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Habitat Preference and Distribution of Herpetofauna in the City of Rajkot and Vicinities, Gujarat

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ABSTRACT

Habitat preference and distribution of amphibians and reptiles in the city of Rajkot and their vicinities, Gujarat carried out on urban to rural gradients from August 2015 to December 2017.Total survey of 22 microhabitats, 13 species of amphibians were recorded from 16 microhabitats and 28 species of reptiles from 21 microhabitats. Data analysis on presence/ absence records in various micro-habitats including species-specific habitat preference of amphibians and reptiles were obtained. The cluster analysis of urban habitats occupied by amphibians resulted in two main clusters: (1) aquatic/semi-aquatic (2) terrestrial habitats; water streams habitats clearly distinguished at 1% as the other remaining aquatic and terrestrial habitats were divided into two groups at 84% faunastic similarity; as reptiles divided into two groups at 60% faunastic similarity. Hill index reflects Vacant land (H^0:12H^1: 24.8) was most species-rich habitat in amphibians dominated by Green Wart Frog (*Euphlyctis cyanophlyctis*); as in reptiles Farm (H^0:12 H^1: 23.4) and Large low-rise built-up areas (H^0:20 H^1: 20.8) dominated with Common Garden Lizard (*Calotes versicolor*) and Spectacled Cobra *(Naja naja)* respectively. Rural to urban gradients species of amphibians were more (13 species) in rural and sub-urban than urban (3) with more stenotypic (06 species) as reptiles were higher in sub-urban (21) than rural (19) and urban (9) with 23 stenotypic species. This clears a decreasing distribution pattern in herpetofauna from periphery to the city center.

Keywords Urban habitats, Urban-rural gradient, Amphibians, Reptiles, Cluster analysis.

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INTRODUCTION

Amphibians have a three biphasic life cycle and different life-history stages; which are spent in different macro and micro habitats, i.e. aquatic, wetland and terrestrial habitats (Wells 2007) for food web and energy dynamics. Different species of amphibians occupy different habitats due to evolutionary adaptations such as reproductive modes, ovipositor, parental care and feeding (Dodd 2003, 2010). Reptiles are cold blooded animals their life depends on temperature so their habitat preference is depends of thermoregulation, food availability and shelter (Gardner *et al*.2007, Gibbons *et al*. 2000, Semlitsch and Bodie 2003).

Currently habitat based studies on herpetofauna in various habitats of urban ecosystem in India are scarce. The several state records in urban habitat are 22 species herpetofauna (Tsetan and Ramanibai 2011), 41 species of herpetofauna by Ganesh and Arumugam (2015), 13 species of amphibians (Karunakaran and Jeevanandham 2017), 17 species of reptilians (Alexandar and Jayakumar 2014) and 17 species of reptilians (Jayakumar and Nameer 2018) from Tamilnadu state. 17 anurans (Seshadri *et al.* 2008) and 16 species of anurans reported by Alexandar (2018) from Union Territory of Puducherry. Himachal Pradesh listed 6 species of herpetofauna (Singh and Banyal 2014). Ansari (2018) reported 19 species of herpetofauna from Chhattisgarh. 16 species of serpents (Khobragade and Pawar 2015), 31 species of serpents by Bansode *et al.* (2016) from Maharashtra. 20 species of serpents (Pradhan *et al.* 2014) and 46 species of herpetofauna (Pradhan *et al.* 2015) from Orissa. Jammu and Kashmir reports 17 species of reptilian (Manhas *et al.* 2018).

From Gujarat state most of past studies on herpetofauna focused on National parks, Sanctuaries and Protected areas very few herpetologist have worked on herpetofauna diversity in various habitats such as Naik and Vinod (1993) reported 15 species of anurans; Munjpara *et al*. (2018) studied marine and coastal area, the Gulf of Kachchh reports 28 species of herpetofauna. This is first attempts and such kind of work in urban areas of Kathiawar Peninsula, Gujarat, India.

Background of urban habitats

Rajkot is spread on both banks of River Aji, which cuts through the city. The area under built-up includes total land 126.95 km^2 among them 70.02 km^2 is old Rajkot city (Fig. 1), new city includes 36 villages and 56.99 km^2 (RUDA 2015). Ecological overview of old Rajkot city provides 88 public gardens about 2% green cover, as water bodies spread 32.95 km^2 (viz. Aji dam, Lalpari Lake, Anandpar and Randarda Lake). In new Rajkot city agro-lands spread by 416.79 km^2, major water reservoirs are Aji-2, Nyari-1 and some protected areas i.e. Thorala and Khirasara vidi.

