Carrying Capacity Study of Teesta Basin in Sikkim

Volume-VI

BIOLOGICAL ENVIRONMENT - TERRESTRIAL AND AQUATIC RESOURCES

Commissioned by :

Ministry of Environment & Forests, Government of India

Sponsored by :

National Hydroelectric Power Corporation Ltd., Faridabad

CENTRE FOR INTER-DISCIPLINARY STUDIES OF MOUNTAIN & HILL ENVIRONMENT
UNIVERSITY OF DELHI, DELHI

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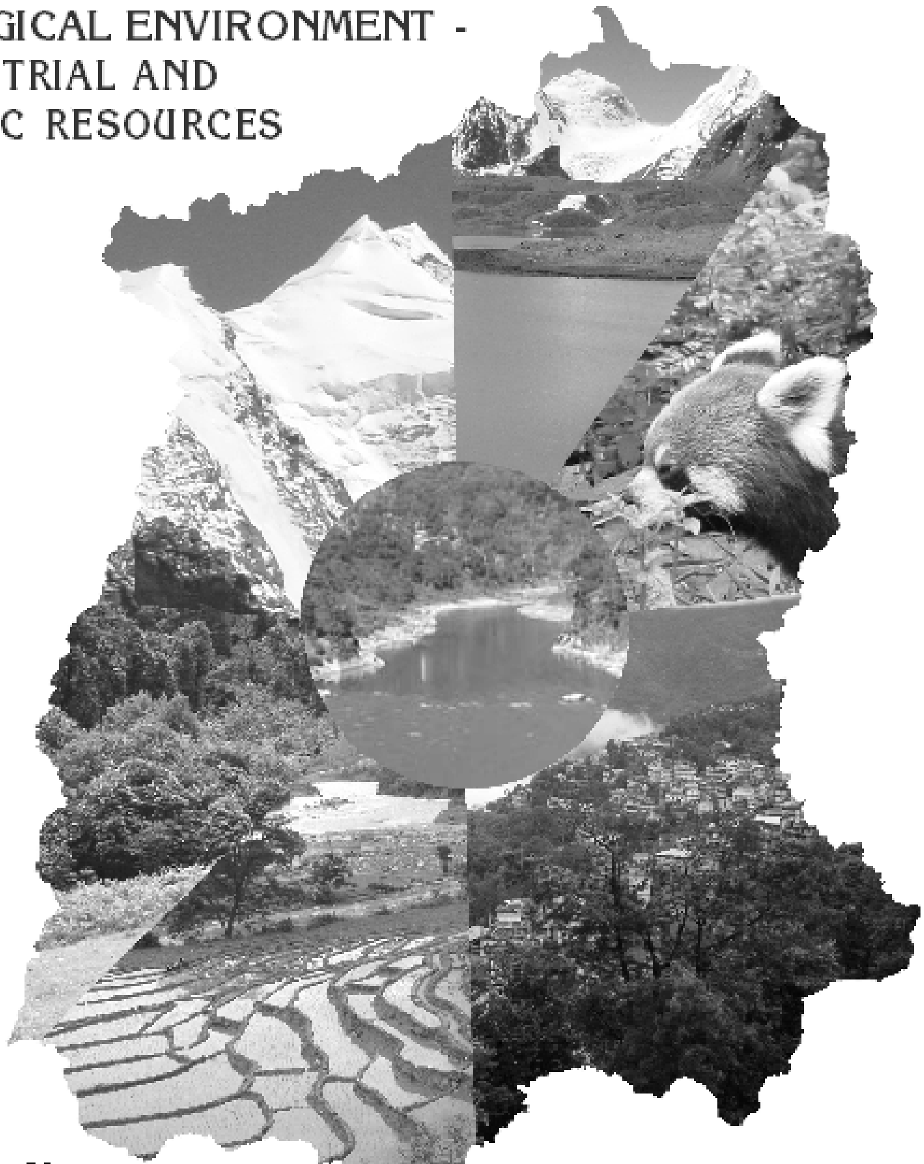

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CENTRE FOR INTER-DISCIPLINARY STUDIES OF
MOUNTAIN & HILL ENVIRONMENT
UNIVERSITY OF DELHI, DELHI

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VOLUMES INDEX*

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CHAPTER - 1

FOREST TYPES AND VEGETATION

The forests of Sikkim are covered under four forest divisions *viz*. East, North, South and West Forest Divisions. The forest types in Teesta basin have been described as per the classification of Champion and Seth (1968). Main forest types encountered in the basin are given in Table 1.1.

Table 1.1 Principal forest types found in Teesta basin

Groups		Characterstic Species	Altitude (m)	Places
1.	Tropical moist Deciduous Forests	*Dillenia pentagyna*, *Dysoxylum floribundum*, *Gymnema arborea*, *Lagerstroemia parviflora*, *Shorea robusta*, *Toona ciliata*	250-900	Rangpo Chhu, Sherwani, Jorethang, Rangit
2.	Sub-tropical forest			
i)	Sub-tropical broad leaved hill forest	*Albizia procera, Alnus nepalensis, Bauhinia purpurea*, *Castanopsis indica, Macaranga denticulata, Michelia champaca*, *Schima wallichii*	1000-2000	Tong, Gyalzing, Sangklang, Selem Chakung Chhu
ii)	Sub-tropical Pine forests	*Pinus roxburghii*, *Engelhardtia colebrookiana*, *Quercus leucotrichophora*	1000-1800	Gangtok, Gyalzing, Rongli
3.	Montane wet temperate forest			
i)	Temperate broad leaved forests	*Acer campbellii*, *Engelhardtia spicata*, *Machilus edulis, Michelia cathcartii, Quercus lamellosa*, *Taxus baccata*	1700-2700	Chunthang-Lachung, Yumthang

ii)	Mixed coniferous temperate forests	*Abies densa, Acer campbellii*, *Betula utilis. Rhododendron arboreum,Abies densa,* *Taxus baccata*, *Tsuga dumosa, Larix griffithianum*	2700-3000	Lachen, Zemu, Yathang, Lachung
4.	Sub-alpine forest	*Abies densa, Betula utilis*, *Cassiope fastigiata*, *Rhododendron* sp.	Above 3000	Above Yathang
5(a)	Moist alpine Scrub			
i)	Birch-Rhododendron scrub forests	*Betula utilis, Sorbus foliolosa*, *Rhododendron campanulatum*,	Above 3600	Thangu, Menmoi Chho
ii)	Deciduous alpine scrub	*Betula utilis, Berberis* sp., *Lonicera* sp., *Rosa* sp.	3600-3900	Changu Thangu
iii)	Dwarf Rhododendron Scrub	*Rhododendron lepidotum*	Above 3600	Thangu
iv)	Alpine pastures	*Allium, Anemone, Delphinium*, *Fritillaria, Gentiana, Iris, Primula,* etc.	Above 4000	Chhoptha Yumesamdong
5(b)	Dry alpine scrub			
i)	Dwarf Juniperus scrub	*Juniperus recurva* and *J. wallichiana*	Above 3600	Chhoptha Chhangu
ii)	Dry alpine scrub	*Ephedra gerardiana*, *Meconopsis* sp., *Ribes* sp.	Above 4000	Chhoptha

1.1 TROPICAL MOIST DECIDUOUS FORESTS

These forests are found in the foothills of South Sikkim and at low altitude areas bordering West Bengal in Teesta and Rangit river valleys. The predominant species of these forests are *Adina cordifolia, Aglaia lawii, Altsonia neriifolia, A. scholaris, Artocarpus integrifolia, Bombax ceiba, Chukrasia tabularis, Dillenia indica, Duabanga grandiflora, Ficus semicordata, Mangifera sylvatica, Pterospermum acerifolium, Shorea robusta, Terminalia myriocarpa, Tetrameles nudiflora*, etc. The shrubs are *Clerodendrum japonicum, Dendrocalamus sikkimensis, Phyllostachys bambusoides, Saurauia roxburghii, Leea aquatica, L. indica* and *Ziziphus mauritiana*. Twiners are *Bauhinia vahlii, Capparis olacifolia, Celastrus paniculatus, Stephania glabra*, etc.

1.2 SUB-TROPICAL FORESTS

These forests are found on hilly terrain between elevations of 1,000 and 2,000 m and are comprised mainly of evergreen tree species. At some places Chir pine (*Pinus roxburghii*) are found as scattered trees but form pure stands in drier valleys of Sikkim. This forest type is further divided as broad leaved forest and pine forests.

1.2.1 Sub-tropical Broad Leaved Forests

These forests are usually occur above 900 m and extending up to 1,700 m along the Teesta and Rangit rivers and their tributaries. The forest of this group are divided into two sub-types according to rainfall, viz. warm broad leaved hill forest and cool broad leaved hill forest. Warm broad leaved hill forests occurs at higher altitudes with lower rainfall and contain a mixture of evergreen and deciduous broad leaved tree species. Many of the tropical genera like *Bischofia*, *Duabanga, Pterospermum, Tetrameles*, etc. are absent and more temperate genera viz., *Alnus, Lithocarpus, Lyonia* and *Quercus* are found. This type of forest is found in Tong, Chakung Chhu valley, between Tong, Chungthang in North Sikkim, Khamdong, Tashiding in South Sikkim and Gyalzing, Pelling in West Sikkim. Cool broad leaved forests further are of two types and are found above the Warm broad leaved forests. The wetter type, Cool broad leaved forest is of mixed forest type in which *Quercus* sp. is less common and other trees like *Litsea, Machilus, Michelia, Phoebe, Schima, Semingtonia*, etc. are more abundant with dense growth of shrubs, climbers and epiphytes. This type of wetter cool broad leaved forest is found in Chakung Chhu catchment, Selem (Dzongu catchment) in North Sikkim, Rumtek in East Sikkim, Legship, Jorthang in South Sikkim and Gyalzing, Tashiding in West Sikkim. The drier type, cool broad leaved forest, is comprised of evergreen elements like *Castanopsis* sp., and *Quercus* sp. The type is found in Rorathang in East Sikkim, Chakung Chhu, Selem in North Sikkim, Khamdong, Namchi, Rangit in South Sikkim and Gyalzing, Tato Pani in West Sikkim areas. Understorey is very dense and is formed by bamboo thickets, shrubs and climbers. Predominant shrubs are *Brassiopsis mitis, Eurya* sp., *Maesa chisia, Mussaenda roxburghii, Melastoma hispida, Oxyspora paniculatus, Rhamnus nepalensis, Rubus ellipticus* and *Vitex negundo*. The climbers are numerous varying from herbaceous to woody. The species of *Cissus, Cassia, Entada, Piper, Pothos, Raphidophora, Tetrastigma*, etc. are the common twiners in these forests. The thickets of *Calamus, Musa* and *Pandanus* are often observed in shaded and damp areas. *Cyathea spinulosa* is found abundantly in moist and shady places. Some exotic weeds like *Eupatorium adenophorum, E. odoratum, Lantana camara* and *Parthenium hysterophorus* grow profusely in disturbed forest areas. Bryophytes and ferns with many species of orchids constitute epiphytic flora.

1.2.2 Sub-tropical Chir Pine (*Pinus roxburghii*) Forests

Chir pine forests are found between 1,000-1,800 m in the Rangit and Teesta valleys. The forests are dominated by chir pine (*Pinus roxburghii*) but the shrub layer in the understorey is very poor. The associated species are *Alnus nepalensis*, *Engelhardtia spicata, Lyonia ovalifolia, Quercus glauca, Rhus chinensis, Rubus ellipticus, Viburnum* sp. and *Woodfordia fruticosa*. *Arundinella nepalensis, Chrysopogon aciculatus, Cymbopogon pendulus, Digitaria ciliaris, Imperata cylindrica, Oplismenus compositus, Pennisetum orientale, Pogonatherum crinitum, P. paniceum, Saccharum spontaneum* and *Themeda arundinacea* are the common grasses in these forests.

1.3 MONTANE WET TEMPERATE FORESTS

These forests are found between elevations of 1,700 and 3,000 m. Towards higher altitudes they merge with Sub-alpine forests. This type of forest are further sub-divided into two sub-types i.e. Wet temperate forest (1,700-2,700 m) and mixed coniferous forest (2,700-3,000 m).

1.3.1 Wet Temperate Forests

These forests are found between 1,700 and 2,700 m in Teesta basin and comprised of the following three sub-types.

1.3.1.1 *Lauraceous forest*

These forests are mixed evergreen forests with medium sized trees. These are found in Chakung Chhu, Chungthang, Pakyong, Gangtok, Namchi, Pelling, Tashiding areas. There are many deciduous tree species mixed with evergreen oaks and laurels. The oaks and laurels form large patches and are covered with many epiphytic mosses and ferns. *Acer campbellii, Alnus nepalensis, Betula alnoides, Castanopsis hystrix, Cinnamomum obtusifolium, Litsea elogata, L. sericea, Magnolia campbelli, Machilus edulis, Michelia cathcartii, Mahonia nepaulensis, Prunus nepalensis, Quercus lineata, Symplocos theaefolia,* etc. are frequenly met up to 2100m. *Alnus nepalensis* grows mainly along streams and water courses in these forests.

1.3.1.2 *Buk oak forests*

This forest is dominated by 'buk oak' (*Quercus lamellosa*) and found between 2,100 and 2,400 m in Chungthang, Chakung Chhu, Lachung and Lachen areas in North Sikkim, Ravongla and Temi areas in South Sikkim, Pakyong, Rhenok in East Sikkim and Pelling, Yoksum in West Sikkim. Other species in the tree canopy are *Acer campbelli, Castanopsis hystrix, Lithocarpus pachyphylla, Litsea zeylanica, Magnolia campbelli, Michelia doltsopa,* etc. Dense thickets of small bamboos (*Thamnocalamus aristatus*) form understorey with other woody species. Second storey is comprised of *Berberis umbellata, Pieris formosa, Piptanthus nepalensis, Prinsepia utilis, Rhododedron falconeri, Viburnum erubescens,* etc. Climbers are few and are represented by species of *Clematis, Lonicera, Parthenocissus, Smilax,* etc. Epiphytes are many and are loaded on the trunks of tree species.

1.3.1.3 *High level Oak forests*

These forests occur between elevation of 2,400 and 2,700 m in the Lachen, Yumthang, Dzongu and Talung areas. Important species found in the tree canopy are *Acer campbelli, Castanopsis tribuloides, Lithocarpus pachyphylla, Magnolia campbelli, Quercus griffithii, Q. lamellosa* and *Taxus wallichiana*. The shrub layer is poorly represented. The bushes of *Cotoneaster, Ilex, Lonicera, Rhododendron, Salix*, etc. are found in the understorey.

1.3.2 Mixed Coniferous Forests

The forests of this zone are dense evergreen and mainly composed of *Rhododendron* and conifers. The main species found in the forest are *Abies densa, Acer campbellii, Betula utilis, Picea spinulosa, Rhododendron arboreum, Tsuga dumosa* and *Zanthoxylum oxyphyllum*.

1.3.2.1 *Hemlock (Tsuga dumosa) forest*

This species grows as a dominant tree between 2,700 and 3,000 m and forms pure forests in more humid valleys and mountain slopes of Chhaten, Lachen and Zemu. It also grows at Chhoka in West Sikkim.

This species is seen intermixed with *Picea spinulosa* but does not reach the heights above 3000m. The high humidity of this forest is suitable for dense growth of shrubby and arborescent rhododendrons and ferns. Dense thickets of small bamboos (*Thamnocalamus aristatus*) are often seen along mountain slopes in understorey. Besides bamboos, some stunted and dwarf plants of *Hippophae, Salix* and *Cotoneaster* are also present in the understorey.

1.3.2.2 *Fir (Abies densa) forest*

Fir forest is characteristic of the highest forest ridges and reach up to 3,600 m in North & East Sikkim. *Abies densa* occurs in pure formations between Karponang and Chhangu in East Sikkim and above Lachen, Yathang to Thangu and Yumthang to Yumesamdong in North Sikkim. The dense canopy of fir provides a humid environment for a luxuriant growth of rhododendrons and *Viburnum* sp. in the understorey. Some herbs like *Anaphalis, Anemone, Dipsacus, Primula, Rheum, Saxifraga, Senecio*, etc. form a carpet in the ground layer. After the tree line i.e. beyond 3,600 -3,800 m, the fir becomes stunted and are mixed with junipers and dwarf rhododendron species.

1.3.2.3 *Spruce (Picea spinulosa) forest*

Picea spinulosa forest is found at lower altitude as compared to hemlock and fir. This is a mixed coniferous forest found in the inner dry valleys of Sikkim. The other species found in the tree canopy are *Larix griffithiana, Pinus wallichiana, Rhododendron* sp. and *Tsuga dumosa*.

1.3.2.4 *Larch (Larix griffithiana) forest*

This is an open mixed forest found in the inner dry valleys of the North Sikkim. These forests are found above 3,000 m elevation between Zema and Yathang, and Yumthang areas in North Sikkim. The other tree species in association are *Abies densa, Picea spinulosa, Rhododendron* sp. and *Tsuga dumosa.*

1.4 SUB-ALPINE FOREST

This Sub-alpine forest is found above elevations of 3,000 m in the North, East and West Sikkim. Important species found in the forest are *Abies densa, Betula utilis, Juniperus recurva, Rhododendron* sp., etc. In North Sikkim, some seral and degraded type of Sub-alpine forests like *Hippophae*/*Myricaria* brakes, *Hippophae*/ *Thamnocalamus* brakes and Sub-alpine pastures are often seen along roadside.

1.5 ALPINE SCRUBS AND PASTURES

These are meadows lying below the snowline all along the higher Himalayan parts of North, East and West Sikkim. Very heavy snowfall is received in the winter season and summers are mild with a short growing season. The vegetation of this group consists of the following forest types:

1.5.1 Alpine Scrub Forest

This is low evergreen forest dominated by *Rhododendron* and some deciduous species. These forest are found in the alpine areas of North, East and West Sikkim. The important species are *Acer capadocicum, A. campbellii, Betula utilis, Rhododedron decipiens, R. maddenii, R. sikkimensis, R. vaccinnioides* and *Sorbus foliolosa*.

1.5.2 Dwarf Rhododendron Scrub

This scrub vegetation is dominated by the *Rhododendron anthopogon, R. cilliatum, R. lepidotum, R. lanatum, R. nivale* and *R. setosum*. These scrubs are found in Chola, Dzongri, Nathula, Lachen, Lachung, Yumthang and Kupup areas.

1.5.3 Alpine Pastures

These are meadows lying below the snowline and above 3,600 m where the tree line ends all along the higher Himalaya in Sikkim. In open meadows, the gentle mountain slopes composed of many perennial mesophytic herbs and some grasses. Important herbs are species of *Aconitum, Allium, Anemone, Delphinium, Caltha, Cassiope, Fragaria, Fritillaria, Geum, Gentiana, Iris, Juncus, Podophyllum, Potentilla, Primula* and *Ranunculus*.

1.5.4 Dry Alpine Scrub

This is an alpine xerophytic formation in which dwarf scrubs predominate. These are found at high elevations in the Thangu, Chhoptha valley in North Sikkim, Chhangu in East Sikkim and Dzongri in West Sikkim. *Berberis angulosa, Ephedra gerardiana, Juniperus recurva, Rosa sericea, Rhododendron anthopogon, R. nivale,* etc. are important dwarf scrubs.

1.5.5 Dwarf Juniper Scrub

Juniperus recurva grows in bushy formations in North and East Sikkim particularly on the exposed sunny hill slopes around Thangu and Chhangu between 4,200 – 4,300 m elevation. Other dwarf junipers are *Junipers squamata* and *J. pseudosabina* in the alpine region.

1.6 VEGETATION PROFILE

During the field surveys and explorations, the treks are conducted in the following routes and areas.

(i) Rangpo-Singtam, Gangtok, Kyongnosla, Sherathang, Menmoi Chho, Kupup in East Sikkim

(ii) Singtam-Tarko, Khemdong, Ravongla, Maenam Wildlife Sanctuary in South Sikkim

(iii) Dikchu, Mangan, Tong, Chakung Chhu, Chungthang, Chhaten, Lachen, Zemu, Yathang, Thangu, Gurudongmar in Sikkim

(iv) Chungthang, Lachung, Shingba, Yumthang, Yumesamdong in North Sikkim

(v) Sangklang, Selem, Sakkyong, Talung, Lingzah, Lindem, Lingmum in North Sikkim

(vi) Melli Bazar, Jorethang, Sombaria, Okhrey, Hilley and Barsey Rhododendron Sanctuary in West Sikkim

(vii) Legship, Gyalzing, Pelling, Yuksom, Bakhim, Tshoka, Dzongri in West Sikkim

1.6.1 Rangpo-Singtam, Gangtok, Kyongnosla, Sherathang, Menmoi Chho, Kupup in East Sikkim

This area covers the large proportion of Reserved Forest range of Sherathang and one wildlife sanctuary, Kyongnosla Alpine Sanctuary, in the upper reaches. The lower reaches in this trek are characterized by tropical moist deciduous forest in which Sal (*Shorea robusta*) is dominant species between Melli-Rangpo and Singtam-Sirwani. Other tree associates are *Adina cordifolia*, *Bombax ceiba*, *Duabanga grandiflora*, *Choreospondias axillaris*, *Garuga pinnata*, etc. The river terraces especially along roadside are often occupied by tall bamboos, *Toona ciliata*, *Glochiodon* sp., *Macaranga denticulata* and *Oroxylum indicum*. These trees and some woody scrubs offer unique natural habitats for epiphytic orchids, parasitic plants, climbers, lichens and some ferns. Few thickets of canes and kewra palm were often found in patchy distribution especially along rocky slopes. Beyond Singtam especially towards Tarko where Sal does not occur, show evidence of habitat disturbance due to encroachment by local people. Only some scattered trees of *Aglaia lawii, Bombax ceiba, Duabanga grandiflora, Syzygium cuminii, Mangifera sylvatica* and *Spondias pinnata* were recorded in the canopy. In addition to these trees, few semi evergreen trees like *Ficus semicordata*, *Oroxylum indicum*, *Toona ciliata*, etc. are seen all along roadside.

Between Ranipul and Sarmasa (on way to Gangtok), forest is Sub-tropical broad leaved evergreen type. *Alnus nepalensis*, *Castanopsis indica, Engelhardtia spicata, Malotus philippensis, Quercus glauca, Toona ciliata*, etc. were observed in the tree canopy. Climbers, parasitic plants and orchids are often seen in these forests. At many places especially degraded and disturbed localities the weeds are seen found growing in wasteland and road side. *Ageratum conyzoides, Bidens bippinata, Eupatorium adenophorum, E. odoratum*, etc. are some important invading species in these areas.

At some places chir (*Pinus roxburghii*) was also seen found growing with other associates like *Albizia chinenesis, Alnus nepalensis, Lyonia ovalifolia*, etc.

Vegetation around Gangtok is very sparse, however, with the increase an altitude, gradually temperate elements appear. Gangtok, the capital of Sikkim, is situated at an altitude of about 1,660 m and spread over a ridge. At present there is no forest but there are some sacred grooves of trees at some places. The important trees in the grooves and along the roadside are *Albizia chinensis, Alnus neplalensis, Betula alnoides, Castanopsis indica, Daphniphyllum himaleyense, Echinocarpus dasycarpus, Elaeocarpus sikkimensis, Engelhardtia spicata, Eurya acuminata, Evodia fraxinifolia, Juglans regia, Lyonia ovalifolia, Melia dubia, Michelia retusa, Pinus roxburghii, Pyrus pashia, Prunus cerasoides, Quercus lineata, Schima wallichii* and *Terminalia myriocarpa*. Besides these trees, *Rhododendron arboreum, Cryptomeria japonica, Erythrina arborescens, Eucalyptus globulus, Ficus auriculata, Pinus kesiya, Populus ciliata* and *Salix babylonica* have been planted in Gangtok. Among shrubs are *Daphne bholua, Edgeworthia gardeneri, Mahonia napaulensis, Leucosceptrum canum, Mussaenda roxburghii, Osbeckia crinita, Oxyspora paniculata, Rubus ellipticus, Zanthoxylum alatum*, etc. Important herbs are *Acorus calamus, Anaphalis contorta, Arisaema speciosum, Artemisia nilagirica, Begonia* spp., *Carex* spp., *Cautleya gracilis, Didymocarpus pulchra, Drymaria cordata, Eragrostis nutans, Eupatorium adenophorum, Fragaria nubicola, Girardinia palmata, Hedychium coccineum, Houttuynia cordata, Impatiens* spp., *Juncus* sp., *Oplismenus compositus, Pilea* spp., *Poa annua, Polygonum spp., Rumax hastatus, R. nepalensis, Solanum nigrum, Swertia bimaculata, Thysanolaena laltifolia, Urtica parviflora* and *Viola* spp. Most of the old trees are laden with epiphytic plants or orchids. Among these are *Aeschynanthus hookeri, Coelogyne* spp., *Dendrobium chrysanthum, Hedychium gracile, Piper* spp., *Pepromia* spp., *Raphidophora glauca* and *Vittaria* spp. Many bamboos like *Bambusa arundinacea,* *Chimnobambusa hookeriana, Dendrocalamus hamiltonii, D. sikkimensis*, etc. are common in this town. Besides these, there are many ferns and fern allies in and around Gangtok. *Adiantum caudatum, Cheilanthus farinosa, Dicranopteris lineris, Lycopodium cernum, Lygodium flexuosum, Microsorum membranceum, Polyypodium* spp., *Pteris* spp., *Selaginella* spp. In addition to ferns, there are some common liverworts and lichens found on the bark of trees and stones.

Gangtok to 15th mile area show almost treeless vegetation due to various developmental activities and army deployment in the area. Only vertical slopes with some herbs were seen all along roadside. At some places a patchy distribution of planted Junipers are seen especially along roadside. But in upper reaches of these slopes dense mixed wet temperate evergreen forest are seen.

Kyongnosla Alpine Sanctuary is located to the east of Gangtok *en route* to Nathula Pass at a distance of about 31 km. The sanctuary area is rich in flora which starts from 15th mile and extends up to Chhangu (Tsomgo) lake. Among important forests found in the sanctuary area are Sub-alpine, Mixed coniferous forest and alpine scrub and alpine pasture. The Sub-alpine forest of this area start above El. 3,000 m and are compised of mixture of conifers and rhododendrons. Important trees in the canopy are *Abies densa, Acer campbellii, Betula utilis, Juniperus recurva* and *Rhododendron arboreum*. In Alpine scrub forest, *Betula utilis, Rhododendron anthopogon, R. ciliatum, R. vaccinniodes* and *Sorbus foliosa* are found. The species of *Aconitum, Allium, Delphinium,* *Caltha, Cassiope, Geum, Gentiana, Iris, Podophyllum, Primula*, *Saussurea*, etc. are the predominant herbaceous flora of this area.

Above Tsomgo lake the vegetation is characterized by typical Alpine moorland forest type except in Menmoi Chho area in Sherathang forest range. Menmoi Chho lake area is situated loer slopes of Sherathang and comprised of dense Mixed sub-alpine type of forest. *Abies densa, Acer campbellii, Betula utilis, Juniperus recurva, Prunus* spp*., Rhododendron* spp., *Sorbus* spp., etc. are found in the tree canopy. In the understorey of this forest, endemic plant species of Himalaya such as *Aconitum bisma, A. ferox, A. elwesii, Angelica nubigena, Meconopsis* spp*., Podophyllum hexandrum,* etc. were observed and collected.

Beyond Tsomgo lake and above Menmoi Chho and higher elevations alpine vegetatation i.e. without trees. Near Baba Dham the trek route is bifurcated and one goes for Nathula pass and other to Kupup areas. Both areas are located at very high range of elevation i.e. above 4,000 m and consist of typical scrub and alpine meadow vegetation. Nathula area has very rugged topography and shows only some herbs on glacial deposited morains. While Kupup area has a luxuriant vegetation of herbs and some stunted shrubs. Among shrubs are *Cassiope fastigata, Juniperus recurva, Rhododendron ciliaris, Ribes* sp*., Rosa sericea*, etc. A number of herbaceous species form a thick carpet of beautiful flowers. *Aconitum novoluridum, A. bisma, Allium wallichii, Chamaesium novem-jugum, Codonopsis ovata, Fritillaria cirrhosa, Heracleum sublineare, Juncus sikkimensis, Lilium oxypetalum,* *Lactuca cooperi*, *Primula* spp., *Saussurea aitchisonii*, etc. are the important herbs of these meadows.

1.6.2 Singtam-Tarko, Khemdong, Ravongla, Maenam Wildlife Sanctuary in South Sikkim

This area covers the reserve forest blocks of South and East Sikkim and one wildlife sanctuary in the temperate region. The vegetation in and around Singtam is characterised by Tropical mixed deciduous and Semi-evergreen riverine type. Among tree species are *Duabanga grandiflora, Ficus semicordata, Oroxylum indicum, Pandanus nepalensis, Shorea robusta, Terminalia myriocarpa, Toona ciliata*, etc., which are found along roadside and the riverbank. But on way to Sirwani, Sal (*Shorea robusta*) is seen as the dominant tree species with other planted species like *Lagerstroemia lanceolata, Terminalia myriocarpa, Tectona grandis,* etc. This route is again bifurcates at Tarko, one goes to Khamdong *via*. Mangalbare and other goes to Tarko and Ravongla. At Tarko, dense Tropical broad-leaf forest is seen on N-W aspects. *Altsonia scholaris, Amoora wallichii, Canarium strictum, Castanopsis indica, Duabanga grandiflora, Garuga pinnata, Dysoxylum excelsum, Gynocardia odorata, Holarrhena pubescens, Schima wallichii*, etc. constitute in the tree canopy. Dense thickets of tall bamboos and some shrubs form the understorey. Among shrubs are *Dendrocalamus hamiltonii, D. sikkimensis, Eupatorium odoratum, Ficus hederacea, Lantana camara, Mussaenda roxburghii, Rhamnus nepalensis, Woodfordia fruticosa,* etc. These are a number of climbers which are draped on large and small trees and some cover the ground strata.

Under trees and shaded slopes, there are many types of herbs and liverworts. Among herbs are *Ageratum conyzoides, Begonia megaptera, B. nepalensis, B. rubravina, Circaester agrestis, Eupatorium adenophorum, Houttuynia cordata, Pepromia pellucida, Pilea* spp., *Polygonum* spp., etc.

At Mangalbare village, in the upper reach, there is a large patch of Sal tree (*Shorea robusta*) along the dry forest ridge. In lower reaches and near the river banks, a few trees like *Alangium himalaicum, Anthocephalus cadamba, Bombax ceiba, Ficus religiosa, F. semicordata, Garuga pinnata, Oroxylum indicum, Premna cordata*, etc. are found with abundance of climbers. This area is characterized by comparatively dry conditions as compared to Tarko. Again towards Rangpo Khola, shaded and dense Mixed wet tropical broad-leaved forest was seen but different in species composition. *Alangium alpinum, Castanopsis indica, Dysoxylum excelsum, Gynocardia odorata, Ostodes paniculata*, etc. comprise the tree canopy. Among shrubs are *Brassiopsis mitis, Oxyspora paniculata, Psychortia calocarpa, Rubus ellipticus*, etc.

The vegetation between Rangpo Khola to Khamdong is highly disturbed due to agricultural and road construction activities and vary from place to place. In lower reaches, Mixed deciduous as well as riverine tree species were found. *Alnus nepalensis, Artocarpus* sp., *Gymnema arborea, Quercus glauca, Rhus wallichii*, etc. were the main components. Shrubs were very few. *Berberis aristata, Debregeasia salcifolia, Prinsepia utilis* and *Rubus elliptica* seen frequently along the roadside. But at Khamdong the vegetation is of temperate type. Owing to its location at the top of the ridge, oak is the dominant species of forest.

In another trek route i.e. from Tarko to Ravongla, the vegetation was found disturbed in lower reaches especially above Tarko due to expansion of agricultural activities. But as one moves towards to Ravongla, the elevation gradually increases and vegetation changes from sub-tropical to temperate type in upper reaches. On the middle elevations, mixed sub-tropical type of forest was found. *Alnus nepalensis* was found as a dominant tree species especially along the water courses and streams. Understorey is open and comprised of many small trees and some shrubs. Bamboos are rarely seen along the way. Near the Ravongla town, the vegetation turns into more temperate and is comprised of mixed oak forest. There are many shrubs in the understorey and are comprised of *Elsholtzia fruticosa, Lecoseptrum canum, Lyonia ovalifolia, Prinsepia utilis, Rhamnus nepalensis, Rubus ellipticus, Viburnum erubescens*, etc. Epiphytes and climbers are very few. Ground flora is very rich and comprised of the many species of

herbs like *Anaphalis contorta, Bidens pilosa, Begonia palmata, B. cathcartii, B. josephii, Chirita* sp.*, Cirsium wallichii, Corydalis* sp.*, Didymocarpus pedicellata, Gaultheria numularioides, Helinia elliptica, Hedychium* spp.*, Houttuynia odorata, Inula racomosa, Lepisanthus* sp.*, Pilea scripta, Poa* sp.*, Solidago virga-aurea*, etc. In and around the Ravongla, some planted conifers like *Cupressus corenema, Juniperus recurva* and *Thuja orientalis* were also seen. Above Ravongla, is situated a famous Maenam wildlife sanctuary. There are two forest types found within sanctuary i.e. Mixed broad leaf and evergreen coniferous forest. *Alnus nepalensis, Acer* spp*., Lyonia ovalifolia* and *Quercus lamellosa* were fround in the tree canopy. Shrubs and climbers are many. *Berberis aristata, Desmodium elegans, Debregeasia salicifolia, Callicarpa arborea, Leucoceptrum canum, Pyrus pashia, Prinsepia utilis, Rubus ellipticus*, etc are important shrubby species in the area. Among climbers are *Aristolochia* sp*., Cissus discolor, Clematis montana, Dioscorea bulbifera, Smilax apera* and *Stephania glabra*. *Tsuga dumosa* form the top canopy in upper reaches of mixed coniferous forest.

1.6.3 Dikchu, Mangan, Tong, Chakung Chhu, Chungthang, Chhaten, Lachen, Zemu, Yathang, Thangu, Gurudongmar in Sikkim

This area covers two floristically rich valleys i.e Lachen or Zemu Valley and Lachung Valley with two cold frigid regions like Gurudongmar and Yumesamdong or Momesamdong in the upper reaches of North Sikkim. The lower reaches, adjoining the tropical moist deciduous forest lie between Singtam-Dikchu and below Mangan. In the lower reaches of left bank of Teesta river where Singtam is located, the vegetation is very sparse and is of tropical deciduous type, whereas right bank vegetation is very dense comprised of mixed and wet evergreen forest especially near Rangpo Khola and at Khamdong ridge. Left bank slopes of the lower reach up to Dikchu are comprised of *Duabanga grandiflora, Dysoxylum excelsum, Ficus semicordata, Lagerstroemia speciosa, Schima wallichii, Terminalia myriocarpa*, etc. At Dikchu, few large trees of *Ficus elastica* were seen planted along roadside. Between Dikchu to Mangan route, only a few trees are seen interspersed with shrubs and grasses along the vertical slopes. On the grassy slopes, a tall orchid (*Arundina graminifolia*) is seen flourishing with other herbs. At Mangan, only a few wild and planted trees can be seen along the roadside. *Alnus nepalensis, Ficus semicordata, Macaranga denticulata, Fraxinus floribunda, Toona ciliata*, etc. were seen in the tree canopy.

The vegetation of Mangan to Tong (870-1,350 m) area is characterized by sub-tropical type and forest are mostly broad leaved deciduous. At many places the vegetation of the surrounding forest is degraded and disturbed due to frequent land slide and road extension activities. *Albizia lebbeck, Alnus nepalensis, Bombax ceiba, Duabanga grandiflora, Erythrina arborescens, Rhus chinensis*, etc are found in the tree canopy. At some places dense thickets of tall bamboos were found along roadside. *Amomum subulatum* is being cultivated as a cash crop along forest slopes of this area.

Chakung Chhu catchment

This area covers dense mixed evergreen oak forest in the upper reaches and Mixed deciduous and Riverine semi evergreen broad leaved forest in the lower reaches of Chakung Chhu catchment. A large proportion of the forest is being gradually cleared in the lower reaches for the cultivation of large cardamon (*Amomum subulatum*). The vegetation of the downstream areas consists of Sub-tropical deciduous and Riverine semi evergreen type.

The tree canopy of left bank was comprised of *Albizia labbek, Alnus nepalensis, Anthocephalus cadamba, Duabanga grandiflora, Erythrina arborescens, Ficus semicordata, Rhus chinensis, Schima wallichii*, etc. Among shrubs are: *Boehmeria platyphylla, Brassiopsis mitis, Callicarpa arborea, Debregeasia salicifolia, Eupatorium odoratum, Oxysopra paniculata, Rhamnus nepalensis* and *Rubus ellipticus*. Epiphytes and lianas are abundant. *Cissus repens, Celastrus paniculatus, Dioscorea bulbifera, Piper boehmerifolia, Raphidophora glabra, Rubia sikkimensis, Stephania glabra*, etc. are important climbers in the forest. Some dense thickets of wild banana (*Musa* sp.) were also observed in shaded and damp areas. Due to forest lopping and extensive clearing for large cardamon (*Amomum cardamomum)* cultivation, the ground flora is occupied by mainly weeds like *Ageratum conyzoides, Bidens bipinata, Eupatorium adenophorum, E. odoratum, Lantana camara,* etc.

The vegetation in upper reaches is of temperate evergreen type. But in the middle elevations some warm and cool sub-tropical forest elements are met with. *Alnus nepalensis, Castanopsis indica, Litsea doshia, Lithocarpus elegans, Machilus duthei*, etc. are some warm sub-tropical representatives. Temperate vegetation is comprised of *Acer campbellii, Alnus nepalensis, Castanopsis hystrix, Engelhardtia spicata, Lyonia ovalifolia, Quercus lamellosa, Rhododendron arboreum*, etc. Besides some small bamboos (*Schizostachyum munroi* and *Thamnocalmus* sp.), the understorey consists of other shrubs like species of *Berberis, Cotoneaster, Daphne, Hydrangea,* and *Viburnum*. Climbers and epiphytes are not common. Species of *Ampelocissus, Cissus, Dioscorea, Parthenocissus, Smilax, Vitis*, etc. are some important climbers. Ferns and fern allies are abundant and constitute the ground flora with other shrubby associates. Ground flora is represented by species of *Anaphalis*, *Anemone, Begonia, Clematis, Fragaria, Geranium, Impatiens, Spiraea* and *Ranunculus*.

The vegetation of lower hills near Chungthang is comprised of mixed deciduous and evergreen type of elements. Tree canopy at left bank is comprised of *Albizia lebbeck, Alnus nepalensis, Erythrina arborescens, Ficus semicordata, Lithocarpus elegans, Litsea doshia, Rhus wallichii, Toona ciliata,* etc. Bamboos and many shrubs like *Boehmeria platyphylla, Cinnamomum tamala, Callicarpa arborea, Rhamnus nepalensis, Rubus elllipticus*, etc. constitute second storey. Some tall undrshrubs like *Artemisia nilagirica, Eupatorium adenophorum, E. odoratum, Girardinia diversifolia, Sida acuta*, etc. were

found in the ground vegetation. Right bank composition of the forest is totally different to the left and has more temperate elements in composition. The first storey is comprised of *Alnus nepalensis, Engelhardtia spicata, Lyonia ovalifolia, Quercus glauca*, etc. Second storey is thin and comprised of mainly some seral species like *Macaranga denticulata, Rhus chinensis, Rhododendron grande* and *R. arboreum*.

The vegetation is dense mixed in upper hills but is of degraded type along the roadside especially near settlement areas. At about 1,600m, Utis (*Alnus nepalensis*) is the dominant tree species on the right bank of Lachen Chhu. Other tree associates include *Erythrina arborescens, Juglans regia, Neolitsea pallens, Populus ciliata, Prunus cerasoides, Rhus chinensis*, etc. Among shrubs are *Brassiopsis mitis, Callicarpa arborea, Debregeasia salicifolia, Oxyspora paniculata, Rhamnus nepalensis, Rubus ellipticus*, etc. Left bank is characterized by steep rocky slopes with few trees of *Alnus nepalensis* in patches. Between Ravang to Bonsai village, patches of dense mixed coniferous forest (*Tsuga dumosa*) are observed in the upper reaches of right bank, whereas lower and middle portion of this bank is comprised of mixed oak forest. At many places dense thickets of small bamboos (*Thamnocalamus aristatus*) were seen with other woody and shrubby species. Above Bonsai area, *Tsuga dumosa* was observed as a dominant and the tallest tree species along the shaded and wet slopes of left banks. This species shows both pure and patchy distribution up to Chhaten and Lachen areas. Many medicinal herbs like *Anaphalis contorta, Houttuynia cordata, Panax pseudoginseg, Polygonatum cirrhifolium, Swertia chirayita*, etc. were seen in upper reaches of Chhaten and Lachen villages.

The vegetation of surrounding areas of Lachen (2,600-2,800 m) is characterised by mixed and isolated population of maples, laurels, oaks, rhododendrons, conifers and open grasslands. Besides these, this area harbours many endemic and threatened species like *Acer hookeri, Anaphalis hookeri, Ceropegia hookeri, Cypripedium himalaicum, C.*

elegans, Panax pseudoginseng, etc. Above Lachen village, the lower reaches are highly disturbed. Only shrubs can be seen along the streams and shaded slopes. Some seral type of associations like *Hippophae/ Salix, Thamnocalamus/ Salix, Alnus/ Rhododendron*, etc. were found along roadside.

At about 2,800 m, from Zema to Yathang dense mixed forest of *Abies densa* and *Larix griffithiana* were observed. Some seral and dwarf plant communities like *Juniperus-Salix-Ribes* or *Viburnum-Salix-Ribes* type were observed all along the roadside. Above Yathang flat and grassy slopes with carpet of beautiful flowers were observed. These slopes were comprised of sedges and grasses in lower portion while upper slopes were represented by bushy and scrub vegetation. Important constituents are the species of *Acer, Juniperus, Ribes, Rhododendron* and *Salix*.

At Thangu (3,860 m), a fairly dense mixed forest of stunted and dwarf trees such as *Abies densa, Betula utilis, Corylus ferox*, etc. were observed along right bank of Lachen Chhu. The vegetation of left bank is highly degraded and disturbed type due to road extension and other developmental activities. The moraines and meadows of this bank harbour many herbs which have high medicinal importance. At many places scattered growth of some dwarf trees and shrubs were also observed. Among scrubs are species of *Cassiope, Cotoneaster, Ribes, Rhododendron* and *Salix*. Herbaceous flora of this area is very rich and represented by *Aconitum spicatum, A. navicularae, Allium wallichii, Arenaria thangoensis, Caltha palustris, Ephedra gerardiana, Fritillaria* *cirrosa, Meconopsis* spp., *Podophyllum hexandrum, Primula sikkimensis, Ranunculus* spp., *Rheum acuminatum* and *Saxifraga* spp.

Above Teesta bridge and on way to Gurudongmar lake few patches of tufted rhododendrons can be seen along the mild and steep slopes up to few miles. Upper reaches are rocky. Only some herbs like *Rheum nobile, Pedicularis* spp., *Primula* spp., etc. could be seen along with some sedges and grasses in lower flattened slopes or morains.

1.6.4 Chungthang, Lachung, Shingba, Yumthang, Yumesamdong in North Sikkim

Area between Chungthang to Bichhu (Lachung) is a rocky and mainly covered by some grassy slopes interspersed with few deciduous trees like *Bombax ceiba, Eurya acuminata, Callicarpa arborea, Erythrina arborescens, Evodia fraxinifolia,* etc. Beyond Bichhu, the slopes are gentle with little cultivation.

Above Lachung dense mixed temperate broad leaved and mixed coniferous forest occur. Among the tree associates are species of *Abies, Acer, Corylus, Hydrangea, Quercus, Viburnum* and *Taxus*. Yumthang valley is a rich repository of rhododendrons set up. Important forest types found in the valley are, Wet temperate broad-leaved and mixed coniferous forest. In the lower portion of the valley (between 2,400-2,700 m elevation), forest type is wet temperate broad leaved. The tree canopy of this forest is represented by *Acer hookeri, A. caudatum, Magnolia campbellii, Quercus lamellosa, Rhododendron arboreum,* etc. Mixed coniferous forest in the valley occur above 2,700 m elevation and represented by *Abies densa, Larix griffithiana, Picea spinulosa, Taxus baccata*, etc.

Above Yumthang, only low height bushes and some small trees like *Betula utilis, Juniperus recurva, Sorbus* sp., *Rhododendron* spp., etc. were found growing along the morains and steep rocky slopes. At Yumesamdong, (about 4,500 m) only some small herbs and grasses are seen along the moraines and flat alpine meadows. Important herbs are *Aconitum hookeri, Elymus sikkimensis, Festuca polycolea, F. undata, Gentiana tubiflora, Kobresia curvata, K. esenbeckii, K. nepalensis* var. *vaginosa, Meconopsis* sp., *Rheum nobile*, etc.

1.6.5 Sangklang, Selem, Sakkyong, Talung, Lingzah, Lingdem, Lingmum in North Sikkim

This area is rich in plant wealth especially of timber yielding trees. Dense mixed and multistoreyed forests of Tropical moist deciduous and Riverine semi-evergreen type were observed at the lower warmer altitudes. However, upper reaches and adjoining areas like Selem, Sakkyong, Tolung Chhu, etc. are characterized by dense mixed broad-leaved sub-tropical as well as wet temperate forests. At many places the mixed forest is replaced by tall bamboo patches on the steep slopes. This area experiences hot and humid summers and mild winters. Near the confluence of Teesta with Talung, the vegetation is of dense mixed tropical and riverine semi-evergreen type. At left bank of Teesta, the tree canopy is comprised of *Adina cordifolia, Albizia procera, Alnus* *nepalensis, Bischofia javanica, Castanopsis indica, Dysoxylum excelsum, Erythrina arborescens, Ficus semicordata, Oroxylum indicum,* etc. Second storey is also very dense and comprised of many small trees and shrubs like *Abroma anguistifolia, Brassiopsis mitis, Leea aequata, Macaranga denticulata, Meliosma pinnata* and *Musaenda roxburghii,* etc. Few dense thickets of wild banana (*Musa* sp.) were observed in the upper shaded and damp areas. Tree fern (*Cyathea spinulosa*) was found growing in slopes far above. Climbers are many and some are very thick. *Ampelocissus sikkimensis, Cissus repens, Entada phaseoloides, Piper boehmerifolia, Raphidophora decursiva, Stephania glabra*, etc. were observed as climbing and trailing species on trees and forest floor.

Right bank vegetation is of open type and disturbed due to many developmental activities. Tree canopy is comprised of *Alnus nepalensis, Artocarpus lakoocha, Auricaria imbricata, Canarium bengalense, Duabanga grandiflora, Ficus auriculata, F. semicordata, Michelia kisopa, Schima wallichii* and *Terminalia myriocarpa*. In addition to wild tree species, there is a large orchard of horticultural species like *Artocarpus, Calistemon, Citrus, Ficus, Pinus, Psidium, Prunus* and *Thuja* in a flat land near river bank. Rich population at Kewara trees (*Pandanus nepalensis*) were observed on mountain slopes at this bank. Few patches of wild banana (*Musa* sp.) were seen found growing in shaded and damp localities. Herbaceous flora is represented by *Ageratum conyzoides, Begonia megaptera, Commelina benghalensis, Costus speciosus, Floscopa scandens, Hedychium thrysiforme, Pilea scripta*, etc. Climbers were common like left bank. Epiphytes are abundant and represented by orchids and ferns on the trunks of large trees.

Some woody trees like *Alnus nepalensis, Duabanga grandiflora* and *Macaranga denticulata* were noticed growing along the channel bar of the Teesta river. At left bank near submergence, lower as well as upper slopes of the valley are mostly vertical and do not have dense growth of larger trees. However, few large trees like *Alnus nepalensis, Duabanga grandiflora, Engelhardtia spicata, Schima wallichii, Terminalia myriocarpa*, etc. were seen growing at right bank of Talung (Rangyong) Chhu.

Some crop cultivation like rice and large cardamon (*Amomum subulatum*) is being practiced in the lower river bed area.

In areas upstream of the confluence, the vegetation of the surroundings is dense mixed sub-tropical and temperate type. However, at many places these mixed forests are replaced by scrubs like thickets of tall and small bamboos. At left bank of Talung Chhu, species composition varies with altitudes and aspects. Lower portion of North West facing slopes have comparatively warm sub-tropical broad leaved forests. Whereas South East facing slopes i.e. upper reaches have mixed Oak forests with dense growth of small bamboos in the under storey.

