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Amphibian Diversity and Distribution in Uttara Kannada District, Karnataka

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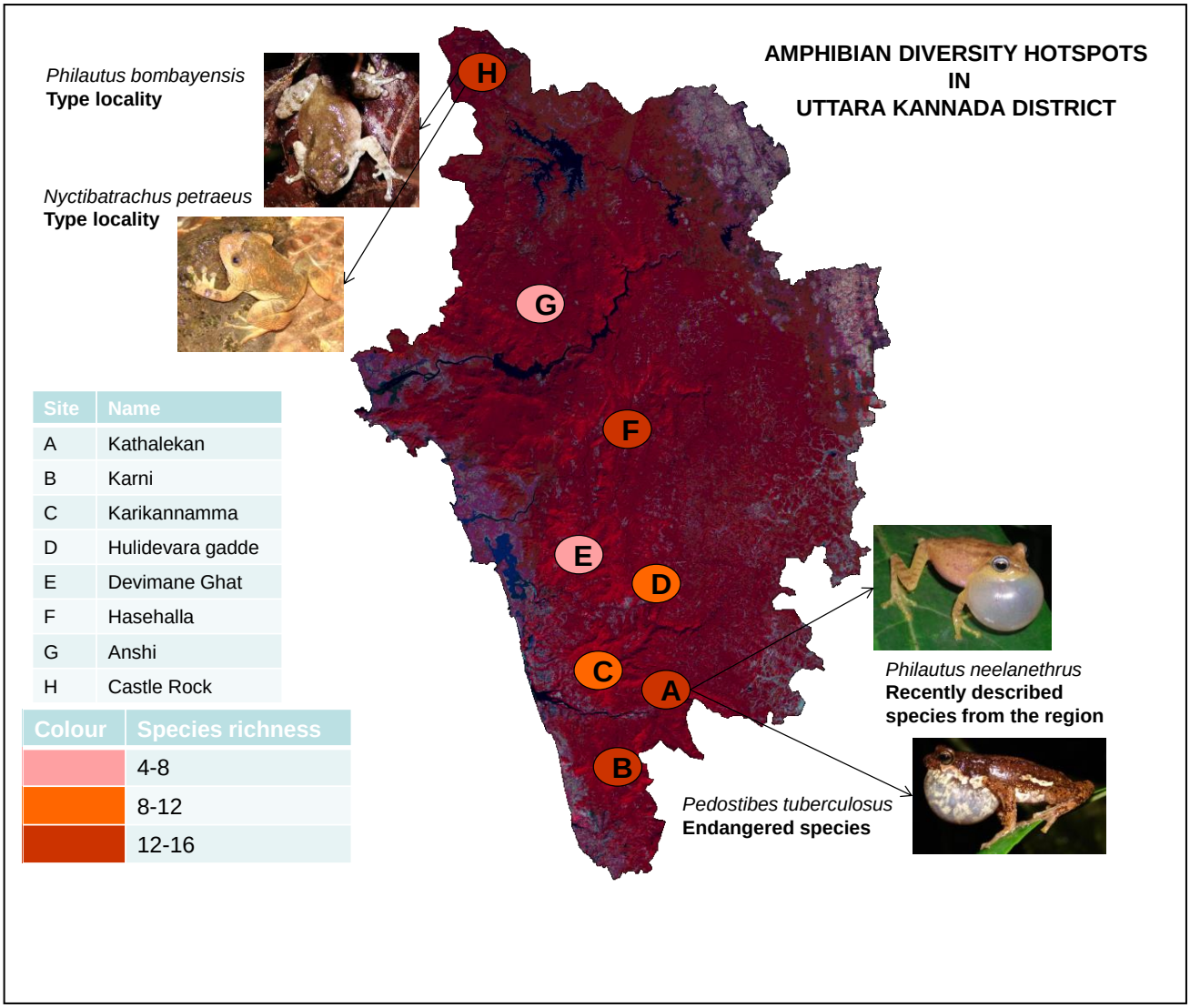

Site	Name
A	Kathalekan
B	Karni
C	Karikannamma
D	Hulidevara gadde
E	Devimane Ghat
F	Hasehalla
G	Anshi
H	Castle Rock

Colour	Species richness
	4-8
	8-12
	12-16

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Amphibian Diversity and Distribution in Uttara Kannada District

Summary

Amphibians are considered as biological indicators for their susceptibility to even very small changes in the surrounding environment and their habitats typically spread across the interface between terrestrial and aquatic habitats. They are the only vertebrate group with dual life stages (*i.e.,* tadpoles and adults) and perform vital ecological functions. Semi-permeable skin, anamniotic eggs and biphasic life style make them particularly vulnerable to changes and contamination of their habitats on land and in water. Habitat destruction and overexploitation are the major threat for amphibians, apart from *Chytrid* fungus and other synergistic effects of human induced changes. Presence of a diverse population of amphibians in a region is indication of a healthy environment. They are being used as surrogates in conservation and management practices. Monitoring amphibian diversity and their distribution would provide insights to the prevailing conditions of an ecosystem and its health, which in turn helps in prioritizing the region for conservation and management action in the Western Ghats.

River basins/catchments are topographically and hydrologically well defined unit of space and the present study has been carried out in five river basins namely Sharavathi, Aghanashini, Bedti and Kali of Uttara Kannada district using amphibians as biological indicators to arrive at conservation priority regions in the district. Forty six species were recorded from the five river basins. Sharavathi river basin forms species rich and endemic rich, while Venkatapura is species poor and endemic poor. Kathalekan of Sharavathi river with 34 species of which 24 of are endemic, is an apt candidate for the status of heritage site of biological diversity as per biodiversity act 2002 (Chapter IX, Biodiversity heritage sites).

Keywords: Biological indicators, Western Ghats, River catchment, Amphibians, Heritage sites

Amphibian Diversity and Distribution in Uttara Kannada District

Introduction

The Western Ghats of the Indian peninsula constitute one of the 34 global biodiversity hotspots along with Sri Lanka, on account of exceptional levels of plant endemism and by serious levels of habitat loss (Conservation International, 2005). The rugged range of hills stretching for about 1600 km along the west coast from south of Gujarat to the end of the peninsula (lat. 8° and 21° N and long. 73° and 78° E), is interrupted only by a 30 km break in Kerala, the Palghat Gap (Radhakrishna 2001). Covering a geographical area of about 160,000 km^2, the Western Ghats have an average height of 900 m, with several cliffs rising over 1000 m. The Nilgiri Plateau to the north and Anamalais to the south of the Palghat Gap exceed 2000 m in many places. Towards the eastern side the Ghats merge with the Deccan Plateau which gradually slopes towards the Bay of Bengal. The northern half of the Western Ghats is covered with basaltic rocks of volcanic origin whereas the southern half is of Pre-Cambrian rocks of different kinds like the crystalline rocks, the peninsular gneisses and the charnokites. Nearly a hundred rivers originate from these mountains and most run their westward courses towards the Arabian Sea that is close-by. Only three major rivers, joined by many of their tributaries flow eastward, longer distances, towards the Bay of Bengal (Dikshit 2001; Radhakrishna, 2001). The Western Ghat rivers are very critical resources for peninsular India's drinking water, irrigation and electricity (Subash Chandran et al., 2010, Ramachandra et al., 2007). The region has varied forest types from tropical evergreen to deciduous to high altitude sholas. It is also an important watershed for the peninsular India with as many as 37 west flowing rivers, three major east flowing rivers and innumerable tributaries. The richness and endemism in flora and fauna of this region is well established with over 4,000 species of flowering plants (38% endemics), 334 butterflies (11% endemics) [Kunte , in Press], 290 fishes (65% endemics) [Dhanukar, et al., 2011], 157 amphibians (86% endemics) [Biju et al., 2010], 157 reptiles (62% endemics) [Hegde, 2011, Ganesh et al., 2008a, Ganesh et al., 2009., Chandramouli and Ganesha, 2010, Dasa et al., 2006], 508 birds (4% endemics) [Molur et al.,

2011] and 140 mammals (12% endemics) [Karanth et al., 2009]. This mountain stretch has influenced regional tropical climate, hydrology and vegetation and endemic plant species.

The entire region is reeling under tremendous pressure from human induced changes in terms of developmental projects like hydroelectric or thermal power plants, big dams, mining activities, unplanned agriculture practices, monoculture plantations, illegal timber logging, etc. This has led once contiguous forest habitats to fragmented patches, which intern led to shrinkage of original habitat for the wildlife, change in the hydrological regime of the catchment, decreased inflow in streams, human-animal conflicts, etc. Under such circumstances, a proper management practice is called for requiring suitable biological indicators to show the impact of these changes, set priority regions and in developing models for conservation planning.

