CHAPTER 4

QUANTITATIVE ANALYSIS OF THE COMMUNITY STRUCTURE OF AMPHIBIAN ASSEMBLAGES IN VADODARA DISTRICT, GUJARAT

4.1. INTRODUCTION

Most of the amphibians have narrow physiological tolerance and ecological distributions and in their endeavor to attain a successful independence from water and colonizing the land, they have undergone a remarkable adaptive radiation. The living amphibians exhibit a greater diversity of life history than any other vertebrates, and because of their diversity and abundance, they are among the most important vertebrate components of wetland ecosystems. Both adult and larval amphibian populations have important implications on prey-predator relationship and also on community energy dynamics (Seale, 1980; Holomuzki *et al.*, 1994; Blaustein *et al.*, 1996). From the ecological perspective, amphibians are regarded as good ecological indicators. Most of the amphibians are exposed to terrestrial and aquatic habitats at different stages of their life cycles, and due to high degree of sensitivity a change in either or both the ecosystems can lead to a catastrophic effect in their diversity (Blaustein and Wake, 1990). It appears likely that understanding the problem of amphibian decline requires much more information on the ecology of the metapopulations in which many species live (Green, 1997). The effects that amphibian declines have on ecosystem structure are of concern to community ecologists as well as to conservation biologists (Beebee, 1996).

Recently, importance is being given to the conservation of amphibians and to the study of environmental resource utilization by different amphibian species. Contemporary studies in biology should focus more on the quantitative aspects of biodiversity that can be used to understand fluctuations in ecosystem functioning and help in prioritization of areas for conservation (Myers *et al.*, 2000). Determining the status of species, i.e. species occupancy and abundance, and whether its populations are stable, increasing or decreasing, is of fundamental interest to both ecologists and conservation biologists. Because of the increasing global loss of biological diversity, there is increased urgency to accurately determine the status of species. However, the focus of the community ecology is to understand the ways in which assemblage of species is distributed in nature and the ways in which these assemblages can be influenced by interactions between species and by the physical forces in the environment (Begon *et al.*, 1996). Further, community ecology can be

divided into two broad areas that are often confounded in community studies: Species composition and species richness. Species composition is herein defined as the combination of species encountered in a habitat or community. Species richness (diversity) is defined as the number of species and has been divided into two major components: alpha or within habitat diversity and beta or between habitat diversity (Whittaker, 1970).

Several studies have been carried out on amphibian communities in different ecosystems worldwide. Turner (1960) studied the population structure and dynamics of a species belonging to Ranidae family. Niche overlap and interspecific competition in three species of genus Rana in Sarawak have been reported by Inger and Greenberg (1966). Inger (1969) also studied the organization of communities of frogs in lowland streams in Sarawak. Crump (1971) made a quantitative analysis of ecological distribution of tropical herpetofauna. A study was made on the organization of contiguous communities of amphibians and reptiles in Thailand (Inger and Colwell, 1977). Inger (1980) studied the densities of the floor dwelling frogs in lowland forests of Southeast Asia and Central America. A comparative study was done on the Bornean amphibian communities by Inger and Voris (1993). Hecnar and Closkey (1996) studied the regional dynamics and status of amphibians in Southwest Ontario, Canada. However, there exists only limited information on the amphibian community function of Indian, which is important for formulating important conservation measures (Inger *et al.*, 1987; Dash and Mahanta, 1993; Das, 1996; Vasudevan *et al.*, 2001; Andrews *et al.*, 2005a, b). The discovery of quite a few undescribed frog and caecilian species in India (Ravichandran and Pillai, 1996; Bhatta, 1997; Biju, 2001, Dubois *et al.*, 2001; Biju and Bossuyt, 2003) during the last decade illustrates that our knowledge on the amphibian diversity of this region is still far from complete.

Gujarat has a poor amphibian diversity compared to other states of India. Only 8% of the total amphibian species of India are found in Gujarat. Previous studies (Naik and Vinod, 1992, 1993, 1996; Vyas, 1996; Bhatt *et al.*, 1999) on amphibians of Gujarat have mainly focused on systematics and preparation of checklists. Hitherto no quantitative ecological studies have been done on the amphibian community for any ecosystem within Gujarat.

In order to formulate potential conservation strategies, the widespread approach of surveys for species richness should be combined with quantitative estimates. In the present study therefore, an attempt was made to quantify and analyze the community structure of amphibian assemblages in varied ecosystems of Vadodara district, so as to design effective conservation strategies for this group of organism that is facing threat for survival globally.

4.2. INTENSIVE STUDY SITES

The intensive study area selected during the one year study period i.e 2005 includes the non-urban and urban areas within the Vadodara district

Site-I: Timbi (Position: 22^{0}21'08" N and 73^{0}18'02" E)

Timbi is situated about 13Km east of Vadodara city. Timbi irrigation tank is one of the important water body situated near the viscinity of the city. There are several other small settlements around this tank, other than the Timbi village, which includes Bakrol, Hanumanpura and Khatamba villages. The surrounding fields are mainly gaucher lands partly used for livestock and partly for agriculture.

Site-II: Sindhrot (Position: 22^{0}19'38" N and 73^{0}04'13" E)

The second study site is about 14km west of Vadodara city and forms part of the great Mahi ravines, at the bank of one of its tributaries, the Mini River. It is a non-urban area and is more of a scrub land.

Site-III: Fofalia (Position: 21^{0}57'02" N and 73^{0}19'35" E)

Fofalia is 40 Km south of Vadodara city. It is a non urban area, which comes under Sinor taluka. The nearby villages include Kanjetha, Manjhral and Karala. This area is less polluted and is more vegetated as urbanization has not yet impacted this region.

Site-IV: Campus of Maharaja Sayajirao University (MSU) (Position: 22^{0}19'34" N and 73^{0}11'16"E)

The last site is an urban area within the city of Baroda, where the urbanization is rapidly transforming the landscape. This urban site is comprised of land consisting of educational institutes, parking areas, hostels, road sides and other residential area. A tributary of river Vishwamitri passes through the campus site. River at this point receives high amount of sewage that is evident from the black colour and the strong distasteful odour the water exudes.

4.3. MATERIALS AND METHODS

The methodology adopted in the present study was strictly in accordance with the standard methods formulated for measuring and monitoring the amphibian diversity by IUCN/SSC-DAPTF (Heyer *et al.*, 1994). Visual encounter survey (VES) method and transect sampling were employed in the present study. All the study sites were visited regularly for observing amphibians and recording the field data on their ecology and biology with the help of VES data sheet. Searching for amphibians included rolling and ripping of logs, turning of rocks,

raking of litter and examination of vegetation. Confusing specimens if found in abundance were collected and stored in 10% formalin for further taxonomic studies in laboratory. Other specimens of each species were observed, their morphometric measurements taken and recorded and released into the same areas from where they were captured. All the amphibian species were photographed. Collected specimens were numbered, labeled and deposited in the Department of Zoology, Maharaja Sayajirao University of Baroda. Microhabitat, occurrence and distribution of each species were determined by field observations. An annonated list of amphibian species, encountered during the study period, with their description, distribution and their habit and habitat is given in the Chapter. Population census, diversity, evenness, ecological distribution, niche breadth and niche overlap of amphibians at all the study sites were studied using the following formulae (Krebs, 1999) (Refer Chapter 3 for details)

1. Simpson's index of diversity
2. Shannon-Wiener Diversity index
3. Brillouin's diversity
4. Margalef's equation for evenness
5. Levins's Measure of Niche Breadth
6. Levins's measure of standardized niche breadth
7. Horn's index of niche overlap
8. Jaccard index of Similarity coefficient
9. Coefficient of Community

4.4. RESULTS

4.4.1. Species richness

The extensive survey spanning one year (2005) covering all the seasons revealed the presence of nine species of anurans from the study sites. These anurans belonged to nine genera and 4 families. Family Dicroglossidae and Microhylidae were the most dominant with 33.3% each of the total anurans encountered in the study sites. Bufonidae was the next, contributing to 22.2 %, while only one species from the family Rhacophoridae was sighted.

