PART - II

Chapter 6

Species Richness of Amphibians in Shoolpaneshwar Sanctuary: an Ecosystem Perspective

Many reasons are attributed to the mysterious decline of amphibian populations. Major among them is the large scale destruction of habitats. Despite the recent resurging realization in the issue of habitat degradation, herpetologists cannot explain its obvious relationship with the decline of amphibian populations. It is the crash of some populations in the pristine environments that confounds the issue. Scientists admit the need of systematic field studies to appreciate the causes of such declines. To deal with the declining amphibian populations in India, there is a need to study the ecology of each species along with the impact of environmental stresses.

India has a rich and interesting amphibian fauna. About 50 million hectares of land has been estimated to be available as the habitat of amphibians (Pandian and Marian, 1986). Amphibian fauna of India comprises 181 species of anurans belonging to 29 genera and 6 families, 15 species of caecilians belonging to 4 genera and 3 families, and a single species of Salamander (Dutta, 1992). The status and problems of herpetological studies in Indian subcontinent were reviewed during the three day conference of the IUCN/SSC-ISRAG held at Bhubaneshwar (23-25 February, 1992). During this conference it was revealed that in India, little progress has been made to study the status, distribution and habitat requirement of amphibian populations. Though it is generally believed that pesticide residues in agro-ecosystems and denudation of habitats are factors contributing to the species decline, the published data on the community structure of amphibians are very rare (Daniels, 1991; Dash and Mahanta, 1993).

Taxonomy is the most basic tool in ecology and particularly in a country like India with its rich amphibian fauna. There are many species yet to be discovered and described. Without knowing the distribution and geographical ranges, it is not possible to deal with the declining amphibian populations. Amphibians of Gujarat have been greatly neglected even in the fundamental works on Indian amphibians by Boulenger (1890, 1920). The available information was mainly confined to a few retrospective studies by the Bombay Natural History Society (Mc Cann, 1938; Soman, 1960; Daniel and Shull, 1963) providing short accounts of the amphibian fauna of Kutch and Surat-Dangs. The first review of amphibians of Gujarat was published by Sarkar (1984) in which nine species of anurans were dealt with. However, in this report two species, *Ichthyophis bombayensis* and *Ramanella montana* which were reported by Daniel and Shull (1963) were not included. Further, in 1986 Naik and Patel have reported the occurrence of *Rana malabarica* in Navsari. One more species, the baloon frog *Uperodon systoma* was reported from Baroda by Naik in 1991. In 1991, Daniel and Sekhar have reported *Rana leithii* from Dangs. The studies in the Shoolpaneshwar sanctuary provided two more new records for the Gujarat State (1) *Kaloula pulchra* (Naik *et al.*, 1993) (2) *Rana keralensis* (Naik and Vinod, 1993). The distribution of 15 species of amphibians were presented by Naik and Vinod in 1993. An updated checklist of amphibian fauna hitherto reported from Gujarat contains 19 species of amphibians (Naik and Vinod, in press).

The health of an ecosystem can be assessed by noting alterations in the organization of biota at the population, or at the community level (Kovacs and Podani, 1986; Maltby and Calow, 1989). By comparing the structure of populations or communities occurring both in regions suspected of being stressed by pollution paired with areas that are relatively clear in the same geographical locality, a general evaluation of the quality of environment is possible (Maltby and Calow, 1989).

Gujarat is a highly industrialized State in India and also a region faced with heavy pollution. Most of the industrial pollutants reach the major rivers such as Narmada, Tapti and Mahi which also support fishery, agriculture and drinking water requirements. A recent literature survey of the assessment of biodiversity status of the State has revealed that so far no comprehensive attempt has been made to measure the extent of pollution and its effects on ecosystems (GEC, 1996).

Shoolpaneshwar sanctuary, situated on the left bank of Narmada river is comparatively a less disturbed area having a good species richness. In the present investigation, amphibian fauna of this sanctuary has been selected for a case study to deal with various biological and physical attributes that influence the species richness of an area. Collections from other parts of the State have also been verified to prepare an updated status record on the distribution of amphibian fauna of the State. Further, various aspects that affect the amphibian distribution have been assessed by comparing the species richness in different agroclimatic regions.

Study Area and Methods

Though a two and a half year study was mainly carried out on the Narmada valley in South Gujarat region, many specimens were also collected from various parts of Gujarat during the last five years. Studies, especially in the Shoolpaneshwar wildlife sanctuary were promising as many species were recorded in this region. I feel it is imperative here to discuss precisely the physiography and vegetation of the State before dealing with the detailed account on the Shoolpaneshwar Wildlife Sanctuary.

Gujarat : Physiography and Climate

The State of Gujarat, located on the west coast of India, has a land mass of 1,96,02,400 hectares of which 8,48,300 hectares are under permanent pasture and grazing land. In addition to this, 8,62,800 hectares are under fodder crops. The State has a great intrinsic variation in the pattern of vegetation in the different regions. The major reasons for this variation are wide range of variation in rainfall, soil, altitude, distance from the arid regions of Kutch and Rajasthan and different levels of biotic interference. All along the eastern border of Gujarat State there is a discontinuous chain of hilly forest areas. These hilly regions forms the part of Aravallis, Vindhyas and western most spurs of Satpura ranges and northern spurs of Sahyadri ranges. The vegetation becomes denser from the north to South Gujarat, as the rainfall increases towards the south and is maximum at Dharampur and in the Dangs forests. The soil is also richer in South Gujarat than in north Gujarat and Saurashtra. South of the river Narmada, patches of moist deciduous forests start and slowly merge with the completely moist deciduous forests with some elements of evergreen species on the

southern side of the Tapti river. On the other hand, the forests are dry deciduous in the hilly areas in the north and central Gujarat slowly merging with thorny scrub jungles, especially where grazing pressures and other biotic interferences are high. Saurashtra and Kutch together form about half of Gujarat State. Tropical dry deciduous forest also exist in Junagadh district. Northern part of Saurastra are more arid and the vegetation is more like that of the Rann of Kutch (scrub jungles). Littoral type of forest is found in the creeks along the coastal line in Kutch, Jamnagar and Junagadh district.

Considering the rainfall pattern, the topography, soil characteristics and the climate in general the State can be divided into seven agroclimatic zones (Table 1, Fig. 1). Rainfall varies from about 340 mm in the western arid district of Kutch to about 1800 mm in the southern hills of Dangs and Bulsar. Most parts receive rainfall of around 800 mm. The climate varies from arid to dry sub-humid in Kutch and Bulsar districts. Nearly 25 per cent of the geographical area in the western part is arid. Another 34 per cent of the area in north is semi-arid and about 50 per cent of the talukas in Central Gujarat are arid/semi-arid. Nearly 20 per cent of the area (42 talukas in 19 districts) is considered drought prone.

A large variation in soil types can be seen across the State. Deep black and coastal alluvium soils are predominant in South Gujarat. Medium black is prevalent in Central Gujarat, grey brown and coastal alluvial soils are in north and north-west whereas the Saurashtra peninsula has calcareous medium black and to some extent coastal alluvial soils.

Shoolpaneshwar Wildlife Sanctuary

The Shoolpaneshwar wildlife sanctuary (73° 32' and 73° 54' E and 21° 34' and 21° 32'N), part of old Rajpipla forest, is situated on the left bank of Narmada river in South Gujarat, (Bharuch district) (Fig. 2). The Narmada river which flows between the mountain ranges of Vindhya and Satpura enters the alluvial plains of Gujarat at this point. The Vindhya range is on the right bank of the river and Satpura range makes up the left bank. These ranges run in the east west direction diagonally across the country and separates the Deccan peninsular plateau in the south from the northern