From the left bank of Talung Chhu (near Forest Guest House, Sangklang) upstream (750-1,400 m), the vegetation is of mixed warm broad leaved sub-tropical type. The tree canopy is comprised of *Alnus nepalensis, Engelhardtia spicata, Fraxinus floribunda, Macaranga denticulata, Michelia champaca, Quercus glauca, Schima wallichii,* etc. Second storey is comprised of many small tree species, scrubs and tall arborescent bamboos. *Bambusa tulda, Brassiopsis mitis, Callicarpa arborea, Dendrocalmus hamiltonii, Euonymous pendulus, Eupatorium odoratum, Eurya acuminata, Meliosma pinnata, Mussaenda roxburghii, Oxyspora paniculata, Rhus chinensis, Rubus ellipticus*, etc. were observed in the second storey. Climbers are many and often found entangled on the trees and scrubs. *Ampelocissus sikkimensis, Cayratia geniculata, Cissus repens, Entada fasioloides, Mimosa himalayana, Parthenocissus semicordata, Stephania glabra, Tetrastigma affine, Vitis heyneana*, etc. are important trailing species in these forests. Few patches of Kewara trees (*Pandanus nepalensis*) were found growing in lower areas. Herbaceous flora is represented by many small herbs and tall grasses like *Arthraxon hispidus, Arundinella nepalensis, Begonia megaptera, Calanthe* sp., *Carex* sp., *Cyperus* sp., *Hedychium spicatum, Imperata cylindrica, Pennisetum flaccidum* and *Pilea scripta*. In the middle elevations, the vegetation is disturbed and degraded at some places due to settlements. But in upper reaches, the vegetation is totally different from the lower reaches.

Species composition in South-East aspects and above 1,400 m is totally different from the lower slopes. Oaks were emerged as the most dominant tree species with some other woody associates. *Lyonia ovalifolia, Magnolia insignis, Michelia doltsopa, Phoebe obovata, Quercus lineata, Q. lamellosa,* etc. were important trees in the vicinity.

Many thickets of shrubby and climbing bamboos like *Drepanostachyum intermedium* and *D. polystachyum* were observed in understorey. Other associates of second storey are *Eurya acuminata, Litsea doshia, Magnolia hodgsonii, Lyonia ovalifolia, Rhododendron arboreum* and *Viburnum erubescens.* Many dense patches of branched and spreading ferns like *Dicranopteris lineris* were observed with other fern species in the understorey. Rich diversity of many epiphytic species of orchids like *Coelogyne, Cymbidium* and *Dendrobium* were observed frequently on trunks of some large trees specially oaks. Lianas were not so abundant.

On the upper reaches of Rangyong Chhu catchment, forest composition changes according to topography and slope aspects. Tropical deciduous forest is gradually replaced by mixed evergreen sub-tropical and temperate forest. *Alnus nepalensis, Engelhardtia spicata, Lyonia ovalifolia, Magnolia hodgsonii, Quercus glauca, Schima wallichii,* etc. were found in dense as well as patchy population along the steep forest slopes. Since the area is mainly bounded by vertical hills, at many places the mixed forest is replaced by some patches of population of small scrubs like *Bambusa tulda, Dendrocalmus hamiltonii* and *Thamnocalmus falconeri*. Majority of the catchment area is under dense mixed forest with limited intervention by some surrounding villages like Sakkyong, Phantong, Myong, Lingzah, Lingdem and Nung. Between 1,800-2,400 m elevations open scrub forest was found near Lingmum, while from 2,400-3,400 m Oak forest was predominant especially in upper reaches.

1.6.6 Melli Bazar, Jorethang, Sombaria, Okhrey, Hilley and Barsey Rhododendron Sanctuary in West Sikkim

Right from the confluence of the Rangit with Teesta river at Melli Bazar (240 m) and towards Jorethang (300 m), the hilly tracts of South Sikkim are inhabited by dense mixed broad-leaved deciduous forest. Sal (*Shorea robusta*) is a dominant tree species which covers large tract along the Rangit river and form a pure patches at many places. Other tree associates include *Adina cordifolia, Albizia lebbeck, Amoora walllichi, Bauhinia purpurea, Bischofia javanica, Bombax ceiba, Celtis tetrandra, Chukrasia tabularis, Dillenia indica, Duabanga grandiflora, Dysoxylum excelsum, Garuga pinnata, Gynocardia odorata, Lagerostroemia parviflora, Schima wallichii, Terminalia myriocarpa, T. bellirica, Tetrameles nudiflora, Toona ciliata*, etc. Besides these trees, teak (*Tectona grandis*) is often seen planted along the roadside and in surrounding village localities. The undergrowth is also luxuriant but the composition varies from place to place. Second storey is comprised of many small trees and shrubs in the forest. Important species are *Bambusa tulda, Callicarpa arborea, Euonymus* sp., *Ixora* sp., *Lantana camara, Eupatorium odoratum, Rhamnus nepalensis, Rhus chinensis, Rubus ellipticus* and *Saurauia nepalensis*. Climbers and epiphytes are abundant. Climbers are represented by many woody as well as herbaceous species. *Bauhinia vahlii, Mimosa himalayana, Entada physeoloides, Pothos scandens, Raphidophora glabra* and *Stephania glabra* are important woody climbers. Many epiphytic as well as terrestrial orchids can be seen growing on large tree species.

The vegetation near Jorethang and at left bank is characterized by mixed tropical deciduous type in which Sal (*Shorea robusta*) is found as dominant tree species in lower reaches. Due to road extension activities and human settlements the vegetation was found in degraded and disturbed form at many places especially along the roadside. The right bank of river Rangit at Jorethang has a gentle slope interspersed with terrace cultivation. Some tree species can be seen planted along the river bank and boundry of terraces. Towards Naya Bazar (West Sikkim) a patchy distribution of Sal trees was seen along the roadside with few other planted trees like *Albizia lebbeck, Altsonia scholaris, Eucalyptus* sp*., Ficus bengalensis, F. religiosa, Tectona grandis*, etc. On way to Sombaria from Naya Bazar, dense forest of Sal (*Shorea robusta*) is found in lower reaches. But in upper reaches tree canopy is mixed deciduous type. Important tree associates in the canopy were *Adina cordifolia, Altsonia scholaris, Duabanga grandiflora, Gynocardia odorata*, etc. Second storey was represented by many small trees and some shrubs. *Callicarpa arborea, Bauhinia purpurea, Dendrocalamus hamiltonii, Rhamnus nepalensis, Rhus chinensis, Saurauia nepalensis*, etc. At some places steep grassy slopes were also observed along the roadside. Among herbs and grasses are *Ageratum conyzoides, Carex* sp*., Chrysopogon serrulatus, Pogonatherum palecium, Saccharum rufipelum* and *Thysanolaena latifolia*. Due to the presence of a number of settlement and agriculture, the vegetatation is very sparse especially in lower and upper Thambuk Basti areas. Among cultivated crops are paddy, maize and beans. Near Sombaria the vegetation is of sub-tropical type and comprised of the tree species like *Alnus nepalensis, Cryptomeria japonica, Erythrina arborescens, Lyonia ovalifolia, Prunus* *cerasoides, Terminalia myriocarpa, Schima wallichii*, etc. In areas above Sombaria, from Okhrey, the vegetation is of wet temperate type. *Acer* sp., *Alnus nepalensis, Hamiltonia sualens, Juniperus recurva, Juglans regia, Lyonia ovalifolia, Quercus lineata, Rhododendron arboreum, R. barbatum,* etc. were found in the tree canopy. Above Okhrey (2,300 m) dense mixed Oak- rhododendron forest is found upto Hilley, near Barsey Rhododendron Sanctuary. Important trees are *Acer* spp., *Alnus nepalensis, Ilex* sp., *Lithocarpus pachyphylla, Lyonia ovalifolia, Quercus lineata, Q. lamellosa, Rhododendron barbatum*, etc.

1.6.7 Jorethang-Legship, Rangit Nagar, Tashiding, Yuksom, Gyalzing, Pelling, Yuksom, Bakhim, Tshoka, Dzongri in West Sikkim

The vegetation between Jorethang and Legship is comprised of dense mixed broad-leaved tropical type. Towards Legship, it is disturbed and degraded at many places due to agricultural and road extension activities. *Acacia catechu, Adina cordifolia, Bischofia javanica, Castanopsis indica, Dysoxylum excelsum, Garuga pinnata, Gynocardia odorata, Mangifera indica, Terminalia myriocarpa* and *Toona ciliata* form the tree canopy. The understorey is not very dense and found degraded at many places. *Callicarpa arborea, Dendrocalamus hamiltonii, Jatropha curacas, Lantana camara, Mimosa mimosoides, Musaenda roxburghii, Sapium insigne*, etc. are important constituents of the second storey. Among lianas are *Aristolochia griffithii, Bauhinia vahlii, Cryptolepis buchnani, Mimosa himalayana, Pueraria tuberosa, Spatholobus roxburghii*, etc. Some tall grasses like *Capilipedium assimile, Miscanthus* *nepalensis, Pennisetum* sp., *Saccharaum spontaneum, Thysanolaena latifolia,* etc. can be seen found growing along the steep forest slopes.

The vegetation of left bank onwards up to Rangit Nagar and beyond Legship is degraded and patchy type due to road construction and landslide. The right bank of the river has steep rocky slopes with patchy vegetation of small trees and shrubs. Above Rangit Nagar and towards Tashiding, the vegetation is again of degraded type in lower reaches due to presence of number of settlements. Tree canopy in the lower reaches is comprised of *Alnus nepalensis, Bombax ceiba, Duabanga grandiflora, Erythrina arborescens, Ficus auriculata, Gymnema arborea, Macaranga denticulata, Mallotus philippensis, Oroxylum indicum, Ostodes paniculata* and *Schima wallichii*. These trees are interspersed with some tall grasses and bamboos along the left bank of river Rangit. Among shrubs are *Brassiopsis mitis, Callicarpa arborea, Ficus hederacea, Mussaenda roxburghii,* and *Saurauia roxburghii*. Some endemic and threatened plant species like *Begonia satrapis* and *B. scutata* were recorded from the lower reach of river Rangit at left bank. In the upper reaches, the vegetation changes with the elevation. The tree species found growing here are *Alnus nepalensis, Castanopsis indica, Engelhardtia spicata, Eurya acuminata, Macaranga denticulata, Michelia velutina, Prunus cerasoides, Schima wallichii*, etc. The understorey is not very dense and is comprised of some small shrubs and bamboos thickets. *Actinidia strigosa, Bambusa* sp., *Edgeworthia gardeneri, Rhus chinensis, Rubus ellipticus,* etc. are important shrubs in the second storey. Climbers are very few and represented by species of *Cissus, Dioscorea, Smilax, Stephania,* etc.

The vegetation near of Yuksom is dense mixed and show many temperate tree species like *Alnus, Cryptomeria,, Engelhardtia, Juglans, Lyonia, Pyrus, Prunus, Rhododendron* and *Quercus*. The understorey is also very dense at many places. Among shrubs are *Dichroa febrifuga, Edgeworthia gardeneri, Musaenda roxburghii, Rhamnus nepalensis, Rubus ellipticus, Saurauia nepalensis* and *Viburnum* sp. There are many tall undershrubs like *Aconogonum molle, Artemisia nelagirica, Anaphalis busua, Eupatorium adenophorum*, etc. were also seen growing in the understorey. Climbers are very few and are represented by species of *Cissus, Cryptolepis, Dioscorea, Stephania* and *Vitis*.

The vegetation of lower reaches on way to Gyalzing consists of dense tropical broad-leaved deciduous forest, with Sal (*Shorea robusta*) as a dominant tree species. Towards Gyalzing the vegetation is sparse and patchy at few places. Gyalzing, district headquater of West Sikkim, is characterized by terrace cultivation. The vegetation between Gyalzing and Pelling is of degraded type along the roadside due to road construction and other developmental activities. Oak (*Quercus lineata*) starts appearing beyong Gyalzing town and forms association with other tree species such as *Alnus nepalensis, Lyonia ovalifolia, Prunus cerasoides, Pyrus* sp., etc. Besides oak trees, Chir (*Pinus roxburghii*) is also seen in scattered patches all along the way to Pelling. The shrubs are represented by species of *Berberis, Hypericum, Indigofera, Prinsepia, Rubus,* etc. Alder (*Alnus nepalensis*) is a dominant tree species in lower reaches especially along the streams and debris of landslides. The herbaceous flora is represented by species of *Ageratum,* *Begonia, Bergenia, Commelina, Didymocarpus, Houttuynia, Impatiens, Pilea, Sedum, Spiraea,* etc.

Towards Yuksom, the vegetation changes and many seral and mixed type of elements like *Engelhardtia spicata, Erythrina arborescens, Ficus semicordata, Macaranga denticulata, Magnolia pterocarpa, Schima wallichii*, etc. can be seen in the tree canopy. Understorey is represented by many small tree and shrub species such as *Callicarpa arborea, Edgeworthia gardeneri, Ficus* sp., *Musaenda roxburghii, Rhamnus nepalensis, Rubus ellipticus, Sarcococca saligna, Thamnocalamus arundanacea,* etc.

Near Karthok lake, patches of population of oak trees (*Quercus lineata*) were seen along with other small trees and shrubs. Above Yuksom village, tree canopy was represented by *Albizia procera, Alnus nepalensis, Macaranga denticulata, Magnolia pterocarpa, Populus ciliata, Prunus cerasoides, Saurauia nepalensis,* etc. Understorey is comprised of many small trees and shrubs like *Bambusa* sp., *Brassiopsis mitis, Callicarpa arborea, Dichroa febrifuga, Edgeworthia gardeneri, Mussaenda roxburghii, Rhamnus nepalensis* and *Viburnum erubescens*. Climbers are many and are represented by epiphytic as well terrestrial species. *Edgaria darjeelensis, Ageptes serpens, Cissus discolor, Passiflora* sp., *Piper boehmerifolia, Raphidophora glabra, Stephania glabra*, etc. are important twiners in the forest. Besides these, rich diversity of many epiphytic ferns and orchids were also noticed. Among herbs and grasses are *Anaphalis busua, Bidens pilosa, Eleusine* *indica, Eragrostis nigra, Plantago major, Pilea umbrosa, Lecanthus* sp.*, Polygonatum capitatum* and *Saccharum rufipilum.*

Between Pah Khola and near Susa Chhu, the vegetation is of wet temperate type and is represented many tall tree species like *Castanopsis indica, Elaeocarpus lancifolius, Hamiltonia suavens, Lithocarpus elegans, Lyonia ovalifolia, Michelia velutina, Persea clarkeii, Rhododendron arboreum*, etc. Some dense thickets of *Thamnocalamus falconeri* can be seen in the understorey along with other woody species like *Actinidia strigosa, Cinnamomum, Rhododendron* spp.*, Sambucus* sp.*, Spiraea* sp.*, Viburnum* spp., etc. Many interesting species of herbs like *Arisaema* sp.*, Begonia lacinata, B. palmata, Chlorophytum khasianum, Didymocarpus pedicillata, Panax elegans, Paris polyphylla, Pilea umbrosa* were seen in the understorey.

From Mintogang Chhu and Sarjan (2,080 m) dense mixed forest of oak were seen. The associates of them were *Acer* sp., *Betula alnoides*, *Quercus lamellosa*, *Rhododendron barbatum*, etc. Second storey was represented by *Eurya* sp.*, Mahonia neaulensis, Rubus ellipticus, R. linneatus and Viburnum* sp*.* But some riverine elements like *Rhus succedania* and *Toona ciliata* were seen towards Prek Chhu. Understorey is of open type and occupied by many interesting herbaceous plants like species of *Arisaema, Begonia, Cautleya, Costus, Hedychium, Panax,* etc. Rich growth of some epiphytic ferns and orchids were also seen growing on the large trees. In addition to these some tall ferns like *Dicranopteris lineris* and *Gleichenia longissima* were seen found growing along the forest slopes.

On the right bank of Prek Chhu and above Prek Chhu especially towards Bakhim (2,650 m) dense mixed forest of oaks were seen along the moderately steep slopes. *Acer* sp., *Betula alnoides, Castanopsis tribuloides, Lithocarpus pachyphylla, Eribotrya petiolata, Michelia* sp., *Rhododendron* sp., etc were seen the tree canopy. Among shrubs were *Gamblia ciliata, Pieris villosa, Rhododendron* spp., *Viburnum erubescens* and *V. nervosum.* Climbers are very few and represented by species of *Clematis* and *Rubus*. Herbaceous flora was represented by species of *Anemone, Aster, Corydalis, Clematis, Galium, Ranunculus, Rubia, Saussurea, Senecio, Spiraea, Thalictrum,* etc.

Above Bakhim, Mixed coniferous forest is present and *Tsuga dumosa* forms the top canopy in upper reaches. The tree associates in the canopy are represented by species of *Acer, Lithocarpus, Michelia, Prunus* and *Rhododendron*. From Tshoka (2,950 m) village onwards, mixed fir forest starts and oaks are completely absent. *Abies densa, Betula alnoides, Corylus ferox, Magnolia* sp., *Michelia* sp., *Rhododendron* sp., etc. form the tree canopy. Some species of *Rhododendron* and *Viburnum* forms the understorey. Among herbs were *Anaphalis triplinervis, Fragaria nubicola, Geum* sp., *Gaultheria numularoides, Galium* sp., *Nepeta* sp., *Panax elegans, P. pseudophragmites* spp. *Bippinatifidus, Primula* spp. and *Ranunculus* sp. Further away from Tshoka and onwards to Phadang, *Abies densa* becomes the dominant tree species forming the top canopy up to 3,800 m. The species of Rhododendron like *R. campanulatum, R. thomsiana, R. camelliflorum* etc. form the under storey with *Rosa sericea* and *Ribes* sp. Above 3,800 m, *Abies densa* is found in dwarf and stunted form. Only some shrubby species of rhododendrons can be seen as a dominant species up to 4,000 m. Above 4,000 m the shrubby growth of rhododendron starts decreasing and only some herbs can be seen in the upper reaches. Herbs which form the carpet and luxuriant growth along the meadows and morains are *Caltha, Geranium, Lilium, Oxygraphis, Ranunculus, Rheum, Potentilla, Saxifraga, Saussurea*, etc.

CHAPTER - 2
FLORISTICS

2.1 INTRODUCTION

Teesta river basin in Sikkim is characterised by wide altitudinal range from 234 m to above 8,598 m; adverse climatic conditions from cold and frigid in the north to extremely wet conditions in south, west and eastern parts of Sikkim. The region has deep valleys and ravines to gentle slopes in glaciated valley floors in north. The basin is also interlaced with numerous rivers and lakes resulting in many beautiful valleys, ravines and wetlands. All these characteristics provide uniqueness to the Teesta basin in Sikkim and making it rich in floristic diversity.

For these reasons only IUCN has recognized this region as a part of Indo-Burma hot spot. The Table 2.1 clearly shows its floristic richness in terms of number of flowering plant species and endemic species among the Himalayan states of India and neighbouring countries. There are more than 4000 species of flowering plants reported from Sikkim. Due to wet conditions that persist for long periods, the area is also very rich in lower plants like liverworts, mosses, algae, fungi and bacteria. Sikkim Himalaya is also home to a number of primitive taxa like *Alnus, Betula, Magnolia* and *Michelia*. It also provides habitats and acts as a cradle for speciation and evolution of new species. This rich floristic diversity also acts an important germplasm resource for many cultivated ones. It is very important to maintain and preserve this resource in nature which is needed for the genetic improvement of the cultivated species. The strategic location of the basin is evident from the presence of floristic elements having diverse phytogeographical affinities. The floristic elements of Indo-Malayan, Sino-Himalaya, Caucasian-Trans-Himalayan and Indian Peninsula are found in the Teesta basin. In recent times, the increase in human population as well as increase in various developmental activities have posed a serious threat to the floristic diversity of Teesta basin. In this report, an attempt has been made to asses the floral wealth of the basin and suggestions have been made for the protection and preservation of this wealth along with on going developmental activities.

Table 2.1 Floral richness of Teesta basin in Sikkim vis-a-vis other Himalayan regions and north-east India

State/Country	Geographic area (sq km)	Number of flowering plant species	Endemic plant species
Sikkim	7,096	4,250	123
Nepal	1,40,800	5,067	246
Bhutan	47,000	5,500	60
Arunachal Pradesh	83,743	5,000	114
Assam	78,523	3,017	14
West Bengal	88,752	3,580	07
Manipur	22,347	3,000	75
Meghalaya	22,549	1,517	65
Nagaland	16,579	2,431	35
Tripura	10,486	1,545	-
Mizoram	21,081	2,141	46
Jammu & Kashmir	2,22,235	4,252	124
Himachal Pradesh	55,673	3,343	82
Uttaranchal	53,483	4,220	45

2.2 PLANT EXPLORATIONS IN TEESTA BASIN

Sikkim Himalaya has since long attracted many plant collectors, scientists and plant hunters from India and abroad (Table 2.2). In Indian sub-continent Sikkim is the place, which has attracted maximum number of plant collectors or botanists worldwide. Griffith (1843) was the first person to visit Sikkim for the collection and study of the flora. For the first time he gave scientific description of the plants from Sikkim. However, it was J. D. Hooker, the famous botanist, who visited Sikkim in 1848-49 and made first comprehensive and descriptive account of the flowering plants of the region and also gave detailed account of the rhododendrons of Sikkim (Hooker, 1849). King and Pantling (1898) gave an account of orchid diversity from Sikkim Himalaya. Similarly, many other botanists and naturalists studied the plants and vegetation of different parts of Sikkim in detail. Smith (1909-10) visited South-east Sikkim and gave a detailed account of alpine and sub-alpine vegetation of the region. He also described the vegetation of Zemu and Lhonak valleys (Smith, 1911). Gammie (1894) toured Sikkim and studied the alpine and temperate vegetation of Lachen and Lachung valleys. From the later part of 19th century to middle of 20th century, up 1940, the area was visited by few explorers. Botanists like G. King, J.M. Cowan, G.H. Cova are the main explorers who visited the Sikkim Himalaya during this period. From 1940 to 1975 very little collections were made from the region. The area was visited by mainly K. P. Biswas, R. S. Rao, B.D. Sharma, B. Gosh and Hara. However, the plant exploration gained momentum after merging of Sikkim with India in 1975. Considering the importance of the floristic diversity of Sikkim Himalaya, Botanical Survey of India established a regional centre at Gangtok in Dec. 1979 to understand and preserve the regional floristic wealth of the region. Numerous botanist from Botanical survey of India, like P.K. Hajra, P. Chakarborty, B. Krishna, A.K. Verma, D.C.S. Raju, R.C. Srivastava, S. Kumar and N. R. Mandal, P. Basu, M. Sanjappa, M. Ahmedullah and many others visited the Sikkim region to study its floral wealth, which is highest among all Himalayan states/ countries (see Table 2.1). A lot has been written on the floral wealth of Sikkim (Table 2.3). However, still a lot of efforts are required for the exploration, compilation and conservation of this wealth for the future generation. Along with the above mentioned tasks, there is an urgent need to develop methodologies for the sustainable utilization of this invaluable resource in this region.

Table 2.2 Some important plant explorers of Sikkim

Year	Visitor	Area visited in Sikkim
1843	Griffith, W.	First plant collector to visit Sikkim
1848-49	Hooker, J.D.	Darjeeling to Tonglu and interior regions of Sikkim Himalaya
1873	Clarke, C.B.	Cho La and Tank La in East Sikkim
1877	Clarke, C.B.	Dzongri
1892-96	Pantling, R.	Various parts of Sikkim, with emphasis on orchids
1892	Gammie, G.A	Singalila range, Mt. Khangchendzonga area, Rangit valley, Tumlong, Tonglu, Sandakphu, Dzongri, Yuksom, Chungthang, Lachen, Yumthang, Lachung valley, Tankara La & Dongkia pass
1909-10	Smith, W. W.	Lower Lhonak valley and Zemu valley, Namchi, Temi, Gangtok, Chhangu, Lagep, Yakla Chakung Chhu valley, Kupup and Nathang
1960	Kanai, H.	Darjeeling, Dzongri, Singalila range, Gangtok
1960-63	Team of Tokyo University	Various parts of Sikkim
1964	Rao, R.S.	Various parts of Sikkim

Table 2.3 Literature on floral wealth of Sikkim

	Books	Year	Author/ Editors
1.	Vegeatation of Temperate and Alpine Sikkim, Gazatteer of Sikkim	1844	C.A. Gammie
2.	Himalayan Journals. Notes of a Naturalist Vol. I	1852	J.D. Hooker
3.	Himalayan Journals. Notes of a Naturalist Vol. II	1854	J.D. Hooker
4.	The Rhododendrons of Sikkim Himalaya	1849	J.D. Hooker
5.	The Orchids of the Sikkim Himalaya	1898	G. King and R. Pantling
6.	The vegetation of the Zemu & Llonakh valleys of Sikkim	1911	W.W. Smith
7.	Records of the Botanical Survey of India. Vol. IV – No.7. The alpine and sub-alpine vegetation of South-East Sikkim	1913	W.W. Smith
8.	A Guide to the Orchids of Sikkim	1926	Paul Bruhl
9.	Sikkim Himalayan Rhododendrons	1970	U.C. Pradhan and S.T. Lachungpa
10.	Flora of Bhutan Including a Record of Plants from Sikkim Vol. I, part I	1983	A.J.C. Grierson and D.C. Long
11.	Flora of Bhutan Including a Record of Plants from Sikkim Vol. I, part II	1984	A.J.C. Grierson and D.C. Long
12.	Flora of Bhutan Including a Record of Plants from Sikkim Vol. I, part III	1987	A.J.C. Grierson and D.C. Long
13.	Medicinal Plants of the Sikkim Himalaya	1994	Lalitkumar Rai and Eklabya Sharma
14.	Flora of Bhutan Including a Record of Plants from Sikkim and Darjeeling Vol. 3, part I	1994	J. Noltie
15.	Cultivation of Medicinal Plants and Orchids in Sikkim Himalaya	1995	R. C. Sundriyal and Eklabya Sharma
16.	Some Useful Trees of Sikkim	1996	R. C. Srivastava
17.	Flora of Sikkim Vol. 1, Monocotyledons	1996	P.K. Hajra and D. M. Verma
18.	Flora of Sikkim	1998	R.C. Shrivastava
19.	Flora of Bhutan Including a Record of Plants from Sikkim and Darjeeling Vol. 2, Part 2	1999	A.J.C. Grierson, D.G. Long
20.	Asteraceae of Sikkim	2001	S. Kumar and V. Singh

21.	Zingiberaceae of Sikkim	2001	S. Kumar
22.	Biodiversity of the Sikkim Himalaya	2002	J. R. Subba

2.2.1 Objectives

In the present study extensive and intensive field surveys along with documentation of the floral wealth of the Teesta basin from secondary sources has been done. For this, field explorations were made from 2002 to 2005 in different seasons in various regions of Teesta basin, right from Melli Bazar in East Sikkim to Gurudongmar and Yumthang in North Sikkim, Kupup to Pangulakha in East Sikkim and Jorethang, Ravongla in South Sikkim. Efforts were also made to understand the reasons for fast disappearance of many plant species or decrease in their population size in nature. In addition to this, the observations were also made on the effect of increasing human population and haphazard development on higher as well as lower plants. Various developmental activities in the region generally do not take account of the forest vegetation of the area. Very rarely the status of endemic and endangered plant species are taken into account before taking up the developmental activities like road building, constructions of dams, etc. Also very little attention is paid for the cultivation of plants which have medicinal or other uses and directly collected from the wild. During the field surveys, more emphasis was laid on the efforts to locate the habitats of endangered and endemic plant species of Sikkim and study the population size of these plants.

2.3 TAXONOMIC DIVERSITY

Teesta basin has different kinds of vegetation cover due to various climatic, edaphic, topographical and altitudinal variations. Among different areas in East Himalayan region Teesta basin in Sikkim is the richest in floristic diversity (see Table 2.1 and Plates 2.1-2.2). Teesta basin in Sikkim is richest in terms of number of flowering plant species that are found per 100 sq km of its geographic area (Fig. 2.1). In Sikkim the number of plants per 100 sq km is 70 whereas, in other states of India this diversity varies from 2 to 15. Sikkim harbours nearly one fourth of the total flowering plants of India. In the present study 3418 species of angiosperms and gymnosperms could be recorded from Teesta basin in Sikkim (Table 2.4). This list, however, is still incomplete. The region is also very rich in other groups of plants like pteridophytes, bryophytes, lichens, fungi, algae, etc.

Table 2.4 Number of species in different plant groups from Sikkim

Name of Group	Number of Families	Number of Genera	Number of Species
Angiosperms			
Dicotyledons	165	913	2183
Monocotyledons	26	339	1217
Gymnosperms	9	14	18

2.3.1 Flowering Plants

In an area of only 7,096 sq km, more than 3,400 species of angiospermic plants could be recorded. These plants are observed throughout Sikkim inhabiting the extreme frigid region of Gurudongmar, Yumesamdong, alpine regions of Thangu, Yumthang and Dzongri and temperate areas of Mangan, Chungthang and Lachen-Lachung valleys to sub-tropical and tropical areas of Namchi, Rangpo, Jorethang and also found in lakes and wetlands (see Plates 2.1 - 2.2).

2.3.1.1 *Monocots*

Monocots are comprised of 1217 species belonging to 26 families & 339 genera (see Table 2.4). Orchidaceae is the largest family with 445 species followed by Poaceae and Cyperaceae with 280 and 149 species, respectively (Table 2.5). Liliaceae is represented by 95 species. Monocot

Table 2.5 Monocot families in Sikkim

Sl. No.	Name of Family	Total no. of Genera	Total no. of Species
1.	Orchidaceae	117	445
2.	Poaceae	104	280
3.	Cyperaceae	18	149
4.	Liliaceae	36	95

Plate 2.1 Some of the important medicinal plants from Sikkim Himalaya
a) *Aconitum bisma*, b) *Rheum nobile,* c) *Podophyllum hexandrum*, d) *Picrorhiza kurrooa*, e) *Taxus baccata*, f) *Panax pseudoginseng*

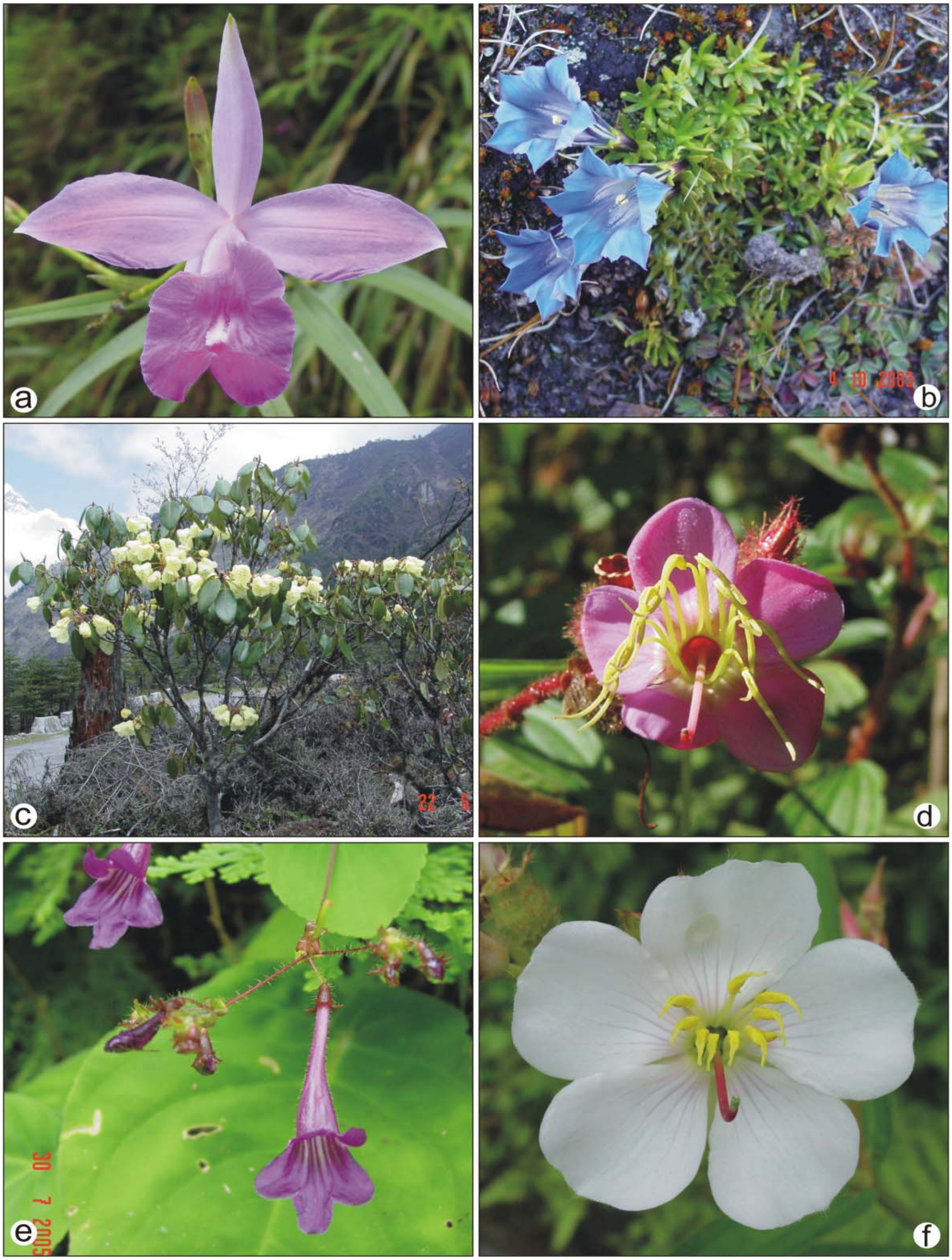

Plate 2.2 Some of the beautiful flowering plants of Sikkim Himalaya
a) *Arundina graminifolia*, b) *Gentiana depressa,* c) *Rhododendron campylocarpum*, d) *Osbeckia stellata*, e) *Chirita primulacea*, f) *Osbeckia nepalensis*

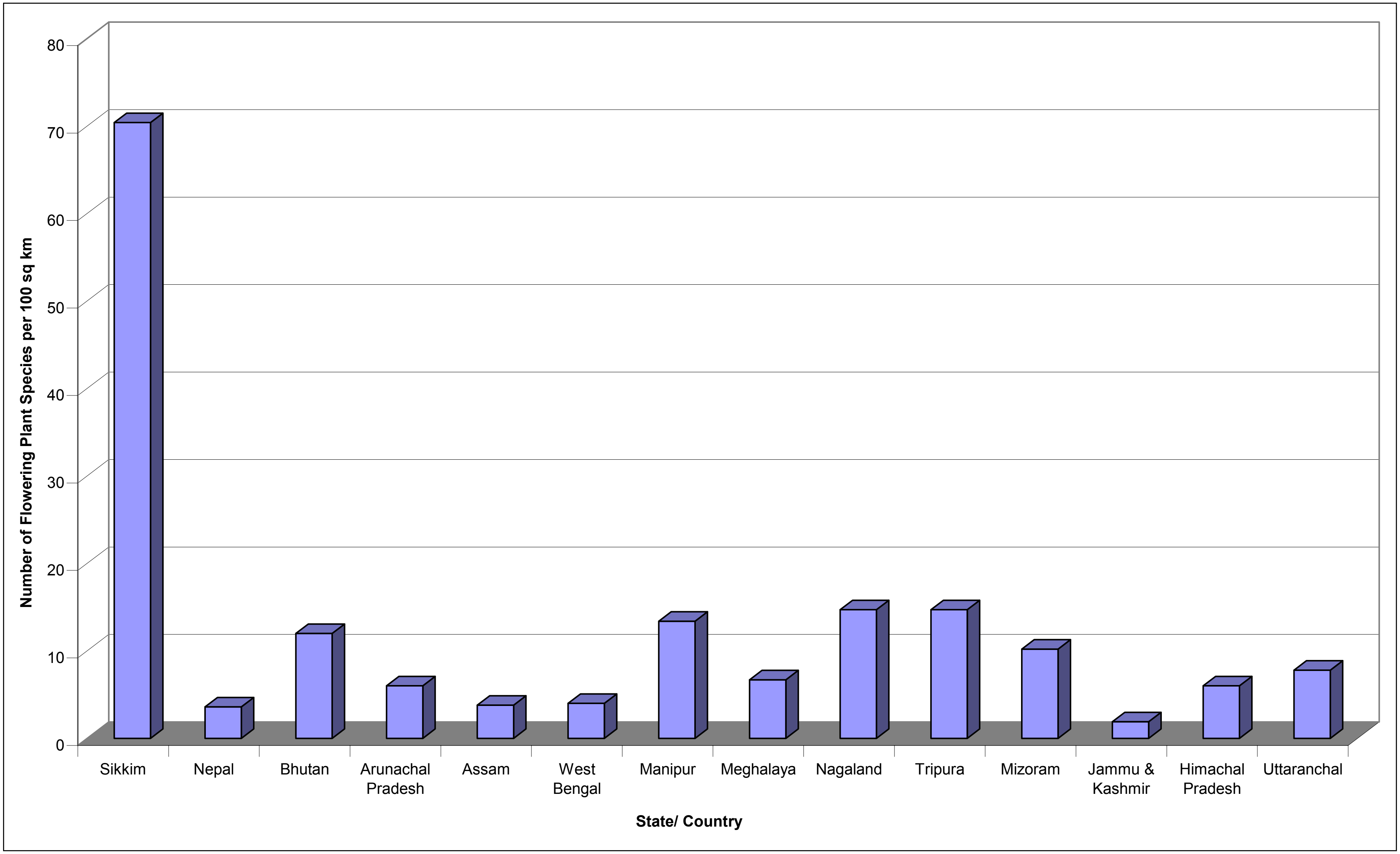

Fig. 2.1 Floral richness of Teesta basin in Sikkim

5.	Zingiberaceae	14	57
6.	Araceae	12	40
7.	Juncaceae	2	36
8.	Commelinaceae	9	22
9.	Arecaceae	10	18
10.	Smilacaceae	1	14
11.	Iridaceae	4	6
12.	Amaryllidaceae	4	6

species are found throughout the Teesta basin. The species found in extreme cold regions like Gurudongmar, Kholama region and Lhonak valley are *Elymus* sp., *Kobresia* sp., *Festuca* sp. and *Poa* sp. The alpine grasses like *Briza media, Cyathopus sikkimensis, Poa sikkimensis* are mainly found in Thangu and Yumthang areas. The basin is not so rich in cane and bamboo species in contrast to other north-eastern states. However, prominent bamboo species of the basin are *Bambusa* spp., *Dendrocalamus* spp., *Drepanostachyum* spp. Among these, *Bambusa arundinacea, B. tulda, Dendrocalamus sikkimensis* and *Thamnocalamus falconeri* are tall bamboos and *Drepanostachyum intermedium, D. gracilis*, etc. are small shrub bamboos. These bamboo species are restricted to tropical and sub-tropical regions particularly in Rangit valley, Pedong, Chungthang, Gangtok and the main Teesta valley. The bamboo species found at higher altitudes (Chungthang, Yuksom above 1,500 m) are *Dendrocalamus hamiltonii, D. hookeri, Drepanostachyum intermedium* and *Thamnocalamus falconeri*. Sikkim is endowed with maximum number of species of orchids. Though these species occur throughout Sikkim, hot spot for orchids in Sikkim are Lachen, Lachung, Chungthang, Pelling and Selem regions. These plants are found as epiphytes attached to tree trunks and rocks or terrestrial, growing under shade or in open places. Orchid genera that have maximum species are *Bulbophyllum* (46 species), *Dendrobium* (36 species), *Eria* (23 species) and *Liparis* (20 species). Generally orchid species prefer wet moist conditions, however, some of the species like *Coelogyne cristata, Cypripedium himalaicum, Ponerorchis chusua*, etc. are restricted to higher altitudes in Singalila range, Tendong peak, Khangchendzonga and Shingba regions, which are comparatively drier.

2.3.1.2 *Dicots*

Dicots are represented by 2183 species, which belong to 913 genera and 165 families (see Table 2.4). The dicot species of higher altitudes are *Acronema, Aconitum* spp., *Gentiana* sp., *Primula*, *Saxifraga, Picrorhiza, Nardostachys grandiflora*, which grow in the cold regions of Gurudongmar, Yumesamdong, Thangu, Chhangu and Dzongri (see Plates 2.1 - 2.2). Table 2.6 gives the list of dicot families represented by more than 10 plant species in Sikkim. Asteraceae is the largest family with more than 81 genera in Sikkim (see Table 2.6). The species of this family are mostly found in alpine regions of Kupup, Chhangu, Gurudongmar and Yumesamdong regions. The prominent genera in Sikkim, with number of species in brackets, are *Primula* (56), *Saxifraga* (52), *Ficus* (36), *Pedicularis* (43), *Rhododendron* (36), *Impatiens* (35), *Saussurea (32)* and *Rubus* (28) (Table 2.7). The species of *Aconitum, Thalictrum, Corydalis* and *Meconopsis* are mostly found above 2,000 m in Thangu, Yumthang, Kupup, Bakhim Cave and Dzongri regions. Many monotypic genera distributed in different parts of Teesta basin were also recorded. Species like *Arcyosperma primulifolium* (Brassicaceae) *Thylacospermum caespitosum* (Caryophyllaceae), *Oxyria digyna* (Polygonaceae) and *Picrorhiza kurrooa* (Scrophulariaceae) are found at higher altitudes, whereas, *Circaester agrestis* (Circaesteraceae), *Cissampelos pareiera* (Menispermaceae) and *Gynocardia odorata* (Flacourtiaceae) are mainly tropical and sub-tropical species.

Table 2.6 Dominant dicot families in Sikkim

Family	No. of Genera	No. of Species
Asteraceae	81	253
Fabaceae	41	133
Scrophulariaceae	21	112
Lamiaceae	22	95
Ranunculaceae	18	89
Euphorbiaceae	29	87
Rubiaceae	34	76
Ericaceae	8	60
Saxifragaceae	6	64
Brassicaceae	30	57
Caryophyllaceae	14	50
Fumariaceae	4	27

Balsaminaceae	1	35
Rosaceae	24	26
Rutaceae	14	26
Begoniaceae	1	14
Meliaceae	9	13
Anacardiaceae	9	13
Sterculiaceae	7	12

Table 2.7 Some dominant dicot genera in Sikkim

Sl. No.	Name of Genus	Family	No of Species
1.	*Primula*	Primulaceae	56
2.	*Saxifraga*	Saxifragaceae	52
3.	*Pedicularis*	Scrophulariaceae	43
4.	*Rhododendron*	Ericaceae	36
5.	*Impatiens*	Balsaminaceae	35
6.	*Saussurea*	Asteraceae	32
7.	*Rubus*	Rosaceae	28
8.	*Potentilla*	Rosaceae	23
9.	*Elatostema*	Urticaceae	22
10.	*Ficus*	Moraceae	21
11.	*Corydalis*	Fumariaceae	21
12.	*Desmodium*	Fabaceae	19
13.	*Arenaria*	Caryophyllaceae	18
14.	*Persicaria*	Polygonaceae	16

15.	*Prunus*	Rosaceae	14
16.	*Sorbus*	Rosaceae	14
17.	*Anemone*	Ranunculaceae	12
18.	*Astragalus*	Fabaceae	12
19.	*Crotalaria*	Fabaceae	12
20.	*Draba*	Brassicaceae	12
21.	*Aconitum*	Ranunculaceae	11
22.	*Thalictrum*	Ranunculaceae	11
23.	*Phyllanthus*	Euphorbiaceae	11

2.3.1.3 *Gymnosperms*

In Sikkim Himalaya, very few gymnosperm species are met with. A total of 18 species of gymnosperms are recorded in Teesta river basin. Most of these species are trees except *Ephedra* sp. and *Cycas pectinata*, distributed mainly in Lachen-Lachung valley, Thangu region, Yumthang, Dzongri and Chhoka areas. These species are mostly used as timber for house construction, furniture. However, species like *Ephedra gerardiana* and *Taxus baccata* are medicinally very important (Table 2.8).

2.3.1.4 *Pteridophytes*

Sikkim is very rich in pteridophyte plants also. Most of these species are found in the wet tropical and sub-tropical regions of Rangit

Table 2.8 Gymnosperms of Sikkim Himalaya

Species	Family	Ver./Nep. name	Alt. (m)	Habit	Distribution in Sikkim	Uses
Cycas pectinata	Cycadaceae	Thakal	600-1050	Shrub	Singtam	Stem pith used to produce sago
Pinus kesiya	Pinaceae	Khasia pine	800-1000	Tree	Sangklang	Timber and resin
P. roxburghii	Pinaceae	Dhup	1000-1800	Tree	Rangit and Teesta valleys	Timber; trees tapped for resin
P. wallichiana	Pinaceae	Dhupi	1700-3300	Tree	Lachung	Timber
Larix griffithiana	Pinaceae	Barge Salla	2600-3600	Tree	Zema, Yumthang	Timber
Picea spinulosa	Pinaceae	She	2400-3000	Tree	Lachen	Timber
Tsuga dumosa	Pinaceae	Tengre Salla	2400-3000	Tree	Chhaten, Lachen, Zema, Chhoka	Timber used in house construction
Abies densa	Pinaceae	Gobre Salla	2950-4000	Tree	Yathang, Yumthang	Timber
Cryptomeria japonica	Taxodiaceae	Dhupi	1500-2500	Tree	Damthang, Ravongla	Timber
Cupressus corneyana	Cupressaceae	Tsendeng Shing	2500-3000	Tree	Rhenok	Timber for dzong construction
Thuja orientalis	Cupressaceae	Morpankhi	1600-2000	Tree	Gangtok	Timber
Juniperus recurva	Cupressaceae	Shupo Shing	2900-4200	Tree/shrub	Chhangu, Thangu	Twigs and leaves used as incense material
J. squamata	Cupressaceae	Shupo Shing	3200-4700	Tree	Thangu	Twigs and leaves used as incense material
J. pseudosabina	Cupressaceae	Kaalu Shupo	3500-4500	Tree/shrub	Yumthang, Zema	Wood as incense material
Podocarpus neriifolius	Podocarpaceae		900-1400	Tree	Lower Teesta valley	Timber
Taxus baccata	Taxaceae	Dhengre Salla	1800-2700	Tree	Lachung, Tholung,	Used medicinally
Ephedra gerardiana	Ephedraceae	Shomlata	4000-4500	Shrub	Thangu	Plant contain ephedrine; used in treatment of asthma and cold
Gnetum montanum	Gnetaceae		270-800	Tree	Lower Teesta valley	Timber

Valley, Teesta valley, Lachung Chhu, Chakung Chhu and Rangpo Chhu valley (Table 2.9).

2.4 PHYSIOGNOMIC DIVERSITY

In Teesta basin, flora was also assessed in terms of physiognomy i.e. with respect to habit of the plant. In the forests of Sikkim, all types of plants like herbs, shrubs, trees, climbers were seen associated with each other. However, the bulk of flora is herbaceous. Around 64 per cent of plant species are herbs. The portion of trees and shrubs in the flora is nearly equal, which is around 16.21 and 13.17 per cent, respectively. Some families like Caesalpinaceae, Mimosaceae, Fabaceae, Euphorbiaceae have plants of all growth forms. The genus *Cassia* (Caesalpinaceae) has species in the form of tree, shrubs and herbs and climbers. *Cassia fistula* is tree generally found in tropical region whereas, *C. lechenaultiana* is a herb and distributed in Mankha, Dikchu and Singtam areas, *C. sophera* is shrub found in Singtam and Rangpo regions and *C. ternata* is climber mostly found in Tarko, Tong and Jorethang. Some families like Annonaceae, Bignoniaceae, Dipterocarpaceae, Meliaceae, Sterculiaceae, Tiliaceae are represented by only tree species. Berberidaceae, Ericaceae, Flacourtiaceae, Leeaceae, Rhamnaceae, are some of the families having mostly plants of shrubby nature. The species of Capparaceae, Cucurbitaceae, Dioscoreaceae, Menispermaceae and Vitaceae are exclusively climbers. These climbers are mostly found in tropical to temperate region of Rangpo, Jorethang, Legship, Dikchu, Mangan, Tong and Lachen-Lachung valley.

2.5 PHYTOGEOGRAPHICAL AFFINITIES

As such India has strategic position on the globe and within India the position of Sikkim or Testa basin is very important with respect to phytogeography. Plants from all directions immigrated to Sikkim as well as migrated out of this region. Floral elements from South East Asian region, which included Myanmar, Thailand, Indo-China, Indonesia and Malaysia were found in the tropical and subtropical forest of Sikkim. In this region the spices like *Bauhinia vahlii, Dendrophthoe falcata, Ficus benghalensis, Murraya koenigii, Plumbago zeylanica* and *Woodfordia fruticosa* are also found, which have come from peninsular India. The temperate flora of Himalaya, China and Japan has an overlapping link. Some species like *Cardiocrinum giganteum, Cornus macrophylla, Houttuynia cordata* and *Hypoxis* are present from western Himalaya to Japan. Some species like *Acronema, Acer oblongum, Allium pratii, Leycesteria formosa, Myrsine semiserrata* are present only in Himalaya to China and absent from the islands of Japan (Table 2.10). Similarly the xerophytic and high altitude species of Sikkim Himalaya have relationship with the flora of Tibet, Europe-Caucasia and Arctic regions. Table 2.10 shows some common species of Sikkim Himalaya and these regions.

