



AN INVENTORY OF HERPETOFAUNAL DIVERSITY IN URBAN ECOSYSTEM, WESTERN INDIA

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AUTHORS' CONTRIBUTIONS

This work was carried out in collaboration among all authors. Author YK designed the study, performed all the field study and wrote the protocol. Author HP performed the statistical analysis and author VT managed valuable comments and inputs for improvement of the manuscripts. All authors read and approved the final manuscript.

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ABSTRACT

An inventory of herpetofaunal diversity of Jamnagar city and vicinity areas, Gujarat, India carried out from August 2015 to December 2017, using visual encounter, auditory strip transect, scanning of leaf-litter, rescue call and road kill survey. Data recorded by random sampling (Total Visits = 153, Sampling unit (N) = 236) from rural to urban gradient level of Jamnagar city; 4 to 8 times survey per month using plots and strip transects during day and night. The presence of 39 herpetofaunal species belong to 13 families reveal 17 species of anurans dominated by family - Dicroglossidae (568) and 22 species of reptiles by Agamidae (131). Skipper Frog (*Euphlyctis cyanophlyctis*) was most abundant species, single time sighted species was Jerdon's Bull Frog (*Hoplobatrachus crassus*) and 01 endangered species Nilgiri Frog (*Minervarya nilagirica*). From reptiles most abundant species was Common Garden Lizard (*Calotes versicolor*) and very common species Northern House Gecko (*Hemidactylus flaviviridis*). Overall species richness and diversity of reptiles were higher than amphibians (Simpson's diversity 1-D = 0.86/0.66; Simpson reciprocal diversity 1/D = 7.69/3.03; Shannon-Weiner H' = 2.39/1.73; Margalef's species richness (d) = 3.44/2.47; Pielou's evenness e = 0.49/0.33); whereas population density (390 individuals per km²/265 individuals per km²) and Dominance (0.34/0.14) were higher in amphibians than reptiles. This is the first records of such studies of these urban ecosystem.

Keywords: Checklist; conservation status; herpetofauna; Jamnagar city; Gujarat.

ABBREVIATION

VES : Visual Encounter Survey

AST : Auditory Strip Transect

IUCN : International Union for Conservation of Nature

CITES: Convention of International Trade in Endangered Species database

LED : Light-Emitting Diode

DSLRL : Digital Single-Lens Reflex

PAST : Paleontological Statistics software

App. : Appendix

Sch. : Schedule

EOS : Electro-Optical System

1. INTRODUCTION

Herpetofauna (amphibians and reptiles) are cold-blooded animals found in almost all the parts of the world, except the very cold regions. Worldwide 8,095

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species of amphibians include 7,140 species from anura (frogs and toads), 742 species from caudata (salamanders and newts), 213 species of gymnophiona (caecilians) [1] and 10,793 species of reptiles record 196 species of amphisbaenia (worm lizards), 6,512 species of sauria (lizards), 3,709 species of serpentes (snakes), 351 species of testudines (turtles, tortoises, terrapins), 24 species of crocodilia (crocodiles) and 1 species of rhynchocephalia (tuataras) [2]. In India 432 species of amphibians, include 391 species anura, 02 species caudata and 39 species gymnophiona [3]. Reptilian species records 572 species among them 3 species of crocodiles, 34 species of turtles and tortoises, 231 species of lizards and 304 species of snakes [4].

Since 1990 to 2018 herpetofaunal studies in Gujarat was highly concentrated in Protected Areas and Wildlife Sanctuaries [5,6,7,8,9,10,11,12,13,14,15,16,17]. Earlier records of herpetofauna from Gujarat in urban ecosystem has been studied by Stoliczka [18], Murray [19], McCann [20] from Kutch; Daniel and Shull [21] from Surat, amphibians of Gujarat [22,23,24,25]; reptiles of Gujarat studied by Sharma [26] and Gayen [27]. Recently anurans record from Jamnagar city [28] and herpetofaunal records of Rajkot city reported by Parmar and Trivedi [29]. Since no earlier records on the occurrence of herpetofauna in the Jamnagar city or of their population status are available in literature. So, the present paper on herpetofaunal studies give precise information about their occurrence, population, species and conservation status with update systematics of such urban ecosystem.

