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Diversity and distribution of anurans in Phansad Wildlife Sanctuary (PWS), northern Western Ghats of India

Unmesh Katwate [1], Deepak Apte [2] & Rupesh Raut [3]

[1,2] Bombay Natural History Society (BNHS), Hornbill House, Opposite Lion Gate, Shaheed Bhagat Singh Road, Mumbai, Maharashtra 400001, India
[3] Department of Zoology, Elphinstone College, Mumbai, Maharashtra 400032, India
[1] theunmesh@gmail.com (corresponding author), [2] spiderconch@gmail.com, [3] rupesh.raut@gmail.com

Abstract: In global consequences of rapidly changing climate and increased amphibian population decline, mapping amphibian diversity in biodiversity hotspots is essential. In this study we have systematically studied anurans of Phansad Wildlife Sanctuary in terms of species diversity, population structure, threat status and distribution. We recorded a total of 22 anuran species, of which 11 species are endemic to Western Ghats biodiversity hotspot. Family Dicroglossidae was found to be more species-rich. Spatial and temporal variation in anuran diversity was observed by using Shannon diversity and evenness indices. Most of the endemic and threatened anuran species are found to be associated with evergreen undisturbed forest patches. Habitat parameters like humidity, forest type, canopy coverage, riparian canopy coverage, stream persistence and litter depth are found to be major variables governing species diversity and distribution. Major anthropogenic threats to amphibians of Phansad Wildlife Sanctuary are discussed along with future conservation objectives. With range extension of species like *Fejervarya caperata* and *Minervarya sahyadris* further north in the Western Ghats, taxonomic ambiguities recorded during study are discussed briefly.

Keywords: Amphibians, diversity, endemism, species composition, threat status.

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Author Details: Unmesh Katwate is a zoology postgraduate currently working as Scientist-A in BNHS. He is studying ecology and conservation aspects of freshwater fishes and amphibians in northern Western Ghats and currently working on diversity and ecology of costal plateaus of Konkan in Western Ghats.
Deepak Apte a marine biologist and conservationist, currently a Chief Operating Officer (COO) of BNHS.
Rupesh Raut is a head of Department of Zoology, Elphinstone College. He works on ecology, systematic biology and molecular phylogeny of freshwater fishes and amphibians of Western Ghats.

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INTRODUCTION

The Western Ghats of India, ranked among 34 biodiversity hotspots (Mittermeier et al. 2005), are well known for rich amphibian diversity. Around 6,771 amphibian species are listed throughout the world, of which 333 species are recorded from India (Frost 2011). With the addition of one *Raorchestes* (Seshadri et al. 2012) the total number of amphibian species listed in the Western Ghats are 183, among them 162 (88.5%) are endemic (Gururaja 2012). Deforestation, changes in land use, urbanization and industrialization are major threats for the amphibians of Western Ghats (Daniels 1991; Ghate & Padhye 1996). Recent record of pathogenic fungus is also alarming (Nair et al. 2011). Out of total 160,000km^2 area of the Western Ghats only 9% area is protected under national parks and wildlife sanctuaries (Gunawardene et al. 2007) therefore management of biological resources is critical in the Western Ghats. To implement strong policies for amphibian conservation in the Western Ghats, systematic study, spatial mapping and long term monitoring of amphibian species are needed (Padhye & Ghate 2002; Dahanukar & Padhye 2005).

Amphibians of northern Western Ghats are relatively less studied as compared to the central and the southern Western Ghats. Species discoveries like *Gegeneophis nadkarnii* (Bhatta & Prashanth, 2004), *Indotyphlus maharashtraensis* (Giri et al., 2004), *Gegeneophis goaensis* (Bhatta et al., 2007), *Pseudophilautus amboli* (Biju & Bossuyt, 2009) and *Nyctibatrachus danieli* (Biju et al., 2011) are significant findings from this region. Taxonomic as well as certain ecological studies by Daniel (1974), Yazdani & Mahabal (1976), Ravichandran & Pillai (1990), Daniels (1992), Ghate & Padhye (1996), Sekar (1999), Padhye et al. (2002), Dahanukar & Padhye (2005), Biju & Bossuyt (2009), Kumbar & Patil (2010) and Biju et al. (2011) in Maharashtra region of northern Western Ghats are mostly confined to Bhimashankar, Mulshi region of Pune District, Satara, Sangli District and Amboli region of Sindhudurg District. Knowledge of amphibian diversity and its species assemblage structure is still unknown from other parts of northern Western Ghats, which is especially true for the Konkan region.

Gokhale & Velankar (1996) demarcated Phansad Wildlife Sanctuary (PWS) as a highly diverse region in Western Ghats because of its unique evergreen type of vegetation. Presence of regionally endangered and endemic semi-evergreen to evergreen plant communities rank this area to be one among the highest conservation priority zones of Maharashtra (Rodgers & Panwar 1998). Although forests of PWS are not directly connected to the main Western Ghats range but the similarity in the occurrence of flora and fauna is striking (Rodgers & Panwar 1988; Pande & Pathak 2005). Diversity and distribution of amphibians in PWS is not fully understood yet. In this study we have systematically documented diversity and distribution pattern of anurans in PWS. To our knowledge this is the first systematic effort ever taken to document amphibian fauna in PWS.

MATERIALS AND METHODS

Study area

PWS is situated on the lower hills of the Konkan coast, west of Sahyadri and it covers about 52.66km^2 area in the Raigad District, Maharashtra. It lies between 18.33–18.5^{0}N & 72.90–73.0625^{0}E with altitude ranging from 20m to 300m. Annual rainfall ranges between 2162mm and 3469mm. Parts of the study area have perennial sources of water bearing old evergreen type of forest. Small hilly regions and slopes show *Memecylon umbellatum* tree dominating the stunted evergreen type of forest. Plateau regions shows grassland type of habitat whereas boundary line areas of PWS are dominated by degraded moist deciduous type of forest. We have selected a total of eight different localities in the sanctuary area representing different habitats (Table 1 & Fig. 1). We surveyed this area from June to September 2011. Even though our study period was limited to four months, significant efforts were taken to give a broad exposure on status of amphibian fauna of PWS.

Data collection and analysis

Anuran species diversity in PWS was studied using two different methods. Ad-hoc search method was used to prepare a checklist of species present in the study area and belt transect method was used to quantify anuran diversity in different locations in PWS. Surveys were conducted mostly during late evening and early night; some areas were also searched during day time. At all sampling locations different habitat features like floor litter, underside rocks and boulders, tree barks and leaves, water pools, rocky crevices near flowing streams were documented and scanned for anurans. Sampling was performed by hand picking the specimen. Efforts were maintained to identify specimens up to species level in the field, body measurements of species taken with a digital caliper and individuals were released back at original location. In case of unidentified species representative voucher specimens were collected,

fixed in 4% formalin and stored in 70% alcohol. IUCN guidelines were followed for scientific collection of some threatened anuran species (IUCN 2011). Total of 3260 individuals were recorded of which only 17 were preserved for further investigation and others were released in the same location. Voucher specimens were deposited at Konkan field station museum of Bombay Natural History Society, Ratnagiri (accession numbers BNHS A1 to BNHS A17). Identification of specimens was done using standard taxonomic literatures like Boulenger (1890), Annandale (1919), Daniel (1963 a,b; 1975), Daniel & Sekar (1989), Bossuyt & Dubois (2001), Biju & Bossuyt (2009), and Biju et al. (2011). The threat status of the anuran species is adopted from IUCN Red List of Threatened Species-Version 2011.1 (IUCN 2011). Site specific anthropogenic threats observed in the study sites are listed in Table 1.