Table 1. Different agro-climatic zones in Gujarat State

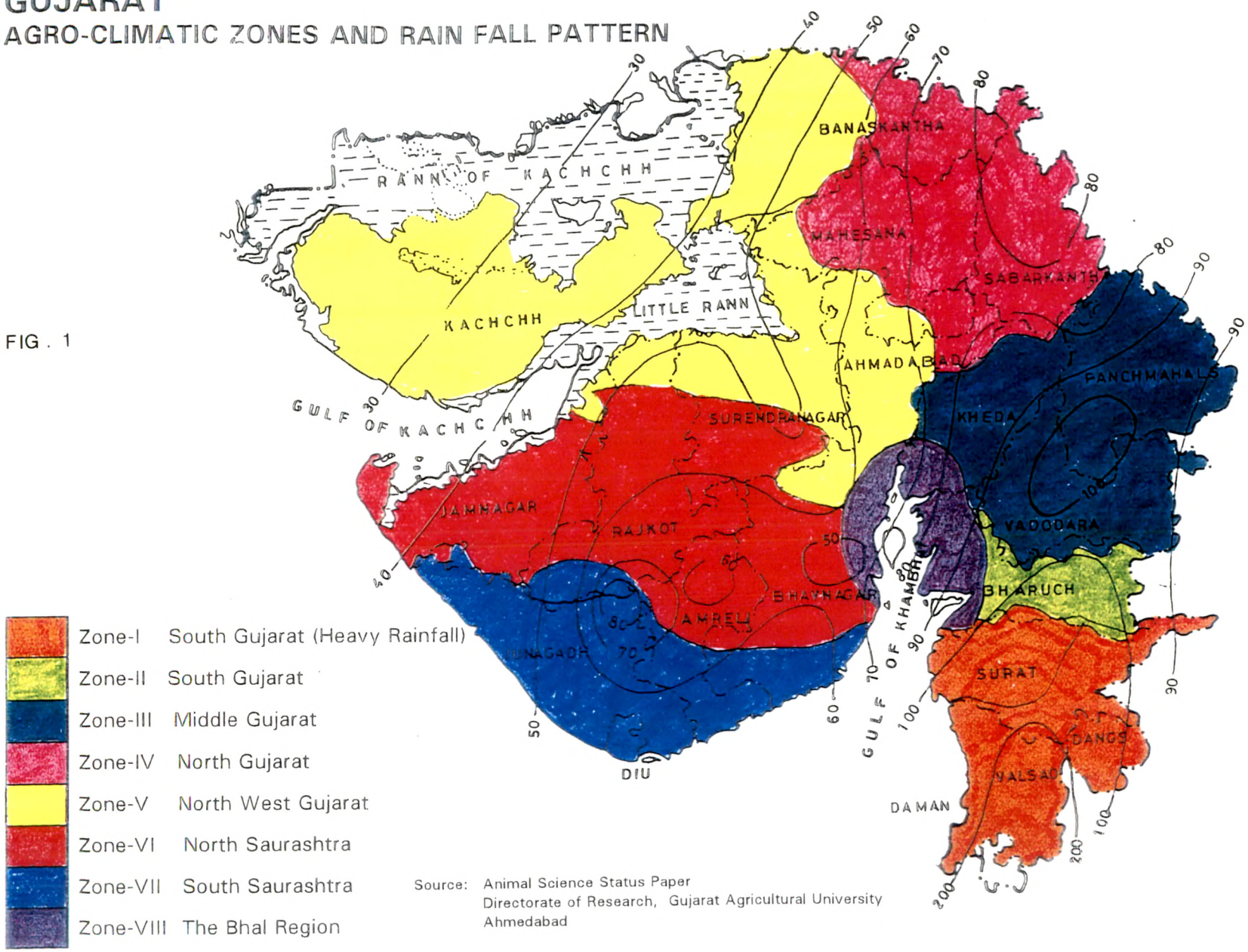
S. No.	Zones	Districts	Average Rain fall in mm	Climate	Soils
1	Southern hills	Dangs, Bulsar	1793	Semi-arid dry sub-humid	Deep black, coastal alluvium
2.	Southern Gujarat	Surat, Bharuch	974	-do-	-do-
3.	Middle Gujarat,	Baroda, Kheda, Panchmahals	904	Semi-arid	Medium black
4.	North Gujarat	Ahmedabad, Gandhinagar, Mehsana, Sabarkantha, Banaskantha	735	Arid to Semi-arid	Gray brown coastal alluvium
5.	North West arid	Kutch	340	Arid	Gray brown Deltaic alluvium
6.	North Saurashtra	Amreli, Bhavnagar, Jamnagar, Rajkot, Surendra-nagar	537	Semi-arid	Medium black calcareous
7	South Saurashtra	Junagadh	844	Dry sub humid	Coastal alluvium Medium black

Zone VIII (Bhal region) is a small saline region and hence has been avoided.

GUJARAT

AGRO-CLIMATIC ZONES AND RAIN FALL PATTERN

FIG . 1



- Zone-I South Gujarat (Heavy Rainfall)
- Zone-II South Gujarat
- Zone-III Middle Gujarat
- Zone-IV North Gujarat
- Zone-V North West Gujarat
- Zone-VI North Saurashtra
- Zone-VII South Saurashtra
- Zone-VIII The Bhal Region

Source: Animal Science Status Paper
Directorate of Research, Gujarat Agricultural University
Ahmedabad

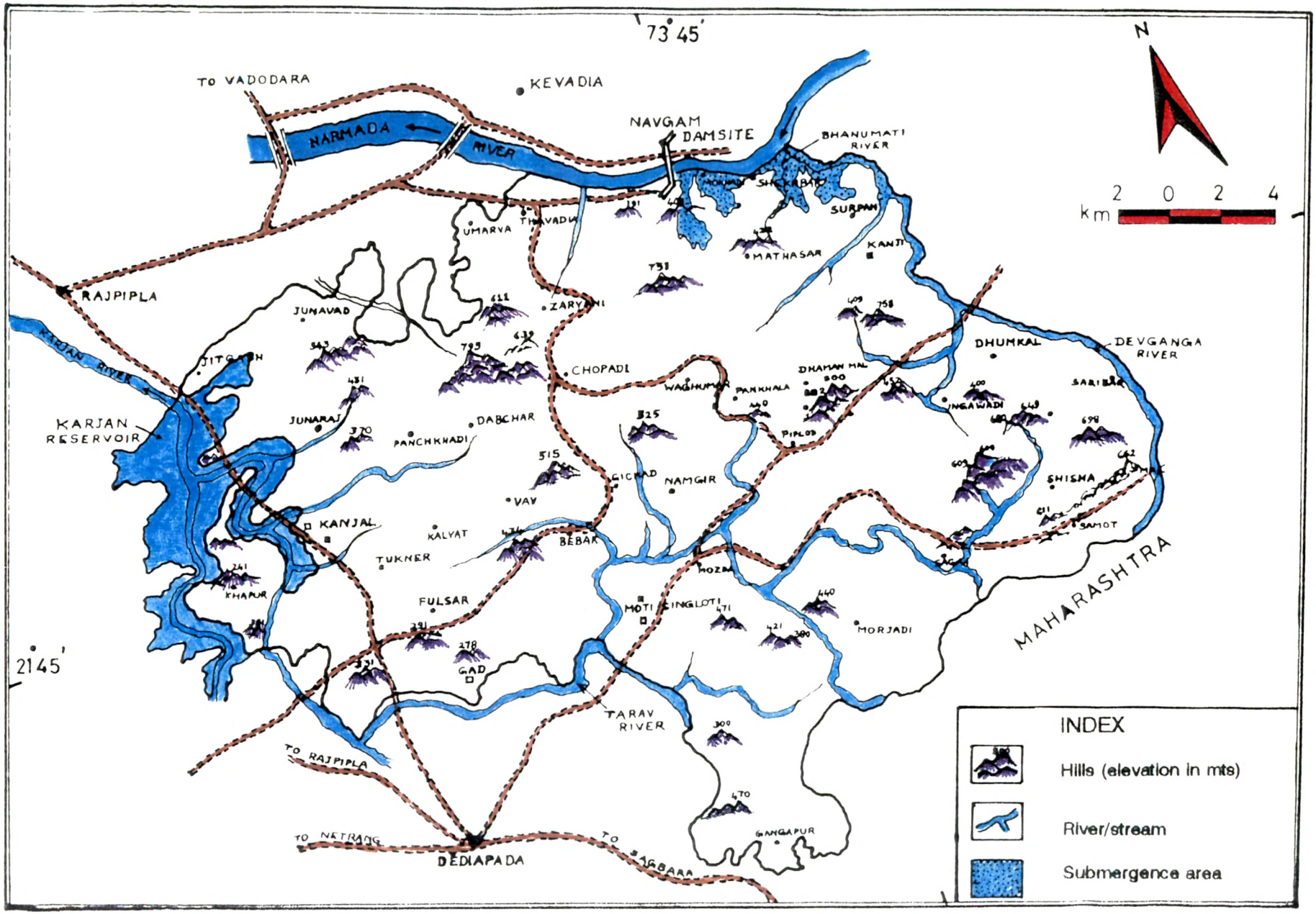
Fig. 2. Map of Gujarat showing the study area.

