Anuran Diversity and Distribution in Dandeli Anshi Tiger Reserve

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2012

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Section 1

Section 2

Section 3

Acknowledgements

Introduction

What are Amphibians?

Amphibians include frogs, toads, salamander and caecilians, are the first tetrapod vertebrates dwell on land. They evolved from the bony fishes nearly 360 million years ago (in the late Devonian period). The early amphibian fossil records are from Madagascar Island. Amphibians got their name because they possess two life stages (in *Greek*, *amphi*-dual and *bios*-life form), one as tadpoles and other as adults. In general, tadpoles live in water and feed on algae, while adults (frog or toad) dwell on land or water and feed on insects. One can find amphibians in almost all the continents (except Antarctica). They are found in many habitats and microhabitats ranging from human habitations to desert regions. They are found inside the water, muddy and rock crevices, burrowing deep in the soil, or bushes, high canopy trees, etc. Rainy season are the best time to find amphibians. As rains provide adequate moisture to keep eggs from drying, many of the amphibians breed during this period having maximum chance of survival of their eggs. Generally, amphibians are active during night (nocturnal) and one can easily locate and identify the amphibian species based on their calls in the night hours.

MALABAR GLIDING FROG

TADPOLE OF SKITTER FROG

Amphibian Systematics: Present Scenario in the Western Ghats

All living and described amphibians are divided into three groups, namely, gymnophiona (caecilians and ichthyophis), caudata (salamanders and newts) and anura (frogs and toads). There are over 6,771 species of amphibians world over, of which India harbours about 337 species (Anil *et al.,* 2011a, 2011b; Biju *et al.,* 2011;Dinesh *et al.,* 2011). Species belonging to all three extant orders are recorded in India. The species distribution across India is not uniform, attributed mainly to the prevailing climate, phenology and topography (zoogeography) associated with habitat preferences of the species. Nearly 60% of the India amphibians are endemic to three important hotspots of

biodiversity, namely, the Western Ghats, the north-eastern Himalaya and the Andaman and Nicobar Islands.

The Western Ghats are 1600km long mountainous terrain from Kanyakumari to river Tapti (8°N to 21°N) along the West coast of India having an average width of about 100km, forms a key amphibian hotspot. Of the 180 species available from the Western Ghats (Dinesh and Radhakrishnan, 2001 and personal compilation), 160 species are described from the region. In the last decade, 80 new species are described from the region. This supports the estimation of Aravind *et al.*, (2004) and Gower *et al.*, (2004) of more species to be described from the Western Ghats. Among the described species, 87.8% (158 species) are endemic to the region.

Despite being rich in amphibians and their endemism, the Western Ghats still lack comprehensive list of amphibians available from the region, again due to the skewed availability of research output from Southern and Northern Western Ghats. Research on species distribution in the Western Ghats are limited to few studies, more scanty are on the protected areas (Inger *et al.*, 1984a, b; 1987; Daniels, 1992; Krishnamurthy, 2003; Naniwadekar and Vasudevan, 2007; Sameer Ali *et al.*, 2007).

There are several Protected Areas in the Western Ghats of Karnataka (for details please refer Sameer Ali *et al.*, 2007), but systematic amphibian research are carried out only in Kudremukh National Park (Krishnamurthy, 2003; Vasudevan *et al.*, 2006) and Sharavathi Valley Wildlife Sanctuary (Sameer Ali *et al.*, 2007). This is quite evident for Protected Areas of rest of the Western Ghats also (KalakkadMundanthurai Tiger Reserve, Vasudevan *et al.*, 2001; Naniwadekar and Vasudevan, 2007; Ponmudi, Inger *et al.*, 1984a, b; 1987). Das *et al.*, (2006) stress that amphibians are poorly represented from Protected Areas of the Western Ghats.

This study was carried out in DandeliAnshi Tiger Reserve to address the aforesaid issues in a systematic and scientific manner, so as to provide baseline information on amphibians of the region from Western Ghats and more specifically from a Protect Area.

Why study amphibians?

Amphibians inhabit two different habitats (water and land) during their life cycle.For surviving in two diverse habitats, they have unique adaptations to thrive well in these habitats. In their early life stage, amphibians are fish like (called tadpoles) with streamlined body (without scales), breath through gills and feed with labial palp (keratinized lips) on algae. Later on, they get retrogressively metamorphosed to adult frog/toad, where in the body completely loses fish like appearance. It now possesses lungs to respire, hands and legs to move, and frontally attached tongue and bony mouthparts to catch insects. In addition, amphibians also breathe through their skin. Generally,

amphibians have relatively wide distribution, bimodal life style, ectothermic conditions with stable environmental temperature of 20-30°C and moist permeable skin. All these have made them highly sensitive and susceptible to the external changes. Hence amphibians are regarded as the best ecological indicators among the vertebrates.

In the ecosystem, amphibians function both as prey and predator, and they constitute a vital component of the ecosystem. In ecosystem management, they are the best biological pest controllers. Amphibians are part of human culture (folk stories, frog marriages to get rain, Rig Vedic verses, etc) and food delicacy. In science education they have immense value as model specimen to understand anatomy and histology. Anti-microbial peptides are unique group of chemicals available in amphibian skin with very high therapeutic values in developing anti bacterial and anti fungal medicines.

WOLF SPIDER PREYING ON FROG

Over the last two decades, the amphibians are exhibiting decline in their population throughout the world as an indication of increased degradation, deterioration and alteration of habitat/microhabitat and changes in global climate (evidenced by increased UV-B radiation) due to anthropogenic activities. Land use and land cover changes coupled with indiscriminate usage of pesticide and fertilizers are the main drivers of habitat deterioration. Diseases, road kills and culling for trade (illegal smuggling) have also reduced the amphibian population. Amphibian decline has been considered as an early warning to human welfare in the future.

MALFORMATION IN BRONZED FROG

In tropics, diversity of amphibians are exceptionally high at the same time, these regions are prevailing under tremendous pressure from anthropogenic and anthropocentric activities. The amphibian declines in this region are sudden, selective and more pronounced that has necessitated the evolving of strategies for conservation and restoration of

amphibians and their habitats. Monitoring anuran diversity and their distribution would provide an insight into the prevailing conditions of an ecosystem and its health. Such monitoring and documentation are important towards assessment and conservation of biodiversity of a region, which in turn helps in prioritizing the region for immediate conservation and management action.

Captive breeding, *ex-situ* conservation practices like putting them in artificial amphibian parks are not effective for amphibian conservation. Catchment based conservation plans with holistic approaches are more suitable for amphibian conservation. This requires information on vital habitat variables such as humidity, temperature, vegetation, etc., of individual species. A well planned systematic study would provide such necessary information, ultimately helping in proper conservation measures for amphibians. Continuous monitoring and creating awareness in public and especially in the young minds will certainly help in effective conservation of amphibians (Gururaja, 2004).

Objectives

DandeliAnshi Tiger Reserve is one of among the protected areas along the Western Ghats and so far no systematic studies on anurans are carried out in DATR. Hence the present study was carried out with following objectives

- Systematic study on the anuran diversity in the region
- Anuran distribution maps, with comprehensive account on species rich regions within the ADTR.
- Monitoring protocols for the region

Materials and Methods

Study area

Dandeli Wildlife Sanctuary (DWS) and Anshi National Park (ANP), encompassing 475.02sq.km and 339.87sq.km respectively, were declared as DandeliAnshi Tiger Reserve (DATR) on 4th January 2007(Vide GO No. FEE 254 FWL 2006) with total area of 814.89sq.km. This region falls in the Western Ghats Protected Area Network. DATR is located in Uttara Kannada district of Karnataka state between 14.9564°-15.33227°N latitude and 74.2521°-74.7196°E longitude. In 1956, DWS was declared as a game sanctuary covering an area of 127.71sq.km. In 1975, the area was declared as a wildlife sanctuary and it was expanded to 5,729.07sq.km. In 1987, the wildlife sanctuary was divided into two protected areas: ANP and DWS, reducing the area of DWS to 834.157sq.km. In 1994, DWS was reduced again to 475.02sq.km. The present DATR boundary is based on Govt. of Karnataka order in 1998 (Figure 1). For more detailed account please refer to Tiger Conservation Plan (2008-2018).DATR forms major catchment area for River Kali with tributaries like Nagazhari and Kaneri.

Vegetation: The area of study is covered by moist deciduous and tropical semi-evergreentype of forests. There is a gradation of forest from moist deciduous with bamboo in eastern parts (Kulgi, Ambikanagar, Phansoli, Gund and Ulvi) to semi-evergreen in western parts (Kumbarwada, Amboli, Nujji, Badapoli and Anshi). According to Pascal (1988), the forest type in the Dandeli Wildlife Sanctuary, consists of *Lagerstroemiamicrocarpa-Tectonagrandis-Dileniapentagyna*with a very abundant population of bamboo (*Bamboo sp).* According to Champion and Seth (1968), five types of forests are identified in the DATR, namely, i) south Indian moist deciduous teak forest; ii) southern moist mixed deciduous forests; iii) west coast semi-evergreen forests; iv) moist bamboo brakes and v) cane brakes. However, this classification requires a proper ground truth in the present from DATR.

Climate and Geology: Seasonality is marked in DATR with pre-monsoon(March-June), monsoon (July-October) and post-monsoon (November-February) periods respectively. The south-west monsoon brings heavy rainfall in DATR with an average 2500mm (range 1250-4000mm). Rainfall gradient is very distinct in DATR with 5000mm on the Western part which gradually becomes 2000mm on the eastern part. Temperature varies from 13°C to 37°C, January and February being coldest and April and May being the warmest.

The rocks have undergone laterization to varying degrees in DATR. Gneiss is the underlying rock. It is often foliated and mixed with shale and mica schist. It isimportant to point that the economically

important ore that are found in this area are: iron,manganese, bauxite, limestone and clay.In the area soils are mainly lateritic soils, clayey rich in humus and well drained.

The average elevation of the area is 473 meters (minimum 40 m in Kali River,maximum 943 m in Dhavarlitemba).The Kali River and its tributaries (NagazhariHalla, SatkhandaHalla, and ShivapurHalla) originate in DWS. The Kali River is one of many rivers that flow in the WesternGhats. It is 184 km long and flows into the Arabian Sea.
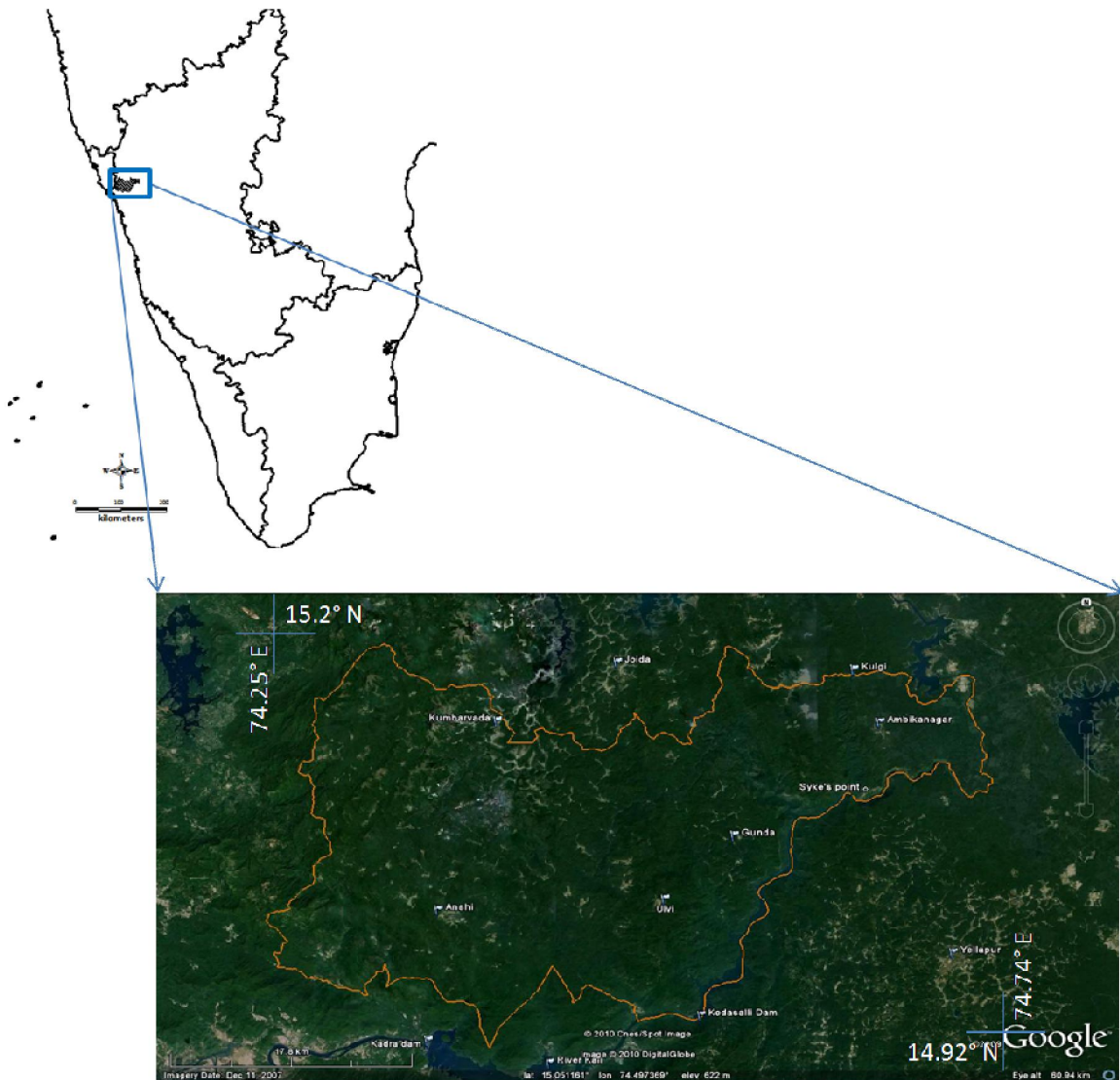

Figure 1.Boundary of Dandeli-Anshi Tiger Reserve. Image Source: Google

Amphibian Sampling

Sixteen sampling localities within DATR and four localities outside DATR were marked randomly with systematic stratified sampling method. Stratification is based on the land-use categories, namely, Forest, Teak/plantation, Water-bodies, Agriculture and Mining. Based on the percentage land-use composition, sampling is weighted accordingly, with ten sampling localities in forest, followed by water, plantation and agriculture with three each and one sampling in defunct mining areas. Table 1 and Figure 2 depict the sampling localities of the study area.