Biological parameters like percentage canopy cover, forest type, forest floor litter depth, riparian canopy cover (10m on both sides of the main stream) and physical parameters like altitude, atmospheric temperature and relative percentage humidity were recorded for each species during the study. Temperature and relative percentage humidity were recorded using digital hygro-thermometer. Canopy cover was estimated using spherical densiometer. All habitat variables were graded from lowest to highest values. Details of habitat guild classification are depicted in Table 2. Canonical Correspondence Analysis (CCA) has been proven to be one of best multivariate statistical tool to extract correlation between biological assemblage of species and their environment (Gururaja & Ramachandra 2012). We analyzed the relationship between biological and physical habitat parameters, study sites and species abundance data through CCA by using PAST ver1.98 (Hammer et al. 2001). Quantification of anuran diversity was performed by using the belt transect method. During the study period, two 100x5 m belt transects were laid at each study location every month. Transects were laid in such a way that they would overlap all possible breeding habitats. Active search for amphibians on transect were conducted by four people from 1700–2300 hr. Number of species and abundance of each species were recorded for each transect by visual encounter. Actual number

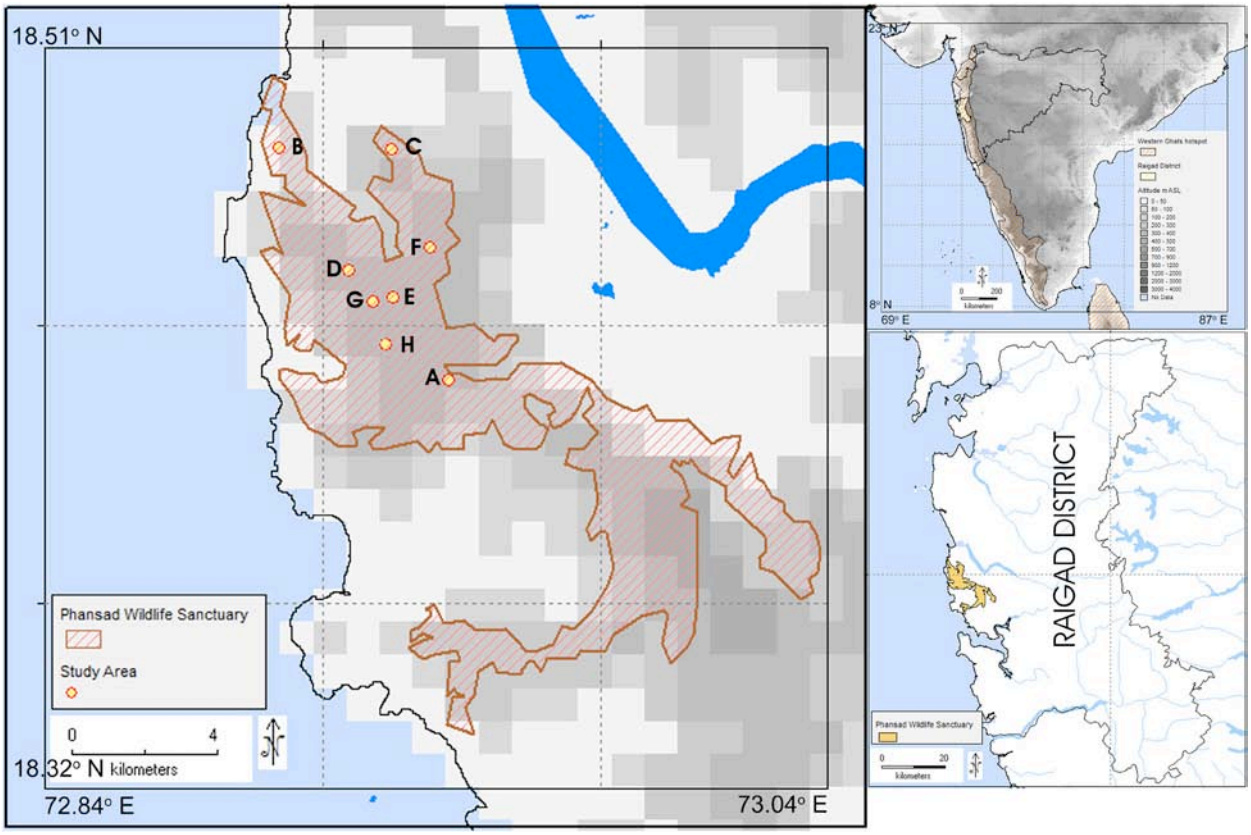

Figure 1. Sampling locations in Phansad Wildlife Sanctuary
A - Supegaon, B - Barshiv, C - Par Gaan, D - Chikhal Gaan, E - Phansad Gaan, F - Savarat Gaan, G - Chakacha Maal, H - Ghunyacha Maal.

Table 1. Habitat parameters recorded at the study sites.

Habitat parameters	Study sites							
	Supegaon	Barshiv	Par Gaan	Chikhal Gaan	Phansad Gaan	Savarat Gaan	Chakacha Maal	Ghunyacha Maal
Lat./long.	18.42°N 72.95°E	18.48°N 72.90°E	18.48°N 72.93°E	18.45°N 72.92°E	18.44°N 72.93°E	18.46°N 72.94°E	18.44°N 18.44°E	18.43°N 72.93°E
Canopy coverage (%)	40–60	20–50	40–60	80–91	70–80	60–80	Nil	Nil
Riparian canopy coverage (%)	50–63	0–40	30–63	83–91	78–87	75–87	Nil	Nil
Forest floor litter depth (mm)	0–100	0–50	0–100	100–200	70–150	70–180	Nil	Nil
Altitude (m)	245	104	159	236	237	227	281	294
Atmospheric temperature (°C)	29–32	30–33	28–31	26–29	27–29	27–29	28–33	28–33
Humidity (%)	70–86	68–83	77–85	88–97	89–97	87–97	75–90	75–91
Stream type	secondary streams	ephemeral primary stream	ephemeral primary stream	perennial primary stream	perennial primary stream	perennial primary stream	Nil	Nil
Stream habitat	cascade	cascade	cascade, run and dammed pools	cascade, run and dammed pools	cascade, run and dammed pools	cascade, run and dammed pools	Nil	Nil
Forest type	degraded moist deciduous forest, semi-evergreen forest	degraded moist deciduous forest	degraded moist deciduous forest	evergreen forest	evergreen forest	evergreen forest	grassland	grassland
Observed disturbances	deforestation for fire wood purpose, cattle grazing in forest area, laterite soil and boulder mining	deforestation by slash and burn, rice cultivation in reserved forest area, cattle grazing	deforestation by slash and burn method, rice farming, shift cultivation	Nil	Nil	cattle grazing, hunting are predominant human disturbances, deforestation for fire wood purpose	cattle grazing	cattle grazing

