolf (c) (n=8 eight), Great Indian Bustard *Ardeotis nigriceps* (Vigors, 1831) (n=1) and blackbuck (*Antelope cervicapra*) (n=59). Observations documented in our study clearly demonstrate the faunal significance of this potential remnant semi-arid grassland patch that has been earmarked for the construction of the airport. Protecting such sites based on explicit ecological studies should be on the priority list of protected area managers as they are not just significant for maintaining ecological integrity but also for their role in provisioning of ecosystem services.

Keywords: Ecology, Ecosystem services, Lizards, Semi-arid grassland, Shannon Diversity Index

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Introduction

Bulk of publications from Maharashtra on lizards (Reptilia: Sauria) were on description of new species and an account of which is included in the Lizard database (http://www.reptile-database.

org) and only a handful of publications deal with ecology of lizards at local level. Majority of checklists published in last two decades provide only anecdotal record of species. A thorough literature survey of lizards documented from Maharashtra state include contributions from Konkan region (Smith, 1935; Mirza and Pal, 2008; Walmiki *et al*., 2012; Editor-Director, 2012); from North Maharashtra (Smith, 1935; Editor-Director, 2012; Dandge, 2018); from Western Maharashtra (Smith, 1935; Editor-Director, 2012; Deshpande *et al*., 2012; Yadav *et al*., 2014; Agarwal *et al*., 2016; Sayyed, 2016; Birje and Kengar, 2017; Dandge, 2018; Khate *et al*., 2020); from Marathwada region (Smith, 1935; Editor-Director, 2012; Dandge, 2018), and from Vidarbha region (Editor-Director, 2005, 2012; Bhandarkar *et al*., 2012; Kumbhar *et al*., 2013; Joshi *et al*., 2017; Khan and Kaur, 2018; Gulhane, 2018; Dandge, 2018). Moreover, the semi-arid landscape from the Solapur region has not yet received much attention for investigating lizard fauna in terms of determining diversity, population dynamics, ecology and behavior. Apart from one publication listing the gecko species from this area (Talwad *et al*., 2016), there are no rigorous efforts to investigate lizards from Solapu.

Historically, the semi-arid grasslands of Deccan landscape and those surrounding the study area are home to the last surviving individuals of the Great Indian bustard (*Ardeotis nigriceps*) and are resting, roosting and breeding ground for many grasslands associated birds and mammals (Rahmani, 1989). This study showcases part of our effort to evaluate lizard ecology from this ecosystem. The study site is historically under moderate grazing by Dhangars, a traditional grazing community from Deccan Plateau. Since last two decades, the grassland habitat from this region is under high peril of annihilation owing to unsustainable anthropogenic activities like urbanization, conversion of grassland into arable land, intensive grazing, monoculture plantation and quarrying (Hippargi *et al*., 2012). The significance of species occurrence data for conservation and management has been stated (Venugopal, 2010). Furthermore, as the study site and its surrounding area is earmarked for the construction of the airport, it is vital to improve upon the knowledge on the current status of faunal diversity from this ecosystem for the conservation and management of remnant patches of semi-arid grasslands.

Materials and Methods

Study area:

The study area taken for documenting overall diversity of lizards is a 15 km^2 patch of semi-arid grassland that surrounds the proposed airport near Boramani village, Solapur, Maharashtra, India (17°46'18.6"N 76°02'11.7"E) (Fig. 1). This landscape has been modified around 1975 to 1985 under the World Bank financed program-Drought Prone Areas Programme (DPAP). Much of the area is under plantations, which mainly includes *Acacia leucophloea* (Roxb.) Wild., *Acacia nilotica* (L.) Wild. Ex Del., *Acacia torta* (Roxb.) Craib., *Albizia lebbeck* (L.) Benth., *Azadirachta indica* Juss., *Gliricidia sepium* (Jacq.) Kunth ex Walp., *Hardwickia binata* Roxb., *Lysiloma latisiliquuum* (L.) Benth. Recently, private properties in this area have been converted into agroecosystem and plotting due to booming real estate business after this area has been proposed airport construction. Part of the area remains under Forest Department.

The region lies in the Biogeographic Zone 6 (Deccan Peninsula-Central Plateau), Province 6 B (Chhota Nagpur) in India (Rodgers *et al.*, 2002). Climatic and physiognomic features (Fig. 2) of the region support the growth of thorn and scrub forest with an interspersed semi-arid grassland ecosystem. The plateau is at an average elevation of 450-500 meters.