List of amphibian recorded from Vadodara District

ORDER –ANURA

FAMILY-BUFONIDAE

SPECIES- *Bufo stomaticus* Lütken, 1864

SPECIES- *Duttaphrynus melanostictus* (Schneider, 1799)

FAMILY- DICROGLOSSIDAE

SPECIES- *Euphlyctis cyanophlyctis* (Schneider, 1799)

SPECIES- *Fejervarya limnocharis* (Gravenhorst, 1829)

SPECIES- *Hoplobatrachus tigerinus* (Daudin, 1802)

FAMILY-MICROHYLIDAE

SPECIES- *Kaloula pulchra* Gray, 1831

SPECIES- *Microhyla ornata* (Duméril and Bibron, 1841)

SPECIES- *Uperodon systoma* (Schneider, 1799)

FAMILY-RHACOPHORIDAE

SPECIES- *Polypedates maculatus* (Gray, 1833)

4.4.2. Diversity and evenness

Table 4.1 provides data on population density of amphibians at the study sites. The average density of amphibians was found high at Timbi, while the lowest density was observed in Fofalia. Among all the species *E. cyanophlyctis* followed by *B. stomaticus* occurred in high density while the microhylids *viz. M. ornata*, *U. systoma* and *K. pulchra* showed the low average density. Simpson's, Shannon Wiener's and Brillouin's indices indicated maximum species diversity in Fofalia, followed by Sindhrot and Timbi. MSU campus had the least diversity, according to the three indices (Table 4.2). At Timbi, *E. cyanophlyctis* and *D. melanostictus* contributed more than 60% of the total diversity index value. However, at Sindhrot *E. cyanophlyctis*, *B. stomaticus* and *D. melanostictus* were the most frequently encountered species. While at MSU campus *B. stomaticus* alone constituted 61.8% of the total diversity index value (Table 4.3). Distribution of amphibians in Fofalia was found to be even with high evenness value however the lowest value was recorded at MSU Campus.

4.4.3. Analysis of ecological distribution

The distribution of frogs and toads within the four study sites were observed to be different (Table 4.1). The percentage species richness was high in Fofalia followed by Timbi and Sindhrot, whereas MSU campus in the urban area showed the lowest percentage of species richness. Fofalia having highest species richness i.e. 8 (88%) followed by Timbi with 6 (66%), out of the total 9 species occurring in the study sites. On the other hand MSU campus which is an urban site has the least species richness with 4 (> 50%) of the total species occurring and Sindhrot showed the presence of 5 species (55%) in the study area (Table 4.4).

The abundance values (Crump, 1971) for each species in each site were coded as follows: 0=apparently absent (not found in any sample), 1=not commonly found (≤ 15% samples contained the species), 2= moderately common (16-40% samples contained the species), 3=common (41-50% samples contained the species) and 4=abundant (> 50% samples contained the species). The total abundance value is highest for Timbi followed by Sindhrot and Fofalia. The ecological distribution and the relative abundance of each species are shown in Table 4.5.

For the purpose of analysis, the habitats were further divided into vertical and horizontal components such as arboreal, terrestrial, terrestrial burrowing, aquatic margin and aquatic as described by Dash and Mahanta (1993). The distribution of different species of frogs and toads in these subdivisions of each of the study sites is given in Table 4.6. All the microhylids in the study sites belonged to terrestrial burrowing habitat while the Bufonids are found to be terrestrial. The only arboreal species encountered during the study period was *Polypedates maculatus*. *Euphlyctis cyanophlyctis* was found to be completely aquatic and very rarely seen on the margins of the water bodies. While *Hoplobatrachus tigerinus* and *Fejervarya limnocharis* were both semiaquatic, found equally in the water as well as on the margin of the water bodies. They were frequently encountered away from the water bodies. The availability of the particular microhabitat generally determines the presence or absences of an anuran in any habitat. The microhabitat utilized by these anurans in all the study sites is described in Table 4.7.

4.4.4. Coefficients of community

The Jaccard's similarity coefficient (SC_j) and the coefficient of community (C) are measures of relative similarity of samples from two communities (study sites). The values for SC_j and C are given in Table 4.8 and Table 4.9 respectively. In case of SC_j, the coefficients are given in the table along with the common species found at both the study sites. Timbi and Sindhrot have the most species in common (5) with the highest value of similarity coefficient (0.82) and coefficient of community (89.61). Fofalia and the urban site (MSU campus) shared the least species between them (SC_j 0.5). However, the Timbi and MSU campus was found to be the most dissimilar in terms of coefficient of community value.

4.4.5. Niche breadth

In the present study niche breadth measurement was used to find out how the amphibians utilize their environment. It was measured by observing the distribution of individuals within set microhabitats (Table 4.10). Levins's standardized niche breadth score was found to be high in MSU campus followed by Sindhrot and Timbi. It indicates that the habitat generalist

were abundant in MSU campus. At Fofalia the standardized niche breadth score was low indicating the presence of habitat specialist in the area. Among the anuran species, *B. stomaticus,* had the highest standardized niche breadth score of 0.3391 followed by *H. tigerinus* (0.2900). Microhylids had very low niche breadth score.

4.4.6. Niche overlap

Niche overlap (Horns index) is the measure of association of two or more species. In the present study *B. stomaticus/D. melanostictus* and *E. cyanophlyctis/F. limnocharis* showed more than 98% overlap value at Timbi indicating them as a pair utilizing the common microhabitat. The association was also high between *F.limnocharis/H. tigerinus* and *M. ornata/B. stomaticus*. Among the 6 species recorded in Timbi, *H. tigerinus* was found to share the microhabitat with four other species, with varying degrees of overlap (Table 4.11). Whereas at Sindhrot *B. stomaticus/D. melanostictus* and *E. cyanophlyctis/H .tigerinus* were found to be more associated (Table 4.12). However, *E. cyanophlyctis* was the least associated species in its association or sharing of the microhabitat and it was limited to only one species i.e *H. tigerinus*.

In the urban site, i.e MSU campus, the niche overlap score was highest for *E.cyanophlyctis/H .tigerinus* followed by *B. stomaticus/D. melanostictus* as they used to share more number of resources with each other than with any other species (Table 4.13). At Fofalia, like other sites, the Bufonids showed greater association when compared with other species. The Microhylids *M. ornata/U. systoma* were more associated in terms of the microhabitat resource utilization, while the Rhacophorid *P. maculatus* being arboreal showed 0% overlap with any other species in that study area (Table 4.14).

4.5. DISCUSSION

Frogs occupy high trophic levels in the food chain and therefore, are sensitive to broad range of environmental stress agents that disrupts lower trophic levels (Zug, 1993). The life cycle of most amphibian species depends on both aquatic and terrestrial habitats. They have a permeable skin and are sensitive to environmental degradation in both the habitats. For this reason, amphibians are potentially excellent target species for monitoring fragmented or degraded areas (Lips, 1998). Due to the lack of any earlier studies on the amphibian communities in Gujarat, no convincing conclusion can be made regarding the extent/rate of decline in its population through space and time. However, the data on diversity and species richness obtained in the present study can be used as a baseline data for comparison in the future and also to initiate similar studies elsewhere.

The amphibian species recorded from Vadodara district represents 47 % of the total amphibian fauna in Gujarat. All the species encountered in the study area belonged to the Order Anura, no Caecilians were observed during the entire study period. Earlier studies (Siliwal *et al.*, 2003; Pilo *et al.*, 2004; Vyas, 2004a) had reported the presence of caecilians only in Dangs in south Gujarat. Species richness is the simplest way to describe community and regional diversity (Magurran, 1988). Nevertheless, quantifying species richness is important for basic comparisons among various sites (Cornell, 1999). In the present study species richness was found much higher in rural area *viz.* Fofalia and was lower in urban area i.e MSU campus. Microhylids like *Uperodon systoma*, *Kaloula pulchra* and Rhacophorids *viz. Polypedates maculatus* were encountered only in Fofalia, which is a rural area. The tree frog *P. maculatus* was reported only from few regions in south Gujarat (Naik and Vinod, 1993, 1996; Siliwal *et al.*, 2003; Vyas, 2004a). Microhylid, *K. Pulchra* was also reported only from south Gujarat (Naik and Vinod, 1992, 1996; Siliwal *et al.*, 2003; Vyas, 2004b) as well as from places like Anand in central Gujarat (Vyas, 2004). The high species richness in Fofalia can be attributed to its diverse vegetation and less pollution while low species richness at MSU could be due to anthropogenic pressure, urbanization and pollution which might have reduced the quality of species composition. Similar observations made by Knutson *et al.*, (1999) and Krishnamurthy (2003) while analyzing the amphibian community from different parts of the world give credence to the present notion of greater amphibian species abundance and diversity at non-urban sites than at urban sites. Moreover, depletion of faunal wealth due to urbanization and attended alteration/loss of habitat is well documented (Khanna, 1998).