Uttara Kannada district with a spatial extent of 10,291sq.km is the second largest district in south India with good vegetation cover (68%). Dandeli Anshi tiger reserve (814.89sq.km), which is about 8% of the total area is the only protected area in the district. It is a clear indication that a single large protected area is not sufficient for the conservation and management of biodiversity of this district. The rationale for protected area networks or any region to consider for conservation and management must be based on a well-defined functional unit. A river basin (catchment) is topographically and hydrologically well defined unit, which can be very well considered for conservation management. Across various spatial scales a river basin helps to understand the ecological processes and landscape influence on biodiversity. The current focus is to prioritise conservation regions in five river basins in Uttara Kannada district, using biological indicator - amphibians (surrogate for many other species). Objectives of the current research are:

1. mapping of diversity and distribution of amphibian species - river basin wise in the district

2. Prioritise areas for conservation based on amphibian richness and association to habitat characteristics.

Materials and methods

Study area: Five river basins, namely Kali, Bedti, Aghanashini, Sharavathi and Venkatapura of Uttara Kannada district in the Central Western Ghats (between 12°-16°N) were considered for the this study as depicted in Figure 1. These rivers are west flowing rivers and form the part of Uttara Kannada, the district with highest forest cover (78%) in Karnataka.

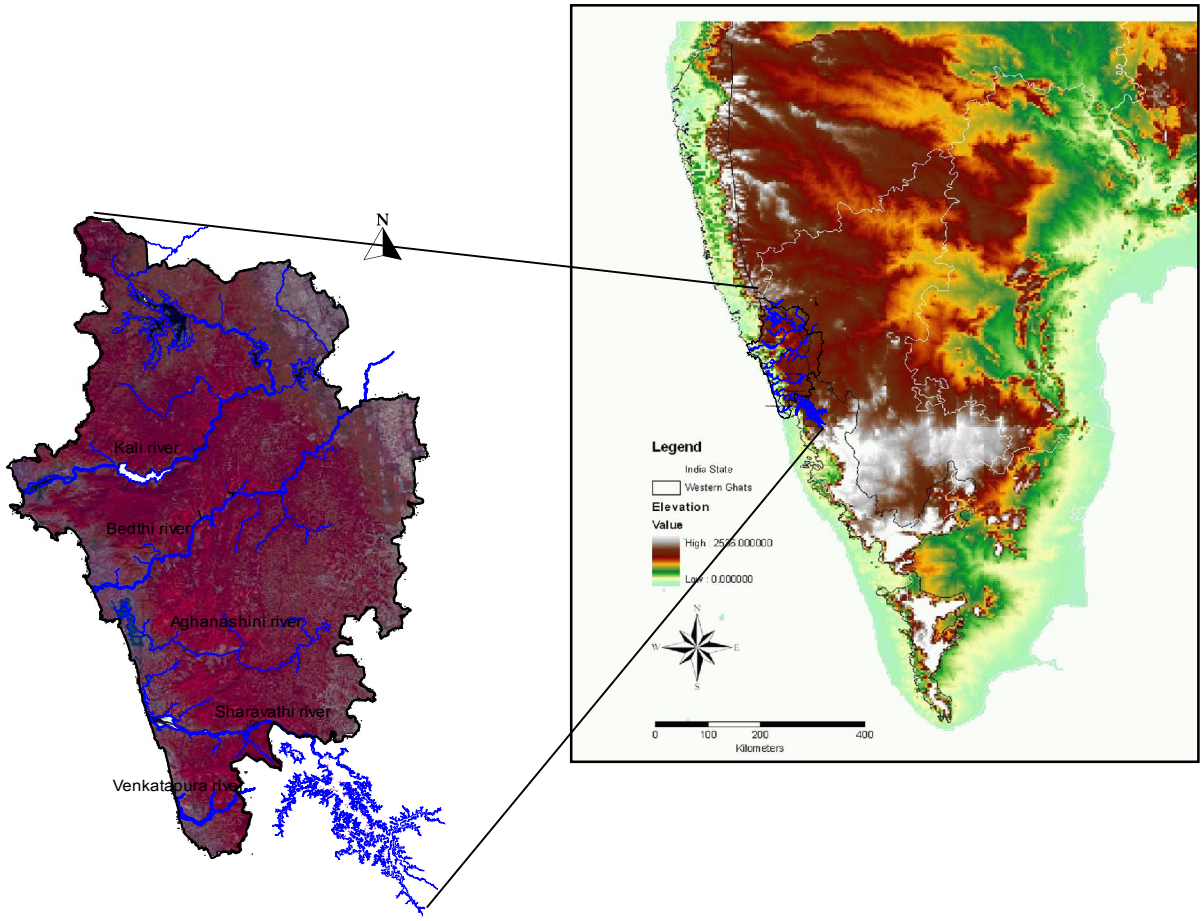
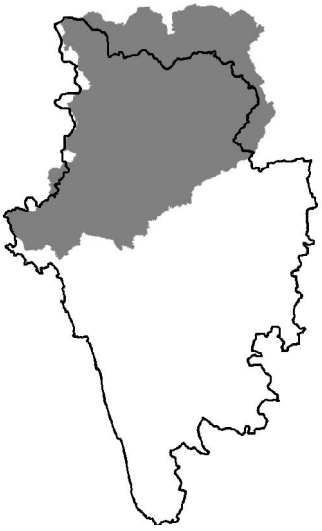


Figure 1. False colour composite image of Uttara Kannada district.

River Kali – It is the northern most rivers in coastal Karnataka, originates at Diggi in Supa Taluk, Uttara Kannada district and traverses for about 184km before joining Arabian Sea at Karwar. For the initial 100 km, the river flows south eastwards and at Thattihalla due to geological fault it flows towards southwest. The river has four major and two minor dams constructed across river Kali. Major dams are at Supa, Bommanalli, Kodasalli and Kadra, while minor ones are at Tattihalla and Kaneri. Pandri, Ujli, Nujji, Thananala, Kaneri and Vaki are the other strems that joins Kali at various places. The entire river basin is about 5,104 sq. km, encompassing dry deciduous-evergreen-mangroove vegetation of the Western Ghats. The Kali river basin receives on an annual rainfall between 850-3200 mm. Figure 2 illustrates drainage network and sampling sites in River Kali.



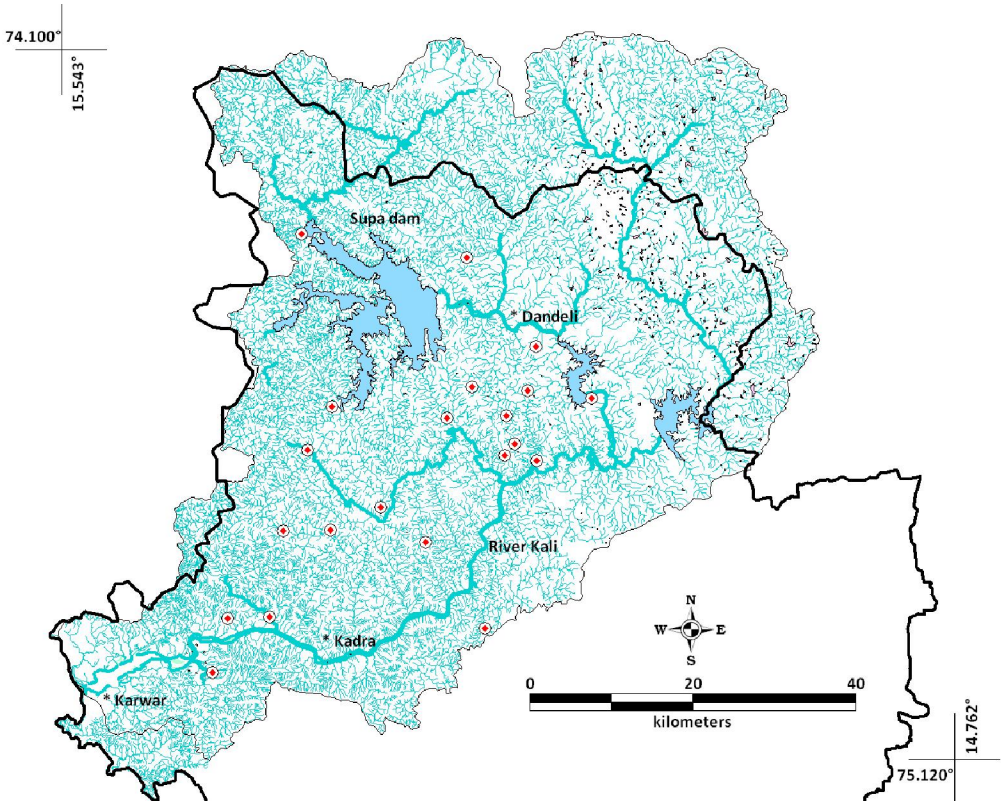
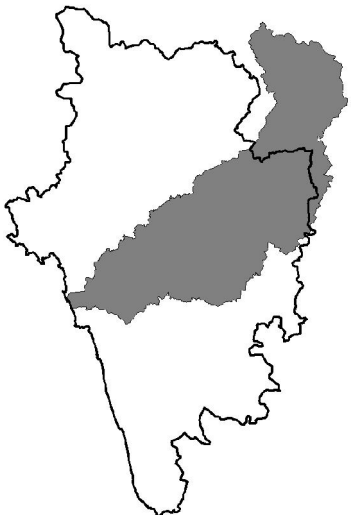


Figure 2. Drainage network and sampling sites in Kali River basin.