Intensive Study Patch:

The lizard data for ecological studies was obtained from 7 km^2 patch. The study area is characterized with continuous open grassland that have flat topped hills with lateral gentle slopes characterized with absence of trees and presence of moderate to low herbaceous ground cover,

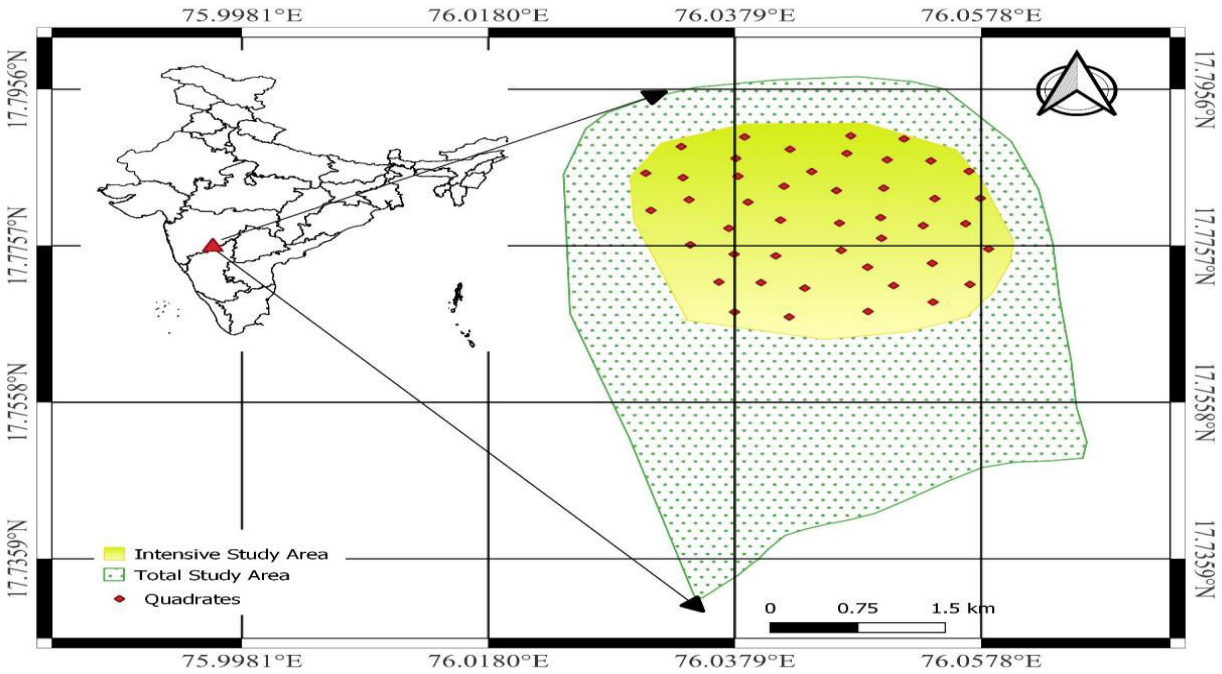

Fig. 1: Map showing intensive study area.

Fig. 2: Physiognomic features of study area.

interspersed termite mounds, exposed weathered rocks, crevices during summer season, rodent holes, country roads and rock piles along the roads as boundary marks of privately owned property. This patch still retains most of its original microhabitat features, excepting that the region is now experiencing moderate pressure from conversion of grassland into arable land, episodes of fires, grazing and quarrying. This study patch is an ecologically significant but neglected site located 25 km from Solapur city.

Sampling Methodology:

Lizards were sampled at monthly intervals to cover each season viz. summer season: February and April; Wet Season (Monsoon/rainy): June and September and Winter Season: October and January. The selected study patch was critically examined for lizards through visual encounter survey (VES) (Campbell and Christman, 1982), quadrats and belt transects. Sampling comprised of monthly four surveys of 50m x 50m quadrats and belt transects of 300-meter distance connecting two quadrats. Overall, 44 quadrat samples and 22 belt transect were taken during the entire study period spanning 11 months from June 2020 to April 2021. Time taken for each sampling effort was five hour, with one hour devoted to each sampling method that involves documenting lizards with visual encounter survey (VES) and active searching under rocks and boulders; herbs, shrubs and grasses; underneath bark, within the canopy, near and within termite mounds and rock mounds. Microhabitat choice of each species has been recorded. Most of the sampling was performed between 8:00am - 1:00 pm. The main goal of this sampling design was to produce a baseline data on lizard species along with sound knowledge on their spatio-temporal variation. As permission to procure voucher samples was waiting for from the Forest Department, we resorted to taking good images and morphometry in the field followed by immediate release of the specimens in their habitat. Identification was done by referring to standard literature (Daniel, 2002; Das, 2008; Lajmi *et al*., 2016) and through consultation with experienced herpetologists and the nomenclature and distribution in the checklist follow standard literature (Aengals, 2018; Uetz *et al*., 2022). Unidentified specimens were listed with 'cf.' before the species name to denote similarity with known species**.** Status assessment of species follows IUCN Red List (2021).