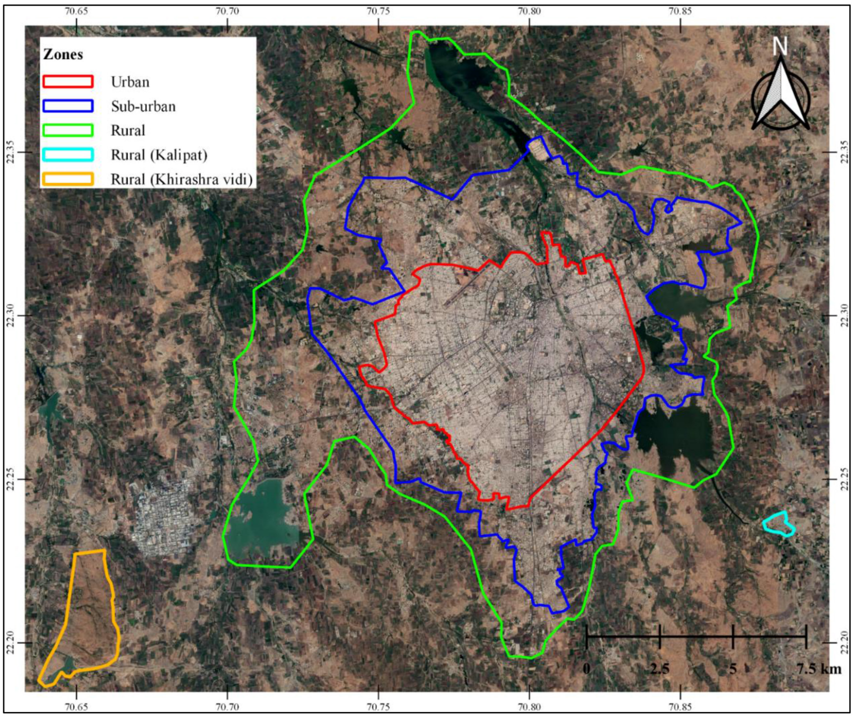

Fig. 1. Rajkot city and its vicinity area.

Table 1. Total surveyed areas of herpetofauna from rural to urban gradients. T1=10m x 50m; T2=20m x 100m; P1=50m x 50m; P2=250m x 250m; RC=Rescue Call; RK-Road Kill. (T- Line transect, P-Plotting).

Zone	T1	T2	P1	P2	RC	RK	Total	Total Surveyed area (km^2)	Total Zone area (km^2)
Rural	1	8	31	5	5	5	50	0.40	104.06
Sub-urban	13	6	45	10	56	56	130	0.75	72.13
Urban	29	13	24	29	5	2	98	1.90	54.06
Total	43	27	100	44	63	1	278	3.05	185.25

The topography is undulating with low flat-top hillocks and shallow valley. The classification of urban habitats in Rajkot city and surrounding areas comes under IUCN Habitats Classification Scheme version 3.1: 14 includes artificial-terrestrial i.e. arable land, rural gardens, urban includes buildings, lawns and parks; heavily degraded former forest; and version 3.1: 15 includes artificial- aquatic that covers water storage areas, ponds, excavations, irrigation land, canals and drainage channels, ditches, wastewater treatment areas (IUCN 2019).

As per "Urban heat island' (i.e. atmospheric warmth of a city that depends on population growth and climate change) investigation and their impacts on urban modification surface energy and solar radiation balance depends upon "local climate zones" properties (i.e. variable land cover properties) of urban that change significantly with synoptic weather patterns, agricultural practices and/or seasonal cycles (Stewart and Oke 2012). Rajkot city and vicinities areas covers ten built types and land cover properties as per Stewart and Oke (2012). Rajkot has a hot semi-arid climate. There are three defined seasons. The physical factors (i.e. rainfall and temperature) that total annual rainfall of year 2015 to 2017 was 1830.2 mm, an average maximum temperature 34.6 ºC and minimum temperature 21.4 ºC. The Rajkot city is characterized by very hot in May of summers and very cold (January- 13.2 ºC) winters. The temperature was varies during study period minimum to maximum 13.2˚C to 42.1˚C.

METERIALS AND METHODS

Sampling methods

The work was carried out from August 2015 to December 2017 with an average 62 survey per year, total 278 sampling units (N) were under taken with two man hours in each survey both day and night, morning (07:00 to 10:00 hrs), evening (17:00 to 20:00 hrs) and late night (23:00 to 02:00 and 03:00 to 06:00 hrs) using LED torch for nocturnal survey. Samplings followed using various size of plots (P1=50 m × 50 m; P2=250 m ×250 m) and strip transect (T1=10m × 50 m ; T2=20 m × 100 m) at random along with active searches except inner space of human residency built-up areas.Total survey for samplings in urban

Table 2 Types of Macro and Micro-habitats and their codes.

Macro and Micro habitat	Code
A. Aquatic and Semi-Aquatic habitats	
1. Downstream basin	DowB
2. Pond	Po
3. Water stream	Ws
4. Water well	Ww
B. Terrestrial habitats	
5. Artificial plantation	ArP
6. Compact low-rise built-up area	CoLrBa
7. Compact mid-rise built-up area	CoMrBa
8. Farm	Far
9. Large low-rise built-up area	LlrBa
10.. Lightweight low-rise built-up area	LwlrBa
11. Lawn	La
12. Natural vegetation	NaV
13. Nursery	Nu
14. Open low-rise building	OLrBa
15. Open mid-rise building	OMrBa
16. Protected area	ProA
17. Road	Ro
18. Shrub-land	ShL
19. Sparsely built-up area	SpBa
20. Tree-covered vegetation	TcV
21. Urban Garden	UrG
22. Vacant land	Val

Table 3. Habitat distribution of recorded amphibians in Rajkot city and vicinity areas.