of individuals encountered during transect sampling were used to calculate percent species abundance at each study location in every month of the study period. Quantitative data generated from transect studies were used to calculate diversity and evenness indices (Magurran 1988). The Shannon index of diversity was calculated using the equation:

$$H' = -\sum p_i (\ln p_i),$$

where $p_i = n_i/N$ and n_i is the number of individuals of ith species and $N = \sum n_i$. Evenness index was calculated by the equation:

$$E = H'/\ln S.$$

Cluster plot indicating species composition similarity between different study locations was generated using Bray-Curtis similarity index (Magurran 1988). Observed species abundance may not always represent the true abundance of the communities therefore adequacy of sampling efforts was assessed by using species accumulation curves. Here, we have used EstimateS (version 8.0.0) software developed by Colwell (2006) for generating species accumulation curves, which uses Monte Carlo simulations of random samples drawn from the total set of samples for estimating the average species richness. We ran 200 randomizations for a given number of samples to estimate the species richness values and their means which were used for plotting species accumulation curves with respect to number of samples as well as against number of individuals recorded during study period. Species accumulation curves were found to be best fitted by using Michaelis-Menton equation

$$S_{obs} = S_{max}\, n/ (B + n),$$

where S_{max} is the maximum number of species, n is the number of individuals in the set of samples so far,

Table 2. Biological and physical habitat variables guild gradation for anurans recorded in study area.

Biological habitat variables		
Canopy coverage (%)	<50	1
	50–80	2
	80–100	3
Riparian canopy coverage (%)	<50	1
	50–80	2
	80–100	3
Forest type	Grassland/plateau	1
	Moist/semi-deciduous	2
	Evergreen	3
Forest floor litter (mm)	<50	1
	50–100	2
	100–200	3
Stream persistence	Seasonal	1
	Perennial	2
Physical habitat variables		
Altitude (m)	<100	1
	100–200	2
	200–300	3
Relative humidity (%)	<60	1
	60–80	2
	80–100	3

and B is the number of individuals needed to get half the maximum number of species, ie. When n = B, Sobs = $S_{max}/2$. Geographical map of study site (Fig. 1) was prepared by using DIVA-GIS (Hijmans et al. 2002).

RESULTS AND DISCUSSION

In the four-month study period we documented a total of 22 anuran species belonging to seven families and 15 genera (Table 3, Images 1–12). Family Dicroglossidae was found to be more species-rich covering about 41% (nine species) of the total anuran species recorded. Family Rhacophoridae was the second most species-rich family in our study area covering 23% of total anuran species (five species of arboreal frog). Family Microhylidae and Ranixalidae contributed 13.63% and 9.09%, respectively to the total anuran species found in the study area. Bufonidae, Nyctibatrachidae and Ranidae contributed 4.5% individually to total anuran species. We have reported total 11 anuran species (50% of total) from PWS showing exclusive endemism to Western Ghats. In the transect study we documented total 22 anuran species with an abundance of 3260 individuals in 64 samples. Our study period was restricted to four months only therefore there are possibilities of missing some rare and cryptic species during sampling efforts. Figs. 2a & 2b shows species accumulation curves plotted against number of samples (a) and number of individuals (b). The curves were found to best fit (R^2 =0.89) with S_{max} value at 22.

Study site A and F reported 15 and 14 species respectively. Minimum species were observed at sites G and H with 10 species each. Shannon H' diversity index values also predict the same pattern. Site A has highest H' value (1.01), while site G and H have lowest index values with 0.86 and 0.87. Despite of low species richness sites C, D and E have more evenly distributed species abundance with an E index value (S=11, E=0.94), (S=11, E=0.93) and (S=11, E=0.89) (Table 4). Anurans at site D and E show maximum species endemism with seven species followed by site F and A having six endemics of Western Ghats. Table 5 reveals that species richness and H' index value are found to be almost equal

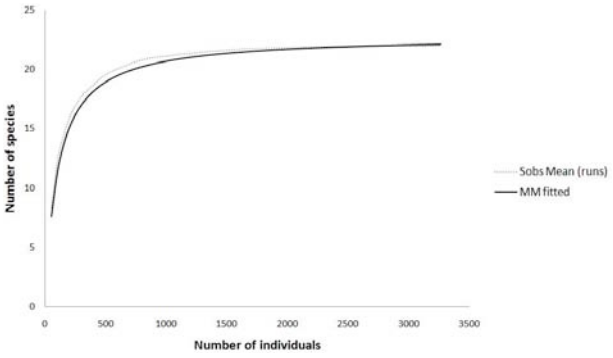

Figure 2 (a): Species accumulation curve – individuals vs. species richness (dotted grey line indicates observed species mean and black solid line indicates Michaelis-Menten mean).

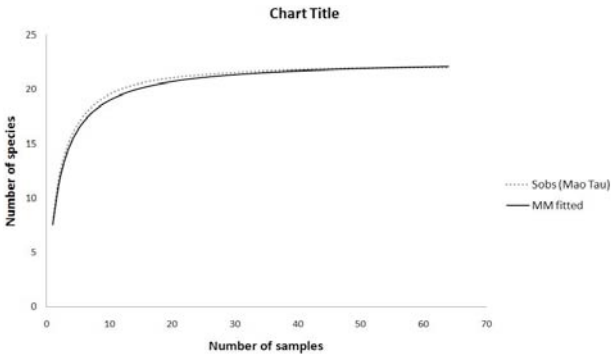

Figure 2(b). Species accumulation curve – samples vs. species richness (dotted grey line indicates observed species mean and black solid line indicates Michaelis-Menten mean).

Table 3. Anuran abundance recorded at different study localities in Phansad Wildlife Sanctuary (PWS).