Data Analysis:

Statistical analysis is based only on the data collected during diurnal surveys. Data on lizards gathered from all samples within the 7 km^2 intensive study patch were pooled together to estimate species composition, spatio-temporal variation and microhabitat preferences. Community structure was analyzed through parameters such as diversity, dominance, evenness, correspondence and two-way cluster analysis to illustrate species distribution along with the use of microhabitat features using PAST© **s**oftware version 4.09 (Hammer *et al*., 2001). Hierarchical clustering routine procedure with UPGMA (Unweighted Pair-group Average) algorithm, which joins clusters based on the average distance between all members in two groups was employed. The distance matrix was calculated by using the Bray-Curtis measure. The correspondence analysis figures are edited using photoshop for better illustration of results.

As there are no recent checklists of lizards from Maharashtra, we performed our calculations based on 61 species derived from an exhaustive literature survey of published data from Maharashtra.

Results

Pattern of Lizard Composition in Semi-arid Grassland Patch:

A total of 18 species (29.51% of lizard species found in Maharashtra) belonging to nine genera (56.25% of lizard genera from Maharashtra) and six families (85.71% of lizard families from Maharashtra) have been documented from the 15 km^2 study area. However, an intensive ecological study from a 7 km^2 typical semi-arid grassland patch led to the documentation of 888 adult lizards representing five families, eight genera, and 14 species. *Sitana laticeps* with 325 individuals is the most abundant species. Other species with more than 100 individuals are *Calotes vultuosus* (n=132), *Sarada* cf. *deccanensis* (n=113), and *Hemidactylus gracilis* (n=111). Together these four species contribute 76.69% of abundance as compared to the remaining 10 species that comprise 23.31% of individuals. Of these, *Eutropis beddomei* is least represented with just four individuals. At the family level, Agamidae is the

most abundant family with 570 individuals followed by Gekkonidae with 191 individuals, Scincidae with 57 individuals, Lacertidae with 40 individuals and Varanidae with 30 individuals (Table 1).

Pattern of Species Distribution across Microhabitats:

The pattern of microhabitat features used by species at the local scale shows that 82.77% of individuals (n=735) with the maximum number of species (n=11) are associated with rocks on the plateau as their preferred microhabitat with the highest Shannon Diversity Index (H'=1.74). Two species (n=94) used rock mounds along the road as their preferred microhabitat features. Termite mound is favored by 2 species (n=35) while 3 species (n=13) were found to be associated with crevices on the ground. Microhabitat features such as rocks along the gentle slope and rodent holes are least favored with minimum abundance by two species (n=11) (Table 2).

Furthermore, the dendrogram generated through two-way cluster analysis based on abundance data illustrates the pattern of lizard distribution across microhabitats in the landscape (Fig. 3). The dendrogram shows that 7 species (*Sitana laticeps*, *Hemidactylus gracilis*, *Sarada* cf. *deccanensis*, *Eutropis rubriventris*, *Ophisops jerdonii, Hemidacylus murrayi* and *Hemidacylus* cf. *parvimaculatus*) exclusively use rocks on the plateau as their preferred microhabitat and they constitute most abundant group with 677 individuals. 2 species (*Riopa lineata* and *Riopa guentheri*) cohabit rocks on plateau and crevices as their habitat, *Hemidactylus sahgali* shares termite mound and rocks on the plateau as their habitat; *Calotes vultuosus* exploits 'rock mound along road' and rocks on the plateau as their habitats and *Eutropis macularia* has been observed to regularly prefer 'rocks along gentle elevation'.

Pattern of Species Distribution across Seasons:

The seasonal variation of species shows an increasing trend with the onset of the summer season that continues to rise in summer till April and then stabilizes in the monsoon. The number of adult individuals begins to decline from August till October and the abundance remains at its minimum during the winter season (Fig. 4). Overall, 48.99% (n=435; 14 species) of individuals are found during monsoon, 36.71% (n=326; 8 species) during summer and 14.30% (n=127; 14 species) during winter season (Fig. 5). Shannon Diversity Index and evenness remains almost same during monsoon (H': 2.215) and winter (H': 2.219) season and least during summer (H': 1.099) months (Table 3).

Correspondence analysis (CA) of species dynamics in three seasons shows a discernible pattern of species abundance with season. *Eutropis beddomei*, *Hemidacylus cf. parvimaculatus*, *Riopa guentheri*, *Hemidactylus gracilis*, *Ophisops jerdonii*, *Eutropis rubriventris*, *Riopa lineata*, *Varanus bengalensis* show observable correlation with monsoon season. Abundance of species *Hemidactylus sahgali*, *Eutropis beddomei* and *Eutropis macularia* show visible correlation with winter season and the abundance of species *Sitana laticeps* and *Sarada* cf. *deccanensis* shows clear correlation with summer season (Fig. 6).