In the selected sampling sites, anurans were systematically sampled between 18:30-20:30hr from June-September 2008 and June-September 2009. Amphibians have been sampled similarly outside the DATR since 2007 in a project on Kali river catchment. Apart from these systematic surveys, opportunistic samplings were also done both in breeding and non-breeding period so as to include most of the species in the region. Visual encounters, calls, tadpoles, foam nests, spawn would be used to record the anurans in the field. Two man hours of searching is made using torch lights by walking across the streams, forest floors, gleaning leaf litters, prodding bushes, wood logs, rock crevices etc.

Species were measured (snout-vent length and weight) and released back. All species encountered are identified up to species level using the keys of Bossuyt and Dubois (2001), Daniels (2005) and Biju and Bossuyt (2009). In cases of likely new species, voucher specimens up to 6 individuals werepreserved in 70% alcohol morphological and molecular analysis in due course of time.

Table 1: Sampling plots for amphibian survey at DATR.

| Place	Code	Latitude (°N)	Longitude (°E)	Altitude (m)	Remarks
Within DATR					
Goira	DATR I	14.96194	74.28962	47	Agriculture
Badapoli	DATR II	15.01441	74.35596	532	Forest
Anshi	DATR III	15.01148	74.39502	529	Forest
Jhalavali	DATR IV	15.10174	74.38209	546	Forest
Kaneri bridge	DATR V	15.02469	74.46763	527	Forest
Cyntheri rock	DATR VI	15.08591	74.52303	446	Plantation
Ulvi	DATR VII	15.01365	74.50061	634	Agriculture
Gunda road	DATR VIII	15.13708	74.53978	483	Forest
Water	DATR IX	15.17264	74.56855	578	Water
Amgaon	DATR X	15.13677	74.61419	556	Agriculture
Water	DATR XI	15.10789	74.61771	563	Water
Mines	DATR XII	15.09609	74.60576	659	Mining
Nagazhari	DATR XIII	15.09002	74.64248	181	Forest
Nagazhari	DATR XIV	15.15467	74.63223	394	Forest
Kulgi	DATR XV	15.16804	74.65769	500	Plantation
Virnolii	DATR XVI	15.15933	74.7055	456	Plantation
Outside DATR					
Sakatihalla	DATR OUT I	14.9185	74.33778	30	Forest
Beegaru	DATR OUT II	14.90581	74.58308	283	Forest
Kanshirda Lake	DATR OUT III	15.21615	74.64164	479	Water
Deriye	DATR OUT IV	15.15003	74.4089	592	Forest
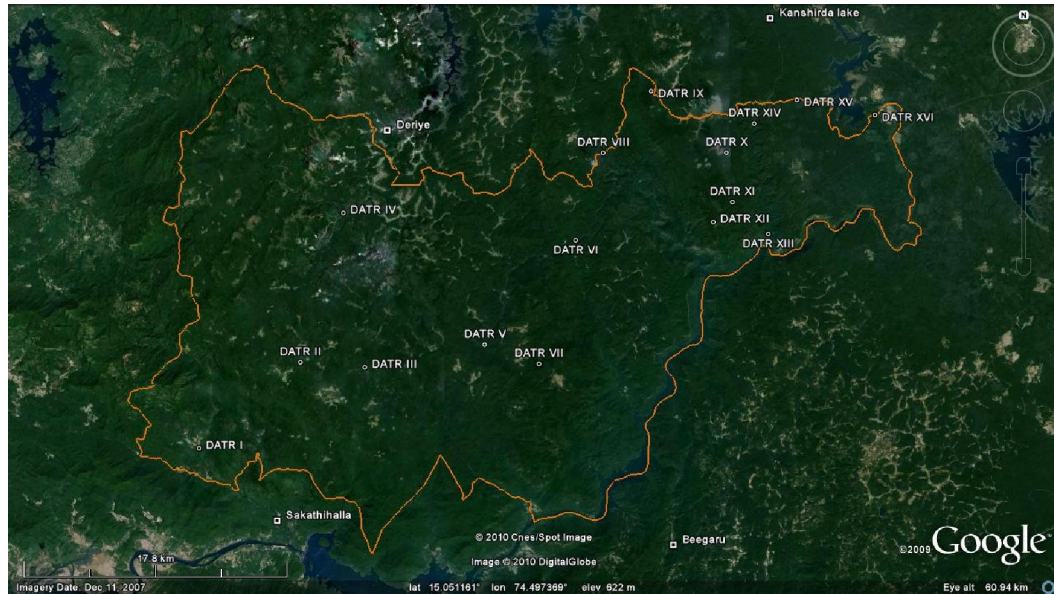
Figure 2. Amphibian sampling localities in DATR. Image Source: Google
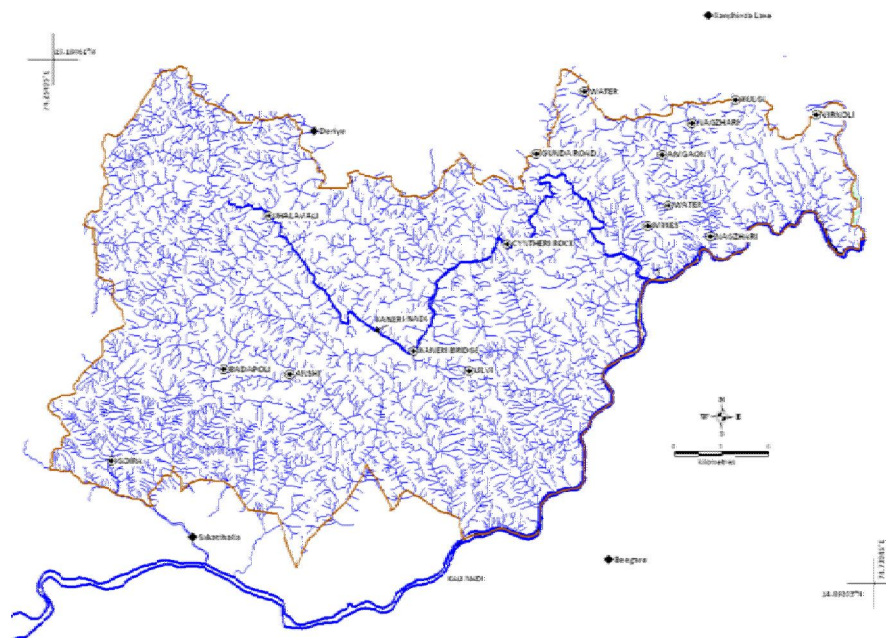

Figure 3. Drainage network of DATR with sampling localities.

Land-use and land-cover (LULC) Analysis

Multispectral satellite remote sensing images (IRS P6, LIS 3, 23.5m resolution) of 6 and 11 January 2004 were procured from National Remote Sensing Centre (NRSC), Hyderabad. Path and row corresponding to DATR were in three scenes, namely, 97:63, 97:62 and 96:62. These images were geo-corrected referring Survey of India toposheets (scale, 1:50 000; 48 I/8, I/12, J/5 and J/9) in IDRISI® remote sensing software. Band2, 3 and 4 corresponding to green, red and near-infra red (electromagnetic spectrum of 0.5-0.6, 0.6-0.7 and 0.7-0.9µm respectively) were used for false colourcomposite(FCC) generation. Land-cover analysis was done using vegetation index. The analogous behavior of red (R) and near infrared (NIR) bands over vegetated areas is used in this index, which clearly demarcates vegetated and non-vegetated areas. Normalized difference vegetation index (NDVI) based on the following formula, NDVI=(NIR-R)/(NIR+R). The output image values ranges from -1 to +1, wherein -1 indicates bare soil and +1 indicates complete vegetation. Land-use analysis was based on fuzzy classifiers of supervised classification approach. Ground truth data was used to assign a particular land-use. Fuzzy classification has yielded higher overall accuracy and Kappa statistic than most commonly used maximum likelihood approach.

Habitat Variables

Altitude (meters above sea level), rainfall (annual, mm), stream perenniality (seasonal or perennial), canopy cover (open, partial or closed) and predominating land-use (from the LULC analysis) are used to determine anuran distribution. These habitat variables were graded from lowest to highest. For the analysis, these grades are used than the actual values. Details of gradation are given in Table 2.

Table 2.Habitat variables with their grades.

Variable	Range	Grade
Altitude (m asl)	<150	1
	150-300	2
	300-450	3
	450-600	4
	>600	5
Rainfall (mm annual)	<2000	1
	2000-4000	2
	>4000	3
Stream persistence	Seasonal	1
	Perennial	2
Landuse	Mining	1
	Agriculture	2
	Plantation/Teak	3
	Water bodies	4
	Forest	5
Canopy cover	Open	1
	Partial	2
	Closed	3

Ecological Guild Analysis

For understanding complex patterns in biogeography, evolution and community structure, putting species into ecologically similar groups or guilds, irrespective of their taxonomic position has been an extremely useful tool(Wiens, 1989). Guild classification is also used to gain a greater understanding of spatial patterns of species richness and assemblage structure (Williams, 1997). Anuran amphibians in this study were classified into guilds on the basis of four variables describing their functional ecology, namely, endemism (referring to their spatial extent of occurrence), threat status (based on IUCN red data base, 2009), habitat specificity (aquatic to arboreal, considering aquatic to be very primitive) and finally tadpole habitat (direct development being considered most advanced). Table 3 details the ecological guild classification in the present study.

Table 3. Ecological guild gradation used in the present study.

Variable	Range	Grade
Endemism	Non-endemic	1
	India	2
	Endemic to Western Ghats-Sri Lanka Hotspot	3
	Endemic to the Western Ghats	4
Threat status	Data deficient	1
	Least concerned	2
	Near threatened	3
	Vulnerable	4
	Endangered	5
Habitat specific	Aquatic	1
	Semi-Aquatic	2
	Terrestrial	3
	Fossorial	4
	Arboreal	5
Tadpole	Aquatic	1
	Semi-aquatic	2
	Arboreal/Direct development	3

Diversity Measures

Alpha ( ) diversity is a measure of species diversity in a given habitat. It is measured both parametrically and non-parametrically. A simple species-abundance curve is a parametric measure of alpha diversity. Shannon's and Simpson's index are non-parametric measure of the same. Evenness is measured so as to know how evenly species are distributed in a locality. Beta ( ) diversity is the measure of degree of variation in diversity from two habitats, patches or communities. Bray-Curtis similarity measure is used to calculate beta diversity. These indices were measured using formula given in Table 4.

Table 4.Alpha and beta diversity measures used in the present study.

Index	Equation	Remarks	Reference
Shannon's	$H' = - p_i \ln p_i$	p_i is the proportional value of the ith species. Value ranges from 0-4.6	Ali *et al.,* 2007
Simpson's	$D = 1/ p_i^2$	p_i is the proportional value of the ith species.	Ali *et al.,* 2007
Evenness	$E = H'/ \ln S$	H' is Shannon's index, S is species richness	Ramachandra *et al.,* 2006
Bray-Curtis	$B_c = b+c/2a+b+c$	a is species common to both sites A and B, b is species unique to Site A and C is species unique to site B.	Ramachandra *et al.,* 2006

Statistical Analysis

Ecological data are quite distinct from the multivariate data for the following two reasons. First, most species occur only in a subset of the samples; hence they are indicative more of either presence or absence. Second, relationships between species and environmentalvariables are generally nonlinear, and non-monotonic. These two features make very difficult to analyze ecological data using linear based multivariate statistics like Principal component analysis. Canonical correspondence analysis (CCA) based on weighted averaging and ordination of reciprocal averaging of species and environmental data helps to elucidate the relationshipsbetween biological assemblages of species and their environment. Relationship between habitat variables, sampling localities and species abundance was estimated through CCA using PAST ver1.98 (Hammer *et al.,* 2001). CCA is a direct gradient analysis, where the gradient in environmental variables is known *a priori* and the species abundances are considered to be a response to this gradient (Legendre and Legendre, 1998). It is a multivariate methoddesignedtoextract synthetic environmental gradients from ecological data-sets.

Results and Discussions

Anuran Diversity

Twenty nine species of anurans were recorded from this region belonging to seven families and eighteen genera. This is nearly 19% of Western Ghats amphibians and 10% of Indian amphibians recorded till date. Table 5 details the species list with distribution and threat status. Twenty species among the total of twenty nine species (69%) are endemic (Endemism is categorized into species exclusive to the Western Ghats and Western Ghats-Sri Lanka hotspot). There are four endangered species recorded from DATR.

Table 5. Anuran amphibians recorded from DATR

Species	Common name	Distribution	Threat status‡
Family: Bufonidae			
Duttaphrynus melanostictus (Schneider, 1799)	Common Indian Toad	India	Least concerned
Duttaphrynus scaber Schneider, 1799	Ferguson's Toad	Endemic WG-SL	Least concerned
Pedostibes tuberculosus Gunther, 1875	Malabar Tree Toad	Endemic WG	Endangered
Family: Dicroglossidae			
Euphlyctis aloysii Joshy, Alam, Kurabayashi, Sumida and Kuramoto, 2009	Aloys skittering Frog	Endemic WG	Data deficient
Euphlyctis cyanophlyctis (Schneider, 1799)	Skittering Frog	India	Least concerned
Fejervarya caperata Kuramoto, Joshy, Kurabayashi and Sumida, 2007	Wrinkled Fejervarya	Endemic WG	Data deficient
Fejervarya rufescens (Jerdon, 1853)	Reddish Burrowing Frog	Endemic WG	Least concerned
Fejervarya Sp. 1			
Fejervarya Sp. 2			
Hoplobatrachus tigerinus (Daudin, 1802)	Indian Bull Frog	India	Least concerned
Minervarya sahyadris Dubois, Ohler and Biju, 2001	Minervarya Frog	Endemic WG	Endangered
Sphaerotheca breviceps (Schneider, 1799)	Indian Burrowing Frog	India	Least concerned
Sphaerotheca leucorhynchus? (Rao, 1937)	Rao's Burrowing Frog	Endemic WG	Data deficient
Family: Microhylidae			
Kaloula taprobanica Parker, 1934	Sri LankanKaloula	India	Least concerned
Microhyla ornata (Dumeril and Bibron, 1841)	Ornate Narrow-mouthed Frog	India	Least concerned
Microhyla rubra† (Jerdon, 1854)	Red Narrow-mouthed Frog	Endemic WG-SL	Least concerned
Ramanella marmorata Rao, 1937	Marbled Ramanella	Endemic WG	Endangered

Family: Nyctibatrachidae				
Nyctibatrachus petraeus Das and Kunte, 2005	Castle rock Night frog	Endemic WG	Least concerned
Family: Ranidae				
Clinotarsus curtipes (Jerdon, 1853)	Bicoloured Frog	Endemic WG	Near threatened
Hylarana malabarica (Tschudi, 1838)	Fungoid Frog	India	Least concerned
Hylarana temporalis (Gunther, 1864)	Bronze Frog	Endemic WG-SL	Near threatened
Family: Ranixalidae				
Indirana beddomii (Gunther, 1875)	Beddome's Indian Frog	Endemic WG	Least concerned
Indirana semipalmata (Boulenger, 1882)	South Indian Frog	Endemic WG	Least concerned
Family: Rhacophoridae				
Pseudophilautus amboli (Biju and Bossuyt, 2009)	Amboli bush frog	Endemic WG	Data deficient
Raorchestes bombayensis (Annandale, 1919)	Maharashtra Bush Frog	Endemic WG	Vulnerable
Raorchestes tuberohumerus† (Kuramoto and Joshy, 2003)	Kudremukh Bush Frog	Endemic WG	Data deficient
Pseudophilautus wynaadensis† (Jerdon, 1854)	Dark-eared Bush Frog	Endemic WG	Endangered
Polypedates maculatus (Gray, 1833)	Chunam Frog	India	Least concerned
Rhacophorus malabaricus Jerdon, 1870	Malabar Gliding Frog	Endemic WG	Least concerned

Note: WG-Western Ghats; WG-SL-Western Ghats and Sri Lanka † opportunistic sightings and not included in further analysis, ‡ based on IUCN, 2009;

Considering number of species in each family, Dicroglossidae represents maximum of 10 species, followed by Rhacophoridae and Microhylidae with six and four species respectively. Nyctibatrachidae is represented by only one species. All species in Nyctibatrachidae, Ranidae and Ranixalidae families are endemics. Dicroglossidae and Microhylidae, even though have more species, but have only 50% of them as endemics. Familial break up of genera, species and endemics are given in Table 6.