Family/species [a]	Anuran abundance at different study localities [b]								Global Status [c]
	A	B	C	D	E	F	G	H	
Bufonidae									
Duttaphrynus melanostictus (Schneider, 1799)	40	25	16	0	0	9	0	0	LC
Dicroglossidae									
Euphlyctis cyanophlyctis (Schneider, 1799)	113	150	48	0	0	55	94	100	LC
Fejervarya cf. *keralensis** (Dubois, 1980)	32	2	25	0	0	0	26	26	LC
*Fejervarya caperata** (Kuramoto, Joshy, Kurabayashi & Sumida, 2007)	4	0	0	0	0	0	26	24	DD
*Fejervarya rufescens** (Jerdon, 1853) (Image 1)	56	47	33	51	29	7	86	66	LC
Fejervarya syhadrensis (Annandale, 1919)	82	43	40	0	0	6	84	52	LC
Hoplobatrachus tigerinus (Daudin, 1803)	30	54	19	0	0	29	16	12	LC
*Minervarya sahyadris** (Dubois et al. 2001) (Image 2)	83	41	90	0	0	27	102	80	EN
Sphaerotheca breviceps (Schneider, 1799) (Image 3)	83	45	23	0	0	10	46	39	LC
Sphaerotheca dobsonii (Boulenger, 1882) (Image 4)	6	0	0	40	25	0	2	1	LC
Microhylidae									
Microhyla ornata (Dumeril & Bibron, 1841) (Image 5)	0	0	0	0	0	0	11	17	LC
*Ramanella mormorata** (Jerdon, 1854) (Image 6)	4	1	0	0	0	0	0	0	EN
Uperodon globulosus (Gunther, 1864) (Image 7)	3	0	0	0	0	0	0	0	LC
Nyctibatrachidae									
*Nyctibatrachus humayuni** (Bhaduri & Kripalani, 1955) (Image 8)	0	0	0	18	7	0	0	0	VU
Ranidae									
*Hylarana malabarica** (Tschudi, 1838)	14	14	13	24	13	3	0	0	LC
Ranixalidae									
*Indirana beddomii** (Gunther, 1875) (Image 9)	0	0	0	30	23	3	0	0	LC
*Indirana leithii** (Boulenger, 1888)	0	0	0	16	10	1	0	0	VU
Rhacophoridae									
Polypedates maculatus (Gray, 1834)	48	46	14	45	66	33	0	0	LC
Polypedates cf. *maculatus* (Gray, 1834)	0	0	0	15	8	1	0	0	LC
Pseudophilautus cf. *amboli** (Biju & Bossuyt, 2009) (Image 10)	0	0	0	38	32	2	0	0	CR
*Raorchestes bombayensis** (Annandale, 1919) (Image 11)	17	0	8	98	68	45	0	0	VU
Raorchestes cf. *bombayensis** (Annandale, 1919) (Image 12)	0	0	0	28	23	0	0	0	VU

* Species endemic to Western Ghats.
a - Taxonomic status adapted from Boulenger (1890), Annandale (1919), Daniel (1963 a,b; 1975), Daniel & Sekar (1989), Bossuyt & Dubois (2001), Biju & Bossuyt (2009), and Biju et al. (2011).
b - Study area: A - Supegaon; B - Barshiv; C - Par Gaan; D - Chikhal Gaan; E - Phansad Gaan; F - Savarat Gaan; G - Chakacha Maal; H - Ghunyacha Maal.
c - Global status adapted IUCN 2011. IUCN Red List of Threatened Species. Version 2011.1. <www.iucnredlist.org>. Downloaded on 03 October 2011. LC Least Concern, DD- Data Deficient, VU- Vulnerable, EN- Endangered, CR- Critically Endangered.

throughout June, July and August with (S=21, H'=1.14), (S=20, H'=1.15) and (S=21, H'=1.11), respectively. A drastic fall in species richness and H' index value was observed in the month of September (S=15, H'=0.92). Similar pattern was found to be followed by evenness in anuran abundance with E= 0.78.

Our study period covers wet period of northern Western Ghats as it starts from June as south-west monsoon and ends in September. It has been already known that frogs in northern Western Ghats reproduce mainly in June and July because of longer dry period (Dahanukar & Padhye 2005). Maximum abundance was found in the month of June, about 1167 individuals were recorded. It is possibly because June marks the onset of south-west monsoon and it's a peak time for amphibian reproduction. Furthermore no drastic fluctuations in

Image 1. *Fejervarya rufescens*

Image 2. *Minervarya sahyadris*

Image 3. *Sphaerotheca breviceps*

Image 4. *Sphaerotheca dobsonii*

Image 5. *Microhyla ornata*

Image 6. *Ramanella mormorata*

abundance were observed from July to September but species diversity in the month of September declines drastically, only 15 species were observed in this month (Table 5). Fall in species richness, Shannon diversity and

Image 7. *Uperodon globulosus*

Image 8. *Nyctibatrachus humayuni*

Image 9. *Indirana beddomii*

Image 10. *Pseudophilautus* cf. *amboli*

Image 11. *Raorchestes bombayensis*

Image 12. *Raorchestes* cf. *bombayensis*

Table 4. Variation in species abundance, endemism, Shannon index and evenness index at various study locations in PWS.

Study sites	A	B	C	D	E	F	G	H
Species	15	11	11	11	11	14	10	10
Individuals	615	468	329	403	304	231	493	417
Endemic species	6	4	4	7	7	6	4	4
Endemic species (%)	40	36.3	36.3	63.6	63.6	42.8	40	40
Shannon H' index	1.016	0.881	0.942	0.972	0.935	0.918	0.868	0.876
Evenness index	0.863	0.845	0.942	0.933	0.897	0.800	0.868	0.876

A - Supegaon; B - Barshiv; C - Par Gaan; D - Chikhal Gaan; E - Phansad Gaan; F - Savarat Gaan; G - Chakacha Maal; H - Ghunyacha Maal.

Table 5. Changes in species abundance, Shannon index and evenness index of amphibians in total study period.

Month	June	July	Aug	Sep
Species	21	20	21	15
Individuals	1167	679	769	645
Shannon diversity index (H')	1.144	1.158	1.116	0.921
Evenness index	0.865	0.890	0.844	0.783

evenness index values in September (Table 5) indicates that the frogs in this region prefer earlier three months of wet period to reproduce and at the end of September their breeding activity drastically declines. We have never observed any calling activity of direct developing frogs like *Pseudophilautus* cf. *amboli, Raorchestes bombayensis* and *Raorchestes* cf. *bombayensis* as well as Wrinkled Frog, *Nyctibatrachus humayuni* in September. At broad level this might explain that these species prefer highly humid early and mid wet seasons for reproductive activity.

Habitat features plays an important role in governing species diversity and distribution of amphibians (Becker et al. 2007; Santos-Barrera & Urbina-Cardona 2011). Alteration and loss of habitat structure by multiple anthropogenic activities and changes in land use have been identified as the most critical factors affecting amphibian survival (Cushman 2006; Gardner et al. 2007; Urbina-Cardona 2008). In our study period we have recorded different habitat features at each study site. Table 1 shows that study areas in PWS were divided into three major types of habitats. Supegaon, Barshiv and Par Gaan bears degraded moist deciduous forest, Chakacha Maal and Ghunyacha Maal plateau showing typical grassland habitat while core areas of sanctuary like Chikhal Gaan, Phansad Gaan and Savarat Gaan showing *Memecylon umbellatum* dominated evergreen type of forest. Table 1 reveals that areas like Supegaon, Barshiv and Par Gaan are facing anthropogenic threats like human encroachment in sanctuary areas, extensive grazing, monotypic teak wood plantation, deforestation for firewood, slash and burn for shift cultivation (agriculture purpose) etc. In comparison of some physical and biological habitat parameters (Table 1) the Chikhal Gaan, Phansad Gaan and Savarat Gaan stands unique among other study sites in PWS because of atmospheric temperature of these areas ranges between 26–29 ^{0}C (vs. 28–33 ^{0}C in other areas), Humidity varies between 88–97 % (vs. 68–86 %) except Chakacha Maal and Ghunyacha Maal, canopy cover stands between 60–91 % (vs. 20–60 %), riparian canopy cover varies between 75-91% (vs. 0–63 %) and forest floor litter depth stands between 70–210 mm (vs. 0–70 mm at other sites). For implementation of systematic conservation efforts in the Western Ghats, biodiversity hotspot prioritization of highly diverse areas is essential (Myers 1990; Myers et al. 2000; Dahanukar & Padhye 2005; Mittermeier et al. 2005). Analysis of species assemblage similarity (Fig. 3) between study areas reveals Chikhal Gaan and Phansad Gaan forming a single and distinct cluster while other study areas remains separated.