Indo-Gangetic plains. Shoolpaneshwar sanctuary is an extension of old Dumkhal Sloth bear sanctuary, part of Rajpipla East forest division, which falls in Dediapada and Nandod Taluka of Bharuch District and spreads on four forest ranges, Piplod, Fulsar, Dediapada and Gora. Located at the western end of the Satpura range, the area is resplendent with hilly terrain and valleys, spanning 675 sq. km (Fig. 3). Hills vary in height between 400 m and 882 m above msl. Rich black soil of the Deccan trap support a luxurious and varied vegetation at the core of the sanctuary and a fairly thick vegetation in the rest of the region. Numerous small streams arise from the mountain tops as tributaries that ultimately run into Karjan and Narmada rivers. The vegetation of the sanctuary is composed of moist and dry deciduous as well as evergreen trees. There are also a large number of shrubs and herbs that give a lush green appearance to the sanctuary during monsoon and post-monsoon periods. The trees bloom mostly in late winter and summer while shrubs and herbs flower in monsoon and post-monsoon. Thus throughout the year, there are enough flowers that provide food to ample number of insects. The presence of a thick canopy for a longer period makes the soil rich with leaf litter and inorganic materials thus providing ideal habitat for terrestrial forms especially amphibians.

The sanctuary is surrounded by watersources along its three sides. Northern side is bounded by the Narmada river and the proposed Sardar Sarovar. On the western side the area is bordered by Karjan river and the southern side by Devganga river. There are two rivers (Tarav and Sankli Kadi) that snake through the sanctuary. Due to the high rising Satpura peaks, the north west monsoon clouds are trapped more in this region and the average rainfall is about 1200 mm. Beyond Devganga river, the eastern region falls on the shadow side of Western Ghats that reach up to Dangs in Gujarat and Dhule district in Maharashtra. Thus a good rainfall, adequate water retention capacity of the hilly terrain due to the vegetational cover and the presence of large number of evergreen trees make the sanctuary practically a moist and cool region even in summer months.

On the northern side, especially in Zarvani area, there are several streams that support a luxurious vegetation. The humid and moist soil conditions along the stream bank coupled with loose laval gravel and coarse sand provide ideal habitat to several fossorial amphibians. Other major groups of animals that are dominant and

FIG. 3. TOPOGRAPHY AND DRAINAGE MAP OF SHOOLPANESHWAR SANCTUARY



characteristics of this sanctuary are insects, spiders and raptors.

Climate

Temperature: April and May are the hottest months of the year and the maximum temperature rises up to 40 °C. During winter season the minimum temperature varies between 6 °C and 10 °C. January is the coldest month.

Rainfall: The rainy season usually begin in June and lasts up to the second week of October. On the whole the area receives an average rainfall of 1000 mm.

Relative humidity : The relative humidity is maximum during July and August which ranges between 81% to 93%. During winter it decreases to its minimum and ranges between 30% to 40%.

Methodology

The study was carried out for about two and half years (1990-1993). Field trips were conducted at least twice a month. Duration of trips varied from three days to one week. The studies on fauna and flora as well as the ecology of the area were conducted by a team under the project entitled 'Ecoenvironmental and Wildlife Management Studies on the Sardar Sarovar Submergence Area in Gujarat.' As a member of that team I was entrusted with the study of amphibian fauna.

Collection and preservation of the animals were done as per the standardized methods. The animals were identified with the help of relevant literature (Boluenger, 1890, 1920; Daniel, 1965, 1975)or experts in the field (ZSI, Calcutta).

Results

The present study has yielded 13 species belonging to 7 genera and 4 families (Table 2). Six species from Ranidae, one from Rhacophoridae, four from Microhylidae, and two from Bufonidae. Key to the identification of species is given separately [This key was prepared incorporating all the species hitherto recorded from the study area, as the possibility of these species in the study area cannot be overruled].

Table 2. Amphibian species recorded from Shoolpaneshwar sanctuary

No.	Species	Common Name
	FAMILY : RANIDAE	
	ORDER : ANURA	
1	*Rana limnocharis* (Gravenhorst, 1829)	Indian Cricket Frog
2	*Rana tigerina* (Daudin, 1802)	Indian Bull Frog
3	*Rana keralensis (Dubois, 1980)*	Verrucose Frog
4	*Rana hexadactyla* (Lesson, 1834)	Indian Pond Frog
5	*Rana cyanophlyctis* (Schneider, 1799)	Skipper Frog
6	*Tomopterna breviceps* (Schneider, 1799)	Indian Burrowing Frog
	FAMILY : RHACOPHORIDAE	
7	*Polypedates maculatus* (Gray, 1834)	Common Tree Frog
	FAMILY : MICROHYLIDAE	
8	*Kaloula pulchra* Gray, 1831	Ceylon Kaloula
9	*Uperodon globulosus* (Gunther, 1854)	Baloon Frog
10	*Microhyla ornata* (Dumeril and Bibron, 1841)	Ornate Microhylid
11	*Microhyla rubra* Jerdon, 1854	Red Microhylid
	FAMILY : BUFONIDAE	
12	*Bufo melanostictus* Schneider, 1799	Common Indian Toad
13	*Bufo stomaticus* Lutken, 1862	Marbled Toad

The systematic account of each species is given elsewhere. Table 3 deals with the distribution of species . The rare species (as far as the distributional status in Gujarat is concerned) recorded from the study area include the verrucose frog, *Rana keralensis*, four microhylid species viz., *Kaloula pulchra, Uperodon globulosum, Microhyla rubra* and *Microhyla ornata* (Table 4). The most common species in the study area were *Rana cyanophlyctis* and *Bufo melanostictus*. Amphibians recorded in the sanctuary belong to all four principal habitat types viz., aquatic, fossorial, terrestrial and arboreal. The species collected from the area, along with their habitat, reproductive modes and food preferences are given in table 5. The left bank of Narmada river, especially the Shoolpaneshwar sanctuary is very rich in amphibian population in contrast to the right bank where only five species are present.

In the present study, maximum species richness was found in the core area (Fig. 4) of the sanctuary where the leaf litter, biomass and foliage availability are more in comparison to other parts of the study area.

The leaf litter and trees are the major microhabitats of Microhylid and Rhacophorid species. The vegetation around the waterbodies also give shelter to many aquatic marginal frogs. Majority of recorded amphibians are insectivorous and some species exclusively feed on ants. However, most amphibians are generalists, feeding on a wide array of small vertebrates or arthropods (Table 5).

Systematic Account of Species Recorded from the Study Area

1. *Rana limnocharis*, the Cricket frog (Plate 10, Fig. 1)
Material: 25 examples were collected from various parts of the study area.
Remarks: A common species in the study area, they were collected from stagnant water bodies, banks of streams, marshes and paddy fields.
Distribution: Throughout Indian region, Iran, South Arabia, Sri Lanka, Nepal and Thailand.

2. *Rana tigerina*, Indian bull frog
Material: 25 species collected from various parts.

Table 3. Distribution of amphibians in Shoolpaneshwar sanctuary

No.	Species	Locality
	FAMILY : RANIDAE	
1	*Rana limnocharis*	*
2	*Rana tigerina*	*
3	*Rana keralensis*	Sagai, Mozda
4	*Rana hexadactyla*	Mozda
5	*Rana cyanophlyctis*	*
6	*Tomopterna breviceps*	Chopadi, Jarvani, Namgir
	FAMILY : RHACOPHORIDAE	
7	*Polypedates maculatus*	Sagai, Namgir, Fulsar
	FAMILY : MICROHYLIDAE	
8	*Kaloula pulchra* Gray	Mal-Samot
9	*Uperodon globulosum*	Piplod, Mozda, Sagai
10	*Microhyla ornata*	Namgir, Mozda, Sagai
11	*Microhyla rubra*	Sagai
	FAMILY : BUFONIDAE	
12	*Bufo melanostictus*	*
13	*Bufo stomaticus*	*

* Found throughout the study area

Table 4. Status of amphibian species in Shoolpaneshwar sanctuary

Species	Status/Number
Rana limnocharis	++
Rana tigerina	++
Rana keralensis	+ (3)
Rana hexadactyla	+ (1)
Rana cyanophlyctis	+++
Tomopterna breviceps	+ (9)
Polypedates maculatus	+ (8)
Kaloula pulchra	+ (1)
Uperodon globulosum	+ (4)
Microhyla ornata	+ (4)
Microhyla rubra	+ (1)
Bufo stomaticus	++
Bufo melanostictus	+++

++ Common; +++ Very Common; + Species are found very rarely (number in parenthesis indicates the total number of animals collected)

Table 5. Habitat preference, mode of reproduction and food preferences of amphibians in the Shoolpaneshwar Wildlife Sanctuary.