The analysis of dominance, diversity and evenness indices provide valuable quantitative information about animal communities in different habitats (Krebs, 1999). Three indices were used in the present study for the analysis of diversity, i.e Simpson's diversity, Shannon-wiener diversity and Brillouin's diversity. According to all the three indices, the species diversity and evenness is more at Fofalia followed by Sindhrot and Timbi. The value is lowest for MSU Campus.

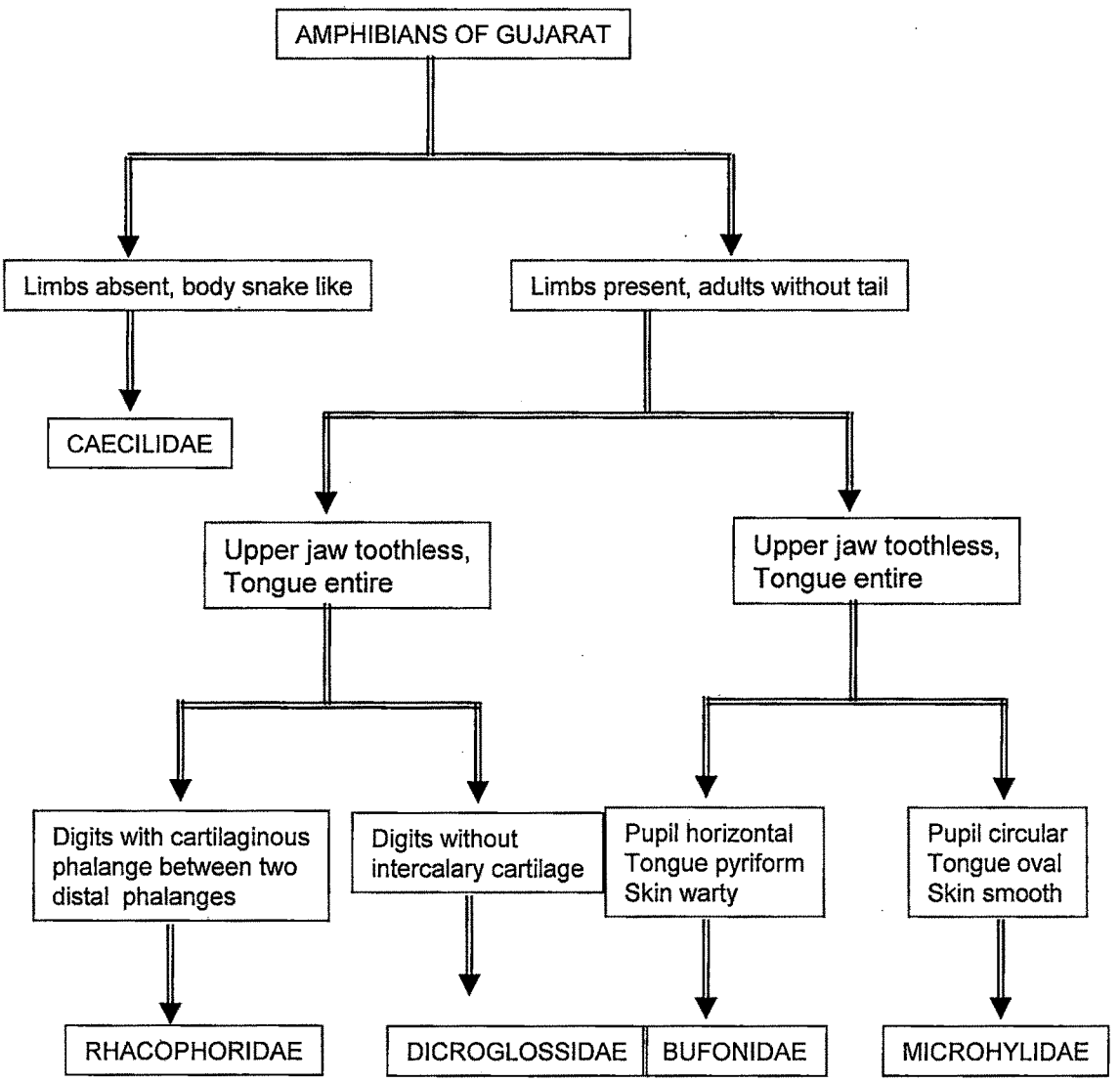
Similarity coefficient and the coefficients of community were used to compare the community structure at different study sites (Krebs, 1999). The Jaccard's similarity coefficient and the Coefficient of community value between the sites namely Timbi and Sindhrot was the highest and therefore, it can be inferred that these two communities are similar in its amphibian compostition. From the low Jaccard's value between Fofalia and MSU Campus it can be comprehended that the community structure of these two areas was very different.

Levins (1966) proposed that niche breadth can be estimated by measuring the uniformity of distribution of individuals among the resource states. In the present study, niche breadth measurement was used to find out how the amphibians utilize their environment. It was measured by observing the distribution of individual organism with a set of resource i.e microhabitat (Andrews *et al.*, 2005a). Amphibians are one of the best indicators of the health of an ecosystem. This is mainly due to their close intimacy with their microhabitat, where condition for their survival is favourable and is different from that of the surroundings. The availability of appropriate microhabitat helps them build "world of their own" within which they are most comfortable (Daniels, 1992). Any slight change in their microhabitat would lead to local extinction of the species from that area as they are very sensitive to changes. Categorization of species on the basis of their niche breadth score was followed as described by Dash and Mahanta (1993). The species that utilized a broad spectrum of the environment and were found in all the study sites were considered as habitat generalists. They had high niche breadth scores. Species which were apparently restricted in their distribution and seemed to live in a narrow range of the environmental spectrum and had low niche breadth score were considered as habitat specialist. All other species were considered as habitat intermediates. In the present study the highest niche breadth score was obtained for MSU Campus, which harbored only the common amphibian species, the habitat generalists *viz B. stomaticus, D. melanostictus, E. cyanophlyctis and H. tigerinus.* Fofalia showed the lowest niche breadth score, as majority of the habitat specialists were observed only in this area. Tree frog *viz. P. maculatus* and microhylids like *U. systoma* and *K. pulchra* were solely encountered in Fofalia, and therefore were considered habitat specialists. This could be due to the undisturbed patch of land in this rural area. The Niche breadth score for these species was very low as compared to other species. *M. ornata* was encountered only in rural areas like Fofalia, Timbi and Sindhrot, while *F. limnocharis* was seen only in Timbi. This further indicates that these two species prefer an undisturbed area or can be said that these species must have slowly disappeared from the urban settlement due to various reasons, which needs to be evaluated. *B. stomaticus, D. melanostictus, H. tigerinus and E. cyanophlyctis* were observed in all the study areas thus categorizing them as habitat generalists and therefore can be deduced that these species have a wide tolerance to any change in their habitat and microhabitat. The uneven distribution of these anurans in the study sites can be indicative of a pattern of disturbance. A careful study of the microhabitat and habitat requirement of these amphibians and the patterns of geographic distribution and habitat choice may provide insights into using them as indicators of environmental health (Daniels, 1992).

In order to understand the community organization, it is essential to measure the overlap in resource use among the different species in community guild. The most common resources measured in order to calculate overlap were food and space (microhabitat) (Krebs, 1999). In the present study niche overlap was measured by looking at the association of two or more species sharing a common resource *i.e* microhabitat. The measurements were obtained indirectly by the degree of coexistence of the species in the various plots sampled. The high niche overlap value for two species indicated that they were found together more often than other species in a particular habitat. The minimum and the maximum niche overlap values were 1 and 0 respectively. A value of zero indicates no overlap and 1 indicates 100 % overlap (Inger and Colwell, 1977). In the present study, *B. stomaticus / D. melanostictus* showed maximum overlap value at all the study sites and that of *E. cyanophylictis /F. limnocharis* was maximum at Timbi indicating that they were found together more often than other species in these areas. Similarly all the Microhylid species were found to share the microhabitat with each other as well as with the species belonging to the Bufonidae family.