River Bedti – River Bedti (also called Gangavalli) originates at Dharwad District as Shalmala and confluences at Kalghatgi with another stream from Hubli, flows westward for about 161km to merge with Arabian sea. It has a catchment of about 3878sq.km, the second largest catchment in Uttara Kannada district. There are two tributaries to this river Shalmala and Sonda. The river forms a fall at Magod from about 220m. The river has dense evergreen, semi-evergreen to deciduous forests along its path. Soils are mainly lateritic. Annual rainfall ranges from 1,700 - 6,000 mm. Figure 3 depicts sampling sites and drainage network in River Bedti.



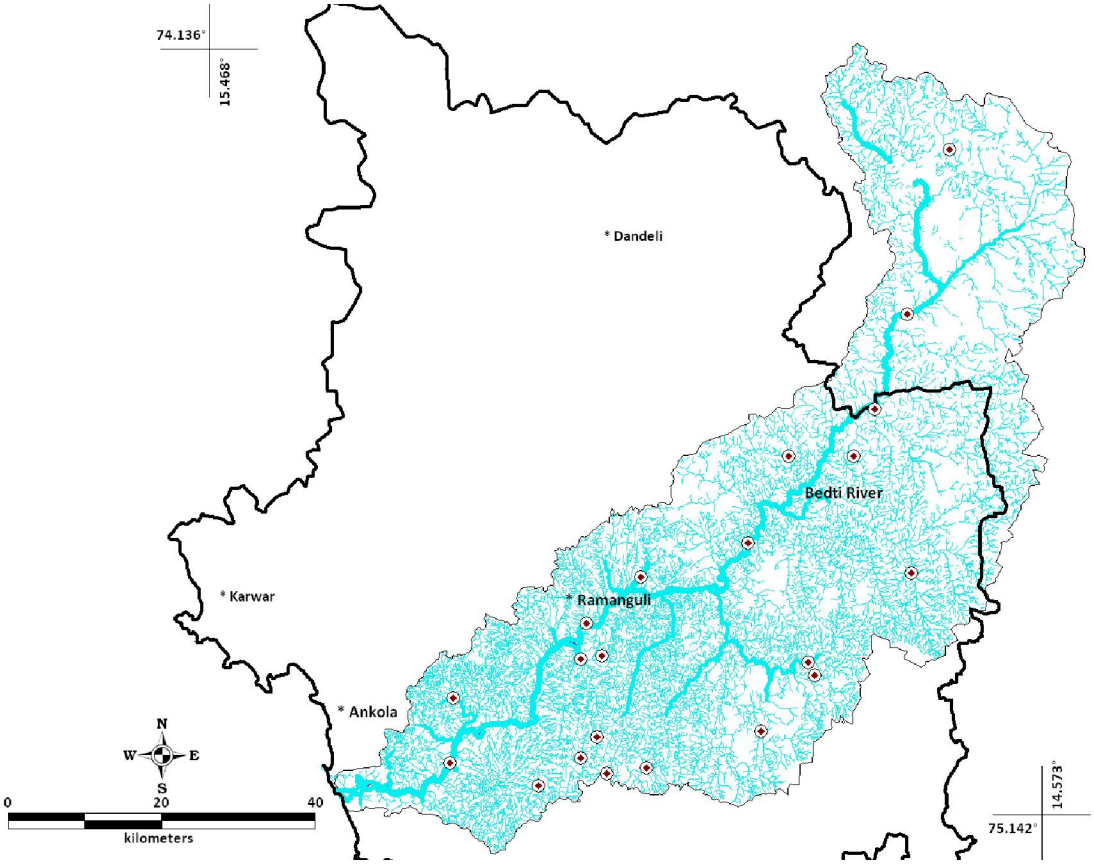
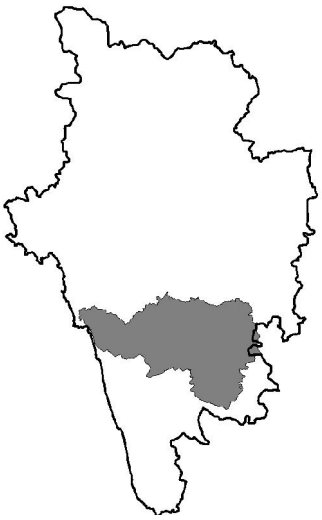


Figure 3. Drainage network and sampling sites in Bedti River basin.

River Aghanashini - River Aghanashini having a catchment of about 1390.52 sq.km traverses westward for about 121km from the origin at Manjguni of Sirsi Taluk, and confluences with Arabian Sea at Tadri. Estuarine part of Aghanashini is 13km long making it as the longest among Uttara Kannada rivers. Unchalli falls (Lashington falls) forms a major water fall of this river. Figure 4 shows drainage map and sampling sites in River Aghanashini. Despite being a small river basin, Aghanashini has diverse vegetation predominates with evergreen-semi-evergreen to mangrove.



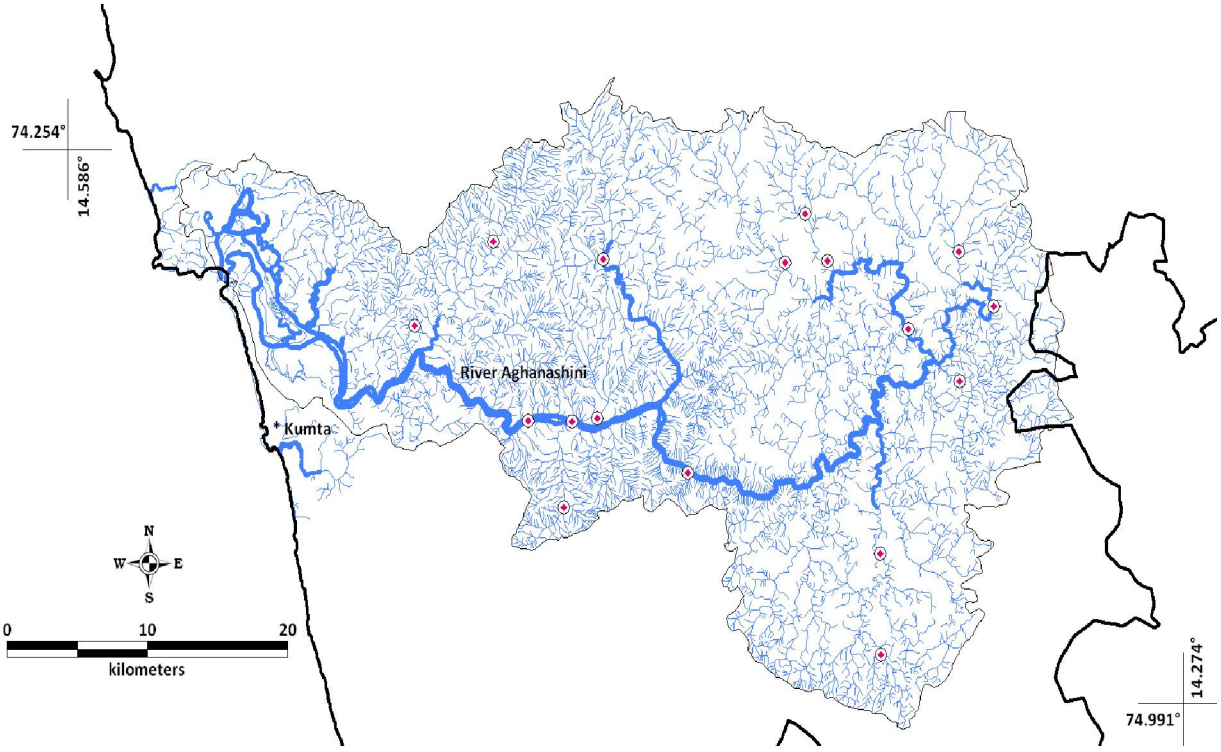
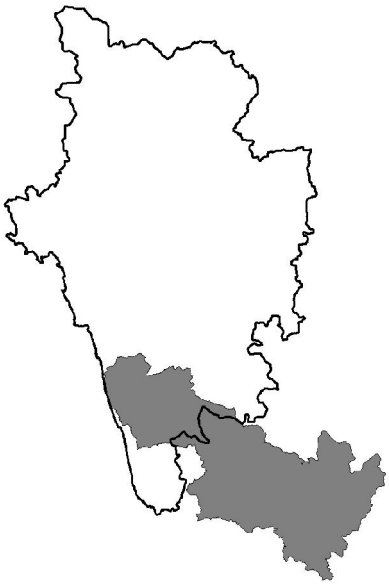


Figure 4. Drainage network and sampling sites in Aghanashini River basin.