Species	Habitat	Mode	Food
RANIDAE			
Rana cyanophlyctis	A	TW/PW	Ivc
R. tigerina	AM	TW (R)	vIc
R. hexadactyla	A	TW (R)	FIv
R. keralensis	AM	TW	Iwc
R. limnocharis	AM	TW/SB	Ic
Tomopterna breviceps	F	TW/PW	I
RHACOPHORIDAE			
Polypedates maculatus	T	TW (R)	IA
MICROHYLIDAE			
Kaloula pulchra	AM/T	TW (R)	AT
Microhyla ornata	G	TW (R)	IA
M. rubra	F/LL	TW (R)	T
Uperodon globulosum	F	TW (R)	T
BUFONIDAE			
Bufo melanostictus	G	TW (R)	I
B. stomaticus	G	TW (R)	I

A -- Aquatic, AM - Aquatic margin, F - Fossorial, T - Trees, G - Ground, TW - Temporary water pools, PW - Permanent water pools or ponds, SB - Stream Banks, (R) - Rainy season

I - Insects, V- Small vertebrates, A - Ants, C- Small crustaceans, W - Worms, T - Termites, F - Fish

Remarks: Common species throughout the study area. Very large specimens were collected from Sagai and Piplod areas.
Distribution: Throughout India; also reported from Nepal, Sri Lanka and Burma, Thailand, South China and Taiwan.

3. *Rana keralensis*, the verrucose frog (Plate 9. Figs. 1 & 2)
Material: three examples were collected from Sagai and Mozda.
Remarks: Though this species is known to be nocturnal, they were collected during day time from forest rivulets. This little known species was until recently, considered as endemic to Kerala or Tamilnadu. However, Daniels (1993) has indicated that the range of this species extends further north through Karnataka up to Maharashtra. It is now known that the range of this species extends further at least up to the left bank of Narmada river in Gujarat.
Distribution: Kerala, Karnataka, Goa, Maharashtra and Gujarat.

4. *Rana hexadactyla*, the pond frog
Material: One example collected from Mozda.
Remarks: Only one specimen was found floating in a stagnant water body.
Distribution: Common in South India. Also reported from Punjab, Rajasthan, Maharashtra, Goa and West Bengal.

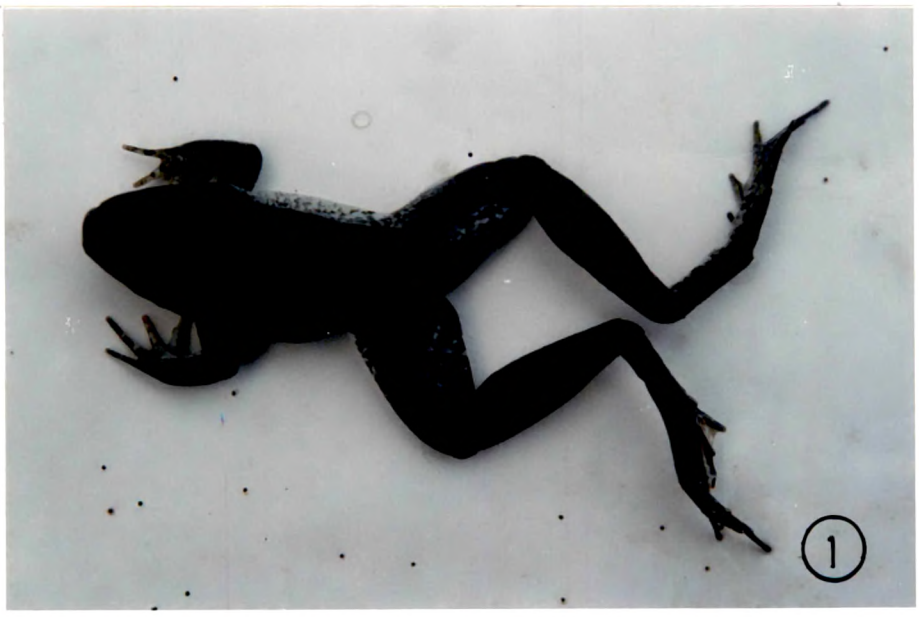
5. *Rana cyanophlyctis*, the skipper frog
Material: 150 examples from various parts of the study area.
Remarks: This was the most common species in the study area. They were found floating in most of the ponds, ditches, rivulets and other water bodies.
Distribution: Throughout India. Also reported from Pakistan, Afghanistan, Iran, South Arabia, Nepal, Thailand and Sri Lanka.

6. *Tomopterna breviceps*, the Indian burrowing frog
Material: Five examples collected from Chopadi, Jharvani and Namgir.
Remarks: They were collected from riverbanks and bushes very close to ant nests or termitaria.
Distribution: All over India, Sri Lanka, Malaya and Southern China.

Plate 9

Figure 1. *Rana keralensis,* example 1 (dorsal side).

Figure 2. *Rana keralensis,* example 2 (ventral side).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7. *Polypedates maculatus*, the common tree frog
Material: Seven examples collected from Sagai, Namgir and Fulsar.
Remarks: The species was very common in Sagai area, often found on walls and window panes of forest guest house. They were also seen in gardens and bushes.
Distribution: All over India except Haryana, Punjab and Rajasthan.

8. *Kaloula pulchra* (Plate 11, Fig. 1)
Material: One example collected near Mal-Samot village.
Remarks: This single specimen constitute a new record of the species for Gujarat. This beautiful frog was seen at night, resting on tree trunk at a height of about 2.4 m, on the river bank. It was spotted on a rainy day and was giving shrill and loud calls.
Distribution: All over South India, Assam and West Bengal. Also reported from Sri Lanka.

9. *Uperodon globulosum* (Plate 10, Fig. 2)
Material: four examples collected from Piplod, Mozda and Sagai.
Remarks: This fossorial frog appears to be of rare occurrence in this region. They were not seen above the ground during day time except perhaps during breeding season. These frogs were found buried about a foot beneath the soil surface from small stream beds.
Distribution: Assam, West Bengal, Orrisa, Madhya Pradesh, Maharashtra, Karnataka and Kerala. Occurrence of this species was reported in Dangs by Daniel (1963).

10. *Microhyla ornata*
Material: four examples from Namgir, Mozda and Sisha.
Remarks: This narrow-mouthed frog is nocturnal in habit. During day they hide under leaves or stones. It feeds mostly on insects.
Distribution: All over India, Sri Lanka, Southeast Asia to Malay Peninsula.

11. *Microhyla rubra* (Plate 11. Fig. 2)
Material: One example was collected from Sagai area
Remarks: This microhylid frog appears to be very rare in the areas as it was collected from only one locality. The frog was found resting under the stone during day time. This species has not been recorded earlier from Gujarat State.