Scientific name	Micro habitats ArP	CoLrBa	CoMrBa	DowB	Far	La	LlrBa	LwlrBa	NaV	Nu	OLrBa	OMrBa	Po	ProA	Ro	ShL	SpBa	TcV	UrG	VaL	Ws	Ww	Total
(i) Bufonidae Gray, 1825																							
1. *Duttaphrynus melanostictus*	41	0	0	1	3	0	9	0	0	1	1	0	0	3	8	1	1	1	1	0	0	0	**71**
2. *Duttaphrynus scaber*	0	0	0	1	1	0	0	0	1	1	0	0	0	0	0	0	0	0	0	3	0	0	**7**
3. *Duttaphrynus stomaticus*	19	0	0	12	0	0	5	0	0	0	0	0	4	0	0	0	0	0	0	13	0	0	**53**
(ii) Dicroglossidae Anderson, 1871																							
4. *Euphlyctiscyanophlyctis*	0	0	0	110	7	0	0	0	0	1	0	0	65	36	0	52	0	0	10	87	0	0	**368**
5. *Fejervarya limnocharis*	0	0	0	20	2	0	0	0	8	1	0	0	4	0	0	21	0	0	0	68	0	0	**124**
6. *Hoplobatrachus tigerinus*	0	0	0	2	15	0	0	0	0	0	0	0	0	1	0	13	0	0	5	21	0	0	**57**
7. *Minervarya syhadrensis*	2	0	0	24	29	0	3	0	17	0	0	0	47	6	0	21	0	0	0	69	0	0	**218**
8. *Minervarya* sp.1	1	0	0	0	2	0	0	0	0	0	0	0	0	0	0	5	0	0	1	13	0	0	**22**
9. *Minervarya* sp.2	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	**7**
10. *Minervarya* sp.3	0	0	0	3	7	0	0	0	0	1	0	0	3	2	0	5	0	0	0	13	0	0	**34**
11. *Sphaerotheca paschima*	0	0	0	7	5	0	3	0	0	0	0	0	9	2	0	9	0	0	0	15	4	0	**54**
12. *Sphaerotheca* sp.1	0	0	0	1	1	0	0	0	0	0	0	0	8	0	0	3	0	0	0	1	0	0	**14**
(iii) Microhylidae Günther, 1858																							
13. *Microhyla ornata*	2	0	0	3	2	0	1	0	2	2	0	0	10	0	0	14	0	0	0	11	0	0	**47**
Total	**65**	**0**	**0**	**184**	**76**	**0**	**21**	**0**	**28**	**7**	**1**	**0**	**150**	**50**	**8**	**144**	**1**	**1**	**17**	**319**	**4**	**0**	**1076**

areas was 0.40 km^2, sub-urban 0.75 km^2 and rural 1.90 km^2 (Table 1). Data records by Visual Encounter Survey (VES) (Crump and Scott 1994), Audio Strip Transects (AST) (Crump and Scott 1994), Rescue Call (RC) and Road Kill (RK).

Micro-habitat coding establishment and species characteristics

Various macro and micro-habitat types within urban, sub-urban and rural areas of Rajkot are established and presented with their full names, codes and abbreviations (Table 2); which is modified from"Palearctic Habitat Classification" (Mollov 2011) and "Urban Climate Zone" (Stewart and Oke 2012). Herpetofaunal species specific habitat distribution (Table 3 and 4) and ecological classification of the species over synantropy (Klausnitzer 1990); of these the eurytopic/stenotopic (Table 6) was considered as ecologically tolerant species that occur in more than 5 habitat types, while stenotopic that one's occurring in less than 5 habitat types.

Data analysis

Similarity index of amphibians (Fig. 2) and reptiles (Fig. 3) calculation are followed as: The classification of the habitat types are based on the similarity of their species composition (presence/absence data) and the cluster analysis were performed using the Bray-Curtis index and group average linking. Bray-Curtis index is calculated by the following formula (Bray and Curtis 1957):

$$BC_{ij} \; \frac{S_i - S_j + 2\,C_{ij}}{S_i + S_j}$$

Where C_{ij} is the sum of minimum abundances of the various species (abundance at the site where the species is the rarest). S_i and S_j are the total number of specimens captured at both sites.

Hill's Diversity index (Hill's numbers) was discussed with recorded macro and micro-habitats (Table 5). The Hill's numbers estimation and cluster analysis were performed with the software "Bio Diversity Pro" (McAleece *et al.* 1997).

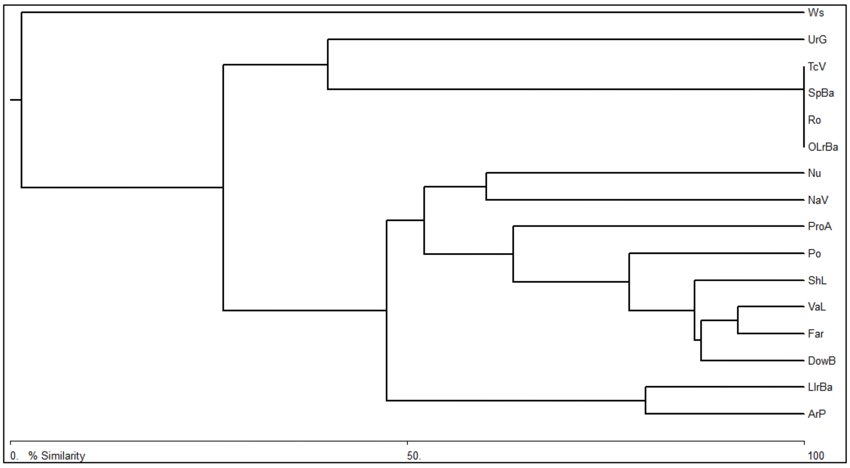

Fig. 2. Classification of the urban habitats in the city of Rajkot based on presence-absence similarity of amphibians (index of Bray-Curtis). Legend: habitat's names and abbreviations as per Table 2.