Table 2.9 Some common pteridophytes of Sikkim Himalaya

Species	Family	Herb	Altitude (m)	Distribution/Habitat
Selaginella chrysocaulos	Selaginellaceae	Herb	1000-2000	Shaded and damp forest areas
S. ciliaris	Selaginellaceae	Herb	Up to 1000	Moist hill slopes
S. nepalensis	Selaginellaceae	Herb	1000-2000	Moist hill slopes
Equisetum diffusum	Equisetaceae	Herb	500-2500	River banks and water logged areas
E. ramosissimum	Equisetaceae	Herb	1000-2800	Along bushes and moist soils
Dicranopteris linearis	Dicranopteridaceae	Undershrub	1000-2800	In moist and damp forest edges
Lepisorus loriformis	Polypodiaceae	Herb	1000-2000	Epiphytes or lithophytes; in shaded places
Microsorium membranaceum	Polypodiaceae	Herb	1200-2200	Lithophytes on shaded and humus covered rocks
Phymatopteris oxylobe	Polypodiaceae	Herb	2000-3000	Epiphytes or lithophytes; in shaded places
Polypodioides lachnopus	Polpodiaceae	Herb	1700-2700	Epiphytes on tree trunks
Pyrrosia lanceolata	Polypodiaceae	Herb	Up to 1500	Epiphyte on tree trunks
Lygodium japonicum	Lygodiaceae	Herb	900-1800	Epiphytes on tree trunks or rocks
Lycopodium clavatum	Lycopodiaceae	Climber	1800-2800	On grassy and forest slopes
Cheilanthes bicolor	Cheilanthaceae	Herb	600-1200	On shaded and moist forest slopes
Onychium contiguum	Cryptogrammaceae	Herb	1200-2400	On roadside and forest slopes
Pteris cretica	Pteridaceae	Herb	1400-2400	In open moist places
P. subquinata	Pteridaceae	Herb	1500-2500	Shaded and open hill slopes
Adiantum capillus-veneria	Pteridaceae	Herb	700-1700	Shaded forest slopes
A. incisum	Adiantaceae	Herb	700-1400	On shaded and open hill slopes
Emodiopteris appendiculata	Dennstaedtiaceae	Herb	1000-2000	In rock crevices
Asplenium ramosum	Aspleniaceae	Herb	3000-4000	Between boulders
Ampelopteris prolifera	Thelypteridaceae	Tall herb	1000-2000	In marshy places
Athyrium pectinatum	Athyraceae	Herb	1500-2500	In shaded soils
Diplazium maximum	Athyraceae	Herb	1200-2400	In shaded places
D. spectabile	Athyraceae	Herb	900-2200	Along streams of marshy places
Dryopteris cochleata	Dryopteridaceae	Herb	700-1400	In shaded places along the streams
Polystichum discretum	Dryopteridaceae	Herb	2000-3000	In shaded hill slopes
P. lentum	Dryopteridaceae	Herb	1200-2400	On shaded moist places; tropical and sub-tropical zone
P. sqarrosum	Dryopteridaceae	Herb	Up to 1200	On moist shaded rocks
Cyathea spinulosa	Cyatheaceae	Herb	Up to 2000	On shaded hill slopes
Nephrolepsis cordifolia	Nephrolepidaceae	Tree	Up to 1200	On shaded and damp areas; sub-tropical forests
Araiostegia pseudocystopteris	Davalliaceae	Herb	1700-2700	As an epiphyte or lithophytes
Woodwardia unigemmata	Blechnaceae	Herb	1400-2400	On moist and shaded hill rocks

Table 2.10 Floristic elements in Sikkim Himalaya from different regions of world

Species	Family
(i) Sino-Himalayan -Japanese elements	
Acer oblongum	Aceraceae
Alnus nepalensis	Betulaceae
Aucuba himalaiaca	Cornaceae
Adenocaulon himalaicum	Asteraceae
Boenninghausenia albifora	Rutaceae
Cardiocrinum giganteum	Liliaceae
Carpinus viminea	Betulaceae
Clintonia udensis var. *alpina*	Liliaceae
Cotoneaster microphyllus	Rosaceae
Enkiananthus deflexa	Ericaceae
Geranium nepalense	Geraniaceae
Houttuynia cordata	Saururaceae
Hydrangea anomala	Hydrangeaceae
Juniperus recurva	Cupressaceae
Lyonia ovalifolia	Ericaceae
Magnolia globosa	Magnoliaceae
Mimulus nepalensis	Scrophulariaceae
Nardostachys grandiflora	Valerianaceae
Oxalis acetosella	Oxalidaceae
Panax pseudoginseng	Araliaceae
Paracarpa carnosa	Campanulaceae
Pieris formosa	Ericaceae
Saurauia napaulensis	Actinidiaceae
Swertia bimaculata	Gentianaceae
Stachyurus himalaicus	Stachyuraceae
Tirarella polyphylla	Saxifragaceae

(ii) South East Asian –Malaysian elements

Actinidia callosa	Actinidiaceae
Ampelocissus barbata	Vitaceae
Antidesma acuminatum	Euphorbiaceae
Bauhinia purpurea	Caesalpinaceae
Bischofia javanica	Euphorbiaceae
Brassiopsis glomerulata	Araliaceae
Choreospondias pinnata	Anacardiaceae
Cycas pectinata	Cycadaceae
Debregeasia longifolia	Urticaceae
Dendrobium aggregatum	Orchidaceae
Duabanga grandiflora	Lythraceae
Engelhardtia spicata	Juglandaceae
Eria paniculata	Orchidaceae
Firmiana colorata	Sterculiaceae
Garuga pinnata	Burseraceae
Gnetum montaneum	Gnetaceae
Hedychium coccineum	Zingiberaceae
Lithocarpus elegans	Fagaceae
Magnolia hodgsonii	Magnoliaceae
Mangifera indica	Anacardiaceae
Meliosma simplicifolia	Sabiaceae
Michelia champaca	Magnoliaceae
Musa bulbisiana	Musaceae
Oroxylum indicum	Beignoniaceae
Podocarpus neriifolius	Podocarpaceae
Rauwolfia serpentina	Apocynaceae
Tetrameles nudiflora	Verbenaceae

(iii) Peninsular Indian elements

Bauhinia vahlii	Caesalpiniaceae
Capparis olacifolia	Capparaceae
Casearia graveolens	Falcourtiaceae
Dendrophthoe falcata	Loranthaceae
Ficus bengalensis	Moraceae
Plumbago zeylanica	Plumbaginaceae
Sophora wightii	Fabaceae
Thunburgia coccinea	Apocynaceae
Tylophora rotundifolia	Asclepiadaceae
Woodfordia fruticosa	Lythraceae

(iv) Tibetan elements

Lilium fasciculatum	Liliaceae
Arabis glandulosa	Brassicaceae
Arenaria bryophylla	Caryophyllaceae
Caragana spinata	Fabaceae
Dracocephalum speciosum	Lamiaceae
Ephedra gerardiana	Ephedraceae
Juncus thomsonii	Juncaceae
Lonicera spinosa	Caprifoliaceae
Parrya platycarpa	Brassicaeae
Ranunculus tricuspis	Ranunculiaceae
Saussurea gossypiphora	Asteraceae

(v) Euro-Siberian elements

Carex echinata	Cyperaceae
Cimcifuga foetida	Ranunculaceae
Epipactis helleborine	Orchidaceae
Erysimum hieracifolium	Brassicaceae
Goodyera repens	Orchidaceae

Hedera nepalensis	Zingiberaceae
Hippophae rhamnoides	Elaeagnaceae
Polygala sibirica	Polygalaceae
Prunella vulgaris	Lamiaceae
Ranunculus scleratus	Ranunculaceae
Stellaria ulginosa	Caryophyllaceae
Verbascum thapsus	Solanaceae
Veronica anagallis-aquatica	Scrophulariaceae
Viola biflora	Violaceae
(vi) Arctic –alpine elements	
Androsace chamaejasme	Primulaceae
Carex atrofusca	Cyperaceae
Juncus triglumis	Juncaceae
Myosotis alpestris	Boraginaceae
Oxyria digyna	Polygonaceae
Oxytropis lapponica	Fabaceae
Sagina saginoides	Caryophyllaceae
Thalictrum alpinum	Ranunculaceae

2.6 ENDEMICS

In Teesta basin, with such a small area, large numbers of endemic plants are reported. A list of more than 120 species of plants, which are exclusively endemic to the state of Sikkim is given in Table 2.11. Most of them are herbs and around 10 species are shrubs. Trees or climbers are very few. Only three tree species, *Rhododendron lanatum* of Ericaceae, *Litsea sikkimensis* of Lauraceae and *Mallus sikkimensis* of Rosaceae are endemic to Sikkim. *Litsea sikkimensis* is found in Lachen and

Kyongnosla Alpine Sanctuary area, whereas *Rhododendron lanatum* is found in Dzongri in West Sikkim as well as in Nathula region in East Sikkim. In case of *Mallus sikkimensis*, only one tree could be located in the Lachung area near a stream. Most of the endemic species are found above 2,500 m in Lachen, Lachung, Lhonak and Zemu valleys. However, most of the endemic orchid species are found in tropical and sub-tropical regions in Teesta, Sebu and Chungthang valleys below elevation of 1,600 m (see Table 2.11). More than 20 species of orchids are endemic to Sikkim region. Another family having maximum number of endemic species is Asteraceae. There are around 18 species from this family that are endemic to Teesta basin in Sikkim, mostly distributed above 3,000 m in alpine and sub-alpine area. Only *Blumea sikkimensis* of Asteraceae is found in tropical region. Some other families like Primulaceae, Gentianaceae, Apiaceae, Rosaceae and Urticaceae have 9, 8, 8, 7, and 5 species, respectively that are endemic to Sikkim. In nine families, there is only one and in five families there are two species that are reported endemic to Sikkim region (see Table 2.11). Many of these endemic species have various medicinal and other uses and collected by local people from the wild only. In the present studies efforts were made to locate them in the wild and record their population size and to make an assessment of nature of any threat to their survival in the wild. The species like *Podophyllum sikkimensis*, *Panax sikkimensis*, *Anaphalis cavei* and *Acer hookeri* are used for medicinal purpose and are extensively extracted from the wild. In some areas, the depletion of forest cover has resulted in the shrinking of the habitats of *Panax* *sikkimensis, Cymbidium gammieanum, Dendrobium densiflorum, Habenaria cumminsiana* and *Zeuxine pulchra.*

2.6.1 Field Survey of the Endemic Species

The specimens of various endemic plant species were first examined in the herbaria at Gangtok (BSHC) and Kolkata (CN). The specimens were available for only 14 per cent endemic of flowering plants in the herbaria at these two places. Most of the specimens available in these herbaria were collected nearly 20 to 30 years back and some of the collections are more than 100 years old. Extensive field explorations were conducted in different parts of Sikkim in different seasons for nearly four years for these endemic plant species mentioned in the literature. However, only 36 species of endemic plants could be located, which is about 29 per cent of the total endemic species reported for Sikkim (Table 2.12). It was in regions like Lachen, Thangu, Yumthang, Lachung, Kupup, Menmoi Chho, Nathula and Chhangu lake, where maximum number of such species could be located (Table 2.12).
In these areas the developmental and agricultural activities are minimum due to inhospitable terrain and there is very little human disturbance. In case of some of the species, the population sizes were very small, represented by individuals ranging from only one to few. For example in case of *Mallus sikkimensis,* only one individual could be found on the bank of a stream in Lachung. In some species, a number of morphotypes were found, which made the taxonomical identification very difficult. In the case of *Panax sikkimensis,* reported endemic to

Sikkim, more than five variants were found in Lachung, Lachen and Kyongnosla region. Now detailed investigation is going on different species/ varieties of *Panax* at various levels including taxonomy, cytology, population dynamics, seed biology, medicinal properties and conservation measures. A holistic approach is required to survey and study endemic species. The study requires interdisciplinary approach involving experts from fields like taxonomy, ecology, conservation, molecular biology, etc. An awareness compaign is required to make aware the local people about the importance of these endemic species and their involvement in conservation of these species as Sikkim is the only abode of these species. The habitat of the species, whose population sizes have become very small, is required to be declared as protected zone with no anthropogenic activity. Not only illegal and unscientific exploitation of these species from the wild is to be discouraged rather cultivation of these species by the local people for their medicinal and other purposes is required to be encouraged.

2.6.2 District-wise Distribution of Endemic Species

The distribution of these endemic species in the four districts of Sikkim reveals that the maximum number of endemic species are found in the North Sikkim (Fig. 2.2). In all 25 endemic species are found in this district, which is more than 62 per cent of the total number of endemic species found during the present surveys (Table 2.12). Some of the important endemic species of the North Sikkim are, *Ranunculus sikkimensis* found at Thangu, *Berberis umbellata* found at Lachen,

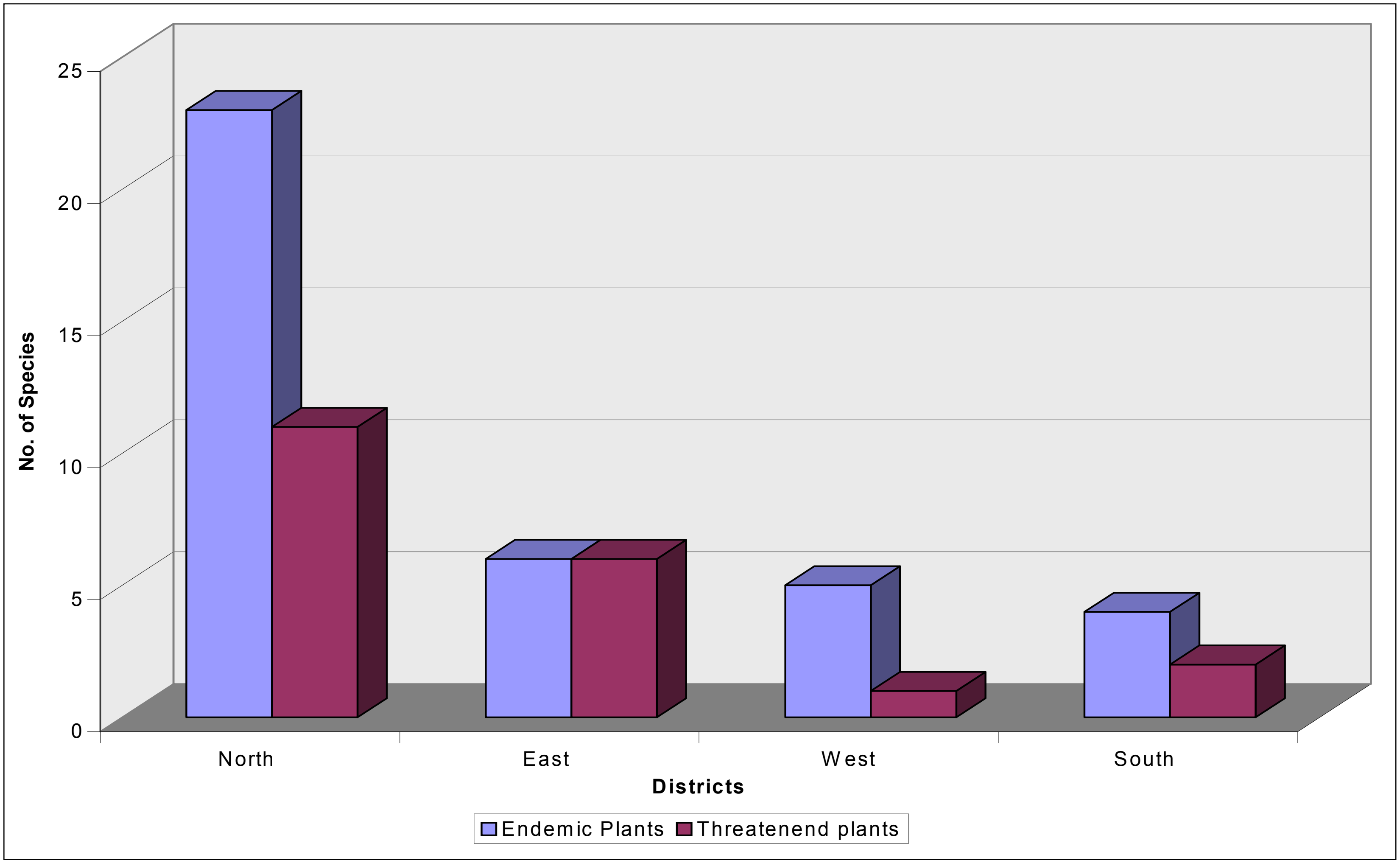

Fig. 2.2 Occurrence threatened endemic plants in different districts of Sikkim

Mallus sikkimensis found at Lachung. In East Sikkim, around 15 per cent endemic species are found. The distribution of these endemic species is restricted to Kupup, Tsomgo and Nathula region (Table 2.12). The species like *Lactuca cooperi*, *Saussurea andersonii*, *Crawfordia puberula* and *Phoenix rupicola* were found only in East Sikkim (Table 2.12). In other two districts, South and West Sikkim, few endemic species were found (Table 2.12). In West Sikkim, five endemic taxa were found, whereas in South Sikkim, four endemic species were found. Two species, *Pimpinella sikkimensis* and *Scrophularia sikkimensis* were found only in West Sikkim, whereas *Begonia satrapis*, *Chirata calva*, *Piper sikkimensis* and *Litsea sikkimensis* were recorded only from South Sikkim. These two districts are subjected to human disturbance and the forests at steep slopes have been cleared and used for tea and cardamon cultivation.

Table 2.11 Endemic flowering plants of Sikkim

Species	Family	Altitude (m)	Habit	Distribution in Sikkim
Anemone demissa var.*monantha*	Ranunculaceae	3200-4600	Herb	Sikkim
Clematis andersonii	Ranunculaceae	-	Herb	Sikkim
Ranunculus brotherusii var. *tanguticus*	Ranunculaceae	3000-4300	Herb	Sikkim
R. sikkimensis	Ranunculaceae	ca 4800	Herb	Sikkim
Arenaria thangoensis	Caryophyllaceae	ca 4500	Herb	Thangu
Stellaria decumbens var. *acicularis*	Caryophyllaceae	Above 3300	Herb	Sikkim
Uvaria lurida var.*sikkimensis*	Annonaceae	Up to 800	Climber	Sikkim
Berberis concina	Berberidaceae	3350-3950	Shrub	Lachen valley
B. umbellate	Berberidaceae	2000-3500	Shrub	Sikkim
Podophyllum sikkimensis	Podophyllaceae	3000-3500	Herb	Thangu
Mahonia sikkimensis	Berberidaceae	ca 2500	Shrub	Sikkim
Corydalis caevei	Fumariaceae	2700-4300	Herb	Sikkim
C. chagoensis	Fumariaceae	3660-3900	Herb	Chhangu, E. Sikkim

Draba humillima	Brassicaceae	4500-5000	Herb	Sikkim
D. stenobotrys	Brassicaceae	4000-5000	Herb	Sikkim
Parrya platycarpa	Brassicaceae	2000-3000	Herb	Lhonak
Viola placida	Violaceae	2500-3000	Herb	Sikkim
Hypericum filicaule	Hypericaceae	3500-4000	Herb	Sikkim
H. williamsi	Hypericaceae	-	Shrub	Sikkim
Sabia campanulata var. *kingiana*	Sabiaceae	800-1600	Climber	Sikkim
Astragalus zemuensis	Fabaceae	ca 3600	Herb	Zemu, N. Sikkim
Brachycaulos simplicifolia	Rosaceae	ca 4575	Herb	Gaoring
Cotoneaster sikkimensis	Rosaceae	-	Shrub	Lachung
Potentilla forrestii var. *segmentata*	Rosaceae	4000-4900	Herb	Lhonak, Lachen
Rubus niveus var. *micranthus*	Rosaceae	1050-2500	Shrub	Sikkim
Spiraea subrotundifolia	Rosaceae	3000-4300	Shrub	Dzongri
Saxifraga coarctata	Saxifragaceae	ca 4570	Herb	Yumchho La
S. gageana	Saxifragaceae	ca 4400	Herb	Ningbil and Chola range
S. pulviarum	Saxifragaceae	4250-4570	Herb	Tosa, Chola range
S. inconspicua	Saxifragaceae	4265-5000	Herb	Yumchho La, Tanka La
S. umbellulata	Saxifragaceae	3600-5300	Herb	Thangu & Lhonak; Bhutan
Epilobium gouldii	Onagraceae	3600-4300	Herb	Lachung, Chumbi
Trichosanthes cucumeriana var. *anguina*	Cucurbitaceae	Up to 2500	Climber	Sikkim
Begonia satrapis	Begoniaceae	ca 660	Herb	Rangit
Acronema sikkimense	Apiaceae	ca 3600	Herb	Chola, Lachung
A. pseudotenerum	Apiaceae	3000-4000	Herb	Yumesamdong
Pimpinella sikkimensis	Apiaceae	1000-2600	Herb	Sikkim
P. hookeri	Apiaceae	2600-3600	Herb	Samdong, Lachen
P. tongloensis	Apiaceae	2400-2800	Herb	Singalila range
Pternopetalum radiatum	Apiaceae	ca 3600	Herb	Yumthang
Pleurospermopsis sikkimensis	Apiaceae	4300-5300	Herb	Dzongari
Angelica nubigena	Apiaceae	3000-4200	Herb	Chola and Yakla passes
Panax sikkimensis	Araliaceae	-	Herb	Sikkim
Anaphalis cavei	Asteraceae	5000-5300	Herb	Guchala
A. hookeri	Asteraceae	3000-3600	Herb	Lachen, Lachung
A. subumbellata	Asteraceae	3400-4000	Herb	Sikkim
Blumea sikkimensis	Asteraceae	800-1200	Herb	Sikkim
Cacalia chola	Asteraceae	-	Herb	Chola E. Sikkim
Cremathodium discoideum	Asteraceae	-	Herb	Sikkim
C. palmatum	Asteraceae	4000-4500	Herb	Lhonak, Zemu, Thangu
Inula macrosperma	Asteraceae	-	Herb	Sikkim
Lactuca cooperi	Asteraceae	4500-5000	Herb	Kupup

Ligularia dux	Asteraceae	ca 3000	Herb	Sikkim
L. kingiana	Asteraceae	3500-4000	Herb	Sikkim
L. pachycarpa	Asteraceae	ca 4000	Herb	Sikkim
Saussurea andersonii	Asteraceae	3500-4000	Herb	Kupup
S. gossypiphora var. *liliputa*	Asteraceae	4300-5000	Herb	Chola E. Sikkim
S. laneana	Asteraceae	ca 4000	Herb	Sikkim
S. nimborum	Asteraceae	4000-5300	Herb	Sikkim
S. obscura	Asteraceae	-	Herb	Sikkim
S. pantlingiana	Asteraceae	ca 4000	Herb	Sikkim
Codonopsis affinis	Campanulaceae	ca 4000	Herb	Lachen
Lobelia terminalis	Campanulaceae	Up to 800	Herb	Foot hills
Rhododendron sikkimensis	Ericaceae	ca 3700	Shrub	Lachung
Primula pulchra	Primulaceae	4000-5000	Herb	Lachen, Dzongri
P. listeri	Primulaceae	3000-3300	Herb	Tonglu and Singalila ranges
P. glabra	Primulaceae	4300-5000	Herb	Sikkim
P. sikkimensis	Primulaceae	3600- 5000	Herb	Thangu
P. whitei	Primulaceae	3000-4800	Herb	Changu
Crawfurdia puberula	Gentianaceae	3000-3300	Herb	Yakla
Jaeschkea microsperma	Gentianaceae	3600-5600	Herb	Samdong
Gentiana glabrisuscula	Gentianaceae	-	Herb	Sikkim
G. sikkimensis	Gentianaceae	3300-4300	Herb	Sikkim
G. prainii	Gentianaceae	4300-5000	Herb	Sikkim
Swertia hookeri	Gentianaceae	4000-4300	Herb	Chungthang, Lachen
S. rex	Gentianaceae	-	Herb	Sikkim
Trigonotis caespitosa	Boraginaceae	ca 3300	Herb	Sikkim
Argyreia sikkimensis	Convolvulaceae	Up to 400	Climber	Sikkim Terai
Scrophularia sikkimensis	Scrophulariaceae	-	Herb	Sikkim
Chirita calva	Gesneraceae	1600-2100	Herb	Lachen
C. clarkei	Gesneriaceae	2100-2600	Herb	Lachen
C. primulacea	Gesneriaceae	600-1000	Herb	Sikkim
Persicaria glacialis	Polygonaceae	ca 4400	Herb	Lhonak
P. sibirica	Polygonaceae	ca 4900	Herb	Lhonak
Rheum globulosum	Polygonaceae	3900-5200	Herb	Lungnak La
Piper sikkimensis	Piperaceae	-	Climber	Sikkim
Litsea oreophila	Lauraceae	3000-3500	Tree	Lachung
L. sikkimensis	Lauraceae	3350-3650	Tree	Lachen, Kyongnosla
Elatostema treutleri	Urticaceae	ca 1500	Herb	Sikkim
Salix pseudocalyculata	Salicaceae	ca 3800	Shrub	Gamothang
S. radinostachya	Salicaceae	ca 2745	Shrub	Lachen

Phoenix rupicola	Arecaceae	ca 400	Tree	Rangpo
Juncus sikkimensis	Juncaceae	3600-4800	Herb	Lachen, Zemu, Kupup
Roscoea auriculata	Zingiberaceae	2130-3960	Herb	Lachung, Lachen, Lamteng, Chungthang
Acrochaene punctata	Orchidaceae	1500-1800	Herb	Sikkim
Agrostophyllum myrianthum	Orchidaceae	ca 3600	Herb	Teesta valley
Bulbophyllum yoksunense var. *Parviflorum*	Orchidaceae	1800-2400	Herb	Sikkim
Coelogyne treutleri	Orchidaceae	-	Herb	Sikkim
Corybas himalaicus	Orchidaceae	ca 3000	Herb	Lamteng, Lachen valley
Calanthe chloroleuca	Orchidaceae	1800-2400	Herb	Sikkim
C. herbacea	Orchidaceae	1200-1800	Herb	Sikkim
C. whiteana	Orchidaceae	ca 1800	Herb	Chungthang
Cymbidium gammieanum	Orchidaceae	Up to 2100	Herb	Sikkim
C. sikkimense	Orchidaceae	ca 1880	Herb	Lachen
C. whiteae	Orchidaceae	to 1750	Herb	Gangtok
Didiciea cunninghami	Orchidaceae	ca 3600	Herb	Lachen valley
Dendrobium pauciflorum	Orchidaceae	600-1200	Herb	Teesta valley
D. wardianum	Orchidaceae	750-1200	Herb	Deorali
Goodyera alveolatus	Orchidaceae	-	Herb	Sikkim
Habenaria comminsiana	Orchidaceae	ca 3300	Herb	Lachung valley
Liparis gamblei	Orchidaceae	1800-1950	Herb	Sikkim
Listera alternifolia	Orchidaceae	ca 3000	Herb	Lachen
L. dentate	Orchidaceae	ca 3900	Herb	Dzongri
L. longicaulis	Orchidaceae	ca 2100	Herb	Lachen valley
L. brevicaulis	Orchidaceae	ca 2700	Herb	Lachen valley
Malaxis saprophyta	Orchidaceae	ca 1800	Herb	Chungthang, Lachen
Nephelaphyllum sikkimensis	Orchidaceae	-	Herb	Sikkim
Zeuxine pulchra	Orchidaceae	ca 2250	Herb	Lachung valley
Taeniophyllum retrospiculatum	Orchidaceae	Up to 1500	Herb	Sub-trop. forest
Uncifera lancifolia	Orchidaceae	ca 1800	Herb	Rissisum
Cyathopus sikkimensis	Poaceae	ca 3300	Herb	Lachung valley
Isachne sikkimensis	Poaceae	ca 2300	Herb	Karponang, Lachung
Dendrocalamus sikkimensis	Poaceae	1200-1800	Shrub	Sikkim
Poa sikkimensis	Poaceae	3500-4700	Herb	Patang La, Sebu Valley

Table 2.12 Endemic species recorded from different parts of Sikkim

Species	Family	Altitude (m)	Located at	
Ranunculus skimmensis	Ranunculaceae	3,659	Thangu	North Sikkim
Berberis concina	Berberidaceae	2,735	Lachen	North Sikkim
Berberis umbellate	Berberidaceae	2,735	Lachen	North Sikkim
Podophyllum sikkimensis	Podophyllaceae	4,000	Thangu, Chopta	North Sikkim
Mahonia sikkimensis	Berberidaceae	3,659-4,000	On way to Dzongri, Yumthang	North Sikkim
Cotoneaster sikkimensis	Rosaceae	2,625	Lachung	North Sikkim
Rubus niveus var. *micranthus*	Rosaceae	2,625-3,659	Yumthang, Lachung	North Sikkim
Begonia satrapis	Bigoniaceae	1,800	Rangit, Sumbuk	South Sikkim
Pimpinella sikkimensis	Apiaceae	3,900	On way to Dzongri	West Sikkim
Pleurospermum sikkimense	Apiaceae	2,625	Lachung	North Sikkim
Angelica nubigena	Apiaceae	3,668-3,900	Menmoi Chho, Dzongri	East Sikkim, West Sikkim
Panax sikkimensis	Araliaceae	2,625	Lachung, Yuksom	North Sikkim, West Sikkim
Anaphalis hookeri	Asteraceae	2,735	Lachen	North Sikkim
Blumea sikkimensis	Asteraceae	1,585	Chungthang	North Sikkim
Cremathodium discoideum	Asteraceae	3,659	Yumthang, Lachung	North Sikkim
Lactuca cooperi	Asteraceae	4,000	Kupoop	East Sikkim
Ligularia dux	Asteraceae	3,659	Yumthang Valley	North Sikkim
Saussurea andersonii	Asteraceae	4,000	Kupup	East Sikkim
Lobelia terminalis	Campanulaceae	3,659	Yumthang Valley	North Sikkim
Mallus sikkimensis	Rosaceae	2,625	Lachung	North Sikkim
Rhododendron sikkimensis	Ericaceae	2,625	Lachung	North Sikkim
Primula sikkimensis	Primulaceae	3,659	Thangu, Dzongri	North Sikkim, West Sikkim

Primula cooperi	Primulaceae	1,290	Tong	North Sikkim
Crawfordia puberula	Gentianaceae	3,753	Tsomgo, Nathula	East Sikkim
Argyreia sikkimensis	Convolvulaceae	1,780	Yuksom	West Sikkim
Scrophularia sikkimensis	Scrophulariaceae	3,659	Yumthang	North Sikkim
Chirita calva	Gesneriaceae	2,009	Ravongla	South Sikkim
Piper sikkimensis	Piperaceae	-	South Sikkim	South Sikkim
Litsea sikkimensis	Lauraceae	2,735	Lachen	North Sikkim
Phoenix rupicola	Arecaceae	1,500	Rangpo	East Sikkim
Juncus sikkimensis	Juncaceae	3,659-4,000	Thangu, Kupup	North Sikkim, East Sikkim
Roscoea auriculata	Zingiberaceae	3,659	Lachen	North Sikkim
Calanthe herbacea	Orchidaceae	1,400	Selem	North Sikkim
Cymbidium gammieanum	Orchidaceae	3,659	Dzongu, Yumthang Valley	North Sikkim
Dendrocalamus sikkimensis	Poaceae	-	South Sikkim	South Sikkim
Poa sikkimsnis	Poaceae	3,659	Yumthang	North Sikkim

2.7 THREATENED FLORA

In various parts of Sikkim, day by day populations of many plant species are becoming rarer due to increasing human population pressure and decrease in forest area. The forests are being cleared for various developmental activities like road building, dam construction, establishment of colonies, for plantation of cshcrops and industrial developments. More than 50 species of plants from Teesta basin in Sikkim have been included in threatened, endangered, vulnerable or rare categories as defined by IUCN (International Union for the Conservation of Nature) and compiled by Nayar and Sastry (1987, 1988, 1990) (Table 2.13). The list includes plants from higher groups only, and the status of the lower group like bryophytes, lichens, fungi and algae are still not known. According to Nayar and Sastry (1987, 1988, 1990), 13 species of plants are under the endangered category, two of them *viz*. *Zeuxine pulchra* (Orchidaceae) and *Dennstaedtia elwesii* (Dennstaedtiaceae) in all probability have already disappeared from Sikkim Himalaya. Around 10 species of plants are in vulnerable category and 18 species have become rare. Six species of plants have indeterminate status (Table 2.13).

2.7.1 Present status of some endangered Taxa

In the present study, attempts were made to know their status from herbaria at Gangtok and Kolkata. The specimen of most of these species could not be found at these herbaria. The herbarium collections of about

Table 2.13 Threatened flowering plant species in Sikkim

Species	FAMILY	Fl. & Fr.	Altitude (m)	Habitat	Distribution in Sikkim	Status
Acer hookeri var. *majus*	Aceraceae	Apr-Nov	600-1500	Sub-tropical hill forest	Lachung-Rishi and Richingpong	Endangered
Aconitum ferox	Ranunculaceae	Aug-Nov	3300-5000	Moist sub-alpine forests among rhododendron scrubs	Menmoi Chho	Vulnerable
Acronema pseudotenera	Apiaceae	Aug-Sep	2500-4500	Alpine meadows	North Sikkim, Yumesamdong	Indeterminate
Angelica nubigena	Apiaceae	Aug-Sep	ca 3800	Open places along stream courses	Yakla, Chola	Indeterminate
Aphyllorchis parviflora	Orchidaceae	Jun-Jul	3600-3700	Grows on humus rich black soils under forest canopy of *Quercus*	Lachen, Yumthang, Lachung	Rare
Arenaria thangoensis	Caryophyllaceae	Jun-Jul	4200-4500	Alpine meadows	Thangu, Chugya	Vulnerable
Athyrium duthei	Athyriaceae	-	-	Terrestrial, growing along the margins of forests in semi-shaded streams, river or water courses	-	Vulnerable
Begonia rubella	Begoniaceae	Jun-Sep	600-1800	Moist shaded banks	-	Rare
Begonia satrapis	Begoniaceae	Aug	Below 700	Between wet rock faces in shaded and damp forest slopes	Rangit, Tashiding Reserve forest	Rare
Begonia scutata	Begoniaceae	Sep	1000-1500	Open degraded mixed forest near agriculture fields	Khamdong, Legship, Sikkim	Rare
Calamus inermis	Arecaceae	Mar-Oct	600	Moist tropical forests along shaded streams in ravines	Sikkim Terai	Endangered
Calanthe alpina	Orchidaceae	Jul-Aug	2000-3300	Shaded places near streams in temperate/sub-alpine forest	Lachen, Zemu	Rare

Calanthe mannii	Orchidaceae	Aug	ca 2050	On rock boulders and along the streams in *Quercus* forest	Rungbe, Lachen	Rare
Carex kingiana	Cyperaceae	Jul-Aug	ca 1000	Not known	Phodong	Indeterminate
Ceropegia hookeri	Asclepiadaceae	Jul-Aug	2000-3000	Sub-alpine grassy slopes	Lachen	Endangered
Ceropegia lucida	Asclepiadaceae	Jul-Aug	1900	Open grassland/scrub forest	Rayong Khola; on way to Lachung	Endangered or Possibly extinct
Christella clarkei	Thelypteridaceae	-	1500-2500	-	-	Vulnerable
Christopteris tricuspis	Polypodiaceae	-	Up to 900	Not known	Sikkim Terai	Indeterminate
Cissus spectabilis	Vitaceae	Jun	ca 500	Tropical damp forest	Sikkim Terai	Endangered
Codonopsis affinis	Campanulaceae	Jul-Sep	1830-3335	Temperate Himalaya	Lachen	Rare
Coelogyne truetleri	Orchidaceae	-	-	Not known; probably epiphytic	Not known	Possibly extinct
Cotoneaster simonsii	Rosaceae	Aug-Sep	1545-3152	Restricted to open scrub forest	Lachung	Indeterminate
Cyclogramma squamaestipes	Thelypteridaceae	-	ca 1500	Along streams in sub-tropical forests	Simonbong	Rare
Cymbidium eburneum	Orchidaceae	Mar-Apr	1000-1500	Epiphyte found growing in sub-tropical forest	Teesta valley	Vulnerable
Cymbidium hookerianum	Orchidaceae	Feb	1700-2500	Epiphyte found growing on *Quercus* trees in temp. forest	Gangtok, Deorali	Vulnerable
Cymbidium whiteae	Orchidaceae	Nov	1500-1700	Epiphyte found growing on *Schima* trees	Gangtok, Rumtek	Endangered
Cypripedium elegans	Orchidaceae	Jun-Aug	3300-4200	Shaded and damp alpine slopes	Lachen valley	Rare
Cypripedium himalaicum	Orchidaceae	Jun-Jul	3000-4300	Open alpine meadows	Lachen, Thangu	Rare

Dennstaedtia elwesii	Dennstaedtiaceae	-	ca 2700	Open hill slopes	Lachen valley	Possibly extinct
Didiciea cunninghamii	Orchidaceae	Jul	ca 4000	In sub alpine and alpine Himalaya	Lachen valley	Endangered
Juncus sikkimensis	Juncaceae	Aug-Sep	4000-4500	Alpine meadows	Chopta valley	Rare
Lactuca cooperi	Asteraceae	Aug-Sep	ca 5000	Open alpine meadows	Kupup	Endangered
Lagerstroemia minuticarpa	Lythraceae	Aug-Sep	1200-1500	Subtropical forest	Teesta valley	Rare
Livistona jenkinsiana	Arecaceae	-	Up to 1000	Tropical moist forest	Terai foot hills	Endangered
Lloydia himalensis	Liliaceae	May-Aug	3695-3810	On rock cliffs and alpine meadows	Dzongu, Chhangu	Rare
Mecodium levingei	Hymenophyllaceae	-	2100-2600	On moist rocks, tree trunks	Lachen	Rare
Nardostachys grandiflora	Valerianaceae	Jul-Sep	3000-5000	On boulders or rocks of alpine meadows	Samdong	Vulnerable
Ophiorrhiza lurida	Rubiaceae	May-Nov	300-1500	On damp and shady mountain slopes	Dikchu, Rangpo Chhu	Rare
Oreopteris elwesii	Thelypteridaceae	-	2700-4200	Open hill slopes	Lachen	Rare
Panax pseudo-ginseng	Araliaceae	Aug-Sep	2900-4000	Temperate conifer-oak-rhododendron forest	Zema, Kalep, Lachung, Chhangu	Vulnerable
Paphiopedilum fairrieanum	Orchidaceae	Sep-Oct	1400-2200	On moss covered boulders in oak forest	Rangit river	Endangered
Paphiopedilum venustum	Orchidaceae	Sep-Oct	to 1200	Moist and damp areas, associated with *Selaginella*	Tropical zone	Vulnerable
Phoenix rupicola	Arecaceae	Sep-Nov	ca 450	In rocky slopes	Teesta valley	Rare
Picrorhiza kurrooa	Scrophulariaceae	Oct-Dec	3300-5000	Rocky damp alpine slopes	Samdong	Vulnerable
Pimpinella tongloensis	Apiaceae	Oct-Dec	3500-4500	Not known	Singalila range	Endangered
Pimpinella wallichii	Apiaceae	Oct-Nov	ca 1450	Not known	Southern districts	Endangered
Pternopetalum	Apiaceae	Aug-Sep	3000-3500	Alpine meadows	Kupup	Indeterminate

radiatum						
Rhopalocnemis phalloides	Balanophoraceae	Jul-Sep	2000-2500	It grows either solitary or in clusters on roots in cool temperate forest	Not known	Rare
Zeuxine pulchra	Orchidaceae	Aug	ca 2250	Cool and shaded rocky area in temperate forest	Lachung Valley	Endangered or extinct

Plant species threatened in Sikkim flora but not mentioned in Red Data Book of India

Podophyllum hexandrum	Podophyllaceae	Feb-Aug	2400-4500	Alpine meadows	Menmoi Chho, Thangu	-
Ephedra gerardiana	Ephedaceae	May-Aug	4000-5000	Alpine meadows	Thangu, Chhangu	-
Polygonatum cirrhifolium	Liliaceae	Aug-Sep	2000-2800	Open temp and sub-alpine forest slopes	Lachen	-
Malus sikkimensis	Rosaceae	Apr-May	2500-2800	Open temperate forest	Lachen, Lachung	-
Fritillara cirrhosa	Liliaceae	Aug-Sep	4000-4500	Open alpine meadow	Thangu	-
Pandanus nepalensis	Pandanaceae	Aug-Sep	Up to 1000	Tropical and subtropical forest	Rangpo, Singtam, Temi, Sangklang	-
Aristolochia griffithii	Aristolochiaceae	Apr-May	1800-2900	Temperate forest	Lachung	-
Fraxinus floribunda	Oleaceae	Apr-May	1200-2700	Subtropical and temp. broad leaved forest	Selem, Mangan, Chungthang	-
Rhododendron sikkimensis	Ericaceae	Mar-May	ca 2700	Temperate open scrub forest	Lachung	-
Taxus baccata ssp. *wallichiana*	Taxaceae	Mar-May	2100-3400	Temperate broad leaved forest	Lachung	-
Rheum acuminatum	Polygonaceae	Aug-Sep	3600-4300	Alpine meadows	Yumthang, Menmoi Chho	-
Swertia chirayita	Gentiniaceae	Aug-Sep	2200-2900	Open forest slopes especially shaded areas	Chhaten, Lachen	-
Dioscorea deltoidea	Dioscoreaceae	Apr-May	1250-1800	Subtropical and temp. forest	Yuksom, Dikeeling	-
Jatropha curcas	Euphorbiaceae	Mar-Jun	Up to 1000	Tropical/ subtropical forest border; cultiv.	Legship, Gangtok, Singtam	-

Table 2.14 Threatened plant species recorded from Sikkim Himalaya during the survey

Name of the species	Family	Altitude (m)	Locations	District
Aconitum ferox	Ranunculaceae	3668	Menmoi Chho	East Sikkim
Angelica nubigena	Apiaceae	3668	Dzongri, Menmoi Chho	North Sikkim, East Sikkim
Arenaria thangoensis	Cryophyllaceae	3659	Thangu	East Sikkim
Athyrium duthei	Athyriaceae	1585-2713	Lachen, Chungthang	North Sikkim
Begonia satrapis	Begoniaceae	1800	Rangit, Soombuk	South Sikkim
B. scutata	Begoniaceae	-	Khemdong	South Sikkim
Juncus sikkimensis	Juncaceae	3659-4000	Kupup, Thangu	East Sikkim, North Sikkim
Lactuca cooperi	Asteraceae	4000	Kupup	East Sikkim
Lagerstroemia minuticarpa	Lythraceae	-		South Sikkim
Lyoydia himalensis	Liliaceae	3049	Barsey	West Sikkim
Mecodium levingel	Hymenophyllaceae	2735	Lachen	North Sikkim
Nardostachys grandiflora	Valeriaceae	3659	Thangu	North Sikkim
Panax pseudoginseng	Araliaceae	26-2735	Lachen, Lachung	North Sikkim
Phoenix rupicola	Recaceae	1500	Rangpo	East Sikkim
Picrorhiza kurrooa	Scropholariaceae	4625	Yumesamdong	North Sikkim
Carex kingiana	Cyparaceae	1908	Phodong	North Sikkim
Ceropegia hookeri	Asclepiadaceae	2735	Lachen	North Sikkim
C. lucida	Asclepiadaceae	2625	Lachung	North Sikkim
Cissus spectabilis	Vitaceae	1700	Legship	North Sikkim
Cotoneaster simonsii	Rosaceae	2625	Lachung	North Sikkim

20 threatened species could be found in Central National Herbarium (CN), Kolkata and BSHC at Gangtok. At BSHC, Gangtok, the specimen of only two species *viz*. *Lactuca cooperi* (Asteraceae) and *Ophiorrhiza lurida* (Rubiaceae) could be found, which were collected around 1998-99. After the extensive surveys in the different parts of Sikkim and at least 21 species mentioned in the category of threatened, could be located in the field (Table 2.14). Two species of *Begonia, B. satrapis* and *B. scutata* belonging to rare category (Nayar and Sastry, 1990) were found growing in Tashiding (660 m), Gyalzing (400 m), Legship and Khamdong village area in South Sikkim. However, at all these places the populations of these species were very small, ranging from 4 to 10 plants only. These were found in wet and shaded conditions in association with *Begonia picta, Selaginella aitchisonii, Didymocarpus pedicillatus, Impatiens racemosa* and *Arenaria neelagheriensis. Ceropegia*, a genus in which around 28 species are endemic to India and 30 species from India are mentioned in threatened category (Nayar, 1996, Nayar and Sastry 1987, 1988), two species of it, *C. hookeri* and *C. lucida* found in Teesta basin are reported as endangered by Nayar and Sastry (1988). *C. lucida* has been mentioned as extinct by Nayar and Sastry (1988). However, in 2002-2003 some plants of these two species were collected by our team of scientists from Lachen and Lachung regions in North Sikkim. In addition, *C. hookeri* from Lachen (2,700 m) was also collected. The species was first reported from Sikkim Himalaya by Hooker (1885) and later it was collected from Zemu valley, Lingtham, Rangrang Khola, Bichhu and Chungthang areas. The population of *C. hookeri* at Lachen was comprised of only 8-10 plants growing along with

grasses. Another species, *C. lucida* was also spotted at Lachung. *C. lucida* reported for the first time from Sylhet by Wallich (1831) and in Sikkim it was reported from Rayong Khola in Rangit valley by King, (1874). The populations of *Panax pseudoginseng* (vulnerable,), *Nardostachys grandiflora* (vulnerable), *Aconitum ferox* (vulnerable) (see Plates 2.2) and *Picrorhiza kurrooa* (vulnerable, Plate 2.1d) also are under severe stress as these are collected from the wild for their medicinal use by local people (see Table 2.14). *Picrorhiza kurrooa* and *Nardostachys grandiflora* of alpine region were found at Yumesamdong and Samdong regions (see Table 2.14). *Panax pseudoginseng* was found growing in Lachen, Samdong, Kalep, Zema valley, Lachung valley, Kyongnosla and Pangulakha area (see Table 2.14). The number of individuals in each population in all these areas, ranged from 8 to few hundred plants only. Local people collect the tubers of this species for various medicinal uses. The plant is slow growing and mainly propagated through rhizomes and tubers. Due to its commercial importance there is a need to develop the cultivation practices and also its natural habitat to be protected.

Other threatened species occurring in Teesta basin are: *Juncus sikkimensis* (rare), *Arenaria thangoensis* (vulnerable), *Lloydia himalensis* (rare), *Cotoneaster simsonii* (indeterminate) and *Acer hookeri* (endangered) and these are found in alpine regions above 2,500 m and some of these species are endemic to Sikkim Himalaya (see Tables 2.14 and 2.15). *Juncus sikkimensis* was found in North Sikkim at Chhoptha and near Kupup and Menmoi Chho lakes in East Sikkim. Very little information is available about this species. *Arenaria thangoensis*, also a little known species of Sikkim, was found at

Thangu in North Sikkim above 4,000 m. The species was found growing in association with *Arenaria ciliaris, Juncus sikkimensis, Meconopsis, Primula* sp. and *Rhododendron anthopogon*. In Lachung region, some populations of *Acer hookeri* were found growing in association of *Corylus, Rhododendron, Prunus* and *Tsuga*. *Lilium himalensis* of rare category (Nayar and Sastry, 1988) was observed growing in Yumthang and Lachen valleys and *Cotoneaster simsonii* was also found at Lachung. Some of the species have very narrow niche with *Podophyllum hexandrum,* is extensively collected in Sikkim for medicinal purposes, is found in Thangu-Chhoptha region in North Sikkim (see Plate 2.1a). Only few plants could be seen in Menmoi Chho area.

There is an urgent need to know the status of these threatened plant species and develop the strategy for the conservation of these species, particularly those species, which are extracted by people for medicinal and various other uses.

2.7.2 DISTRICT-WISE DISTRIBUTION OF THREATENED SPECIES

It is really a matter of concern to have more than 60 species at the brink of extinction from such a small area like Sikkim Himalaya (total geographic area is 7096 sq km). Increase in human population and various developmental activities are the main reason for the habitat loss of these threatened species. Most of these species are restricted to places where human interference is least or the habitat of these plants are inaccessible to humans as well as for animals, those feeding on these plants. In the present survey, most of the threatened species were found in North and East Sikkim districts (see Fig. 2.2).

More than 50 per cent species were found in North Sikkim. Then it was East Sikkim where nearly 30 per cent species were found in West and South Sikkim, one and two species, respectively were found. *Begonia satrapis* and *B. scutata* are the two threatened species which are now restricted to Ravongla region of South Sikkim. Few plants *Lloydia himalensis* were observed in West Sikkim. Lachen, Thangu, Lachung, Yumthang and Zemu area are some of the important regions in North Sikkim above Chungthang, where maximum threatened species were found in the present survey (Table 2.14). In East Sikkim above Kyongnosla are the main areas where maximum number of threatened species were found. Kupup, Nathula, Menmoi Chho and Tsomngo in East Sikkim comprise the for threatened and rare plants. The species like *Aconitum ferox* and *Lactuca cooperi* were found only in East Sikkim. *Lactuca cooperi* is endemic to Sikkim and it appears that it is the last survival abode of this species. (Table 2.15).