Plate 10

Figure 1. *Rana limnocharis*

Figure 2. *Uperodon globulosum*


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Plate 11

Figure 1. *Kaloula pulchra*

Figure 2. *Microhyla rubra*


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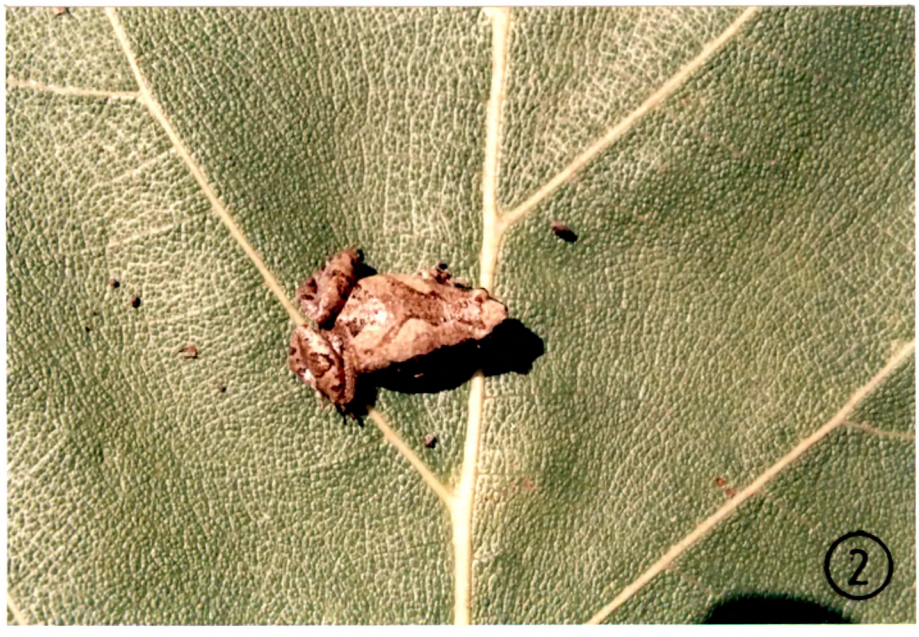
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Distribution: Widely distributed in Assam, South India and Sri Lanka.

12. *Bufo melanostictus*, the common toad
Material: 15 examples were collected from various parts of the study area.
Remarks: This toad was very common in the study area. Hill specimens were found be larger than from plains. The species usually remain hiding in holes or under the bushes and stones and come out for eating insects during night.
Distribution: Throughout Indian region, Sri Lanka, Burma, Southern China, Malay Peninsula and Archipelago.

13. *Bufo stomaticus*
Material: six examples were collected from Sagai, Mal-Samot and Namgir areas.
Remarks: This specimen was not common as *Bufo melanostictus*. Strictly nocturnal in habit. Habitat preference was found to be almost similar to that of the common toad.
Distribution: In India: West Bengal, Bihar, Andhra Pradesh, Rajasthan, Uttar Pradesh, Gujarat and Maharashtra. Also found in Nepal, Burma, Sri Lanka and Pakistan.

Discussion

Factors Affecting the Amphibian Diversity in Shoolpaneshwar Sanctuary
Shoolpaneshwar sanctuary is comparatively a less disturbed area which provides the habitat for 13 anuran amphibians. The species richness of amphibians is undoubtedly maximum in this region compared to other parts of Gujarat (Table 6). In 1984, Sarkar has reported only 9 species of amphibians from Gujarat. Further, the studies on the distribution of amphibian fauna in Gujarat revealed the presence of 15 species of anurans belonging to seven genera and four families (Naik and Vinod, 1993). Out of these 19 species of amphibians hitherto recorded from Gujarat, 13 species are present in the Shoolpaneshwar wildlife sanctuary that implies the species richness of the study area. The verrucose frog *Rana keralensis*, a typical Western Ghat species has been reported from the sanctuary. Other peculiar forms include microhylid frogs, *Kaloula pulchra* and *Uperodon globulosum*. Even though amphibians are the most striking group of animals in this area, the faunal inventory of the sanctuary revealed a general species richness (Sabnis and Amin, 1992). The sanctuary support a wide variety of

Table 6. Amphibian species hitherto reported from the Gujarat State

No.	Species	Common Name
	ORDER : APODA	
1	*Icthypophis bombayensis* Taylor,1960	Ichthyophis
	FAMILY : RANIDAE	
	ORDER : ANURA	
2	*Rana limnocharis* (Gravenhorst, 1829)	Indian Cricket Frog
3	*Rana tigerina* (Daudin, 1802)	Indian Bull Frog
4	*Rana keralensis* (Dubois, 1980)	Verrucose Frog
5	*Rana hexadactyla* (Lesson, 1834)	Indian Pond Frog
6	*Rana cyanophlyctis* (Schneider, 1799)	Skipper Frog
7	*Rana malabarica* Tschudi, 1838	Fungoid Frog
8	*Rana leithii* Boulenger, 1888	Leith's Frog
9	*Tomopterna breviceps* (Schneider, 1799)	Indian Burrowing Frog
	FAMILY : RHACOPHORIDAE	
10	*Polypedates maculatus* (Gray, 1834)	Common Tree Frog
	FAMILY : MICROHYLIDAE	
11	*Kaloula pulchra* Gray, 1831	Ceylon Kaloula
12	*Ramanella montana* (Jerdon) 1854	Jerdon's Ramanella
13	*Uperodon globulosus* (Günther, 1854)	Baloon Frog
14	*Uperodon systoma* (Schneider, 1799)	Marbled Baloon Frog
15	*Microhyla ornata* (Duméril and Bibron, 1841)	Ornate Microhylid
16	*Microhyla rubra* Jerdon, 1854	Red Microhylid
	FAMILY : BUFONIDAE	
17	*Bufo melanostictus* Schneider, 1799	Common Indian Toad
18	*Bufo stomaticus* Lütken, 1862	Marbled Toad
19	*Bufo viridis* Laurenti, 1768	Green Toad

The new generic names of some Ranid species (Dubois, 1986; Dutta, 1992)
Limnonectes limnocharis = Rana Limnocharis; Limnonectes tigerinus = Rana tigerina; Limnonectes keralensis = Rana keralensis, Occidozyga cyanophlyctis = Rana cyanophlyctis; Occidozyga hexadactyla = Rana hexadactyla; Indirana leithii = Rana leithii

plants and animals. Major taxa of animals (other than amphibians) reported from the sanctuary include 210 species of insects (Radhakrishnan *et al.*, unpublished), 57 species of spiders (Radhakrishnan *et al.*, 1995), 15 species of reptiles (Naik *et al.*, 1993) 173 species of birds (Desai *et al.*, 1993) and 28 species of mammals (Sabnis and Amin, 1992). Importance of preservation of the biodiversity of amphibians in this region has already reported (Naik *et al.*, 1995). It is essential to deal with various aspects, such as geographic, physical and biologic factors that affect the amphibian diversity in an area in order to appreciate the biotic and abiotic stresses on amphibians. These factors are dealt with as follows.

(a) History and community composition: The historical factors influencing the assemblage of species composing a given community should be an essential component of the ecological studies of a particular area. This aspect of community analysis must include the history of the study area (Duellman, 1989).

Floristically, South Gujarat below Narmada belongs to Malabar region. Again, floristically and faunally, the Malabar or the West coast region is unique with large number of endemic species. The evergreen forests have the largest wild gene pools, India could boast of. The Indian subcontinent and the peninsular regions are separated mainly by Vindhya and Satpura ranges. Between these two ranges, the Narmada river flows. Zoogeographically, the Narmada divides the Indian region into northern continental and southern peninsular regions. The region south of Satpura range is elevated to form the Deccan plateau. The soil, climate and vegetation and the flora of the Deccan plateau are different from the rainfed evergreen forest region of Western Ghats. Humidity, temperature and vegetation are the main factors that determine the ecological features of the two regions, north of Vindhya and south of Satpura. Many dominant South Indian amphibians are found in the forests of Dangs and Satpura ranges. The species such as the spade foot frog *Uperodon globulosum*, abundant in the Satpura range is absent in the northern part of Vindhya range. For many Western Ghat species such as *Rana hexadactyla, Rana keralensis, Kaloula pulchra,* found in the Satpura ranges, the northern border is Narmada. In other words, Narmada divides the semi-arid continental north from the humid peninsular south with respect to animal distribution. The forest of Rajpipla (part of Satpura range) was earlier contiguous with the forests of Dangs, which is a typical Western Ghat forest with several Malabar

fauna. The forest of Rajpipla also has many semi-arid forms that are abundant in the northern continental region. At present, the Shoolpaneshwar sanctuary is one of the few surviving forests of Satpura range that once extended from Rajpipla to Hoshangabad and beyond, all along the Narmada valley, linking north east forest with Western Ghat forests. Because of this earlier confluence, the forest of the sanctuary has a few north east forms and a large number of Western Ghat forms. The uniqueness of this region is due to this microzoogeographical distribution of animals. Besides, the forest in this area is composed of dry-deciduous and moist deciduous trees sprinkled with evergreen ones.