Environmental parameters play an important role in species distribution, therefore understanding relationships between habitat characteristics and species distribution pattern is vital for developing effective conservation strategies for threatened taxa (Boyd et al. 2008). Anthropogenic activities like deforestation, construction of dams, human encroachment, slash and burn techniques for shifting cultivation, road construction and mining. had been known to be possible causes of changes in the habitat structure at landscape level which ultimately affects species diversity and their assemblage (Gururaja et al. 2008). It is already known that habitat destruction due to several anthropogenic activities has had a negative impact on amphibian diversity and distribution in Western Ghats (Krishnamurthy 1996,

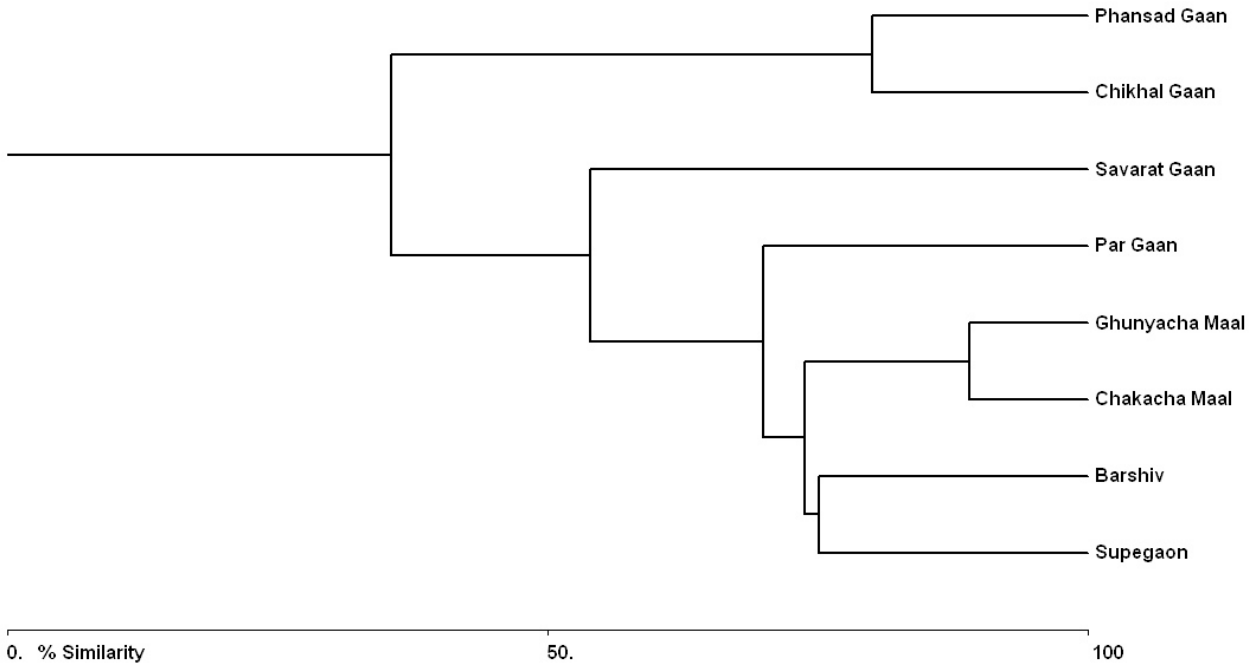

Figure 3. Dendrogram based on transect data analyzed by using Bray-Curtis similarity index, representing species assemblage structure similarity between different study areas of Phansad Wildlife Sanctuary.

2003; Padhye et al. 2002; Dahanukar & Padhye 2005; Krishnamurthy & Reddy 2008). Relationship between anuran species, study sites and habitat variables were predicted by using canonical correspondence analysis (CCA). Axis 1 & 2 represents species points which are determined by weighted average of axis values of preferred habitat variables and study sites in which they were occurred. CCA analysis extracted different axis scores for species point, study site and for habitat variables. Two best axis scores representing maximum variation in data were selected to draw the ordination plot (Fig. 4). Species points in this triplot formed their unique niche clusters with respect to different study locations and habitat variables. *Nyctibatrachus humayuni, Sphaerotheca dobsonii*, *Indirana beddomii, I. leithii*, *Polypedates* cf. *maculatus, Pseudophilautus* cf. *amboli, Raorchestes bombayensis* and *R.* cf. *bombayensis* forms a distinct species cluster showing two dimensional unique niche because they share similar type of habitat and prefers more humid evergreen forest patches. Like species points, similar habitat sharing study sites also form their clusters. CCA ordination triplot indicates variables like canopy cover, riparian canopy cover, forest floor litter depth, humidity, temperature, stream persistence and forest type shows high negative correlation with axis 1. Species and study sites present in ordination with axis 1 have high influence of environmental variables. Variable like altitude found to be positively correlated on axis 2. Species like *Duttaphrynus melanostictus, Euphlyctis cyanophlyctis*, *Fejervarya* cf. *keralensis, F. syhadrensis, Hoplobatrachus tigerinus, Minervarya sahyadris, Sphaerotheca breviceps, Ramanella mormorata* and *Uperodon globulosus* were found to be present in human disturbed areas like Supegaon, Barshiv and Par Gaan as well as it has been found that they are independent from habitat variable influence.

On a broad scale our current analysis of anuran distribution in PWS with respect to different study localities and habitat parameters (Fig. 4) indicates that anuran species like *Nyctibatrachus humayuni, Indirana beddomii, I. leithii*, *Polypedates* cf. *maculatus, Pseudophilautus* cf. *amboli, Raorchestes bombayensis* and *R.* cf. *bombayensis* were restricted to evergreen forest areas like Chikhal Gaan, Phansad Gaan and Savarat Gaan because of their specific habitat requirements like dense canopy coverage, maximum forest floor litter, low atmospheric temperature and high humidity. Whereas species like *Duttaphrynus melanostictus, Euphlyctis cyanophlyctis*, *Fejervarya* cf. *keralensis*, *F. syhadrensis, Hoplobatrachus tigerinus, Minervarya sahyadris* and *Sphaerotheca breviceps* showing maximum occurrence in human disturbed areas like Supegaon, Barshiv and Par Gaan having minimum canopy cover, minimum forest floor litter, low humidity and comparatively high