2.7.3 Threatened Endemic Plant Species

There are around nine species, which are endemic as well as threatened in the present Sikkim state (Table 2.15). During the present surveys only six species out of these nine species could be found. Species like *Zeuxine pulchra* are now considered extinct. In 1898 King and Pantling had collected two specimens of this species from Lachung in North Sikkikm. Later in 1974, the species was also found in Khasia Hills (Nayar and Sastry 1987). Since then, it has not been reported from anywhere and all efforts to locate, the plant in the wild failed. It has been reported that the genus *Zeuxine* is characterized by highly delicate terrestrial plants with very specific habitat conditions. Even the slight alteration, degradation, clearing of forest would bring the plants to extinction. Like most of the epiphytic species of orchids this species is also not adaptable or hardy (Nayar and Sastry, 1987). *Cymbidium whiteae* and *Didiciea cunninghamii* are two other orchid species, which are endemic as well as threatened in Sikkim Himalaya (Nayar and Sastry 1987). *Cymbidium whiteae* was discovered in Gangtok at 1,700 m by Mrs. Claude White and named after her (Nayar and Sastry 1987). The original habitat of the species has been converted in to human settlements. However, the species has sporadically been seen in Rumtek area, where the area is under agriculture. Despite the extensive surveys in Rumtek area, this species could not be found. The species, *Didiciea cunninghamii* has now also been reported from Garhwal Himalayas (Nayar and Sastry 1987). However, its authenticity is yet to be established. *Acronema pseudotenera* is another endemic as well as threatened species from Sikkim Himalaya. The species has been collected only once in 1892 by Gammie from Momay Samdong (Nayar and Sastry 1988). In spite of extensive efforts in North Sikkim no specimen could be found in this area. Other five species, which are endemic as well as threatened, were collected from different parts of Sikkim. *Begonia satrapis* was found in the South Sikkim in Rangit area. Nayar and Sastry (1990) mentioned that the specimens of *B. satrapis* were collected before 1914 by C. B. Clarke, Ribu and Rhomo, G. H. Cave and I. H. Burkill from Rangit valley. In the present survey also, this species has been collected from Rangit valley and Soombuk in South Sikkim. The plants were located at few spots only with 5 to 10 individuals attached to the rocks.

Table 2.15 Endemic as well as threatened plant species of Sikkim Himalaya

Species	Family	Distribution in Sikkim (earlier reports)	Status	Present Survey 2002- 2006		Last Collected
Acronema pseudotenera	Apiaceae	Samdong	Indeterminate	Not observed	Endemic to Sikkim	1892, North Sikkim
Angelica nubigena	Apiaceae	Yakla, Chola	Indeterminate	Menmoi Chho, Dzongri	Endemic to Sikkim, Chola, Yakla	1849, North East Sikkim, Chola, Yakla
Arenaria thangoensis	Caryophyllaceae	Lachen, Yumthang, Lachung	Vulnerable	Thangu	Endemic to Sikkim,Thangu, Chugya	1912
Begonia satrapis	Begoniaceae	Rangit, Tashiding	Rare	Sombuk, Rangit	Endemic to Sikkim, Rangit	1914, Rangit
Cymbidium whiteae	Orchidaceae	Gangtok, Rumtek	Endangered	Not observed	Endemic to Sikkim, Gangtok	
Didiciea cunninghamii	Orchidaceae	Lachen Valley	Endangered	Not observed	Endemic to Sikkim (also mentioned from Garhwal)	
Juncus sikkimensis	Juncaceae	Chhopta Valley	Rare	Thangu, Kupup	Endemic to Sikkim	
Lactuca cooperi	Asteraceae	Kupup	Endangered	Yumesamdong, Kupup	Endemic to Sikkim	1913
Zeuxine pulchra	Orchidaceae	Lachung Valley	Endangered or Extinct	Not observed	Endemic to Sikkim, Lachung Valley	1974

2.7.4 Economic Importance of Threatened Species

Many of these species mentioned in threatened category are used for various purposes and directly harvested from the wild for the use. Species like *Panax pseudoginseng*, *Begonia rubella*, *Picrorhiza kurrooa* and *Nardostachys grandiflora* are used for medicinal purposes (Table 2.16). In the field we observed that rhizomes of *Panax pseudoginseng*, *Picrorhiza kurrooa* and *Nardostachys grandiflora* are collected for local use as well as for the export. None of these species are cultivated for their rhizomes or other parts of use. Some species, mostly of Orchidaceae, are of ornamental value. There are around nine endemic as well as threatened orchid species, which have beautiful flowers and foliage. *Begonia satrapis*, *Lilium himalensis* and *Phoenix rupicola* are other species which also have ornamental value and collected from the wild. The endosperm of *Livistona jenkinsiana*, which is an endangered species, is eaten by local people and affects the seed development. It is now required to ban the use of these species for any purpose. People should be encouraged to cultivate these species for their use rather than collect from the wild.

Table 2.16 Economic Importance of some of the endemic and threatened species of Sikkim Himalaya

Species	Economic Use
Endemic as well as Threatened Species	
Angelica nubigena	Used in flavouring sweetmeats and bevearages, roots used as a cardiac stimulant by the local men
Coelogyne truetleri	Ornamental value
Begonia satrapis	Ornamental value

Cymbidium whiteae	Ornamental value
Zeuxine pulchra	Very high ornamental value due to dark velvety brown leaves having a white mid-rib
Threantend Species	
Aconitum ferox	Used for curring many diseaes and also used as arrow poison
Aphyllorchis parviflora	Saprophytic orchid, is of biological interest
Begonia rubella	Medicinally important
Calamus inermis	Used for furniture making, also used as baton stick
Calanthe alpine	Ornamental value
C. mannii	Ornamental value
Cymbidium hookerianum	Ornamental value
Cypripedium elegans	Ornamental value
C. himalaicum	Ornamental value
Livistona jenkinsiana	Endosperm is edible, ornamental value
Lloydia himalensis	Ornamental value
Nardostachys grandiflora	Rhizomes used as medicine and perfumery
Panax pseudoginseng	Medicinal value
Paphiopedilum fairrieanum	Ornamental value
P. venustum	Ornamental value
Phoenix rupicola	Ornamental value
Picrorhiza kurrooa	Rhizomes used for medicine

2.7.4.1 Case study of a threatened species; *Panax pseudoginseng*

Panax pseudoginseng of family Araliaceae is distributed in Eastern Himalaya and South China. In India, this species has been declared as threatened and put in vulnerable category (Nayar and Sastry, 1990). The rhizomes of the plant are used for various medicinal uses and in North East Himalaya it is considered equivalent to *P. ginseng* of Korea and China. In India, this species is found in Sikkim, Meghalaya, Assam, and Arunachal Pradesh. In Sikkim, this species has been reported from Lachung and Lachen Valley in North

Sikkim and Tsomgo and Kyongnosla area in East Sikkim (Table 2.17). The plant is perennial, rhizomatous and slow growing. In Sikkim its rhizomes are extracted from the wild for medicinal use. With the result, population of the species is decreasing day by day (Table 2.17). A census of this species was done in the entire Sikkim State lasting three years for its occurrence in the wild. In 2005 around 10678 individuals of *P. pseudoginseng* from entire Sikkim could be documented and recorded. Maximum number of individuals (more than 8000) were recorded from North Sikkim followed by around 1500 individuals in West Sikkim. In East Sikkim only 777 individuals were recorded in the wild (Table 2.17). From South Sikkim not a single individual of *P. pseuoginseng* could be located. Maximum number of individuals (around 40%) were in vegetative stage followed by at seedling stage (31.96 %) at these places. Less than 30 per cent of individuals were observed at flowering stage. At seed production stage, only 15 to 20 per cent individuals were found. Human interference and activities like clearing of forest and extraction of rhizomes were found to be the major causes of rapid decrease in the population of this plant from Sikkim Himalaya. Within one year (2004 to 2005), there was 9.28 per cent decrease in the population of *P. pseudoginseng*, which is mainly due to harvesting of the rhizomes from mature plants of more than 15 years old.

The case study of *P. pseudoginseng* clearly indicates that lot more attention and efforts are required to make people aware of vulnerability of species like these and any illegal and unscientific exploitation of these kind of species from the wild should be checked and discouraged. It is, therefore, very essential to involve the local people in conservation programmes and make them aware about vulnerability of these plant species in their region.

2.8 RHODODENDRONS

Sikkim is considered as second home of rhododendrons in India after Arunachal Pradesh as 36 species of rhododendrons are found in Teesta basin with several forms and varieties. Hooker (1849) described 34 species of rhododendrons. Pradhan and Lachungpa (1990) have also given a good account of these plants from Sikkim. Owing to their rich diversity in Sikkim, two sanctuaries have been notified i.e. Shingba in North Sikkim and Barsey in West Sikkim for the conservation and protection of the diversity of this genus.

The genus *Rhododendron* has very wide ecological amplitude and is distributed in an altitudinal range of 1,800 to 4,800 m (Table 2.18). *R. nivale* is found up to 4,800 m growing on alpine slopes exposed to the bitter cold, wind and scorching sun rays. However, most of the species are found between 2,500 and 4,500 m. About eight species of *Rhododendron* are either epiphytes or lithophytes. *R. leptocarpum*, *R. camelliiflorum* and *R. lindleyi* are primarily epiphytic but are also be found growing as lithophytes. *R. maddenii* is however, usually lithophyte growing among sedges and rocky scrubs on steep slopes above Chungthang at the confluence of Lachen Chhu and Lachung Chhu in North Sikkim. *R. vaccinioides* grows under moss covered trees and rocks in deep shade. *R. dalhousie* and *R. lindleyi*

Tabel 2.17 Census of *Panax pseudoginseng* individuals in Sikkim Himalaya (2004-2005)

Location	Altitude (m)	No. of individuals at different stages							
		2004				2005			
		Flowering	Vegetative	Seedling	Total	Flowering	Vegetative	Seedling	Total
EAST SIKKIM									
Tsomgo region									
Laghep	3278	46	18	32	96	19	21	9	49
Rai-limbo dara	3489	18	2	5	25	3	4	1	8
Rongchu nala dara	3531	126	23	69	218	41	38	15	94
Pangolakha region									
Pangolakha	3043	18	5	43	66	5	35	13	53
NORTH SIKKIM									
Lachen region									
Tsudatsu	2675	8	34	56	99	8	15	8	30
Nyankha	2712	17	30	14	61	8	22	18	48
Gangep phu	2887	36	41	32	109	20	34	17	71
Thumbuk	3252	77	67	148	292	60	60	41	161
Samdong	3520	209	277	251	737	225	473	355	1053
Lower Kalep	3689	39	31	36	106	13	22	11	46
Upper Kalep	3789	89	149	230	468	45	158	157	360
Lachung region									
Thomchi	2695	41	55	16	112	18	42	47	97
Tazeychen	2508	26	13	4	43	29	15	9	53
Teeling	2673	36	26	22	84	53	33	20	106
Dombang	3110	133	60	56	249	135	120	74	329
Chuyum	3397	67	21	18	106	47	25	14	86
Yumthang	3532	39	32	19	90	34	16	11	61
Giguphya	3537	97	26	13	136	94	25	11	130
Bakhumpchen	3599	41	67	51	159	16	76	27	119

are found on oaks and magnolias and also on large boulders in association with ferns, orchids and other plants. *R. pendulum* is found on the trees of *Abies densa* and huge rocks on northern aspects. *R. virgatum* is found on fresh exposed slopes in shady areas in Chungthang, Lachen and Lachung in association with *Drosera* and *Primula* species and are barely 10-15 cm in height. The plants of *R. anthopogon* and *R. lepidotum* in alpine regions in North Sikkim form large thickets along the banks of rivers. *R. ciliatum* is found growing on wet moss laden boulders on open marshy grounds in association with *Primula* and *Sphagnum* species in Yakchey above Lachung.

Table 2.18 Rhododendron species of Sikkim

Sl. No.	Species	Vern. Name	Habit	Altitude (m)	Distribution
1.	*Rhododendron aeruginosum*	Nilo-pate Chimal	Shrub	4500-5000	Endemic, Lachung and Yumthang
2	*R. anthopogon*	Dhupi Gurans	Shrub	3000-5500	Bakhim, Dzongri, Lachen, Yumthang
3.	*R. arboreum*	Lali Gurans	Tree	1700-3400	Zemu valley
4.	*R. baileyi*	Bailey ko Chimal	Shrub	3000-4800	Yumthang
5.	*R. barbatum*	Lal Chimal	Tree	3000-3700	Lachen
6.	*R. camelliiflorum*	Chia-phule Gurans	Epiphytic Shrub	2500-3500	Sikkim
7.	*R. campanulatum*	Nilo Chimal	Tall shrub	3300-4500	Zemu valley Yumchho La, Dzongri
8.	*R. campylocarpum*	Bango-phale Gurans	Shrub	3200-4000	Zemu
9.	*R. ciliatum*	Junge Chimal	Lithophytic Shrub	3000-3800	Lachen, Lachung
10.	*R. cinnabarinum*	Sao chimal	Shrub	1900-4000	Sikkim
11.	*R. campylocarpum*	Bango-phale Gurans	Shrub	3200-4000	Sikkim
12.	*R. dalhousiae*	Lahre Chimal	Epiphytic Shrub	1500-2500	Sikkim

13.	*R. decipiens*	Jhukane korling	Small tree	3300-3800	Lachung
14.	*R. edgeworthii*	Edgworth ko Chimal	Epiphytic	2400-4000	Lachen
15.	*R. fulgens*	Chimal	Small tree	4000-5000	Sikkim
16.	*R. glaucophyllum*	Takma Chimal	Shrub	2700-4000	Lachen, Lachung,
17.	*R. grande*	Patle Korlinga	Tree	2000-3000	Chungthang, Lachen, Lachung
18.	*R. griffithianum*	Sito chimal	Tree	2000-3200	Sikkim
19.	*R. hodgsonii*	Glabi Korlinga	Tree	3000-4000	Lachen, lower Zemu valley
20.	*R. lanatum*	Bhutle Gurans	Small tree	2000-4000	Nathula, Dzongri, Chola
21.	*R. lepidotum*	Bhale Sunpate	Shrub	2500-4500	Sikkim
22	*R. leptocarpum*	Jhiophale Gurans	Epiphytic Shrub	3000-3500	Choka village, Dzongri
23.	*R. lindleyi*	Sao lahre Chimal	Epiphytic Shrub	2000-3000	Sikkim
24	*R. maddenii*	Maj. Madden ko Chimal	Shrub	2500-4000	Chungthang
25	*R. nivale*	Hiun Gurans	Shrub	4500-6000	Sikkim
26.	*R. niveum*	Hiun-pate Gurans	Shrub	3000-3800	Lachen, Lachung Chola, Yumthang
27.	*R. pendulum*	Juhuniae Chimal	Epiphytic Shrub	3300-4000	Yakchey and Phuni between Lachung and Yumthang
28	*R. pumilum*	Purke Gurans	Shrub	3500-4500	Zemu, Lhonak and Yumthang
29.	*R. setosum*	Tsallu Gurans	Shrub	3000-5500	Sikkim
30.	*R. sikkkimense*	Sikkimae Gurans	Tree	ca 2700	Phuni, Lachung
31.	*R. thomsonii*	Dr. Thomson Gurans	Shrub	3300-4500	Sikkim
32.	*R. triflorum*	Pahenle Chimal	Shrub	2300-4000	Sikkim
33.	*R. vaccinioides*	Khiaune pate gurans	Epiphytic Shrub	2400-3000	Lachen, Lachung, Nathula
34.	*R. virgatum*	Hanginae Gurans	Shrub	2500-3300	Chungthang, Lachen,

					Lachung
35.	*R. wallichii*	Dr. Wallich ko chimal	Shrub	4000-4500	Lachung, Yumthang
36.	*R. wightii*	Dr. Wight ko Gurans	Small tree	3500-4500	Sikkim

Shingba Rhododendron Sanctuary in North Sikkim has the largest number of rhododendron species in Teesta basin. Barsey Rhododendron Sanctuary is another area rich in diversity of rhododendrons.

2.8.1 Important Uses of Rhododendrons in Sikkim

Many of these rhodhodendron species have various uses for the local people ranging from landscaping to making household implements, for religious purposes to medicinal uses. The most common use of these species by local people is for fuel. The wood of most of these species is used for wood. *R. arboreum* is most common species extensively used for fuel in Lachung and Yumthang region. The leaves of *R. anthopogon* are mixed with *Juniperus* species provide incense widely used in Buddhist monastries. This plant is called 'Palu' by Sikkimese and Tibetian people. The leaves and flowers of some species are used for the preparation of decoction and juice to treat various diseases and ailments. Like the decoction from the leaves of *R. maximum* are used to treat rheumatism. However, leaves of most of these species contain phenolic compounds, which have poisonous properties causing slow pulse, lowering of blood pressure progressive paralysis and death (Tiwari and Chauhan 2006). The flowers of *R. arboreum* are used to brew a wine, called Rhodododendron Wine' in Maney, Bhajyang, Meghma, Tonglu and Sandakphu. The fresh prepared wine is pleasant and prevent high altitude sickness. The vegetative parts of *R. thomsonii* are highly poisonous. The boiled extract of leaves and other vegetative parts is used as natural insecticides in the Lachung region (Tiwari and Chauhan 2006). The leaves of *R. campanulatum* are exported to plains, where these are grouped up with tobacco and used as snuff, which is said to be useful in cold. The Lamas of Sikkim use the flowers of *R. cinnabarinum* for making jams and local people of Lachen and Lachung fry corolla of this plant to a tasty delicacy. The wood of some of these rhododendron species is also used for making various implements of domestic and weapon use. Fine and hard wood of *R. arboreum* and *R. hodgsonii* is used in making Khukari handles, pack saddles, gift boxes, gun stocks, spoons and cups.The trees of *R. fulgens, R. falconeri* and *R. hodgsonii* have manifold uses in North Sikkim. The rough leaves are used in packaging fruits, vegetables, yalk butter and cheese. Tiny leaves of *R. nivale* have fragrance that can be used for aesthetics. The plants of *R. pendulum* are the host for caterpillar of butterflies. This species is the first to colonize the sheltered rock at alpine region of Sikkim Himalaya. The plants also help in the prevention of erosion. All the rhododendron species of Sikkim have the potential economic value, which can be exploited for the well being of the local people on sustainable use.

2.8.2 Conservations Measures for *Rhododendron* Species

Recently Tiwari and Chauhan (2006) studied the status of *Rhododendron* species in Sikkim. More than fifty per cent species of *Rhododendron* are mentioned in different categories of threats (Table

2.19). The species like *R. aeruginosum, R. baileyi, R. ciliatum, R. cinnabarinum, R. pendulum* are endemic to Sikkim and adjoining areas of Nepal, South Tibet and Bhutan. Many of these species have been mentioned as acutely localized in their distribution and number of individuals in each species has been recorded as few to extremely few. Due to ignorance of local people more than 20 per cent species (9 species) are now either at the stage of endangered, rare or vulnerable in their natural habitat. Increase in the various developmental activities in the higher altitude regions of Sikkim, is causing the habitat loss of these species. There may be numerous biological reasons also for the decrease in the population of these species but anthropogenic activities are more pronounced than any other factors.

Sikkim government has rightly declared two sanctuaries, Barsey in west and Singba in north for the protection of *Rhododendron* species in their natural habitat. There is a need to do more for the protection of this beautiful and useful genus from the extinction. Following are few suggestions in this direction.

i) Population count (census) of all the species occurring in Teesta basin in Sikkim and then categorize them critically endangered, rare or vulnerable based on actual field data.

ii) Establish the cause of decrease in the population of these species, whether the decrease is natural or due to anthropogenic activies.

iii) Awareness campaign among the local people for the conservation of these species.

iv) Cultivation of those species, which are of high economic importance in the region.

v) Adopt an integrated approach involving local people, forest department, scientists and others for the conservation and protection of *Rhododendron* species in Sikkim Himalaya.

Table 2.19 Threatened species of *Rhododendron* from Sikkim Himalaya*

Species	Space vs availability	Number	Status
R. aeruginosum	Localized	Few	Threatened, Endemic
R. anthopogon	Acutely localized	Large	Threatened
R. arboreum	Ubiquitous	Large	Vulnerable
R. baileyi	Acutely localized	Few	Theatened
R. ciliatum	Acutely localized	Few	Threatened
R. decipiens	Acutely localized	Few	Threatened
R. falconeri	Ubiquitous	Large	Threatened
R. fulgens	Localized	Extremely few	Rare
R. grande	Ubiquitous	Large	Threatened
R. leptocarpum	Acutely localized	Extremely few	Endangered
R. maddenii	Localized	Extremely few	Rare
R. nivale	Localized	Few	Threatened
R. niveum	Acutely localized	Extremely few	Endangered
R. pendulum	Localized	Extremely few	Rare
R. pumilum	Localized	Extremely few	Endangered
R.setosum	Localized	Large	Rare
R. sikkimense	Acutely localized	Extremely few	Endangered
R. thomsonii	Localized	Large	Vulnerable
R. triflorum	Localized	Few	Threatened
R. wightii	Localized	Few	Threatened

* Adopted from Tiwari and Chauhan (2006)

2.9 *PRIMULA* SPP.

Primula, commonly called primrose, includes 400 to 500 species worldwide. The plant is herbaceous distributed mainly in the temperate and alpine regions of Northern Hemisphere. In Southern Hemisphere the genus is distributed in the high altitude of tropical mountains in Ethiopia, Indonesia and in temperate South America. The genus includes annual as well as perennial species mostly bloom in the spring. In India around 130 species are found mostly distributed in the alpine and temperate regions of Himalaya. In Eastern Himalaya more than 50 species of *Primula* are reported from Sikkim region (Table 2.20). Most of the species are found above elevation of 1,500 m in the temperate and alpine areas. The species have been recorded up to 5,040 m. *Primula denticula* has wide distribution, ranging from 1525 to 4110 m. It has been reported from Yumthang and Lachen Valley. *P. tenuifolia* has been reported from higher elevations, at 4,100 to 5,040 m or above in Megu, Sherathang, Lhonak Valley, Zemu Valley, Goecha La, Thangshing and Yak La. During spring, areas like Katao, Yumthang, Chopta are totally covered with various species of *Primula* (Plate 2.1). The habitats of many of these species are great stress due to various anthropogenic activities. In case of some species like, *P. uniflora,* only five to ten plants were observed in the field. It is found growing near the glacial melt waters (Plate 2.1b). The species was found only in the Katao region.

Three species of *Primula* are reported endemic from the Sikkim region. *P. pulchra* is reported from Lachen, Dzongri and Tari area. It is a very rare species endemic to Sikkim. However, some plants were also found adjacent to East Nepal. *P. ianthiana* is another species, which is mentioned as endemic to the Singalila ridge of Western Darjeeling and Sikkim. The species has been reported from Sandakphu and Phalut in Sikkim. *P. cooperi* is yet another endemic species, which has been reported from Tonglu region. The species has been mentioned as endemic to the Sikkim area. The species, like *P. listeri*, *P. glabra*, *P. sikimensis* and *P. whitei* are also mentioned endemic to Sikkim. However, these species are also reported from Bhutan (Grierson *et al* 1999). However, detailed demographic investigation is needed to understand the status of these species in Sikkim, particularly those species, which are mentioned endemic to the region.

2.10 ORCHID DIVERSITY

Teesta basin harbours about 445 species belonging to 117 genera of orchids, the maximum number of orchid species in India. Orchids are found in all parts of Teesta basin, from alpine, temperate to tropical region and have diverse habitats right from soil, stones to tree branches. Hooker (1875-1897), King and Pantling (1898) and Bruhl (1926) have given detailed account of orchids in Sikkim.

TABLE 2.20 SPECIES OF PRIMULA AVAILABLE IN SIKKIM HIMALAYA

Genus	Species	Altitude (m)	Distribution in Sikkim	Distribution at other places	Fl & Fr	Habitat
Primula	*vaginata*	2740-3650	Laghep, Kyongnosla, Phusum. Karponang	Bhutan, SE Tibet	Apr - Jun	Rain forest
Primula	*geraniifolia*	2740-3660	Lachung, Phusum, Dik chu, Kyongnosla, Karponang, Laghep, Tsango, Kupup	Bhutan	May – Aug	Fir forest
Primula	*listeri*	2440-3800	Tsoka, kalipokhari, karponang, Lodhrema	Bhutan, Darjeeling, Sandakphu, Tonglu	May - Aug	Fir forest
Primula	*gracilipes*	1980-4720	Chhurong Chu, Legship, lachen, Yumthang, Karponang	Bhutan, Arunachal Pradesh, Darjeeling, Phalut, Singalila	Apr - Jun	Fir & bamboo forest
Primula	*deuteronana*	3960-4400	Jongri, Nyegu La, Sirkia La,	-	Feb - Jun	Abies & Rhododendron forest
Primula	*bracteosa*	2130-3350	Gangtok, Karponang,	Bhutan	May - Aug	Open alpine forest
Primula	*scapigera*	2300-3000	Chhurong Chhu, Dzongri	Darjeeling	Mar-Apr	Abies & Rhododendron forest
Primula	*irregularis*	3050-3960	Chia Bhanjang, Gowsar Chuli, Kyongnosla, Nathual		Jan - Apr	Abies & Rhododendron forest

Primula	*hookeri*	3200-4720	Lachung, Tholoong	Bhutan	May - Jun	Abies & Rhododendron forest	
Primula	*drummondiana*	2440-3960	Tsomgo, Gnatong, Kyongnosla, Karponang, Lingtoo, Sherathang	-	Sep - Feb	-	
Primula	*pulchra*	-	Dzongri, Lachen, Tari,	-	May-Jun		Endemic to Sikkim
Primula	*calderiana*	3000-4880	Wide spread in Sikkim	Bhutan, Darjeeling	May- Aug		
Primula	*tanneri*	2440-3650	Chiya Bhanjan, Djongri, Kyongnosla, Phalut, Singalila ridge	Bhutan	Apr- Jun		
Primula	*macrophylla*	3810-4880	Lhonak, Chola, Lachung, Chemathang, Nathu La, Korpho Chu	Bhutan	May- Aug		
Primula	*megalocarpa*	3960-4880	Thangshing, Koraphu Chu, Thanka La, Tosa, Cho La, Chemathang	Bhutan	Jun- Aug	-	
Primula	*oboliqua*	3200-4570	Tsangu, Dzongri, Cho La, Churong Chu, Momay Samdong, Gnathang, Tari	Bhutan	Jun - Aug	-	
Primula	*elongata*	3050-4720	Tsomgo, Yak La, Kupup, Gnathang, Sherabthang, Cho La, Zemu Valley	Bhutan	Apr - Jul		

Primula	*gambeliana*	3650-4570	Alookthang, Jamlinghang, Lachung, Jongri, Megu, Phedup & Singalila	Bhutan	May- Jul		
Primula	*caveana*	3960-4880	Lhonak, Lungnak La, Naku La,	Bhutan	Jun- Jul		
Primula	*kingii*	3500-4265	Joloong, Kupup, Nathong, Nathu La	Bhutan	May-Jun		
Primula	*dickieana*	3200-4260	Eumtso La, Lachen, Thangu, Tsomgo	Bhutan	May- Aug	Boggy ground & Marshes	
Primula	*ianthiana*	3500-4265	Sandakphu & Phalut, Megu	Darjeeling	Jun- Jul	-	Endemic to Singalila ridge of Western Darjeeling & Sikkim
Primula	*cooperi*	3050	Above Tong	-	July		Endemic to Sikkim
Primula	*prenantha*	2440-3650	Phedang, between Dzongri & Yuksom	Bhutan	Jun- Jul		
Primula	*sikkimensis*	2745-4420	Dzongri, Bikbari, Nathu La, Sherathang, Chamnago, Tsomgo	Bhutan, Darjeeling	May- Aug		
Primula	*waltonii*	3050-3650	Singalila Ridge	Bhutan, Arunachal Pradesh	May- Jul		

Primula	*reticulata*	3500-4265	Tsomgo, Megu, Kupup, Jongri, Nathu LaTari, Dobinda Pass, Yak La	Bhutan	May- Aug		
Primula	*munroi*	3650-4570	Kupup, Nathu La, Lhonak, Lam Pokhari, Lachen	Bhutan	May-Sep		
Primula	*tibetica*	3600-4570	Lhonak, Lama, Gongra, Thangu	Bhutan, Chumbi	May-Sep		
Primula	*glabra*	3650-4510	Bikbari, Kupup, Ningbil, Dzongri, Rathong Chhu, Yampung	Bhutan	Apr-Aug		
Primula	*concinna*	4265-4880	Kanglanomo Pass, Kinchin Jhow, Momay Samdong, Lhonak, Tsomgo, Rathong Glacier	Bhutan	Jun –Jul	-	-
Primula	*primulina*	3860-4920	Tsomgo, Nathu La, Dzongri, Lachen, Zalep La, Bikbari, Lungnak La, Phaklung	Bhutan	Jun-Sep.	-	
Primula	*walshii*	3960-4570	Samiti Lake, Chemathang, Tsomgo	Bhutan, SE Tibet	May-Jul		
Primula	*muscoides*	4265-4875	Kanko La, Goecha La, Dobina La, Eumtso La, Chakung Chhu, Cho La	Bhutan	Jun- Aug	-	
Primula	*tenuifolia*	4100-5040	Megu, Sherabthang, Lhonak, Zemu Valley, Goecha La, Thangshing, Yak La, Tosa, Sebu La	Bhutan	Jun-Aug	-	-

Primula	*spathulifolia*	3050-4400	Sebu La, Lachung, Tosa	Bhutan	May-Aug
Primula	*tenella*	3960-4570	Zemu Valley, Lachen	Bhutan	Jun-Aug
Primula	*denticulata*	1525-4110	Dzongri,Chungthang, Yumthang, Lachen, Lachung	Bhutan	Feb-Jun
Primula	*atrodentata*	3650-4870	Lachen, Lhonak Valley, Thangu, Thangchang La	Chumbi	May- Jul
Primula	*glomerata*	3650-4570	Tanka La, Lachung, Bikbari, Dzongri	Chumbi	July-Sep
Primula	*capitata*	2740-4720	Chemathang, Lachen, Thangu, Lhonak, Samiti Lake, Bikbari, Yumthang, Dzongri, Yumesamdong	Bhutan	Jun-Aug
Primula	*bellidifolia*	3650-4570	Yak La, Tsomgo	Bhutan	Jun-Jul
Primula	*sapphirina*	3800-4680	Tsomgo, Kupup, Cho La, Gnathong, Dzongri, Lam Pokhari	Bhutan	Jun-Aug
Primula	*soldanelloides*	4100-4730	Tsomgo, Lam Pokhari, Patang	Bhutan	Jun-Aug
Primula	*klattii*	3960-4720	Chakung Chhu, Tanka La	Bhutan	Jul-Aug
Primula	*wattii*	3800-4400	Tsomgo, Chola	Bhutan	Jun-Aug

Orchids in Teesta basin in Sikkim are distributed right from 300m in southern part of Sikkim at Singtam and Rangpo area up to 4,500m in North Sikkim. The species like *Cypripedium elegans*, *C. himalaicum, Dactylorhiza hatageria, Ponerorchis ua, Habenaria arietina, Satyrium nepalense* are found at higher altitudes above 2,500 m in alpine and sub-alpine regions of Thangu, Yumthang and Kyongnosla. In temperate regions i.e. in Chungthang, Namgah, Tendong and Lachen valleys, the most dominant species are *Oberonia* spp., *Microstylis* spp., *Liparis* spp., *Bulbophyllum* spp., *Coelogyne* spp. The species like *Dendrobium* spp., *Bulbophyllum cornucervi, Cirrhopetalum* spp., *Nephelaphyllum* spp. are found in the tropical and sub-tropical region of Sevoke, Rungbee, Teesta valley and Tendong. Around 23 species are recorded from alpine region growing above 3,600 m in Dzongri, Talung, Samdong, Lachung valley and Shingba region. The orchid species have diverse habitats, however, majority of orchids are epiphytes attached to tree branches, stones, etc. covered with thick moss. Around 250 species of orchids are epiphytes and more than 175 species are terrestrial. However, 7-10 species grow as epiphytes as well as terrestrial. Some species are terrestrial saprophytes (*Microstylis saprophyta, stigmatodactylus paradoxus*) and 5-6 species are terrestrial parasites. *Didymoplexis pallens* is a climber and *Microstyris aphylla* is a leafless plant parasite on roots.

Worldwide orchids have very high commercial value and countries like Thailand, Singapore, Malaysia and New Zealand dominate in the export of cut orchids and plants. In 2005, Thailand earned $ 54 million by exporting orchid plants and cut flowers. In

Sikkim there are nearly half the number of species than that are present in Thailand (1000 species of orchids). However, commercially Sikkim has insignificant place in orchid trade. In Sikkim, there are more than 27 species (Table 2.13), which have very high commercial value in the orchid market of the world. Some orchids like *Coelogyne, Cymbidium, Cypripedium, Dendrobium, Paphiopedilum* and *Vanda* have very high market value and in Sikkim we have many species of these genera in wild (see Table 2.13).

Table 2.21 Some ornamental species of orchids from Sikkim

Sl. No.	Botanical Name	Local/Eng. Name	Altitude (m)	Distribution in Sikkim	Habit*	Flowering	Distrbution in other parts of India
1.	*Aerides multiflorum*	Bhuin Sunkhari	Up to 1000	Tropical valley	E	Apr	Uttaranchal, Assam, Arunachal Pradesh; Burma
2.	*A. odoratum*	Bhuin Sunkhari	Up to 1200	Tropical valley	E	May-Jun	Nepal, Khasia Hills, Sylhet; Burma, China and Java
3.	*Arundina graminifolia*	Bans Sunkhari	to 1700	Rang-Rang, Gangtok, Rangit valley, Dzongu	T	Aug-Sep	Nepal, Khasia Hills, Assam, Manipur, Nilgiri and Annamalai ranges
4.	*Anoectochilus crispus*	-	1800	Mahalderum Peak	T	Sep	Khasia Hills
5.	*A. sikkimensis*	-	900-1500	Sikkim	T	Sep	Arunachal Pradesh
6.	*Calanthe alismaefolia*	Fan Orchid	600-900	Tropical valley	T	May-Jun	Garhwal, Khasia Hills
7.	*C. herbacea*	Fan Orchid	1300-1900	Rungbe	T	Jun	Arunachal Pradesh
8.	*Coelogyne cristata*	Coelogyne	1500-2400	Sikkim	E	Mar-Apr	Kumaon to Bhutan, Khasia Hills
9.	*C. occulata*	Chandiguala	1300-2300	Sikkim	E	May-Jun	Kumaon to Bhutan and Assam Hill ranges
10.	*Cymbidium longifolium*	Cymbidium	1500-2100	Sikkim	T	Sep-Oct	Garhwal to Bhutan; Bhutan; Khasia and Naga Hills
11.	*Cymbidium aloifolium*	Epidendrum sunkhari	300-1000	Singtam, Gangtok (Deorali)	E	Apr-May	Bengal, Assam, Andaman Islands
12.	*Cypripedium elegans*	Lady's slipper	3000	Lachen valley	T	Jul	Eastern Tibet

13.	*C. himalaicum*	Lady's slipper	3000-4500	Lachen, Thangu	T	Jun-Jul	Bhutan
14.	*Dendrobium amoenum*	Dendrobium	Up to 1000	Trop. valleys	E	Jun	Garhwal to Bhutan, Sylhet; Burma
15.	*D. densiflorum*	Dendrobium	Up to 1800	Pamiachi, Sarmsa-Gangtok	E	Apr-May	Nepal, Khasia Hills, Burma
16.	*Dactylorhiza hatagirea*	Panchaunle	2500-3500	Khangchen-dzonga, Kyongnosla, Shingba	T	May-Jun	Uttranchal, Arunachal Pradesh, Pakistan to S.E. Tibet
17.	*Gastrochilus calceolaris*	-	1200-1800	Sikkim	E	Mar-Apr	Garhwal to Bhutan, Silhet and Khasia Hills
18.	*Paphiopedilum fairrieanum*	Slipper orchid	1000-1800	Tinktem	T	Sep-Oct	Arunchal Pradesh
19.	*P. venustum*	Slipper orchid	Upto 1200	Tropical valley	T	Sep-Oct	Arunachal Pradesh
20.	*Phaius tancervilleae*	Ground orchid	Upto1000	Tropical valley	T	Mar-Apr	Arunachal Pradesh
21.	*Phalaenopsis parishii*	Phulaenepsis	Up to1200	Teesta valley	E	Mar-Apr	Bhutan, Cachar
22.	*Pleione humilis*	Pleione orchid	2100-2500	Tendong peak	E or L	Feb-Mar	Arunachal Pradesh, Nepal
23.	*P. praecox*	Pleione orchid	1800-2400	Dentam-Pamianchi	E or L	Sep-Oct	Garhwal to Bhutan, Khasia hills; Burma
24.	*Ponerorchis chusua*	Ground orchid	3000-3900	Singa-le-la range, Tallum Samdong in Lachen valley	T	Jul-Aug	N.W. India, China
25.	*Thunia alba*	Ground orchid	600-1200	Rangit valley	T	May	Garhwal, Khasia Hill, Burma
26.	*Rhyncostylis retusa*		upto 1200	Rumtek, Gangtok, Sarmsa	E	Jun-Jul	Garhwal to Bhutan, Khasia Hills, Assam; Burma, Sri Lanka, Malayan Archipelago
27.	*Vanda cristata*	Vanda orchid	ca 1800	Gangtok, Tendong	E	May-Jun	Kumaon, Bhutan, Sylhet

* E=Epiphyte, T=Terrestrial, L=Lithophyte

Since time immemorial local people have been using orchid plants for different purposes like curing ailments, as tonic, dyeing, etc. (Table 2.14). Species like *Vanda testacea, Pholidota imbricata* and *Acampe papillosa* are used for rheumatism. There are many species, which are used as aphrodisiac (see Table 2.14). The yellow dye obtained from the flowers of *Dendrobium hookerianum* is used to impart bright yellow colour to the yarn. *Dactylorhiza hatagirea* is highly valued for its medicinal properties in entire Himalaya. In Sikkim, its tubers are used as expectorant, astrigent and aphrodisiac. *Flickingeria macraei* is known as "Jevanti" in Ayurveda and used as aphrodisiac, astringent, expectorant in curing asthma, and bronchitis as well as reported to be very effective in night blindness. The constant extraction of whole plants and their parts directly from wild is leading to fast disappearance from their natural habitats. The populations of some of the endemic orchid species are decreasing with an alarming rate due to over exploitation or due to disturbance in their habitats. Around 18 orchid species (see Table 2.10), which are available in India only from Sikkim, have very narrow niche width. They are found at places like Lachen valley, Lachung valley, Dzongri and in north east Sikkim. In these areas human population has increased manifold along with various development activities that are going on in these regions. About 15 species (see Table 2.11) of orchids are threatened in Sikkim flora and categorized as extinct, endangered, rare and vulnerable by Nayar and Sastry (1987, 1988, 1990). The species like *Cymbidium hookerianum* is endemic and endangered, whereas *C. eburneum* and *Zeuxine pulchra* are endemic and rare in Sikkim. *Cymbidium* spp. have very high market value in the international market and most of these species are found in Sikkim and East Himalaya.

Table 2.22 Orchid species used for curing various ailments in Sikkim

S. No.	Species	Habit*	Altitude (m)	Flowering	Part/s Used	Distribution in Sikkim	Therapeutic Uses
1.	*Acampe papillosa*	E	Up to 800	Oct-Jan	Root	Teesta valley	Roots used as tonic; useful in rheumatism

2.	*Aerides odorata*	E	Up to 1200	May-June	Whole plant	Teesta valley	Plant is used for anti-tuberculosis
3.	*Anthogonium gracile*	T	1200-2100	Sep	Tuber/root	On way to Lachen	Paste of the tuber is used as gummy substance in medicine
4.	*Coelogyne corymbosa*	E	1500-2400	Apr-May	Pseudo-bulb	Dzongu	Effective in burning; pain killer
5.	*Coelogyne ovalis*	E	600-1800	Sep-Nov	Whole plant	Trop and sub-tropical forest	Plant used as aphrodisiac
6.	*Coelogyne punctulata*	E	Up to 1800	May-Jul	Pseudo-bulb	Gangtok	Dried powder of Pseudobulb is used in burn injuries; also relieved pain and helps in healing of the wound
7.	*Cymbidium aloifolium*	E	300-1000	Apr-May	Whole plant	Singtam	Plant used as purgative, tonic, useful in treating earache
8.	*C. ensifolium*	T	ca 400	May	Root, flower	Teesta valley	Decoction of roots in water is used in curing gonorrhoea; decoction of flowers is useful in sore eyes.
9.	*Dactylorhiza hatagirea*	T	2500-3500	Aug-Sep	Tuber	Shingba Sanctuary	Tubers are used as expectorant, astringent and aphrodisiac
10.	*Dendrobium hookerianum*	E	1000-1500	Sep	Flower	Moist sub-tropical forest	Yellow dye is obtained from the flowers is used to impart bright yellow colour to the yarn
11.	*D. nobile*	E	to 1800	Apr-May	Seed	Kabi, Phodong, Gangtok	The powdery seeds are applied to the fleshy cut woulds for early healing
12.	*Eria pannea*	E	to 1000	May	Root, leaf	Teesta valley	Decoction of roots and leaves are useful in boneache
13.	*Eulophia nuda*	T	to 400	Apr-Jul	Tuber	Teesta valley	Tubers are used as tonic, aphrodisiac, blood purifier
14.	*Flickingeria macraei*	E	to 800	May	Pseudo-bulbs	Teesta valley	Plant is known ‘Jeevanti’ in

							Ayurveda; is used as aphrodisiac, astringent, expectorant, in curing asthma and bronchitis; also reported to be very effective in night blindness
15.	*Habenaria arietina*	T	1800-2700	Jul-Aug	Root/tuber	Tumlong, Pemiongchi	Roots or tubers used as 'Salep'
16.	*Malaxis acuminata*	T	900-2100	Aug-Sep	Pseudo-bulb	Singhik, Rangit valley	Pseudobulbs are used as tonic; also in treating tuberculosis
17.	*Phaius tancarvilleae*	T	Up to 800	Mar-Apr	Pseudo-bulb, root, leaves	Teesta valley	Psedobulbs, roots and leaves are used as poultices for boils, infected wound
18.	*Pholidota imbricata*	E	1000-1500	May-Aug	Pseudobulb	Gangtok	Psedobulbs crushed and mixed with mustard oil and used in curing rheumatic pains
19.	*Rhynchostylis retusa*	E	Up to 1200	Jun-Jul	Whole plant	Rumtek, Gangtok (Sarmsa)	Plant is used as emollient
20.	*Satyrium nepalense*	T	2400-3000	Sep-Oct	Tubers	Karponang, Changu	Tubers are used for treating malaria, dysentery; also as a tonic
21.	*Spiranthes sinensis*	T	Up to 2700	Apr-May	Stem	Kyongnosla, Lachen, Phodong	Stem is useful in caring sores
22.	*Tropidia curuligoides*	T	ca 300	Nov	Root	Teesta valley	Roots are useful in diarrhoea
23.	*Vanda testacea*	E	350-700	Apr-Jun	Leaves, flowers	Rangpo	Leaves and flowers are used for treating rheumatism
24.	*Zeuxine strateumatica*	T	Up to 1200	Jan	Stem	Teesta valley	Stem used as 'Salep'

* E = Epiphyte, T = Terrestrial

2.11 ECONOMICALLY IMPORTANT PLANT SPECIES

In Indian sub-continent majority of population has been vegetarian since long and always depended on local plants and trees for its all needs like food, clothing, for medicines to cure all types of diseases, house building material and for other various purposes. In every part and region of the country, whether it is Eastern or Western Ghats, islands of Andaman and Nicobar or Eastern and Western Himalaya, people discovered various uses of the plants around them. This is the very reason around 20 per cent of Indian Angiosperm flora is comprised of useful plants, which is very high in comparison to other countries or regions of the world. Similarly in Teesta river basin around 40-60 per cent of the flowering plants are used for various purposes ranging from food, medicines to furniture, instruments for games and arms and various other miscellaneous purposes. The uses of some of the plants are similar in entire Teesta basin, whereas some plants are used in very specific manner depending upon community or locality (Annexure-I).

2.11.1 Medicinal Uses

In Sikkim flora more than 400 species of plants are used to cure various ailments (Biswas, 1956). These plants are not only used to cure human beings but the domestic animals also. The plants are used as tonic, aphrodisiac, to cure simple diseases like fever, diaorrhea to very serious diseases like cancer, rheumatism, asthma, etc. Plants like *Podophyllum hexandrum* and *Taxus baccata* are useful for treatment of cancer. In Sikkim there are two systems of using the plants to cure the disease. One is Ayurvedic, practiced mainly by Nepali community and another is Tibetan system, which is a mixture of Ayurvedic and Chinese system and is mainly followed by Tibetan and Bhotiya people. Lepchas, though use a number of herbs, but are more inclined towards other medicinal sources, that is animals, etc.

These medicinal herbs or trees are found in each and every part of Teesta basin. However, they are concentrated mainly in the higher altitudes (2,500 to 3,000 m). Plants like *Aconitum ferox*, *Alnus nepalensis, Arisaema speciosum, Daphne bholua, Ephedra gerardiana, Hedychium spicatum, Heracleum wallichii, Impatiens racemosa, Nardostachys jatamansi, Panax pseudoginseng, Picrorhiza kurrooa, Podophyllum hexandrum* and *Taxus baccata* are found in the alpine and sub-alpine regions of Teesta basin. *Aloe barbadensis, Brassica campestris, Bridelia retusa, Cissampelos pariera, Piper longum* and *Terminalia belerica* are restricted to 1,000-1,200 m altitudes in tropical parts of Teesta basin. There are many species like *Artemisia vulgaris, Acorus calamus, Bergenia cilliata, Berberis aristata* and *Dioscorea deltoidea* which are found in the temperate and sub-tropical parts of Sikkim (see Annexure-I).

Besides herbs there are a number of arborescent trees and shrubs, which are also used to cure various diseases. *Abies densa, Acer campbelli, Berberis aristata, Jatropha curcas, Prinsepia utilis, Skimmia laureola, Spondias pinnata, Taxus baccata* and *Zanthoxyllum oxyphyllum* are some important trees or shrub species which are extensively used for various medicinal purposes in different parts of Sikkim.

2.11.2 Timber, Fuelwood and other Uses

In all 639 species of trees constitute the flora of Teesta basin. These tree species belong to 278 genera and 93 families of angiosperms and gymnosperms. Gymnosperms are represented only by 18 species belonging to 10 genera of 5 families. Lauraceae is the biggest family having maximum number of tree species i.e. 58 species followed by Euphorbiaceae with 51 species. *Ficus* is the dominant tree genus with 30 species mainly distributed in tropical and lower temperate zone (1,000-2,400 m). *Sorbus, Litsea, Symplocos, Prunus, Acer, Persea* and *Syzygium* are other prominent tree genera having 15 to 10 species and distributed in tropical to alpine zone (150-4800 m).

Tree species are sued in various ways in Sikkim ranging from timber, fruit yielding to medicinal uses. *Abies densa, Betula utilis, Prunus roxburghii* and *Tsuga dumosa* mostly found in Lachen, Lachung and Yumthang regions are used for timber. In tropical and sub-tropical regions of Rangit, Ravongla, Singtam, and Rangpo, *Shorea robusta, Terminalia myriocarpa, Quercus lamellosa, Castanopsis indica* and *Canarium bengalense* are used for furniture and material for house building. There are many fruit yielding tree species like *Morus laevigata, Citrus maxima, C. aurantifolia, C. medica, C. reticulata, C. sinensis, Juglans regia, Ficus auriculata, F. racemosa*, etc. Some tree species like *Abies densa, Acer campbelli,* *Berberis aristata, Taxus baccata, Zanthoxyllum alatum* and *Betula utilis* are used to cure various ailments. There are many trees species belonging to *Rhododendron, Magnolia, Michelia, Prunus*, etc. have very beautiful flowers and attract tourists in very large numbers.

2.11.3 Cultigens and Aliens

Teesta basin has very fertile soil and excellent climatic conditions for the growth of various plants used for food, fodder, fiber, fruits and vegetables (Annexure-I). Some species are introduced, which have adapted very well in the climatic conditions of Sikkim. Very high floristic diversity of Sikkim is also visible in the diversity of plants, which are used for human consumption. Various cultivars and varieties of cultivated plants have come up in different watersheds and deep valleys with different climatic and edaphic conditions. In Sikkim majority of population lives near or inside the forest and they harvest various plants for their subsistence. In Teesta basin, more 7-15 cultigens of different fruit species like oranges, etc. are found.

2.11.4 Cereals and Pseudocereals

In Teesta basin 8 to 10 species of plants are used as cereals. *Oryza sativa, Triticum aestivum, Hordeum vulgare, Zea mays* and *Eleusine coracana* are the main cereals grown in the basin. *E. coracana* is mainly used for making a fermented product called Chhang. In alpine and sub-alpine region of Thangu, Muguthang and Lachung two species of *Fagopyrum* are cultivated for seeds and leaves. There are also some other minor cereals like *Echinochloa* *furmentacea, Pennisetum americanum*, etc. which are cultivated in some parts of Sikkim (see Annexure-I).

2.11.5 Pulses

Cajanus cajan, Cicer arietinum, Glycine max and various species of *Phaseolus* and *Vigna* are extensively cultivated in various parts of Sikkim ranging from tropical to alpine and sub-alpine region of Chhoptha, Lachen, Lachung and Kupup. Many of these species have their wild relatives growing in the forest, which serve a good source of germplasm for the genetic improvement of the cultivated species (see Annexure-I).