Table 6. Species, genera and endemics represented in each family recorded from DATR.

Family	Genera	Species	Endemics
Bufonidae	3	3	2
Dicroglossidae	5	10	5
Microhylidae	3	4	2
Nyctibatrachidae	1	1	1
Ranidae	2	3	3
Ranixalidae	1	2	2
Rhacophoridae	3	6	5

MALABAR TREE TOAL

Bufonidae

Bufonidae represents three species belonging to two genera. Species in this family are called 'toads' and generally prefer terrestrial habitat. Malabar tree toad (*Pedostibestuberculosus*) is an arboreal toad recorded from DATR. It is an endangered and endemic species.

Dicroglossidae

Maximum species (10) were recorded in this family. This family represents most common and diverse habitat dwellers in a region. They can be observed in majority of the habitats, including human habitations. *Minervaryasahyadris* being the smallest species in this family, while *Hoplobatrachustigerinus*(Indian Bull Frog) being the largest. Recently described species, *Euphlyctisaloysii*s recorded for the first time from DATR. Burrowing frogs (*Sphaerothecabreviceps*and *S. leucorhynchus?*) are also recorded in this family.

MINERVARYA FROG

ALOYS SKITTER FROG

Microhylidae

Four species belonging to Microhyla, Kaloula and Ramanella genera are recorded in the present study. *Ramanella mormorata* (Marbled Ramanella) is an endemic and endangered species recorded in DATR. Microhylidmembers are known for their loud advertisement calls during breeding season. *Microhylaornata*, *M. rubra* and *Kaloulataprobanica* are the other species in this family.

ORNATE NARROW MOUTHED FROG

MARBLED RAMANELLA

Nyctibatrachidae

Castle rock night frog (*Nyctibatrachuspetraeus*) is the only species observed from this family. This species was discovered from Castle rock in 2005. The species is known lay eggs on leaves and tree trunks.

Ranidae

Bicoloured frog (*Clinotarsuscurtipes*), Bronze frog (*Hylarana temporalis*) and Fungoid frog (*Hylaranamalabarica*) represent Ranidae. Bicoloured frog is the most common species among the three.

CASTLEROCK NIGHT FROG

Ranixalidae

*Indiranabeddomi*and*I. semipalmatus* represent this family. Members of this family are generally called leaping frogs for their agility. Both species are endemic to the Western Ghats.

BRONZED FROG

SOUTH-INDIAN FROG

Rhacophoridae

Arboreal frogs (Tree and Bush frogs) are members of Rhacophoridae. *Raorchestes bombayensis*(Maharashtra bush frog), is a species discovered from Castle rock by Annandale in 1919. Amboli bush frog (*Pseudophilautus amboli*)is a recently described species (Biju and Bossuyt, 2009) recorded from DATR. Malabar gliding frog (*Rhacophorusmalabaricus*) is an endemic tree frog observed from DATR. *Polypedatesmaculatus* (Chunam frog) is other tree frog from DATR.

MALABAR GLIDING FROG

CHUNAM FROG

AnuranAbundance

Table 7 provides sampling localities and species abundance recorded in the present study from DATR. *Euphlyctiscyanophlyctis* is the most abundant and most frequently encountered species. According to IUCN red list (2009), it is least concerned in threat status. Similarly, *Nyctibatrachuspetraeus*, also a least concerned species is the second most abundant species at DATR. Species total abundance and frequency are illustrated in Figure 4. It is quite evident that high threat status species and endemic species are recorded with low abundance and low frequency, excluding *Duttaphrynus scaber, Euphlyctisaloysii, Indiranabeddomii, Kaloulataprobanica*and*Sphaerothecaleucorhynchus?*

Table 7.Anuran abundance in sampling localities at DATR.

Species	I	VII	X	XII	VI	XVI	XV	II	III	IV	V	XIII	XIV	VIII	IX	XI	O_I	O_II	O_III	O_IV
Bu_sc							1													
Cl_cu	1				2	4				1										
Du_me		2		3	2	2					2		2			1				
Eu_al																			1	
Eu_cy	28	12	40	2	10	2	4				16	6	4	2	6	10	28	20	48	
Fe_ca		4	1		4		1	1			2				3	5	4			7
Fe_ru	1														2	1				2
Fe_sp1			1			2			2					2		23			5	3
Fe_sp2						1										2				
Ho_ti		1						3		1	1			2						
Hy_ma																2				
Hy_te				2				2		3		2	2			1		5		
In_be													1							
In_se					3			2			2	4						6		
Ka_ta							1													
Mi_or		6					3								2					
Mi_sa		4					2		1			2				1				
Ny_pe								3	5	1	3	2	3	11		1		15		3
Pe_tu								2												
Ph_am	4		1	2	3		4	6	7	1	4			4		3				6
Ph_bo					2		3	10	2	1	2					1				6
Po_ma							2					2				1				
Ra_mo							1		1					2						
Rh_ma											2									
Sp_br						1	1								2					
Sp_le							1													

Note: Species names are abbreviated with two letters from genus and two from species. Sites with roman numerals are coded in Table 1.
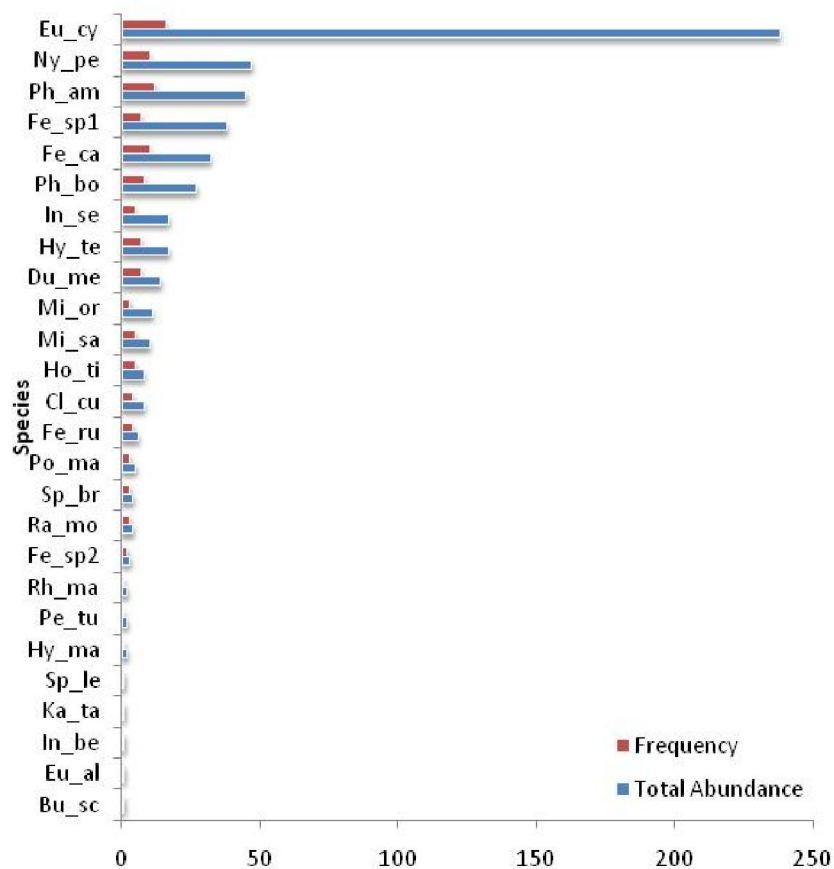
Figure 4.Total abundance and frequency of occurrence in anurans of DATR.
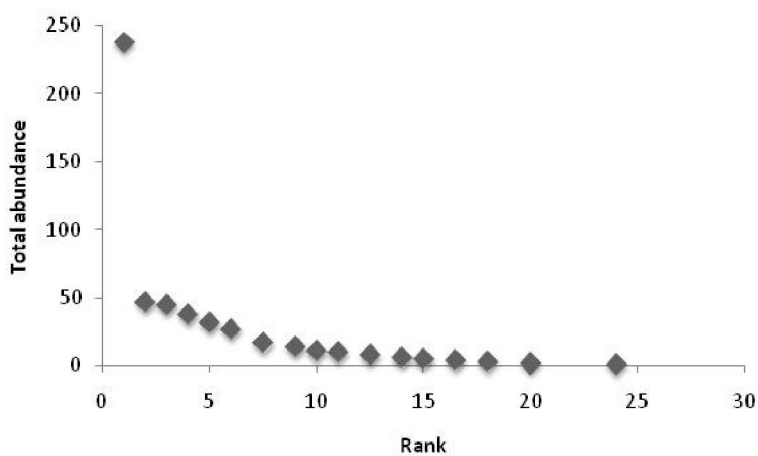

Figure 5. Rank versus total abundance plot of anurans of DATR.

Rank abundance plot is illustrated in Figure 5. As observed in Table 7, rarer species are less abundant and common species are most abundant is clearly depicted in this plot. Most abundant species, in this study, *Euphlyctiscyanophlyctis,* inhabits in almost all study localities, while rarer species like *Pedostibestuberculosus* and *Rhacophorusmalabaricus* are found in particular habitats of very few localities.

Alpha and Beta Diversity

Table 8a and b provides alpha diversity measures of DATR. Species richness is highest in locality XI and XV with 13 species. It was least in O_I with 2 species. Shannon's and Simpson's diversity index also reveal the same with highest index value for site XI and XV. It is very interesting to note that, despite low species richness, site XII has evenly distributed species abundance (0.98), followed by site O_IV (S=6, E=0.91) and site XIV (S=4, E=0.9).

Table 8a. Alpha diversity measures of anuran amphibians at DATR.

Indices	I	VII	X	XII	VI	XVI	XV	II	III	IV
Species richness	4.00	6.00	4.00	4.00	7.00	6.00	13.00	6.00	8.00	6.00
Shannon's	0.62	1.54	0.33	1.37	1.75	1.68	2.42	1.52	1.82	1.67
Simpson's	1.44	3.88	1.15	3.86	4.63	4.80	9.99	3.74	4.96	4.57
Evenness	0.46	0.78	0.35	0.98	0.82	0.89	0.86	0.76	0.77	0.88

Table 8b. Alpha diversity measures of anuran amphibians at DATR.

Indices	V	XIII	XIV	VIII	IX	XI	O_I	O_II	O_III	O_IV
Species richness	7.00	7.00	4.00	7.00	5.00	13.00	2.00	4.00	3.00	6.00
Shannon's	1.54	1.83	1.28	1.67	1.49	1.85	0.38	1.23	0.40	1.70
Simpson's	3.24	5.56	3.33	3.98	3.95	3.99	1.28	3.08	1.25	5.10
Evenness	0.67	0.89	0.90	0.75	0.89	0.49	0.73	0.86	0.50	0.91

Beta diversity measure based on Bray-Curtis similarity values are given as dendrogram in Figure 6. All the twenty sites are clustered into five groups based the similarity between sites. Maximally dissimilar sites, namely, XVI, XII, XIII, XIV and IV form one cluster, while maximally similar sites, X, O_III, O_I and I for another cluster. O_II stands out separate among all sites. XV, II, O_IV, III and VIII forms fourth cluster and finally, VI, V, VII, XI and IX forms fifth cluster. Species richness is poor in maximum similarity sites and is governed by the abundance of *Euphlyctiscyanophlyctis* in these sites. Low abundance and higher species richness marks the maximally dissimilar sites, attributed to the difference in species composition and low abundance in each species.
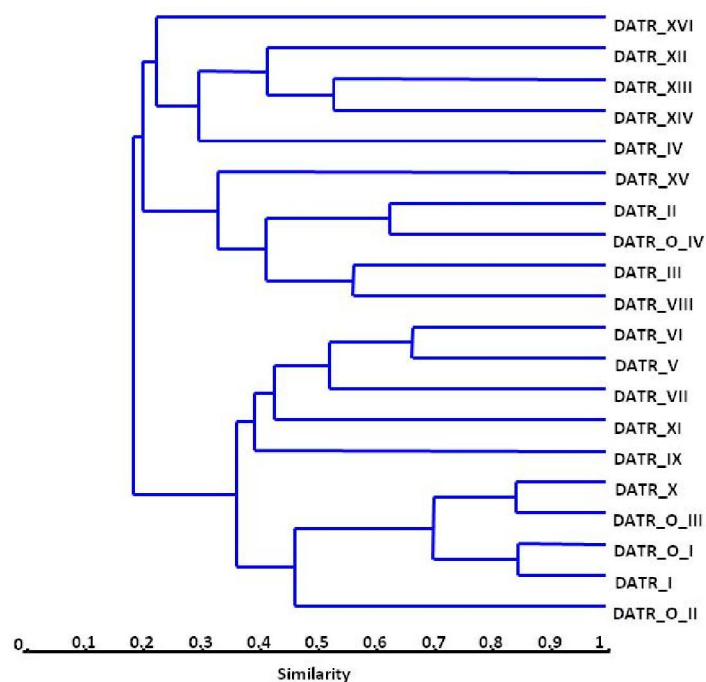
Figure 6.Dendrogram of Bray-Curtis similarity values for all sites in DATR.