Thus it is evident from the present study that the amphibian community in the study area show greater ecological similarity (greater niche overlap) among the coexisting species. Such similiarities are already established for amphibian communities as revealed by earlier workers (Inger and Colwell, 1977, Andrews *et al.*, 2005b). Resources used by ecologically more similar pairs of species are more likely to be subject to evolutionary adjustments through the combined effects of competition and environmental fluctuations (Inger and Colwell, 1977). However, no such conclusion is possible due to paucity of previous studies in this region.

Key to the Families of Amphibians in Gujarat



Key to the Identification of Species from Vadodara District (Based on Naik and Vinod, 1996)

1. Limbs present, tail absent in adult - 2,3
2. Parotid gland present, Skin rough and well developed warts - 4,5
3. Parotid gland absent - 6,7
4. Head with bony ridges - *Duttaphrynus melanostictus*
5. Head without bony ridge - *Bufo stomaticus*
6. Upper Jaw toothed - 8,9
7. Jaw toothless -15,16
8. An intercalary ossification present between the distal and penultimate phalanges - *Polypedates maculatus*
9. An intercalary ossification absent between the distal and penultimate phalanges - 10
10. Outer metatarsal separated by web at least in the distal half - 11,12
11. Toes completely webbed -13,14
12. Toes ½ webbed, 3 phalanges of 4^{th} toe free, outer metatarsals united in the basal half; tibio tarsal articulation reaches nostril - *Fejervarya limnocharis*
13. Skin of back with longitudinal folds - *Hoplobatrachus tigerinus*
14. Skin of back with tubercles and warts - *Euphlyctis cyanophlyctis*
15. Tips of fingers dilated into discs - 17
16. Tips of fingers not dilated into discs - 18,19
17. A bony ridge immediately below internal nares - *Kaloula pulchra*
18. No papillae behind internal nares, size small - 20
19. Papillae present below internal nares, size large - 21
20. Body slender, 2 normal metatarsal tubercles - *Microhyla ornata*
21. A pair of papillae below the internal nares and papillae below each internal nare. Inter orbital width about twice the upper eyelid. Back marbled - *Uperodon systoma*

1. **Scientific Name:** *Hoplobatrachus tigerinus* (Daudin, 1802)

Common Name(s): Indian Bullfrog

IUCN Status: Least Concern (LC)

Classification:

Class: Amphibia

Order: Anura

Family: Dicroglossidae

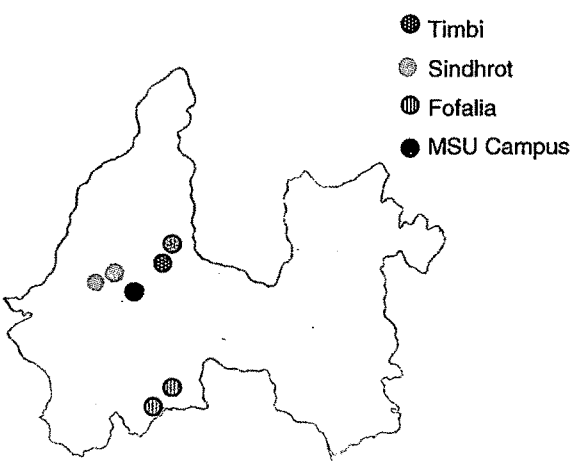
Genus: *Hoplobatrachus*

Species: tigerinus

Distribution: It is widely distributed in many parts of the Asian countries. This species is found throughout most wetland areas of India, Bangladesh and much of northern Pakistan, and is recorded from the southern parts of Nepal, and from upper and northern central Myanmar (Smith, 1940; Dubois, 1976; Zug *et al.*, 1998), also reported in Afghanistan (Kullmann 1974).

Distribution in Gujarat: Distributed widely all over Gujarat (Naik and Vinod, 1993; Vyas, 1996).

Distribution in Vadodara:



Conservation Measures: It is listed in Appendix II of CITES. It is included in Schedule IV of the Indian Wildlife (Protection) Act, 1972 (as amended in 2003).

Description: It is the largest of all the Indian frogs (Figure 4.1). In the present study they were encountered in all the study area and thus can be said to be distributed widely in Vadodara district. The total length of female ranged from 150 -165 mm from snout to vent,

while males measured from 120 -145 mm. The skin of the back is with longitudinal folds. A strong glandular fold extends from the eye to the shoulder. Skin on the ventral side is generally smooth. Head is moderately large, and has an obtusely pointed snout. Tympanum is distinct, with a strong fold of skin above it and is almost about two-third the diameter of the eye. Tibiotarsal articulation usually extends beyond the tip of the snout. The toes are fully webbed, but the web does not reach the tip of the third toe. Fingers are short; first finger is longer than the second. Subarticular tubercles were small and feebly developed. Heels overlap when legs are folded at right angle to the body. This character separates this species from *Hoplobatrachus crassus.*

Color: Olive green or brown above with darker markings. A light yellow/light green colored vertebral stripe extending from snout to vent often present in adults as well as juveniles (Figure 4.3). Breeding males are often greenish yellow to bright yellow above (Figure 4.2).

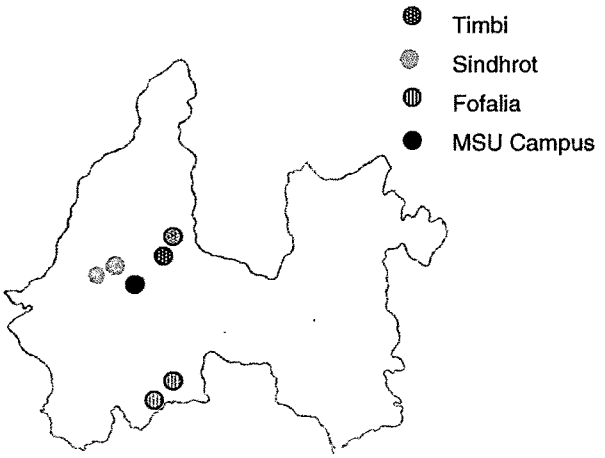
Habit and Habitat: They were seen inhabiting temporary and permanent water bodies, both natural and artificial, also common in wells, tanks and small ponds. During the present study they were also observed in effluent channels and drainage system. It is generally opined that this species avoids forested areas and coastal regions. They were commonly sighted near the margin of the water bodies inhabiting the bushes and camouflaging amidst the vegetation. They were solitary and nocturnal. Its diet included invertebrates, aquatic organisms like fishes and reptiles like lizards. Breeding takes place during the monsoon season, when adults congregate at ephemeral rainwater pools. During breeding season the external vocal sac in males are bright blue in colour. Few of the breeding males were pale yellowish in colour. Eggs were laid in both permanent as well temporary water bodies. Tadpoles were usually seen attached to the substratum.

2. Scientific Name: *Euphlyctis cyanophlyctis* (Schneider, 1799)
Common Name(s): Common Skittering Frog
IUCN Status: Least Concern (LC)
Classification:
Class: Amphibia
Order: Anura
Family: Dicroglossidae
Genus: *Euphlyctis*
Species: *cyanophlyctis*

Distribution: This species ranges throughout much of South Asia including southern Afghanistan and Sri Lanka, Bangladesh; India; Islamic Republic of Iran; Nepal; Pakistan;

Distribution in Gujarat: Distributed widely all over Gujarat (Naik and Vinod, 1993; Vyas, 1996)

Distribution in Vadodara:



Conservation measures: There are no specific conservation measures for this species

Description: It is a medium sized frog (Figure 4.4). The snout to vent length ranged between 40 and 60 mm. Skin is dorsally covered with small tubercles and warts but it is ventrally smooth. The limbs bear dark spots which do not form complete bands. Head is moderate and the snout is scarcely pointed. Tympanum is distinct and is about two third the size of the eye. A single line of porous warts on flanks is present, from behind the shoulder to the groin. Above the anus, there is a U-shaped line of warts. A strong fold of skin can be seen, from behind the eye to the shoulder. Fingers are slender and pointed however the length of the first digit does not extend beyond second. Toes are webbed to the tips and toe tips are slightly swollen and rounded.Subarticular tubercles present and are small in size; inner metatarsal tubercle is also small, conical and is much like a rudimentary toe. The tibio-tarsal articulation usually reached a little beyond the eye.