2. MATERIALS AND METHODS

2.1 Study Area

Jamnagar city is located (22.4707°N Latitudes and 70.0577°E Longitudes) at the Northern Kathiawar Peninsula from Western India and height of approximate 20 m above mean sea level. The selected study areas are bounded by Gulf and Desert of Kutch in the North coast and Arabian Sea in the West (Fig. 1); topography of Jamnagar is almost flat, having gentle slope towards North and towards Rangmati River in East. The entire study areas spreads in 285 km² which includes approximate 33.70 km² area of Jamnagar Municipal Corporation (i.e. urban site), Nagarsim area (Out Growth i.e. sub-urban site) and 26 villages (i.e. rural site) of Jamnagar Taluka as per Jamnagar Area Development Authority [30]. Ecological overview of Jamnagar city has major 09 parks and plenty of Municipal Corporation gardens; some seasonal river streams of Rangmati and Nagmati; both rivers flow towards the Gulf of Kutch

in the North and North-West; small Ranmal Lake is heart of the city. From rural sites major reservoirs are Ranjitsagar dam, Sasoi dam and Vijarkhi dam; more agro-lands and Protected Areas like Marine National Park and Khijadiya Bird Sanctuary are present.

2.2 Climate

The climate of Jamnagar city can be regarded as one of the extreme kind with hot summers and cold winters except in the coastal region, where it is generally pleasant all throughout the year. The air is humid due to the coastal location. Average maximum temperature ranges from 26°C to 36.5°C, minimum temperature ranges from 12°C to 28°C and average range of humidity 65.4% to 90.7% for morning and 28.1% to 77.9% in the evening throughout the study period. The area receives total annual rainfall 303 mm (2015), 435 mm (2016) and 697.2 mm (2017) (Pearl-Millet Research Station, Junagadh Agricultural University, Jamnagar, 2015-2017).

2.3 Field Survey Period and Time

The field surveys obtained for 29 months between August 2015 to December 2017 at Jamnagar city and its surroundings. Data collection followed by random sampling (Total Visits = 153, Sampling unit (N) = 236, Total survey of sampling unit areas (A)=1.67 km²) from rural to urban gradient level; using various sizes of plots (50m x 50m, 250m x 250m) and strip transects (10m x 50m, 20m x 100m) methods; approximate 4 to 8 times survey per month with two man hours 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.

2.4 Field Survey Techniques

Data records followed by Visual Encounter Survey (VES), Audio Strip Transects (AST) [31], Rescue Call (RC) and Road Kill (RK). Identification done by using various literatures and field guide as [32,33,34,35,36,37,38,39,40,41,42,43,44,45,46,47,48,49,50]. Systematic updates of amphibians and reptilians followed as per Frost [1] and Uetz et al., [2]. Morphological features observed in field and examined by photographs (Canon EOS 700D, 1100D and Canon Power shot A2300 digital camera) using Photoshop software and documented in Plate A, B, C, D.

2.5 Data Analysis

Checklist with updated systematics, local and conservation status (Table 1), class-wise herpetofauna

are summarized (Table 2), order wise population and species status (Fig. 2) and familial status up to genus (Fig. 3) and reptiles (Fig. 4).