Anuran Distribution

Anuran distribution is illustrated in Figure 6. Species richness and endemic species are marked on the sampling localities both within and outside DATR. Total richness and endemic species were high in sites III, V, VI, XI and XV, where as I, VII, XII, X, XVI, O_I, O_II and O_III were low in species richness as well as in endemic species. The low richness localities are either Agriculture or Mining areas, while high richness areas belong to water, forest or plantations.
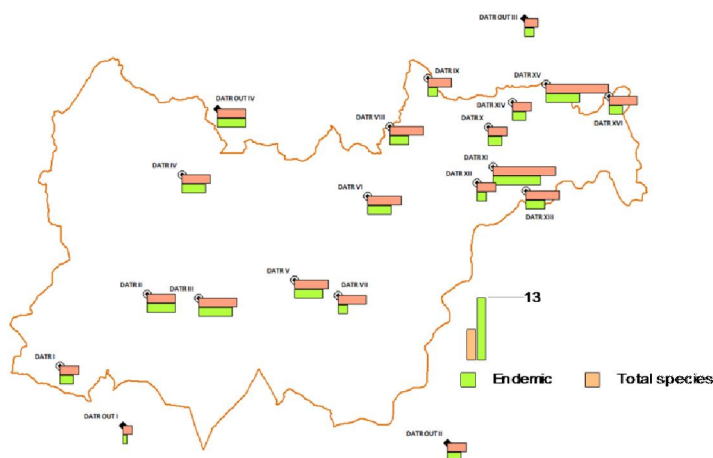

Figure 7.Anuran distribution in sampling localities of DATR. Maximum bar length indicates 13 species.

Land-use land-cover analysis

Land-cover analysis based on NDVI provided vegetation and non-vegetation cover in the study region. Figure 8 depicts NDVI for DATR. DATR has 98% area in vegetation cover (irrespective of whether natural or artificial) and remaining 2% are in agriculture fallow lands, dry river bed, sand, and waterbodies. Value ranges from -1 to 1, where in values from 0 to -1 indicates non-vegetated areas, 0 to 1 indicates vegetated areas. Eastern part of the DATR, especially near Ambikanagar, Kulgi, Bhagavati, BP dam areas are relatively poor in vegetation. Such non-vegetated areas are also on KumbarvadaJoida section, Gund, Ulvi and Anshi area, attributed mainly to agriculture clearings and dry river beds.
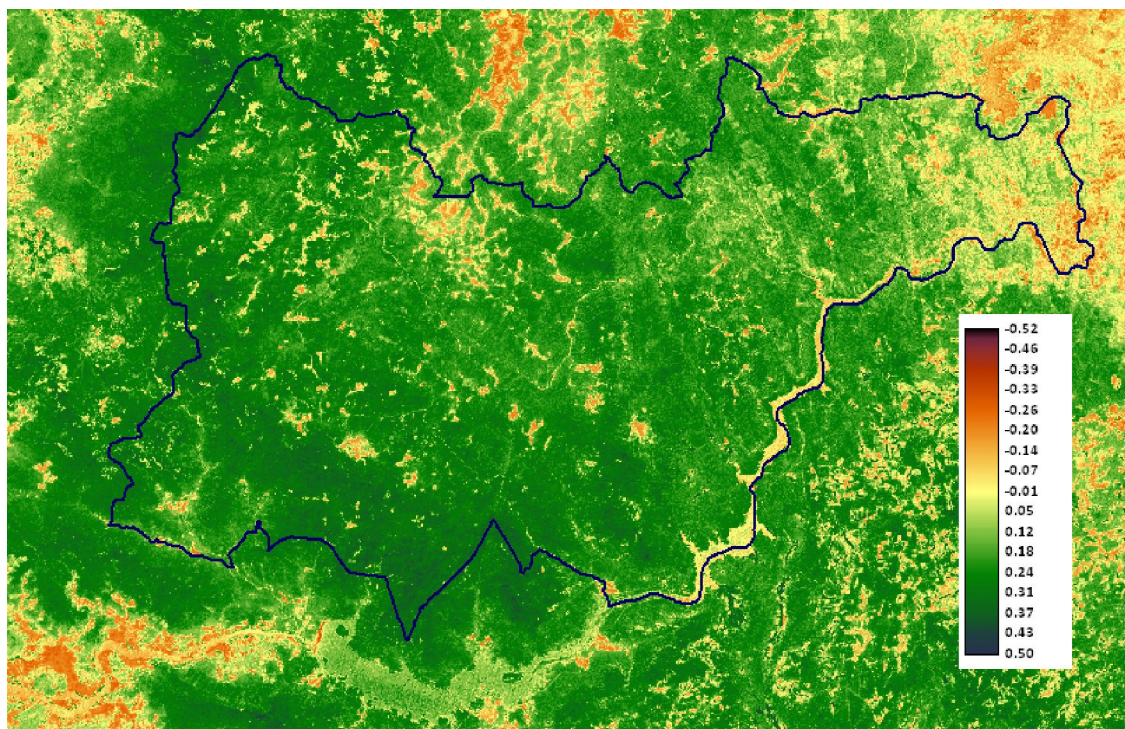

Figure 8. Normalized difference vegetation index (NDVI) of DATR.

Based on fuzzy supervised classification approach, land-use analysis of DATR was carried out. Error matrix is provided in Table 9. Kappa statistic (the measure of agreement between ground truth and computer based classification) is calculated using K= Pr(a)-Pr(e)/(1-Pr(e)), wherePr(a) is the relative observed agreement among classes, and Pr(a) is the hypothetical probability of chance agreement, using the observed data to calculate the probabilities of each classification randomly in each category. If the overall classification are in complete agreement then   = 1. If there is no agreement among the classification and ground truth, then   0. In the present classification, =0.89. Overall accuracy is 92.83% computed using agreement in classification divided by total number of pixels.

Table 9. Error matrix computed for fuzzy classification technique used for land-use classification.

Class		1	2	3	4	5	6	7	8	9	10	Total	EC
							Ground truth						
1		448	6	1	12	24	46	24	3	3	2	569	0.2127
2		0	1239	0	0	0	0	0	17	75	3	1334	0.0712
3		0	0	20655	0	0	0	0	0	0	0	20655	0
4		0	0	0	747	0	0	0	0	0	0	747	0
5		0	0	0	0	2222	17	0	0	12	0	2251	0.0129
6		12	0	0	0	27	492	3	0	0	0	534	0.0787
7		37	1	0	0	0	5	559	0	1	0	603	0.073
8		0	204	0	1	0	0	0	3178	727	93	4203	0.2439
9		1	679	0	0	7	0	0	303	3367	14	4371	0.2297
10		0	0	0	0	0	0	0	184	17	265	466	0.4313
Total		498	2129	20656	760	2280	560	586	3685	4202	377	35733	
EO		0.1004	0.418	0	0.0171	0.0254	0.1214	0.0461	0.1376	0.1967	0.2971		

Note: 1-Builtup, 2-Scrub, 3-Waterbodies, 4-Agriculture (Wet), 5-Agriculture (Dry), 6-Dry riverbed, 7-Grassland, 8-Forest (dense), 9-Forest (sparse), 10-Plantation (Areca, Coconut,etc.); EC-Error of commission, EO-Error of omission.

Figure 9 illustrates the land-use classification of the region and details of each land-use class are provided in Table 10. Note: Overall area from the cropped area of DATR is 879.48sq.km, which is 64.59sq.km more than actual area of DATR. This could be due to boundary delineation. The boundary was re-digitised considering half of the River Kali as part of DATR, which was along the bank in earlier boundary provided. Nearly 98% of the region is covered with vegetation, among this; dense forest occupies nearly 57% followed by spare forest 26.5%. Plantation including Acacia/Areca/Coconut, etc., has 8.69% cover in DATR. Built-up occupies 0.5% of the area, indicating that DATR still has not been invaded by human habitation. It is also evident with almost 1% of area under agriculture. Hence, DATR is one of potential protected area in the northern Western Ghats for conservation priority. On careful examination, eastern part of DATR is predominant with sparse forest (logged/teak plantation). This is due to selective logging and teak plantation in the region in early 1980's. Anshi, Ulvi, Gund, Ambikanagar, Kulgi, and places near Kumbarwada have agriculture areas. West, South, North-western and south-western parts are among the very less disturbed regions in DATR. It is a very good initiative from Forest Department, Government of Karnataka, to include regions up to Kadra in south and up to Diggi in North, which are also of less disturbed forested areas in the vicinity.
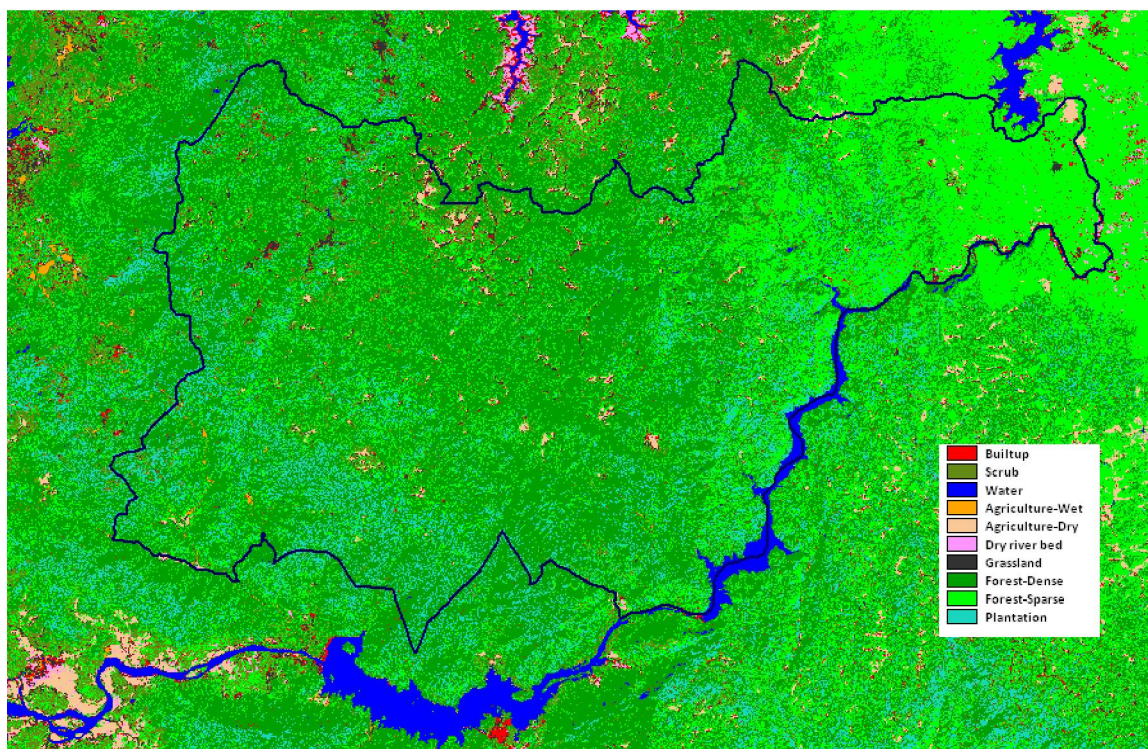
Figure 9.Fuzzy based supervised classification of DATR region.

Table 10. Fuzzy classified land-use composition in DATR. Values are in sq.km and percentage.

	Class	Area (in sq.km)	Percentage
1.	Built-up	4.57	0.52
2.	Scrub	35.45	4.03
3.	Waterbodies	5.37	0.61
4.	Agriculture (wet)	0.79	0.09
5.	Agriculture (dry)	8.19	0.93
6.	Dry riverbed	0.84	0.10
7.	Grassland	10.69	1.22
8.	Forest (dense)	503.87	57.29
9.	Forest (sparse)	233.26	26.52
10.	Plantation	76.45	8.69
	Total	879.48*	100.0

Note: Difference of 64.59sq.km to the actual area of DATR. Refer text for explanation.

Relationship between Habitat Variables and Anuran Abundance

The ordination diagram, with points of species (Figure 10),sites (Figure 11) and classes of qualitative habitat variables (Figure 11) illustrates relationship of each other. Niche centres along each axis (Axis 1 and 2) represents species point, which is determined by weighted average of axis values of sites in which they occur. Hence, each species point in this ordination diagram is at the centroid of sites points in which they were recorded. It is also indicative of relative locations of their two dimensional niches. In Figure 10, *Euphlyctiscyanophlyctis* and *E. aloysii;* despite being difference in their endemism, they form a cluster as they share similar habitat (aquatic) and also have similar tadpole development (aquatic). Except for *Pedostibestuberculosus* and *Indiranabeddomii,* other species have formed their cluster of unique niches. First three axes scores are given in Table 11.
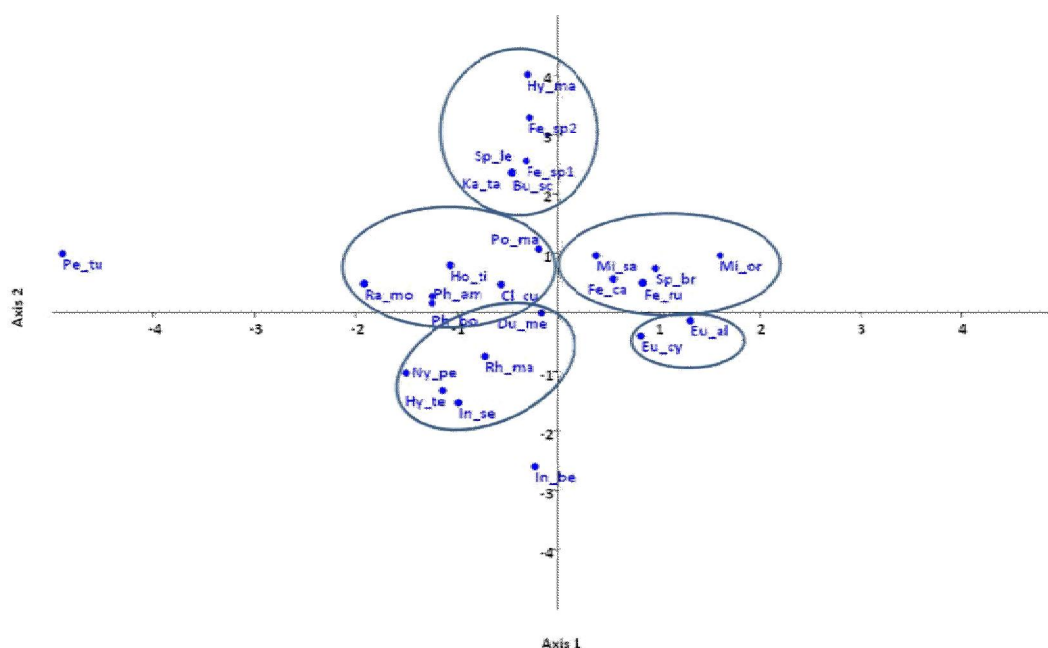

Figure 10. CCA ordination plot of species recorded at DATR.

Table 11. CCA scores of each species along three canonical axes.