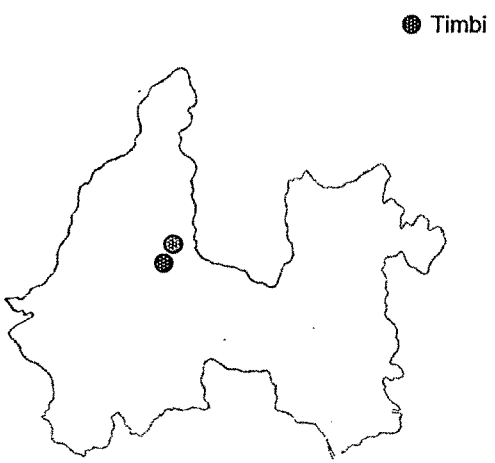
Color: Brown or olive above, dark spotted or marbled; two blackish streaks on the hinder side of the thighs.

Habit and Habitat: It is the most common frog seen throughout the study period in all the study sites. This frog is an aquatic species found in temporary as well as permanent water bodies. During the study period they were frequently encountered in stagnant water bodies and effluent channels. This species is commonly found in modified habitats. Due to its widespread distribution it can be construed that they are tolerant to habitat modification. It prefers stagnant waters where it can float placidly on the surface. During the day adults were seen basking at the edge of the water bodies. With slight disturbance they jump into

the water and remain under the soil for small fraction of time. Due to its ability to skit on the surface of the water, they are commonly known as the skittering frog. They breed during the breeding season as commonly seen in other amphibians. The species breeds in both temporary and permanent aquatic systems. Vocal sacs in males were bluish white in color. Eggs are laid in frothy mass in standing water. Tadpoles are brown in color and are mainly herbivores.

3. **Scientific Name:** *Fejervarya limnocharis* (Gravenhorst, 1829)
English Common Name: Indian Rice Frog
IUCN Status: Least Concern (LC)
Classification:
Class: Amphibia
Order: Anura
Family: Dicroglossidae
Genus: *Fejervarya*
Species: *limnocharis*

Distribution: This species is widespread throughout much of South Asia and Southeast Asia. It is found from sea level up to 2,000m asl.
Distribution in Gujarat: Distributed widely all over Gujarat (Naik and Vinod, 1993; Vyas, 1996).
Distribution in Vadodara



Conservation Measures: Taxonomic analysis of the *F. limnocharis* is very complex and it is protected by national legislation in India.
Description: It is a small sized frog (Figure 4.5). Length from tip of the snout to vent varied from 25-35mm. Skin is warty above often with longitudinal glandular folds, short and

interrupted. A fold of skin is present above tympanum, another distinct transverse fold behind the eyes. Head is broader than long, while the snout is pointed. Tympanum is distinct and measures half the diameter of the eyes. Fingers are pointed and free with the first finger slightly longer than the second. Toes are half webbed. Inner and outer metatarsal tubercles are present and the subarticular tubercles are distinct. Tibiotarsal articulation usually reaches till the tip of the snout.

Color: The dorsal surface of the frog is Brown with darker markings. It also shows the presence of darker bars on the lips and the legs. A yellowish vertebral band of varying width often present in the animals.

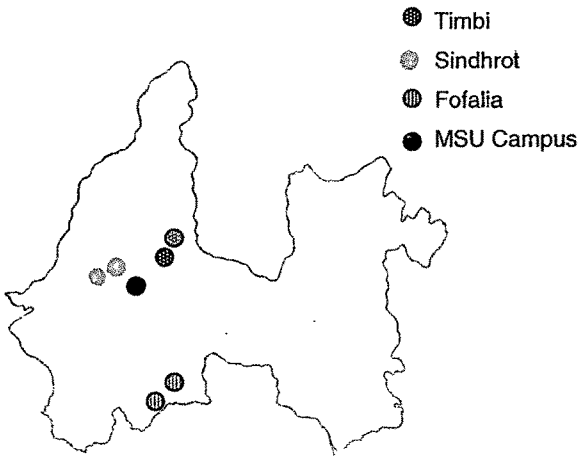
Habit and Habitat: They were found in and around small and large water bodies and were also commonly encountered in agricultural areas. During the study period they were also frequently seen in the edges of water bodies. During the dry season, they were found in damp places or under the boulders or logs. They were seen far from human habitations. Breeding takes place during monsoon. Eggs were laid more frequently in temporary water pools.

4. **Scientific Name:** *Bufo stomaticus* Lütken, 1862
Common Name: Marbled Toad
IUCN Status: Least Concern (LC)
Classification:
Class: Amphibia
Order: Anura
Family: Bufonidae
Genus: *Bufo*
Species: *stomaticus*

Distribution: Its altitudinal range is from sea level to 4,500m asl. This species is widely distributed in India, Pakistan, Nepal, Afghanistan and Bangladesh. Chanda (2002) does not report its occurrence in Gujarat where it's the most common toad, as observed during the present study period.

Distribution in Gujarat: Distributed widely all over Gujarat (Naik and Vinod, 1993; Vyas, 1996).

Distribution in Vadodara



Conservation Measures: No conservation measure is stated for this species as they are very common in occurrence and is widely distributed.

Description: It is a moderately sized toad (Figure 4.6). The total length of the body from the tip of the snout to vent ranged from 40-55mm. Dorsal surface of the body is tuberculated and the ventral surface coarsely granulated. Few species showed heavy tuberculation on the dorsal surface. Parotid glands are present which in few individuals are slightly tuberculated. There is a presence of a row of white tubercles along the outer region of the forearm. Tympanum is distinct. Fingers are free and the first finger is longer than the second. Hindlimbs are moderate in size with two-third webbed toes. Tibiotarsal articulation is reaching in between the shoulder and the eyes.

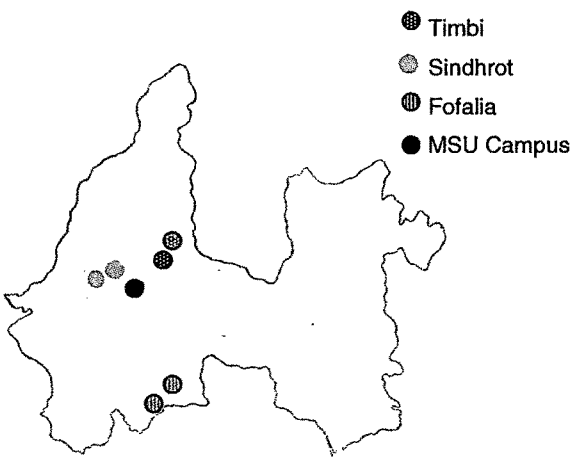
Color: Dorsal surface of the body is grey with dark green marbling, which is conspicuous in some species. The juveniles are light brown with darker marblings which may have a pinkish centre (Figure 4.7).

Habit and Habitat: It was the most common toad seen near the human habitations and many were seen to be a permanent part of the house. During day time, they were commonly encountered under rocks, under logs of wood and in crevices. During the study this species was the most abundant and widely distributed in all the study areas. They are solitary. Breeding was observed to occur frequently in temporary seasonal pools and rarely occur in permanent ponds. A comprehensive study of the breeding behaviour of this species is given in Chapter-2. Eggs were laid in thousands. Tadpoles are black and were seen always attached to the substratum of the water bodies. Tadpoles are herbivores but

cannibalistic during unfavourable conditions. Thousands of froglets come out of the water after metamorphosis but only few survive to attain adulthood.

5. Scientific Name: *Duttaphrynus melanostictus* (Schneider, 1799)
Common Name: Common Toad
IUCN Status: Least Concern (LC)
Classification:
Class: Amphibia
Order: Anura
Family: Bufonidae
Genus: *Duttaphrynus*
Species: *melanostictus*

Distribution: This species occurs widely from northern Pakistan through Nepal, Bangladesh, India (including the Andaman and Nicobar Islands), Sri Lanka, southern China, Myanmar, Vietnam, Thailand and Cambodia to Malaysia, Singapore, and Indonesia. It has been recorded from sea level up to 1,800m asl.
Distribution in Gujarat: Distributed widely all over Gujarat (Naik and Vinod, 1993; Vyas, 1996).
Distribution in Vadodara:



Conservation Measures: It is very common in occurrence and is widely distributed and thus no conservation measure is stated for this species.

Description: It's the largest of the Indian toad. The snout vent length varied from 60-110 mm. Dorsal surface of the body is heavily tuberculated with prominent warts (Figure 4.8).

There are two series of large warts along the middle of the back. Parotid glands present, which were tuberculated in few individuals. Cranial ridge is prominent. Tympanum is distinct and two third the diameter of the eye. Upper lip, tips of fingers and toes, metatarsal tubercle and tubercle on the palm have black cornifications in the adult. First finger is equal to or longer than second. Tips of fingers and toes are blunt. The toes are nearly two third webbed.