Satpura hypothesis: The uniqueness of the sanctuary can also be ascribed to the Satpura hypothesis (Hora, 1937). This hypothesis explains the presence of several common species in north-east region and south-west region as there existed a probable route by which several north-east species could spread to south-west India through Satpura mountain range. Several such anuran species have been recorded from the study area. These include *Rana hexadactyla, Micohyla rubra, Uperodon globulosum* and *Kaloula pulchra.*

In fact, Hora envisaged a lost mountainous connection between the present terminus of Satpuras, the Rajmahal Hills of Bihar and the Garo-Khasi-Mikir hills (GKM complex) of Assam which lie approximately in line with the Satpuras. But this Rajmahal-Garo gap is now 250 km of alluvium through which the Ganges and Brahmaputra make their way to the Bay of Bengal. Geologists deny the existence of any such mountainous feature either recently or in the past. Hora, however, knew that several genera of torrential fishes and frogs with South-east Asian and Himalayan distributions were found in the mountains of peninsular India.

The mountain regions of peninsular India are separated from the Himalaya by the Indus-Ganges and Brahmaputra plains because of the historical depression of the Indian plate along the Himalayan front as it converged upon the Tibetan portion of the Asian plate. Then the question is how the taxa of mountainous regions of Southern Asia managed to cross the plains and populated the mountains of peninsular India. The most universally accepted answer assumed that during various phases of Pleistocene glaciation, the lowered temperatures of the region allowed more temperate

forests to range across the plains and create a pathway for montane species to cross the barrier. However, the torrential fishes and frogs can live only in freshwater and could not cross the flat lands of the Ganges-Brahmaputra plains. That the eggs of such species in this category may have been carried on the feet of birds is just an enigmatic explanation.

Swan (1993) has conducted the studies on the distribution of amphibians and reptiles in Southern Asia. His studies revealed that about 70% of the montane fauna of the Sikkim-Darjeeling region is found in the Khasi Hills near Shillong. Swan has proposed an amazing inference with geological evidence. According to him the eastward movement of the GKM complex has presumably accompanied with the spectacular movement of the Earth's surface. The distribution of the herpetofauna around a rim of a new Brahmaputra valley appears like a thumb-like extension eastward. Hora's torrential fishes along with much of the mountainous biota of peninsular India, must have used the new displaced GKM complex as their pathway across the plains. Perhaps the Himalayan loss of contact with peninsular India preceded the loss of contact with the GKM complex because the peninsular relationship with the eastern Himalaya is largely on generic level while the relationship with the GKM complex remains closely on the species level (Swan, 1993).

(b) Habitat heterogeneity: The habitat heterogeneity enables a large number of taxonomically or ecologically related species to co-occur in a same environment. Large modular organisms (particularly large trees), whose architecture provides a variety of habitat resources, increase the habitat heterogeniety of an area. The Shoolpaneshwar sanctuary is endowed with a rich vegetation composed of moist and dry deciduous as well as evergreen trees. The standing biomass of this area is estimated to be 1,650,849 tonnes in dry wood equivalent terms (Sabnis and Amin, 1992). High biomass production is restricted to the core area of the sanctuary. These areas are characterized by well-drained soil, rich wildlife and less man-induced biotic stresses. Biomass production is poor in the areas near Sardar Sarovar and small patches on the eastern and western parts of the sanctuary. Recorded data show that species richness is high in biomass rich areas.

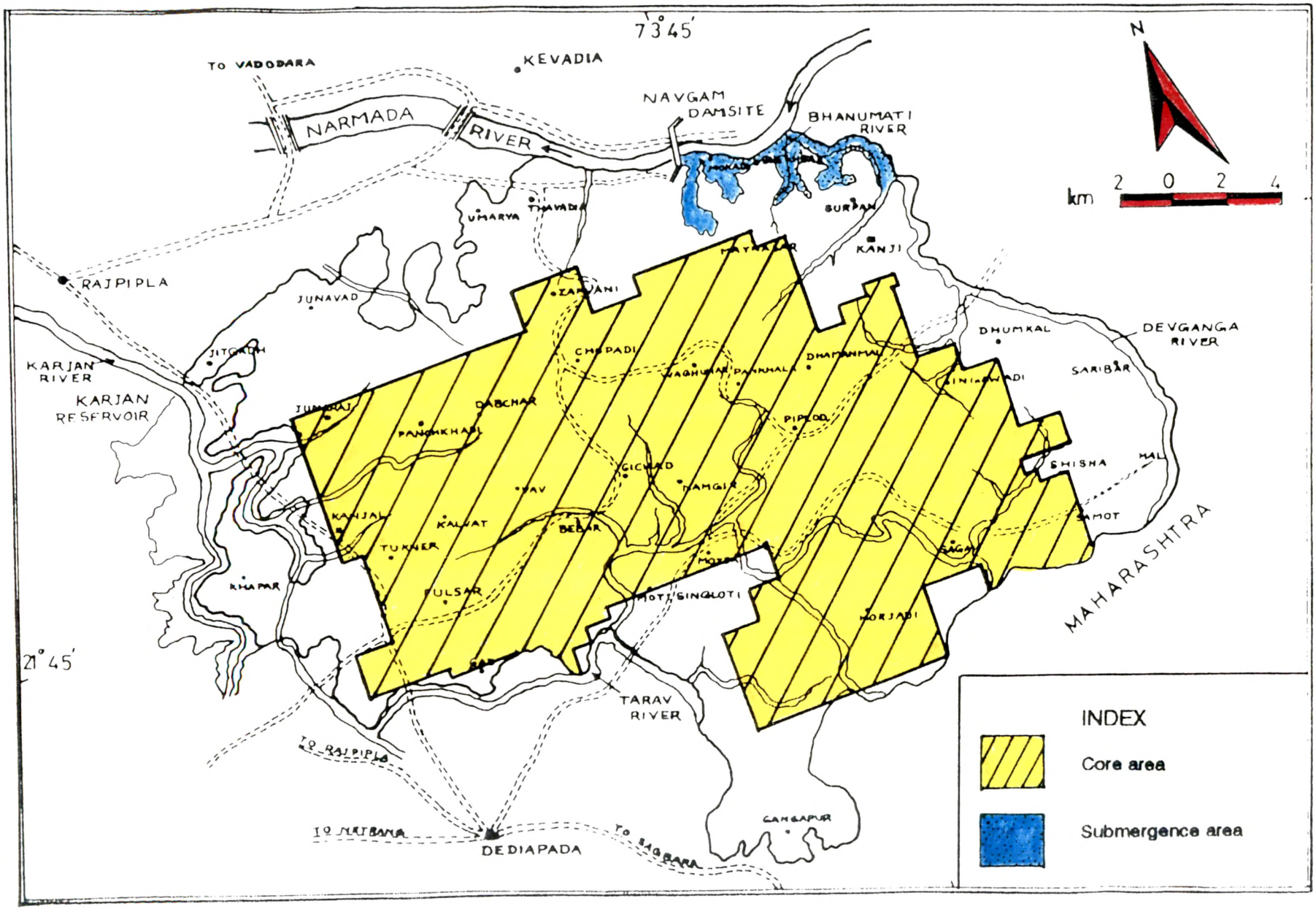
Leaf litter is an important component that support many amphibians especially

the microhylid frogs. Species such as *Microhyla ornata* and *Microhyla rubra* were recorded in the leaf litters. The quantity of biomass, foliage availability and leaf litter are more in least disturbed ecosystems, which are found in the core area of the sanctuary. That maximum species richness was recorded from the core area of the sanctuary indicates that habitat heterogeneity is an important factor in determining the species richness of an area(Fig. 4).

(c) Food resources: The maintenance of high animal species diversity mostly depends on the steady availability of a wide and diverse array of food resources. In a less disturbed ecosystem, these resources are provided, the year long and in a predictable way, both by the plant and animal component of the ecosystems (Bourliere and Harmelin-Vivien, 1989). Such a large spectrum of resources allows an extreme variety of life forms and life styles to be adopted by a large number of species. As for the amphibians and reptiles which are for their most part carnivorous, their species richness in the humid tropics can be better explained by the abundance of their animal preys-than their diversity (Bellairs, 1969; Duellman and Trueb, 1986). In Shoolpaneshwar sanctuary, majority of anurans are insectivorous, most are generalists feeding on a wide array of available insects up to a maximum size dictated by the predator's gape. Several species of anurans specialize on ants and a few on termites. Sanctuary support the habitat of a wide variety of insects. Ants and termites are predominant in the area. Large ant nests and termitaria were found in various parts of the sanctuary. The species such as *Uperodon globulosum* and *Rana breviceps* were found inhabiting near the termataria. Narrow mouthed frogs such as *Microhyla* species are also specialized on ants.