For the species richness estimation of each urban habitat type used the Hill's Diversity index (Hill's numbers) (Hill 1973): H^0-number of species; H^1-Exponential function of the Shannon-Wiener diversity index, exp (H'); H^2-reciprocal value of the Simpson's diversity index.

Shannon-Weiner Diversity index is calculated using formula (Magguran 1988):

$$H' = -\sum_{i=1}^{S} (pi\ ln\ pi)'$$

Where, S - the number of species, pi - the relative abundance of each species i, calculated as the proportion of individuals of a given species to the total number of individuals in the community.

The reciprocal value of the Simpson's Diversity index is calculated by the following formula (Magguran, 1988):

$$S = \frac{1}{\sum pi^2}$$

Where, S - Simpson's Diversity index; pi - proportion of species i.

RESULTS AND DISCUSSION

Habitat distribution and species composition

Herpetofaunal species population, distribution and various macro and micro-habitat use at Rajkot city and vicinity areas has shown wide range of microhabitat (22 types) utilization.

Amphibians: Out of 22 microhabitats 13 species of amphibians were found in 16 types of microhabitats (Table 3); among them 3 species of toad prefer wide range of microhabitats (15 microhabitats).The most dominant population from toad group were Asian Black-spined Toad (*Duttaphrynus melanostictus*) and Marbled Toad (*Duttaphrynus stomaticus*) recorded from artificial plantation (ArP; 41 and 19 individuals respectively) terrestrial habitat. In comparison frogs prefers less range of microhabitats (12 types) then toads (15 types). Out of 10 species of frog group Green Wart Frog (*Euphlyctis cyanophlyctis*) were dominant and prefers Downstream basin (DowB; 110 individuals) and pond (Po; 65 individuals) of aquatic land and vacant land (VaL; 87 individuals) and shrub land (ShL; 52 individuals) from terrestrial habitat. Second most dominant Syhadry Frog (*Minervarya syhadrensis*) recorded from vacant land (VaL; 69 individuals) and pond (Po; 47 individuals). Among

Table 4. Habitat Distribution of recorded reptilians in Rajkot city and vicinity areas.

Scientific name	Micro habitats																					
	ArP	CoLrBa	CoMrBa	DowB	Far	La	LlrBa	LwlrBa	NaV	Nu	OLrBa	OMrBa	Po	ProA	Ro	ShL	SpBa	TcV	UrG	VaL	Ws	Ww	Total
(i) Trionychidae Fitzinger, 1826																							
1. *Lissemys punctata*	0	0	0	0	0	0	0	1	0	0	0	0	0	0	2	0	0	0	0	0	0	2	**5**
(ii) Agamidae Gray, 1827																							
2. *Calotesversi color*	5	0	0	1	0	3	1	1	15	23	5	0	0	13	8	24	1	0	12	9	0	0	**121**
3. *Sitana spinaecephalus*	1	0	0	0	0	0	0	0	0	3	0	0	0	2	1	10	1	0	0	4	0	0	**22**
(iii) Gekkonidae Gray, 1825																							
4. *Hemidactylus flaviviridis*	0	0	0	0	3	0	8	2	0	0	0	0	0	1	0	4	13	0	1	0	0	0	**32**
5. *Hemidactylus frenatus*	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	**1**
6. *Hemidactylus murrayi*	6	0	0	2	2	0	2	0	10	0	0	0	0	11	0	4	1	0	0	7	0	0	**45**
7. *Hemidactylus sahgali*	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	3	0	**4**
(iv) EublepharidaeBoulenger, 1883																							
8. *Eublepharis fuscus*	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**
(v) Lacertidae Oppel, 1811																							
9. *Ophisops jerdonii*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	1	0	0	**4**
10. *Ophisops kutchensis*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	12	0	0	**22**
(vi) Scincidae Gray, 1825																							
11. *Eutropis carinata*	3	0	0	0	2	0	0	0	0	5	0	0	0	0	0	3	0	0	0	0	0	0	**13**
12. *Eutropis macularia*	13	0	0	0	3	0	0	0	4	0	0	0	0	0	0	0	0	0	0	4	0	0	**24**
13. *Riopa punctata*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	**1**
(vii) Varanidae Merrem, 1820																							
14. *Varanus bengalensis*	1	0	0	0	0	0	3	0	0	0	0	0	1	0	2	0	0	0	0	0	1	0	**8**
(viii) Erycidae Daudin, 1803																							
15. *Eryx johnii*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	**1**
16. *Eryx conicus*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	**1**
(ix) Colubridae Oppel, 1811																							
17. *Boiga trigonata*	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	**2**
18. *Coelognathus helena*	0	0	0	0	0	0	5	0	0	0	0	0	0	0	8	0	2	0	0	0	0	0	**15**
19. *Fowlea piscator*	0	0	0	1	1	0	1	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0	**9**
20. *Lycodon aulicus*	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	**3**
21. *Oligodon arnensis*	0	1	0	0	1	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	**4**
22. *Oligodon taeniolatus*	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**
23. *Ptyas mucosa*	0	0	0	0	0	0	4	0	0	0	1	1	1	0	1	0	0	0	0	0	0	0	**8**
(x) Lamprophiidae Fitzinger, 1843																							
24. *Psammophis leithii*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	**1**
(xi) ElapidaeBoie, 1827																							
25. *Bungarus caeruleus*	1	1	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	**4**
26. *Naja naja*	0	1	1	3	0	0	16	3	0	0	3	1	0	0	6	0	3	0	0	0	0	0	**37**
(xii) ViperidaeOppel, 1811																							
27. *Echis carinatus*	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	**2**
(xiii) TyphlopidaeMerrem, 1820																							
28. *Indotyphlops braminus*	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**3**
Total	**30**	**3**	**4**	**8**	**12**	**3**	**42**	**7**	**32**	**31**	**9**	**2**	**8**	**29**	**33**	**61**	**23**	**0**	**13**	**38**	**4**	**2**	**394**