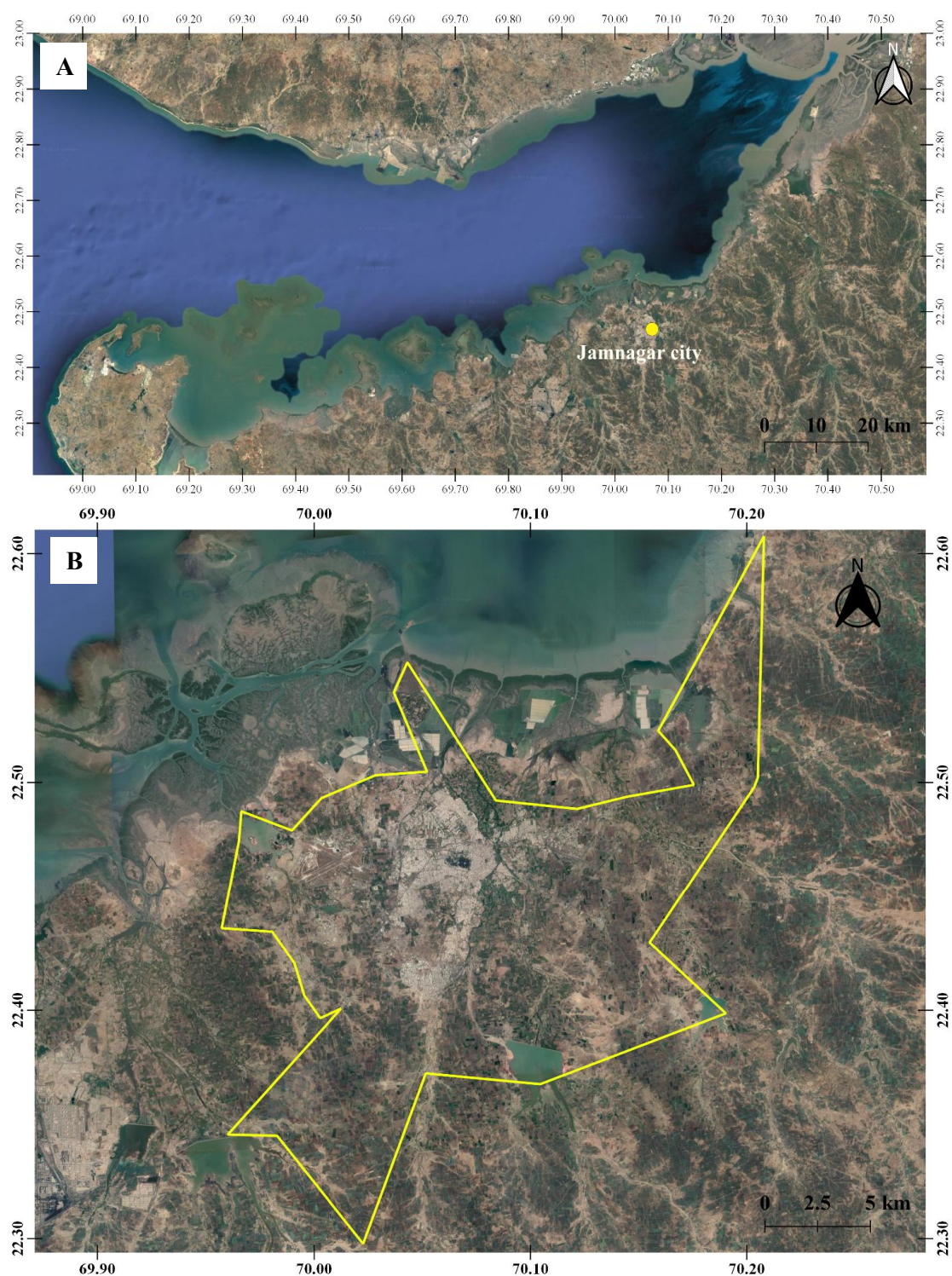


Fig. 1. (A) Location of Jamnagar city in Gujarat State. (B) Sampling areas of Jamnagar city and vicinities (Yellow line indicates last occurrence sampling areas)



1. *Duttaphrynus melanostictus*



2. *Duttaphrynus scaber*



3. *Duttaphrynus stomaticus*



4. *Euphlyctis cyanophlyctis*



5. *Fejervarya limnocharis*



6. *Hoplobatrachus crassus*



7. *Hoplobatrachus tigerinus*



8. *Minervarya brevipalmata*



9. *Minervarya chilapata*

Plate A. Recorded amphibian fauna of Jamnagar city and vicinities



10. *Minervarya keralensis*



11. *Minervarya nilagirica*



12. *Minervarya rufescens*



13. *Minervarya syhadrensis*



14. *Sphaerotheca breviceps*



15. *Sphaerotheca dobsonii*



16. *Sphaerotheca rolandae*



17. *Microhyla ornate*

Plate B. Recorded amphibian fauna of Jamnagar city and vicinities



18. *Lissemys punctata*



19. *Calotes versicolor*



20. *Sitana spinaecephalus*



21. *Hemidactylus brookii*



22. *Hemidactylus flaviviridis*



23. *Hemidactylus frenatus*



24. *Ophisops kutchensis*



25. *Eutropis carinata*



26. *Eutropis macularia*



27. *Lygosoma punctata*

Plate C. Recorded reptilian fauna of Jamnagar city and vicinities

The abundance status of the recorded amphibian species was established on the basis of frequency of sightings as, abundant (A) >17, common (C) between 12 to 16, frequent (F) - 6 to 11 and rare (R) - 1 to 5

times; for reptiles as, abundant (A) - >60, common (C) – 31 to 60, frequent (F) – 6 to 30 and rare (R) – 1 to 5 times (Table 1).



28. *Varanus bengalensis*



29. *Gongylophis conicus*



30. *Eryx johnii*



31. *Boiga trigonata*



32. *Coelognathus helena*



35. *Ptyas mucosa*



36. *Xenochrophis piscator*



37. *Bungarus caeruleus*



38. *Naja naja*



39. *Echis carinatus*

Plate D. Recorded reptilian fauna of Jamnagar city and vicinities (D33 & 34 Photos are not availed)

Ecological indices like Simpson diversity (1-D and 1/D); Shannon-Weiner diversity-H', evenness - $e^{-H/S}$ and Margalef's species richness (d) were computed (Table 3) using software PAST [51]. Interpretation regarding of biological diversity are followed as per Magurran [52]. [Where species density (S/A) = Total no. of Taxa (S) / Total survey of sampling unit areas (A); Population density (n/A) = Total no. of Individuals (n) / Total survey of sampling unit areas (A)].