Colour: Dorsal surface of the body is usually brown with darker reddish markings. These markings were very prominent in few species but in some it was dull. Ventral surface is white.

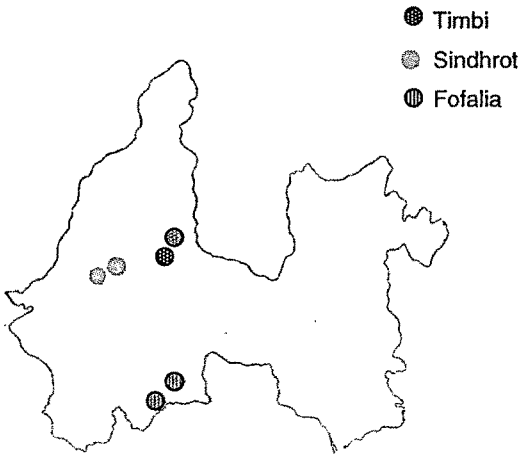
Habit and Habitat: They are terrestrial anurans and were encountered in all the study sites. They were more abundant in rural area than the urban set up, and thus can be inferred that they prefer less disturbed settlements. They favored moist habitat and were found under ground cover (*e*.g. rocks, leaf litter, logs), and they were also associated with human habitations. Several toads where seen to prefer same hideout during the day time. In the study site they were seen breeding in temporary and permanent ponds and pools. The larvae looked similar to that of the tadpoles of *B. stomaticus*. Juveniles of this species can be distinguished from that of the marble toad by the absence of red spot on the dorsal surface.

6. Scientific Name: *Microhyla ornata* (Duméril and Bibron, 1841)
Common Name: Ornate Microhylid
IUCN Status: Least Concern (LC)
Classification:
Class: Amphibia
Order: Anura
Family: Microhylidae
Genus: *Microhyla*
Species: *ornata*

Distribution: This is a very widespread species. It is found through most of South Asia. Recorded from Nepal, India, Sri Lanka, and Bangladesh.

Distribution in Gujarat: This species is the most common Microhylid from Gujarat. Its is reported from south Gujarat (Naik and Vinod, 1993) and also from Central Gujarat (Suresh *et al.*, 2005).

Distribution in Vadodara:



Conservation Measures: It is very common in occurrence and is widely distributed.

Description: This is a small sized frog (Figure 4.9). The total length from the tip of the snout to vent ranged from 20-30mm. Skin on the dorsal surface is smooth. Snout is obtuse and broadly rounded. The pupil is erect and the tongue is elliptical. Interorbital width wide and broader than the diameter of the upper eyelid. Tympanum is invisible. Two prominent metatarsal tubercles is present. Subarticular tubercles is distinct. Tibio-tarsal articulation reaches the shoulder or between the shoulder and the eye. The heels meet when the legs are held right angles to the body. The fingers and toes are rather slender, with tips dilated into very small discs.Colour: Dorsal surface of the body reddish brown with a large dark marking on the back extending posteriorly between the eyes and widening posteriorly. Another dark streak extending posteriorly from behind the eyes upto the shoulder. Limbs conspicuously marked with dark cross bars. Ventral surface uniformly white in color.

Habit and Habitat: During the present study it was reported from undisturbed pasture land, non-intensively farmed agricultural land and were totally absent from urban area. This species was quite agile. It is the most common microhylid of the family and one of the smallest of Indian amphibians. They are nocturnal, burrowing in habit and were observed only during monsoon. It breeds in temporary rain pools and other water bodies which are stagnant. Breeding commenced once the monsoon rains are well set and continues throughout the monsoon. They prefer temporary water bodies than the permanent ones. Clutch size varies from 150-400 eggs. Breeding behaviour is described in detail in Chapter-2. Tadpoles are transparent and have a diamond shape mark on the head. They move in shoals just below the surface of the water.

7. **Scientific Name:** *Uperodon systoma* (Schneider, 1799)

English Common Name: Marbled Balloon Frog

IUCN Status: Least Concern (LC)

Classification:

Class: Amphibia

Order: Anura

Family: Microhylidae

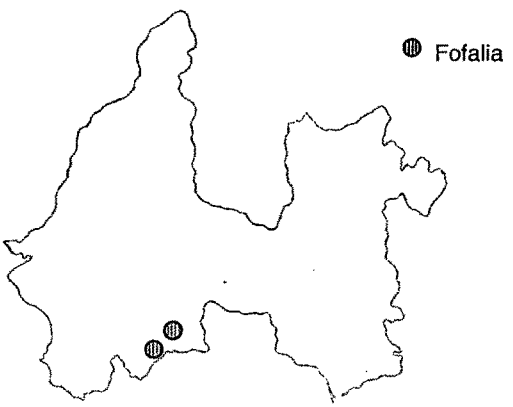
Genus: *Uperodon*

Species: *systoma*

Distribution: It is found throughout much of southern and eastern India, and has been recorded from northeastern Pakistan, Nepal and northern and southeastern Sri Lanka. It is present from sea level up to approximately 1,000m asl

Distribution in Gujarat: Though stated to be common it is reported only from South Gujarat (Naik and Vinod, 1992; 1996). It was also reported from Vadodara (Naik, 1984)

Distribution in Vadodara



Conservation Measures: No conservation measures is stated for this species due to its common occurrence and wide distribution.

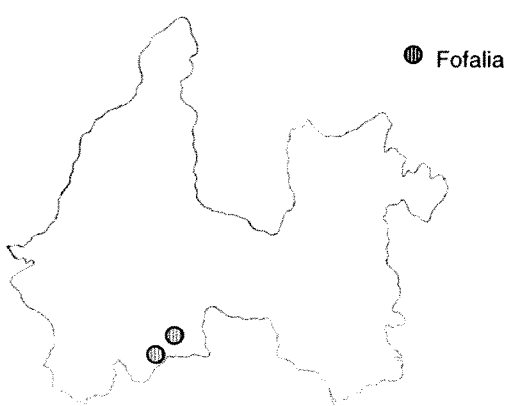
Description: It is a medium sized frog (Figure 4.10). The total length from the tip of the snout to vent ranged from 45-55mm. Dorsal surface of the skin is smooth. Head is comparatively smaller than the body. Snout is round. This frog has a roundly shaped stout body that is kept puffed round like a ball. The interorbital width twice the width of the upper eyelid. As seen in other Microhylids, tympanum in this species is also hidden. Fingers are moderately long with the first finger slightly shorter than second; toes are short and webbed

at the base. A pair of strong shovel-shaped metatarsal tubercles is present with the inner tubercle being larger in size. Tibiotarsal articulation does not reach to the shoulder
Color: Body dorsum with more or less symmetrical dark brown pattern on a pinkish brown background. The ventral surface is uniformly whitish, without spots.

Habit and Habitat: This Microhylid species is burrowing in habit and used to bury itself in loose and moist soil. The shovel shaped metatarsal tubercles are well adapted for burrowing in soft ground. Specimens have been collected from rural and undisturbed areas. The adults surfaced only during the monsoons; during the dry months they retreat into the soil. Breeding takes place during the monsoon rain. Male's call from the banks of water bodies and the eggs are laid in masses which float on the water surface.

8. Scientific Name: *Kaloula pulchra* Gray, 1831
English Common Name: The painted frog
IUCN Status: Least Concern (LC)
Classification:
Class: Amphibia
Order: Anura
Family: Microhylidae
Genus: *Kaloula*
Species: *pulchra*

Distribution: India: Karnataka, West Bengal; Srilanka; Myanmar; Southern China; Malay Peninsula
Distribution in Gujarat: This rare microhylid is reported from South Gujarat ((Naik and Vinod, 1992; 1996) and from Anand and Surat (Vyas and Parasharya, 2004).
Distribution in Vadodara



Conservation Measures: There is no conservation measure for this species at present.