frog species only two time seen species was *Minervarya* sp. 2 recorded from farm (2 individuals) and vacant land (3); five time seen species was *Minervarya* sp. 1 (22 individuals) and *Sphaerotheca* sp. 1 (14) recorded from artificial plantation, downstream basin, farm, pond, shrub-land and vacant land; 07 time seen species Paddy field Frog (*Fejervarya limnocharis*) and *Minervarya* sp. 3 recorded maximum from vacant land (68 and 13 individuals respectively), downstream basin (20 and 03), shrub-land (21 and 05); 08 time seen speciesWestern Burrowing Frog (*Sphaerotheca pashchima*) abundantly recorded from vacant land (15); 09 times seen species *Minervarya syhadrensis* (Syhadry Frog) and Ornamented Pigmy Frog (*Microhyla ornata*) mostly observed from vacant land (69 and 11 individuals respectively), pond (47 and 10) and shrub-land (21 and 14). In brief most of toad prefers aquatic habitats for breeding purpose and dispersion mostly artificial plantation; whereas frogs prefers wide range aquatic as well as terrestrial micro habitats and primly populated in vacant land. This may due to less anthropological interference.

Reptilians: Out of 22 microhabitats 28 species of reptilians were obtained from 21 types of microhabitats (Table 4); among them only single species of turtle *Lissemys punctata* were found from water-well (Ww, 2 individuals), road side (Ro, 2 individuals) and only one from light weight low rise built-up areas (LwlrBa). From lizard group most dominant populated (121 individuals) species Oriental Garden Lizard (*Calotes versicolor*) recorded from wide ranges in 14 microhabitats (Table 4), among all most preferred lands were shrub lands (24 individuals) and nursery (23 individuals). From gecko group species Murray's House Gecko (*Hemidactylus murrayi*) recorded from 09 microhabitats; out of 45 individuals most occurrences were protected areas (ProA, 11 individuals) and natural vegetation (NaV, 10 individuals). Second dominant species *Hemidactylus flaviviridis* (Northern House Gecko) recorded primly from built-up areas of outer and inner space of buildings; whereas Common House Gecko *(Hemidactylus frenatus)* prefers mainly from inner space built up areas. Sahgal's Termite Hill Gecko (*Hemidactylus sahgali*) were recorded chiefly near water stream (Ws, 3 individuals) and natural vegetation (NaV, 1 individuals). Only single time rare seen species Westindischer Leopard Gecko (*Eublepharis fuscus*) was recorded from natural vegetation (NaV). Other Lacerta group only two time seen most populated (22 individuals) species was Kutch small-scaled Snake-eye (*Ophisops kutchensis*) and less individuals (04) was *Ophisops jerdonii* (Jerdon's Snake-eye) recorded from vacant and shrub lands. 03species of Skink were recorded from 6 microhabitats and most populated skink *Eutropis macularia* (Bronze Mabuya) observed from artificial plantation, farm, natural vegetation, nursery, shrub lands and vacant lands. Single species *Varanus bengalensis* (Indian Monitor) of Monitor Lizard recorded from 5 microhabitats (i.e. artificial plantation, large-low rise built up areas, pond, road and water stream). Total 14 species of Serpents were recorded from 17 microhabitats; among them most dominant venomous species was *Naja naja* (Spectacled cobra) recorded from 09 microhabitats with significant populations (16 individuals) obtained from large low-rise built-up areas (LwlrBa); second dominant non-venomous Trinket Snake (*Coelognathus helena*) recorded from road side (Ro, 08 individuals) areas (Table 4). This clears as reptilians species prefer wide verities of habitat in comparison to amphibians, because of their mode of life. As they are poikilothermic animals their life depends on temperature so their habitat preference is depends on thermoregulation, food availability and shelter (Gardner *et al*. 2007, Gibbons *et al.* 2000 Semlitsch and Bodie 2003).