2.11.6 Vegetables

Roots, leaves and shoots of various plants in Teesta basin are used for vegetables. There are more than 40 plant species, which are cultivated and 17 to 20 species of plants that are collected from the wild for vegetables. *Amaranthus* sp., *Colocasia esculenta*, *Spinacea oleracea*, *Brassica oleracea, Chenopodium album, Trigonella* sp., etc. are some of the important species cultivated as leafy vegetables. Roots and rhizomes of many species are used as vegetables. Most common ones *are Manihot esculenta, Colocasia esculenta, Amorphophallus campanulatus* and six to seven species of *Dioscorea*.

2.11.7 Spices and Condiments

In Sikkim Himalaya there are numerous plant species, which have strong aroma in their leaves, flowers and roots. Many of these are used as spices or condiments for adding taste to the food and for preservation. *Amomum subulatum, Zingiber officinale* and *Curcuma domestica* are the major species cultivated in the tropical and temperate region. *Amomum cardmomum* is cultivated in Mangan, Ravongala and Namchi area. It is one of the major commercial crop of Teesta basin which gives employment to many people ranging from cultivation to marketing.

2.11.8 Exotic species

Many exotic plant species like *Achyranthes bidentata, Bidens biternata, Datura stramonium, Eupatorium adenophorum, Galinsoga parviflora*, etc. were seen mainly along the roadside, in agriculture fields or in cleared forest area. There are more than 30 species of flowering plants, which have come from outside and are now very conspicuous in every part of Sikkim (Table 2.15). These plants are seen in every part of Sikkim from tropical to temperate regions. Some species like *Cestrum auranticum* and *C. fasciculatum* are still restricted to smaller area like Gangtok. However, some species like *Galinsoga parviflora, Ageratum conyzoides, Eupatorium adenophorum* and *E. odoratum* have taken the status of invasive species and can be seen everywhere in fallow land, cleared forest area or disturbed area. Most of these species are herbs, fast growing, neither eaten by any domestic or wild animal nor local people have made any use of these species. Many of these species may have allelopathic effect and do not allow any other species to grow wherever they have invaded. These species are very fast in colonizing the new area, which has been cleared from old vegetation or forest. In some areas these exotic species have become a great problem.

Table 2.23 Some naturalized exotic weeds in Sikkim

Sl. No.	Species	Family	Vern. Name	Habit	Altitude (m)	Distribution in Sikkim	Native Place
1.	*Achyranthes bidentata*	Amaranthaceae	Chir-chita	Herb	Up to 2400	Singtam, Chungthang, Gyalzing	Java
2.	*Ageratum conyzoides*	Asteraceae	Osarii	Herb	Up to 2700	Sangklang, Chungthang, Chhaten, Lachen	Mexico
3.	*Artemisia nilagirica*	Asteraceae	Titapati	Herb	Up to 2000	Chungthang, Lachung	S. America
4.	*Bidens biternata*	Asteraceae	Kurroa	Herb	Up to 2500	Rangpo Khola, Gangtok	Africa
5.	*Cynodon dactylon*	Poaceae	Dhub	Herb	Up to 2000	Singtam, Tarko, Legship	S. Africa
6.	*Cestrum auranticum*	Solanaceae	Dhub	Shrub	Up to 2000	Gangtok	Guatemala
7.	*C. fasciculatum*	Solanaceae	Dhub	Shrub	Up to 1800	Gangtok	Mexico
8.	*Crassocephalum crepedioides*	Asteraceae	Dhub	Shrub	Up to 1200	Tazko, Mangalbari, Selem, Legship	Africa
9.	*Cuscuta reflexa*	Cuscutaceae	Akasbel	Climber	Up to 1800	Mangalbari, Selem	Cosmopolitan
10.	*Conyza bonariensis*	Asteraceae	Kumen	Herb	Up to 2000	Mangalbari, Chakung Chhu	Europe
11.	*Chenopodium album*	Chenopodiaceae	Bhetu	Herb	Up to 2500	Rangpo, Singtam, Gangtok	N. temp
12.	*Dahlia imperilis*	Asteraceae	Dahalia	Herb	Up to 2000	Gangtok	Mexico
13.	*Datura stramonium*	Solanaceae	Dhatura	Herb	Up to 2000	Tarko, Chakung Chhu, Chungthang	N. America
14.	*Eleusine indica*	Poaceae	Wild millet	Herb	Up to 2700	Selem, Chungthang	Africa
15.	*Emilia sonchifolia*	Asteraceae	Hirankuri	Herb	Up to 1200	Mangan, Dikchu	Africa
16.	*Eragrostis curvula*	Poaceae	Weeping grass	Herb	Up to 1200	Rangpo khola, Singtam	S. Africa
17.	*Erigeron karvinskianus*	Asteraceae	-	Herb	Up to 1800	Chakung Chhu, Chungthang	Mexico to Panama
18.	*Eupatorium adenophorum*	Asteraceae	Kalobansu	Herb	Up to 2000	Tarko, Rangpo, Tong	Mexico
19.	*E. odoratum*	Asteraceae	Lali	Shrub	Up to 1800	Rangpo Khola, Lower Dzongu, Chungthang	Mexico

20.	*Fagopyrum esculentum*	Polygonaceae	Buck wheat	Herb	Up to 2500	Mangan, Chung-thang, Lachung	Europe & N. Asia
21.	*Galinsoga parviflora*	Asteraceae	Kumain	Herb	Up to 2400	Gyalzing, Gangtok Chungthang	Trop. America
22.	*Galium aparine*	Rubiaceae	Kuriya	Herb	Up to 3000	Dikchu, Chung-thang, Lachung	S. America
23.	*Gnaphalium affine*	Asteraceae	Gublu	Herb	Up to 1200	Gangtok, Chungthang	Europe
24.	*Jasminum mesnyi*	Oleaceae	Jasmine	Climber	Up to 2000	Gangtok	W. China, Yunan
25.	*Laggera alata*	Asteraceae	-	Herb	Up to 1500	Jorethang Singtam	Egypt
26.	*Lantana camara*	Verbenaceae	Kuri	Shrub	Up to 1800	Tarko, Legship, Tong	Trop. America
27.	*Nicandra physaloides*	Solanaceae	Apple of Peru	Herb	Up to 2000	Singtam, Gangtok	Peru
28.	*Ricinus communis*	Euphorbiaceae	Arundi	Shrub	Up to 2000	Gangtok, Rangpo, Chungthang	Africa
29.	*Swertia bimaculata*	Gentianaceae	Chirato	Herb	1600-2000	Chungthang, Lachung	Asia
30.	*Rubia sikkimensis*	Rubiaceae	Manjista	Climber	600-1600	Dikchu, Mangan, Chungthang	Temp. Asia
31.	*Tropaeolum majus*	Brassicaceae	Nasturtium	Climber	Up to 2000	Gangtok, Gyalzing	Peru; Brazil
32.	*Tibouchina semidecandra*	Melastomaceae	Glory Bush	Shrub	Up to 2500	Gangtok	China
33.	*Zantedeschia aethiopica*	Araceae	Arum Lily	Herb	Up to 1800	Rangpo, Singtam, Rumtek, Gangtok	S. Africa

2.12 FLORAL HOT SPOTS OF SIKKIM

Sikkim state has been divided into four districts, North, South, East and West. With respect to forest cover East Sikkim is having maximum, around 70%, followed by South and West districts. North Sikkim is having around 30% forest cover. However, North Sikkim is at top with respect to the number of flowering plants or number of endemic and threatened species of flowering plants. More than 60% of endemic species are located in North Sikkim only. In other districts the number of endemic species are less than 25 per cent. Similarly maximum number of flowering plants categorized as threatened are found in North Sikkim only. From Sikkim Himalaya more than 50 species of flowering plants are mentioned as threatened (Table 2.16). Of these 27 species are located in North Sikkim, particularly in Lachen-Lachung valley and Zemu valley. In North Sikkim there are some locations which are ideal for speciation of various plant species. Like Singhba for *Rhododendron* species, Thangu-Chhoptha region for *Aconitum* and *Podophyllum*, Lachen-Lachung valley for *Panax pseudoginseng,* Katao and Zemu valley for *Primula* species. At Singhba, which has been declared as Rhododendron Sanctuary, various morphotypes of this genus and its species having different flower colours, leaf size, plant height, etc. are found. From Thangu region a new type of *Aconitum* has been identified which has new chromosome number 2n = 48. From North Sikkim, 8-10 different types of *Panax pseudoginseng* were identified based on only leaf characters. Further work is needed to identify these plants based on chromosome number and other molecular characters. In North Sikkim many other plant explorers also have identified Lhonak valley, Lachen-Lachung valley, Yumthang valley and Zemu valley rich in floristic diversity (Gammie, 1894)

Table 2.24 District-wise floristic richness of Sikkim

Districts	Geographic Area (sq km)	Forest Cover (%)	No. of Endemic Plant Species	No. of Threatened Species
North Sikkim	4,226	30.79	63	27
South Sikkim	750	68.00	07	12
East Sikkim	954	70.23	23	09
West Sikkim	1,166	61.06	05	05

2.13 PERSPECTIVE PLANNING

These new reports of plant species clearly indicate for the need to do a lot yet to understand and document the floral wealth of Sikkim. In addition to locate and identify a new plant species, there is a need to study the ecology, physiology and evolution of these species. There is also need to understand about commercial aspect for this plant wealth and its preservation for our future generation. There are a number of reports of collection and identification of new species from Sikkim Himalaya. Lucksom (2004) reported a new species, *Zeuxine seidenfadenii* from East Sikkim. Even new species are being reported in the genus which includes many endangered species from Sikkim. A new species of *Lactuca*, *L. pseudo-umbrella*, has been reported from Kupup in East Sikkim (Maity and Maiti, 2001). The species is very close to *L. cooperi* which is endemic to Sikkim and reported as endangered (Nayar and Sastry, 1987).

During the present studies also, two *Ceropegia* species were collected from Sikkim after a gap of nearly 100 years. These two are endangered and endemic species in the Teesta basin. Similarly three species of *Begonia* have been recorded and rediscovered after a gap of more than fifty years. These species are either considered extinct or are in the endangered category (Nayar and Sastry 1990).

Teesta river basin is an ideal place for the cultivation and commercialization of orchids and many other ornamental plants. Various government agencies and private companies are coming up now in orchid cultivation. Central government (ICAR) has rightly selected Sikkim to establish a National Research Center on Orchids at Pakyong with an objective of conservation, protection and propagation of Orchid germplasm and various other aspects. A lot is required to do for the conservation, protection and commercial exploitation of these beautiful plants. The documentation of orchids from such a small area is still not complete, and complete record of orchids from Sikkim is still lacking. Even then new records of Orchid species from Sikkim (Lucksom, 2004) are being reported. Species like *Liparis dongchenii, Calanthe anganii, C. keshabii* and *C. yuksomensis* are the recent records from the Sikkim Himalaya.

Plate 2.3 Few beautiful wild *Primula* species from Sikkim Himalaya
a) *P. obliqua*, b) *P. uniflora,* c) *P. glomerata*, d) *P. elliptica*

CHAPTER - 3
AQUATIC ENVIRONMENT AND WATER QUALITY

3.1 INTRODUCTION

Of the earth's total resource of water (70%), only 3% is present in the form of fresh water and glaciers and available for the human consumption (Mason, 2001). Only 0.03% of total water is exploitable and more than 20 percent of world's population does not have access to safe drinking water. Glaciers, rivers and lakes are the main source of water in Himalaya. In Indian subcontinent, Indus, Ganga and Brahmaputra are the major river systems or basins with a large number of subsidiary river systems like Jhelum, Ravi, Beas, Satluj, Yamuna, Bhagirathi, Alaknanda, Kosi, Teesta, etc. draining areas west to east in Himalaya. These river systems bring water and fertile soil from mountain slopes, glaciers and lakes to the plains of Indian sub-continent. In addition to the river systems, numerous fresh water lakes *viz*. Wular lake, Dal lake, Manimahesh lake, Mansarovar, Deoria Tal, Naini Tal, Phewa lake, Gurudongmar lake, Chhangu lake, etc. are also distributed from North-west Himalaya to Eastern Himalaya and are also important source of water for many rivers. These lotic and lentic water bodies of Himalaya sustain lives of myriad macro- and micro-organisms *vis*-a-*vis* rich biodiversity.

In Eastern Himalaya, Teesta is one of the important river systems or basins, which originates in Greater Himalaya, collects water from numerous streams, rivulets, brooks and finally merges with Brahmaputra river in Bangladesh. The state of Sikkim with a geographical area of 7,096 sq km, falls solely in Teesta basin except for an area of 75.62 sq km of Jaldhaka river watershed which does not drain into Teesta river. The main tributaries of Teesta river are Rangit river, Rangpo Chhu, Rani Khola, Lachung Chhu, Zemu Chhu and Rangyong Chhu. Most of these streams originate from Greater Himalaya in Sikkim and after traversing through alpine, temperate and tropical regions drain into Teesta river which after leaving Sikkim flows through West Bengal. These rivers and streams while traversing through various valleys and ravines change the ecology of the surrounding area as well as physical and chemical characteristics of the streams (Vijaykumar, *et al*., 1999).

3.2 METHODS

The studies were conducted in Teesta river and its tributaries *viz*. Rangit river, Rangpo Chhu, Rangyong Chhu and Rani Khola while some observations also have been made in Ramam Khola, Rishi Khola and Rangpo Khola. In case of river Teesta, investigations were carried out in almost entire stretch of the river right from its headwater zone up to the confluence of Rangit with Teesta at Melli Bazar. In its tributaries, the studies were conducted in lower stretches. The water samples in Teesta, Rangit, Rangpo Chhu, Rani Khola and Rangyong Chhu were collected during all three seasons (pre-monsoon, monsoon and post-monsoon) while rest of the streams were sampled only during post-monsoon. The selection of sampling stations were largely focused in the vicinity of proposed river valley projects in Sikkim and variation in the altitudinal gradient. Simultaneously lower stretches of Rangit, Rangpo and Rani Khola and their tributaries (Rishi Khola, Ramam Khola, etc.) were selected for the study to assess their impacts on the main river Teesta.

3.2.1 Physical and Chemical Characteristics

Physical properties of the water in any aquatic system are largely regulated by the meteorological conditions, while chemical properties are affected by the physical forces and have a significant influence on the distribution and metabolic activities of life forms. In the present study samples were collected in triplicate at each site and an average value for each parameter was computed for final result. The following 14 characteristics (see Tables 3.1 and 3.2) were studied from all sites selected in the rivers.

i) *Water current velocity*

The water current velocity was measured with float method

ii) *Water temperature*

The water temperature was recorded with the help of graduated mercury thermometer. An average value of the temperature from readings taken at surface, column and bottom of the river.

iii) *pH*

The pH was recorded with the help of pH Scan (Eutech) in the field. The samples were also brought to the laboratory and pH of all samples were analysed with the help of HANNA pH meter (HANNA Hi 8519).

iv) *Turbidity*

For the turbidity of water, samples were collected in sampling bottles from different sites in the field and brought to the laboratory for analysis. The turbidity was recorded with the help of Nephelometer.

Before examination of samples, Nephelometer was calibrated by prepared samples of zero ntu and 100 ntu turbidity. The samples having more than 100 ntu turbidity, were diluted with help of distilled water (zero ntu) and finally calculated with dilution factor.

v) *Total dissolved solids (TDS) and conductivity*

The water samples were lifted from 2-3 meters away from river bank to avoid the disturbed sand particles. The water was taken in a sampling vial and total dissolved solids and conductivity were measured using TDScan 1 and TDScan 3 (Eutech), respectively at sampling sites.

vi) *Dissolved oxygen (DO)*

Dissolved oxygen was measured by using oxygen test kit (Aquamerck), which is based on Winkler's Iodometric Method (Welch, 1952). 125 ml of water was collected in a sample bottle, 5 drops of mangnous sulphate and alkali iodide-azide solutions were added. Bottle was shaken and brown precipitates thus formed were allowed to settle. The precipitates were dissolved by adding 10 drops of sulphuric acid. After shaking, 5 ml of the sample was taken separately and 1 drop of starch indicator was added. The sample was titrated with sodium thiosulphate solution. The total amount of sodium thiosulphate used was considered as dissolved oxygen (DO) in mg/l.

vii) *Alkalinity*

Total alkalinity, alkalinity of carbonates and bicarbonates were measured as per the method described in APHA (1992), adopted by

Adoni (1985). 25 ml of water sample was taken in a bottle and phenolphthalein (p) indicator was added to record the carbonate alkalinity. The sample was titrated with sulphuric acid (0.02 N). After measuring the carbonate alkalinity (if present), methyl orange (m) indicator was added in the same sample and titrated with sulphuric acid (0.02 N). The alkalinity was calculated as follows:

Carbonate alkalinity (mg/l) = ml of titrant for ‘p’ x 1000/ ml of sample

Bicarbonate alkalinity (mg/l) = ml of titrant for ‘m’ x 1000/ml of sample

Total alkalinity (mg/l) = carbonate alkalinity + bicarbonate alkalinity

viii) *Total hardness*

Total hardness, Ca++ and Mg++ were also measured as per the method described in APHA (1992), adopted by Adoni (1985). For the total hardness, 1 ml of ammonia buffer and a pinch of EBT (Eriochrome Black -T) indicator was added in the water sample. Standard EDTA solution (0.01 M) was used for the titration of sample. The total hardness was calculated as:

Total hardness (mg/l) = ml of titrant used x 1000/ ml of sample

To take the calcium hardness, 1 ml of sodium hydroxide solution and a pinch of murexide indicator were added in the water sample. The sample was titrated with the help of EDTA solution (0.01 M). The Ca++ and Mg++ were measured as :

Ca++ = ml of titrant x 400.5 x 1.05/ml of sample

Mg++ = (Total hardness – Calcium hardness) x 0.243

ix) *Nutrients*

Among the nutrients, nitrate (NO_3-N), phosphate (PO_4-P) and chloride were recorded by the methods adopted by Adoni (1985). The samples were collected in sample bottles and brought to the laboratory for analysis. For nitrates, 25 ml of water sample was evaporated to dryness on a hot water bath. The residue was rubbed with 0.5 ml phenoldisulphonic acid reagent to dissolve all solids. The process was followed by adding 5 ml of distilled water and 1.5 ml of 12 N KOH. Yellow color appeared. The supernatant was taken and reading was recorded with the help of spectrophotometer at 410 ηm against distilled water blank.

To know the quantity of phosphate, 1 ml of ammonium molybdate solution was added in 25 ml of water sample, followed by 0.12 ml stannous chloride. A blue color appeared. After 10 min the value was recorded with the help of spectrophotometer at 690 nm against a blank sample.

For the estimation of chloride, potassium chromate indicator was used to develop a yellow color. The sample was titrated by silver nitrate solution (0.0141 N). The readings were noted as:

Chloride in mg/l = (ml of titrant used x N x 35.46 x 1000) / ml of sample

3.2.2 Biological Characteristics

Animal and plant communities are dependent upon the water quality of rivers and lakes in which they live. The density, diversity and species composition of aquatic plants and animals have great significance in indicating the water quality. In the present study biological characteristics involved the plankton, phytobenthos, macro-invertebrates and fish of lotic and lentic water bodies in Sikkim.

3.2.2.1 *Plankton*

For phytoplankton study 50 liters of water was filtered at each site by using plankton net made up of fine silk cloth (mesh size 25 μm). The process was repeated three times at each site and samples were pooled. The filtrate collected was preserved in Lugol's solution. Further analyses were conducted in the laboratory.

i) *Density*

Before going further for other analysis of the above colleted samples, the density was estimated by using Sedgwick Rafter cell (SR cell). Each sample was made up to 100 ml in volume. The diluted sample was mixed thoroughly and 1 ml of each sample was then transferred into SR cell. The plankton was counted randomly in 100 chambers. The total density was computed as follow.

$$\text{No. of cells/lit} = \frac{a \times b}{l} \times 1000$$

Where, 'a' is average number of cells per chamber
'b' is volume of concentrated sample in ml
'l' is volume of filtered water in lit

ii) *Species composition*

Permanent mounts were prepared for the estimation of species composition and relative abundance of the plankton. The samples were centrifuged at 10,000 rpm for 30 min and supernatant was decanted. The diatom samples obtained were cleaned with nitric acid and potassium dichromate and left overnight. Subsequently, pellet was washed twice with 100% iso-propanol followed by a single wash with xylene. Permanent mounts were prepared as per the methods given in APHA, (1992). The diatoms were identified with the help of Sarod and Kamat (1984) and Hustedt and Jensen (1985).

3.2.2.2 *Phytobenthos*

Epilithic phytobenthos were obtained by scrapping the surface of rocks and boulders (3 cm^2) with the help of a hard brush. Three replicates, obtained from each site were pooled and preserved in Lugol's solution for further analyses.

i) Density

For the quantitative analysis of benthic algae, the total volume of the scrapings was made up to 100 ml with distilled water. The diluted samples were thoroughly mixed and 1 ml of each sample was then transferred to Sedgwick Rafter cell. Algae were counted randomly in 100 chambers. The total density was computed as follows:

$$\text{Cells (cm}^2) = \frac{N \times At \times Vt}{Ac \times Vs \times As},$$

Where, N is the number of organisms counted

At is the total area (cm^2) of chamber bottom

Vt is the total volume (ml) of original sample suspension

Ac is the area (cm^2) counted

Vs is the sample volume (ml) used in chamber

As is the surface area of substrate.

ii) *Species composition*

The method applied for the phytoplankton was also used for the qualitative analysis of phytobenthos.

3.2.2.3 *Macro-invertebrates*

The macro-invertebrates were obtained with the help of a square foot Surber's sampler. The substrate, mainly stones were disturbed and immediately transferred to a bucket underwater and later rinsed thoroughly to dislodge all the attached macro-invertebrates. The organisms trapped in the Surber's sampler were also transferred to the bucket. The material was sieved through 100μm sieve. Samples were collected in three replicates and pooled for further analysis. The samples were preserved in 3% formalin. The organisms obtained were then counted after identifying them up to family level by the procedure described by Pennak (1953) and Edmondson (1959).

3.3 TEESTA RIVER

For the present study river Teesta was divided into three stretches – i) lower stretch from Melli Bazar (Tr1) to Tong (Tr8), ii) upper stretch from Rangma (Tr9) to Yongdi (Tr12) and iii) Lachung Chhu from Chungthang (Tr13) to Yumesamdong (Tr16) (see Fig. 3.1). The physical, chemical and biological characteristics of these stretches have been described as follows.

3.3.1 Physical and Chemical characteristics

3.3.1.1 *Water current velocity*

The velocity of river or stream is a function of the average slope of its bed. The water current velocity is usually influenced by water discharge, water falls, solid boundaries and free surface (Dubey and Kaul, 1971). In glacial streams river depth and width are not constant and water abruptly loses altitude. These all factors cause irregularities in current velocity (Kaul and Bhagat, 1991). It is almost static in pools in lower stretches while it may be as high as 9.0 m/s in head water (Negi, 1994). The water current velocities in river Teesta are characterized spatially by non-uniform and non-steady flow of water as it varied with humped profile (Tables 3.1 and 3.2). However, generally higher values

Table 3.1 Physical and chemical characteristics of lower stretch of Teesta river in Sikkim

	Tr1 *			TR2 *			Tr3 *			Tr4			Tr5			Tr6			Tr7			Tr8		
	PrM'	M'	PoM'	PrM	M	PoM	PrM	M	PoM	PrM	M	PoM	PrM	M	PoM	PrM	M	PoM	PrM	M	PoM	PrM	M	PoM
Elevation (m)	240.00	240.00	240.00	300.00	300.00	300.00	323.00	323.00	323.00	368.00	368.00	368.00	380.00	380.00	380.00	550.00	550.00	550.00	775.00	775.00	775.00	1350.00	1350.00	1350.00
River discharge (m^3/s)	94.20	532.00	245.00	92.00	476.00	243.00	76.80	415.00	210.00	64.10	392.00	188.00	58.12	380.00	184.00	56.16	292.00	180.00	52.13	280.00	134.00	39.20	220.00	122.00
Water current velocity (m/s)	1.40	1.25	1.66	0.82	0.91	1.35	1.50	1.00	1.50	1.41	1.20	1.05	0.90	1.40	1.75	1.20	1.60	0.90	1.30	2.00	1.28	1.30	1.50	1.50
Turbidity (ntu)	6.00	55.00	9.00	7.00	45.00	9.00	10.00	50.00	8.00	8.00	50.00	8.00	5.00	50.00	5.00	5.00	50.00	4.00	10.00	60.00	1.00	20.00	40.00	3.00
Temperature (°C)	19.00	19.00	17.50	19.00	18.5	17.00	17.00	18.00	17.00	16.5	19.00	16.50	15.0	17.50	17.00	16.00	17.00	15.00	14.5	15.50	13.50	12.00	14.50	12.00
Total dissolved solids (mg/l)	30.00	20.00	10.00	30.00	20.00	10.00	40.00	10.00	10.00	40.00	10.00	10.00	20.00	10.00	10.00	30.00	10.00	10.00	20.00	10.00	10.00	30.00	20.00	10.00
Conductivity ($\mu S/cm$)	-	30.00	-	-	30.00	-	-	20.00	-	-	20.00	-	-	20.00	-	-	20.00	-	-	20.00	-	-	20.00	-
pH	7.40	7.75	7.80	7.50	7.20	7.77	7.80	6.90	7.75	7.80	7.00	7.70	7.80	7.75	7.70	8.00	7.37	7.00	7.20	7.80	6.90	7.30	7.00	8.00
Dissolved oxygen (mg/l)	7.60	8.20	8.40	7.40	8.20	7.90	8.6	8.30	8.20	8.6	8.50	8.60	9.6	8.60	8.70	9.6	8.60	9.10	9.8	9.10	9.20	9.8	8.90	9.20
Total alkalinity (mg/l)	80.00	36.00	32.00	84.00	28.00	30.00	84.00	18.00	27.60	76.00	18.50	27.60	76.00	19.20	28.40	60.00	16.00	23.20	52.00	17.60	26.40	60.00	20.40	27.60
Total hardness (mg/l)	30.4	30.00	24.80	32.00	15.60	24.80	33.60	14.40	24.80	33.00	14.40	24.80	32.00	14.40	24.80	32.00	15.20	24.80	24.00	15.20	22.40	31.20	18.40	22.40
Ca^{++}	10.88	9.60	8.16	11.20	6.08	8.00	12.16	5.76	8.16	12.00	5.76	8.16	11.4	5.76	8.16	11.20	6.08	8.16	8.00	4.80	7.60	11.20	6.08	7.60
Mg^{++}	0.77	1.45	1.06	0.97	0.09	1.16	0.77	0.00	1.06	0.77	0.00	1.06	0.58	0.00	1.06	0.97	0.38	1.06	0.97	0.77	0.82	0.77	0.77	0.82
Nitrate (mg/l)	0.007	0.06	0.04	0.001	0.06	0.05	0.001	0.07	0.05	0.001	0.05	0.03	0.002	0.04	0.03	0.001	0.04	0.02	0.001	0.03	0.03	0.001	0.03	0.02
Phosphate (mg/l)	0.07	0.09	0.06	0.05	0.08	0.06	0.06	0.07	0.07	0.05	0.10	0.11	0.03	0.10	0.13	0.06	0.11	0.12	0.09	0.12	0.12	0.02	0.11	0.10
Chloride	5.58	6.25	6.20	6.10	7.50	7.09	6.12	7.54	7.09	7.10	7.77	7.10	7.40	7.90	7.90	7.90	8.24	8.10	7.40	8.24	7.37	6.10	7.75	6.52

* Tr1= Teesta river

' PrM = Pre-monsoon, M = Monsoon, PoM = Postmonsoon

Table 3.2 Physical and chemical characteristics of upper stretch of Teesta (Lachen Chhu) and Lachung Chhu in Sikkim

	UPPER STRETCH OF RIVER TEESTA											
	Tr9*			Tr10*			Tr11*			Tr12*		
	PrM'	M'	PoM'	PrM	M	PoM	PrM	M	PoM	PrM	M	PoM
Elevation (m)	1700.00	1700.00	1700.00	2950.00	2950.00	2950.00	3800.00	3800.00	3800.00	4000.00	4000.00	4000.00
River discharge (m^3/s)	26.00	120.00	81.00	18.70	32.00	40.20	15.10	30.00	28.80	11.80	13.50	24.90
Water current velocity (m/s)	1.30	1.60	2.00	1.30	2.00	1.50	1.20	2.00	1.20	1.20	1.60	1.80
Turbidity (ntu)	13.00	30.00	3.00	10.00	5.00	3.00	10.00	8.00	2.00	10.00	5.00	2.00
Temperature (°C)	12.00	12.50	12.00	10.00	12.00	8.50	10.50	11.00	8.00	10.00	9.50	8.00
Total dissolved solids (mg/l)	30.00	10.00	10.00	30.00	20.00	10.00	40.00	20.00	10.00	30.00	20.00	20.00
Conductivity ($\mu S/cm$)	-	30.00	-	-	30.00	-	-	30.00	-	-	40.00	-
pH	7.20	7.50	7.40	7.10	7.80	6.70	7.40	7.80	7.37	7.10	6.90	7.80
Dissolved oxygen (mg/l)	8.00	9.20	9.10	6.90	8.10	8.30	6.80	8.00	7.80	6.50	7.20	7.70
Total alkalinity (mg/l)	60.00	23.00	24.00	56.00	16.00	16.40	48.00	16.80	16.40	48.00	19.20	21.60
Total hardness (mg/l)	40.00	19.20	22.40	28.00	16.00	22.40	34.40	18.00	27.20	40.80	18.00	38.40
Ca^{++} (mg/l)	13.70	6.40	8.00	9.60	6.24	8.00	11.80	6.40	9.20	14.40	6.40	12.00
Mg^{++} (mg/l)	1.30	1.28	0.58	0.97	0.16	0.58	1.16	0.80	1.16	1.16	0.80	2.04
Nitrate (mg/l)	0.001	0.004	0.001	0.001	0.004	0.001	0.001	0.003	0.001	0.001	0.003	0.001
Phosphate (mg/l)	0.07	0.09	0.06	0.05	0.08	0.06	0.06	0.07	0.07	0.05	0.10	0.11
Chloride	5.50	6.23	6.20	5.50	6.23	5.60	4.90	6.60	6.20	4.90	6.12	5.60

	LACHUNG CHHU											
	Tr13*			Tr14*			Tr15*			Tr16*		
	PrM	M	PoM	PrM	M	PoM	PrM	M	PoM	PrM	M	PoM
Elevation (m)	1600.00	1600.00	1600.00	2500.00	2500.00	2500.00	3500.00	3500.00	3500.00	4600.00	4600.00	4600.00
River discharge (m^3/s)	27.00	109.00	55.80	13.20	82.00	52.20	7.70	46.00	19.40	-	-	3.20
Water current velocity (m/s)	1.20	2.50	1.800	1.20	1.50	1.80	1.00	1.60	1.20	-	-	0.60
Turbidity (ntu)	15.00	20.00	4.00	12.00	15.00	4.00	20.00	15.00	3.00	-	-	2.00
Temperature (°C)	11.00	13.00	11.50	11.50	10.30	11.00	11.00	9.50	9.00	-	-	7.00
Total dissolved solids (mg/l)	20.00	10.00	10.00	20.00	10.00	10.00	10.00	10.00	10.00	-	-	10.00
Conductivity ($\mu S/cm$)	-	20.00	-	-	10.00	-	-	-	10.00	-	-	-
pH	7.20	6.80	7.50	6.90	6.80	7.30	7.40	6.70	7.40	-	-	7.30
Dissolved oxygen (mg/l)	8.00	8.10	9.30	7.10	8.50	7.80	6.30	7.90	7.90	-	-	7.70
Total alkalinity (mg/l)	52.00	16.80	16.80	48.00	10.00	18.00	48.00	10.00	18.00	-	-	14.80
Total hardness (mg/l)	24.00	13.60	20.00	16.00	13.60	16.00	12.00	16.00	33.60	-	-	16.00
Ca^{++} (mg/l)	8.40	4.80	7.20	6.32	4.80	5.60	4.80	5.60	11.20	-	-	5.60
Mg^{++} (mg/l)	0.72	0.31	0.48	0.48	0.31	0.48	0.48	0.48	1.36	-	-	0.48
Nitrate (mg/l)	0.001	0.002	0.001	0.001	0.002	0.001	0.001	0.001	0.001	-	-	0.001
Phosphate (mg/l)	0.03	0.10	0.13	0.06	0.11	0.12	0.09	0.12	0.12	-	-	0.10
Chloride	5.60	6.00	5.60	6.00	6.00	6.50	6.50	6.25	6.80	-	-	7.00

* Tr1= Teesta river

' PrM = Pre-monsoon, M = Monsoon, PoM = Postmonsoon

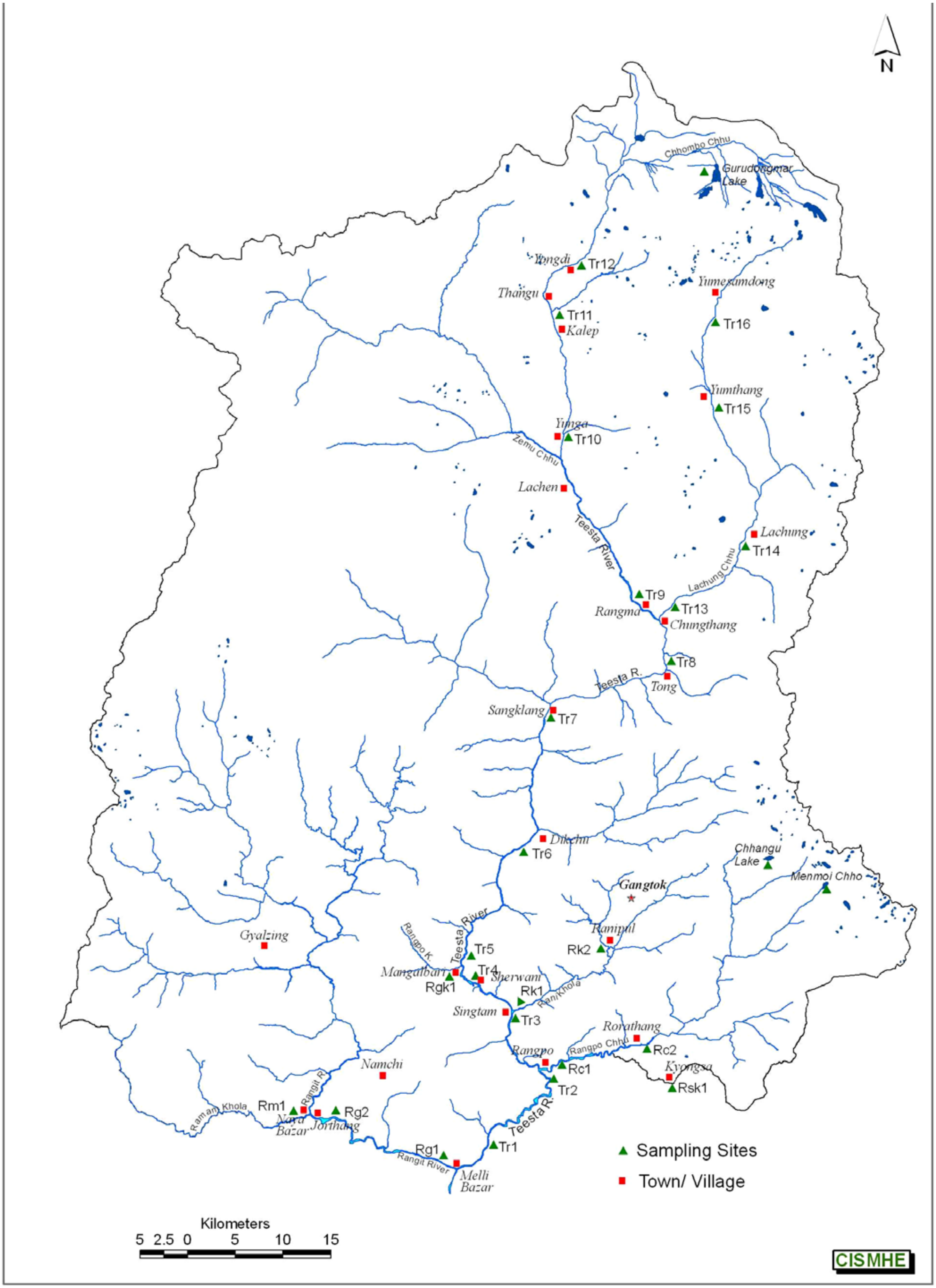

Fig.3.1 Map showing sampling sites in different rivers of Sikkim

can be seen in upper stretch of Teesta and Lachung Chhu where river flows through steep slopes and deep gorges. But it differs temporally, especially in lower stretch of river Teesta as higher current velocities were observed in monsoon season due to high water discharge. The water discharge in upper stretches of river Teesta and Lachung Chhu was less affected by monsoon season and hence low seasonal differences in current velocities were also observed.

3.3.1.2 *Turbidity*

Turbidity is a function of light dispersing and absorbing properties of water. It is caused by the presence of suspended matters like clay, silt, colloidal organic particles and plankton. The turbidity is greatly influenced by surface and drainage run off. Turbidity of water always has a negative effect on the biotic communities. It decreases light penetration in water, checks the process of photosynthesis in aquatic plants and decreases the potability and productivity of water (Pandey *et al*. 1999; Kaushik and Saksena, 1999). Sometimes it becomes lethal to fish species. In Himalayan streams and rivers the turbidity of water largely depends on the rainfall. Along the altitudinal gradient of lower stretch of river Teesta (sites Tr1 to Tr8), there was no definite pattern in the turbidity, especially during pre-monsoon and monsoon seasons (Fig. 3.2). It could be attributed to the confluence of many left and right bank tributaries which recorded different turbidity (see Table 3.1). However, in upper stretch of river Teesta and Lachung Chhu, turbidity generally decreased towards upstream (from sites Tr9 to Tr12 in Teesta river and Tr13 to Tr15 in Lachung Chhu for all seasons (see Table 3.2).

Seasonal fluctuations in rainfall, is directly reflected in turbidity that was observed in river Teesta. Monsoonal rains induced landslides and soil erosion, which carried silt, clay and debris in river water. During monsoon season it increased considerably as peaked 55 ntu at site Tr1 (Melli) in lower stretch of Teesta. The upper reaches of Teesta river (Lachen Chhu) and Lachung Chhu recorded considerably low turbidity even during the monsoon season. This difference in turbidity between lower part and upper part of river could be explained that coarse material and fine material induced siltation in upper and lower stretches, respectively. The fine material is more soluble in water and causes high turbidity (Ahmed, 1991).

3.3.1.3 *Water temperature*

Temperature in aquatic ecosystems is one of the most important limiting factors as it controls the metabolic activities and growth rate in organisms (Dheer, 1988). According to Welch (1952), no other single factor has such a direct or indirect influence on aquatic water ecosystem than temperature. The temperature in river water is largely regulated by solar radiation, air temperature and topography. Temperature, in turn, regulates the dissolved oxygen concentration of water and primary productivity, causes a great variability in plant and animal distribution. In Indian subcontinent water temperature in various water bodies varies from 7.8^0C – 38.5^0C (Quadri and Yusuf, 1980; Ghose and George, 1989). However, in Himalaya it goes below 7.8^0C and does not go beyond 38.5^0C. Temperatures in Teesta river and its headwaters tributaries decreased gradually towards higher elevations in all the seasons (see Tables 3.1 and 3.2). In monsoon season, slightly higher temperatures were recorded as compared to pre- and post-monsoon seasons. In uppermost stretches like that in Thangu (Tr11), Yongdi (Tr12) and Yumthang (Tr15), the temperature remained significantly low. Similar observations were recorded by Kaul (1983) in high altitude stretch of Beas river in Western Himalaya. Other important function of temperature is that it plays an important role in distribution of organisms in rivers, especially in fish distribution. For instance, in Sikkim exotic trout fish are restricted to upper stretch of river Teesta and Lachung Chhu due to low water temperature profile. Temperature beyond 19^0C makes the survival of this species difficult.

3.3.1.4 *Total dissolved solids (TDS) and Conductivity*

A large number of inorganic salts and small amount of organic matter dissolved in water constitute the total dissolved solids (TDS) in the water. Carbonates and bicarbonates are the chief constituents of TDS, however, chloride, nitrate, phosphate, sodium also contribute to it. Total dissolved solids in water originate from natural sources and depend upon bottom deposits, rainfall and geological nature of the area. It is considered as one of the determining factors in water potability and have indirect effect on aquatic organisms (increase trophic status). It may peak to more than 2000 mg/l in Indian waters (Kaushik and Saksena, 1999). In Himalayan waters, its maximum concentration remains near 100 mg/l in normal conditions (Bhatt and Pathak, 1989; Bhatt *et al*., In press). However, low values of TDS (10-40 mg/l) were recorded during all seasons in the river Teesta (see Tables 3.1 and 3.2). Lowest value of TDS in all the streams were recorded during post-monsoon. It was observed that the sites which were under more anthropogenic pressure *viz.* Singtam (Tr3) and Sherwani (Tr4) in the lower stretch of Teesta and Thangu (Tr11) in upper stretch of Teesta recorded highest value of TDS (40 mg/l) (see Fig. 3.2). Electrolytes in a solution dissociate into the respective ions and impart conductivity to it. The higher concentration of TDS are indicative of high conductivity. In Teesta river, conductivity exhibited positive correlation with total dissolved solids and also showed more or less spatial uniformity.

3.3.1.5 *pH*

Hydrogen ion concentration of water is the measure of relative acidity and alkalinity. The pH is generally considered as a measure of environmental suitability and a range of 7 - 8.5 is considered to support a rich biota and fish (Bell, 1971; Verma and Shukla, 1971). The dissolved matters, photosynthesis processes and catabolic processes in water influence the pH greatly. In addition, input of pollutants also reduces it. The pH is also important environmental factor and the variation in pH leads to changes in chemical profile, species composition and life processes of animals and plants. The pH of most of the inland waters of India including Himalaya is alkaline without much variation (Sreenivasan, 1976). However, it may range from 3 -12 in natural waters. In river Teesta, mostly alkaline ranges of pH were observed, which can be correlated with the presence of only bicarbonates alkalinity in Teesta water (see George *et al*. 1986). Sreenivasan (1976) and Spence (1967) have stated that alkalinity and pH are closely related with the accurate measure of the productivity and trophic status of waters.

However, pH in acidic range was recorded sites like Singtam (Tr3) in lower section of Teesta, Yongdi (Tr12) in upper section of Teesta and entire stretch of Lachung Chhu during monsoon season (see Tables 3.1 and 3.2 and Fig. 3.3). The surface run off and high turbidity in monsoon slightly bring down the level of pH in river Teesta (see Shardendu & Ambashit 1988). Along the altitudinal gradient, pH did not show much variation, which is true for all inland waters (Ghosh & George, 1989; Shastree *et al*. 1991).

3.3.1.6 *Dissolved oxygen*

Like temperature and pH, dissolved oxygen (DO) is also a most important limiting factor of aquatic environment. It plays a vital role in metabolic processes of organisms. The occurrence of DO in water depends mainly on a physical process (direct diffusion from air) and biological process (photosynthesis of autotrophs). Its concentration is significantly influenced by the temperature, salinity, concentration of dissolved salts and water movements (Zutshi and Vass, 1989). It is negatively affected by the turbidity and sewage outfall. In Himalayan rivers, the concentration of dissolved oxygen ranges from about 7 to 11 mg/l (Bhatt and Pathak, 1989; Gusain, 1994; Negi, 1994). It generally shows a perfect negative correlation with water temperature (Welch, 1952). Similar observations were made in the lower stretch of river Teesta in all seasons where DO gradually increased from lower to upper reaches with a few exceptions like at site Tr2 (Rangpo) during pre-monsoon and post-monsoon (see Table 3.1). The lower value of DO at this site is attributed to the sewage outfall in the river from Rangpo township. However,an opposite trend was observed in upper stretch of river Teesta (Fig. 3.3). The DO gradually decreased from lower elevations to higher elevations in upper stretch of Teesta and Lachung Chhu during all seasons and showed a positive co-relation with water temperature (see Table 3.2). This is attributed to lower concentration of oxygen in the air at higher elevation which is reflected in lower dissolved oxygen concentration at such elevations.

3.3.1.7 *Total alkalinity*

Total alkalinity of water is its buffering capacity or capacity to neutralize acid. It is an aggregate property of water due to presence of carbonate, bicarbonate and hydroxyl compounds of calcium, magnesium, sodium, potassium, etc. The fluctuation in alkalinity values depends upon nature of bottom deposits, rainfall and autotrophs of water. The total alkalinity is directly related to aquatic productivity (Spence, 1964; Alikunhi, 1957). According to Spence (1994) the alkalinity more than 200 mg/l is good for the biological productivity. In most of the Himalayan waters alkalinity generally peaks up to 120 mg/l in normal conditions. In Teesta, only bicarbonate alkalinity constituted the total alkalinity that peaked at 80 mg/l. Though, spatially there was no definite trend in the concentrations of total alkalinity, it was generally recorded to be high at lower elevations of lower stretch of Teesta, upper stretch of Teesta and Lachung Chhu (Fig. 3.4). This differentiation can be attributed to the bottom deposits with hard and soft bottoms in lower and upper stretches, respectively. The total alkalinity was significantly high during pre-monsoon (48–80 mg/l) season as compared to monsoon

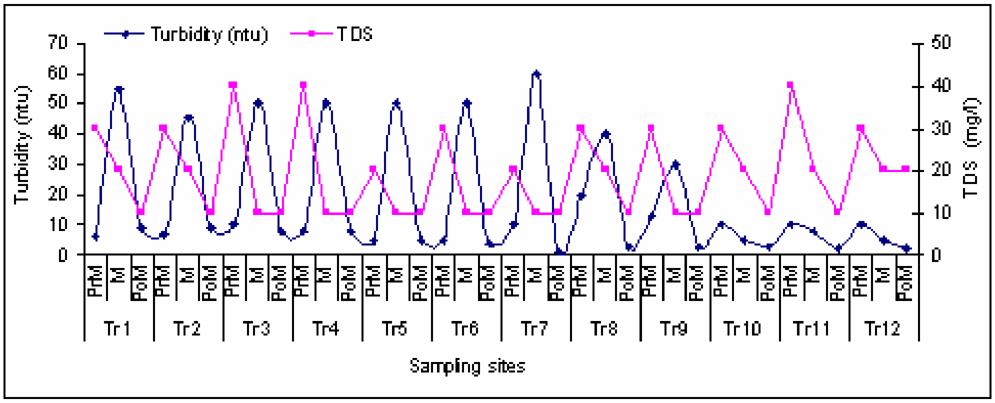

Fig.3.2 Turbidity and TDS profiles along the Teesta river

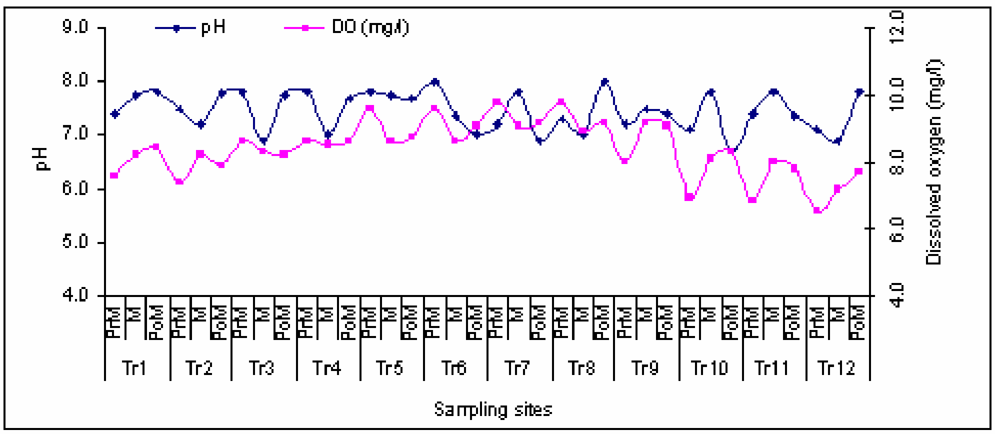

Fig. 3.3 pH and dissolved oxygen profiles of river Teesta

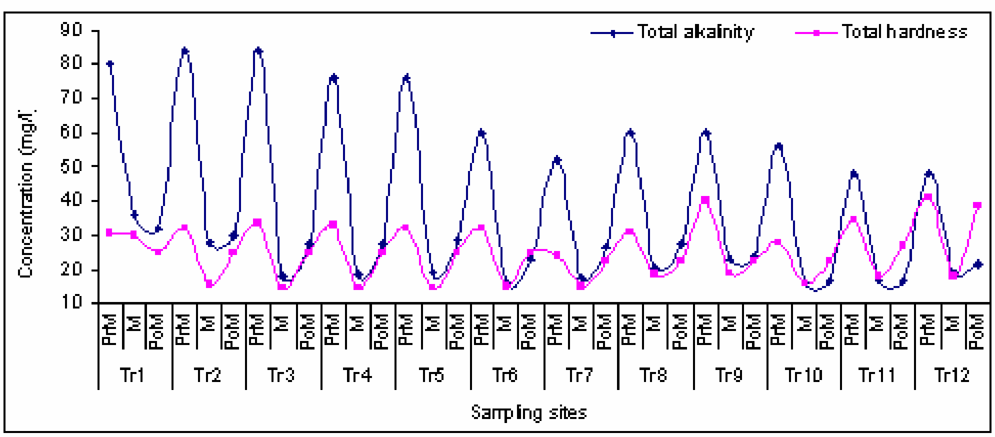

Fig.3.4 Variation in total alkalinity and hardness of water in river Teesta

PrM = Pre-monsoon; M = Monsoon; PoM = Post-monsoon

(10-36 mg/l) and post-monsoon seasons (16.8 - 32 mg/l) (see Tables 3.1 and 3.2). Such significant reduction in alkalinity during monsoon season can be attributed to the fact that dilution of river water was high and ions are responsible for alkalinity in monsoon. Moreover, rain waters increase the acidity and increased runoff adversely affects the alkalinity of Teesta water in monsoon season (Daborn and Clifford, 1969).