River Sharavathi – It originates near Ambuthirtha of Shimoga district, traverses for about 132km and confluences at Honnavar to the Arabian sea. The magnificent waterfall, Jog, is situated in the course of this river. The catchment area of this river is about 3005 sq.km. Only down stream part of the river is within Uttara Kannada district. This river has four dams across its catchment. The first dam was built way back in 1940 at Hirebhaskar, which got submerged after the construction of Linganmakki Dam in 1964. It was among the largest in Asia at that time submerging an area of 326sq.km. Figure 5 illustrates catchment area and sampling sites in Sharavathi River.

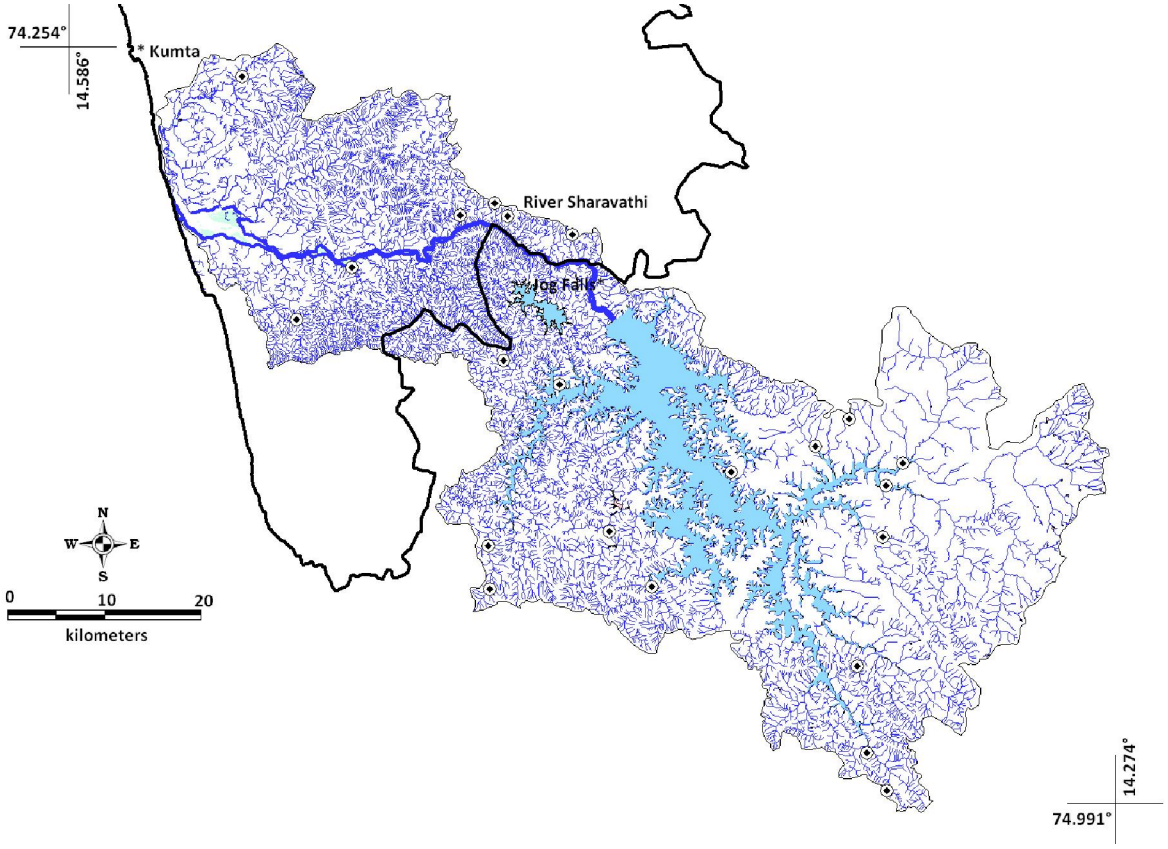


Figure 5. Drainage network and sampling sites in Sharavathi River basin.

River Venkatapura – Smallest of the rivers in Uttara Kannada, Venkatapura has very small catchment area of about 326.2sq.km. The vegetation is predominantly low land evergreen forests. Figure 6 illustrates the sampling sites and catchment of River Venkatapura.

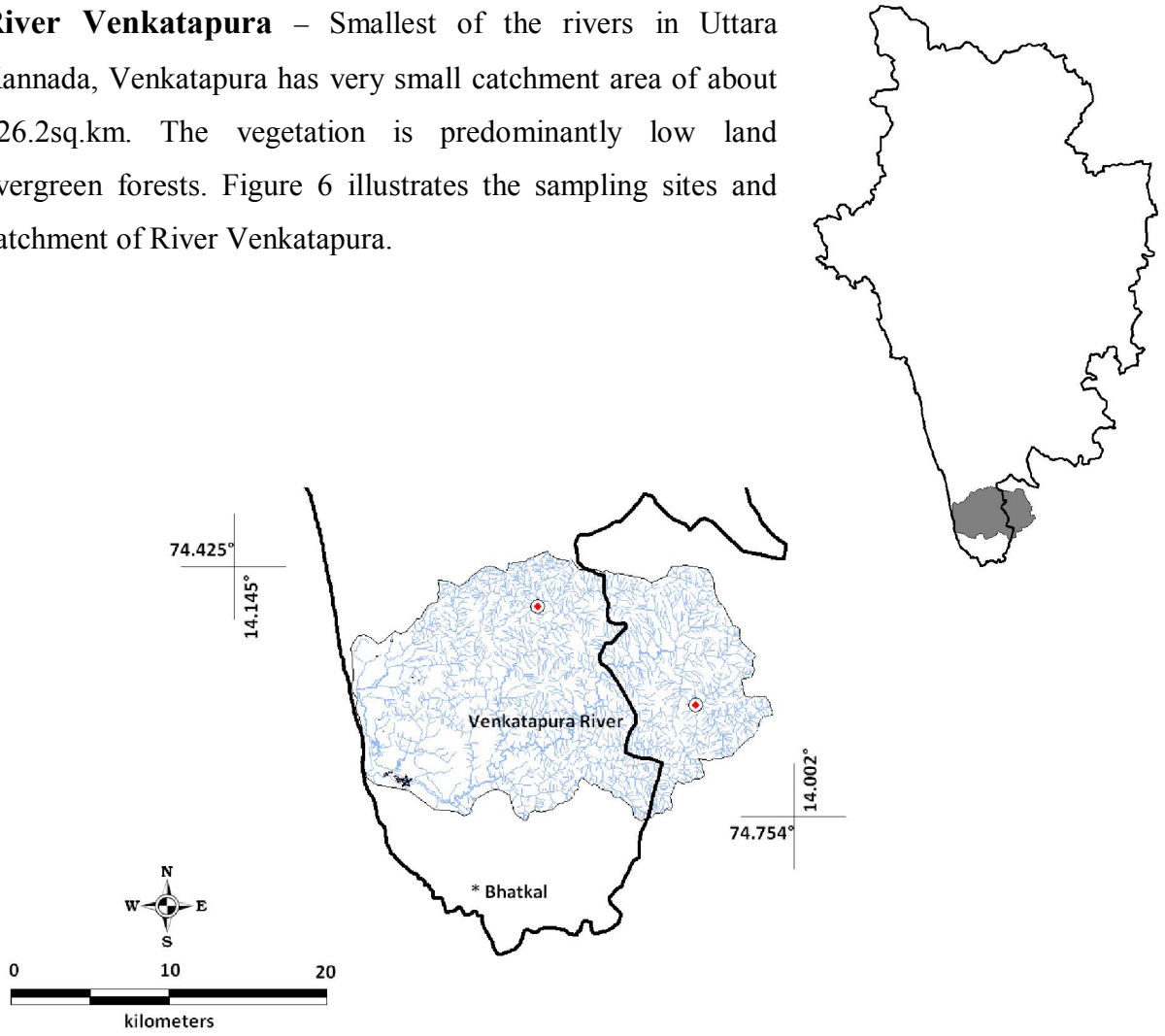


Figure 6. Drainage network and sampling sites in Venkatapura River basin.

Sampling methods

Site Selection: Based on the land use and the extent of catchment area in each river basin, 83 sampling sites were selected: two from Venkatapura, 22 from Sharavathi, 15 from Aghanashini, 22 each from Bedti and Kali river basins.