Comparative analysis of the urban habitats based on qualitative faunistic similarity

The cluster analysis of the urban habitats occupied by amphibians based on presence/absence data resulted in grouping into two main clusters: Aquatic / semi-aquatic habitats and terrestrial habitats with faunistic similarity of about 26% (Fig. 2). From the aquatic and semi-aquatic habitats clearly distinguished were the Pond (Po) and downstream basin (Dow B) at 84 % similarity, these habitat preferred by mostly Green Wart Frog (*Euphlyctis cyanophlyctis*); this species prefer more aquatic habitat and their aquatic diet vegetation are also easily available for their life cycle and shelter of each stages in such-micro-habitat or water bodies which support with Lalremsanga *et al*. (2013).

On the other hand, urban terrestrial habitats, inhabited by amphibians were divided into two groups; the first one of them (about 26% of faunistic similarity) were the group of the tree-covered vegetation (TcV), sparsely built up area (SpBa), Road (Ro) and Open low-rise building (OLrBa) connected with 100% faunistic similarity. Urban garden were distinguished from main cluster at 40% similarity.Whereas second group of terrestrial habitat distinguish into two subgroup (about 52% of faunistic similarity); protected areas (ProA), shrub land (ShL), vacant land (VaL), farm (Far); second group (about 41% of faunistic similarity) of concerted with large low-rise built-up area (LlrBa) and artificial plantation (ArP) at 80 % similarity. The large part of the active season of the post productive explosive breeder amphibians is spent in terrestrial habitats around aquatic habitat. Moreover the terrestrial habitats are important dispersal areas for juveniles and hibernation habitats (such as vacant land, farm and shrub lands).

The urban habitats inhabited by reptiles in Rajkot city were divided into terrestrial, aquatic/semi-aquatic with faunistic similarity of 1% (Fig. 3); of these, only one species from the recorded reptiles was typical aquatic (Ww, 1%) serpent species *Fowlea piscator* (Checkerd Keelback). Micro habitat downstream basin (DowB) of Semi-aquatic macro-habitats were differentiated from the typical aquatic ones (Ww) at about 60% faunistic similarity.

Urban terrestrial habitats that are inhabited by reptiles were divided into two major groups at approximately 38 % of faunistic similarity. The first group included open low-rise building, open mid-rise building, compact low-rise built-up area and compact mid-rise built-up area (OLrBa, OMrBa, CoLrBa, CoMrBa) which were mainly inhabited, and serpent species dominated exclusively by the Spectacled cobra (*Naja naja*).

The second group was divided into two subgroups. The first of them (approximately 39% similarity) includes light weight low-rise built up area, urban gardens, lawn (LlrBa, LwlrBa, SpBa) and protected area, large low-rise built-up area, sparsely built up area; occupied mainly by the Spectacled cobra (*Naja naja*), Oriental Rat-snake (*Ptyas mucosa*) and lizards group by Northern House Gecko (*Hemidactylus flaviviridis*).

Table 5 Diversity indices (Hill numbers) of Herpetofauna of the studied Micro habitats.

Microhabitats	H^0	H^1	H^2
Amphibia			
VaL	12	24.8	0
Far	12	23.4	0
ShL	10	22.2	0
Nu	6	18.0	0
Po	8	12.6	0
LlrBa	5	11.0	0
DowB	11	10.6	0
UrG	4	6.2	0
ProA	6	6.1	0
NaV	4	5.8	0
ArP	5	5.5	0
OLrBa	1	1.4	0
Ro	1	1.4	0
SpBa	1	1.4	0
TcV	1	1.4	0
Ws	1	1.4	0
Reptiles			
Ro	11	27.2	0.000
LlrBa	10	20.8	0.001
ShL	10	19.8	0.000
Far	6	16.9	0.003
VaL	7	16.3	0.000
ArP	7	13.6	0.004
DowB	5	12.5	0.004
SpBa	8	12.2	0.000
NaV	6	9.5	0.001
LwlrBa	4	9.1	0.001
ProA	6	8.9	0.001
CoLrBa	3	7.0	0.004
OLrBa	3	5.6	0.001
Nu	3	4.2	0.001
Po	3	4.2	0.001
OMrBa	2	3.9	0.001
CoMrBa	2	3.2	0.004
Ws	2	3.2	0.000
UrG	2	2.1	0.000
La	1	1.4	0.003

The second group of higher faunistic similarity was (around 67%) urban gardens, lawns (UrG, La) which apparently provide similar environmental conditions for certain species such as Common Garden Lizard (*Calotes versicolor*).

The third group has a higher faunistic similarity (around 31%) and includes natural vegetation (NaV), farm (Far), vacant land (VL), shrub land (ShL), nursery (Nu) and artificial plantation (ArP), which are preferred by mostly Murray's House Gecko (*Hemidactylus murrayi*) and Kutch small-scaled Snake-eye (*Ophisops kutchensis*). From all identified urban habitats the reptiles were absent only in Tree-covered vegetation (TcV).

Those landscape micro-habitats that are not used as habitats but may play a major role in determining the success of the movements or migrations of some amphibians and reptiles represent a matrix (Kindalman *et al*. 2005). A matrix with high permeability assures good movement conditions, which are high quality and safe areas (corridors). Human made structure such as road, rail roads, fences, intensively treated agricultural lands may cause severe mortality of the individuals by crossing them and for many species represent an impermeable matrix (Hein *et al.* 2004). Due to this reason amphibians and reptile population may decline because loss of critical habitats it may reproduction summer or hibernation habitat orloss of connectivity between critical habitats (Hartel *et al.* 2007).