When correspondence analysis was performed based on monthly abundance of lizard species, the analysis highlights community dynamics occurring within the study site reflecting evolution of their life history traits. The CA cluster map shows an increase in abundance of species *Sitana laticeps*, *Sarada* cf. *deccanensis*, *Calotes vultuosus* during February, March and April (Summer) that corresponds with the commencement of their breeding activity when these species begin to occupy their territory that culminates with display and mating in June, egg laying in July and emergence of hatchlings in August. This is followed by species complex represented during monsoon season (from June to August) comprising *Varanus bengalensis, Eutropis rubriventris, Hemidactylus gracilis, Hemidactylus* cf. *parvimaculatus, Ophisops jerdonii* and *Riopa*

Table 1: List of lizards recorded from Boramani Semi-arid grassland patch, Solapur, Maharashtra

S. No.	Taxa	No. of individuals	IUCN threat status	Distribution Status in India Based on Reptile Database
Fam-1.	**Agamidae Gray, 1827**			
1.	*Calotes vultuosus* (Daudin, 1802)	132	LC	• India (incl. Tamil Nadu, Assam, Gujarat, Maharashtra, Madhya Pradesh, Kerala, Himachal Pradesh, Mizoram, Tripura, Andaman Islands, Jammu and Kashmir)
2.	*Sarada* cf. *deccanensis* (Jerdon, 1870)	113	LC	• SW India (Karnataka, Maharashtra)
3.	*Sitana laticeps* Deepak & Giri, 2016	325	LC	• Maharashtra: Balaghat Hill Range near Pune
Fam-2.	**Chamaeleonidae** Rafinesque, 1815			
1.	*Chamaeleo zeylanicus* Laurenti,1768	2	LC	• Gujarat, Maharashtra, Kerala, Madhya Pradesh, Southern plains of the Ganges, Tamil Nadu, Telangana
Fam-3.	**Gekkonidae Gray, 1825**			
1.	*Hemidactylus gracilis* Blanford, 1870	111	LC	• Andhra Pradesh, Gujarat, Maharashtra;
2.	*Hemidactylus leschenaultii* Duméril & Bibron, 1836	8	LC	• Andhra Pradesh, Karnataka, Madhya Pradesh, Kerala, Tamil Nadu, Gujarat, Maharashtra, Andaman Islands India
3.	*Hemidactylus flaviviridis* Rüppell, 1835	12	LC	• Himachal Pradesh, Jammu and Kashmir, Andhra Pradesh, introduced to Assam, West Bengal, Bihar, Uttar Pradesh, Delhi, Punjab, Maharashtra, Gujarat, Rajasthan, Madhya Pradesh, Haryana, Orissa, Mizoram
4.	*Hemidactylus murrayi* (complex) Gleadow, 1887	22	LC	• W India (Gujrat), Myanmar, Peninsular Malaysia (and Borneo)
5.	*Hemidactylus* cf. *parvimaculatus* Deraniyagala, 1953	43	NA	• South-east India (Kerala)
6.	*Hemidactylus sahgali* Mirza, Gowande, Patil, Ambekar & Patel, 2018	15	LC	• India (Gujarat, Rajasthan, Maharashtra, Chhattisgarh, Madhya Pradesh), Pakistan (Sindh)
Fam-4.	**Lacertidae Oppel, 1811**			
1.	*Ophisops jerdonii* Blyth, 1853	40	LC	• Punjab, Rajasthan, Gujarat, Madhya Pradesh, Andhra Pradesh, Karnataka, Tamil Nadu, Himachal Pradesh, Jammu and Kashmir, Haryana
Fam-5.	**Scincidae Gray, 1825**			
1.	*Eutropis beddomei* (Jerdon, 1870)	4	LC	• Berar, Salem, Tinnevelly, Malabar, Savagery Hills, Mysore, Annamalai Hills, Madhya

				Pradesh, Tamil Nadu, Kerala
2.	*Eutropis rubriventris* (Schneider, 1801)	23	LC	• Gujarat, Maharashtra, Madhya Pradesh, Kerala, Himachal Pradesh, Tamil Nadu, Mizoram, Andhra Pradesh
3.	*Eutropis macularia* (Blyth, 1853)	10	LC	• Gujarat, Assam, Himachal Pradesh, Madhya Pradesh, Mizoram, Tripura, etc.
4.	*Riopa guentheri* (Peters, 1879)	13	LC	• Bombay Presidency, Matheran, Sholapur, Kurduwadi, Belgaum, N. Kanara; W Andhra Pradesh, Maharashtra, S Gujarat, Karnataka, Telangana
5.	*Riopa lineata* (Gray, 1839)	7	LC	• Bombay district between Poona and N Kanara, Gujarat, Madhya Pradesh? Tamil Nadu, Maharashtra, Karnataka, Jharkhand
6.	*Riopa punctata* (Linnaeus, 1758)	3	LC	• Gujarat, Madhya Pradesh, Andhra Pradesh, Tamil Nadu, Himachal Pradesh, Kerala, Maharashtra, Mizoram
Fam-6.	**Varanidae Merrem, 1820**			
1.	*Varanus bengalensis* (Daudin, 1802)	30	LC	Assam, Himachal Pradesh, Jammu and Kashmir, Madhya Pradesh, Tamil Nadu, Gujarat, Mizoram, Maharashtra, Kerala, etc.