3. RESULTS AND DISCUSSION

Herpetofauna representing 2 class, 03 orders, 13 family, 26 genera and 39 species (Table 1). Out of total 1099 individuals of herpetofauna total 654 individuals of amphibian belong to 17 species, 07 genera, 03 families and 01 order (anura); while total 445 individuals of reptiles belong to 22 species, 19 genera, 10 families and 02 orders (testudines and squamata) (Table 2). Orderwise population status were maximum in anura (59.51%) and species status were maximum in squamata (53.85%) from reptiles (Fig.2). Among squamata population and species status were maximum in saurians (lizards) 22.93%, 25.64% and serpentes (venomous and non-venomous snakes) 15.10%, 28.21% respectively.

3.1 Species and Community Structure

The familial status among amphibian (anuran) shows that members of family Dicroglossidae (Individuals-568, Genus-05, Species-13) stands on first position

followed by members of Bufonidae (74, 01, 03) and Microhylidae (12, 01, 01) shown in (Fig. 3). Among anurans, most abundant species was Skipper Frog - *Euphlyctis cyanophlyctis* (244 individuals, 33 time sighted) recorded mostly in aquatic and semi-aquatic habitats; common species Ferguson's Toad - *Duttaphrynus scaber* (35, 15) found in ditches, mud cracks, ground cracks and Short Webbed Frog - *Minervarya brevipalmata* (22, 12) recorded in shallow water, grass patches and ground cracks; most frequent species Indian Cricket Frog - *Fejervarya limnocharis* (53, 10) sighted near waterbodies and grass patches; rare species Indian Burrowing Frog - *Sphaerotheca breviceps* (07, 04) seen in grass patches, ground cracks and only single time sighted species was Jerdon's Bull Frog - *Hoplobatrachus crassus* (01, 01) recorded on terrestrial habitat and Southern Burrowing Frog - *Sphaerotheca rolandae* (04, 01) recorded in ground cracks (Table 1).

Among lizards, snakes and terrapins of reptile's maximum population were found in lizards (252 individuals, 10 species) followed by snakes (166, 11) and terrapins (27, 01) (Fig. 4). Most abundant species was Common Garden Lizard - *Calotes versicolor* (124 individuals, 76 time sighted) recorded from vegetation layers, building wall and road kill survey; most common species Northern House Gecko - *Hemidactylus flaviviridis* (71, 36) found primly on building wall; most frequent non venomous group of snake species was Checkered Keelback - *Xenochrophis piscator* (45, 17) recorded from freshwater pond, canal and near human habitation;

Table 1. Checklist of herpetofauna (Sampling unit, N = 236)

Scientific name	English name	Status		
		Local	IUCN	CITES
A. Class: Amphibia				
Order: Anura (Dumeril, 1806)				
(i) Family: Bufonidae (Gray, 1825)				
1. <i>Duttaphrynus melanostictus</i>	Common Indian toad	F	LC	-
2. <i>Duttaphrynus scaber</i>	Ferguson's Toad	C	LC	-
3. <i>Duttaphrynus stomaticus</i>	Marbled Toad	F	LC	-
(ii) Family: Dicroglossidae (Anderson, 1871)				
4. <i>Euphlyctis cyanophlyctis</i>	Skipper Frog	A	LC	-
5. <i>Fejervarya limnocharis</i>	Indian Cricket Frog	F	LC	-
6. <i>Hoplobatrachus crassus</i> ###	Jerdon's Bull Frog	R	LC	-
7. <i>Hoplobatrachus tigerinus</i> ###	Indian Bull Frog	F	LC	App.II
8. <i>Minervarya brevipalmata</i>	Short Webbed Frog	C	DD	-
9. <i>Minervarya chilapata</i>	Chilapata Rainpool Frog	R	DD	-
10. <i>Minervarya keralensis</i>	Verrucose Frog	F	LC	-
11. <i>Minervarya nilagirica</i>	Nilgiri Frog	F	EN	-
12. <i>Minervarya rufescens</i>	Malabar Wart Frog	F	LC	-
13. <i>Minervarya syhadrensis</i>	Long-legged Cricket Frog	R	LC	-
14. <i>Sphaerotheca breviceps</i>	Indian Burrowing Frog	R	LC	-
15. <i>Sphaerotheca dobsonii</i>	Dobson's Burrowing Frog	R	LC	-
16. <i>Sphaerotheca rolandae</i>	Southern Burrowing Frog	R	LC	-