(d) Productivity and equilibrium of ecosystem: The ultimate determinants of the species richness of all animal consumers in the humid tropics depends upon the primary productivity of the ecosystem concerned and in their floral diversity both on land and in water (Bourliere and Harmelin-Vivien, 1989). The Shoolpaneshwar sanctuary provides a large number of undisturbed areas characterized by a closed canopy that promotes moist soil conditions and vegetation resulting in substantial amount of detritus material in both aquatic and terrestrial environment. The nutrient cycle in this undisturbed ecosystems is a complex and complete one (Fig. 6). There are enough primary producers providing ample food to various primary consumers.

FIG. 4. MAP SHOWING CORE AREA OF SHOOLPANESHWAR SANCTUARY



Countless number of insects as well as frugivorous, nectar feeders or graminivorous birds are the major primary consumers. Most tadpoles are the primary consumers in the aquatic food web. There are about 100 species of birds that feed on insects either optionally or obligatorily (Desai *et al.*, 1992). These birds as well as many spiders, crustaceans, microchiropteran bats and reptiles are the secondary consumers. There are about 26 species of raptors which form the tertiary consumers along with other higher carnivores. For many species in the sanctuary there is no specific trophic level due to the complexity of the food web. The interlinkage of terrestrial and aquatic ecosystems is also noticeable. Disturbance in ecosystems compells the organism to deviate from thier normal feeding habits. In the disturbed ecosystems of the sanctuary, the giant wood spider (*Nephila maculata)* was found to feed on tadpoles of frogs and fingerlings of fish, probably an unusual feeding habit (Pradeep and Vinod, 1994). High primary productivity and stability of ecosystems could be an important factor that resist the species extinction in an area, by reducing the biotic pressures on the individuals.

(e) Perturbations in ecosystem due to human intrusion: Even though the sanctuary is undisturbed to a considerable extent, there are several areas within it that are very strongly disturbed or are in the process of destruction. The degradation of forest and altered land use patterns can be directly proportional to the reduction in the density and biodiversity of amphibians. Majority of amphibians are dependent on the forest canopy. Frogs such as *Kaloula pulchra* and *Polypedates maculatus* are arboreal species while the microhylid species are inhabitants of leaf litter. The dense grass cover is a good shelter for all amphibians. The encroachment and subsequent degradation as well as commercial exploitation of the forest are even at a higher rate. Opening of canopy by way of removing trees in the forest can lead to the desiccation of forest floor and reduction in leaf litter cover on the soil surface. In addition to this, one social custom observed by the tribals in the forest area causes greater damage to the microhabitats of some species. The tribals give 'fire bath' to the hills by setting fire to the forest floor that results in massive destruction of forest especially in summer months.

(f) Physical factors: Climatic stability results in environmental predictability. This is significant to amphibians because it assures them of uninterrupted shelter, feeding

sites and food as well as adequate sites for oviposition and larval development (Duelman, 1989). Sanctuary is not having a stable climate. However, the area receives better rainfall compared to other areas. For the amphibians the amount and seasonality of precipitation is more important. The high rainfall results in greater plant productivity which provides an abundance of food for primary consumers, most of which are insects, which in turn are the principal prey of most anurans and reptiles. Further, there are many perennial water sources in the area that provide them habitats for shelter, breeding and development. The entire Shoolpaneshwar sanctuary is well-drained by a large number of streams and rivulets during monsoon. During summer many of these streams get dried and flow of water ceases. However, at various places water get stored in large depressions on the rocky river beds. About 48 such perennial watersources have been located in the sanctuary (Fig. 5).

(g) Distribution of amphibians in different agroclimatic regions: The analysis of distribution of amphibians in different agroclimatic regions within Gujarat indicates a non-uniform distribution pattern of fauna (Table 7). South Gujarat is the richest region in species diversity having almost 90% of the total species reported. All the forms except, *Uperodon systoma* and *Bufo viridis* have been recorded in this region (Naik and Vinod, 1993). Not more than seven species were reported from any other region. South Gujarat region possess a good rainfall in comparison to any other region. The region receives a precipitation between 974 and 1793 mm. The semi-arid dry humid condition of this area could be suitable for both the terrestrial and aquatic species. However, a comparison between the regions North-Saurashtra and Central Gujarat reveals that the diversity is more in the North Saurashtra though the region receives lesser rainfall (537 mm) than middle Gujarat (904 mm) while climate and soil conditions in both regions are same. This difference can be attributed to the increased industrialization in this area. Even North Gujarat is impoverished in species richness having only 5 species; Ahmedabad district must be the area with least diversity. North West arid region has 7 species in spite of least rainfall (340 mm). Though the South Gujarat region possesses maximum diversity, many parts of this region is impoverished having not more than two or three species. The species richness is merely confined to the undisturbed forest areas in Shoolpaneshwar wildlife sanctuary and Dangs.

Table 7. Species richness of amphibians in different agroclimatic regions.

Species	SG	MG	NG	NWA	NS	SS
Icthyophis bengalensis	+	-	-	-	-	-
Rana limnocharis	+	-	+	+	+	+
Rana tigerina	+	+	+	+	+	+
Rana keralensis	+	-	-	-	-	-
Rana hexadactyla	+	-	-	+	-	+
Rana cyanophlyctis	+	+	+	+	+	+
Rana malabarica	+	-	-	-	-	-
Rana leithii	+	-	-	-	-	-
Tomopterna breviceps	+	-	-	-	+	-
Polypedates macualtus	+	-	-	-	-	+
Kaloula pulchra	+	-	+	-	-	-
Ramanella montana	+	-	-	-	-	-
Uperodon globulosum	+	-	-	-	-	-
Uperodon systoma	-	+	-	-	-	-
Microhyla ornata	+	-	-	+	-	-
Microhyla rubra	+	-	-	-	-	-
Bufo stomaticus	+	+	-	+	+	+
Bufo melanostictus	+	+	+	+	+	+
Bufo viridis	-	-	-	-	+	-
Total number of species	17	5	5	7	7	7
Species richness (%)	89.5	26.3	26.3	36.8	36.8	36.8

SG=South Gujarat, MG=Middle Gujarat, NG=North Gujarat, NWA=NorthWest Arid, NS=North Saurashtra, SS=South Saurashtra
For the convenience Zone-I and Zone-II have been combined and Zone VIII has been excluded