Table 2: Pattern of species distribution across microhabitat

	Rocks on Plateau	Rock Mound along Road	Termite Mound	Rocks along Gentle Slope	Crevices	Rodent Holes
Number of Species	11	2	2	1	3	1
Abundance (SD)	735 ± 87.1	94 ± 23.5	35 ± 6.7	10 ± 2.7	13 ± 1.9	1 ± 0.3
Shannon Diversity (H')	1.74	0.2427	0.6572	0	1.17	0

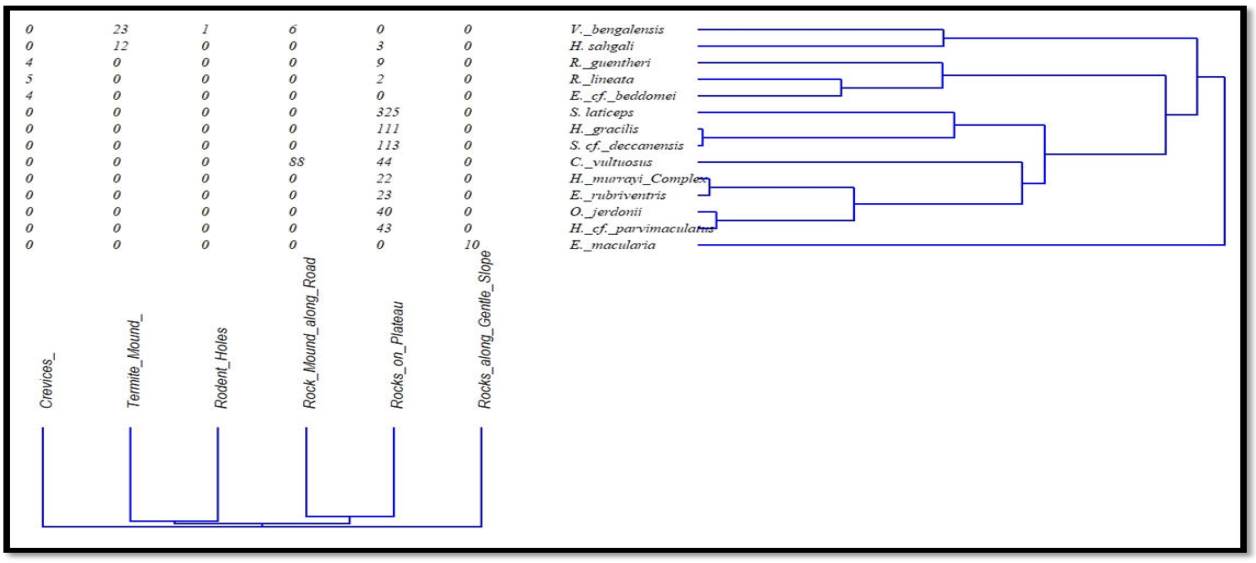

Fig. 3: Two-way dendrogram showing lizard distribution across microhabitats.