Scientific name	English name	Status		
		Local	IUCN	CITES
(iii) Family: Microhylidae (Gunther, 1858)				
17. <i>Microhyla ornata</i>	Ornate Narrow-mouthed Frog	R	LC	-
B. Class: Reptilia				
Order: Testudines (Batsch, 1788)				
Suborder: Thecophora				
(i) Family: Trionychidae (Fitzinger, 1826)				
18. <i>Lissemys punctata</i> #	Indian Flap-shelled Turtle	F	LC	App.II
Order: Squamata (Oppel, 1811)				
Suborder: Sauria (Macartney, 1802)				
(ii) Family: Agamidae (Gray, 1827)				
19. <i>Calotes versicolor</i>	Common Garden Lizard	A	LC	-
20. <i>Sitana spinaecephalus</i>	Spiny-headed Fan-throated Lizard	F	LC	-
(iii) Family: Gekkonidae (Gray, 1825)				
21. <i>Hemidactylus brookii</i>	Brook's House Gecko	F	LC	-
22. <i>Hemidactylus flaviviridis</i>	Northern House Gecko	C	LC	-
23. <i>Hemidactylus frenatus</i>	Common House Gecko	F	LC	-
(iv) Family: Lacertidae (Oppel, 1811)				
24. <i>Ophisops kutchensis</i>	Kutch small-scaled snake-eye	R	NE	-
(v) Family: Scincidae (Gray, 1825)				
25. <i>Eutropis carinata</i>	Keeled Indian Mabuya	R	LC	-
26. <i>Eutropis macularia</i>	Bronze Mabuya	R	NE	-
27. <i>Lygosoma punctata</i>	Common Snake Skink	R	NE	-
(vi) Family: Varanidae (Merrem, 1820)				
28. <i>Varanus bengalensis</i> #	Indian Monitor	R	LC	App.I
Suborder: Serpentes (Linnaeus, 1758)				
(vii) Family: Boidae (Gray, 1825)				
29. <i>Gongylophis conicus</i> ###	Common Sand Boa	F	NE	App.II
30. <i>Eryx johnii</i> ###	Red Sand Boa	R	NE	App.II
(viii) Family: Colubridae (Oppel, 1811)				
31. <i>Boiga trigonata</i> ###	Indian Gamma Snake	R	LC	-
32. <i>Coelognathus helena</i> ###	Trinket Snake	F	NE	-
33. <i>Dendrelaphis tristis</i> ###	Bronzeback Tree Snake	R	NE	-
34. <i>Lycodon aulicus</i> ###	Common Wolf Snake	F	NE	-
35. <i>Ptyas mucosa</i> ##	Oriental Rat Snake	F	NE	-
36. <i>Xenochrophis piscator</i> ##	Checkered Keelback	F	NE	App.III
(ix) Family: Elapidae (F. Boie, 1827)				
37. <i>Bungarus caeruleus</i> ###	Common Krait	R	NE	-
38. <i>Naja naja</i> ##	Indian Cobra	F	NE	App.II
(x) Family: Viperidae (Oppel, 1811)				
39. <i>Echis carinatus</i> ###	Saw-scaled Viper	R	NE	-

Notes: LC-Least Concern, DD-Data Deficient, EN-Endangered, NE-Not Evaluated (IUCN, 2019); (#) denotes Schedule I, (##) Schedule II, (###) Schedule IV (WPA, 1972); A-Abundant, C-Common, F-Frequent, R-Rare

Table 2. Summary of herpetofauna during study period (2015 to 2017)

Class	Order	Family	Genus	Species	Individuals
Amphibia	Anura	3	7	17	654
Reptilia	Testudines	1	1	1	27
	Squamata	9	18	21	418
Total		13	26	39	1099