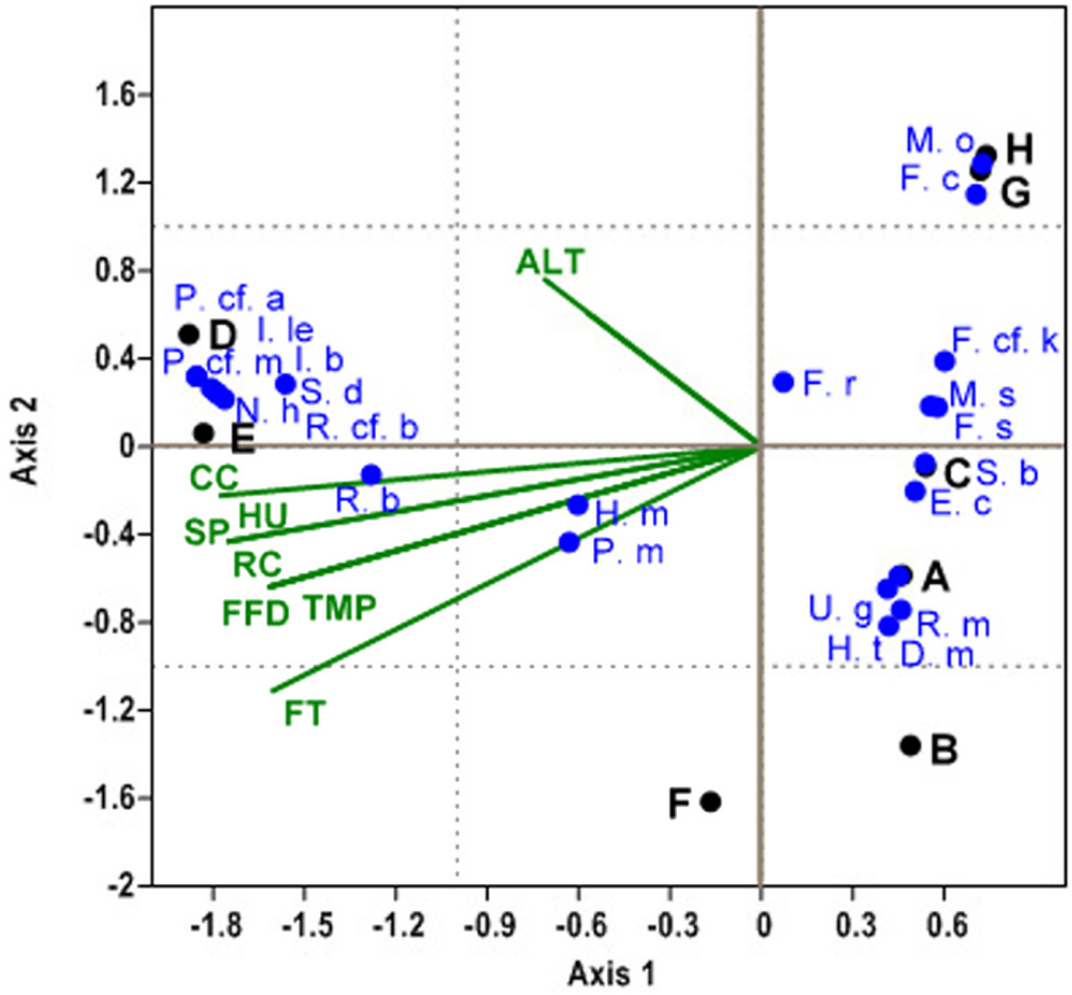

Figure 4. Canonical Correspondence Analysis (CCA) ordination triplot showing anuran species distribution with reference to study sites and habitat variables. Site labels are coded in Figure 1. Habitat variable codes: ALT – altitude; CC – canopy coverage; RC – riparian canopy coverage; HU – humidity; SP – stream persistence; FFD – forest floor litter depth; TMP – temperature; FT – forest type. Species codes: D. m - *Duttaphrynus melanostictus*; E. c - *Euphlyctis cyanophlyctis*; F. cf. k - *Fejervarya* cf. *keralensis*; F. c - *Fejervarya caperata*; F. r - *Fejervarya rufescens*, F. s - *Fejervarya syhadrensis*, H. t - *Hoplobatrachus tigerinus*; M. s - *Minervarya sahyadris*; S. b - *Sphaerotheca breviceps*; S. d - *Sphaerotheca dobsonii*; M. o - *Microhyla ornata*; R. m - *Ramanella mormorata*; U. g - *Uperodon globulosus*; N. h - *Nyctibatrachus humayuni*; H. m - *Hylarana malabarica*; I. b - *Indirana beddomii*; I. le - *Indirana leithii*; P. m - *Polypedates maculatus*; P. cf. m - *Polypedates* cf. *maculatus*; P. cf. a - *Pseudophilautus* cf. *amboli*; R. b - *Raorchestes bombayensis*; R. cf. b - *Raorchestes* cf. *bombayensis*.

temperature. CCA analysis results indicate that maximum conservation priority should be given to regions having high influence of habitat variables. Priority regions for long term anuran species and habitat monitoring in PWS should be Chikhal Gaan, Phansad Gaan and Savarat Gaan.

In this study we have recorded the occurrence of *Minervarya sahyadris* (Image 13) from PWS. Identification characteristics like rictal gland present just behind the mouth commissure, white horizontal band along the upper lip, smaller snout to vent length, pointed snout, fold from eye to shoulder, tympanum dark brown in color with inferior border white, digit tips rounded, very less developed webbing and reddish-brown mid dorsum color were observed among specimens recorded from PWS. This endemic species was earlier recorded from Calicut in Kerala and Gundia, Jog, Dandeli, Castle Rock in Karnataka (Dubois et al. 2001; Gururaja 2012). Occurrence of *M. sahyadris* in PWS shows the northward range extension of this species in Western Ghats. Another endemic dicroglossid *Fejervarya caperata* (Image 14) was also recorded during study. Characters like pointed snout, 20–35 mm snout to vent length, dilations absent on figure or toe tips, presence of fejervaryan line on the sides of abdomen, three distinct cross bars on thigh and four distinct longitudinal ridges on the back were

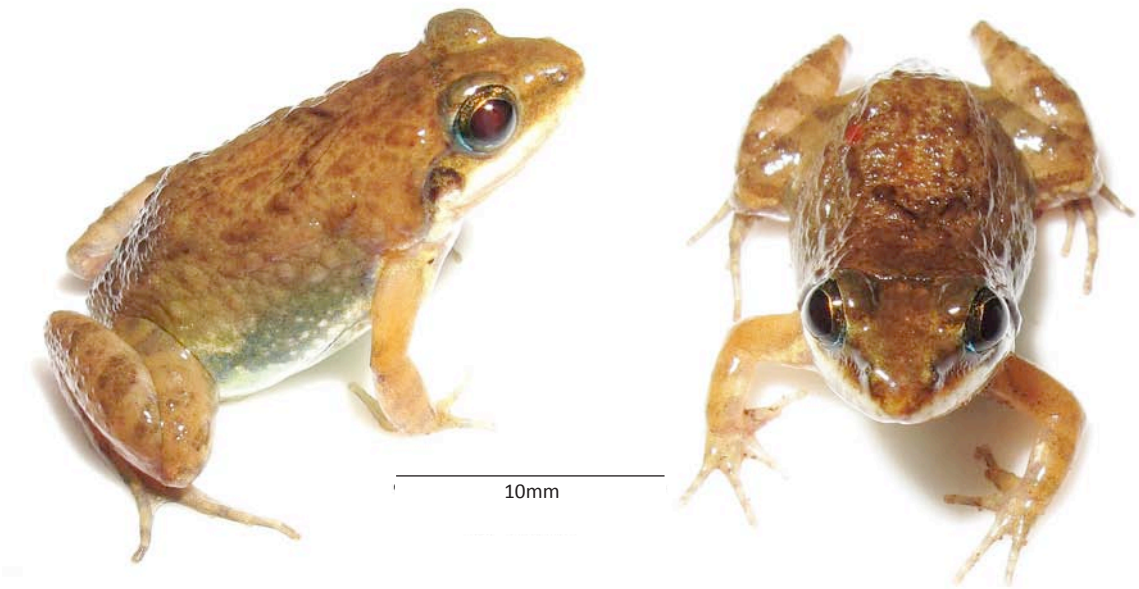

Image 13. *Minervarya sahyadris* recorded from Phansad Wildlife Sanctuary shows details of its body with (a) lateral and (b) anterior dorsal view.