3.3.1.8 *Total hardness and ion concentration*

The hardness of water is its capacity to react with cations. In most of the freshwater bodies, the hardness is imparted by calcium and magnesium ions, combines with bicarbonates and carbonates. In addition, the concentration of Ba, Zn, Mn, Fe, Al also has a little control on the total hardness. The total hardness is governed cumulatively by total alkalinity, water temperature and free CO_2 up to some extent (Daborn and Clifford, 1974). It may be soft to very hard (more than 200 mg/l) in Himalayan rivers and lakes (Bhatt and Pathak, 1989; Bisht and Das, 1985; Shah, 1988). On the basis of Sawyer's classification (1966), the water of river Teesta and its tributaries can be categorized as soft water (hardness less than 75 mg/l). Along the altitudinal gradient of Teesta river and its tributaries, the total hardness of water did not show a specific increasing or decreasing trend. However, there was a temporal variation in the total hardness with the lower values for monsoon season (see Table 3.1 and 3.2) due to increase in the temperature and free CO_2 in water, which ultimately decrease carbonates and hardness.

Our observations indicated that calcium hardness was the main component of total hardness at all sites of river Teesta. High Ca hardness was reflected in the higher concentration of Ca ion (4.8-14.4 mg/l) as compared to Mg ion (0.31-2.04 mg/l) at all sites in the lower and upper stretches of Teesta (see Figs 3.4 and 3.5).

3.3.1.9 *Nitrate-Nitrogen*

Nitrate, nitrite, ammonia, urea and amino acids are available forms of nitrogen in fresh water bodies. Among these forms nitrate is most oxidized form and an important plant nutrient. In aquatic ecosystems nitrogen level is regulated through geological process (groundwater movement, sedimentation), meteorological process (precipitation, atmospheric solution and volatilization) and biological process (nitrogen fixation, hydrophytes pumping, fish and weeds) (Toetz, 1976). The waste water input and agricultural run off affect the natural nitrate to a large extent. In river Teesta, most of these factors are absent or not significant (e.g. ground water inputs, weeds, nitrogen fixation by blue green algae and weeds). Therefore, in pre-monsoon season very low concentrations of nitrate were recorded in the entire stretch of river Teesta and its tributaries. At most of the sites nitrate concentrations were recorded to be 0.001 mg/l (see Tables 3.1 and 3.2). During monsoon and post-monsoon, sedimentation, surface and drainage run off triggered by rains increased nitrate concentrations at least 10 times at respective sites, especially in lower stretch of Teesta. In upper stretch of Teesta (Lachen Chhu and Lachung Chhu), nitrate concentrations increased significantly during monsoon only but post-monsoon samples recorded similar concentrations as recorded during pre-monsoon sampling (Fig. 3.6). The comparatively low concentration of nitrates at upper reaches can be related to low human habitation and lack of agricultural and domestic activities.

3.3.1.10 *Phosphate – Phosphorous*

In aquatic ecosystem, inorganic phosphorus as orthophosphate plays a dynamic role. Phosphate is known as a key nutrient in the productivity of water. The main source of phosphate in natural waters is weathering of phosphorus bearing rocks, leaching of soils of catchment area, temperature, pH, aquatic vegetation, fauna and excreta of birds and other animals. Besides these, surface run off in monsoon and many point sources like small townships in the vicinity also contribute phosphate in natural water. In the lotic system of Sikkim, there is no major point source of phosphorous besides small townships in the vicinity of river. Therefore, phosphate concentration remains below 0.13 mg/l throughout the year. Minor fluctuations are attributed to landuse pattern in the catchment of lower and upper stretches of Teesta and Lachung Chhu. It showed a humped profile on the altitudinal gradient of Teesta (see Table 3.1 and 3.2) and peaked at 0.09 mg/l in pre-monsoon and 0.11 in post-monsoon months. During monsoon, phosphorous concentration was slightly higher at many sites, peaked at 0.13 mg/l.

3.3.1.11 *Chloride*

Chloride in rivers is generally found in the form of salts of sodium, potassium and calcium. Chlorides play metabolically active role in photolysis of water and photophosphorylation reactions in autotrophs. Its higher concentrations are considered as indicators of pollution due to organic waste of animal origin and industrial effluents. In contaminated water its concentration may go beyond 200 mg/l but in oligotrophic water like Himalayan rivers, it remains below 10 mg/l (Pathak and Bhatt, 1991). In the present study, chloride concentration increases gradually from Melli (site Tr1) to Dikchu (Tr6) during pre-monsoon (5.52 – 7.90 mg/l), monsoon (6.25 - 8.24 mg/l) and post-monsoon (6.20 – 8.10 mg/l) seasons (Fig. 3.7; see Tables 3.1 and 3.2). Its concentration generally declined from Tong (site Tr8) to Yongdi (site Tr12) in the upper stretch of Teesta (Lachen Chhu) except Thangu (Tr11) where we observed anthropogenic activities and settlements. However, in case of Lachung Chhu we observed a reverse trend. Monsoon months recorded higher values of chloride as compared to pre- and post-monsoon seasons coinciding with the surface run off in monsoon. Surface run off generally contains more chloride (Skakalskiy, 1966).

3.3.2 Biological characteristics

Biological components of a river are comprised of micro- and macro-organisms in the form of plankton, benthos and nektons. There is an inter-relationship among these different communities to perform the functions of an ecosystem. The phytoplankton and phytobenthos are producers of this ecosystem while zooplankton and macro-invertebrates are the primary or secondary consumers. The fish community itself occupies secondary and top trophic levels in aquatic ecosystem. A balance level of these communities provides stability in food chain and

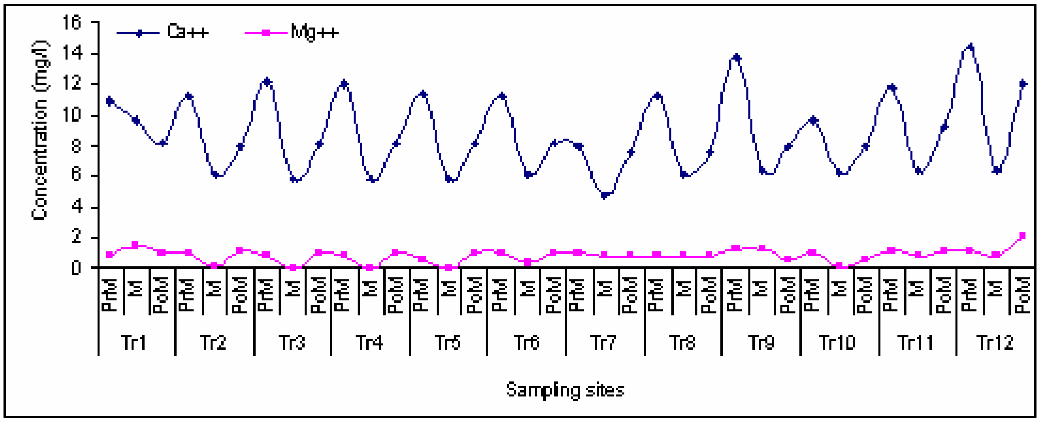

Fig. 3.5 Variation in the concentration of Ca amd Mg ions in river Teesta

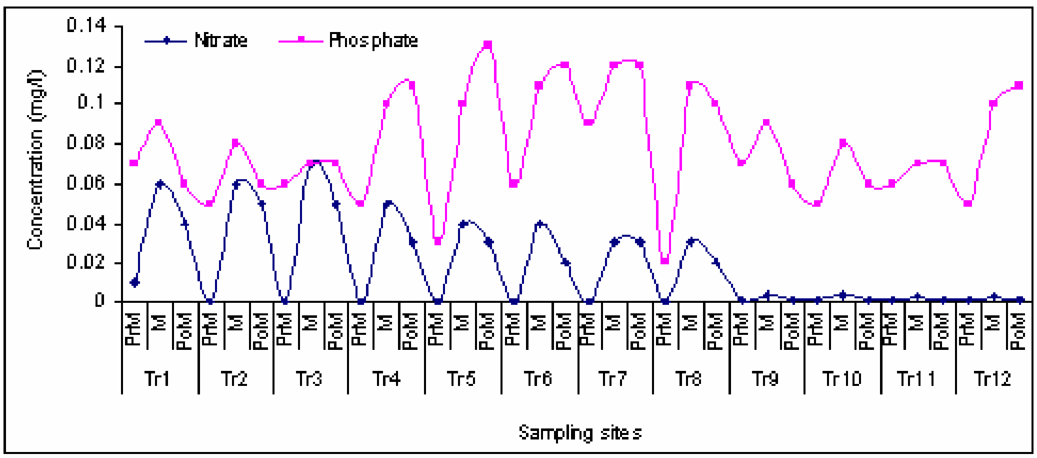

Fig.3.6. Nitrate and phosphate concentration in the river Teesta

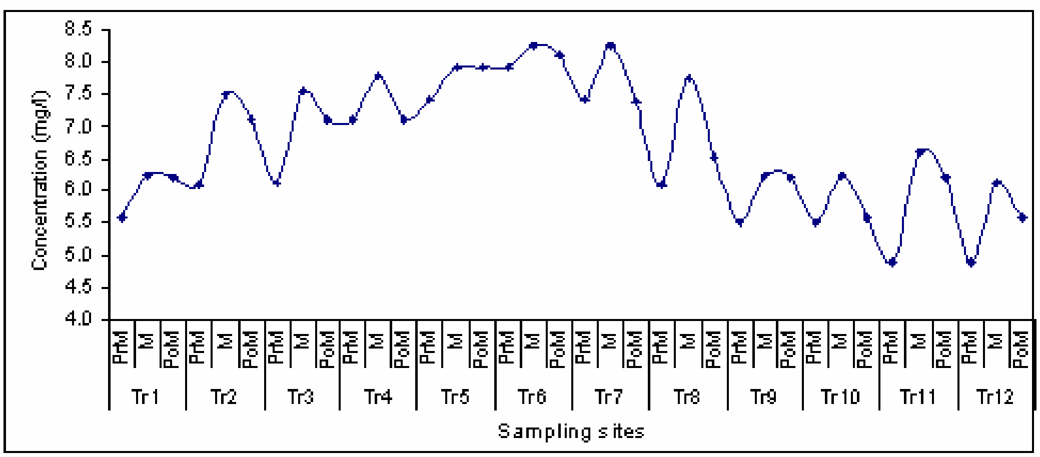

Fig. 3.7 Variation in the concentration of chloride in river Teesta along the altitudinal gradient

PrM = Pre-monsoon; M = Monsoon; PoM = Post-monsoon food web. In the present study of Teesta river we discussed all these communities of river Teesta.

3.3.2.1 *Zooplankton*

Zooplankton is a group of micro-organisms which float at their own energy and are at mercy of water currents. In river Teesta, they accounted for zero to 4.5 % of total density of plankton. In upper reaches they were absent at most of the sampling sites.

3.3.2.2 *Phytoplankton*

Phytoplankton, a group of floating plants, are an important component of aquatic ecosystem and play key role in maintaining proper equilibrium of aquatic ecosystem. They are primary producers and serve as food for zooplankton, macro-invertebrates and fish directly and indirectly. However, in case of hilly streams true plankton are absent especially in upper stretch of the river due to turbulent and rapid flow (Welch, 1952). In Teesta river, phytoplankton community was comprised of Chlorophyceae, Bacillariophyceae, Myxophyceae, etc. But Bacillariophyceae (diatoms) was most important group, contributing more than 85% of total density. The density of phytoplankton was observed to increase from lower to upper stretches of Teesta (Lachen) in pre-monsoon and post-monsoon seasons. The density was maximum at Yunga (Tr10) up to 6174 units/lit in pre-monsoon and at Yongdi (Tr12) up to 5000 units/lit during post-monsoon sampling (Fig. 3.8; Tables 3.3 and 3.4). However, different trend was observed in the density of plankton during monsoon which might be due to physical

Table 3.3 Densities of different biotic communities in the lower stretch of river Teesta

	Tr 1			Tr 2			Tr 3			Tr 4			Tr 5			Tr 6			Tr 7			Tr 8		
	PrM	M	PoM	PrM	M	PoM	PrM	M	PoM	PrM	M	PoM	PrM	M	PoM	PrM	M	PoM	PrM	M	PoM	PrM	M	PoM
Elevation (m)	240	240	240	300	300	300	323	323	323	368	368	368	380	380	380	550	550	550	775	775	775	1350	1350	1350
Phytoplankton (cells/l)	1010	106	225	772	117	157	970	323	475	1016	302	510	1035	206	175	1587	262	495	1663	312	557	1612	384	662
Phytobenthos (Cells/cm^2)	10100	2213	4818	9825	2650	3333	4906	2483	4698	8142	2712	4920	10320	3232	6113	7250	2915	5225	7820	2410	8610	6940	3612	8767
Macro-invertebrates (indiv./m^2)	170	46	525	498	89	272	502	76	199	520	103	290	1310	121	362	610	114	344	688	139	377	719	243	1220

Table 3.4 Densities of different biotic communities in upper stretch of Teesta and Lachung Chhu in Sikkim

	UPPER STRETCH OF RIVER TEESTA												LACHUNG CHHU											
	Tr 9			Tr 10			Tr 11			Tr 12			Tr 13			Tr 14			Tr 15			Tr 16		
	PrM	M	PoM	PrM	M	PoM	PrM	M	PoM	PrM	M	PoM	PrM	M	PoM	PrM	M	PoM	PrM	M	PoM	PrM	M	PoM
Elevation (m)	1700	1700	1700	2950	2950	2950	3800	3800	3800	4000	4000	4000	1600	1600	1600	2500	2500	2500	3500	3500	3500	4600	4600	4600
Phytoplankton (cells/l)	1484	413	1384	6174	443	1728	6019	613	2062	1628	542	5000	810	367	587	1031	452	662	540	459	1125	—	—	600
Phytobenthos (Cells/cm^2)	9133	3982	9012	6133	4252	17400	3040	5623	11162	4245	242	7350	1256	669	37800	4200	853	31754	233	2356	31975	—	—	1370
Macro-invertebrates (indiv./m^2)	899	336	752	242	201	533	471	152	477	588	162	375	1295	423	1309	542	376	480	532	109	547	—	—	175

and chemical characteristics like turbidity and current velocity, that varying greatly during monsoon months and reflect multimodal peaks in plankton (Reinhard, 1931). The planktonic densities decreased significantly during monsoon season at all the sampling sites. Rainfall that triggers fluctuations in water discharge and turbidity, seems to be the determining factor for the seasonal variation in the phytoplankton density while temperature and velocity determine the spatial variation (Berner, 1951).

3.3.2.3 *Phytobenthos*

The phytobenthos is group of microscopic plants, which are found attached on the substratum. This community is important for the bottom dwellers and herbivorous fishes in the aquatic ecosystem. In Himalayan rivers, this community is dominated by non-filamentous form, diatoms accounting for more than 90% of total density. In case of phytobenthos, multimodal peaks were observed in Teesta and Lachung Chhu all along the altitudinal gradient (Fig. 3.9). Such trend can be attributed to irregularities in water current velocity and dissimilarities in substrata selected for the scrapings. These parameters are most limiting factors for the phytobenthos (Holmes and Whitton, 1981). In comparison to plankton, river Teesta (lower and upper stretches) and Lachung Chhu were rich in phytobenthic density. The higher densities were observed at Melli (Tr1), Thangu (Tr11) and at Chungthang (Tr13) during pre-monsoon, monsoon and post-monsoon seasons, respectively (see Fig.3.9). In general, low densities of phytobenthos were observed in lower stretch of Teesta river which can be attributed to higher temperatures. According to Holmes and

Whitton (1981), diatom can grow best at low temperature. Since diatom community is main contributor to phytobenthos, therefore fluctuation in the density of total phytobenthos depended mainly on diatoms. Lowest densities were recorded during monsoon season at all the sites, which might be due to higher discharge and turbidity that distributed and washed out the substrate.

3.3.2.4 *Macro-invertebrates*

Macro-invertebrates are found to be attached on the bottom. In this category, the organisms included are oligochaeta, mollusca and nymph of aquatic insects. Macro-invertebrates are secondary consumers of aquatic ecosystem. They generally feed upon microscopic algae and zooplankton and form the food for carnivorous fish. In river Teesta, water discharge and scarcity of food in monsoon season, reduces the density of macro-invertebrates greatly. In lower stretches, the density decreased from a range of 170 – 1310 individuals/m^2 in pre-monsoon to a range of 43 – 243 individuals/m^2 in monsoon. In post monsoon season when conditions become normal, the macro-invertebrates density is restored up to a range of 199 – 1220 individuals/m^2. More or less similar trend was observed in upper stretch of Teesta and Lachung Chhu.

Along the altitudinal gradient the density of macro-invertebrates generally increased from lower stretches to upper during all seasons with a few exceptions. However, there was a drop in the density of macro-invertebrates and continued to decrease in the upper part of river Teesta

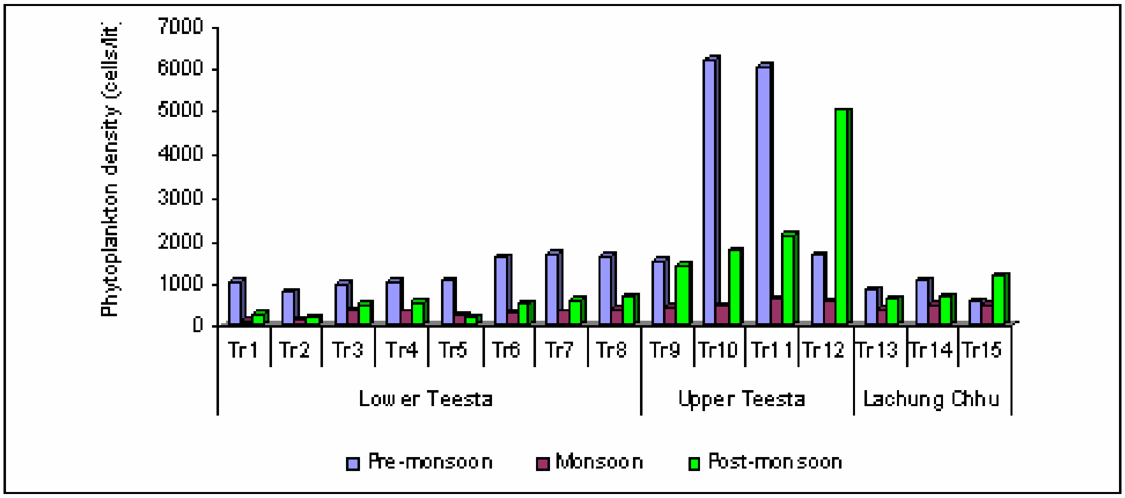

Fig. 3.8 Phytoplankton density in river Teesta

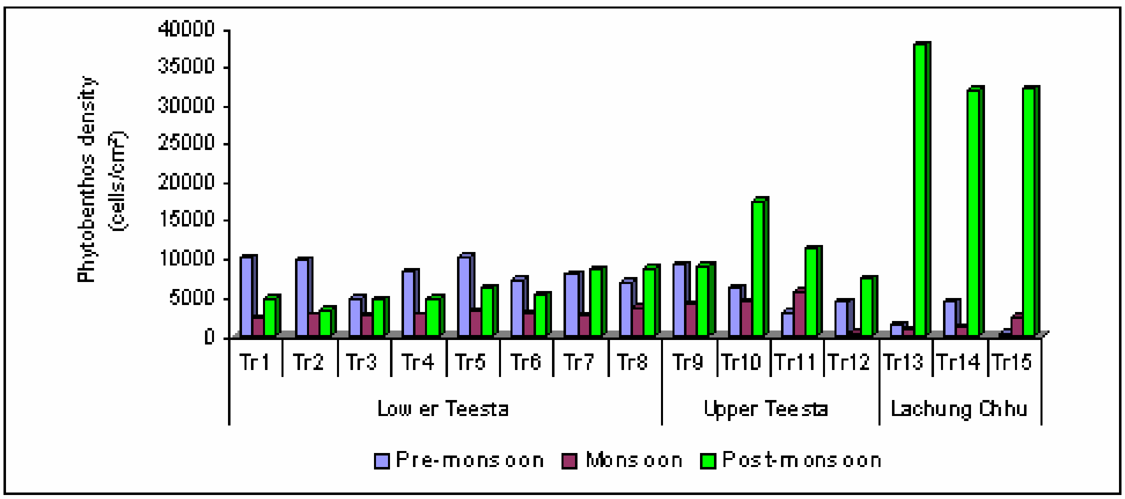

Fig. 3.9 Phytobenthos density in river Teesta

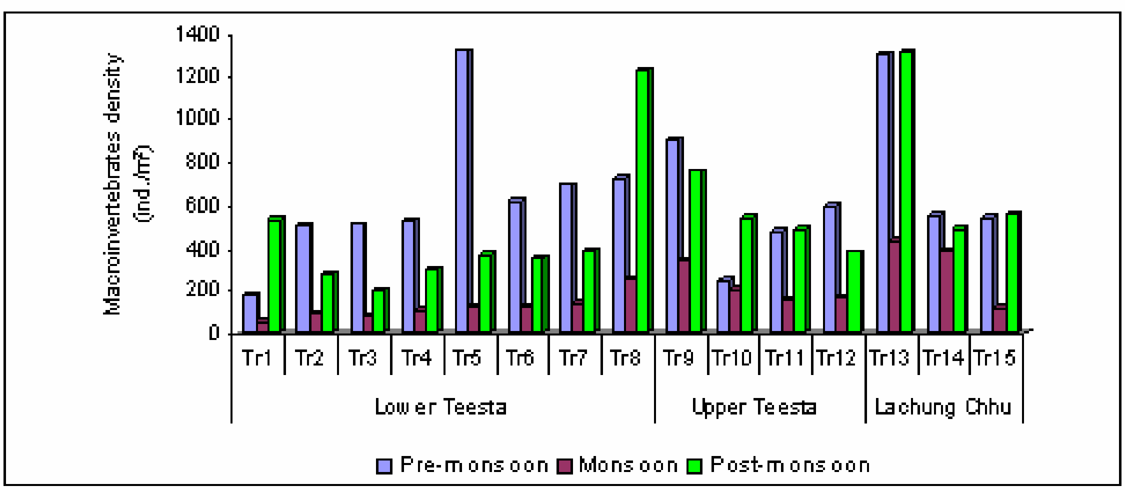

Fig. 3.10 Variation in the density of macroinvertebrates in the water of river Teesta

and Lachung Chhu (see Tables 3.3 and 3.4; Fig. 3.10). The turbidity, water temperature and dissolved oxygen seem to play an important role in the distribution of macro-invertebrates (Ward and Dufford, 1979). The distribution of macro-invertebrates is more closely related to the substrate than water quality (Ruggiero and Merchant, 1979). In lower stretch of Teesta, water volume increases significantly and this is not conducive for insects to lay their eggs in the large volume of water.

3.3.3 Community structure

Among the phytoplankton, around 70 species of non-filamentous algae (diatoms) from river Teesta were recorded, 48 from the lower stretch, 44 from upper stretch of Teesta and 39 from Lachung Chhu (Table 3.5). In addition, a few species of filamentous form like *Lyngbya* sp., *Spirula* sp., *Oscillatoria* sp., *Cladophora*, *Ulothrix* sp., *Spirogyra*, *Schizomeris*, etc. are also found in these rivers. The low presence of filamentous algae was also recorded by Negi (1994) and Rachna and Priti (1994) in other Himalayan rivers. The number of plankton species varied from 34 – 44 with maximum at Mangalbare village (Tr5) in the lower stretch of Teesta (Fig. 3.11). In upper stretch of Teesta, number of species varied from 25 – 33 with maximum at Yungdi (Tr12). In Lachung Chhu, the number of species varied from 23 at Yumesamdong (Tr16) to 29 at Chungthang (Tr13). Five species *viz.*, *Achnanthes minutissima, Fragilaria capucina, Hannaea arcus linearis, H. arcus amphioxys* and *Cocconeis placentula euglypta* were found to be most common species in Teesta river system as they were recorded from all the sampling

Table 3.5 Species composition of phytoplankton in Teesta river and Lachung Chhu in Sikkim during post-monsoon season

	Lower stretch of Teesta								Upper stretches of Teesta							
									Lachen Chhu				Lachung Chhu			
	Tr1	Tr2	Tr3	Tr4	Tr5	Tr6	Tr7	Tr8	Tr9	Tr10	Tr11	Tr12	Tr13	Tr14	T15	Tr16
Cyclotella antiqua	-	-	-	-	-	-	-	-	-	+	+	+	-	+	+	+
A. affinis	+	+	+	+	+	+	-	-	+	+	-	+	+	+	+	+
A. biasolettiana	+	+	+	+	+	+	+	+	+	+	+	-	+	+	+	+
A. haukiana	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-
A. microcephala	+	+	+	+	+	+	+	+	-	+	+	+	-	+	-	-
A. lanceolata	+	+	+	+	+	+	-	-	-	-	-	-	-	-	-	-
A. nodosa	+	-	+	+	+	+	-	-	-	-	-	-	-	-	-	-
A. orientalis	+	-	-	-	+	+	-	-	-	-	-	-	-	-	-	-
A. suchlanditi	+	-	-	-	+	+	-	-	-	-	+	-	-	-	-	-
A. exilis	+	+	+	+	+	+	-	-	-	+	-	+	-	-	-	-
A. fragilarioides	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-
A. inflata	+	+	+	+	+	+	-	-	-	-	-	-	-	-	-	-
A. undata	+	+	+	+	+	+	+	+	-	-	-	-	-	-	-	-
A. minutissima	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
A. minutissima cryptocephala	-	-	-	-	+	+	+	+	+	+	+	+	+	+	+	+
A. linearis	-	-	-	-	-	-	+	+	-	-	-	-	-	-	-	-
Achnanthes sp. 1	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+

Contd...

	Tr1	Tr2	Tr3	Tr4	Tr5	Tr6	Tr7	Tr8	Tr9	Tr10	Tr11	Tr12	Tr13	Tr14	T15	Tr16
Achnanthes sp. 2	+	-	+	+	+	+	+	+	+	+	-	-	+	+	+	+
Anomoeneis sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+
Cocconeis placentula euglypta	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Cymbella affinis	+	+	+	+	+	+	+	+	+	+	-	-	+	+	-	-
C. cincta	+	+	+	+	+	+	-	-	-	-	-	-	-	-	-	-
C. cymbiformes	+	+	+	+	+	+	-	-	-	+	+	+	-	-	+	+
C. gracilis	+	+	+	+	+	+	-	-	-	-	-	-	-	-	+	+
C. helvatica	+	-	-	+	+	+	-	-	-	-	-	-	-	-	-	-
C. laevis	-	-	-	-	-	-	-	-	-	+	+	+	-	-	-	-
C. lanceolatum	-	-	-	-	-	-	-	-	+	-	-	-	-	+	-	-
C. pucilla	+	+	+	+	+	-	-	-	-	-	-	-	-	-	-	-
C. sinuata	-	-	-	-	-	-	+	+	+	-	-	-	+	-	-	-
C. ventricosa	-	-	-	-	-	-	+	+	+	+	+	+	+	+	+	+
C. tumida	-	-	-	-	-	-	+	+	-	-	-	-	-	-	-	-
Cymbella sp.	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Diatoma sp.	+	-	+	+	+	+	+	+	-	-	-	-	+	+	+	+
D. vulgare	-	+	+	+	+	+	+	-	-	-	-	-	+	+	+	+
D. anceps	-	-	-	-	-	-	-	-	+	-	-	-	+	-	-	-
Didymosphenia geminata	-	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Fragilaria capucina	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
F. construense	-	-	-	-	-	-	-	-	+	-	+	+	-	-	-	-
F. pinnata	+	+	+	+	+	-	-	-	-	-	-	-	-	-	-	-

Contd...

	Tr1	Tr2	Tr3	Tr4	Tr5	Tr6	Tr7	Tr8	Tr9	Tr10	Tr11	Tr12	Tr13	Tr14	T15	Tr16
F. vaucheriae	-	-	-	-	-	-	+	+	+	-	+	+	-	-	-	-
Gomphonema lanceolatum	+	+	+	+	+	+	+	+	-	-	-	-	-	-	-	-
G. olivaceum	+	+	+	+	+	+	+	+	-	-	-	-	+	-	-	-
G. nagpurense	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-
G. longiceps	-	-	-	-	-	+	-	-	-	+	+	+	-	+	-	-
G. intricatum	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	+
G. sphaerophorum	+	+	+	+	+	+	-	-	-	-	-	-	-	-	-	-
G. parvulum	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-
G. aungustatum	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-
Gomphonema sp. 1	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Hannae arcus linearis	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
H. arcus amphioxys	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Navicula cryptocephala veneta	+	+	+	+	+	+	-	-	-	-	-	-	-	-	-	-
N. radiosa	+	+	+	+	+	+	-	-	+	+	+	+	+	+	-	-
N. microcephala	-	-	-	-	-	-	+	+	+	-	+	+	-	-	-	-
N. rhynchocephala	-	-	-	-	-	-	+	+	-	-	-	-	-	-	-	-
Navicula sp.	-	+	+	+	+	-	+	+	+	-	+	+	+	+	-	-
Nedium viridis	+	+	-	+	+	-	-	-	-	-	-	-	-	-	-	-
Pinnularia sp.	-	-	-	+	+	-		-	-	-	-	-	-	-	-	-
P. viridis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+
Stauroneis sp	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-

Contd...

	Tr1	Tr2	Tr3	Tr4	Tr5	Tr6	Tr7	Tr8	Tr9	Tr10	Tr11	Tr12	Tr13	Tr14	T15	Tr16
Synedra amphicephala	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-
S. ulna amphirhynchus	+	+	+	+	+	+	+	-	-	-	-	-	+	-	-	-
S. ulna oxyrhynchus	+	+	+	+	+	+	+	+	+	-	+	+	-	-	+	-
S. u. oxyrhynchus mediocontracta	-	-	-	-	-	-	+	+	+	+	+	+	+	+	+	-
S. ulna	+	+	+	+	+	+	+	+	+	-	-	+	+	+	+	+
S. rumpens	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-
S. tabulata	-	-	-	-	-	+	+	+	+	-	-	-	-	-	-	-
Synedra sp.	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-
Surirella linearis	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-
S. didyma	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-
S. robusta	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-
Tabellaria sp.	+	+	-	+	+	+	+	+	-		-	-	-	-	-	-
Unidentified sp. 1	-	-	-	-	-	-	+	+	+		+	+	+	+	-	-

sites. *Synedra ulna* was dominant in the lower stretch of Teesta (sites Tr1 – Tr4) while *Hannaea arcus linearis* was dominant at most of the sites (Tr5 – Tr8) in Teesta as well as Lachung Chhu. In the high altitude region, *Didymosphenia geminata* was the most dominant species. A few species like *Gomphonema olivaceum, G. lanceolata* and *Achnanthes undata*, etc. were observed only in lower stretch of Teesta, whereas a few species *viz.*, *Cyclotella antiqua* (only centrales diatom species), *Anomoeneis* sp., *Cymbella laevis, Gomphonema intricatum* were recorded only from the upper reaches of Teesta river. *Pinnularia viridis*, *Surirella linearis*, *S. robusta*, *S. didyma* and an unidentified species of *Synedra* are some of the rarely occurring species in Teesta river.

About 80 species of phyobenthic community were observed from river Teesta and its tributary Lachung Chhu (Table 3.6). The species composition varied from 30 - 37 in lower stretch of Teesta to 34 – 47 in Teesta river (Lachen Chhu) and 11 - 34 in Lachung Chhu in the upper stretch of Teesta (Fig. 3.12). A few species viz., *Achnanthes minutissima, A. minutissima cryptocephala, A. affinis, A. linearis, Cymbella ventricosa, Fragilaria capucina, Hannaea arcus, H. arcus linearis* and *Synedra ulna oxyrhynchus mediocontracta* were found to be most common, which were distributed from Melli Bazar (Tr1) to Yongdi (Tr12) in river Teesta and in all sites of Lachung Chhu. These species can survive in a wide range of water discharge (24.9 – 245 cumec), temperature (8^0C -17.5^0C) and pH (6.7-8.0). Therefore, these can be categorized as most tolerant phytobenthic species. *Navicula radiosa minutissima* was the most dominant phytobenthic community in river Teesta from Melli (site Tr1) to

Table 3.6 Species composition of phytobenthos in Teesta river and Lachung Chhu in Sikkim during post-monsoon season

	Lower stretch of Teesta								Upper stretches of Teesta							
									Lachen Chhu				Lachung Chhu			
	Tr1	Tr2	Tr3	Tr4	Tr5	Tr6	Tr7	Tr8	Tr9	Tr10	Tr11	Tr12	Tr13	Tr14	T15	Tr16
Cyclotella antiqua	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	+
Achnanthes affinis	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-
A. biasolettiana	-	-	-	+	+	+	+	+	+	+	+	+	+	+	+	-
A. exigua	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-
A. microcephala	-	-	+	+	+	+	-	-	+	+	+	+	+	+	+	-
A. lanceolata	+	+	+	-	-	-	+	-	-	+	+	-	-	+	+	-
A. exilis	+	+	+	-	-	-	-	-	-	+	+	-	-	-	+	-
A. undata	+	+	+	+	+	-	-	-	-	-	-	-	-	-	-	-
A. minutissima	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
A. minutissima cryptocephala	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-
A. linearis	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-
A. clevei	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-
A. lammermani	-	-	-	-	-	+	-	+	-	-	-	-	+	+	-	-
Achnanthes sp. 1	+	+	+	+	+	+	-	+	+	+	+	+	+	-	+	+
Achnanthes sp. 2	+	+	+	+	+	+	+	-	+	+	+	+	+	+	+	+
Anomoeneis sp. 1	-	-	-	-	-	-	+	-	-	-	-	+	-	-	-	-
Amphora veneta	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-

Contd...

	Tr1	Tr2	Tr3	Tr4	Tr5	Tr6	Tr7	Tr8	Tr9	Tr10	Tr11	Tr12	Tr13	Tr14	T15	Tr16
Amphora sp.	-	-	-	-	-	-	-	-	-	-	+	+	-	+	-	-
Cocconeis placentula euglypta	+	+	+	+	+	+	-	-	-	+	+	+	+	+	+	-
C. affinis	+	+	+	+	+	+	+	+	+	+	+	-	+	+	+	-
C. cymbiformes	-	-	-	-	-	-	-	-	-	+	+	+	-	+	+	-
C. gracilis	-	-	-	-	-	-	-	-	-	+	+	-	-	+	-	-
C. laevis	-	-	-	-	-	-	-	-	-	+	+	+	-	+	+	-
C. sinuata	+	+	+	+	-	-	-	+	-	+	+	-	+	-	-	-
C. ventricosa	+	+	+	+	-	+	+	+	+	+	+	+	+	+	+	-
C. tumida	+	+	+	+	+	+	-	+	-	-	-	-	-	-	-	-
C. tumidula	+	+	+	-	-	-	+	+	-	+	-	-	-	-	-	-
C. amphicephala	-	-	-	-	-	-	-	-	+	+	-	-	+	-	-	-
C. prostrata	-	-	-	-	-	-	-	-	+	+	-	-	-	-	-	-
Cymbella sp. 1	+	+	+	-	+	+	+	+	+	+	+	-	+	+	-	-
Diatoma sp. 1	-	-	-	-	-	-	+	+	+	+	+	+	-	-	-	+
Diatoma sp. 2	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-
D. vulgare	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-
D. anceps	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	+
Didymosphenia geminata	-	-	-	-	-	-	-	-	+	+	+	+	+	+	+	+
Diploneis ovalis	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-
Eunotia sp. 1	-	-	-	-	-	+	+	+	+	-	+	-	-	-	-	-
Eunotia sp. 2	-	-	-	-	-	-	+	-	-	-	+	-	-	-	-	-
Eunotia pracrapta	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-

Contd...

	Tr1	Tr2	Tr3	Tr4	Tr5	Tr6	Tr7	Tr8	Tr9	Tr10	Tr11	Tr12	Tr13	Tr14	T15	Tr16
Fragilaria capucina	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-
F. construense	-	-	-	-	-	-	-	-	-	+	+	-	+	+	+	+
F. alpestris	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-
F. pinnata	-	-	-	+	-	-	-	-	-	-	-	+	-	+	-	-
F. leptostauron	-	-	-	-	-	-	-	-	-	-	-	+	-	-	+	-
F. vaucheriae	+	+	+	+	+	+	+	+	+	+	+	-	+	-	+	-
Gomphonema lanceolatum	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-
G. olivaceum	+	+	+	+	+	-	-	+	-	-	-	-	-	-	-	-
G. olivaceoides	+	+	+	-	-	+	+	-	-	-	-	-	-	-	-	-
G. nagpurense	-	-	-	-	+	-	+	-	-	+	-	+	-	-	-	-
G. longiceps	-	-	-	-	-	-	-	-	-	+	+	-	-	-	-	-
G. intricatum	+	+	+	-	-	+	+	-	-	-	-	-	-	-	-	-
G. sphaerophorum	+	+	+	+	+	-	+	-	+	+	+	-	+	-	-	-
G. sphaerophorum var. 2	+	+	+	-	-	-	-	-	-	+	-	+	-	-	-	-
G. parvulum	+	+	+	+	+	-	+	+	-	+	+	+	+	+	-	-
G. gracile	-	-	-	-	+	+	-	-	+	-	-	-	-	-	-	-
G. aungustatum	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-
G. ventricosa	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-
Gomphonema sp. 1	+	+	+	-	+	+	+	+	+	+	+	+	+	+	+	-
Hannaea arcus linearis	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
H. arcus amphioxys	-	-	-	-	-	-	+	+	+	+	+	+	+	+	+	+
Navicula cryptocephala veneta	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-

Contd…

	Tr1	Tr2	Tr3	Tr4	Tr5	Tr6	Tr7	Tr8	Tr9	Tr10	Tr11	Tr12	Tr13	Tr14	T15	Tr16
N. radiosa	+	+	+	+	+	+	-	-	-	+	-	+	-	-	-	-
N. radiosa tenella	+	+	+	+	+	+	+	-	-	-	-	-	-	-	-	-
N. radiosa minutissima	+	+	+	+	+	+	+	-	-	-	-	-	-	-	-	-
N. microcephala	-	-	-	-	-	-	-	-	-	+	+	-	-	-	-	-
N. rhynchocephala	+	+	+	-	-	-	-	+	-	+	-	+	-	+	+	-
N. halophila	-	-	-	-	-	-	-	-	+	+	+	+	+	+	+	-
N. salinarum	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-
Navicula sp.	-	-	-	-	+	-	-	+	+	+	+	+	+	+	+	-
Nitzschia sp.	-	-	-	-	-	-	-	-	-	+	-	+	-	+	-	-
N. palea	-	-	+	+	-	-	-	-	-	-	-	-	-	-	-	-
Pinnularia sp.	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Stauroneis anceps	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-
S. amphicephala	-	-	-	-	-	-	-	+	+	+	+	-	+	+	-	-
S. ulna oxyrhynchus	+	+	+	+	+	+	+	+	+	+	-	-	+	+	+	-
S. ulna oxyrhynchus mediocontracta	+	+	+	+	+	+	+	+	+	+	+	-	+	+	+	-
S. ulna	+	+	+	+	+	+	+	+	+	+	+	-	+	+	+	+
S. rumpens	-	-	-	-	-	-	-	-	+	+	+	+	-	-	-	-
S. tabulata	+	-	-	+	+	-	-	-	+	-	-	-	-	-	-	-
Synedra sp.	+	+	+	-	-	-	+	-	-	-	-	+	-	+	-	-
Tabellaria sp.	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-
Unidentified sp. 1	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-
Unidentified sp. 2	-	-	-	-	-	-	+	+	-	-	-	-	+	+	+	-

Mangalbare (site Tr5). *Hannaea arcus linearis* was most dominant at site Tr6 (at Dikchu in lower stretch) and at site Tr10 (at Yunga) with an altitudinal range of about 600 - 2900 m. Towards higher elevations, *Achnanthes microcephala* was dominant. There were a few species which had a restricted distribution. For instance, *Achnanthes undata, Cymbella tumida* and *Gomphonema olivaceoides* were recorded only from lower stretch of river Teesta while *C. cymbiformes, C. laevis* and *Didymosphenia geminata* were observed from higher reaches only and can be identified as oligotrophic species. *Cyclotella antiqua* was found only at Yongdi upper stretch and Yumesamdong in higher reaches of Teesta river (Plates 3.1 and 3.2).

Among macro-invertebrates, total of more than 21 families were recorded from Teesta river (Table 3.7). Heptagenidae and Baetidae (Ephemeroptera) and Hydropsychidae (Trichoptera) were found to be most common taxa as they were recorded from most of the sites of lower and upper stretches of river Teesta. The altitude, current velocity, temperature and type of substratum are significant variables which influence the distribution of benthic life. Different taxa respond to these variables and have some special structural adaptations. For example Blepharoceridae (Diptera) have structural modifications in the form of suckers (Sehgal, 1991). Their distribution was restricted to fast running waters of upper stretch of Teesta. On the other hand May flies (Heptagenidae) and Stone flies, considered sensitive to organic pollution (Soucek *et. al*. 2000), were found at most of the sites indicative of good quality of water of Teesta river system. Though, pollution tolerant taxa like Chironomidae were also observed from upper stretch of river but its presence can not be correlated with

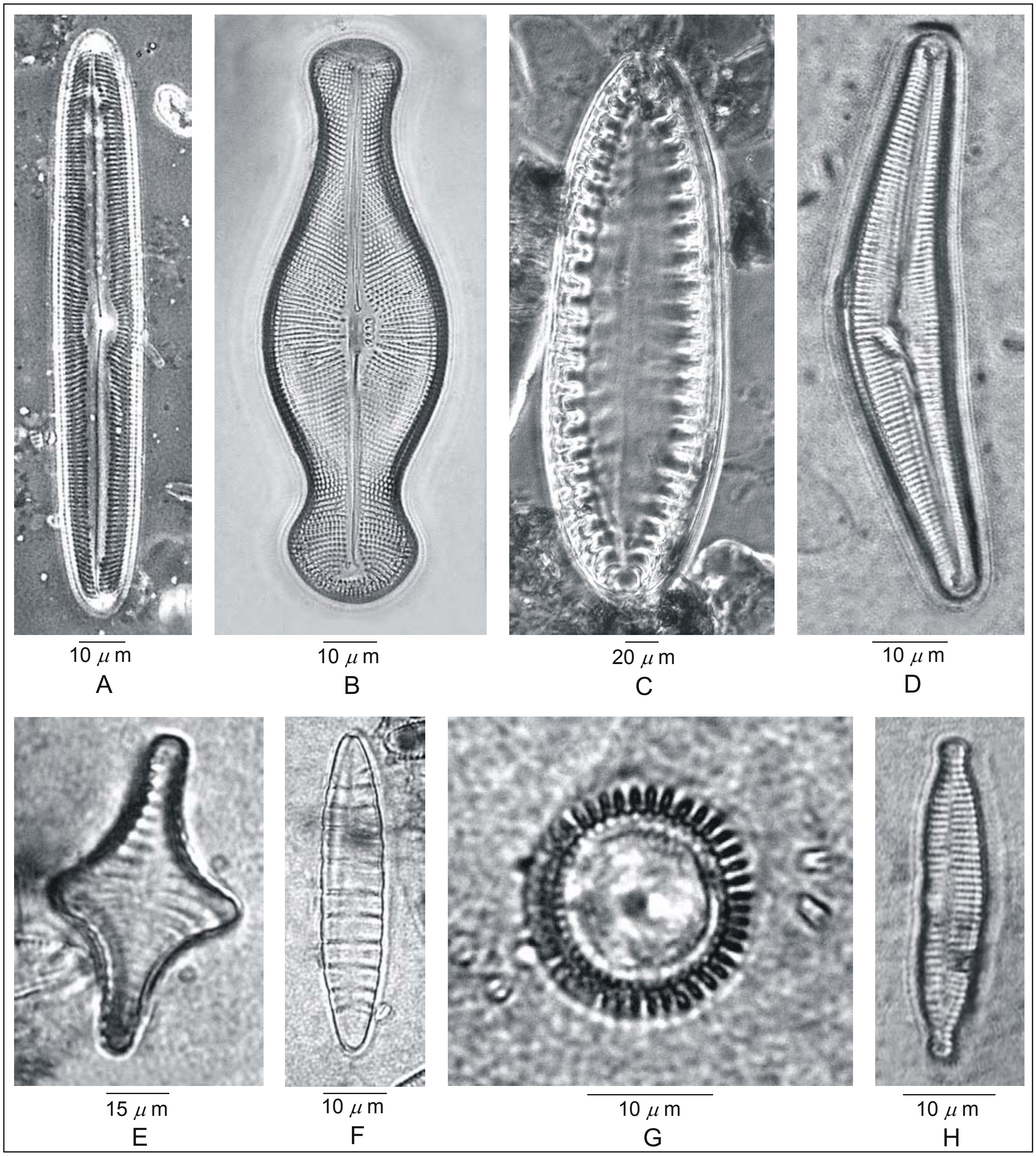

Plate 3.1 A few rare diatom species in the river Teesta: (A) *Pinnularia viridis*, (B) *Didymosphenia geminata*, (C) *Surirella robusta*, (D) *Cymbella cymbiformis*, (E) *Fragilaria leptostauron*, (F) *Diatoma vulgare*, (G) *Cyclotella* sp. and (H) *Fragilaria vaucherae*

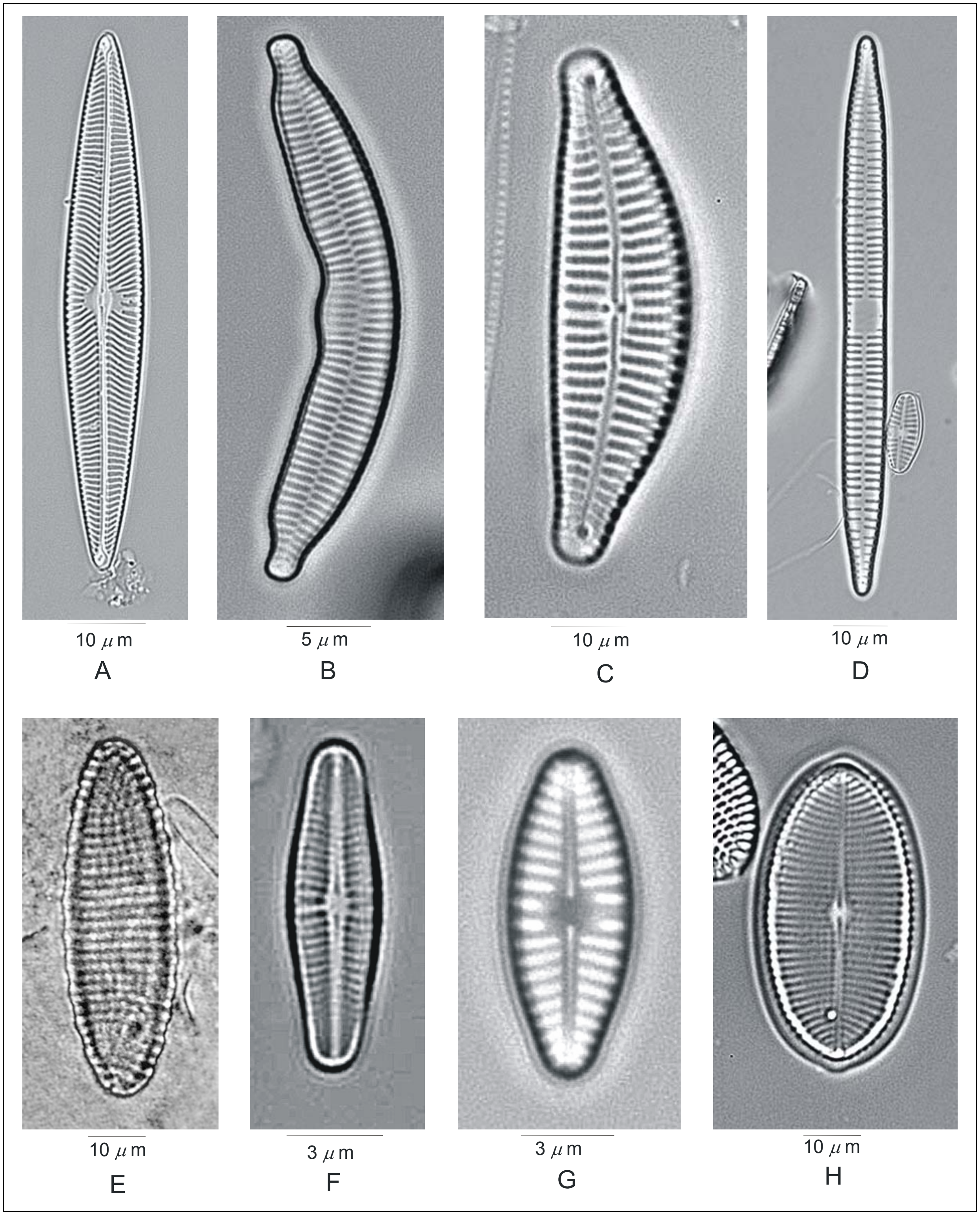

Plate 3.2 Common species of diatoms in river Teesta: (A) *Navicula radiosa*, (B) *Hannaea arcus linearis*, (C) *Cymbella affinis*, (D) *Synedra ulna*, (E) *Achnanthes undata*, (F) *A. minutissima*, (G) *A. biasolettiana* and (H) *Cocconeis placentula euglypta*

Table 3.7 Macro-invertebrates composition in river Teesta and Lachung Chhu in Sikkim during post-monsoon season

	Lower stretch of Teesta								Upper stretches of Teesta							
									Lachen Chhu				Lachung Chhu			
	Tr1	Tr2	Tr3	Tr4	Tr5	Tr6	Tr7	Tr8	Tr9	Tr10	Tr11	Tr12	Tr13	Tr14	T15	Tr16
Heptagenidae	+	+	+	+	+	+	+	+	+	+	-	-	+	+	+	-
Baetidae	+	+	+	+	+	+	+	+	+	+	-	-	+	-	-	-
Caenidae	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-
Leptophelbidae	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Other Ephemeroptera	-	-	-	+	-	-	+	+	+	+	-	-	+	+	-	-
Isoperlidae	-	-	-	-	-	+	-	-	+	-	-	-	-	-	-	-
Pteronarcidae	-	-	-	-	-	-	-	-	+		-	-	-	-	-	-
Perlidae	-	+	-	-	-	-	+	-	-	+	-	-	-	-	-	-
Hydropsychidae	-	+	-	+	-	-	+	+	+	-	-	-	+	+	-	-
Leptoceridae	-	-	-	-	+	+	+	+	-	-	-	-	-	+	+	+
Helicopsychidae	-	-	-	-	-	+	+	+	-	-	-	-	-	+	-	-
Hydroptilidae	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-
Other Trichoptera	-	-	-	-	-	-	-	-	+	+	-	-	-	-	-	-
Chironomidae	-	-	-	-	-	-	-	-	-	+	+	+	-	+	+	+
Ceratopgenidae	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-
Culucidae	-	-	-	-	-	-	-	-	+	-	-	-	+	-	-	-
Psychodidae	-	-	-	-	-	-	-	-	+	-	-	-	+	+	-	+
Ephydridae	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-
Simulidae	-	-	-	-	-	-	-	-	-	+	+	-	-	-	-	-
Blepharoceridae	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-
Oligochaeta	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	+

polluted status of water. Sehgal (1991) stated that pollution tolerant species are found in polluted and unpolluted waters whereas pollution intolerants are always associated with unpolluted waters.