Species	Axis 1	Axis 2	Axis 3
Bu_sc	-0.45	2.34	-5.01
Cl_cu	-0.56	0.46	-0.88
Du_me	-0.15	-0.01	-1.34
Eu_al	1.32	-0.15	0.93
Eu_cy	0.82	-0.41	0.24
Fe_ca	0.55	0.55	0.08
Fe_ru	0.85	0.49	0.62
Fe_sp1	-0.31	2.54	1.60
Fe_sp2	-0.27	3.28	1.23

Ho_ti	-1.05	0.78	-2.67
Hy_ma	-0.30	4.01	2.44
Hy_te	-1.14	-1.33	0.18
In_be	-0.23	-2.61	1.25
In_se	-0.98	-1.53	0.07
Ka_ta	-0.45	2.34	-5.01
Mi_or	1.61	0.96	-3.27
Mi_sa	0.39	0.95	-2.39
Ny_pe	-1.50	-1.03	0.37
Pe_tu	-4.89	0.99	-1.55
Ph_am	-1.24	0.25	-0.25
Ph_bo	-1.24	0.14	0.21
Po_ma	-0.18	1.07	-2.09
Ra_mo	-1.92	0.47	-1.86
Rh_ma	-0.71	-0.75	0.16
Sp_br	0.97	0.73	-2.32
Sp_le	-0.45	2.34	-5.01
Eigenscores	0.37	0.35	0.30

Similar to species ordination, site coordinates are the values of sites on the two best axes, which are standardized to zero weighted mean and unit weighted variance. Figure 11 illustrates the ordination plot of sites of DATR. First three axes scores are given in Table 12. Sites having similar habitat variables, altitude and species richness have formed unique clusters.

Table 12.**CCA scores of each sampling sites along three canonical axes.**

Sites	Axis 1	Axis 2	Axis 3
DATR_I	0.54	-0.28	0.16
DATR_VII	0.75	0.26	-1.08
DATR_X	0.74	-0.31	0.26
DATR_XII	-0.40	-0.33	-0.41
DATR_VI	-0.01	-0.18	-0.07
DATR_XVI	-0.07	0.84	-0.30
DATR_XV	-0.19	0.66	-1.68
DATR_II	-1.17	-0.22	0.09
DATR_III	-1.51	0.29	-0.30
DATR_IV	-1.13	-0.42	-0.34
DATR_V	-0.03	-0.38	0.16
DATR_XIII	-0.21	-0.47	-0.44
DATR_XIV	-0.37	-1.00	0.37
DATR_VIII	-1.07	-0.14	-0.20
DATR_IX	0.90	0.24	-0.55
DATR_XI	-0.08	1.40	0.81
DATR_O_I	0.79	-0.29	0.22

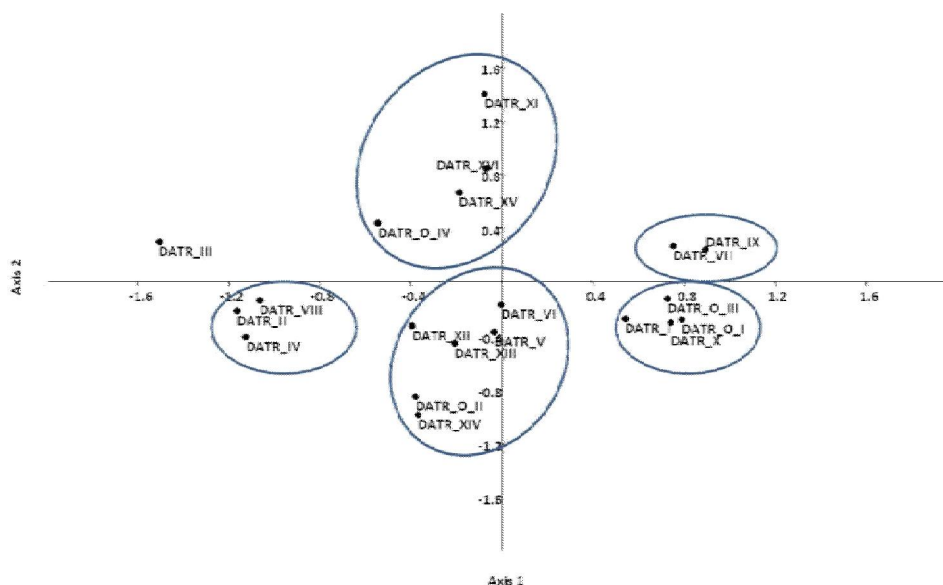|			
DATR_O_II	-0.38	-0.86	0.25
DATR_O_III	0.73	-0.13	0.38
DATR_O_IV	-0.55	0.44	0.28

Figure 11.CCA ordination plot of sampling sites of DATR.

Triplot of habitat variables, sites and species occurrence is illustrated in Figure 12. Variables like altitude, habitat, threat status, endemics, endemism, tadpole habitat and species richness are highly correlated with axis 1. CCA scores of first three axes are given in Table 13. Species and sampling sites in this ordination are positively influenced by aforesaid habitat variables. Stream, rainfall, land-use land-cover and canopy are negatively correlated with axis 2. Negative correlation is strong with canopy than any other variable. It is also interesting to note that, species like *E. cyanophlyctis*, *E. aloysii*, *Minervaryasahyadris*, *Microhylaornata*, *Fejervaryacaperata*, *F. rufescens* and *Sphaerothecabreviceps* seemed to be independent of the influence of these habitat variables. Maximum conservation priority must be given to regions having higher influence from the habitat variables and species endemism. These priority regions in DATR are all the fourteen localities apart from agriculture dominated areas like Ulvi, Goira village, Amgaon village, water body near Patoli cross.
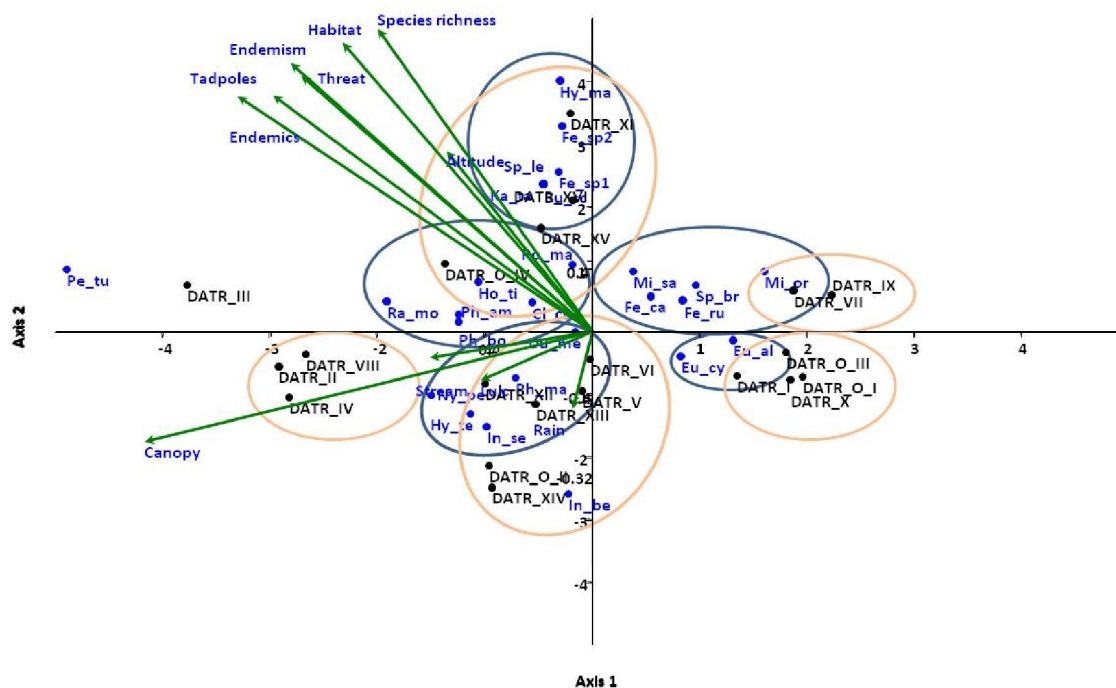
Figure 12. Triplot of CCA showing sampling sites, species and habitat variables.

Table 13. CCA scores of habitat variables explained in first three axes.

Habitat variables	Axis 1	Axis 2	Axis 3
Altitude (m asl)	-0.22	0.40	-0.31
Rainfall (annual, mm)	-0.03	-0.17	0.28
Land-use land-cover	-0.17	-0.11	0.13
Stream	-0.24	-0.06	0.11
Canopy	-0.67	-0.25	-0.06
Species richness	-0.32	0.68	-0.33
Endemic richness	-0.53	0.53	0.08
Endemism	-0.45	0.60	-0.08
Threat	-0.43	0.57	-0.38
Habitat	-0.37	0.65	-0.35
Tadpole habitat	-0.48	0.53	-0.19

Conclusion

This is first every systematic study of anuran amphibians from the DandeliAnshi Tiger Reserve, which will serve as a bench mark for further research on amphibians from this area. Twenty nine species of anurans recorded from DATR is quite comparable to any other place along the Western Ghats (Inger *et al.,* 1984a, b; Vasudevan*et al.,* 2001; Krishnamurthy, 2003;Gururaja *et al.,* 2008). With very precise objectives, the present study provided diversity and distribution of anurans in DATR. Although, this study provided some useful insights on relationship between habitat variables and species distribution, a detailed study on effect of fragmentation, influence of agriculture practices inside DATR and past mining areas are worth exploring.

Batracharium - a unique concept for conservation of amphibians is proposed here, where in few localities inside DATR are identified, habitats are marked and provisions are made for frog watch with sign boards indicating the species to look for, kind of habitat and regular monitoring programmes are scheduled. First such batracharium can be at Nagazhari pond in front of the Kulgi nature camp. This particular pond, proposed for batracharium would have two signboards (15cmx60cm), one indicating it as "Batracharium-stop to watch frogs" and other with 5-10 commonly available amphibian species in that particular locality, along with their images, pointer showing specific colors and/or parts to look out.

References

Anil, Z., Dinesh, K.P., Kunhikrishnan, E., Das, S., David V. Raju and Radhakrishnan, C. **2011a**. Nine new species of frogs of the genus *Raorchestes* (Amphibia: Anura: Rhacophoridae) from southern Western Ghats, India. *Biosystematica*, 5(1): 25-48.

Anil, Z., Dinesh, K.P., Radhakrishnan, C.,Kunhikrishnan, E., Palot, M.J. and Vishnudas, C.K. **2011b**.A new species of Polypedates Tschudi (Amphibia: Anura: Rhacophoridae) from southern Western Ghats, Kerala, India. *Biosystematica*, 5(1): 49-53.

Aravind, N. A., Ganeshaiah, K.N. and Uma Shaanker, R.**2004.** Croak, croak, croak: Are there more frogs to be discovered in Western Ghats? *Current Science*, 86: 1471-1472.

Biju, S.D. and Bossuyt, F. **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 Linnaean Society*,155: 374-444.

Biju, S.D., Bocxlaer, I.V., Mahony, S., Dinesh, K.P., Radhakrishnan, C., Anil, Z., Giri, V. and Bossuyt. F. 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*

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

Champion, H.G. and Seth, S.K. **1968**. A Revised Survey of the Forest Types of India.Govt. of India Publications, New Delhi.

Daniels, R.J.R. **1992**. Geographical distribution patterns of amphibians in the Western Ghats, India. *Journal of Biogeography*, 19:521-529.

Daniels, R.J.R. **2005**.Amphibians of peninsular India. Universities Press, Hyderabad, pp. 268.

Das, A., Krishnaswamy, J., Bawa,K.S., Kiran, M.C., Srinivas, V., Kumar, N.S.andKaranth, K.U.**2006**.Prioritisation of conservation areas in the Western Ghats, India.*Biological Conservation,* 133(2006): 16-31.

Dinesh, K.P. and Radhakrishnan, C. **2011**. Checklist of amphibians of Western Ghats.*Frogleg*, 16: 15-20.

Dinesh, K.P., Radhakrishnan, C., Gururaja, K.V.Deuti, K. and Bhatt, G.K.**2011.**A checklist of amphibian of India.http://zsi.gov.in/checklist/Amphibia_final.pdf

Gower, D. J., Bhatta, G., Giri, V., Oommen, O. V., Ravichandran, M. S. and Wilkinson, M. **2004.** Biodiversity in the Western Ghats: the discovery of new species of caecilian amphibians. *Current Science* 87: 739-740.

Gururaja, K.V., Sameer Ali and Ramachandra, T.V.**2008**. Influence of land-use changes in river basins on diversity and distribution of amphibians. *In:* Environment Education for Ecosystem Conservation (Ed. T.V. Ramachandra). Capital Publishing Company, New Delhi.

Gururaja, K.V.**2004**.Sahyadrimandooka – Amphibians of Western Ghats. http://wgbis.ces.iisc.ernet.in/biodiversity/newsletter/issue6/article.html#wgbis

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

Inger, R.F., Shaffer, H.B., Koshy, M. and Bakde, R. **1984a**.A report on a collection of amphibians and reptiles from the Ponmudi, Kerala, South India.*Journal of the Bombay Natural History Society,* 81: 406-427.

Inger, R.F., Shaffer, H.B., Koshy, M. and Bakde, R. **1984b**.A report on a collection of amphibians and reptiles from the Ponmudi, Kerala, South India.*Journal of the Bombay Natural History Society,* 81: 551-570.

Inger, R.F., Shaffer, H.B., Koshy, M. and Bakde, R. **1987**.Ecological structure of a herpetological assemblage in South India.*Amphibia-Reptilia,* 8: 189-202.

IUCN 2009.IUCN Red List of Threatened Species.Version 2009.2.<www.iucnredlist.org>. Downloaded on **06 March 2010**.

Krishnamurthy, S.V. **2003**.Amphibian assemblages in undisturbed and disturbed areas of Kudremukh National Park, central Western Ghats, India.*Environmental Conservation*, **30**: 274-282 doi:10.1017/S0376892903000274

Legendre, P. and Legendre, L. **1998**. Numerical Ecology, Elsevier Science B.V., Amsterdam, The Netherlands, pp. 853.

Naniwadekar, R. and Vasudevan, K. **2007**. Patterns in diversity of anurans along an elevational gradient in the Western Ghats, South India.*Journal of Biogeography*, 34, 842–853.

Pascal, J.P. **1988**. Wet evergreen forests of the Western Ghats of India: Ecology, structure, floristic composition and succession. French Institute of Pondicherry, India.

Ramachandra, T.V., SubashChandran, M.D., Gururaja, K.V. and Sreekantha.**2006**.Cumulative Environmental Impact Assessment. Nova Publication, USA, pp.371.

Sameer Ali, Rao, G.R., Divakar K. Mesta., Sreekantha, Vishnu D.Mukri, SubashChandran, M.D., Gururaja, K.V., Joshi, N.V. and Ramachandra, T.V. **2007**. Ecological Status of Sharavathi Valley Wildlife Sanctuary. Prism Books Pvt. Ltd., Bangalore.