Image 14. *Fejervarya caperata* sampled during study shows (a) lateral and (b) dorsal portions of its body.

observed among *F. caperata* specimens sampled during the study. Earlier records of this species were found from Karnoor, Bajpe, Shimoga, Jog, and Dandeli in Karnataka parts of Western Ghats (Kuramoto et al. 2007; Gururaja & Ramachandra 2012; Gururaja 2012). Record of this species in PWS also marks its range extension further north in Western Ghats.

We have reported some frog species from study area having ambiguous taxonomic status. Biju & Bossuyt (2009) described *Pseudophilautus amboli* from Amboli, Sindhudurg District of Maharashtra. Our PWS collections of *Pseudophilautus* cf. *amboli* differs from *Pseudophilautus amboli* (Biju & Bossuyt 2009) sensu stricto in the ratio of head width vs. head length as well in the proportion of third finger disc diameter vs. finger width. In consideration of such ambiguities further study is required to obtain presence of this species in PWS. Some population of *Raorchestes bombayensis* from our collection differs from original description of Annandale (1919) and latest reviewed description given

by Biju & Bossuyt (2009). *Raorchestes bombayensis* (Annandale 1919; Biju & Bossuyt 2009) sensu stricto differs from our PWS collection in having head width greater than head length (vs. head width almost equal to head length) and smaller eye length. Occurrence of *Fejervarya* cf. *keralensis* also needs further confirmation as it lacks spinular projections on thigh region. We have also collected some specimens of tree frogs *Polypedates* from our study area. Although some of our specimens matches very closely with description given by Daniel & Sekar (1989) for *Polypedates maculatus*, but they also differ in having comparatively smaller snout to vent length, tympanum almost equal to eye diameter and distinct striped banding pattern on dorsum.

Global threat status analysis of anurans recorded in this study (Table 3) shows that about seven species (32%) are threatened (Vulnerable (VU), Endangered (EN) or Critically Endangered (CR)). Fourteen species come under Least Concern (LC) category while one is Data Deficient (DD). Occurrence of CR species like *Pseudophilautus* cf. *amboli* as well as some EN and VU species like *Minervarya sahyadris*, *Nyctibatrachus humayuni*, *Indirana leithii* and *Raorchestes bombayensis* is important from conservation point of view.

In conclusion occurrence of around 50% endemic anuran species of which 32% are globally threatened marks PWS as key site for amphibian diversity in Western Ghats biodiversity hotspot. Implementation of strong conservation measures and policies are needed in PWS for amphibian conservation. This study would be beneficial in this context.

REFERENCES

Annandale, N. (1919). The fauna of certain small streams in the Bombay presidency. *Records of Indian Museum* 16: 109–161.

Becker, C.G., C.R. Fonseca, C.F.B. Haddad, R.F. Batista & P.I. Prado (2007). Habitat split and the global declines of amphibians. *Science* 318: 1775–1777.

Bhatta G. & P. Prashanth (2004). *Gegeneophis nadakarnii* - a caecilian (Amphibia: Gymnophiona: Caeciliidae) from Bondla wild life sanctuary, Western Ghats. *Current Science* 87(3): 388–392.

Bhatta, G., K.P. Dinesh, P. Prashanth & N.U. Kulkarni (2007). A new species of *Gegeneophis* Peters (Amphibia: Gymnophiona: Caeciliidae) from Goa, India. *Zootaxa* 1409: 51–59.

Biju S. D., I.V. Bocxlaer, S. Mahony, K.P. Dinesh, C. Radhakrishnan, A. Zachariah, V. Giri & F. Bossuyt (2011). A taxonomic review of the Night Frog genus *Nyctibatrachus* Boulenger, 1882 in the Western Ghats, India (Anura: Nyctibatrachidae) with description of twelve new species. *Zootaxa* 3029: 1–96.

Biju, S.D. & F. Bossuyt (2009). Systematics and phylogeny of *Philautus* Gistel, 1848 (Anura, Rhacophoridae) in the Western Ghats of India, with descriptions of 12 new species. *Zoological Journal of the Linnean Society* 155: 374–444.

Bossuyt, F. & A. Dubois (2001). A review of the frog genus *Philautus* Gistel, 1848 (Amphibia, Anura, Ranidae, Rhacophorinae). *Zeylanica* 6: 1–112.

Boulenger, G.A. (1890). *Fauna of British India Including Ceylon and Burma*, *Reptilia and Batrachia*. Taylor and Francis, London.

Boyd, C., T.M. Brooks, S.H.M. Butchart, G.J. Edgar, G.A.B. da Franseca, F. Hawkins, M. Hoffmann, W. Sechrest, S.N. Stuart & P.P. van Dijk (2008). Spatial scale and the conservation of threatened species. *Conservation Letters* 1: 37–43.

Colwell, R.K. (2006). EstimateS: Statistical estimation of species richness and shared species from samples. Version 8.0.0. User's Guide and application published at: http://purl.oclc.org/estimates.

Cushman, S.A. (2006). Effects of habitat loss and fragmentation on amphibians: A review and prospectus. *Biological conservation* 128: 231–240.

Dahanukar, N. & A. Padhye (2005). Amphibian diversity and distribution in Tamhini, northern Western Ghats, India. *Current science* 88(9): 1496–1501.

Daniel, J.C. & A.G. Sekar (1989). Field guide to the amphibians of western India, Part 4. *Journal of the Bombay Natural History Society* 86: 194–203.

Daniel, J.C. (1963 a). Field guide to the amphibians of western India. Part 1. *Journal of the Bombay Natural History Society* 60: 415–438.

Daniel, J.C. (1963 b). Field guide to the amphibians of western India. Part 2. *Journal of the Bombay Natural History Society* 60: 690–702.

Daniel, J.C. (1974). Amphibia. In: Kunte, B.G. (ed.). *Gazetteer of India, Maharashtra - State Gazetteers, General series: Fauna.* Government of Maharashtra publication.

Daniel, J.C. (1975). Field guide to the amphibians of western India—Part 3. *Journal of the Bombay Natural History Society* 72: 506–522.

Daniels, R.J.R. (1991). The problem of conserving amphibians in the Western Ghats, India. *Current science* 60: 630–632.

Daniels, R.J.R. (1992). Geographical range and ecology of the Verrucose Frog *Rana keralensis* (Dubois). *Journal of the Bombay Natural History Society* 89: 199–203.