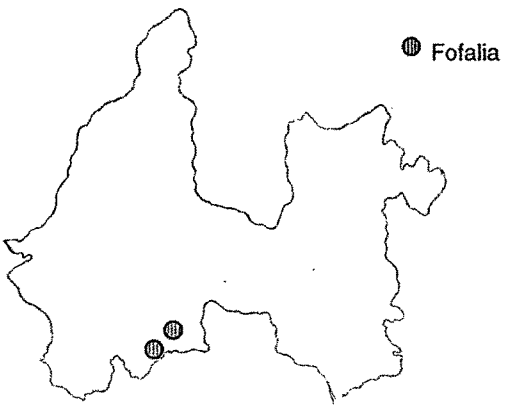
Description: It is a medium sized microhlylid (Figure 4.11). The total length from tip of snout to vent varied from 45-50mm. The skin on the dorsal surface is warty to some extent while the ventral surface is smooth. Head is small with short and rounded snout. Inter orbital space is almost twice the diameter of the eye. Tympanum is hidden as seen in other Microhylids. Fingers are long with the tips dilated into discs. Toes are short and the tibiotarsal articulation reaches till the shoulder. Toes are slightly webbed with well developed sub articular tubercles.

Habit and Habitat: Though it is stated to be a common microhylid in other regions of India, in the present study they were rarely encountered in the study sites. They were found only in Fofalia which is a rural area. This species was seen only during monsoon and post monsoon period. They were commonly encountered among the vegetation and in moist soil. No much information is known about the natural history of this species.

9. Scientific Name: *Polypedates maculatus* (Gray, 1833)
English Common Name: Indian Tree Frog
IUCN Status: Least Concern (LC)
Classification:
Class: Amphibia
Order: Anura
Family: Rhacophoridae
Genus: *Polypedates*
Species: *maculatus*

Distribution: This species is found throughout most of India, Nepal, Bhutan and Sri Lanka, as well as western Bangladesh and Chittagong district in south-eastern Bangladesh. It has been reported from sea level up to at least 1,500m asl.
Distribution in Gujarat: This is the only species of the family Rhacorphoridae recorded from Gujarat. It is reported from South Gujarat only (Naik and Vinod, 1992; 1996).

Distribution in Vadodara:



Conservation Measures: There is no conservation measure for this species.

Description: It's a moderate size frog. Total length from the tip of the snout to vent varied from 35-50mm (Figure 4.12). Dorsal surface of the skin is smooth. Ventrally it is granulate on the belly and under the thigh. Head is broader than long, projecting slightly beyond the mouth. Interorbital width is broader than upper eyelid. Tympanum is three fourth the diameter of the eye. Tibio tarsal articulation is reaching in between the posterior corner of the eye and tip of snout. Fingers with rudimentary web; first finger is equal to the second and tips of fingers and toes bear horse-shoe shaped distinct discs. The inner metatarsal tubercle is prominent with subarticular tubercles on the fingers and toes. Color: Brownish, Greyish or whitish above with dark spots. Ventral white

Habit and Habitat: This tree frog was reported only from one study sites i.e Fofalia. It is largely arboreal, and was found on trees and window panes. It was common in human habitation. During the breeding season males call from the ground. They lay their eggs in a foam nest on leaves of overhanging water. It breeds only in temporary pools.

TABLE 4.1 Average density/100m^2/month of nine amphibian species

Species	Timbi	Sindhrot	Fofalia	MSU campus
Bufo stomaticus	0.765	0.835	0.910	2.350
Duttaphrynus melanostictus	1.162	0.992	1.072	0.590
Euphlyctis cyanophlyctis	2.380	1.637	0.807	0.860
Hoplobatrachus tigerinus	0.587	0.467	0.607	0.302
Fejervarya limnocharis	0.462	-----	-----	-----
Microhyla ornate	0.350	0.196	0.183	-----
Uperodon systoma	-----	-----	0.035	-----
Kaloula pulchra	-----	-----	0.032	-----
Polypedates maculates	-----	-----	0.235	-----

TABLE 4.2 Estimation of species diversity, evenness and niche breadth of amphibian population at the study sites

Parameters	Timbi	Sindhrot	Fofalia	MSU Campus
Species Diversity				
Simpson's Diversity (1-D)	2.4207	3.795	5.4158	2.3151
Shannon Wiener's Diversity (H')	1.2125	1.4306	1.8207	1.061
Brillouin's Diversity (H)	1.2005	1.4049	1.7709	1.0428
Evenness measure				
Equitibilaty J	0.5518	0.6511	0.8286	0.4831
Niche Breadth				
Levin's standardized niche breadth	0.2507	0.2658	0.1479	0.3528

TABLE 4.3 Percentage occurrence of amphibians during the study period

Species	Timbi	Sindhrot	Fofalia	MSU campus
Bufo stomaticus	12.84	14.74	27.25	61.84
Duttaphrynus melanostictus	17.73	17.76	23.60	12.93
Euphlyctis cyanophlyctis	46.63	50.62	19.95	18.64
Hoplobatrachus tigerinus	8.86	13.32	14.84	6.57
Fejervarya limnocharis	8.56	------	------	------

Species	Timbi	Sindhrot	Fofalia	MSU campus
Microhyla ornate	5.35	3.55	5.59	------
Uperodon systoma	------	------	0.97	------
Kaloula pulchra	------	------	0.97	------
Polypedates maculates	------	------	6.81	------

TABLE 4.4 Percentage species richness of amphibians in different study sites

Species	Timbi	Sindhrot	Fofalia	MSU campus
Bufo stomaticus	+	+	+	+
Duttaphrynus melanostictus	+	+	+	+
Euphlyctis cyanophlyctis	+	+	+	+
Hoplobatrachus tigerinus	+	+	+	+
Fejervarya limnocharis	+	-	-	-
Uperodon systoma	-	-	+	-
Microhyla ornate	+	+	+	-
Kaloula pulchra	-	-	+	-
Polypedates maculates	-	-	+	-
Total number of species	6	5	8	4
Species richness (%)	66.7	55.6	88.9	44.4

TABLE 4.5 Ecological distributions of amphibians in the study sites

	TIMBI	SINDHROT	FOFALIA	MSUCAMPUS
Species				
Bufo stomaticus	2	1	1	4
Duttaphrynus melanostictus	3	3	2	2
Euphlyctis cyanophlyctis	4	4	2	1
Hoplobatrachus tigerinus	1	2	1	1
Fejervarya limnocharis	2	0	0	0
Uperodon systoma	0	0	1	0
Microhyla ornate	2	1	1	0
Kaloula pulchra	0	0	1	0
Polypedates maculates	0	0	2	0
Total abundance indices	14	11	11	8

Numbers indicate relative abundance of species within an area, coded 0-4 as follows:

0- absent; 1-not commonly found; 2- moderately common; 3- common; 4- abundant.

TABLE 4.6 Habitats of different species in the study sites

Sr. No.	Habitat	Species
1.	Terrestrial	*Duttaphrynus melanostictus*
		Bufo stomaticus
2.	Terrestrial burrowing	*Microhyla ornata*
		Uperodon systoma
		Kaloula pulchra
3.	Arboreal	*Polypedates maculatus*
4.	Semi Aquatic	*Hoplobatrachus tigerinus*
		Fejervarya limnocharis
5.	Aquatic	*Euphlyctis cyanophlyctis*

TABLE 4.7 Microhabitat of amphibians in the study sites

Sr. No.	Species	Microhabitat
TIMBI		
1.	*Bufo stomaticus*	On bare soil and under stone
2.	*Duttaphrynus melanostictus*	On bare soil and in rock crevices
3.	*Microhyla ornate*	Under leaf litter, under soil
4.	*Hoplobatrachus tigerinus*	In and around the edge of water bodies.
5.	*Euphlyctis cyanophlyctis*	In temporary and permanent water bodies
6.	*Fejervarya limnocharis*	In water bodies, among cropfields, under boulders and wet rocks.
SINDHROT		
1.	*Bufo stomaticus*	On bare soil, under log of wood
2.	*Duttaphrynus melanostictus*	On bare soil and in rock crevices
3.	*Microhyla ornate*	Under soil, under stones
4.	*Hoplobatrachus tigerinus*	In and around the periphery of stagnant water bodies
5.	*Euphlyctis cyanophlyctis*	In stagnant water bodies
FOFALIA		
1.	*Bufo stomaticus*	Among leaf litter and bare soil
2.	*Duttaphrynus melanostictus*	On bare soil
3.	*Microhyla ornate*	Under the soil, Damp pockets, Litter
4.	*Uperodon Systoma*	Under soil, under stones

Sr. No.	Species	Microhabitat
5.	*Euphlyctis cyanophlyctis*	Float on surface of stagnant water bodies
6.	*Hoplobatrachus tigerinus*	On the edge of ponds
7.	*Polypedates maculatus*	On shrubs, on window pan
8.	*Kaloula pulchra*	Under stones, among herbs
MAHARAJA SAYAJIRAO UNIVERSITY CAMPUS		
1.	*Bufo stomaticus*	On bare soil and among leaf litters
2.	*Duttaphrynus melanostictus*	On bare soil and near small water puddles
3.	*Euphlyctis cyanophlyctis*	In small water bodies
4.	*Hoplobatrachus tigerinus*	Edge of small water bodies

TABLE 4.8 Comparison of study sites by similarity coefficients

Study sites	Timbi	Sindhrot	MSU Campus	Fofalia
Timbi	6 *	5**	4**	5**
Sindhrot	0.8333***	5*	4**	5**
MSU campus	0.6666***	0.8000***	4*	4**
Fofalia	0.6250***	0.6250***	0.5000***	8*

*, Actual number of species in study sites; **, Number of shared species of amphibians between two study sites, ***, values for similarity coefficient.