3.4 RANGPO CHHU

Water sampling in rangpo chhu was carried out in a small stretch, which included two sites rc1 (upstream of confluence of rangpo chhu with teesta river) and rc2 (near rorathang) (see fig. 3.1). These sites were separated by a distance of about 9 km.

3.4.1 Physical and chemical characteristics

In Rangpo Chhu low turbidity was recorded in post-monsoon, followed by pre-monsoon season. This different trend in turbidity could be related with sand mining practices in pre-monsoon season by local people. At Rangpo (Rc1), pH was recorded slightly in acidic range (6.9 in pre-monsoon season and 6.6 in monsoon season). The low pH at Rangpo could be due to sewage outfall from the small township Rangpo and anthropogenic activities (Table 3.8). Except in pre-monsoon season, same concentration of total dissolved solids was observed at both sites. But it varied seasonally with a maximum of 30 mg/l in monsoon season. DO seasonally showed a negative correlation with temperature. Bicarbonates constituted the total alkalinity in Rangpo Chhu. The maximum alkalinity was recorded in pre-monsoon season that decreased significantly in monsoon and post-monsoon seasons. The total hardness showed a similar trend in Rangpo, which was slightly higher in pre-monsoon season as compared to the monsoon and post-monsoon seasons. Among the nutrients, nitrate and phosphate concentrations were considerably higher in monsoon season, which can be attributed to monsoon run-off (Badge and Verma, 1985). But chloride was found to be higher during pre-monsoon season.

Table 3.8 Physical and chemical characteristics of Rangpo Chhu water in Sikkim

	Pre-monsoon		Monsoon		Post-monsoon	
	Rc1	Rc2	Rc1	Rc2	Rc1	Rc2
Elevation (m)	300	348	300	348	300	348
Water discharge (m^3/s)	27.9	13.0	108.0	97.2	33.2	27.4
Water current velocity (m/s)	0.76	0.9	1.8	2.0	1.7	1.5
Turbidity (ntu)	21.0	20.0	30.0	30.0	8.0	4.0
Temperature (^0C)	17.0	17.0	21.0	20.0	20.5	19.0
TDS (mg/l)	30	20	30.0	30.0	10.0	10.0
Conductivity (μS/cm)	-	-	30.0	30.0	-	-
pH	6.9	7.0	6.6	7.0	7.4	7.5
Dissolved oxygen (mg/l)	9.3	9.2	7.7	7.6	8.5	8.3
Total alkalinity (mg/l)	52.0	52.0	19.2	19.2	20.5	19.0
Total hardness (mg/l)	20.0	23.2	20.0	15.2	17.6	18.4
Nitrate (mg/l)	0.01	0.01	0.09	0.07	0.04	0.03
Phosphate (mg/l)	0.19	0.21	0.21	0.2	0.09	0.09
Chloride (mg/l)	7.5	7.9	6.1	5.9	5.6	5.1

3.4.2 Biological characteristics

The planktonic community of Rangpo Chhu comprised of zooplankton and phytoplankton, of which phytoplankton constituted more than 95%. Among the phytoplankton, diatoms (Bacillariophyceae) constituted more than 90% of total density. The phytoplanktonic density was low due to sand mining practices in the lower stretch of Rangpo Chhu during pre-monsoon season. At both the sampling sites, highest density of phytoplankton was observed in the post-monsoon season (Table 3.9; Fig. 3.13).

Table 3.9 Density of different biotic communities of Rangpo Chhu water in Sikkim

	Pre-monsoon		Monsoon		Post-monsoon	
	Rc1	**Rc2**	**Rc1**	**Rc2**	**Rc1**	**Rc2**
Phytoplankton (cells/l)	572	390	302	298	1059	1470
Phytobenthos (cells/cm^2)	5260	5010	516	625	550	1484
Macro-invertebrates (indi./m^2)	649	694	209	312	352	176

The density of phytobenthic community was recorded to be 5260 and 5010 cells/cm^2 at sites Rc1 (Rangpo) and Rc2 (Rorathang), respectively in pre-monsoon season, which decreased to 516 and 625 cells/cm^2 in monsoon and 550 and 1484 cells/cm^2 in post-monsoon seasons at the respective sites (see Fig. 3.13). The phytobenthic community of Rangpo Chhu comprised mainly of diatoms (>90%). The density of macro-invertebrates showed more or less similar trend of distribution. The higher densities were recorded during lean season.

3.4.3 Community structure

Phytoplanktonic community comprises of about 5 species of filamentous algae and more than 32 species of diatoms. Among the filamentous forms *Anabaena, Oscillatoria, Spirula* and *Spirotaenia* spp. were most common. Among diatoms, about 19 species viz. *Achnanthes affinis, A. linearis, A. minutissima, A. minutissima cryptocephala, Cocconeis placentula euglypta, Cymbella affinis, Navicula radiosa, Gomphonema sphaerophorum*, etc. were common at both the sites (Table 3.10). *Achnanthes linearis* was the most abundant species among diatoms. The same filamentous forms represented the phytobenthic community. The number of diatom species observed were 35 and 27 at Rangpo (Rc1) and Rorathang (Rc2), respectively. Out of these, 19 species *viz.*, *Achnanthes affinis, A. linearis, A. minutissima, A. minutissima cryptocephala, Cocconeis placentula euglypta, Diatoma hiemale, Cymbella affinis, Cymbella ventricosa, Navicula radiosa tenella*, etc. were the most common species and *Achnanthes linearis* was the dominant one in phytobenthic community also. There were about 15 species of diatoms which were common in planktonic and benthic communities. Macro-invertebrates community comprised of more than 9 families (7 at Rc1 and 6 at Rc2). Heptagenidae, Baetidae and Ephemerelidae were dominant families at Rangpo (Rc1) while Heptagenidae and Isoperlidae dominated site Rc2 (Rorathang) (Table

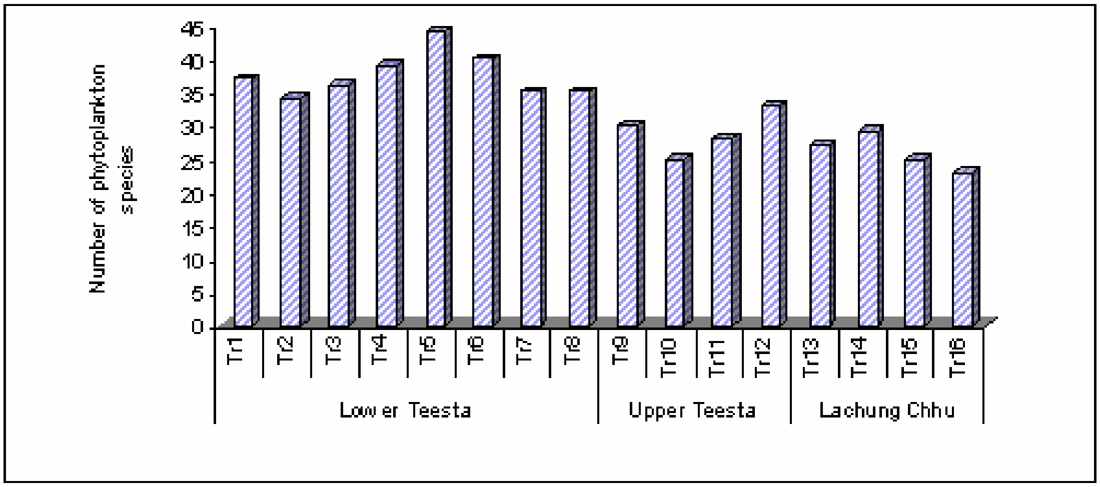

Fig. 3.11 Number of phytoplankton species in different stretches of river Teesta

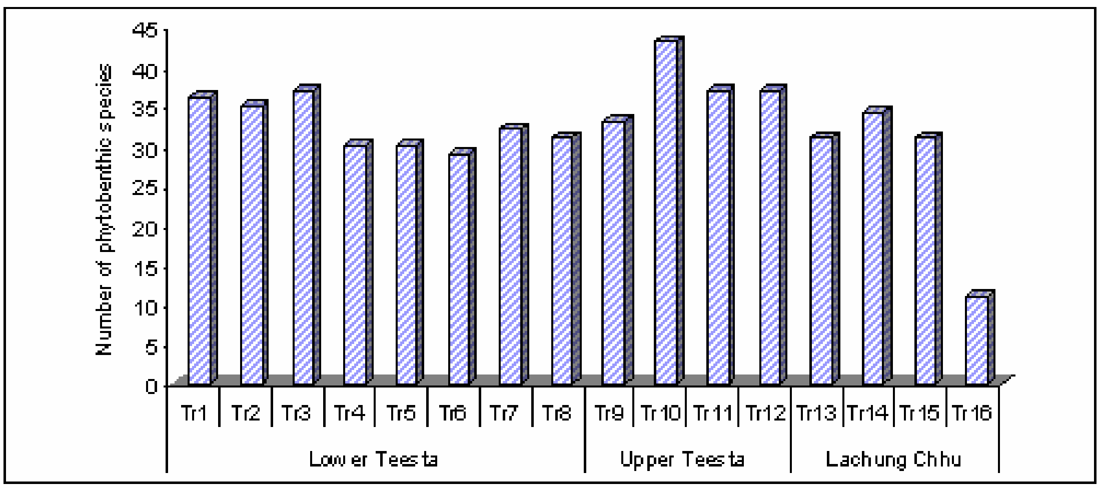

Fig. 3.12 Phytobenthic species diversity in Teesta river

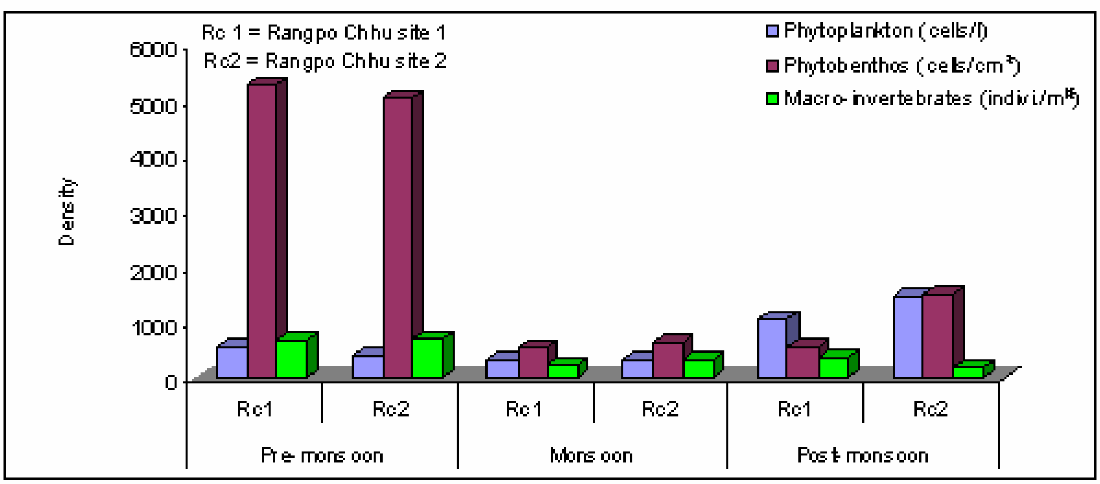

Fig. 3.13 Variation in the different biotic communities of Rangpo Chhu

3.11). Phytoplanktonic density at Teesta river before confluence of Rangpo Chhu was more; phytoplankton (34) and phytobenthos (35) as compared to that of Rangpo Chhu.

Table 3.10 Species composition of planktonic and phytobenthic communities in Rangpo Chhu in Sikkim

	Phytoplankton		Phytobenthos	
Species	**Rc1**	**Rc2**	**Rc1**	**Rc2**
Achnanthes affinis	+	+	+	+
A. didyma	+	-	-	-
A. gibberula	-	+	+	-
A. biasolettiana	-	+	+	+
A. haukiana	-	-	-	+
A. linearis	+	+	+	+
A. minutissima	+	+	+	+
A. minutissima cryptocephala	+	+	+	+
A. saxonica	+	-	-	-
A. sukhlandti	-	-	+	-
A. undata	-	-	+	+
Achnanthes sp. 1	+	+	+	+
Achnanthes sp. 2	+	+	+	+
Achnanthes sp. 3	+	+	-	-
Amphora veneta	-	+	-	+
Cocconeis placentula euglypta	+	+	+	+
C. linearis	-	+	-	-
Cymbella affinis	+	+	+	+
C. leptoceros	+	-	-	-

C. sinuata	+	+	+	+
C. tumidula	-	-	+	-
C. turgida	+	-	-	+
C. turgidula	+	-	+	-
C. ventricosa	+	-	+	+
D. anceps	-	+	+	-
D. hiemale	-	+	+	+
E. lunaris	-	+	-	+
Fragilaria capucina	+	+	+	+
F. leptostauron	+	-	+	-
F. vaucheriae	+	+	+	+
Gomphonema olivaceum	+	+	+	+
G. parvulum	+	-	+	-
G. sphaerophorum	+	+	+	-
G. intricatum	+	+	+	+
Gyrosigma sp.	+	-	-	-
Hannaea arcus linearis	-	+	-	-
Navicula hustedtii	+	+	+	-
N. halophila	-	-	+	-
N. radiosa	+	+	+	+
N. radiosa tenella	-	-	+	+
N. radiosa minutissima	-	-	+	-
N. rhynchocephala	-	-	-	+
N. similis	+	-	-	-
N. subrhynchocephala	-	+	+	-
Nitzschia palea	+	-	+	-
Stauroneis sp.	-	+	-	-
Surirella caproni	+	-	-	-

Synedra ulna	+	+	+	+
S. ulna oxyrhynchus	-	-	-	+
S. ulna oxyrhynchus mediocontracta	+	+	+	-
S. ulna amphirhynchus	+	+	+	+

Table 3.11 Density (individuals/m^3) of macro-invertebrates in Rangpo Chhu in Sikkim

Taxon	Rc1	Rc2
Phemeroptera		
Heptagenidae	80	66
Baetidae	32	22
Ephemerellidae	32	-
Plecoptera		
Isoperlidae	16	44
Perlidae	00	22
Trichoptera		
Hydropsychidae	64	-
Coleoptera		
Psephanidae	16	-
Diptera		
Chironomidae	16	22
Ephydridae	00	22

3.5 RANI KHOLA

To assess the quality of Rani Khola water samples were collected from two sites, i.e. site Rk1 was located at an elevation of 410 m near

Singtam and site Rk2 was about 15 km upstream of Rk1 near Ranipul at 750 m (see Fig. 3.1).

3.5.1 Physical and Chemical characteristics

Normally high turbidity was observed at Ranipul (Rk2) which is possibly due to heavy sewage outfall from Gangtok and Ranipul townships. But in monsoon season site Rk1 (Singtam) recorded significantly high turbidity after the confluence of a right bank tributary, which carries highly turbid waters. Total dissolved solids (TDS) was observed in normal range as in other streams. Except during the monsoon and post-monsoon seasons at Singtam, pH in Rani Khola was in acidic range during all the seasons. The concentration of dissolved oxygen was also observed to be low (6.9-7.8 mg/l), especially at Ranipul. Organic pollution from largest township in Sikkim, Gangtok is the responsible for low concentration of DO. Like other streams in Sikkim total alkalinity comprised of bicarbonates and follow similar trend as recorded maximum concentration during pre-monsoon season (52 to 48 mg/l). During monsoon and post-monsoon seasons, alkalinity decreased significantly. Total hardness also followed similar trend and was observed to be maximum during pre-monsoon season and minimum during monsoon. As compared to other streams, Rani Khola recorded highest concentrations of nitrate, phosphate and chloride. Ranipul (Rk2) sampling site recorded noticeably high concentration of nutrients, which receives sewage directly from the vicinity. However, in the downstream stretch, the concentration of these nutrients decreased which might be due to increase in discharge or by self purification system of the river (Table 3.12).

Table 3.12 Physical and chemical characteristics of Rani Khola in Sikkim

	Pre-monsoon		Monsoon		Post-monsoon	
	Rk1	Rk2	Rk1	Rk2	Rk1	Rk2
Elevation (m)	410	690	410	690	410	690
Discharge (m^3/s)	26.5	14.5	60.0	28.4	33.6	12.6
Velocity (m/s)	0.99	0.97	2.0	1.6	1.4	1.4
Turbidity (ntu)	18.0	19.0	120	20.0	6.0	20.0
Temperature (^0C)	20.5	17.0	23.0	22.0	20.5	19.0
TDS (mg/l)	30.0	20.0	20.0	20.0	10.0	10.0
Conductivity (μS/cm)	-	-	30.0	30.0	-	-
pH	6.7	6.9	7.7	6.0	7.8	6.9
Dissolved oxygen (mg/l)	8.9	7.2	6.7	6.9	7.7	7.8
Total alkalinity (mg/l)	52.0	48.0	12.0	15.2	20.0	20.0
Total hardness (mg/l)	26.4	24.8	12.0	12.0	16.0	18.4
Nitrate (mg/l)	0.1	0.21	0.12	0.16	0.12	0.20
Phosphate (mg/l)	0.16	0.25	0.13	0.16	0.12	0.25
Chloride (mg/l)	10.5	11.5	4.4	7.5	3.7	8.1

The physical and chemical profile of the river indicated that the Rani Khola is highly stressed stream of Teesta basin as compared to other streams.

3.5.2 Biological characteristics

The plankton community mainly comprised of Chlorophyceae, Myxophyceae and Bacillariophyceae. Bacillariophyceae accounted for more than 90% of total density. Vast difference in the density of plankton were observed between two sampling sites. At Ranipul very low density (almost half of the site Singtam) of phytoplankton was recorded (Fig. 3.14 and Table 3.13). Similarly, the water of Rani Khola also showed substantial differences in the densities of phytobenthos and macro-invertebrates between Singtam (Rk1) and Ranipul (Rk2).

Table 3.13 Densities of different biotic communities of Rani Khola in Sikkim

	Pre-monsoon		Monsoon		Post-monsoon	
	Rk1	Rk2	Rk1	Rk2	Rk1	Rk2
Phytoplankton (cells/l)	1451	714	412	264	1216	614
Phytobenthos (cells/cm^2)	4220	2470	516	625	5555	2220
Macro-invertebrates (ind./m^2)	1333	533	210	104	914	679

3.5.3 Community structure

Oscillatoria sp., *Anabaena* spp. and *Ulothrix* sp. were the most common species of filamentous algae at Singtam (Rk1), which were absent at site Rk2 (Ranipul). Among the phytoplankton, a total of 23 species of diatoms were observed at Singtam (Rk1) and 8 species at Ranipul (Rk2) (Table 3.14). The *Navicula radiosa* was the most abundant species at both the sites. Total of 29 species of diatoms were recorded near Singtam that decreased to 16 species at Ranipul. Among diatoms 14 species were common between the two sites. *Navicula radiosa* at Singtam (Rk1) and *Gomphonema sphaerophorum* at Ranipul (Rk2) were the most abundant species. There were about 5 diatom species *viz.*, *Achnanthes biasolettiana, Fragilaria capucina, Gomphonema parvulum, G. sphaerophorum* and *Navicula radiosa*, which were common at both the sites. The abundant occurrence of pollution tolerant species like *Gomphonema shaerophorum* and *Nitzschia palea* (Venkateswarlu, 1981) in Rani Khola at Ranipul indicated that it is comparatively more polluted stream in Sikkim. Though, these species were also observed in the lower sites of river Teesta and in Rangpo Chhu but they were not common and dominant at those sites. Macro-invertebrates community comprised of more than 9 species (Table 3.15). The Ranipul harboured all families while Singtam (Rk1) was found to have only 4 macro-invertebrates families. Heptagenidae at Singtam (Rk1) and Hydropshychiade at Ranipul (Rk2) were the most abundant families.

Table 3.14 Species composition of planktonic and phytobenthic communities in Rani Khola in Sikkim

	Phytoplankton		Phytobenthos	
Species	**Rk1**	**Rk2**	**Rk1**	**Rk2**
Achnanthes biasolettiana	+	+	+	+
A. lanceolata	+	-	+	-
A. linearis	+	-	+	+
A. minutissima	+	-	+	-
A. minutissima cryptocephala	+	-	-	-
A. affinis	+	+	-	+
Achnanthes sp. 1	+	-	+	+

Achnanthes sp. 2	+	-	+	+
Achnanthes sp. 3	-	-	+	+
A. undata	-	-	+	-
Amoneis sp.	-	-	+	-
Cocconeis placentula euglypta	+	-	+	-
Cymbella sinuata	-	-	+	+
C. ventricosa	+	-	+	-
C. affinis	+	-	+	+
Diploneis sp.	-	-	+	-
Eunotia sp.	+		+	-
Fragilaria capucina	+	+	+	+
F. vaucheriae	+	+	+	+
Gomphonema intricatum	+	-	+	-
G. parvulum	+	+	+	+
G. sphaerophorum	+	+	+	+
Navicula exigua	-	-	+	-
N. halophila	+	-	+	-
N. pupula	-	-	+	-
N. radiosa	+	+	+	+
N. rhynchocephala	+	-	+	+
Nedium sp.	-	-	+	-
Nitzschia ignorata	-	-	+	-
N. palea	+	-	+	+
Synedra ulna	+	+	+	-
S. ulna oxyrhynchus	+	-	-	-
S. rumpens	-	-	-	+

Table 3.15 Density (individuals/m^3) of macro-invertebrates in Rani Khola in Sikkim

Taxon	Rk1	Rk2
Phemeroptera		
Heptagenidae	589	93
Baetidae	228	40
Ephemerellidae	-	13
Plecoptera		

Isoperlidae	-	26
Trichoptera		
Hydropsychidae	57	360
Helicopsychidae	-	40
Diptera		
Chironomidae	40	40
Psychodidae	-	40
Culucidae	-	27

3.6 RANGIT RIVER

The samples were collected from two sites i.e. site Rg1 located near Teesta – Rangit confluence (250 m) and site Rg2 was at 1 km downstream of Jorethang at 280 m (see Fig. 3.1).

3.6.1 Physical and Chemical Characteristics

Total dissolved solids were recorded to be maximum during pre-monsoon season (30 mg/l at each site). The pH of water was in alkaline range at all the sites during all the seasons. Dissolved oxygen concentration was more at higher elevations. Like other streams of Sikkim, total alkalinity was comprised of bicarbonates and was recorded to be 42 and 38 mg/l at sites Rg1 and Rg2 during pre-monsoon season. The total alkalinity decreased significantly during monsoon and post-monsoon seasons. Calcium was the main contributor in total hardness. There were no much variations in total hardness among the different seasons. However, during monsoon season relatively low values of hardness were observed at both the sites of river Rangit. Among the nutrients, the maximum concentrations of nitrate and phosphate were observed during monsoon season. The chloride concentration was recorded to be 8.5 and 9.9 mg/l at site Rg1 and Jorethang (Rg2), respectively during pre-monsoon season and its concentration was 6.4 and 6.3 mg/l during monsoon and 6.5 and 7.2 mg/l during post-monsoon season, at the respective sites (Table 3.16).

Table 3.16 Physical and chemical characteristics of river Rangit in Sikkim

	Pre-monsoon		Monsoon		Post-monsoon	
	Rg1	Rg2	Rg1	Rg2	Rg1	Rg2
Elevation (m)	250	325	250	325	250	325
Discharge (m^3/s)	24.9	21.2	82.5	69.5	52.9	43.5
Velocity (m/s)	0.7	0.7	1.1	1.3	0.8	0.8
Turbidity (ntu)	5.0	04.0	65.0	60.0	15.0	10.0
Temperature (^{0}C)	19.5	19.0	22.5	22.0	21.5	20.0
TDS (mg/l)	30.0	30.0	10.0	10.0	10.0	10.0
Conductivity (μS/cm)	-	-	20.0	20.0	-	-
pH	7.3	7.3	7.1	7.2	7.8	7.9
Dissolved oxygen (mg/l)	8.8	8.9	8.0	8.2	7.8	8.1
Total alkalinity (mg/l)	42.0	38.0	18.5	18.5	24.0	22.0
Total hardness (mg/l)	25.6	24.8	22.0	20.5	26.4	22.0
Nitrate (mg/l)	0.1	0.1	0.18	0.16	0.11	0.12
Phosphate (mg/l)	0.17	0.22	0.20	0.22	0.18	0.19
Chloride (mg/l)	8.5	9.9	6.4	6.3	6.5	7.2

A comparison between river Rangit and Teesta river, Rangpo Chhu and Rani Khola showed that river Rangit traverses in wider channel with laminar flow in lower zone. The average temperature was comparatively higher and pH in alkaline range. The DO concentration was higher with higher concentrations of nutrients. These characteristics make this stream conducive for diverse aquatic organisms and Himalayan mahseer to breed preferably in this river.

3.6.2 Biological characteristics

Phytoplankton density was more than that of zooplankton with Bacillariophyceae (diatoms) (more than 95%) being most dominant. The highest density of plankton was recorded during pre-monsoon season (3646 and 3578 cells/lit near confluence (Rg1) and at Jorethang (Rg2), respectively, which was lower during monsoon i.e. 557 and 525 cells/lit, at the respective sites (Table 3.17). However, during post-monsoon it recovers to a large extent. Similarly macro-invertebrates density was maximum during pre-monsoon season and lowest during the monsoon (see Fig. 3.15). The density of phytobenthic community was maximum during post-monsoon season and lowest during monsoon season (see Fig. 3.15). Better physico-chemical profile of river Rangit is reflected in higher density and diversity of different biotic communities.

Table 3.17 Densities of different biotic communities of river Rangit in Sikkim

	Pre-monsoon		Monsoon		Post-monsoon	
	Rg1	Rg2	Rg1	Rg2	Rg1	Rg2
Phytoplankton (cells/l)	3646	3578	557	525	2302	2205
Phytobenthos (cells/cm^2)	1898	1237	490	417	8015	5132
Macro-invertebrates (ind./m^2)	1304	1349	318	226	782	660

3.6.3 Community structure

A total 70 species of planktonic and benthic algae were recorded from the river Rangit (Table 3.18). Filamentous algae like *Ulothrix* sp., *Hormedium* sp., *Spirula* sp., *Oscillatoria* sp., *Anabaena* sp. and *Lyngbya* sp. contributed less than 10% of the total density. Among the plankton, 35 species of diatoms from site Rg1 (near confluence) and 36 species from site Rg2 (Jorethang) were recorded. Approximately 23 species were common in occurrence. *Achnanthes linearis* was the most abundant species in plankton communities. Among the phytobenthic communities more than 40 species were recorded, of which 28 species were common. *Navicula radiosa* was the most abundant species among phytobenthos. The species like *Achnanthes linearis. A.minutissima, A. minutissima cryptocephala, Cymbella ventricosa, Fragilaria capucina, Synedra ulna, S. ulna oxyrhynchus, S. ulna oxyrhynchhus mediocontracta*, etc. were common at both the sites. Majority of common and abundant species were pollution intolerant.

Table 3.18 Species composition in planktonic and phytobenthic communities in river Rangit in Sikkim

	Phytoplankton		Phytobenthos	
Species	**Rg1**	**Rg2**	**Rg1**	**Rg2**
Cyclotella sp.	-	+	-	-
Achnanthes affinis	+	+	+	+
A. andicola	-	-	+	+
A. biasolettiana	+	+	+	+
A. conspicua	-	+	-	-
A. didyma	+	-	-	-

A. lammermanii	-	-	-	+
A. levanderi	+	-	-	-
A. lanceolata	-	+	+	+
A. linearis	+	-	+	+
A. microcephala	-	+	-	-
A. minutissima cryptocephala	+	+	+	+
A. minutissima	+	+	+	+
A. sukhlandti	-	-	+	+
A. saxonica	+	+	-	-
A. taenia	-	+	-	-
A. undata	+	+	+	+
Cocconeis plancentula euglypta	+	+	+	+
Amphora sp.	-	-	-	+
Cymbella affinis	+	-	+	+
C. lanceolata	-	-	-	+
C. prostrata	-	-	-	+
C. sinuata	+	+	+	+
Cymbella sp.	-	-	+	+
C. turgida	+	+	-	-
C. tumida	-	+	+	-
C. turgidula	+	-	-	+
C. ventricosa	+	+	+	+
C. leptoceros	+	-	-	-
Diatoma hiemale	-	+	-	-
Fragilaria capucina	+	+	+	+
F. leptostauron	+	-	-	-
F. vaucheriae	+	+	+	+
Gomphonema accuminatum	-	+	-	-
G. aungustatum longiceps	+	+	-	-
G. helvaticum	-	-	+	-
G. gracile	-	-	-	+
G. intricatum	+	-	-	+
G. nagpurense	-	+	-	-
G. olivaceoides	-	-	+	-
G. olivaceum	+	-	+	-
G. olivaceum calcarea	-	+	-	-
G. parvulum	+	+	+	+

G. sphaerophorum	+	-	+	+
Gyrosigma sp. 1	+	-	+	+
Navicula cryptocephala	-	+	-	-
N. halophila	-	-	+	+
N. hustedti	+	+	-	+
N. radiosa minutissima	-	-	+	-
N. radiosa tenella	-	-	+	+
N. radiosa	+	+	+	+
N. rhynchocephala	-	-	+	+
N. subrhynchocephala	-	-	-	+
N. similis	+	+	-	-
Navicula sp. 1	+	+	+	+
Nitzschia sp. 1	-	-	+	+
N. palea	+	+	-	-
N. intermedia	-	-	-	+
N. gracilis	+	-	-	-
Pinnularia sp. 1	+	+	-	-
Stauroneis lapponica	-	-	+	-
Stauroneis sp. 1	-	-	+	-
Surirella caproni	+	-	+	+
S. ovata	-	+	-	-
Synedra rumpens	-	-	-	+
S. ulna amphirhynchus	-	+	-	-
S. ulna oxyrhynchus mediocontracta	+	+	+	+
S. ulna oxyrhynchus	+	+	+	+
S. ulna	+	+	+	+

In lower stretches of Rangit river, 9 families of macro-invertebrates were recorded (Table 3.19). Family Heptagenidae was the most abundant group, followed by Baetidae at each site. Majority of the taxa were pollution intolerant, however, pollution tolerant group Chironomiade was abundant at the confluence region.

Table 3.19 Density (individuals/m^3) of macro-invertebrates in Rangit river in Sikkim

Taxon	Rg1	Rg2
Phemeroptera		
Heptagenidae	201	182
Baetidae	132	142
Ephemerellidae	68	44
Plecoptera		
Isoperlidae	11	30
Trichoptera		
Hydropsychidae	115	110
Leptophelbidae	46	52
Diptera		
Chironomidae	115	48
Culucidae	33	22
Coleoptera		
Psephanidae	69	30

3.7 RANGYONG CHHU

The study in Rangyong Chhu was conducted its confluence with Teesta (Rng1), near Lingdem village (Rng2) and at Lingza (Rng3). The study sites were stretched within 750 to 1000 m. altitudes.

3.7.1 Physical and chemical characteristics

The discharge of the water reflected to seasonal rhythms of monsoon and river considerably swelled during monsoon season. Water discharge slightly increased from site Rng3 to site Rng2 whereas from site Rng2 to Rng1 it increased considerably due to confluence of its largest tributary Tadung Chhu from left bank. The river flows through deep gorges and steep slopes, therefore, swift flow of water (>1.0 m/s) was measured at all sites (Table 3.20). The water temperature decreased towards downstream and peaked during monsoon season during all seasons. The turbidity is directly related to discharge of water and got peaks in monsoon season (52 – 66 ntu) at all sites. The minimum turbidities were recorded during pre-monsoon season (2-3 ntu). It increased towards lower sites due to mixing of relatively more fine particles in water. The pH was recorded to be more than 7.0 at all sites during all seasons. The concentration of dissolved oxygen was quite negatively correlated with temperature. In river Rangyong DO was found to depend largely on the direct diffusion and water temperature. Annually it varied from 8.99 to 9.86 mg/l. The low concentrations of total dissolved solids (TDS) were found in the river Ragyong. It was recorded 20 mg/l at all sites during pre-monsoon and post-monsoon seasons while in monsoon season it decreased to 10 mg/l at all sites. The electrical conductivity was found to depend largely upon the concentration of TDS. Maximum conductivity (40 µ S) was recorded at site Rng1 during post-monsoon while minimum was found to be 20 µ S at each site during monsoon season. Like most of the running waters, total alkalinity comprised of bicarbonates (Hynes, 1970). The pre-monsoon months recorded considerably high alkalinities (42.5 to 48.5 mg/l) while it fell to minimum (20.3 to 21.3 mg/l) in monsoon season due to heavy rains (e.g. Daborn and Clifford, 1974). Total hardness showed a similar trend in Rangyong Chhu. The most of the hardness of water

Table 3.20 Physical and chemical characteristics of river Rangyong Chhu in North Sikkim

	Winter			Monsoon			Post-monsoon		
	Rng1	**Rng2**	**Rng3**	**Rng1**	**Rng2**	**Rng3**	**Rng1**	**Rng2**	**Rng3**
Water discharge (Cumecs)	66.32	52.12	48.52	138	112	98.2	84.06	67.35	64
Water current velocity (m/s)	1.31	1.15	1.12	2.12	1.9	1.96	1.15	2	1.54
Water temperature (^{0}C)	14.5	14	13.5	17.2	17	16.5	16.5	16.3	15
Turbidity (ntu)	3	2	3	66	59	52	14.6	9	13
pH	7.61	7.56	7.55	7.11	7.05	7.08	7.58	7.45	7.48
Dissolved oxygen (mg/l)	9.66	9.83	9.86	8.99	9	9.22	9.16	9.33	9.73
Total dissolved solids	20	20	20	10	10	10	20	20	20
Conductivity (μS/cm)	30	30	30	20	20	20	40	30	30
Total alkalinity (mg/l)	42.5	43.52	48.56	20.36	20.34	21.33	22	22.4	28.83
Total hardness (mg/l)	18.36	21.25	20.24	11	14.74	14.06	12	17.6	14.53
Ca++	6.76	7.12	6.92	3.6	4.92	4.84	3.81	5.44	5.34
Mg++	0.35	0.83	0.71	0.48	0.59	0.47	0.6	0.99	0.26
Nitrate (mg/l)	0.22	0.21	0.06	0.36	0.32	0.36	0.34	0.32	0.06
Phosphate (mg/l)	0.03	0.01	0.01	0.06	0.08	0.08	0.03	0.007	0.03
Chloride (mg/l)	6.12	5.82	6.14	6.11	6.23	6.23	6.8	6.8	6.8

was contributed by Ca contents. However, the waters of Rangyong Chhu can be considered as soft water. Due to lack of waste water input, ground water movement and agricultural run off in the vicinity of river, low concentrations of nitrate and phosphate were recorded from the river water. However, concentrations (0.32 to 0.36 mg/l and 0.06 to 0.08 mg/l, respectively) increased in monsoon season, which can be attributed to surface run off. The concentration of chloride was more or less similar at all sites during all seasons.

3.7.2 Biological characteristics

The biological characteristics involved analysis of zooplankton, phytoplankton, phytobenthos and macro-invertebrates. We did not come across to presence of total coliforms at all sites during all seasons. The absence of coliforms from the Rangyong Chhu can be attributed to very sparse human population in the vicinity of Rangyong Chhu. Zooplankton contributed a little portion (0.59-9%) of total plankton. The density of zooplankton was found to range from 28 to 46, 0 to 03 and 17 to 78 individuals/lit. during pre-monsoon, monsoon and monsoon seasons, respectively (Table 3.21). The phytoplankton density decreased from sites Rng3 to Rng1during all seasons. The maximum density was recorded in pre-monsoon season while minimum in monsoon season. A similar tend with a few exceptions was observed in phytobenthic density. However, considerably high density (17803 cells/ cm^2) was observed at site Rng2 in post-monsoon season. Likewise phytoplankton monsoon flood washed most of the benthic cells. Macro-

Table 3.21 Densities of different biological components in river Rangyong Chhu during three seasons

	Winter			Monsoon			Post-monsoon		
	Rng1	Rng2	Rng3	Rng1	Rng2	Rng3	Rng1	Rng2	Rng3
Zooplankton (indiv.lit.)	36	28	46	2	3	-	30	17	78
Phytoplankton (cells/lit)	863	1022	1956	312	502	524	462	660	721
Phytobenthos (cells/cm^2)	4122	5168	6028	2410	2448	1854	1045	17803	5924
Macro-invertebr.(indiv./m^2)	254	214	198	18	26	24	99	89	55

invertebrates density was found to be 198 – 254, 18 – 26 and 55 – 99 individuals/m^2 in pre-monsoon, monsoon and post-monsoon seasons, respectively. The density generally decreased towards downstream.

3.7.3 Community structure

The phytoplankton community in Rangyong Chhu dominated with bacillariophyceae. A total of 4 filamentous and 40 diatoms species were recorded from river Rangyong (Table 3.22). The sites Rng3 and Rng1 recorded 31 species of diatoms while Rng2 site was found to have 28 species. *Achnanthes linearis, Hannea arcus* var. *linearis* and *Fragilaria vaucheriae* dominated the river Rangong. *Achnanthes biasolettiana, A. minutissima* var. *cryptocephala, A. minutissima, A. linearis, Cymbella sinuate Gomphonema olivaceum, Hannaea arcus* var. *linearis*, *H. arcus* var. amphioxys, *Synedra ulna* var. *oxyrhynchus, S. ulna* were the most common species in this stream. The majority of diatom species were pollution intolerant, however, a few pollution tolerant species like *Gomphonema spaerophorum*, *Nitzschia palea* and *Cocconeis* var. *placentula* were recorded from site Rng2 of the river. The presence of these species can be attributed to sparse settlement and sewage input in the river at this site.

Among the phytobenthic community a total of 46 species of algae were recorded from the river Rangyong (see Table 3.22). The upper site Rng3 recorded slightly higher number (33) of species, which decreased gradually towards downstream. *Cymbella ventricosa*, *Hannea arcus* var. *linearis, Fragilaria vaucheriae* were found to dominated the river water.

Achnanthes minutissima, A. minutissima var. *cryptocephala*, *A. linearis, Cymbella affinis, Fragilaria vaucheriae*, *Gomphonema nagpurense, G. intricatum, Hannaea arcus* var. *linearis, Synedra ulna var. oxyrhynchus* f. *mediocontracta, S. ulna* were most common species in the river. The majority of species were pollution intolerant but a few species *viz*. *G. sphaerophorum* amd *Cocconeis placrentula* were recorded at site Rng2 where small settlement was present.

Table 3.22 Species composition in phytoplankton and phytobenthos in the river Rangyong Chhu

	Phytoplankton			Phytobenthos		
	Rng1	**Rng2**	**Rng3**	**Rng1**	**Rng2**	**Rng3**
Achnanthes biasolettiana	+	+	+	+	+	+
A. haukiana	-	+	+	-	-	-
A. lanceolata	-	-	-	-	+	-
A. undata	+	+	+	+	-	-
A. minutissima	+	+	+	+	+	+
A. minutissima cryptocephala	+	+	+	+	+	+
A. linearis	+	+	+	+	+	+
Achnanthes sp. 1	+	+	+	+	-	+
Achnanthes sp. 2	+	+	+	+	+	-
Anomoeneis sp.	+	+	-	-	+	-
Cocconeis placentula euglypta	-	+	-	+	+	-
Cymbella affinis	+	+	-	+	+	+
C. laevis	-	-	-	+	-	+
C. sinuata	+	+	+	+	-	+
C. ventricosa	+	-	+	+	+	+
C. tumida	+	-	+	-	-	+
Cymbella sp.	+	-	+	+	+	+
Diatoma sp.	+	+	+	+	+	+
D. vulgare	+	-	-	-	-	-

Eunotia sp. 1	-	-	-	-	+	+
Eunotia sp. 2	-	-	-	-	+	-
Didymosphenia geminata	-	-	+	-	-	+
Fragilaria capucina	+	+	+	+	-	-
F. construense	-	-	-	-	-	-
F. vaucheriae	+	+	+	+	+	+
Gomphonema lanceolatum	+	+	+	+	-	+
G. olivaceum	+	+	+	-	-	+
G. sphaerophorum	-	+	-	-	-	-
G. parvulum	+	+	+	+	+	-
G. olivaceoides	-	-	-	+	+	-
G. nagpurense	-	-	-	+	+	+
G. intricatum	-	-	-	+	+	+
G. aungustatum	-	+	+	+	-	+
Gomphonema sp. 1	+	-	+	-	-	-
Hannaea arcus linearis	+	+	+	+	+	+
H. arcus amphioxys	+	+	+	+	+	+
Navicula radiosa	+	+	-	+	+	-
N. radiosa var. *tenella*	-	-	-	+	+	-
N. radiosa minutissima	-	-	-	-	+	-
N. microcephala	+	-	+	-	-	+
N. rhynchocephala	+	+	+	-	-	+
Navicula sp.1	-	-	-	-	-	+
Navicula sp.2	-	-	-	-	+	+
Navicula sp.	+	+	+	+	-	+
Nitzschia palea	-	+	-	+	+	-
Synedra amphicephala	-	-	+	+	-	+
S. ulna amphirhynchus	+	-	-	-	-	-
S. ulna oxyrhynchus	+	+	+	+	+	+
S. ulna oxyrhynchus mediocontracta	+	-	+	+	+	+
S. ulna	+	+	+	+	+	+
S. tabulata	+	-	-	-	+	-
Synedra sp.	-	+	-	+	+	+
Tabellaria sp.	-	+	+	-	+	+
Total	**31**	**30**	**31**	**31**	**32**	**33**

More than 11 families of benthic insect were recorded from Rangyong Chhu. The diversity gradually increased from sites Rng3 to Rng1 (Table 3.23). All families represented confluence site (Rng1) while more than 7 families were recorded from site Rng2. Site Rng3 was represented by 7 families. The majority of insect nymph *viz*., Hydropshychidae, Leptoceridae, Heptagenidae, Isoperlidae etc. were found to be pollution intolerant. However, a few taxa like Chironomidae and Simulidae represented pollution tolerant species in Rangyong Chhu. Hydropsychidae was the most common and dominant group among the macroinvertebrates while Isoperlidae was recorded only at site Rng1 during pre and post- monsoon seasons. Though, most of the groups were found to be washed out in monsoon season.

Table 3.23 Composition of macro-invertebrates in the river Rangyong Chhu in North Sikkim

Taxa	Rng1	Rng2	Rng3
Hydropshychidae	+	+	+
Leoptoceridae	+	+	+
Heptagenidae	+	+	+
Ephemerellidae	+	+	+
Baetidae	+	+	-
Other Ephemeroptera	+	+	+
Isoperlidae	+	-	-
Chironomidae	+	+	+
Simulidae	+	-	-
Epydridae	+	-	-
Other	+	+	+

3.8 OTHER STREAMS OF TEESTA BASIN

In addition to the main tributaries of river Teesta, the study was also carried out in three small streams namely Rishi Khola, Ramam Khola and Rangpo Khola. The former two streams do not have direct inputs to river Teesta but ultimately they discharge their water to Teesta. All these small streams pass through dense forest cover and join Rangpo Chhu, Rangit and Teesta, respectively. The streams were aimed to study their influence on tributaries of Teesta and river Teesta. Brief descriptions of these streams have been given in following paragraphs.

3.8.1 Rishi Khola

In Rishi Khola water sampling was carried out at Kyongsa (Rsk1) (see Fig.3.1).

3.8.1.1 *Physical and Chemical characteristics*

Due to slopes and deep gorges water current velocity was recorded to be high (0.83 m/s). The turbidity was recorded to be 5 ntu. Due to shallow water and low water discharge a high temperature (23^0C) was recorded in Rishi Khola as compared to Rangpo Chhu into which it drains finally. Total dissolved solids concentration was 40 mg/l, pH was in alkaline range and dissolved oxygen was 8.2 mg/l. The total alkalinity comprised only of bicarbonates and was 42 mg/l and total hardness was observed to be 28 mg/l (Table 3.24).

Table 3.24 Physical and chemical characteristics of different small tributaries of Teesta river system in Sikkim.

	Rishi Khola	Rangbang Khola	Rangpo Khola
Elevation (m)	600.0	400.0	400
Discharge (m^3/s)	3.9	4.1	2.4
Velocity (m/s)	0.83	0.86	0.83
Turbidity (ntu)	5.0	3.0	3.0
Temperature (^0C)	23.0	24.5	22.0
TDS (mg/l)	40.0	20.0	30.0
Conductivity (µs)	-	-	-
pH	7.0	7.1	7.2
Dissolved oxygen (mg/l)	8.2	8.1	8.8
Total alkalinity (mg/l)	42.0	36.2	32.0
Total hardness (mg/l)	28.0	15.2	24.0
Nitrate (mg/l)	0.09	0.08	0.09
Phosphate (mg/l)	0.11	0.13	0.11
Chloride (mg/l)	7.5	7.1	8.7

3.8.1.2 *Biological characteristics*

Rishi Khola was rich in aquatic biota. The densities of the various components were 1503 cells/lit, 19030 cells/cm^2 and 2025 individuals/m^2 of plankton, phytobenthos and macro-invertebrates, respectively (Table 3.25 and Fig. 3.16). The pollution intolerant species were recorded abundantly and frequently in Rishi Khola. Ichthyofauna comprises mainly of *Garra* spp., *Barilius* spp., *Acrossocheilus* sp. and snow trout.

Table 3.25 Densities of different biotic communities in the different small tributaries of Teesta river system

	Rishi Khola	Ramam Khola	Rangpo Khola
Elevation (m)	600.0	400.0	400
Plankton (cells/l)	1503	4128	589
Phytobenthos (cells/cm^2)	19030	7810	4015
Macro-invertebrates (ind/m^2)	2025	1915	799

3.8.2 Ramam Khola

In Ramam Khola water samples were collected at confluence near Naya Bazar (Rm1).