Tiger Conservation Plan (2008-2018). Prepared by Manoj Kumar, DCF, DATR.

Vasudevan, K., Kumar, A., and Chellam, R.**2001**. Structure and composition of rainforest floor amphibian communities in Kalakad-Mundanthurai Tiger Reserve. *Current Science* 80(3): 406-412*.*

Vasudevan, K., Singh, M.,Singh, V.R.,Chaitra, M.S.,Naniwadekar, R.S.,Deepak,V. and Swapna,N. **2006**.Survey of biological diversity in Kudremukh Forest Complex.Karnataka Forest Department report, 60 p.

Wiens, J.A. **1989**. Spatial scaling in ecology.*Functional Ecology*, 3(4): 385-397.

Williams, S. E. **1997.** Patterns of mammalian biodiversity in theAustralian tropical rainforests: are extinctions during historicalcontractions of the rainforest the primarydeterminant of currentregional patterns in biodiversity? *Wildlife Research,*24: 513-530

Conservation and Management

Conservation and Management Guidelines for Amphibians at DATR

Conservation and management needs for Amphibians of the Western Ghats are discussed in length over the years (Gururaja, 2002; 2004; Das *et al.,* 2006; Ali *et al.,* 2007; Gururaja *et al.,* 2008). There is a need for guidelines on these issues, especially for the forest managers, who in fact have more access and accountability of the protected areas. This part of the document deals with conservation management guidelines, keeping amphibians as focal organism.

Anthropogenic changes in land-use like habitat alteration, fragmentation and forest loss are considered to be the primary challenge in the conservation of amphibians. Human populations are ever expanding, needing more and more land for various activities at local scale leading to alteration, fragmentation and loss of pristine forest habitats. This is considered to be the primary issue for the decline of amphibian populations worldwide. A proactive approach for minimizing the impact of such activities and to improve upon existing habitat is the key for conservation of amphibians. These guidelines are not regulations, nor to limit or curtail the activities of forest officials.

Landscape approach based on hydrological regime of DATR will help long term conservation and management of the amphibians. Anuran amphibians of DATR use streams, wetlands, and forest habitats in a very complex manner for breeding, feeding and resting. In addition, majority of amphibians are highly seasonal, having their breeding span spread only in the rainy period. This calls for a better understanding of natural history of these animals, their seasonal movement between habitats, and the natural dynamics of the habitats themselves, which are quintessential in landscape based conservation effort.

For amphibians, water bodies (lentic or lotic) play major role in breeding, egg laying (spawning), tadpole development and foraging, hiding place from predators and thermoregulations, where as terrestrial habitats help in foraging, movement (dispersal), resting place and escape from floods.

The following guidelines are suggested within DATR for maintenance and enhancing habitat quality

- Limit motorized vehicle transit within the DATR during rainy seasons, specifically during monsoon. Amphibians are generally active during night and more so during rainy seasons when they breed. Limiting the motorized vehicle within DATR, either in numbers or in speed would certainly decrease the number of road kills of amphibians in DATR.

- Maintain native vegetation where ever possible (e.g., near Patoli cross, there is native evergreen patch, maintain this patch as it is) and where it is absent, restore native vegetation both in structure and composition. As far as possible avoid introducing/planting exotic species, if management regime permits, remove them and replace plantation of exotic species with native plant species. This is more pertinent to defunct mining areas, which are now planted with *Acacia*. It could have been better, if native tree species were planted here.

- Protect from expansion of roads, agriculture fields and any other developmental activity. These activities are disruptive to amphibians and they generally fragment, degrade and reduce habitats of amphibians.

- Amphibians are very much dependent on natural hydrology of an area, hence, maintain and restore natural hydrology. This allows natural evolution of stream dynamics and associated vegetation. Natural flood cycles are important for maintaining amphibian population as also their prey and predator populations too.

- There are agriculture fields within DATR, hence there must a monitoring on the usage of fertilizers, herbicides and pesticides, which are proved to be detrimental amphibian population.

- Provide conservation related education MATERIALS to farmers, campers, hikers and people who frequent DATR. Batracharium is one such area, where people can watch exclusive for frogs (detailed in Part I). Educating and creating awareness about amphibians among school children who are residing inside and nearby areas (Dandeli, Kulgi, Anshi, Joida, Ambikanagaretc), which can also be extended to all people in and around DATR.

- Grass lands and defunct mining areas needs special attention and continued monitoring for amphibian diversity.

- Research on anuran amphibians over a long time period, with a proper objective, highlighting hydrology related issues must be supported and continued in future.

Amphibian Monitoring Protocols

In DATR, the following protocol is proposed with the clear objective of monitoring the amphibian diversity. This would provide insights on amphibian diversity and their distribution in DATR, the variation in their diversity with reference to various land-uses and influence of protection (abandoned mining areas, agriculture and plantations). Finally at broader scale, both spatially as well as temporally, this protocol would enable us to understand the influence of global climate change, habitat alteration, habitat modification and/or habitat fragmentation on amphibians, which in turn help in conservation and management of DATR.

Amphibian Research Protocol

- Amphibians are seasonal, many of them breed mainly during monsoon, and hence monitoring must be done at least twice during monsoon (June-September).

- To understand the diversity of the region, apart from monsoon, monitoring can be done once during March and December. This is to account for non-monsoon breeding amphibians like *Hylarana temporalis*.

- Amphibians survey must be carried out between 7pm (19:00hr) to 9pm (21:00hr) of a given days majority of the amphibians are nocturnal. Model data sheet is provided next.

- There are 13 proposed permanent plots for amphibian sampling (with clear demarcation based on land-use). Table 1 details the list of proposed permanent plots with altitude and land-use type. In each of these land-uses, for amphibian monitoring, first locate a first/second order stream or a water body. This provides the breeding ground for amphibians and hence enhances inclusion of breeding population in the survey (majority of the amphibians require water source to lay eggs).

- Two persons, with proper protective gears like wader shoes, head lamps and gloves (also well equipped to tackle other nocturnal animals of the forest. Snakes are the natural predators of amphibians; at most care should be taken during amphibian sampling, not to trample snakes and also not to get bitten by them. First aid kit with anti-venom injections are must in this monitoring) will start sampling along, across and on the adjacent areas for two man hours (each person will spend one hour in sampling).

- A well zipped cotton net bag (15cmx15cm) will be carried by each person. During the sampling, each person would locate an amphibian by sight, call or movement. Person should be able to follow these clues and find the specimen. They must also check for crevices on trees, rocks, prod small shrubs, dead wood logs and/or almost all microhabitats. Once a specimen is found, it can be caught and put in the zipped cotton bag. This is to avoid the redundancy in the sampling.

Once the stipulated two man hour search is over, specimens in the cotton bags are brought to the edge of the sampling area and details of each individual must be recorded as prescribed in the data sheet. Datasheets must be entered with utmost care and must be done very meticulously. It would be better, not to mention species name if it appears too confusing, instead it can be identified up to genus and a detailed description of the individual can be provided on the back of the data sheet (with a sketch/photograph of the individual). Common genera occurring in the region are provided below.

- If the species appears to be new or if it is first record for the DATR, a few individuals must be preserved in 70% alcohol and must be vouchered either in the Forest Department or in reputed museum along with collector's name, date and locality. This preservation is specifically mentioned so as to look at available specimen from DATR for any further research work (be it molecular phylogeny or morphological comparison) and also to curtail repeated killing of amphibians.

- Generally sex can be determined on seeing vocalizing individuals. Since female lack vocal sacs, if one finds a calling individual then it must be a male. One can also check for the black coloured vocal sac.

- Other issues in monitoring protocol includes recording the road kills of amphibians along the major and minor roads within DATR.

- Capacity building includes school kids from in and around DATR as well as forest guards.

Data sheet for amphibian monitoring

Date: _____Compiler:_____

Start Time (pm): _____End Time (pm): _____

Latitude(°N): _____ Longitude(°E):_____   Altitude (m): _____

Land-use (major): Agriculture/ Pond/ stream/ Evergreen/ Deciduous/ Grassland/
            Any other specify_____

Air temperature: ___°C___°C___°C; Avg___°C; Sdev:___°C

Water temperature: ___°C___°C___°C; Avg___°C; Sdev:___°C

Relative humidity:___%___%___%; Avg___%; Sdev:___%

Canopy cover: ___%___%___%; Avg___%; Sdev:___%

Asphalted road nearby: _____m

Species	Sex	# Individuals	Microhabitat/Remarks

Other information:

Identification Guide to Anurans of DATR

This write up provides clues for field identification of anuran amphibians recorded from DATR till date and we will not claim that list is complete. It is aimed at forest personal and amateurs interested in batrachology. Personal observations must be made and a record of the same can be maintained for further usage. Before identification, one needs to know the following anatomical features of a frog or toad as illustrated in Figure 1.
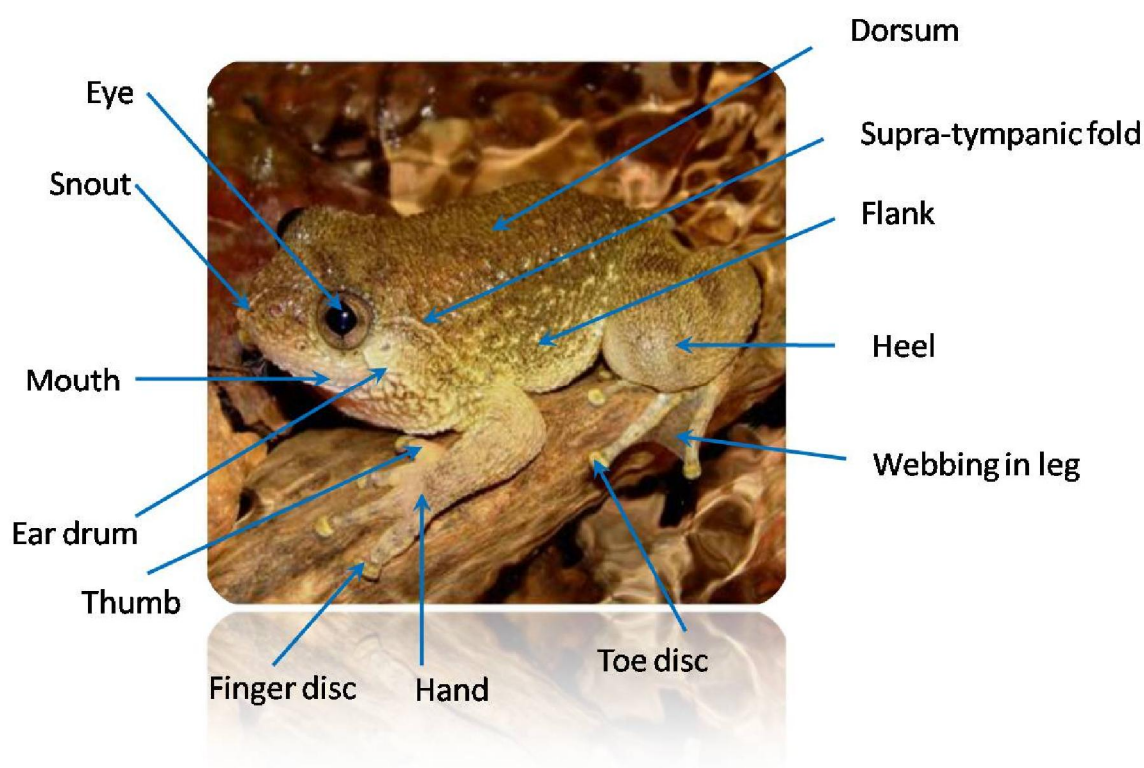
Figure 1. Anatomical features of anuran amphibian.

Family: Bufonidae

Genus: *Duttaphrynus*
Species: *scaber*
Common name: Ferguson's toad
Ecological status: Least concerned
Endemism: Western Ghats and Sri Lanka

Key characters: No dark ridges snout and mouth. Pear shaped poison gland. Dry skin, black warts (cornified) on back, finger tips and toe tips.

Size: Small to medium, Activity: nocturnal, Habitat: terrestrial, human habitation, water bodies

FERGUSON'S TOAL

Genus: *Duttaphrynus*
Species: *melanostictus*
Common name: Common Indian toad
Ecological status: Least concerned
Endemism: Not endemic

Key characters: Dark ridges around eyes, snout and mouth. Elongated poison gland.Dry skin, black warts (cornified) on back, finger tips and toe tips.
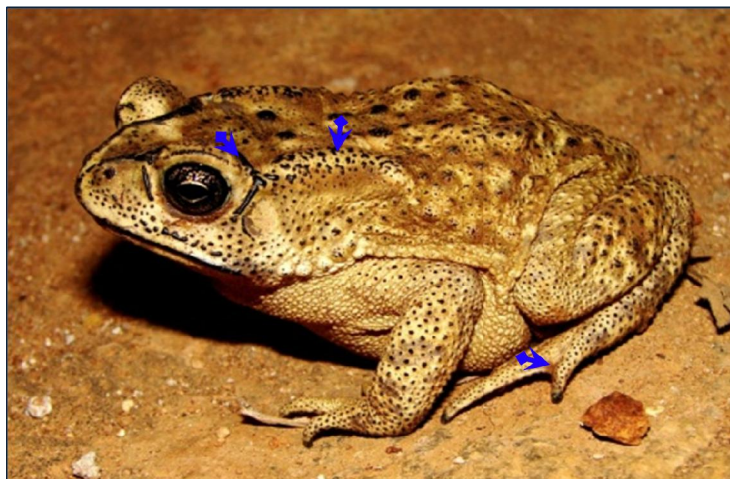
Size: medium to large, Activity: nocturnal, Habitat: terrestrial, human habitation, water bodies

COMMON INDIAN TOAL

Genus: *Pedostibes*
Species: *tuberculosus*
Common name: Malabar tree toad
Ecological status: Endangered
Endemism: Western Ghats

Key characters: No ridges around eyes, snout and mouth. Eyes golden, poison gland not clear, dry skin. Finger tips and toe tips with dilated discs.