Habitat Variables: Altitude (meters above sea level), rainfall (annual, mm), stream perenniality (seasonal or perennial) 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. River basin wise sampling sites and habitat variables are given in Table 1.

Table 1. Sampling sites and respective habitat variables.

#	River	Place	Altitude (m)	Rainfall(mm)	Landuse	Stream
1	Venkatapura	Ondalasu	94	4429	1	1
2	Venkatapura	Kelanur	231	4662	4	2
3	Sharavathi	Malemane	309	4171	4	2
4	Sharavathi	Kathalekan	599	4079	4	2
5	Sharavathi	Watehalla	698	4119	4	2
6	Sharavathi	Mavingundi	611	3859	4	2
7	Sharavathi	Dabbe	609	4302	4	2
8	Sharavathi	Hosagadde	41	4240	1	1
9	Sharavathi	Magod	8	4145	1	1
10	Sharavathi	Chandavar	22	3693	3	2
11	Sharavathi	Nandihole	561	2198	1	1
12	Sharavathi	Haridravathi	563	2339	1	1
13	Sharavathi	Mavinhole	593	2583	3	2
14	Sharavathi	Sharavathi	610	3655	4	2
15	Sharavathi	Hilkunji	601	4402	3	2
16	Sharavathi	Nagodi	572	4040	4	2
17	Sharavathi	Hurli	605	3999	3	2
18	Sharavathi	Karni	657	4877	4	2
19	Sharavathi	Yennehole	578	4744	4	2
20	Sharavathi	Muppane	575	4069	3	2
21	Sharavathi	Mundigesara	657	2284	3	2
22	Sharavathi	Niluvase	763	4124	4	2
23	Sharavathi	Sampekai	578	2516	1	1

24	Sharavathi	Hubse	586	2959	1	1
25	Aghanashini	Kathagal	45	3662	3	2
26	Aghanashini	Ullur	69	3793	1	1
27	Aghanashini	Sapurti	512	3196	3	2
28	Aghanashini	Baillalli	534	3769	4	2
29	Aghanashini	Yanahole	72	3553	2	1
30	Aghanashini	Bennehole	418	3769	3	2
31	Aghanashini	Revankatta	520	3300	1	1
32	Aghanashini	Bolurhole	495	3054	3	2
33	Aghanashini	Bilgihole	489	3655	1	1
34	Aghanashini	Hulidevaragadde	55	3694	1	1
35	Aghanashini	Donnehole	26	3641	3	2
36	Aghanashini	Nellimadke	526	2757	1	1
37	Aghanashini	Neralamane	504	3019	1	1
38	Aghanashini	Deevalli	30	3676	3	2
39	Aghanashini	Mudagi	31	3617	3	1
40	Bedti	Abageri	405	3582	4	2
41	Bedti	Andhalli	491	2642	2	1
42	Bedti	Angadibailu	84	3481	3	2
43	Bedti	Chitageri	524	1574	2	1
44	Bedti	Daanandi	492	2245	2	1
45	Bedti	Dabguli	89	2742	4	2
46	Bedti	Devnalli	541	3322	1	1
47	Bedti	Gundabala	8	3478	1	1
48	Bedti	Gunjavathi	505	1747	2	1
49	Bedti	Hasehalla	71	3044	3	2
50	Bedti	Hemmadi	485	2278	2	1
51	Bedti	Kalghatgi	517	1153	1	1
52	Bedti	Kalleshwara	104	3131	4	2
53	Bedti	Karadrolli	490	2025	2	1
54	Bedti	Kelginkeri	344	3481	1	1
55	Bedti	Makkigadde	52	3427	3	2
56	Bedti	Manchikeri	424	2506	2	1
57	Bedti	Melinkeri	428	3496	4	2
58	Bedti	Nyctisite	531	3496	4	2
59	Bedti	Tarihal	647	849	1	1
60	Bedti	Vajagadde	563	3518	4	2
61	Bedti	Yerebail	497	1555	2	1
62	Kali	Goira	63	3074	1	1
63	Kali	Badapoli	532	3407	2	1
64	Kali	Anshi	529	3332	3	2
65	Kali	Jhalavali	546	3191	2	1
66	Kali	Kaneri	489	3149	2	2
67	Kali	Cyntheri	445	2812	2	1
68	Kali	Ulvi	645	3093	1	1

69	Kali	Gunda road	483	2635	2	1
70	Kali	Water1	579	2430	2	1
71	Kali	Amgaon	557	2370	1	1
72	Kali	Water2	564	2452	2	1
73	Kali	Mines	661	2531	2	1
74	Kali	Nagzhari1	180	2414	2	1
75	Kali	Nagzhari2	391	2224	2	1
76	Kali	Kulgi	502	2085	2	1
77	Kali	Virnolii	457	1932	2	1
78	Kali	Sakatihalla	17	3055	3	1
79	Kali	Beegaru	257	3014	4	2
80	Kali	Kanshirda	473	2012	2	1
81	Kali	Deriye	640	3015	3	2
82	Kali	Castlerock	571	2894	3	2
83	Kali	Gowliwada	534	2125	2	1

Landuse – 1: Agriculture, 2: Deciduous, 3: Semi-evergreen, 4: Evergreen; Stream – 1: Seasonall, 2: Perennial

Ecological Guilds: Anuran amphibians in this study were classified into ecological guilds (Table 2) on the basis of four variables describing their functional ecology, namely, endemism (referring to their spatial extent of occurrence), threat status (IUCN, 2009), habitat specificity (aquatic to arboreal, considering aquatic to be very primitive) and finally tadpole habitat (direct development being considered most advanced).

Table 2. Ecological guild gradation used in the present study.

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

Sampling of amphibians: Amphibian sampling was carried out very systematically covering all seasons. Visual encounters, calls, tadpoles, foam nests, spawn are used to record the amphibians in the field. Two man hours of searching is made using torch lights between 19:00-20:00 hr, by walking across the streams, forest floors, gleaning leaf litters, prodding bushes, wood logs, rock crevices etc. All the species encountered are identified up to species level using the keys of Bossuyt and Dubois (2001), and Daniels (2005). New species names are based on literature by Biju et al, (2010) and Dinesh et al, (2010). Opportunistic encounters are also recorded to enlist the species of the region.

Statistical Analysis: Using presence data for species, grading in ecological guilds and environmental variables, non-metric multidimensional analysis (NMDS) is carried out. Non-metric multidimensional scaling is based on Bray-Curtis distance matrix. In NMDS, data points are placed in 2 or 3 dimensional coordinates system preserving ranked differences. Absolute distances are not taken into consideration. Spatial interpolation by Krigging technique is used to produce map with continuous spatial estimate of species endemism based on scattered data points.

Results

Amphibian diversity and distribution across Uttara Kannada district: Forty seven species of amphibians were recorded from Uttara Kannada district (Table 3). This is nearly 30% of observed amphibians from the Western Ghats (157 species). These species belonged to two orders, nine families and 20 genera. Two families, namely, Nyctibatrachidae and Micrixalidae are among the oldest frog families found in the Western Ghats and are Gondwanan relicts. Of the 46 species recorded, 67% of them are endemic to the Western Ghats (31 species). Family Dicroglossidae has highest species (15) followed by Rhacophoridae with 10 species. Least species were recorded in Ranixalidae and Ichthyophiidae with two each (Table 4).

Table 3. Species recorded and their ecological status in the four river basins of Uttara Kannada.