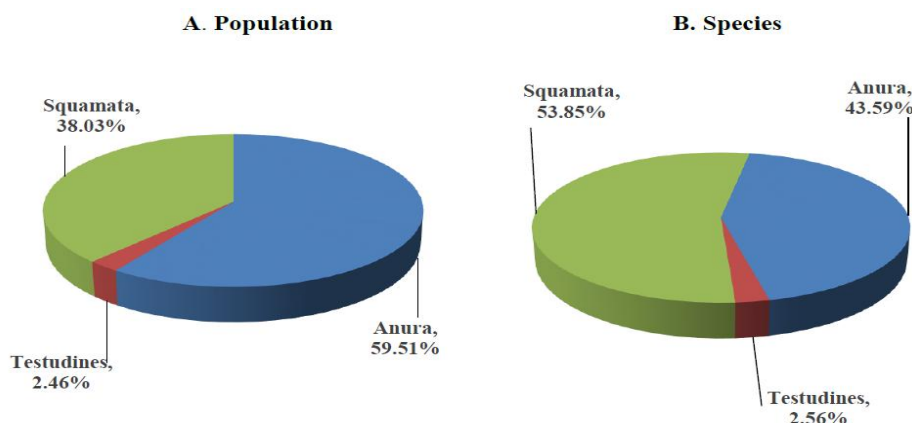


Fig. 2. Order-wise population and species status of herpetofauna

rarely seen species of lizard group was Bronze Mabuya - *Eutropis macularia* (3, 3) recorded from human habitation, leaf-litter and venomous snake species Common Krait - *Bungarus caeruleus* (4, 3) found by rescue call from human habitation; only single time sighted species was Common Snake Skink - *Lygosoma punctata* seen in grass patches and Bronzeback Tree Snake - *Dendrelaphis tristis* by rescue call (Table 1).

3.2 Conservation Status

3.2.1 Amphibians

Out of 17 species of amphibians reveal 14 species of Least concern (LC) category, 02 species (*Minervarya brevipalmata* and *Minervarya chilapata*) Data-deficient (DD) and 01 species (*Minervarya nilagirica*) Endangered (EN) [53]; 02 species (*Hoplobatrachus crassus* and *Hoplobatrachus tigerinus*) of Schedule IV [54]; only single species Indian Bull Frog (*Hoplobatrachus tigerinus*) of Appendix II [55] (Table 1).

3.2.2 Reptiles

Of these 22 species of reptiles represent 09 species of Least concern (LC) [53]; 02 species (*Lissemys punctata* and *Varanus bengalensis*) of Schedule I, 03 species (*Ptyas mucosa*, *Xenochrophis piscator* and *Naja naja*) of Schedule II and 08 species of Schedule IV [54]; 01 species *Varanus bengalensis* of Appendix I, 04 species (*Lissemys punctata*, *Gongylophis conicus*, *Eryx johnii* and *Naja naja*) of Appendix II and one Species Checkered Keelback - *Xenochrophis piscator* occurred from Appendix III [55] (Table 1).

3.3 Statistical Analysis

Population Density (n/A) and Dominance index (D) were higher in amphibians ($n/A=390/\text{km}^2$, $D=0.34$)

than reptiles ($n/N=265/\text{km}^2$, $D=0.14$) during entire study period. In general amphibians are less diverse due to specific habitat preferences and their population determines on aquatic habitat availability, habitat quality, habitat suitability, aquatic vegetation which provides shelter for larval and adult amphibians and oviposition sites [56,57], whereas terrestrial vegetation, fringing ponds and wetlands and upland plant communities provide opportunities for dispersal, food, shelter and overwintering sites, once individuals have metamorphosed [58] (Table 3).

Species Density (S/A), Simpson's index of diversity ($1-D$), Simpson's reciprocal index of diversity ($1/D$), Shannon Weiner index (H'), Pielou's Evenness index (e) and Margalef's index (d) were significant in reptiles (i.e. $S/A=13/\text{km}^2$, $1-D=0.86$, $1/D=7.69$, $H'=2.39$, $e=0.49$, $d=3.44$) than amphibians (i.e. $S/A=10/\text{km}^2$, $1-D=0.66$, $1/D=3.03$, $H'=1.73$, $e=0.33$, $d=2.47$) (Table 3). Amphibians are generally regarded as highly sensitive to environmental pollutants due to their biphasic lifecycle and physiological requirements [59]; whereas reptilians species diversity determines on key responses such as adaptation to wide geographic range, demography, species attributes and life history, response threshold, habitat preferences, acclimatization and high rate of dispersal supports to high diversity and species richness of reptiles than amphibians.

In similar studies of herpetofauna at different locations in urban ecosystem of Kathiawar dominance (D) of amphibians was higher, Simpson's diversity ($1-D$) and species richness (d) also significantly higher in reptiles supports with Parmar and Trivedi [29]. Differences may be due to ecological variations like physiological factors (i.e. temperature, humidity, rainfall, hydroperiod and edaphic factors), geographical structures and habitat characteristic, habitat loss, fragmentation and isolation, aquatic and terrestrial vegetation etc.