FIG. 5. PERMANENT AND TEMPORARY WATERHOLES IN THE SANCTUARY

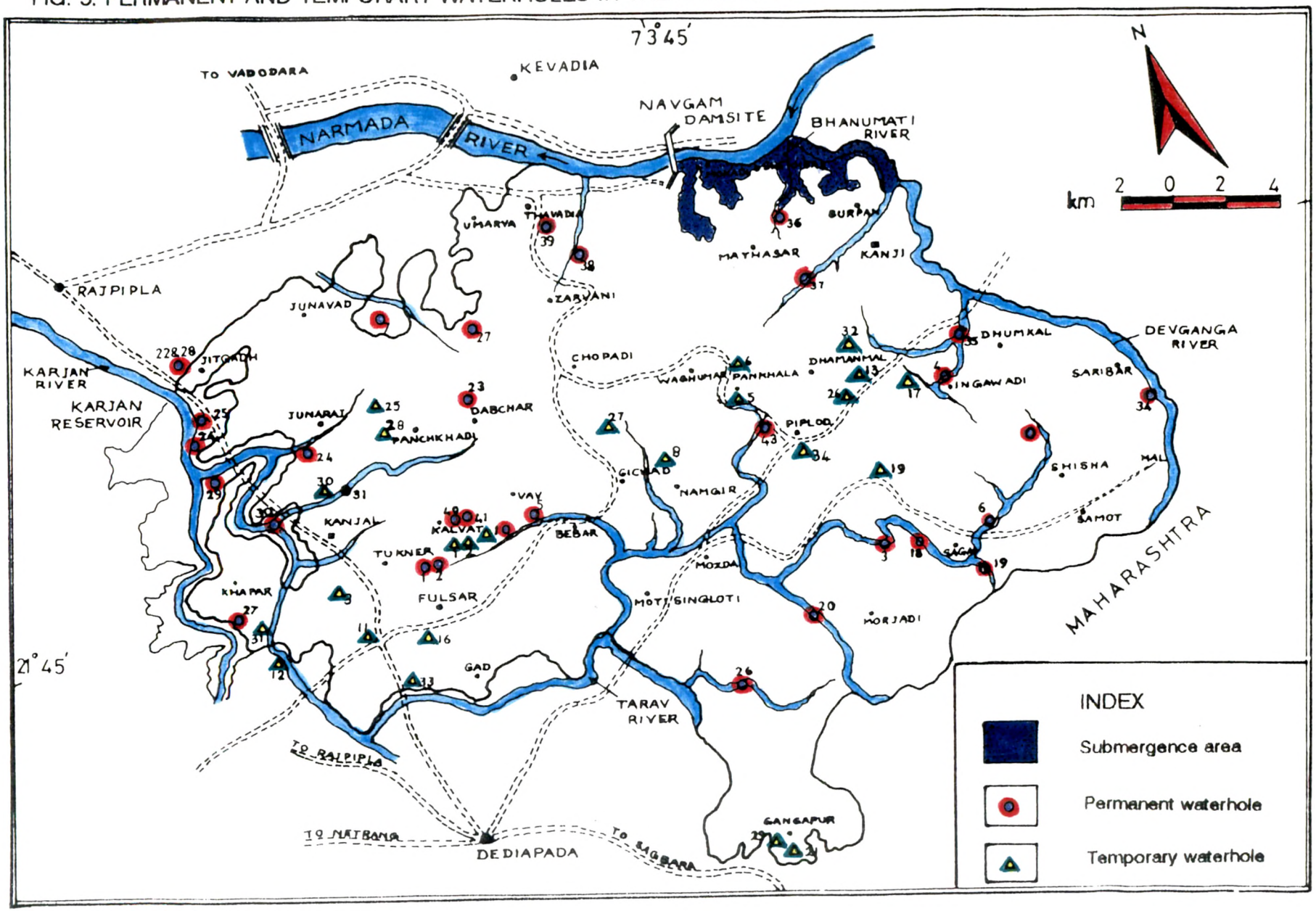
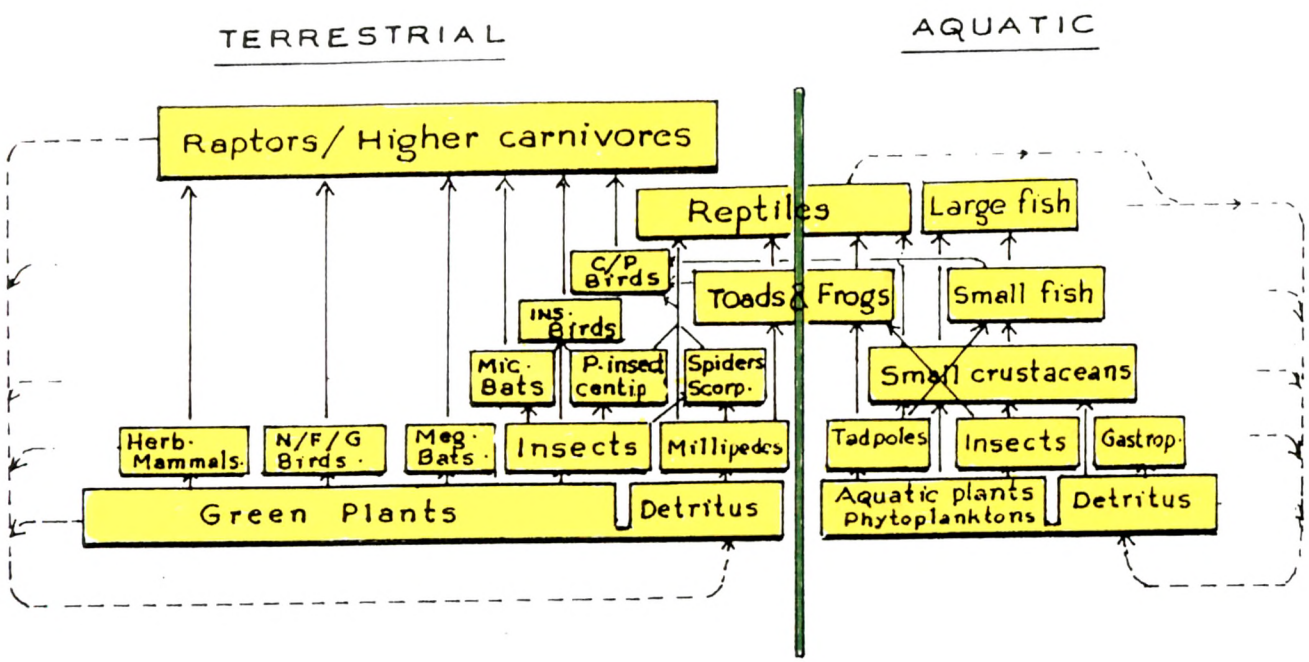


FIG. 6. **FOOD WEB AND TROPHIC LEVELS IN THE UNDISTURBED ECOSYSTEMS OF SHOOLPANESHWAR SANCTUARY**



C.=Carnivorous
P.= Predatory
N.= Nectarivorous
F.= Frugivorous
G.= Graminivorous
Herb.= Herbivorous

Meg.= Megachiropteran
Mic.= Microchiropteran
Ins.= Insects
Centep.= Centipedes
Scorp.= Scorpions

Key to the identification of amphibian species recorded from Gujarat

1. Limbs absent, body snake-like - *Icthyophis bombayensis*
2. Limbs present, tail absent in adult - 3, 4
3. Parotid gland present, Skin rough with well developed warts 5,6
4. Parotid gland absent 9, 10
5. Head with bony ridges - *Bufo melanostictus*
6. Head without bony ridges 7,8
7. Tibial gland present - *Bufo viridis*
8. Tibial gland absent - *Bufo stomaticus*
9. Upper jaw toothed - 11, 12
10. Jaw toothless 27, 28
11. An intercalary ossification present between the distal and penultimate phalanges - *Polypedates maculatus*
12. An intercalary ossification absent between the distal and penultimate phalanges-13, 14
13. Outer metatarsal united or separated only in their distal extremity - *Tomopterna breviceps*
14. Outer metatarsal separated by web at least in the distal half - 15, 16
15. Toes completely webbed - 17, 18
16. Toes incompletely webbed - 21, 22
17. Skin of back with logitudinal folds - *Rana tigerina*
18. Skin of back smooth or with tubercles and warts - 19, 20
19. Size large, skin of back smooth, two rows of porous warts on flanks; snout flat, obtusely pointed - *Rana hexadactyla*
20. Size smaller up to 60 mm. Skin warty, a single row of porous warts on flanks, snout rounded, inner metatarsal tubercles finger like - *Rana cyanophlyctis*
21. Tips of fingers and toes dilated into small discs with circum marginal groove - *Rana leitheii*
22. Tips of fingers and toes not dilated into discs - 23, 24
23 A distinct dorso lateral glandular fold from above tympanum to vent back between the glandular fold bright orange or yellowish red or red crimson - *Rana malabarica*
24. Dorso lateral glandular fold absent, no distinctive colour pattern - 25, 26
25. Toes 1/2 webbed, 3 phalanges of 4th toe free, outer metatarsals united in the basal half; tibio tarsal articulation reaches nostril - *Rana limnocharis*
26. Toes 3/4 webbed, two phalanges of 4th toes free, outer metarsal separated by web nearly to the base. Tibiotarsal articulation reaches nostril or tip of snout - *Rana keralensis*
27. Tips of fingers dilated into discs - 29, 30

28. Tips of fingers not dilated into discs - 31, 32
29. A bony ridge immediately below internal nares - *Kaloula pulchra*
30. A bony ridge someway below internal nares - *Ramanella montana*
31. No papillae behind internal nares, size small - 30, 31
32. Papillae present below internal nares, size large - 35, 36
33. Habit slender, 2 normal metatarsal tubercles - *Microhyla ornata*
34. Habit stout, tow shovel shaped metatarsal tubercles - *Microhyla rubra*
35. A pair of papillae together below internal nares, interorbital width nearly thrice upper eyelid. Colour uniform brown or grey - *Uperodon globulosum*
36. A pair of papillae below the internal nares and a papillae below each internal nare. Interorbital width about twice upper eyelid. Back marbled - *Uperodon systoma*