Species	Common name	Endemic	IUCN
CLASS: AMPHIBIA Gray			
ORDER: ANURA Fischer von Waldheim			
Family: Bufonidae Gray			
Duttaphrynus melanostictus (Schneider 1799)	Common Indian toad	Non endemic	LC
Duttaphrynus scaber (Schneider, 1799)	Ferguson's toad	Non endemic	LC
Duttaphrynus stomaticus (Lutken, 1862)	Assam toad	Non endemic	LC
Pedostibes tuberculosus Günther 1875	Malabar Tree toad	Western Ghats	EN
Family: Dicroglossidae Anderson			
Euphlyctis aloysii Joshy, Alam,Kurabayashi, Sumida and Kuramoto, 2009	Aloys' skittering frog	Western Ghats	DD
Euphlyctis cyanophlyctis (Schneider, 1799)	Skittering frog	Non endemic	LC
Euphlyctis hexadactylus (Lesson, 1834)	Indian Pond frog	Non endemic	LC
Fejervarya brevipalmata (Peters, 1871)	Peter's frog	Western Ghats	DD
Fejervarya caperata Kuramoto, Joshy, Kurabayashi And Sumida, 2007	Wrinkled Fejervarya	Western Ghats	DD
Fejervarya granosa Kuramoto, Joshy, Kurabayashi And Sumida, 2007	Granular Fejervarya	Western Ghats	DD
Fejervarya kudremukhensis Kuramoto, Joshy, Kurabayashi and Sumida, 2007	Kudremukha Fejervarya	Western Ghats	DD
Fejervarya mudduraja Kuramoto, Joshy, Kurabayashi And Sumida, 2007	Mudduraja Fejervarya	Western Ghats	DD
Fejervarya rufescens (Jerdon, 1853)	Reddish burrowing frog	Western Ghats	LC
Hoplobatrachus crassus (Jerdon, 1853)	Jerdon's bull frog	Non-endemic	LC
Hoplobatrachus tigerinus (Daudin, 1803)	Indian bull frog	Non-endemic	LC
Minervarya syhadris Dubois, Ohler and Biju, 2001	Minervarya frog	Western Ghats	EN
Sphaerotheca aff. leucorhychus (Rao, 1937)	Rao's burrowing frog	Western Ghats	DD
Sphaerotheca breviceps (Schneider, 1799)	Indian Burrowing frog	Non-endemic	LC
Sphaerotheca dobsonii (Boulenger, 1882)	Dobson's burrowing frog	Western Ghats	LC
Family: Micrixalidae Dubois, Ohler and Biju			
Micrixalus aff. elegans (Rao, 1937)	Elegant torrent frog	Western Ghats	DD
Micrixalus saxicola (Jerdon, 1853)	Small torrent frog	Western Ghats	VU
Family: Microhylidae Günther			
Kaloula taprobanica Parker, 1934	Painted frog	Non-endemic	LC
Microhyla ornata (Dumeril and Bibron, 1841)	Ornate narrow mouthed frog	Non-endemic	LC
Microhyla rubra (Jerdon, 1854)	Red narrow mouthed frog	Non-endemic	LC
Ramanella aff. Montana (Jerdon, 1854)	Jerdon's Ramanella	Western Ghats	NT
Family: Nyctibatrachidae Blommers-Schlösser			
Nyctibatrachus cf. aliciae Inger, Shaffer, Koshy And Bakde, 1984	Alice's Night frog	Western Ghats	EN
Nyctibatrachus cf. major Boulenger, 1882	Malabar Night frog	Western Ghats	VU
Nyctibatrachus cf. petraeus Das and Kunte, 2005	Castle rock night frog	Western Ghats	LC
Family: Ranidae Rafinesque			
Clinotarsus curtipes (Jerdon, 1853)	Bicoloured frog	Non-endemic	NT
Hylarana aurantiaca (Boulenger, 1904)	Golden frog	Western Ghats	VU
Hylarana malabaricus (Tschudi,1838)	Fungoid frog	Non-endemic	LC
Hylarana temporalis (Günther,1864)	Bronzed frog	Non-endemic	NT

Family: Ranixalidae Dubois			
Indirana beddomii (Günther, 1875)	Beddome's Indian frog	Western Ghats	LC
Indirana semipalmatus (Boulenger,1882)	South Indian frog	Western Ghats	LC
Family: Rhacophoridae Hoffman			
Polypedates maculatus (Gray, 1834)	Chunam frog	Non-endemic	LC
Polypedates occidentalis Das and Dutta, 2006	Charpa tree frog	Western Ghats	DD
Polypedates pseudocruciger Das and Ravichandran, 1998	False hour glass tree frog	Western Ghats	LC
Pseudophilautus amboli (Biju and Bossuyt, 2009)	Amboli bush frog	Western Ghats	DD
Pseudophilautus wynaadensis (Jerdon, 1853)	Wynaad bush frog	Western Ghats	EN
Raorchestes bombayensis (Annandale, 1919)	Maharashtra bush frog	Western Ghats	VU
Raorchestes luteolus (Kuramoto and Joshy, 2003)	Coorg yellow bush frog	Western Ghats	DD
Raorchestes ponmudi (Biju and Bossuyt, 2005)	Large Ponmudi bush frog	Western Ghats	CE
Raorchestes tuberohumerus (Kuramoto and Joshy, 2003)	Kudremukh bush frog	Western Ghats	DD
Rhacophorus malabaricus Jerdon, 1870	Malabar gliding frog	Western Ghats	LC
ORDER: GYMNOPHIONA Müller			
Family: Ichthyophiidae Taylor			
Ichthyophis beddomi Peters, 1879	Beddome's caecilian	Western Ghats	LC
Ichthyophis bombayensis Taylor, 1960	Bombay caecilian	Western Ghats	DD

Note: E-endemic; NE-non-endemic; GAA-GlobalAmphibian Assessment; EX-Extinct from type locality; EN-Endangered; Vu-Vulnerable; NT-Near threatened; LC-Least concerned, DD-Data deficient

Table 4. Family wise species recorded in Uttara Kannada

Family	Genera	Species
Bufonidae	2	4
Dicroglossidae	5	15
Micrixalidae	1	3
Microhylidae	3	4
Nyctibatrachidae	1	3
Ranidae	2	4
Ranixalidae	1	2
Rhacophoridae	4	10
Ichthyophiidae	1	2

River basin wise diversity of Amphibians: Amphibian species recorded in each of the river basin in given in Table 5. There were 45 species from Sharavathi, 32 from Aghanashini, 29 each from Bedti and Kali river basins and five species in Venkatapura river.

Sharavathi river basin: Forty five species were recorded from Sharavathi river basin listed in Table 5. Majority of the species recorded for the entire Uttara Kannada district is known from Sharavathi river basin, except for *Raorchestes bombayensis*. Sharavathi harbours nearly 69% of endemic species of the Western Ghats. The species rich sites (> 10 species) are Kathalekan (34 species), Watehalla and Muppane (14 species each), Hurli (12 species) and Niluvase (11 species). Kathalekan is a well known Myristica swamp having ancient origin (Chandran et al 2010), and provides habitat for uniquely breeding species (Gururaja, 2010). It also has highest number of endemic species (24). *Raorchestes ponmudi*, an endangered species is also recorded from this site.

Aghanashini river basin: Thirty two species are recorded from Aghanashini river basin (Table 5). None of the caecilians were recorded in this river basin. Kathagal with 17 species is species rich site in Aghanashini followed by Sapurthi (15 species) and Baillalli (13 species). Sapurthi harbours higher endemic species in the entire river basin.

Bedti river basin: Twenty nine species were recorded from Bedti river basin. Species rich regions are Makkigadde (13 species), Devnalli (12 species), Kelginkeri and Daanandi (10 species each). Endemism is highest is Makkigadde and Devnalli (8 species each). It is interesting note that Yerebail has no endemic species despite having 6 species.

Kali river basin: Kali river basin has 29 species (Listed in Table 5). Castle rock, Virnolli and Ulvi are species rich (13 species each) followed Gowliwada (10 species). Castle rock leads with higher endemism than Ulvi (6 endmic species) Virnolli (9 endemic species). The species recorded from Deriye were all endemic to Western Ghats.

Table 5. River basin wise species record in Uttara Kannada.

	Sharavathi	Aghanashini	Bedti	Kali	Venkatapura
Family: Bufonidae					
Duttaphrynus melanostictus	+	+	+	+	
Duttaphrynus scaber	+	+	+	+	
Duttaphrynus stomaticus	+		+		
Pedostibes tuberculosus	+	+	+	+	
Family: Dicroglossidae					
Euphlyctis aloysii	+			+	
Euphlyctis cyanophlyctis	+	+	+	+	+
Euphlyctis hexadactylus	+	+			
Fejervarya brevipalmatus	+				+
Fejervarya caperata	+	+	+	+	
Fejervarya granosa	+	+	+		
Fejervarya kudremukhensis	+		+	+	
Fejervarya mudduraja	+	+			
Fejervarya rufescens	+	+	+	+	
Hoplobatrachus crassus	+	+			
Hoplobatrachus tigerinus	+	+	+	+	
Minervarya syhadris	+	+	+	+	+
Sphaerotheca aff. leucorhychus	+	+		+	
Sphaerotheca breviceps	+	+	+	+	
Sphaerotheca dobsonii	+				
Family: Micrixalidae					
Micrixalus aff. Elegans	+				
Micrixalus saxicola	+	+	+		
Family: Microhylidae					
Kaloula pulchra	+			+	
Microhyla ornata	+	+	+	+	
Microhyla rubra	+	+	+	+	
Ramanella aff. Montana	+			+	
Family: Nyctibatrachidae					
Nyctibatrachus cf. aliciae	+	+	+		+
Nyctibatrachus cf. major	+	+			
Nyctibatrachus cf. petraeus	+	+	+	+	
Family: Ranidae					
Clinotarsus curtipes	+	+	+	+	
Hylarana aurantiaca	+	+	+	+	
Hylarana malabaricus	+	+	+	+	
Hylarana temporalis	+	+	+	+	
Family: Ranixalidae					
Indirana beddomii	+	+	+	+	