Dubois, A., A. Ohler & S.D. Biju (2001). A new genus and species of Ranidae (Amphibia, Anura) from south-western India. *Alytes* 19(2–4): 53–79.

Frost, R.D. (2011). Amphibian Species of the World: an Online Reference. Version 5.5 (22 October 2011). Electronic Database accessible at http://research.amnh.org/vz/herpetology/amphibia/ American Museum of Natural History, New York, USA.

Gardner, T.A., J. Barlow & C.A. Peres (2007). Paradox, presumption and pitfalls in conservation biology: The importance of habitat change for amphibians and reptiles. *Biological Conservation* 138: 166–179.

Ghate, H.V. & A.D. Padhye (1996). Impact of urbanization on amphibians of Pune. *Zoos' Print* XI: 14–16.

Giri, V., D.J. Gower & M. Wilkinson (2004). A new species of *Indotyphlus* Taylor (Amphibia: Gymnophiona: Caeciliidae) from the Western Ghats, India. *Zootaxa* 739: 1–19.

Gokhale, V.V. & R.A. Velankar (1996). Documenting Peoples' Knowledge about Biodiversity at Supegaon Village. RANWA Technical Report 6.

Gunawardene, N.R., A.E.D. Daniels, I.A.U.N. Gunatilleke, C.V.S. Gunatilleke, P.V. Karunakaran, K.G. Nayak, S. Prasad, P. Puyravaud, B.R. Ramesh, K.A. Subramanian & G. Vasanthy (2007). A brief overview of the Western Ghats - Sri Lanka biodiversity hotspot. *Current Science* 11: 1567–1572.

Gururaja, K.V. (2012). *Pictorial Guide to Frogs and Toads of the Western Ghats*. Gubbi Labs, India, xviii+153pp.

Gururaja, K.V., S. Ali & T.V. Ramachandra (2008). *Influence of Land-use Changes in River Basins on Diversity and Distribution of Amphibians*. Environmental Education for Ecosystem Conservation. Capital publishing company, New Delhi.

Gururaja, K.V. & T.V. Ramachandra (2012). Anuran Diversity and Distribution in Dandeli Anshi Tiger Reserve. Sahyadri Conservation Series: 8 ENVIS Technical Report 37.

Hammer, Ø., D.A.T. Harper & P.D. Ryan (2001). PAST: Paleontological Statistics software package for education and data analysis. *Palaeontologia Electronica* 4(1):9.

Hijmans, R.J., L. Guarino, E. Rojas (2002). DIVA-GIS a geographic

information system for the analysis of biodiversity data. Manual, International Potato Center, Lima, Peru.

IUCN (2011). Guidelines for appropriate uses of IUCN Red List Data. Incorporating the Guidelines for Reporting on Proportion Threatened and the Guidelines on Scientific Collecting of Threatened Species. Version 2. Adopted by the IUCN Red List Committee and IUCN SSC Steering Committee. Downloadable from: http://intranet.iucn.org/webfiles/doc/SpeciesProg/RL_Guidelines_Data_Use.pdf. Downloaded on 10 September 2011.

IUCN (2011). IUCN Red List of Threatened Species. Version 2011.1. <www.iucnredlist.org>. Downloaded on 09 August 2011.

Krishnamurthy, S.V. (1996). Habitat features of amphibians in Sringeri, Western Ghats. *Zoos' Print* 8: 2–6.

Krishnamurthy, S.V. (2003). Amphibian diversity and consequences of habitat dissimulation on their distribution in central Western Ghats of Karnataka. SERC Research Highlights, Department of Science and Technology, India, 9–38.

Krishnamurthy, S.V. & A.H.M. Reddy (2008). An estimate of local population of *Nyctibatrachus aliciae* at two habitat gradients of forest in Western Ghats. *Acta Herpetologica* 3: 51–55.

Kumbar, S.M. & S.S. Patil (2010). Checklist and habitat of anuran species in the Sangli District, Maharashtra. *Frog leg* 14: 21–24.

Kuramoto, M., S.H. Joshy, A. Kurabayashi, M. Sumida (2007). The genus *Fejervarya* (Anura: Ranidae) in central Western Ghats, India with descriptions of four new cryptic species. *Current Herpetology* 26(2): 81–105.

Magurran, A.E. (1988). *Ecological Diversity and its Measurement.* Chapman and Hall, London, 192pp.

Mittermeier, R.A., P.R. Gil, M. Hoffman, J. Pilgrim, T. Brooks, C.G. Mittermeier, J. Lamoreux & G.A.B. da Fonseca (2005). *Hotspots Revisited: Earth's Biologically Richest and most Endangered Terrestrial Ecoregions.* Cemex, Mexico, 392pp.

Myers, N. (1990). The biodiversity challenge: expanded hotspots analysis. *The Environmentalist* 10: 243–256.

Myers, N., R.A. Mittermeier, C.G. Mittermeier, G.A.B. Da Fonseka & J. Kents (2000). Biodiversity hotspots for conservation priorities. *Nature* 403: 853–858.

Nair, A., O. Daniel, S.V. Gopalan, S. George, K.S. Kumar, J. Merilä & A.G.F. Teacher (2011). Infectious disease screening of Indirana frogs from the Western Ghats biodiversity hotspot. *Herpetological Review* 42: 554–557.

Padhye, A.D., M. Mahabaleshwarkar & H.V. Ghate (2002). An overview of amphibia fauna of Pune district with special reference to their status in and around Pune city. *Zoos' Print Journal* 17(4): 757–763.

Padhye, A.D. & H.V. Ghate (2002). An overview of amphibian fauna of Maharashtra state. *Zoos' Print Journal* 17(3): 735–740.

Pande, P. & N. Pathak (2005). *National Parks and Sanctuaries in Maharashtra.* Bombay Natural History Society, Volume II, 403–413pp.

Ravichandran, M.S. & R.S. Pillai (1990). Amphibia of Maharashtra with description of a new species of Torrent Toad, *Ansonia. Records of the Zoological Survey of India* 86: 505–513.

Rodgers, W.A. & H.S. Panwar (1988). *Planning A Wildlife Protected Area Network in India.* Volume 2. Wildlife Institute of India, Dehra Dun.

Santos-Barrera, G. & J.N. Urbina-Cardona (2011). The role of the matrix-edge dynamics of amphibian conservation in tropical montane fragmented landscapes. *Revista Mexicana de Biodiversidad* 82: 679–687.

Sekar, A.G. (1999). Four new records and checklist of amphibians from Maharashtra. *Journal of the Bombay Natural History Society* 96(1): 152–157.

Seshadri, K.S., K.V. Gururaja & N.A. Aravind (2012). A new species of *Raorchestes* (Amphibia: Anura: Rhacophoridae) from mid-elevation evergreen forests of the southern Western Ghats, India. *Zootaxa* 3410: 19–34.

Urbina-Cardona, J.N. (2008). Conservation of Neotropical herpetofauna: research trends and challenges. *Tropical Conservation Science* 1: 359–375.

Yazdani, G.M. & A. Mahabal (1976). Amphibians of Poona. *Newsletter of the Zoological Survey of India* 2: 138–139.