TABLE 4.9 Comparison of study sites by coefficient of community

Study sites	Timbi	Sindhrot	MSU Campus	Fofalia
Timbi	—	—	—	—
Sindhrot	89.61*	—	—	—
MSU campus	50.98*	52.84*	—	—
Fofalia	64.73*	69.28*	61.74*	—

*, values of coefficient of community.

Table 4.10 Niche breadth of different amphibian species

Species	Timbi	Sindhrot	MSU cam	Fofalia	Total Niche breadth	Total standardized Niche breadth
Bufo stomaticus	2.465	3.383	4.666	2.238	12.752	0.3391
Duttaphrynus melanostictus	2.489	2.71	2.436	3.17	10.805	0.2750
Euphlyctis cyanophlyctis	3.14	2.887	1.83	2.363	10.22	0.2541
Hoplobatrachus tigerinus	2.657	4.20	1.72	3.736	12.313	0.2900
Fejervarya limnocharis	3.337	—	—	—	3.337	0.229
Microhyla ornate	1.514	1.83	—	2.76	6.104	0.0901
Uperodon systoma	—	—	—	1.6	1.6	0.06670
Kaloula pulchra	—	—	—	1.8	1.8	0.0889
Polypedates maculates	—	—	—	1.96	1.96	0.106

Table 4.11 Niche overlap of amphibians at Timbi

	1	2	3	4	5	6
1	1.000	0.983	0.000	0.119	0.000	0.511
2	0.983	1.000	0.000	0.156	0.194	0.407
3	0.000	0.000	1.000	0.169	0.992	0.133
4	0.119	0.156	0.169	1.000	0.218	0.689
5	0.000	0.194	0.992	0.218	1.000	0.152
6	0.511	0.407	0.133	0.689	0.152	1.000

1=*B. stomaticus*; 2=*D. melanostictus*; 3= *E.cyanophlyctis*; 4= *H. tigerinus*; 5= *F. limnocharis*; 6=*M. ornata*

Table 4.12 Niche overlap of amphibians at Sindhrot

	1	2	3	4	5
1	1.000	0.738	0.000	0.311	0.210
2	0.738	1.000	0.000	0.307	0.313
3	0.000	0.000	1.000	0.484	0.000
4	0.311	0.308	0.484	1.000	0.470
5	0.210	0.313	0.000	0.470	1.000

1=*B. stomaticus*; 2=*D. melanostictus*; 3= *E. cyanophlyctis*; 4= *H. tigerinus*; 5=*M. ornata*

TABLE 4.13 Niche overlap of amphibians at MSU campus

	1	2	3	4
1	1.000	0.713	0.000	0.101
2	0.713	1.000	0.000	0.163
3	0.000	0.000	1.000	0.862
4	0.101	0.163	0.862	1.000

1=*B. stomaticus*; 2=*D. melanostictus*; 3= *E. cyanophlyctis*; 4= *H. tigerinus*

Table 4.14 Niche overlap of amphibians at Fofalia

	1	2	3	4	5	6	7.	8.
1	1.000	0.926	0.000	0.158	0.530	0.360	0.344	0.000
2	0.926	1.000	0.000	0.174	0.720	0.586	0.560	0.000
3	0.000	0.000	1.000	0.931	0.000	0.000	0.000	0.000
4	0.158	0.17	0.931	1.000	0.233	0.259	0.249	0.000
5	0.530	0.720	0.000	0.233	1.000	0.867	0.864	0.000
6	0.359	0.587	0.000	0.259	0.867	1.000	0.993	0.000
7.	0.344	0.590	0.000	0.249	0.864	0.993	1.000	0.000
8.	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000

1=*B. stomaticus*; 2=*D. melanostictus*; 3= *E.cyanophlyctis*; 4= *H. tigerinus*; 5= *M .ornata;* 6= *U. systoma*; 7= *K. pulchra*; 8= *P. maculatus.*

FIGURE 4.1 Male *H. tigerinus*

FIGURE 4.2 Male *H. tigerinus* during breeding season

FIGURE 4.3 Juvenile *H. tigerinus*

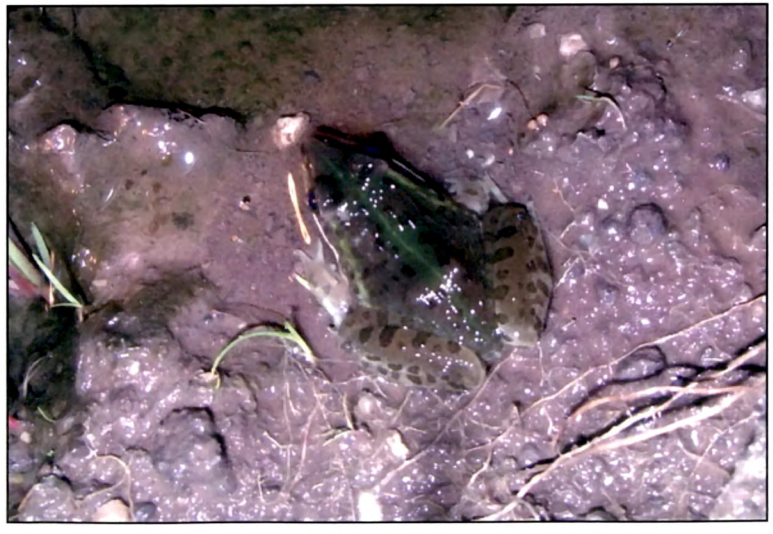


FIGURE 4.4 Adult *E. cyanophlyctis*

FIGURE 4.5 Male *Fejervarya limnocharis*

FIGURE 4.6 Juvenile *Bufo stomaticus*

FIGURE 4.7 Adult *Bufo stomaticus*

FIGURE 4.8 Adult *Duttaphyrnus melanostictus*

FIGURE 4.9 Adult *Microhyla ornata*

FIGURE 4.10 Adult *Uperodon systoma*

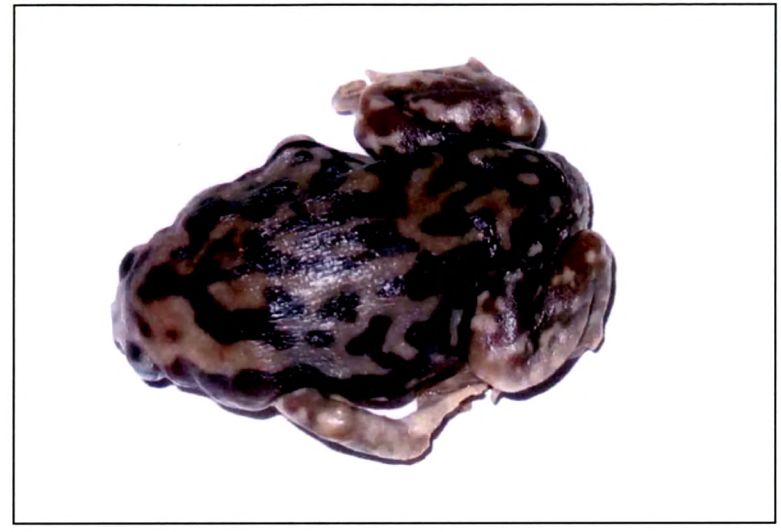


FIGURE 4.11 Adult *Kaloula pulchra*

FIGURE 4.12 Adult *Polypedates maculatus*