Indirana semipalmatus	+	+	+	+	+
Family: Rhacophoridae					
Polypedates maculatus	+	+	+	+	
Polypedates occidentalis	+	+			
Polypedates pseudocruciger	+				
Pseudophilautus amboli	+		+	+	
Pseudophilautus wynaadensis	+	+		+	
Raorchestes bombayensis			+	+	
Raorchestes luteolus	+	+	+		
Raorchestes ponmudi	+				
Raorchestes tuberohumerus	+	+		+	
Rhacophorus malabaricus	+	+	+	+	
Family: Ichthyophiidae					
Ichthyophis beddomi	+				
Ichthyophis malabaricus	+		+		
Species richness	**45**	**32**	**29**	**29**	**5**

Cluster analysis based on species richness and endemics using Bray-curtis distance measure is given in Figure 7. There are four clear groups with Kathalekan standing out exceptionally. Group I is species poor, while Group IV is species rich. Non-metric multidimensional scaling analysis based on habitat variables and species parameters are given in Figure 8. All the 83 sampling sites can be categorically grouped into four. Each quadrant in the graph are representing a unique group. First quadrant carries species rich but endemic poor group, II Quadrant having both richness and endemism very poor, III Quadrant with species poor but endemic rich and IV Quadrant with species rich and endemic rich sites. Kathalekan, Watehalla and Muppanne in Sharavathi, Baillalli in Aghanashini, Kelginkeri in Bedti are in Quadrant IV, needing immediate conservation measures. These sites were also influenced by arboreal species richness, direct developing species, critically endangered and endangered species.

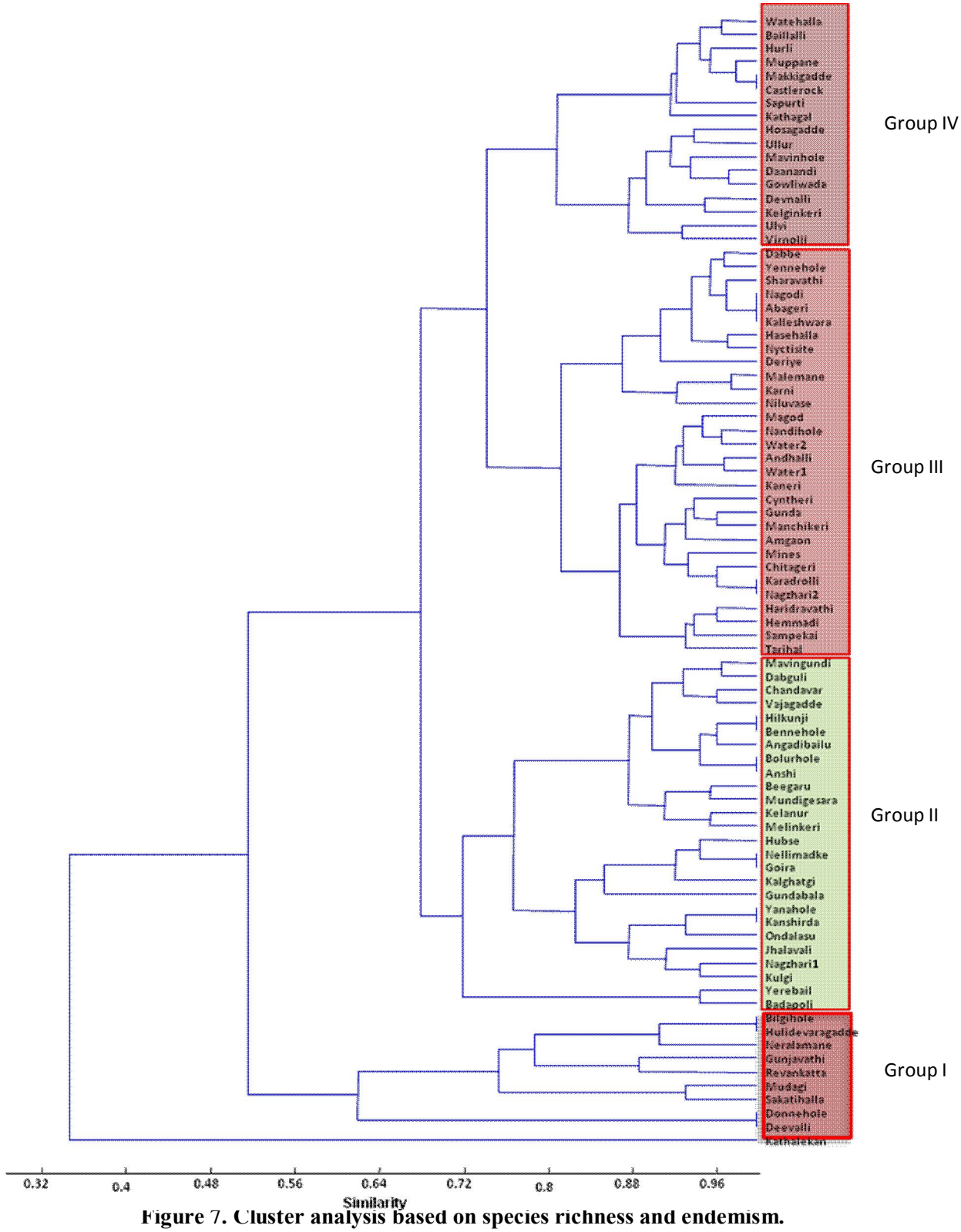


Figure 7. Cluster analysis based on species richness and endemism.

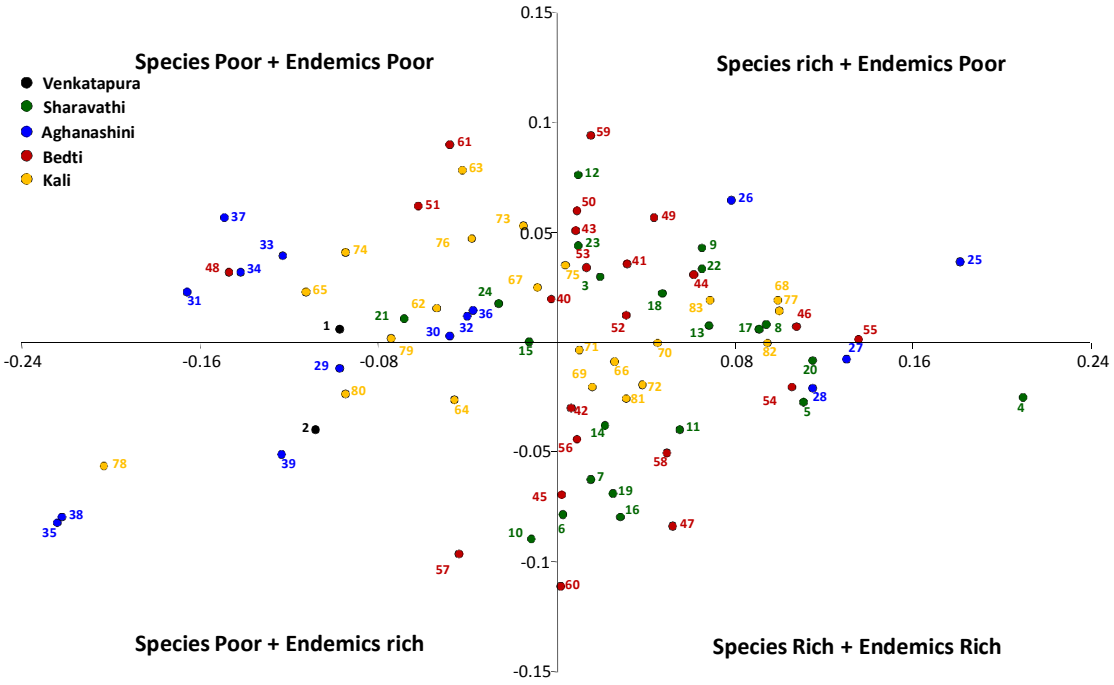


Figure 8. Non-metric multidimensional analysis of amphibians of Uttara Kannada.