Size: medium, Activity: nocturnal, Habitat: Arboreal, on trees near forest streams.
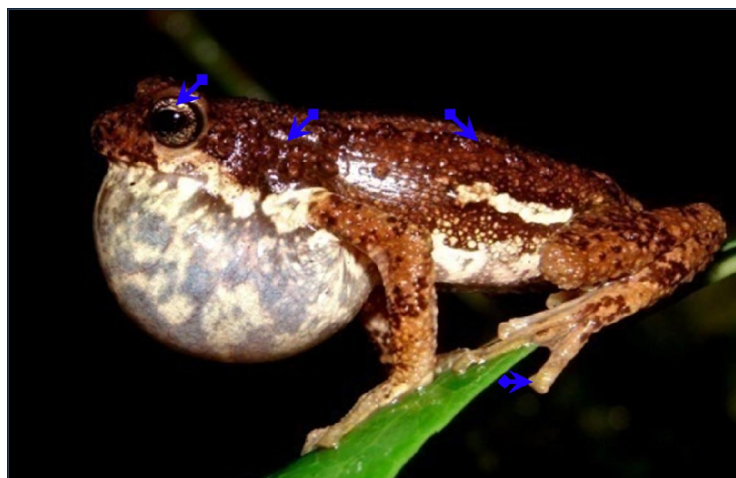
MALABAR TREE TOAD

Family: Microhylidae

Genus: *Microhyla*
Species: *ornata*
Common name: Ornate narrow mouthed frog
Ecological status: Least concerned
Endemism: Western Ghats

Key characters: Ornamentation on back, limbs cross barred. Small head, narrow mouth. No dilation on finger and toe tips.

Size: Small, Activity: nocturnal, Habitat: Semi-aquatic, breeds in monsoon, water bodies, human habitation

ORNATE NARROW MOUTHED FROG

Genus: *Microhyla*
Species: *rubra*
Common name: Red narrow mouthed frog
Ecological status: Least concerned
Endemism: Non endemic

Key characters: No ornamentation on back, uniform red back, limbs cross barred. Small head, narrow mouth.Black dot at the junction of thigh and groin, giving eye like appearance. No dilation on finger and toe tips.Digging apparatus larger than *Microhylaornata.*
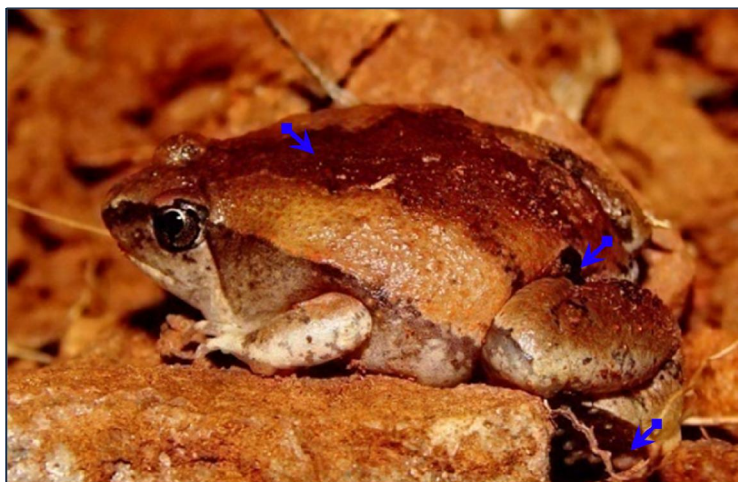
RED NARROW MOUTHED FROG

Size: Small, Activity: nocturnal, Habitat: Semi-aquatic, breeds in monsoon, water bodies, human habitation

Family: Nyctibatrachidae

Genus: *Nyctibatrachus*
Species: *petraeus*
Common name: Castle rock wrinkled frog
Ecological status: Least concerned
Endemism: Endemic

Key characters: Iris rhombus, wrinkles on back, finger tips dilated, webbing in foot. Male individuals have femoral gland on inner sides of thigh and nuptial pad on thumb.
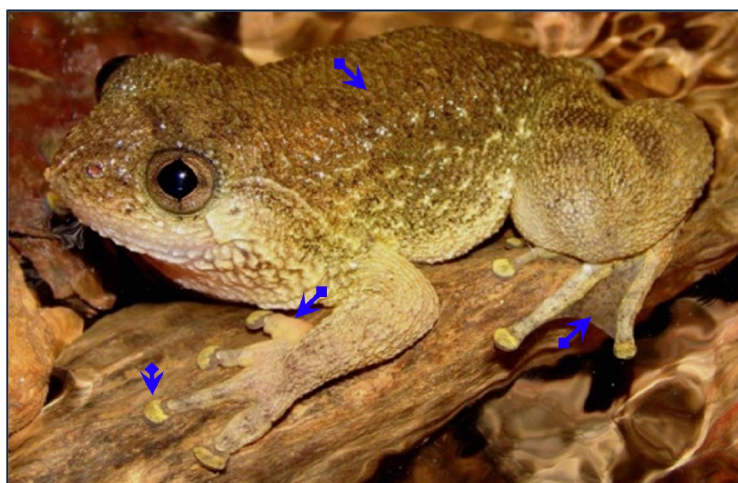
CASTLE ROCK WRINKLED FROG

Size: Medium, Activity: nocturnal, Habitat: Aquatic, breeds in monsoon in forest streams

Family: Dicroglossidae

Genus: *Euphlyctis*
Species: *aloysii*
Common name: Aloys skitter frog
Ecological status: Data deficient
Endemism: Endemic

Key characters: Elongated snout, popped out eyes, two green extension behind eyes, a white stripe on the flank, thighs barred, finger tips not dilated

Size: Medium, Activity: nocturnal, Habitat: Aquatic, seen breeding in ponds and pools.

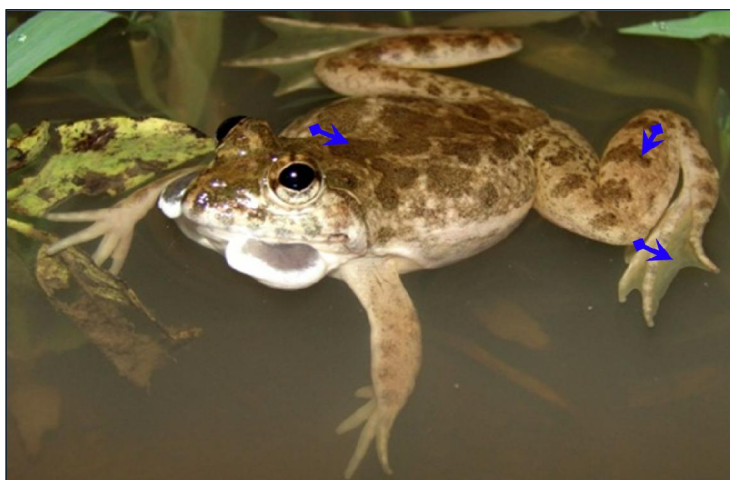ALOYS SKITTER FROG

Genus: *Euphlyctis*
Species: *cyanophlyctis*
Common name: Skitter frog
Ecological status: Least concerned
Endemism: Non endemic

Key characters: Elongated snout, popped out eyes, irregular pattern on back, thighs barred, finger tips not dilated. Webbing in foot.

Size: Medium, Activity: nocturnal, Habitat: Aquatic, seen in almost all water kinds of water bodies.

SKITTER FROG

Genus: *Fejervarya*
Species: *caperata*
Common name: Wrinkled Fejervarya
Ecological status: Data deficient
Endemism: Western Ghats

Key characters: Elongated snout, skin folds along body, thighs barred, finger tips not dilated.

Size: small, Activity: nocturnal,Habitat: semi-aquatic,

seen near human habitation and agriculture fields.

WRINKLED FEJERVARYA

Genus: *Fejervarya*
Species: *rufescens*
Common name: Reddish burrowing Frog.
Ecological status: Least concerned
Endemism: Western Ghats

Key characters: Inverted 'V' skin fold on the back, reddish spot on the back, lower lip barred, forelimb and hind limbs barred, digging apparatus present. No dilation on finger tips

Size: small, Activity: nocturnal,
Habitat: semi-aquatic, seen near human habitation and agriculture fields
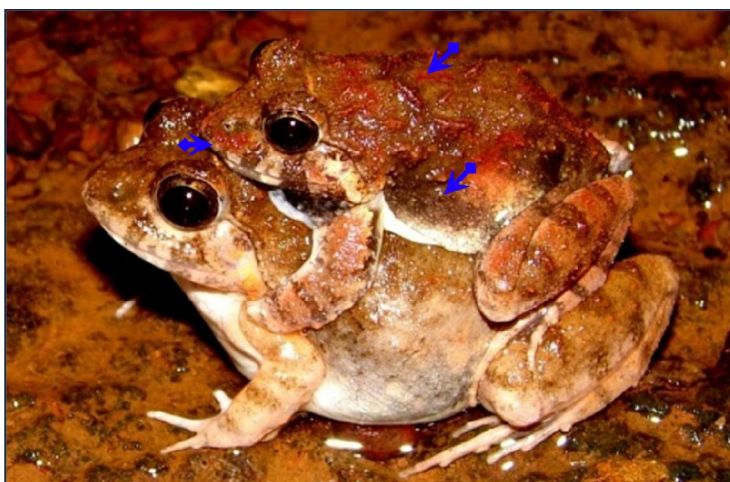
Genus: *Hoplobatrachus*
Species: *tigerinus*
Common name: Indian bull frog
Ecological status: Least concerned
Endemism: Non-endemic

Key characters: Elongated snout, skin folds along body, tiger like stripes and folds on the back, thighs barred, finger tips not dilated.

Size: large, Activity: nocturnal,Habitat: semi-aquatic, seen near human habitation and agriculture fields.

INDIAN BULL FROG

Genus: *Minervarya*
Species: *sahyadris*
Common name: Minervarya frog
Ecological status: Endangered
Endemism: Western Ghats

Key characters: Elongated snout, skin folds along body, thighs barred, finger tips not dilated. Small gland near jaw.

Size: small, Activity: nocturnal,Habitat: semi-aquatic, seen near human habitation and agriculture fields.

MINERVARYA FROG

Genus: *Sphaerotheca*
Species: *breviceps*
Common name: Indian burrowing frog
Ecological status: Least concerned
Endemism: Non-endemic

Key characters: Blunt snout, strong skin from eye to shoulder, sacral hump visible, strong digging apparatus on hind limb. Thighs barred, finger tips not dilated.

Size: medium, Activity: nocturnal, Habitat: Fossorial (burrowing), seen near human habitation and agriculture fields.
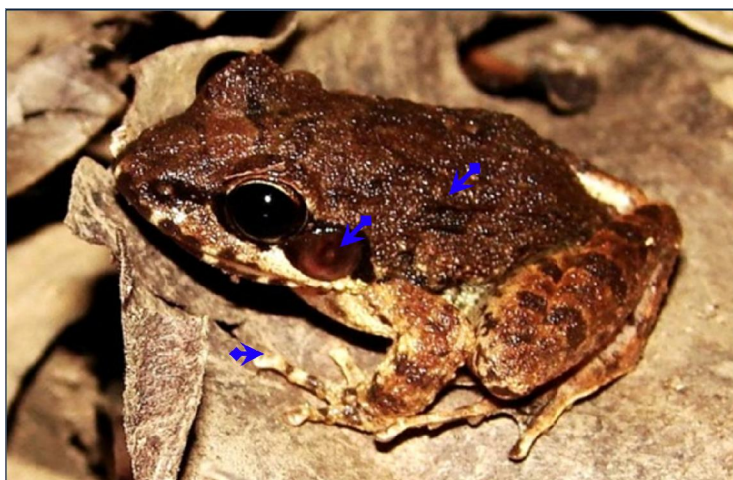

INDIAN BURROWING FROG

Family: Ranixalidae

Genus: *Indirana*
Species: *semipalmatus*
Common name: South Indian frog
Ecological status: Least concerned
Endemism: Western Ghats

Key characters: Elongated snout, skin folds along body, large tympanum, finger tips slightly dilated, and thighs barred.

Size: small, Activity: nocturnal, Habitat: semi-aquatic, found hiding below leaf litters in forest, along streams

SOUTH INDIAN FROG

Family: Ranidae

Genus: *Clinotarsus*
Species: *curtipes*
Common name: Bicoloured frog
Ecological status: Least concerned
Endemism: Western Ghats

Key characters: Elongated body, dorsum and flanks with distinct rufous and chocolate coloured, a longitudinal fold from eye till anus, large tympanum, webbing on foot.
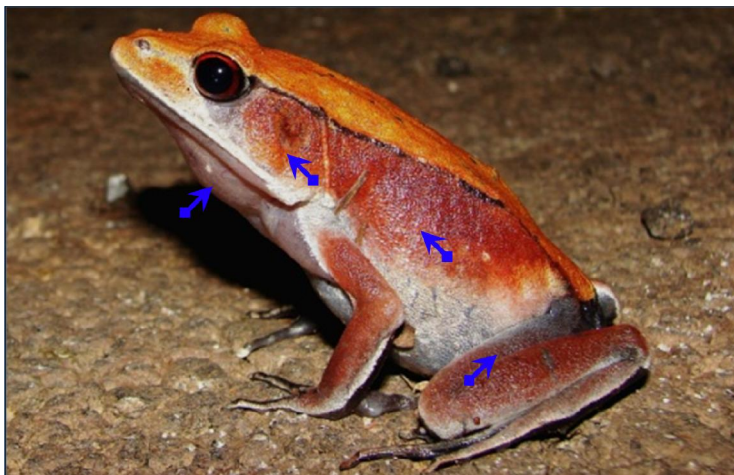

BICOLOURED FROG

Size: Medium to large, Activity: nocturnal, Habitat: semi-aquatic, found near water bodies

Genus: *Hylarana*
Species: *malabarica*
Common name: Fungoid frog
Ecological status: Least concerned
Endemism: Non-endemic

Key characters: Elongated body, dorsum and flanks with distinct colour, a longitudinal fold from eye till anus, small tympanum, webbing on foot. Chocolate

reticulation on thigh

FUNGOID FROG

Size: Medium to large, Activity: nocturnal, Habitat: semi-aquatic, found near water bodies

Genus: *Hylarana*
Species: *temporalis*
Common name: Bronze frog
Ecological status: Near threatened
Endemism: Western Ghats-Sri Lanka

Key characters: Elongated body, a longitudinal fold from eye till anus, large tympanum, webbing on foot, limbs barred.

Size: Medium to large, Activity: nocturnal, Habitat: semi-aquatic, Found near water bodies
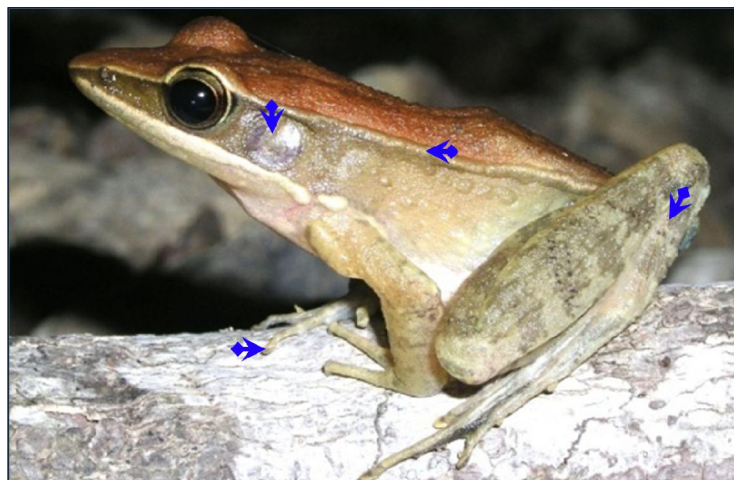
BRONZED FROG

Family: Rhacophoridae
Genus: *Pseudophilautus*
Species: *wynaadensis*
Common name: Dark eared bush frog
Ecological status: Endangered
Endemism: Western Ghats

Key characters: Squat body, Strong fold from eye to shoulder, tympanum with brown colouration, a white patch on snout tip. Finger and toe tips dilated.