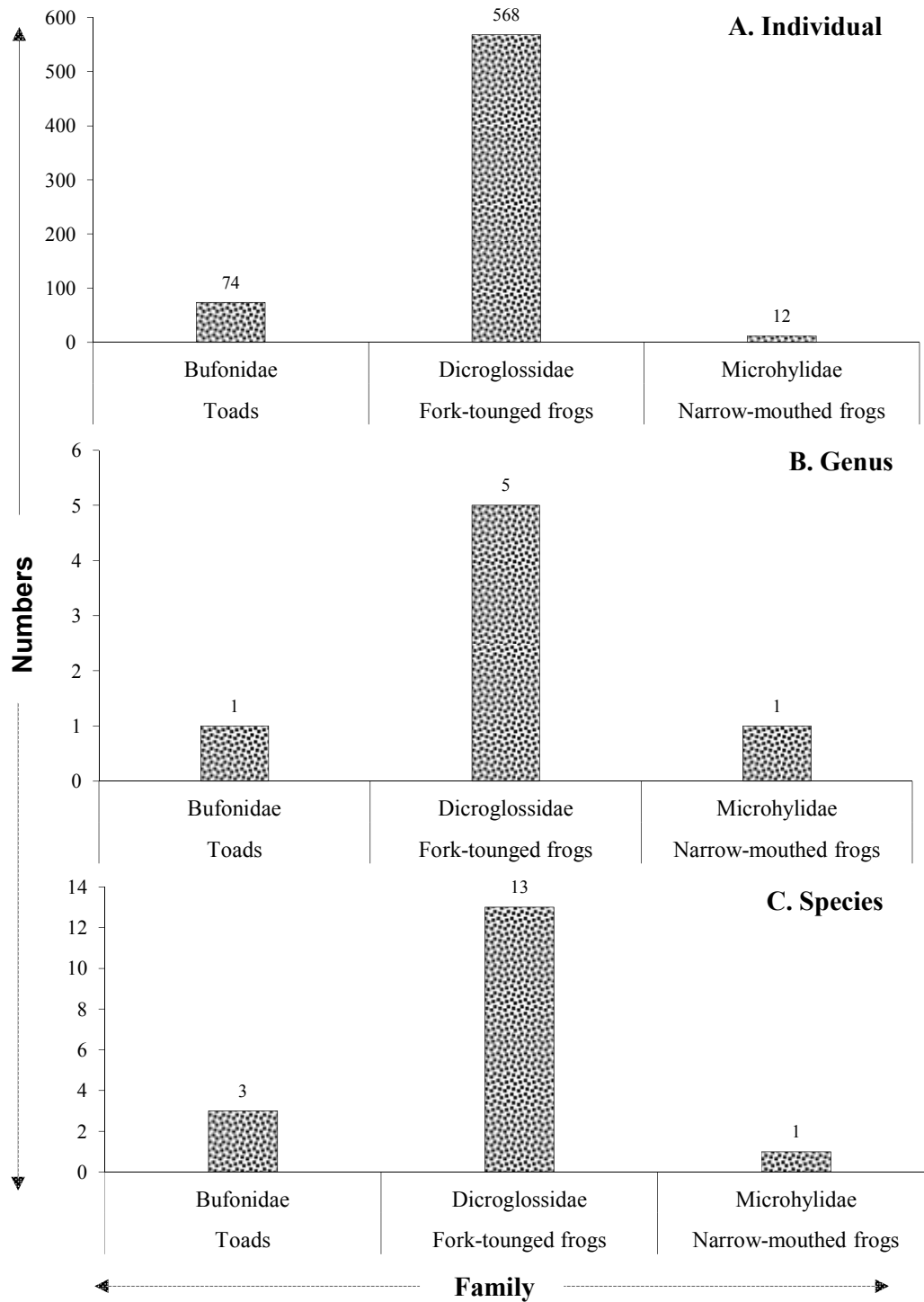


Fig. 3. Familial numbers of individual, genus and species of amphibians

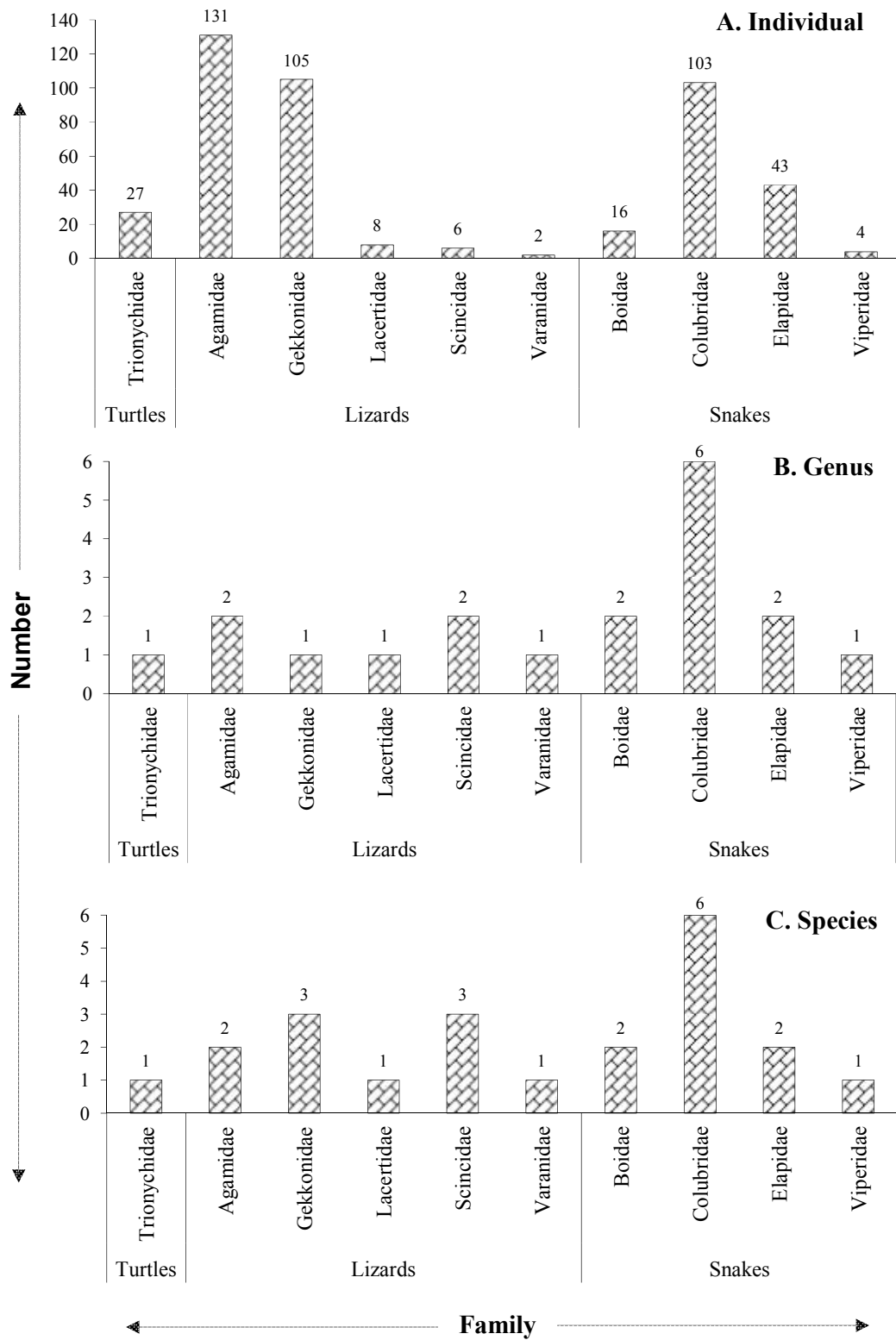


Fig. 4. Familial number of individual, genus and species of reptilians

Table 3. Statistical analysis of herpetofauna with comparison (2015 to 2017)

Sr.No.	Statistical Tests	Value		
		Amphibians	Reptilians	Herpetofauna
1	Total surveyed sampling unit areas (A)	1.67 km ²	1.67 km ²	1.67 km ²
2	Total sampling unit (N)	236	236	236
3	Total no. of Individuals (n)	654	445	1099
4	Total no. of Taxa (S)	17	22	39
5	Population Density (n/A)	390/km ²	265/km ²	656/km ²
6	Species Density (S/A)	10/km ²	13/km ²	23/km ²
7	Dominance (D)	0.34	0.14	0.14
8	Simpson's diversity Index (1-D)	0.66	0.86	0.86
9	Simpson's Reciprocal Index (1/D)	3.03	7.69	7.09
10	Species diversity (H') by Shannon-Weiner Index	1.73	2.39	2.67
11	Evenness index (e) by Pielou's (1966)	0.33	0.49	0.37
12	Species richness (d) by Margalef (1959) $d=(S-1)/\log N$	2.47	3.44	5.43

4. CONCLUSION

In conclusion, herpetofaunal population and species diversity was rich in such urban ecosystem (i.e. Jamnagar city and vicinities) during study period. This may be possible due to macro and microhabitats like agricultural lands in rural sites, water bodies, gardens / parks, vegetation, protected areas, etc. In addition, environmental factors like rainfall, temperature and humidity also provide the survival condition for the herpetofauna in urban environment. Herpetofaunal dominance, diversity and species richness helps to indicate the health of any ecosystems. Occurrence of some rare frog species like Jerdon's Bull Frog - *Hoplobatrachus crassus* and endangered Nilgiri Frog - *Minervarya nilagirica* is interesting of this study sites. This may give an important records for future studies and long term monitoring. Census data on common and specialist species are required for its local conservation and management.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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