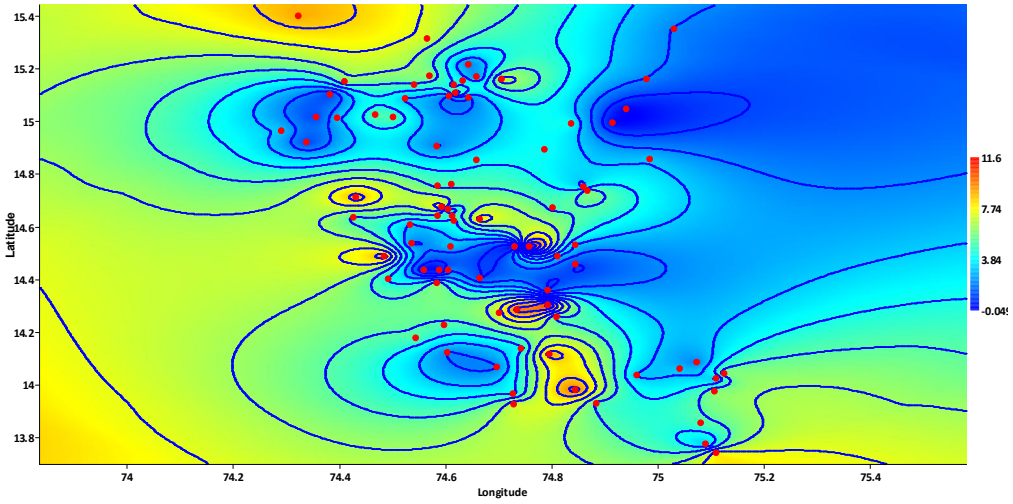


Figure 9. Spatial interpolation using krigging based on species endemism.

Krigging based on species endemism is given in Figure 9. Kathalekan is being deliberately removed from the analysis to know other sites in the Uttara Kannada district with higher endemism. The warm coloration and contours joining them indicates the endemism value. Sites like Castle rock in Kali, Makkigadde in Bedti, Kathagal, Sapurthi and Bailalli in Aghanashini

and Maleman, Nagodi and Hurli in Sharavathi river basin along with Kathalekan are species rich and endemics rich

Conclusion and Recommendation

River basin based studies provide insights on species distribution and diversity as catchments are topographically and hydrologically well defined. Among five rivers, Venkatapura is least rich in terms of amphibians, which could be attributed to its smaller catchment. Among the other four river basins, Sharavathi is species rich and also endemics. One of the sampling site, Kathalekan, a very well known Myristica swamp, harbours 34 species, attributed to the vegetation and seasonality of stream. This site certainly needs immediate attention from decision makers as surrounding areas are used for agriculture purpose and there are instances of human activities inside the region. Muppane also has higher richness, but is already inside Sharavathi valley wildlife sanctuary. As one proceeds further north in Uttara Kannada district, the vegetation also changes to semi-evergreen to deciduous, which could be the reason of less diversity in Kali and Bedti river (29 species each). Kathagal in Aghanashini river basin is relatively closer to coast among the sites is an example for 'refugia' concept, where in amphibian species were found despite a small area surrounded by agricultural activities. Bailalli and Sapurthi also harbor higher species in Aghanashini. In Bedthi, Makkigadde and Kelginkeri are the sites with high amphibian richness and endemism. Similarly, Castlerock, Virnolli, Ulvi and Gowliwad are in Kali with amphibian richness and endemism. However, all these sites with high richness and endemism in all the river basin face the threat, directly are indirectly from human activities such as diversion of streams, encroachment for agriculture, illegal felling and collection of forest yields. Kathalekan in Uttara Kannada district is an ideal heritage sites from Biodiversity perspective. The other sites mentioned needs the attention of forest managers for better conservation and management of biodiversity in Uttara Kannada district.

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Large wrinkled frog *Nyctibatrachus major*

Rufescent frog *Fejervarya rufescens*

Black torrent frog *Micrixalus saxicola*

Malabar tree toad *Pedostibes tuberculosus*

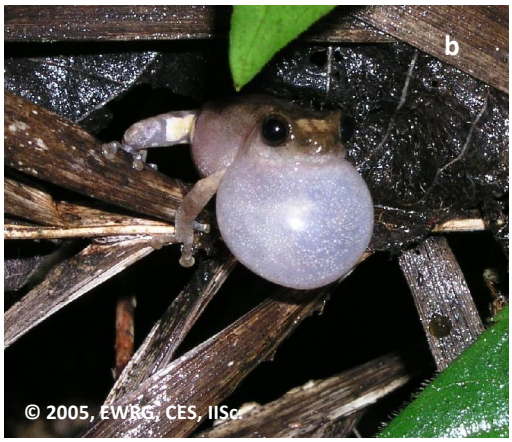
Castle rock wrinkled frog *Nyctibatrachus petraeus*

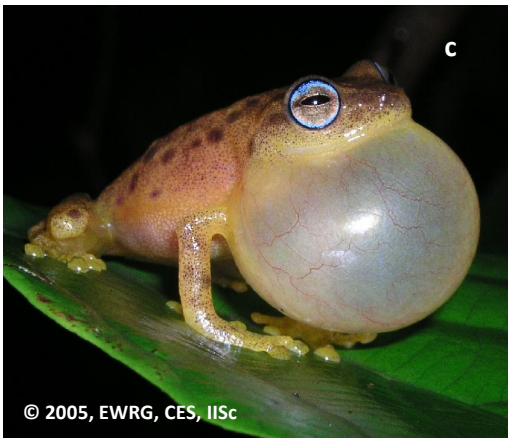
Cricket frog *Fejervarya caprata*?

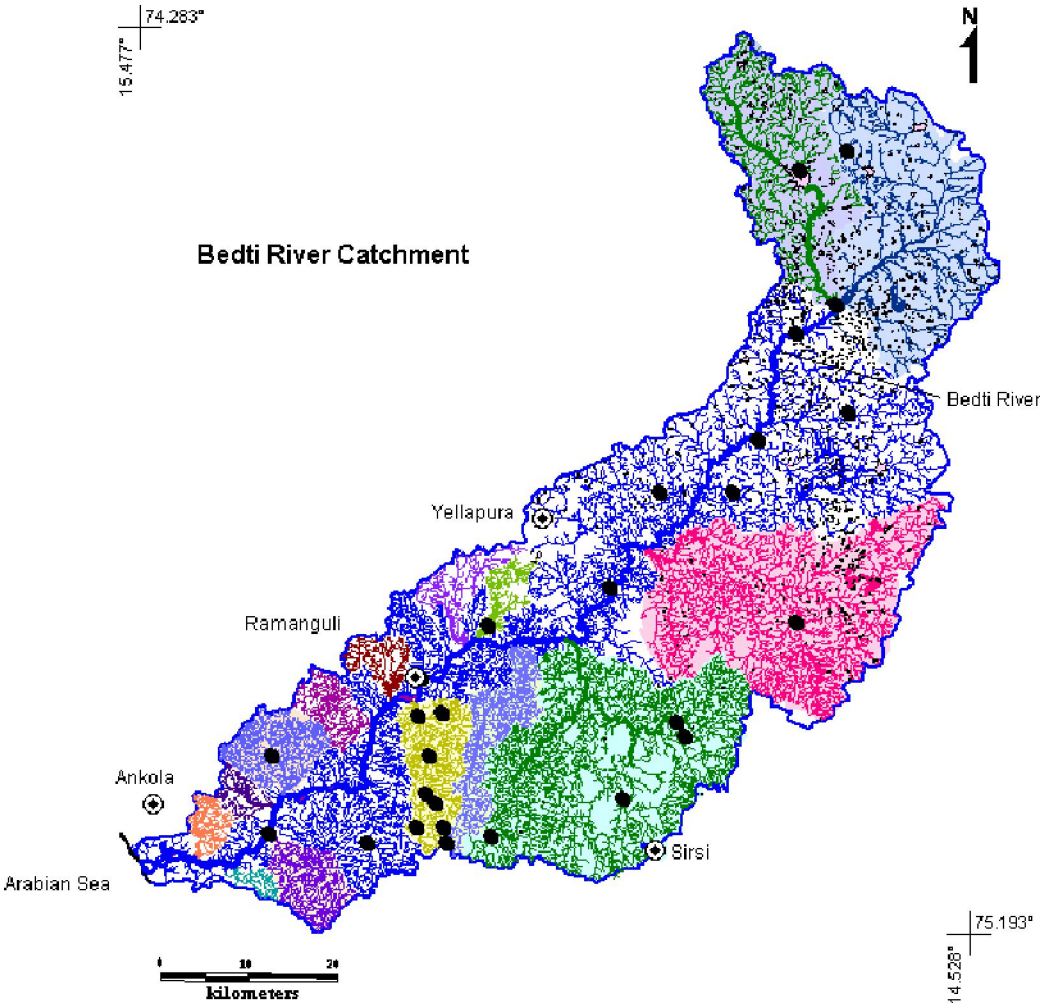
Bull frog *Hoplobatrachus tigerinus*

Jerdon's narrow mouthed frog *Ramanella montana*

Amphibians of Aghanashini river basin. a) *Pedostibes tuberculosus*, endangered frog, b) *Philautus tuberohumerus*, c) *P.* cf. *luteolus*, d) *Nyctibatrachus* cf. *aliciae*, endangered frog, e) *Sphaerotheca rufescens*, and f) *Rana curtipes*.






74.283°
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N
Bedti River Catchment
Bedti River
Yellapura
Ramanguli
Ankola
Sirsi
Arabian Sea
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10
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kilometers
75.193°
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