Species richness in the urban habitats

For the amphibians, most species-rich habitat and Hill (H^1) indices were high in "Vacant land (VaL, H^0 -12 species, H^1 = 24.8), Farm (Far, H^0 -12 species, H^1 = 23.4) and Shrub land (ShL, H^0 -10 species, H^1 =22.2)" (Table 5, Fig. 4). Subsequent habitats were downstream basin (DowB, H^0 =11 species, H^1 = 10.6) and pond (Po, H^0 = 08 species, H^1 = 12.6). In general, such types of habitats are used for the breeding in amphibians.Whereas open low rise build-up area (OLrBa), road (Ro), sparsely build-up area (SpBa), Tree covered vegetation (TcV) and water stream (Ws) of urban micro-habitat were less diverse (H^0 = 01 species, H^1 = 1.4)" and preferred by species such as Asian Black-spined Toad (*Duttaphrynus melanostictus*) and Western Burrowing Frog (*Sphaerotheca pashchima*).

Unlike the amphibians, reptiles had the highest species richness in terrestrial habitats: "Large low rise build-up area" (LlrBa); "Road" (Ro) and "Shrub land" (ShL), followed by the aquatic and semiaquatic habitats (Table 5, Fig. 4). With the lowest species richness only one species recorded per habitat were "Lawn" (La) occupied only by Common Garden Lizard (*Calotes versicolor*). Perhaps from the terrestrial urban habitats the most vulnerable was the vacant lands, which were rapidly being overbuilt. They were essential for the existence of most of reptile species in the city and important for the dispersal and migrations for the amphibians in the post-breeding periods.

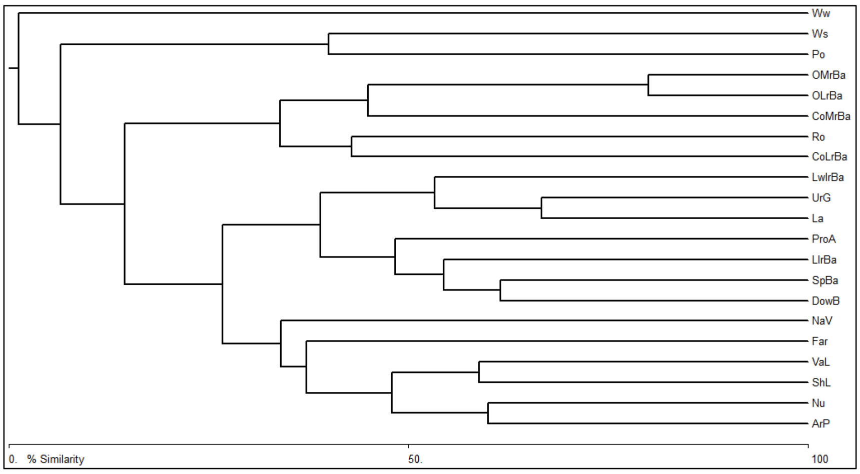

Fig. 3. Classification of the urban habitats in the city of Rajkot based on presence-absence similarity of reptiles (index of Bray-Curtis). Legend: habitat's names and abbreviations as per Table 2.

Table 6. Urban to rural composition and ecological classification of the amphibians and reptiles in the Rajkot city and vicinities.

Scientific Name	Area: Urban	Area: Sub-urban	Area: Rural	Ecological cassification
AMPHIBIANS				
1. *Duttaphrynus melanostictus*	+	+	+	Eurytopic
2 *Duttaphrynus scaber*	-	+	+	Stenotopic
3 .*Duttaphrynus stomaticus*	-	+	+	Stenotopic
4. *Euphlyctis cyanophlyctis*	-	+	+	Eurytopic
5. *Fejervarya limnocharis*	+	+	+	Eurytopic
6. *Hoplobatrachus tigerinus*	-	+	+	Eurytopic
7 .*Minervarya syhadrensis*	-	+	+	Eurytopic
8. *Minervarya* sp. 1	-	+	+	Stenotopic
9. *Minervarya* sp. 2	-	+	+	Stenotopic
10. *Minervarya* sp. 3	+	+	+	Stenotopic
11. *Sphaerotheca pashchima*	-	+	+	Eurytopic
12. *Sphaerotheca* sp.1	-	+	+	Stenotopic
13. *Microhyla ornata*	-	+	+	Eurytopic
REPTILES				
14. *Lissemys punctata*	-	+	+	Stenotopic
15. *Calotes versicolor*	+	+	+	Eurytopic
16. *Sitana spinaecephalus*	-	-	+	Eurytopic
17 *Hemidactylus flaviviridis*	+	+	+	Eurytopic
18. *Hemidactylus frenatus*	-	+	-	Stenotopic
19. *Hemidactylus murrayi*	+	+	+	Eurytopic
20. *Hemidactylus sahgali*	-	-	+	Stenotopic
21. *Eublepharis fuscus*	-	-	+	Stenotopic
22. *Ophisops jerdonii*	-	-	+	Stenotopic
23. *Ophisops kutchensis*	-	+	+	Stenotopic
24. *Eutropis carinata*	-	+	+	Stenotopic
25. *Eutropis macularia*	+	+	+	Stenotopic
26. *Riopa punctata*	-	-	+	Stenotopic
27. *Varanus bengalensis*	-	+	-	Stenotopic
28. *Eryx johnii*	-	+	-	Stenotopic
29. *Eryx conicus*	-	+	-	Stenotopic
30. *Boiga trigonata*	-	+	-	Stenotopic
31. *Coelognathus helena*	-	+	-	Stenotopic
32. *Fowlea piscator*	-	+	+	Stenotopic
33. *Lycodon aulicus*	-	+	+	Stenotopic
34. *Oligodon arnensis*	+	+	-	Stenotopic
35. *Oligodon taeniolatus*	-	-	+	Stenotopic
36. *Ptyas mucosa*	+	+	+	Stenotopic
37. *Psammophis leithii*	-	-	+	Stenotopic
38. *Bungarus caeruleus*	+	+	-	Stenotopic
39. *Naja naja*	+	+	+	Eurytopic
40. *Echis carinatus*	-	+	-	Stenotopic
41. *Indotyphlops braminus*	+	-	-	Stenotopic