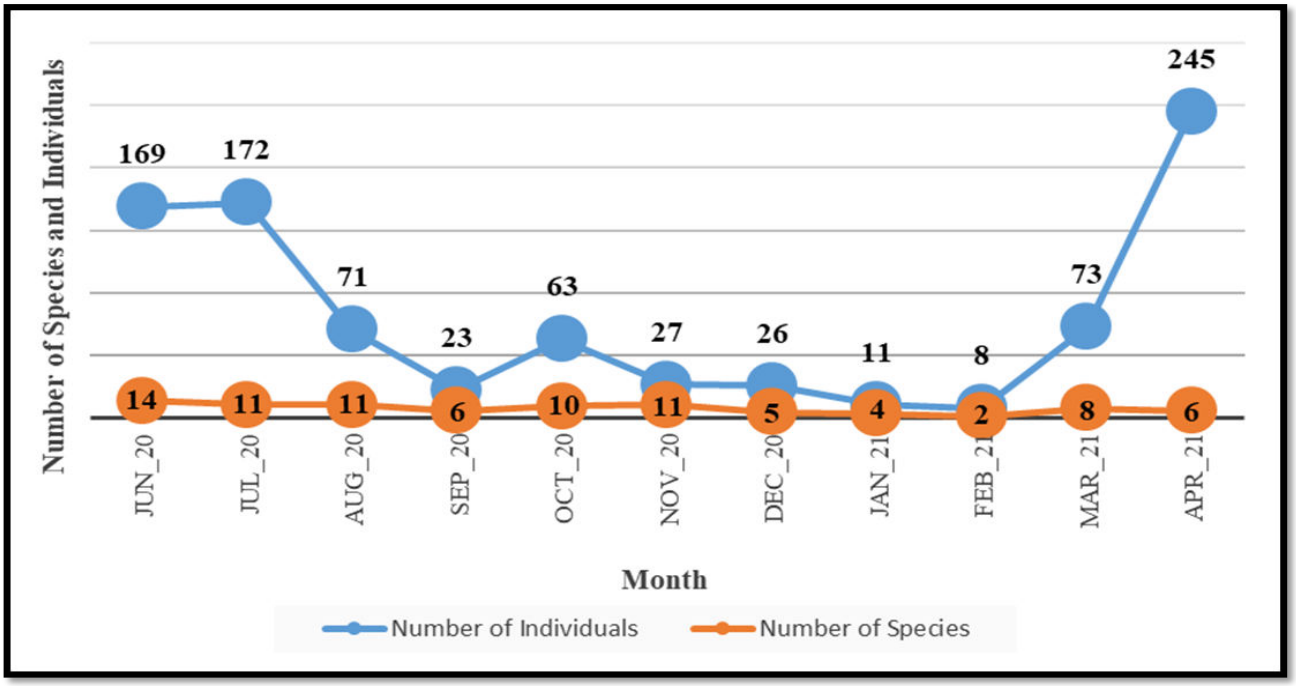

Fig. 4: Monthly variation in the abundance of lizards.

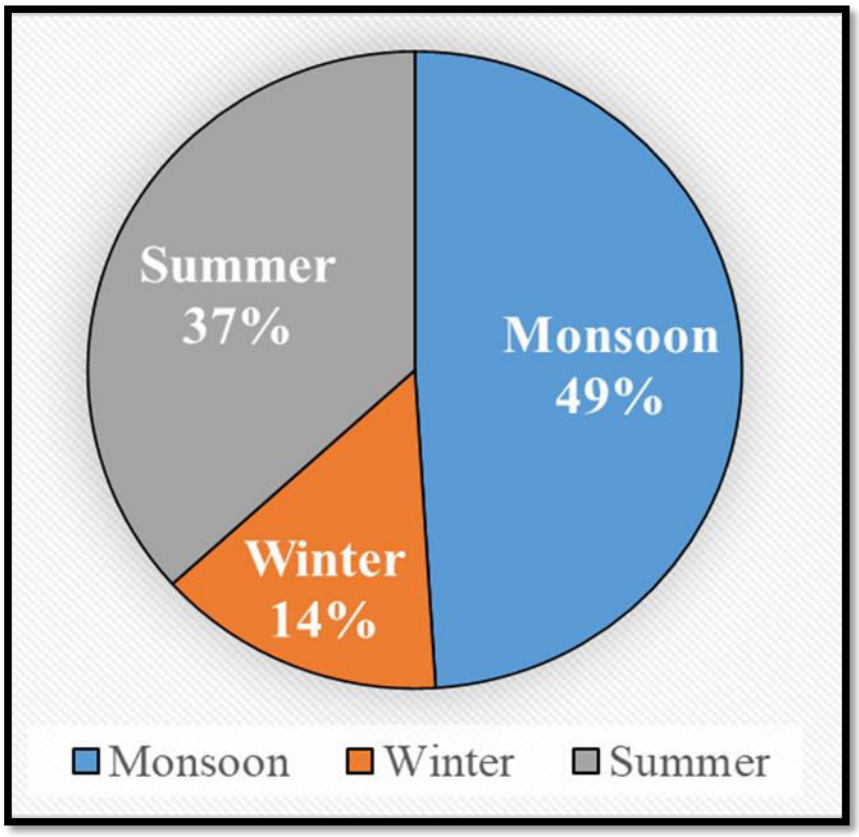

Fig. 5: Seasonal variation in the number of lizards.

Table 3: Seasonal dynamics of lizard species

	Monsoon	Winter	Summer
Number of Species (S)	14	14	8
Number of Individuals (N) (SD)	435 (±30.5)	127 (±10.0)	326 (±55.9)
Dominance (D)	0.1334	0.1461	0.4519
Shannon Diversity (H)	2.215	2.219	1.099
Simpson Diversity (1-D)	0.8666	0.8539	0.5481
Evenness (e^H/S)	0.6547	0.6572	0.3751