DARK EARED BUSH FROG

Size: small, Activity: nocturnal, Habitat: Arboreal, shrubs and trees at about 2m from ground. They skip tadpole stage in life.

Genus: *Polypedates*
Species: *cruciger*
Common name: Chunam frog
Ecological status: Least concerned
Endemism: Western Ghats-Sri Lanka

Key characters: Elongated body, finger and toe tips dilated, large eyes, strong fold from eye to shoulder. Webbing on foot, limbs barred. Finger and toe tips dilated

CHUNAM FROG

Size: Medium, Activity: nocturnal, Habitat: Arboreal, on trees and walls. During breeding period, found near water bodies.

Genus: *Rhacophorus*

Species: *malabaricus*
Common name: Malabar gliding frog
Ecological status: Least concerned
Endemism: Western Ghats

Key characters: Elongated body, green on the back, red webbing, No fold from eye to shoulder, Finger and toe tips dilated. Spur on heels.

MALABAR GLIDING FROG

Size: Medium, Activity: nocturnal, Habitat: Arboreal, on trees. During breeding season, found near water bodies.
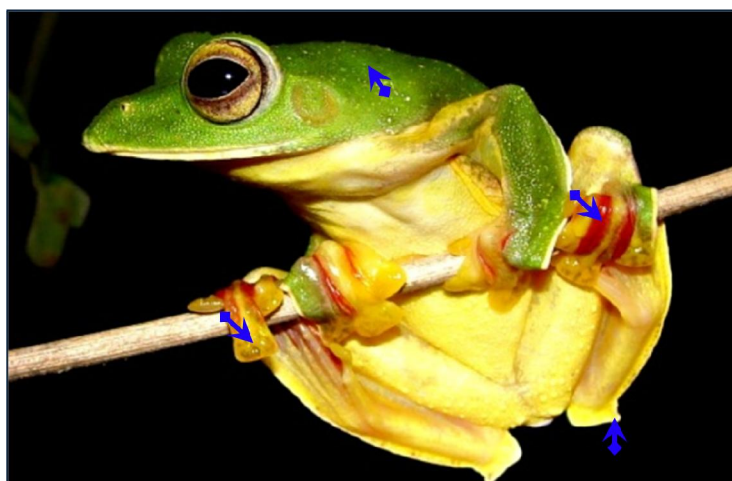
References:

Gururaja, K.V.**2002**.Effect of Habitat Fragmentation on Distribution and Ecology of Anurans in Some Parts of Central Western Ghats .Ph.D. thesis, submitted to Kuvempu University.

Gururaja, K.V.**2004**.Sahyadrimandooka – Amphibians of Western Ghats. http://wgbis.ces.iisc.ernet.in/biodiversity/newsletter/issue6/article.html#wgbis

Das, A., Krishnaswamy, J., Bawa, K. S., Kiran, M. C., Srinivas, V., Kumar, N. S., Karanth, U.K. **2006**. Prioritization of conservation areas in the Western Ghats, India.Biological Conservation, 133, 16–31.

Gururaja, K.V., Sameer Ali and Ramachandra, T.V. **2008**. Influence of land-use changes in river basins on diversity and distribution of amphibians. *In:* Environment Education for Ecosystem Conservation

Sameer Ali, Rao, G.R., Divakar K. Mesta, Sreekantha, Vishnu D.Mukri, SubashChandran, M.D., Gururaja, K.V., Joshi, N.V. and Ramachandra, T.V. **2007**. Ecological Status of Sharavathi Valley Wildlife Sanctuary. Prism Books Pvt. Ltd., Bangalore.

How to Study Amphibians

Study Area in DATR

The boundary area marked in Google map is shown below (Figure 1). Once you know the study area, mark them with grids and look out for different land-use classes as mentioned in Figure 2. Randomly pick up grids and also land-use based on the study objectives.
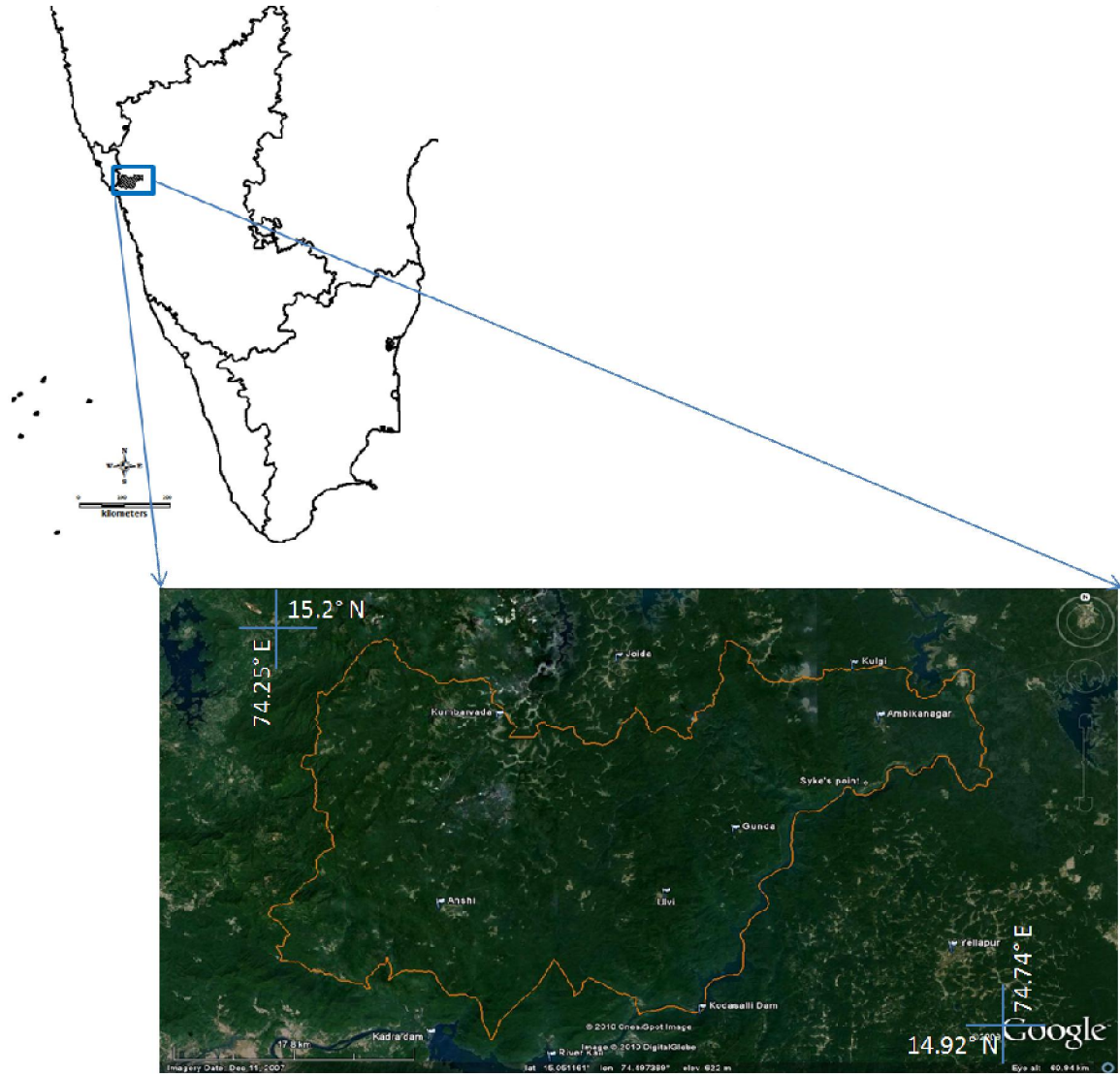

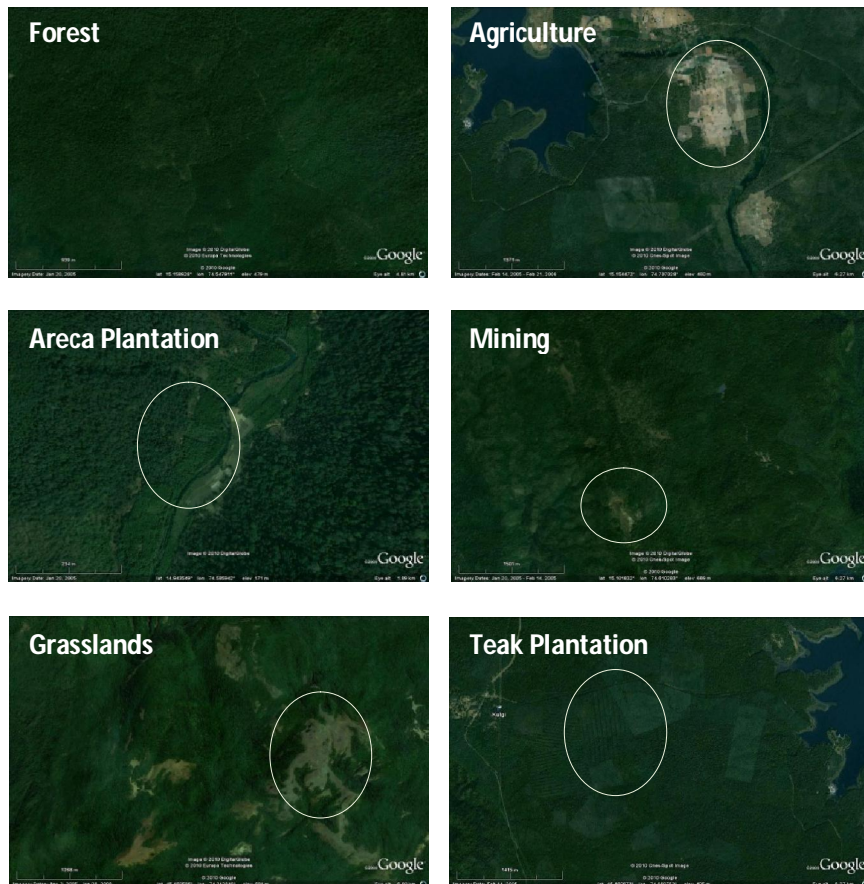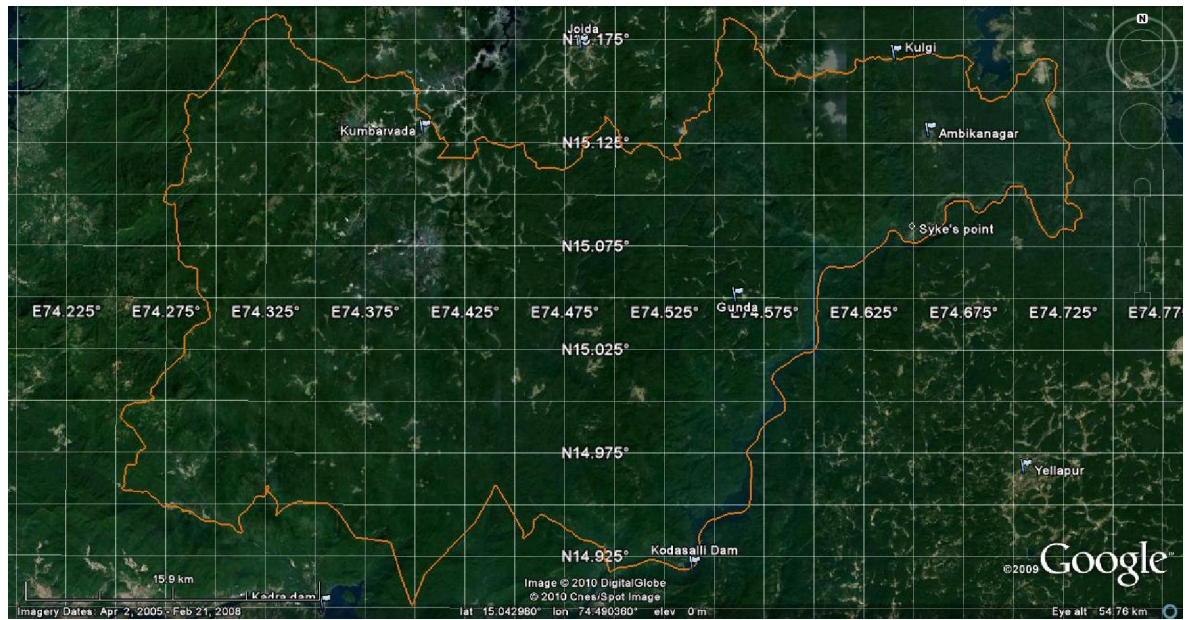Figure 1.DandeliAnshi Tiger Reserve boundary on Google map.

Figure 2.Grid marking and land-use in DATR.

Measuring Habitat Variables

1. Global Positioning System (GPS): This handheld device is used to determine the location of sampling - longitude, latitude and altitude, which can be marked on a map or satellite image.


2. Canopy cover: It is measured to know the amount of shade a place gets. Canopy cover is measured with densiometer. In densiometers, there are 24 grids on a circular convex disc, which are divided again visually into 4 each in each grid. One has to calculate how many of these grids are covered by canopy and multiply by 1.08. This provides the percent canopy cover.

Densiometer
Image source: http://www.state.sc.us/forest/densiometer.jpg

3. Temperature and relative humidity: Temperature and relative humidity are measured at 1m above the ground. If shade is not present, provide artificial shade. Measurements should not be taken in direct sunlight.
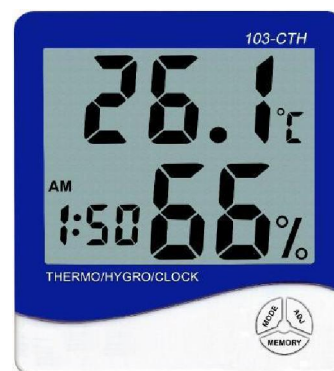
Digital thermohygrometer
Image source: http://www.jnrelectronics.net/images/products/thermohygrometer103cth.jpg

Handling Amphibians

Amphibians have to be handled with at most care and gentleness. There is no single method to catch and handle frogs. With experience in field and interest, one will master handling of frogs. Generally, catch the frogs from behind and hold them at their arm pits. Do not squeeze or over press the individuals. In abundance related studies, carry a wet zipped cloth bag or net bag, and place the caught individuals for later analysis. It is always a good practice to release the frogs back at the same place of collection, after the study.