Urban-to-rural composition and ecological classification of herpetofauna

Urban to rural species specific composition in relation to ecological characteristics according to the habitat selectivity and level of synantropy are shown in Table 6. Which reflects that 29 species were stenotopic and 12 species eurytopic, of these13 species of amphibians among them 07 species were ecologically tolerant species as eurytopic and of theses 2 species *Duttaphrynus melanostictus* (Asian Black-spined Toad) and Paddy field Frog (*Fejervarya limnocharis*) have vide range from urban to rural gradients; as *Minervarya* sp. 3 shows stenotopic from urban to rural gradients.

Out of 28 species of reptiles 23 species were stenotopic and 05 species eurytopic. Among eurytopic 03 species *Calotes versicolor, Hemidactylus murrayi, Hemidactylus flaviviridis* and *Naja naja* inhabiting with wide ranges from urban to rural gradients. Even though, two stenotopic species *E. macularia* and *Naja naja* also were recorded in all the areas (i.e. urban to rural).

CONCLUSION

In conclusion, occurrences of amphibians population were higher in terrestrial macro habitats (65.8%, 738 individuals) than aquatic/ semi-aquatic (31.41%, 338 individuals); as micro-habitat preference and population of amphibians were significantly higher from Vacant land (VaL; 29.6%, 319 individuals), Downstream basin (DowB; 17.1%, 184), Pond (Po; 13.9%, 150) and Shrub-land (ShL; 13.3%, 144). Three species were distributed from rural to urban gradient level, of these two species (*Duttaphrynus melanostictus* and *Fejervarya limnocharis*) eurytopic (Prefers wide range of habitats) and single species of anuran Minervarya sp. 3 is stenotopic. This may due to landscape characteristic, these habitat provide food, shelter and breeding substratum for the amphibian fauna. Unlike amphibians, reptilian fauna also widely distributed in terrestrial macro-habitat (94.4%, 372 individuals) then aquatic and semi-aquatic macro habitats (5.6%, 22 individuals). Of these Shrub-land (ShL; 16.7%) is most populated and preferred microhabitat for reptilians, followed by Large low-rise build-up areas (LlrBa; 10.6%) and Vacant land (VaL, 9.64%). So, amphibians and reptilian fauna distributed equally in terrestrial habitat, this may due to ecological overview and floral distribution, classification of urban

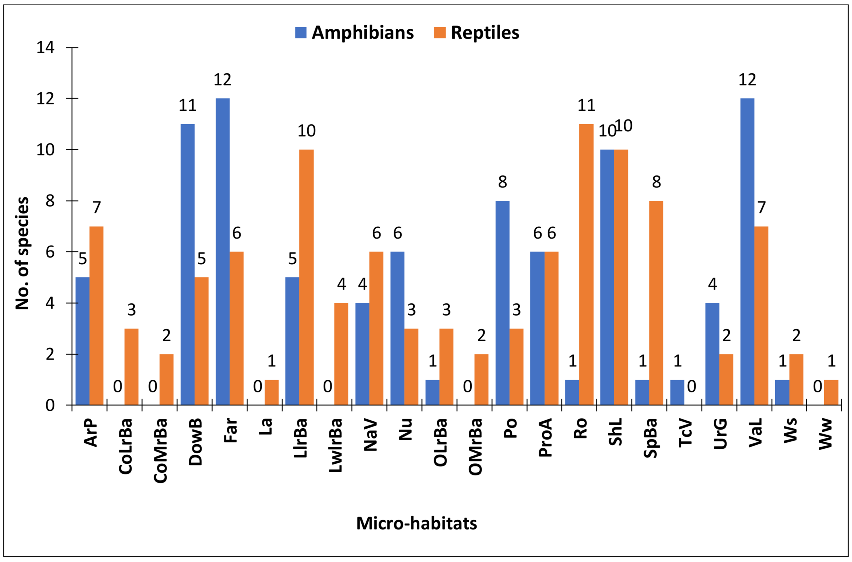

Fig. 4 Number of species of amphibians and reptiles in the studied urban habitats. (Legend: habitat's names and abbreviations as per Table 2).

habitat and physiological factors (i.e. rainfall and temperature) of Rajkot city and surroundings. All the data suggest that microhabitat Vacant land (VaL), Downstream basin (DowB) and Shrub-land (ShL) are most important and prime habitats to sustain and coexistence of herpetofaunal species in the Rajkot city and vicinity areas.

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