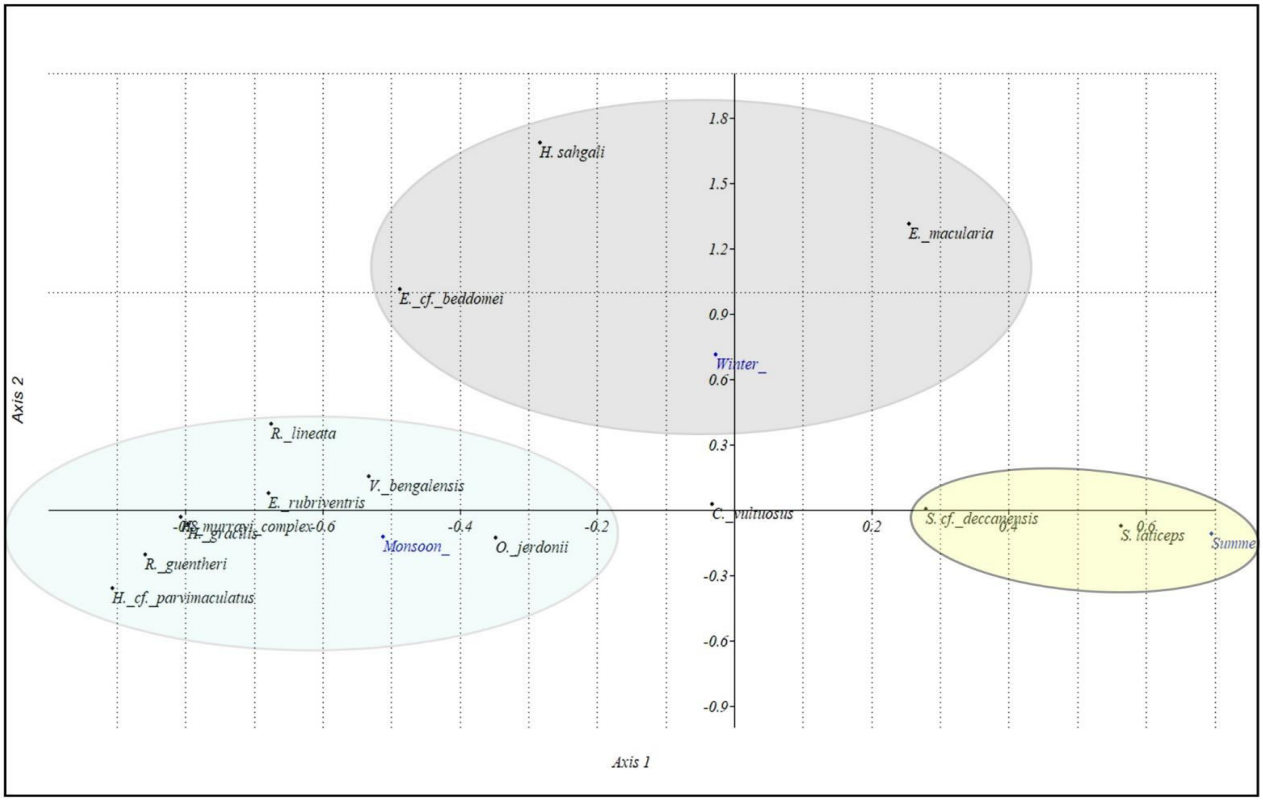

Fig. 6: Correspondence Analysis (CA) of lizard dynamics in three seasons.

guentheri whose breeding activity is mostly completed before the start of monsoon season. Finally, during winter season (October to January) the sub-adults and adults of many of these species disperse around in the area when the density and height of grass and shrubs provide enough concealment and foraging opportunities. This pattern is clearly apparent during the winter season with more scattered distribution of data points during October, November, December and January (Fig. 7). On the whole, CA analysis shows the succession of lizard community during seasons summer, monsoon (rainy) and winter. Photographs of some lizard species documented in the present study area is shown in Figure 8.

Discussion

High abundance reported in our study far exceeds than comparable ecological studies from Maharashtra in other regions (Joshi and Tantarpale, 2015; Hussain and Tantarpale, 2017). These papers have added some knowledge on the ecology of lizards represented from Amravati and Buldhana region of Maharashtra state, India. The overall seasonal trend of species in our study bears resemblance to these earlier ecological

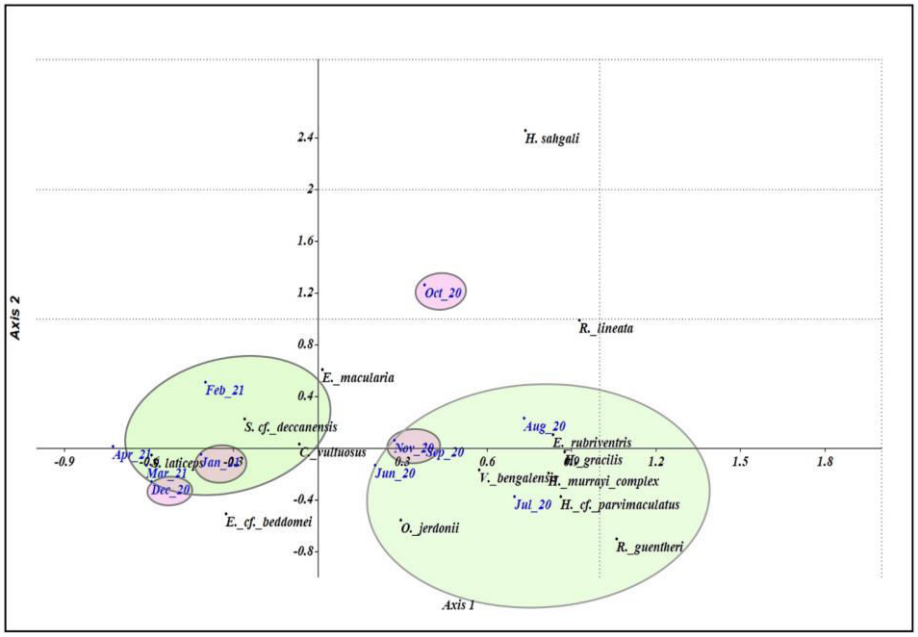

Fig. 7: Correspondence analysis of lizards based on the monthly abundance of species.

studies and decline in abundance during winter season has been attributed to hibernation caused by low temperature. However, in our observations, it has been noted that the sub-adults of *Sarda* cf. *deccanensis*, *Sitana laticeps*, *Calotes vultuosus* and to a certain extent the *Varanus bengalensis* remain concealed within the grass. As the grass height increases from August-September onwards, the probability of detecting lizards with visual encounter survey (VES) becomes challenging. Furthermore, the average temperature rarely comes down to less than 12^0C during winter season, hence, concealment within grass may seem to be one of the valid reasons for low count during the winter season. Additionally, our observations also confirm previous observations that the increased abundance of lizards during monsoon season corresponds to favourable environmental conditions (Pal *et al*., 2012; Joshi *et al*., 2015). Conversely, as noted in our correspondence analysis, we also propose that, there is temporal variation in breeding behaviour within these sympatrically associated species. Species group like *R*. guentheri*, H.* cf. *parvimaculatus, H. gracilis, O. jerdonii*, *E. rubriventris* and to a certain extent *V. bengalensis* breed before the onset of monsoon; while species group comprising *S.* cf. *deccanensis*, *S. laticeps*, *C. vultuosus*, *E. macularia* begin their breeding activity after the onset of monsoon. However, the sub-adults of majority of species use grass and shrub for dispersal and foraging in post-monsoon period from August to February. In addition to this, our observations also prove that, coexisting sympatric species avoid competition with subtle spatial variation in their use of different microhabitat features such as rocks on plateau, rock mound along the road, termite mound, rocks along gentle slopes, crevices and rodent holes. On the whole, the high abundance in study area indicates availability of resources that satisfy resource needs such as food, shelter, concealment, niches and microclimatic conditions for a range of species. This is also obvious with the record of threatened species such as critically endangered Great Indian Bustard (*Ardeotis nigriceps*) (Vigors,

Fig. 8: Lizards species documented in the study area.: a) *Calotes vultuosus*; b) *Sarada* cf. *deccanensis*; c) *Sitana laticeps*; d) *Chamaeleo zeylanicus*; e) *Hemidactylus flaviviridis*; f) *Hemidactylus gracilis*; g) *Hemidactylus leschenaultii*; h) *Hemidactylus* cf. *parvimaculatus*; i) *Hemidactylus sahgali*; j) *Hemidactylus murrayi* (complex); k) *Ophisops jerdonii*; l) *Eutropis* cf. *beddomei*; m) *Eutropis rubriventris*; n) *Eutropis macularia*; o) *Riopa guentheri*; p) *Riopa lineata*; q) *Riopa punctata*; r) *Varanus bengalensis.*

Fig. 9: Threatened species recorded from study patch.

1831) categorized as a Critically Endangered species by IUCN 3.1 and Schedule-I of the Indian Wildlife (Protection) Act, 1972; eight Indian grey wolves (*Canis lupus*) (Linnaeus, 1758) classified as Endangered by IUCN and in Schedule-I of Wildlife (Protection) Act, 1972 and 59 blackbucks (*Antilope cervicapra*) (Linnaeus, 1758) recorded as Least Concern by IUCN 3.1 but included under Schedule-I of Wildlife (Protection) Act, 1972 (Fig. 9). This hints at the biodiversity value of many remnant grassland patches that need to be protected urgently. In addition to threat to many charismatic species as noted in our study, habitat loss and degradation due to anthropogenic activities are cited as threats that cause decline of reptiles (Gibbons *et al*., 2000).

Our literature survey calls for attention to the disparity in the documentation of lizards within the state of Maharashtra as most of the lizard checklists come from Western Maharashtra, Vidarbha and Konkan region and only a few from North Maharashtra and Marathwada region. The plains of the Deccan are most neglected as is evident with complete lack of baseline data. Checklist of lizards from Maharashtra according to changes in taxonomy, revisions and transfers is desperately needed for quality work pertaining to ecology. Most of the published checklists carry many erroneous mistakes affecting conservation and management of lizards. Nevertheless, it is really heartening to see large number of new lizard species being described from India and recently from semi-arid Deccan landscape (Deepak *et al*., 2016). We propose that equal emphasis must be given for collaborations leading to taxonomical and large-scale regional ecological studies for better conservation of saurian fauna.

Conclusion

The checklist along with ecological observations on lizards is the first such study from semi-arid grassland ecosystem from Solapur region, Maharashtra, India. Looking at the high abundance of individuals from a small patch (7 sq.km.), it implies that the semi-arid grassland habitats support high density of lizards. Our study brings to the fore that, though this ecosystem is perceived as wasteland and species poor, the available niches and microhabitat features provide enough resources to support high abundance of species. The biodiversity value of many remnant grassland patches needs to be protected urgently.

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