3.8.2.1 *Physical and Chemical characteristics*

There were no considerable differences in most of the physical and chemical characteristics of Ramam Khola and Rishi Khola (see Table 3.24). However, it differed slightly in a few parameters like water temperature, TDS and total hardness. The water temperature was recorded to be 24.5^{0}C. TDS was found to be 20 mg/l and total hardness was quite low (15.2 mg/l) in this stream as compared to that of Rishi Khola. Similarly it showed considerable differences in water discharge, temperature, total dissolved solids and total hardness with river Rangit.

3.8.2.2 *Biological characteristics*

Like Rishi Khola the Ramam Khola was also highly rich in aquatic biota (see Table 3.25), which comprises plankton, phytobenthos, macro-invertebrates and fish (see Fig. 3.16). A rare pollution tolerant species was recorded from this stream. The physico-chemical profile of water and high density of biotic communities indicated an unpolluted state of water.

3.8.3 Rangpo Khola

Rangpo Khola originates from Maenam Gompha (2,666 m) and drains into Teesta on its right bank at 381 m near Mangalbari.

3.8.3.1 *Physical and Chemical characteristics*

The water was clear during the lean season while pH was alkaline (7.2). Water temperature was recorded to be 22^{0}C while dissolved oxygen 8.8 mg/l. Total dissolved solids (TDS) was found to be 30 mg/l. Like other streams of Teesta, bicarbonates were comprised of total alkalinity that was recorded to be lowest (32 mg/l) as compared to other small streams. The total hardness was recoded to be 24 mg/l. There were no significant differences in the nutrients level among these small streams (see Table 3.24).

3.8.3.2 *Biological characteristics*

Rangpo Khola was poor in aquatic biota as compared to that of Rishi Khola and Ramam Khola (see Table 3.25). The densities of plankton, phytobenthos and macro-invertebrates were recorded to be 589 cells/lit., 4015 cells/cm^2 and 799 individuals/m^2, respectively (see Fig. 3.16).

The Fig. 3.16 showed that small streams like Ramam Khola and Rishi Khola are rich in productivity while largest rivers were poor.

3.9 CONCLUSION

In the upper stretch, generally slopes and current velocities are higher; bed consists of hard ground (rocks, boulders and coarse gravel). In lower stretches water flow is slow and river bed has relatively high mud and sand. The anthropogenic activities are also high in lower stretches. For example sand mining and fishing activities were concentrated in the lower stretches of Teesta, Rangpo Chhu, Rangit and Rani Khola.

The annual profiles of physical and chemical characteristics (especially temperature, TDS, pH, DO) showed that waters were usually unpolluted in most of the streams of Sikkim. However, low pH and DO in Rani Khola and Rangpo Chhu (lower stretches) indicated that the water was comparatively polluted in these streams. This is because Gangtok,

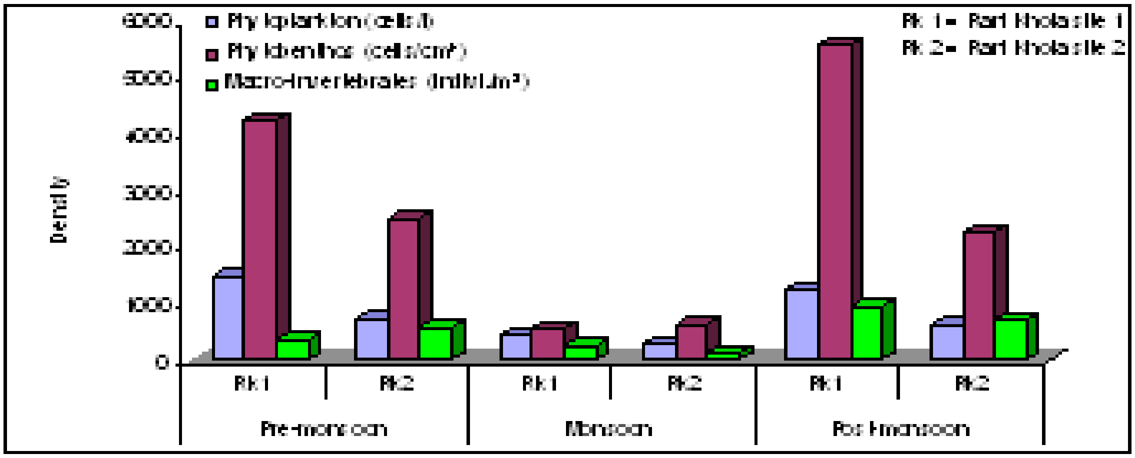

Fig. 3.14 Variation in the different biotic communities of Rani Khola

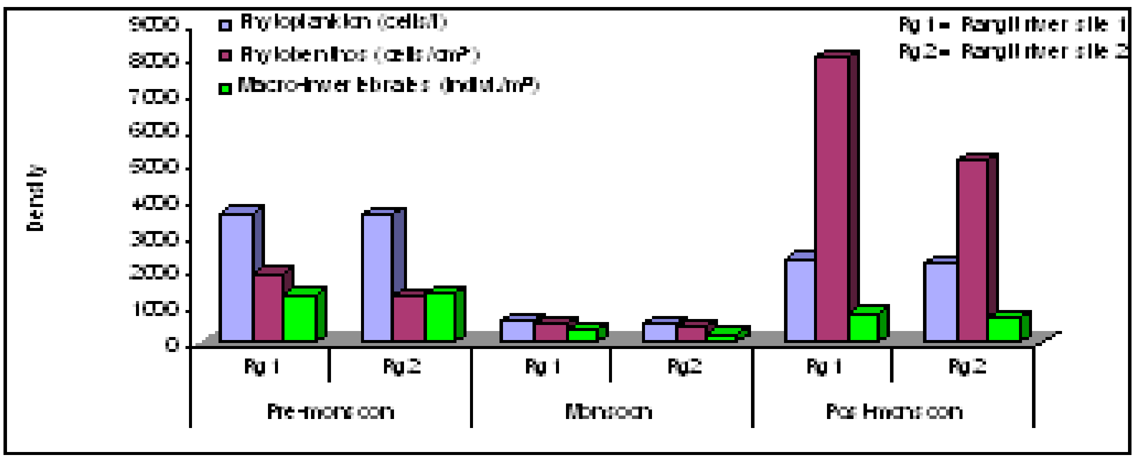

Fig. 3.15 Variation in the different biotic communities of Rangit river

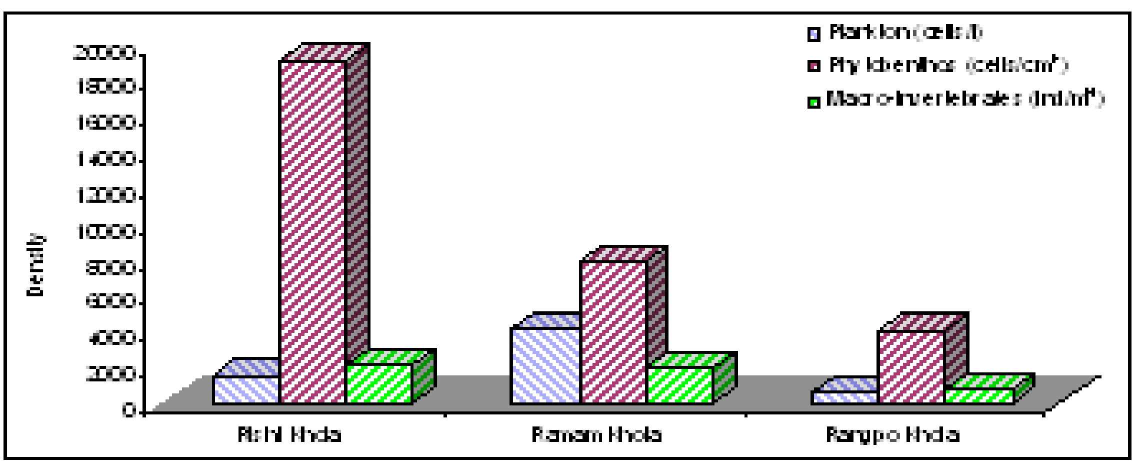

Fig. 3.16 Variation in different biotic communities of different small streams of Sikkim

the capital city of Sikkim, acts as point source of organic substances, which drain into Rani Khola while Rangpo Chhu at Rangpo receives sewage directly from its nearby townships. Though low concentrations of DO were also recorded from upper stretches of river Teesta but they are not attributed to organic pollution. The eco-climatic conditions like low atmospheric oxygen, higher elevations and low diffusion of oxygen are responsible for the lower concentration of DO in upper stretch.

The nutrient concentrations in the water were recorded to be significantly low in upper stretch whereas there were noticeable temporal and spatial variations in nutrient concentrations in lower stretch. In addition to the natural source of nutrients, waste water and agricultural run off contribute to the nutrient levels in the river waters. Therefore, the low concentrations of nutrients (nitrate and phosphate) in upper stretch of river Teesta are attributed to low human population, agricultural practices and lack of waste water drainage in the vicinity of these streams. On the other hand, highly disturbed stretches like Rani Khola recorded higher concentration of nutrients. The physical and chemical characteristics of these streams affected their biological status. The lower stretch of Teesta and Rangit rivers have rich biotic diversity while Rani Khola, the most stressed stream, is low in biotic diversity (Fig.3.17).

The majority of phytoplankton and phytobenthic species in all these streams was pollution intolerant and indicated a non polluted state of these rivers in general. However, in Rani Khola and Rangpo Chhu, common occurrence of a few pollution tolerant diatom species like *Gomphonema sphaerophorum, G. parvulum, Nitzschia palea*, etc., indicate that these streams are relatively more polluted. The anthropogenic activities including fishing activities are more prevalent in Rani Khola, therefore, resulting in poor biological health of Rani Khola. Most of the taxa among macro-invertebrates (Heptagenidae, Baetidae, Hydropshychidae, etc.) were pollution intolerant in all streams of Teesta river.

The present investigations reveal that overall physico-chemical as well as biological health of Teesta river and its tributary stream is in good condition. However, the same is not true for two of its tributaries *viz*. Rani Khola and Rangpo Chhu (Fig. 3.18). Poor water quality and low diversity of biological components coupled with presence of pollution tolerant phytoplankton in these streams points towards the relatively poor condition of these two streams. This is mainly due to the number of townships like Gangtok, Pakyong, etc. that are responsible for their relatively dismal health. In the case of upper stretches of Teesta river, water may be poor in biological diversity comparatively, but their water quality is extremely good.

3.10 LAKES

A large number of natural fresh water lakes exist in the Himalayan region, which are of great scientific and socioeconomic value (Jutshi, 1985). Lakes and ponds are stagnant water bodies of non-drainage

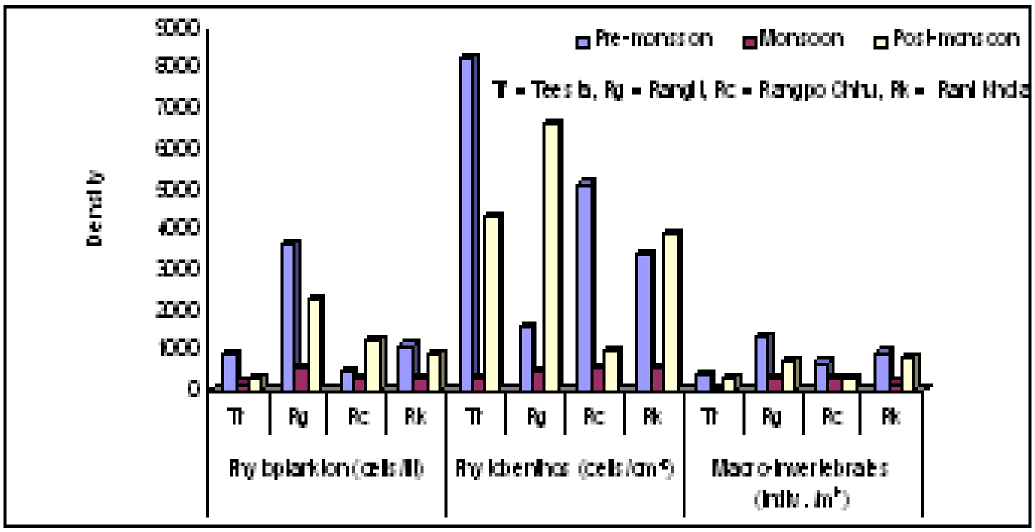

Fig.3.17 Variation in the different biotic communities of lower stretches of major rivers in Sikkim

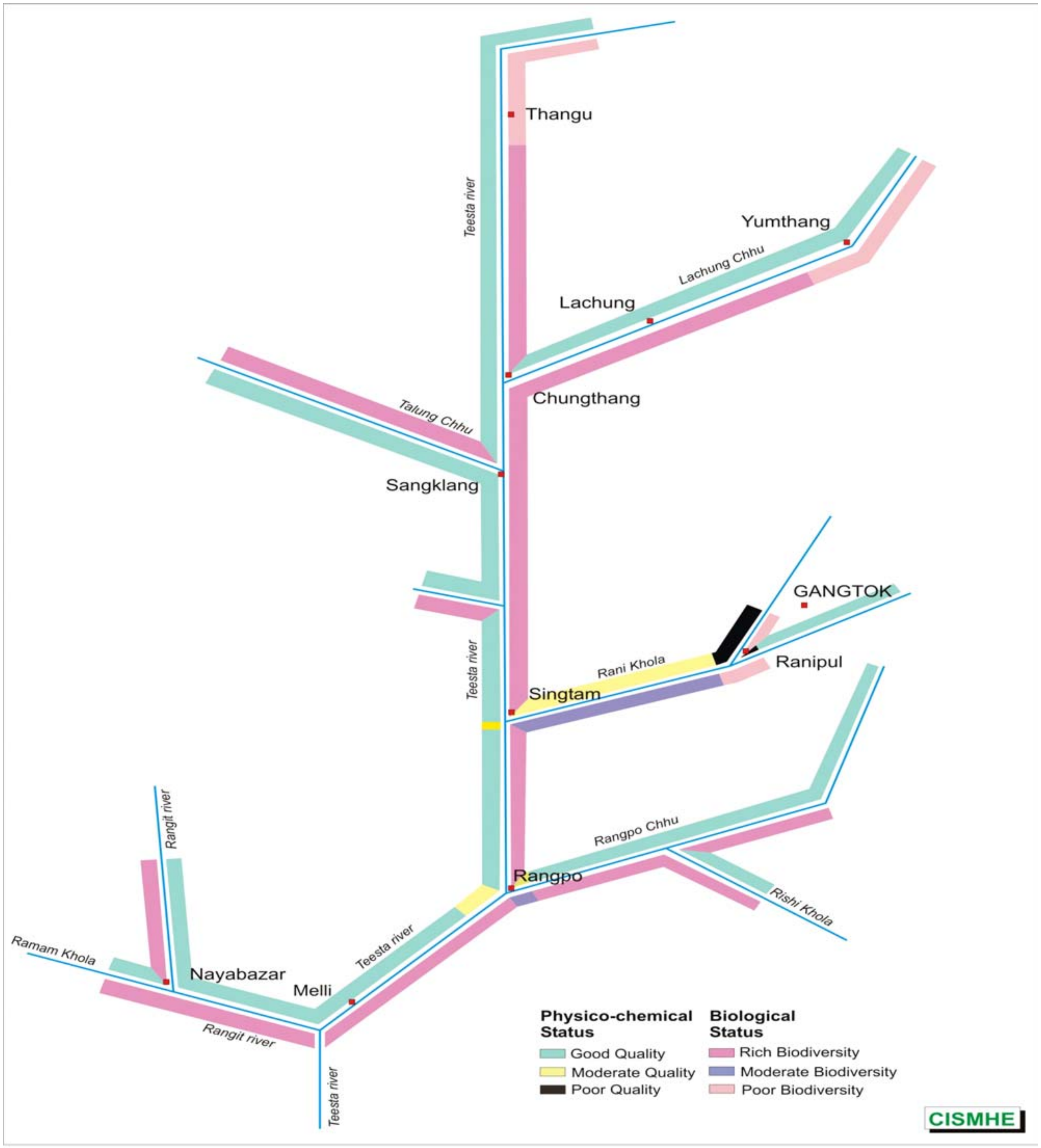

Fig. 3.18 A schematic diagram showing the physico-chemical and biological status along the Teesta river and its major tributaries in Sikkim

to drainage types. In mountains like Himalaya, lakes originated as a result of earthquakes, damming of glaciers, weathering, denudation, floods and cut off of meanders due to alluvial deposits (Zutshi, 1989). The lakes in Sikkim Himalaya are distributed from low to high altitudes. Due to altitudinal variation in location, the lakes of Sikkim largely differ in their hydrobiological conditions and thermal behaviour, which are regulated by their transparency value, geomorphic, depth and vegetational characteristics (Kaul *et al*., 1980). On the basis of water quality in general these lakes can be categorized as oligotrophic (most of the high altitude lakes), mesotrophic and eutrophic lakes (mostly low altitude lakes). These lakes have variable significance like drinking, fishing, tourism, habitat for trans-Himalayan migratory birds in Sikkim. Also, mythological and religious passions of Sikkim people are involved with many lakes. Roy and Thapa (1996) have listed more than 250 lakes.

3.10.1 Distribution of lakes in Sikkim

Zutshi and Khan (1978) classified Kashmir Himalayan lakes into three categories. This classification is more or less similar to classification of Sikkim lakes (Roy and Thapa, 1996). These are mountain or high altitude lakes (above 2,600 m), mid altitude lakes (2,000 – 2,600 m) and low altitude or valley lakes (below 2,000 m). The valley lakes can further be classified into drainage, semi drainage and non-drainage types. According to Roy and Thapa, most of the lakes (238) are high altitude lakes located above 2,600 m. About 26 lakes are found to be mid altitudinal while only three lakes are located in the low altitude zone.

Out of total 250 lakes in Sikkim, 226 are in North Sikkim, in which maximum 64 lakes in East Sikkim, 10 lakes are in West Sikkim (Table 3.26). Out of the 17 watersheds of Teesta basin in Sikkim maximum numbers of high altitudinal lacustrine water bodies were found in Chhombo Chho watershed (69 lakes), followed by Yumthang (60 lakes), Zemu Chhu (56), Prek Chhu (39 lakes) and Rangpo Chhu watersheds (26 lakes).

Table 3.26 District and watershed-wise distribution of lakes in Sikkim

Watershed	No. of lakes	District	Category
Chhombo Chhu	69	North Sikkim	High altitude
Zemu Chhu	56	North Sikkim	High altitude
Lachen Chhu	04	North Sikkim	High altitude
Lachung Chhu	23	North Sikkim	High altitude
	01	North Sikkim	Mid altitude
Yumthang	60	North Sikkim	High altitude
Rangyong	10	North Sikkim	High altitude
	01	North Sikkim	Mid altitude
Dik Chhu	02	North Sikkim	High altitude
	16	East Sikkim	High altitude
Rangpo Chhu	17	East Sikkim	High altitude

	08	East Sikkim	Mid altitude
	01	East Sikkim	Low altitude
Prek Chhu	38	West Sikkim	High altitude
	01	West Sikkim	Mid altitude
Rathong Chhu	4	West Sikkim	High altitude
	03	West Sikkim	Mid altitude
Rel Chhu	01	West Sikkim	High altitude
	01	West Sikkim	Mid altitude
	01	South Sikkim	High altitude

3.10.2 Significance of Lakes in Sikkim

Most of the low altitude or valley lakes in Sikkim are being exploited variably. The developmental activities have caused noticeable degradation of these natural ecosystems where adequate attention has not been given to environmental issues.

i) Lakes as water resource

Some of the lakes in South Sikkim and East Sikkim are being exploited for domestic purposes. The water of Menmoi Chho lake is supplied to downstream villages for drinking. In addition, there are some temporary lakes like Martam lake and Nagi lakes, the water of which are being used for domestic animals.

ii) Tourism

A large number of tourists from different parts of world come to view these lakes due to different reasons. Location, surroundings and myths have made many lakes beautiful and attractive in Sikkim. The burgeoning tourist influx in Sikkim have negatively affected a few lakes like Thosa lake, Rabomthang Tso, Chhangu lake, Khecheopalri lake, Gurudongmar lake, etc. For example Khecheopalri lake receives about 13% of total tourists in Sikkim causing deteriorating the ecological, aesthetic, recreation and biodiversity values of this lake in short time (Maharana *et. al.*, 2000). Similarly, Chhangu lake also receives thousands of tourists arrival every year. The visitors and temporary settlement have subjected the lake water to deteriorate. On the other hand many lakes in Sikkim *viz.*, Menmoi Chho, Green lake, Kupup lake are beautiful and attractive as these are least frequented due to inaccessibility or other causes.

ii) Lake fisheries

Mid altitude and low altitude lakes harbour a number of indigenous fish species. Aritar, Khecheopalri and Kathoak are well known mid altitude and low altitude lakes to harbour indigenous fish fauna. These mid and low altitude lakes are inhabited mainly by Grass carp, *Clarius* sp., Golden fish, Snow trout and Catli. In Sikkim introduction of exotic brown trout (*Salmo trutta fario*) have been occurring for many years through modern fish farms. Chhangu lake, Menmoi Chho and Rabomthang Tso are a few examples where this species has been introduced. This carnivorous fish is supposed to be invasive and harmful for the indigenous fish (Petre, 1999). In Sikkim the downstream drift of fry and fingerlings of brown trout from farms (Lachung, Lachen) and lakes (Chhangu lake and Menmoi Chho) dominate in the upper stretches of rivers like Lachung Chhu, Lachen Chhu, Rangpo Chhu, etc.

3.10.3 Lake Avifauna

Many high altitude lakes in Sikkim like Khangchung lake, Jheutha lake, Chho Lhamo, Chho Nempo, etc. provide a fair ecological niche for the Trans Himalayan migratory birds (Roy and Thapa, 1996). While a few lakes *viz.*, Lamgepui Tso, Makang Tso, Thum Tso, and Kupup lake and Mashya Tso are well known for water fowls.

3.10.4 Mythological Importance of Lakes

Himalaya itself has a great importance in Hindu religion in India. Entire Himalayan belt is a divine place of holy hills, temples, rivers and lakes. In Sikkim society, which comprises mainly of Hindu and Budhist, lakes have great values in mythology and religion. It was observed in Khecheopalri lake of Sikkim, which is regarded as 'wish fulfilling' lake. In addition, there are other lakes like Aritar lake, Syabiyaka lake, Gurudingmar lake etc. where a large number of pilgrims arrived every year. Many lakes have been suffering from tourism as well as pilgrimage activities. The existence of such lakes is now threatened (Jain *et. al*. 1999) due increasing tourism and pilgrimage.

3.10.5 Limnology of a few selected Lakes

The freshwater ecosystems are broadly divided into two major categories namely limnetic and rheatic ecosystems. The limnetic ecosystems are associated with stagnant water bodies. Thus, limnology concerns with physical, chemical and biological characteristics of lentic water bodies. The present study deals with limnological accounts of a few lakes in Sikkim. Due to inaccessibility and adverse climatic conditions all major lakes could not be approached. However, The lakes studies were carried out in post-monsoon season in few lakes in addition to secondary data (Jain *et. al*., 1999; Roy and Thapa, 1996, Maharana *et al*., 2000).

3.10.5.1 *Chhumzomui Chhokha lake*

Chhumzomui Chhokha lake is an high altitude lake, located between 27^0 41' 46" N latitude and 88^0 43' 04 E longitude in North Sikkim at an elevation of 5,480 m. This is a sacred, oligotrophic alpine lake covered with snow in winter season. The surroundings of lake are covered with marginal alpine morains and meadows. It covers an area of about 0.3 sq km.

i) Lake characteristics

Very low dissolved oxygen concentration (3.4-6.0 mg/l) has been recorded from the lake water (Roy and Thapa, 1999). The water pH was in acidic range, varied from 6.1-6.9. The nitrate and phosphate concentrations varied annually from 0.107-1.11 mg/l and 0.004-1.635 mg/l, respectively. The planktonic community comprises *Megacyclopes* sp., *Daphnia* sp., *Spicodiaptomus* sp., *Zygnema* sp., *Spirogyra* sp., *Pinnularia* sp. etc. The fish species are absent from the lake.

ii) Gurudongmar lake

Gurudongmar lake is a oligotrophic and drainage type of high altitude lake, fed mainly by a small snow-fed streams. The outlet of lake drains into the Chhombo Chhu or Lachen Chhu (Teesta). The lake is situated between $88^0$42' E longitude and $28^0$01' N latitude at an altitude of 5,100 m. in North Sikkim. It covers an area of about 1.32 sq km. The lower reaches of lake watersheds are covered with glacial morains and meadows while upper reaches towards the south contain snow clad peaks. The lake has recreation as well as religious value, therefore a large number of pilgrims and tourists visit this lake every year. The water was clear and unpolluted. Though, hundreds of people visit this lake every year, which might increase in future. As a result of which more anthropogenic activities might lead deterioration in the water quality.

The average depth of lake is about 4 m. Therefore, due to low depth the process of stratification is not possible in this lake (Crumrine and Beeton, 1975). The turbidity was nil and the water was crystal clear. Very low dissolved solids (10 mg/l) (Table 3.27) in the lake can be attributed to the low concentration of ions due to absence of the input from ground water and vegetation in surroundings (e.g. Sarwar, 1999). The dissolved oxygen concentration was 6.5 mg/l. The low concentration of DO seems due to very low atmospheric oxygen concentration, low density of algae and absence of turbulent flow. The lake water recorded lowest alkalinity (0.8 mg/l) which can be attributed to very low biological productivity of water and lake bottom deposits (e.g. Kaushik and Saksena, 1999). There are no settlements in the vicinity and area is devoid of any vegetation.

Table 3.27 Physical and chemical characteristics of high altitude lakes of Sikkim

	Gurudongmar	Chhangu lake	Menmoi Chho	Kupup lake
Elevation (m)	5100.0	3759.0	3669.0	3925.0
Area (sq m.)	1.32	0.23	0.2	0.25
Turbidity (ntu)	0.0	3.0	3.0	3.0
pH	6.9	7.2	7.2	8.0
Dissolved oxygen (mg/l)	6.5	7.1	7.8	6.9
TDS (mg/l)	10.0	<10.0	10.0	10.0
Conductivity (μS/cm)	-	10.0	-	10.0
Total hardness	16.5	7.2	22.5	31.2
Total Alkalinity (mg/l)	0.8	14.0	16.0	32.0
Total Nitrate (mg/l)	0.01	0.03	0.03	ND
Phosphate (mg/l)	0.06	0.08	0.0	ND
Chloride (mg/l)	2.2	6.5	3.7	8.7

Diatoma vulgare, D. hiemale and *D. anceps* were the most predominant algae in the lake. The *Cyclotella antique* (a centrale diatom), *Didymosphenia geminata*, *Diploneis* sp., *Surirella* sp., *Stauroneis* sp. etc. (diatoms), *Stigeoclonium* sp. (filamentous algae) were the other important algae. A density of 22 individuals/m^2 of macro-invertebrates was recorded in this lake (Table 3.28).

Table 3.28 Biological profile of some selected lakes in Sikkim

	Zooplankton (indiv./lit)	Algae (cells/lit)
Gurudongmar lake	-	180.0
Chhangu lake	20.0	210.0
Menmoi Chho	114.0	230.0
Kupup Lake	252.0	370.0
Khecheopalri lake	80.0	150.0
Kathok lake	72.0	936.0
Aritar Lake	360.0	220000.0

iii) Chhangu lake

Chhangu lake is one of the most visited lakes in Sikkim. It is located between 88^{o}46’ E longitude and 27^{o}22’ N latitude in East Sikkim at an altitude 3,759 m. The lake covers an area of about 0.23 sq km. The surroundings of lake comprise moraines and alpine meadows on east, south and north slopes and sparse coniferous forest like *Abies densa*, *Aesculu*s spp. and bushes of *Rhododendron* on eastern lower slopes. The lake is fed by perennial and seasonal streams and the lake drains into a stream which ultimately confluences with Rangpo Chhu on right bank.

The turbidity was 3.0 ntu with 7.1 mg/l concentration of dissolved oxygen. The concentration of total dissolved solids and conductivity were very low (<10 mg/l and 10 (µS/cm) (see Table 3.27). It is a mesotrophic lake. Some portions are covered with algal mat.The density of zooplankton and algal is very low, 150 indiv., litre and 20 cells/lit., respectively (see Table 3.28). A few actinopodes comprised the zooplankton. *Tetraspora* spp. and *Spirulina* sp. were important constituents of algae. Spiriotaenia sp. is constituent of make algal patches in the lake. Chironimids constituted the most important part of macro-invertebrates. Among the *Cyclotella catenata* was most abundant in the lake. Other algal diatroms were *Cyclotella striata, Pinnularia gentiles, Surirella ovata pinnata* and *Achnanthes* sp. The lake is well stocked with exotic trout (*Salmo trutta fario*) fish.

iv) Menmoi Chho

Menmoi Chho is located at an elevation of 3,669 m. between $88^0$49' E longitude and $27^0$20' N latitude in East Sikkim. It covers an area of 0.21 sq km. The outlet water of the lake drains into Rangpo Chhu, a tributary of Teesta. The lake is surrounded by the sub-alpine and coniferous forests. Forest composition mainly comprises *Abies densa*, *Acer campbellii, Sorbus microphilus*, bushes of *Rhododendron* etc. The lake is less affected by anthropogenic activities.

The lake water recorded low turbidity (3 ntu) and low TDS (10 mg/l) (see Table 3.27). The dissolved oxygen was recorded to be 7.8 mg/l. Lake water was alkaline and comparatively high in nutrients and alkalinity.

It sustains a good growth of filamentous, non-filamentous algae and macro-invertebrates. The zooplankton and phytoplankton densities were recorded to be 114 indiv./lit and 230 cells/lit, respectively (see Table 3.28). *Ulothrix* sp., *Gomphonema* spp., *Cymbella* spp. *Achnanthes* spp. were important constituents of algae in the lake. It harboured a good growth of chironomids among the macro-invertebrates. In addition, Ephemeroptera were also recorded from the lake water. The lake is well stocked with exotic brown trout (*Salmo trutta fario*).

v) Kupup lake

Kupup lake is situated at an elevation of 3925 m between 88^o 49' 39" E longitude and 27^o 22' 04" N latitude in East Sikkim. It is a drainage type of lake, covers an area of 0.251 sq km. The lake surroundings comprises of morains, meadows and alpine pastures.

Water turbidity was low (3 ntu) (see Table 3.27). Like other high altitude lakes low concentration of total dissolved solids (10 mg/l) and conductivity were recorded. Low concentration of dissolved oxygen (6.9 mg/l) was recorded with pH of the nitrate and phosphate were not detectable in the lake while chloride concentration was recorded to be 8.7 mg/l. Low densities of zooplankton (252 indiv./lit), micro-algae (300 cells/lit) and filamentous algae (70 cells/lit) were recorded from the lake (see Table 3.28). *Keratella cochlearis* was predominant in the zooplankton community while *Spirotaenia condensata, Schizoclonium* sp., *Oscillatoria* sp. and *Stauroneis* sp. were important constituent of the filamentous algae. Among the micro algae, 35 species were recorded. *Melosira* sp. was most dominant in the diatom community of lake. Other important species were *A. affinis*, *A. microcephala*, *Fragilaria pinnata*, *Cyclotella catenata, Tabellaria flocculosa, Eunotia validate, Diatoma anceps, Surirella caproni, Cymbella lanceolata, C. naviculiformes, Pinnularia microstauron* etc. Very low density of macro-invertebrates was recorded from the lake, which mainly comprised of chironomids.

3.10.5.2 *Mid altitude lakes*

i) Khecheopalri lake

Khecheopalri lake is situated between 27^{o} 22’ 24” N latitude and 88^{o} 12’ 30 E longitude in the West Sikkim district having an altitude 1828 m. The lake is regarded as ‘wish fulfilling’ lake by the people of Sikkim. The local inhabitants visit this lake in perspective of pilgrimage while people from different parts of India and abroad come here for tourism. The lake watershed is covered with some agriculture land with two villages and broad leaved mixed forest, comprises *Arundo donax, Shagnum* sp., *Acorus calamus*, *Rhododendron* sp. etc. Lake is fed by two perennial and five seasonal inlets while drained by a major outlet. It supports trans-Himalayan migratory birds and highly disturbed with commercial and recreational tourism.

The turbidity of water was low (6 ntu) low concentration of total dissolved solids (10 mg/l) be 20 (µS/cm) of conductivity. The concentration of dissolved oxygen was 7.6 mg/lit with pH of 8.0 (Table 3.29). The total alkalinity was recorded to be 18.0 mg/l. Lake water was comparatively soft total hardness of 6.4 mg/l. The nitrate and phosphate concentrations were measured to be 0.05 and 0.03 mg/l.

Sediment flow in Khecheopalri lake was recorded to be 346 mg/year and out flow 316 mg/ year. The 30 mg/year sediment is deposited in lake (Jain *et al*. 1999). The lake has been silting and the major contributor is sediment from the surrounding watershed.

Table 3.29 Physical and chemical characteristics of mid and low altitude lakes of Sikkim

	Khecheopalri lake	Kathok lake	Aritar lake
Elevation (m)	1810.0	1770.0	857.0
Area (sq m)	0.109	0.012	-
Turbidity (ntu)	10.0	22.0	32.0
Total dissolved solids (mg/l)	10.0	<10.0	10.0
Conductivity (µS/cm)	10.0	10.0	20.0
Dissolved oxygen (mg/l)	7.6	6.1	7.1
pH	7.8	7.0	8.0
Total alkalinity (mg/l)	18.0	20.0	23.2
Total hardness (Mg/l)	6.4	6.4	4.0
Calcium hardness (mg/l)	4.8	4.8	3.2
Total Nitrate (mg/l)	0.05	0.06	0.09
Phosphate (mg/l)	0.01	0.03	0.01
Chloride (mg/l)	7.9	7.0	7.6

Very low densities of zooplankton (80 indiv./lit.) and phytoplankton (150 cells/lit.) were recorded from Khecheopalri lake (see Table 3.28). The zooplankton community comprised of *Cyclopes* sp., *Sida* sp., *Chydorus* sp., *Nauplius* sp., *Alonella* sp., etc. A few actinopods species like *Diffugia oblonga* and *D. rubescens* were also recorded from this lake. *Ulothrix* sp., *Zygnema* sp., *Closterium* sp. *Scenedesmus* sp. and

Cosmarium sp. were main component of green algae. In all 13 species of diatoms were recorded *viz. Cyclotella glomerata, Melosira islandica, Achnanthes affinis, A. microcephala, A. minutissima, Synedra ulna, Navicula radiosa, Gomphonema constrictum, Tetracyclus* sp., etc. The fish fauna of lake comprised of grass carp (*Ctenopharyngodon idlus*), golden fish and *Clarius batrachus*.

iii) Kathok Lake

Kathok lake is non drainage types of lake, situated between 27^o 22' 20" N latitude and 88^o 13' 26 E longitude in the West Sikkim district near Yuksom at an altitude 1,780 m. The lake covers an area of 0.0125 sq km. It is a permanent eutrophic temperate lake. The lake is under high stress by anthropogenic activities. The lake surroundings comprised of dense mixed trees. The *Alnus nepalensis, Quercus linata, Engelhardia spicata, Lyonia ovalifolia,* etc. Also, the surroundings are inhabited by a sparse human population.

Turbidity was high (22 ntu), mainly comprised of planktonic algae. The pH was slight acidic. The lake recorded low TDS (<10 mg/l) and conductivity (10 μS/cm). Low dissolved oxygen (6.1 mg/l) can be attributed to absence of turbulent flow and anthropogenic activities. The total alkalinity was recorded to be 20 mg/l. The lake water was soft and recorded total hardness of 6.4 mg/l. Among the nutrients nitrate concentration was 0.06 mg/l while phosphate concentration was 0.01 mg/l (see Table 3.29).

The densities of zooplankton and phytoplankton were recorded to be 72 indiv./lit and 936 cells/lit in monsoon season (see Table 3.28). Among the zooplankton, *Cyclopes* spp. *Clamydomonas* sp., *Conochilus* sp. *Monia* sp. and *Eiphanes* sp. were important constituents. *Merismopedia tenuissima*, *Spirogyra* sp. *Scenedesmus accuminatus, Cosmarium depressus, Phacus* sp. constituted the green algae of lake. Diatom flora of lake comprised of *Surirella linearis*., *Pinnularia viridis*., *Navicula navicula radiosa* and *Stauroneis* sp. etc. Among the fish golden fish dominated the lake

3.9.5.3 *Low altitude lakes*

i) Aritar lake

Aritar lake is a eutrophic and drainage type of lake, located at an elevation of 856 m in East Sikkim. The lake is regulated and developed for the tourism. The surrounding of lake is covered with sparse forest, comprised mainly of bamboos. The depth of lake varies from 5.0 to 8.5 ft.

The water was highly turbid (32 ntu) due to high density of phytoplankton. Water was relatively alkaline. Dissolved oxygen was 7.1 mg/l, with total dissolved solids (TDS) and conductivity 10 mg/l and 20 µS/cm, respectively. The nitrate concentration was comparatively high (0.09 mg/l) while the concentration of phosphate was low chloride concentration was 7.6 mg/l (see Table 3.29).

The lake is rich in zooplankton and phytoplankton. The density of zooplankton was recorded to be 360 indiv./lit (seeTable 3.28). The high growth of green algae (2,20,000 cells/l) made water greenish and turbid. The rotifers (*Lindia* sp.) were important component of zooplankton. In the algae *Sphaerocystis schroeteri* was highly dominant. *Scenedesmus longspinia* and *Phacus* spp. were other algae of the lake. About 12 species of diatoms were also recorded from the lake. The important constituents of diatoms were *Synedra ulna*, *S. amphicephala*, *Fragilaria* sp., *Achnanthes minutissima, A. affinis,* etc. Chironomids constitute the macro-invertebrates of the lake. Among the fish golden fish dominated the lake. Other species were *Clarius batrachus*, *Schizothorax progastus, Acrossocheilus hexagonolepis* and *Ctenopharyngodon idlus*.

ii) Nagi Lake Upper

This small lake is situated in South Sikkim near Nathang at an elevation of 1,310 m. The lake is drained by seasonal springs. The water of lake is generally used for domestic purposes. Due to regular anthropogenic activities it is eutrophic in nature.

The dissolved oxygen concentration ranged from very low 0.285 mg/l in dry season to 10.95 mg/l. The water pH was recorded to be 5.5 to 7.7. The nitrate and phosphate concentrations varied from 0.017-2.106 mg/l and 0.802 – 3.963 mg/l, respectively. *Bosmina* sp., *Chydorus* sp., *Daphnia* sp., *Sida* sp. and *Eubosmina* sp. are important zooplankton of lake while *Tetraspora* sp. *Dictyospherium* sp. and *Cosmarium* sp. main constituents of phytoplankton. Some indigenous fish species are found in the lake.

iii) Nagi lake lower

Nagi lake lower is located in South Sikkim near Nathang at 1,225 m. The lake is temporary and drained by a few seasonal springs. The water is used for the domestic purposes. It is a temperate eutrophic lake.

The dissolved oxygen concentration varied from lowest 0.75 mg/l in lean season to highest 8.5 mg/l. The pH was recorded varying from 5.7 to 6.4. Nitrate concentration varied from 0.041 – 2.14 mg/l while phosphate was recorded to be significantly as recorded to range from 1.515 – 28.556 mg/l. *Cyclopes* sp., *Stenocypris* sp., *Alona* sp. and *Cypridopsis* sp. are important constituents of zooplankton while *Desmidium* sp., *Ulothrix* sp. and *Tabellaria* are predominant species of phytoplankton.

3.11 CONCLUSIONS

River is a dynamic system therefore, deteriorated quality of water at a particular site cannot remain for longer distance due to downstream flow of river because stream has capacity to self purify. But lake is dynamic or non dynamic system. The low altitude lakes are generally semi-drainage or non-drainage types, which make them susceptible to deposition of sediments and nutrients. In Sikkim, high altitude lakes (have a well drainage system) are of oligotrophic nature while low altitude lakes are mesotrophic or eutrophic due to different magnitude of human activities. Roy and Thapa (1996) found that the water level and morphological features of many lakes in Sikkim are receding day by day. The forest fires, deforestation, erosion and commercial fishing are important hazards for lakes in Sikkim. In addition, increasing tourism and pilgrimage has affected the lakes badly. The increasing influx of tourists and pilgrims beyond the carrying capacity changes the situation. Therefore, for the protection of lakes tourism needs to be carefully examined. The erosion in lakes and anthropogenic activities (deforestation, forest fire, commercial fishing) should be regulated through proper management, rules and regulations. Moreover, voluntary participation, environmental education, awareness drive must be involved in mitigation measures.

CHAPTER - 4
FISH FAUNA

4.1 INTRODUCTION

Fish have an important role in human life. They are valuable as well as easily accessible source of food being rich in proteins, carbohydrates, vitamins, iron and calcium. Indian waters harbour about 2500 fish species, which make about 11% of total fish species of the world. The inland fishery, which includes about 674 species, comprises very low percentage of total fish composition. However, India has a vast capacity in inland fishery resources in the form of rivers, lakes, brackish waters, back waters, reservoirs, irrigation canals, etc. Of these reservoir river systems are most important source of inland capture fishery, particularly in Himalaya.

The Himalaya is the source of all major river systems in India and well known for cold water fishery due to low temperatures of waters. Sikkim state being a part of inner mountain range of Himalaya is hilly with high snow-clad mountain peaks. Like other Himalayan rivers, Teesta river and its tributaries provide a fair ecological niche for many indigenous and a few exotic coldwater fish species. In addition, there are a large number of lakes in Sikkim and many indigenous and a few exotic fish species are found in these lakes, particularly in the lakes of mid and high altitudes. The earlier studies on the fish and fisheries in Sikkim were carried out by Talwar and Jhingran (1991), Tamang (unpublished) and Menon (1999) with respect to distribution and composition. The detailed description on commercial aspects and fish catch in Sikkim is, however, not available, except for an account prepared by State Fisheries Department. The present study is an attempt to understand the composition, distribution, fish catch, status and migratory behaviour of fish in Teesta river system in Sikkim.

4.2 FISH COMPOSITION AND DISTRIBUTION

Fish composition changes along the altitudinal gradient of river Teesta and its tributaries due to changes in physical and chemical characteristics of water. The water temperature plays a vital role in the distribution of fish in Himalayan rivers. Sehgal (1983) classified Himalayan rivers into three zones with respect to fish distribution. The streams in the upper most zone above 1,400 m dominated by exotic trout is known as ‘trout streams’ (Fig. 4.1). These streams are characterized by low temperature, low turbidity, low alkalinity and hardness. The substratum comprises of boulders and rocks while water carries coarse silt. The streams of middle zone from 850 to 1,400 m inhabited mainly by snow trout and are called as ‘snow trout streams’. These streams record relatively higher temperatures, turbidity, alkalinity and hardness. The water carries fine soil particles while river bed is provided with boulders and stones. The streams of lower zone below 850 m are comprised of a large meandering zone and have much higher temperature and lowest water current velocity. The substratum is comprised of pitted rocks and stones. This zone is inhabited by carp species knows as ‘mahseer streams’. The dominant fish species in accordance with these zones in Teesta river system are given in Table 4.1.

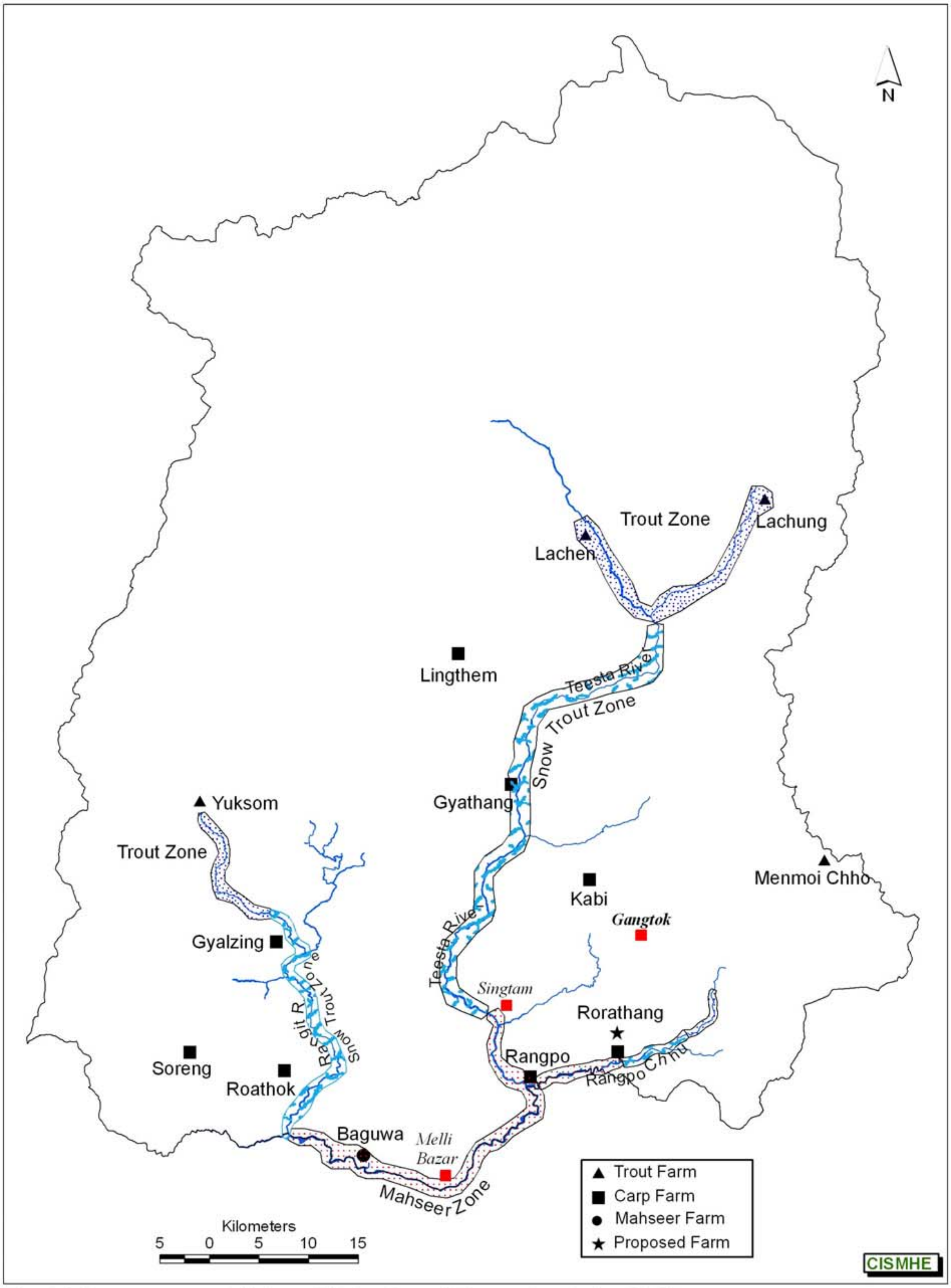

Fig.4.1 Prospectus of fish and fisheries of Teesta basin in Sikkim

Tamang (2001) mentioned about 48 species of fish from Sikkim Himalaya. However, species like *Acrossocheilus spinulosus* (Talwar and Jhingran, 1991) and *Pseudeutropius antherinoides, Ompok bimaculatus* and *Puntius clavatus* (Menon, 1999) were not recorded in that report. A documentation of published information on the number of fish species and field survey during these studies indicate the presence of more than 50 species of fish in the waters of Teesta river. The present studies on fish and fisheries were carried out in all major streams *viz*. Teesta river, Rangpo Chhu, Rangit river, Rangbang Khola, Rishi Khola, Rongni Khola, Talung Chhu, Dik Chhu, Lachen Chhu, Lachung Chhu, etc. The fishes were collected with the help of local fishermen, which were found to land fish by using cast nets, rod and lines, and hooks. About 37 fish species were recorded from the river Teesta and its tributaries, which comprise Salmonidae, Cyprinidae, Cobitidae, Sisoridae, Chanidae, Schilbedae and Anguillidae (Table 4.2).

Table 4.1 Important fish species of three different zones of river Teesta in Sikkim

	Trout streams	Snow trout streams	Mahseer streams
Elevation (m)	Above 1400	850 – 1400	Below 850
Streams	Lachung Chhu and	Teesta from Mangan Lachen Chhu	Teesta below Mangan to Chungthang
Fish species	*Salmo trutta fario*	*Schizothorax richardsonii*	*Tor putitora*
	Euchiloglanis hodgarti	*Schizothoraicthys progastus*	*Acrossocheilus hexagonolepis*
	Schizothorax richardsonii	*Garra lamta*	*Labeo dero*
	Garra spp.	*Garra gotyla gotyla*	*Barilius bendelisis*
	Nemacheilus spp.	*Euchiloglanis hodgarti*	*B. vagra*

Glyptothorax spp.	*Schizothorax richardsonii*
Semiplotus semiplotus	*S. progastus*
	Anguilla bengalensis

Table 4.2 The composition and distribution of fish species in the waters of Teesta river in Sikkim

Species	Local name	Distribution	Altitude (m)
Family Salmonidae			
Salmo trutta fario	Trout	L, La	Above 1400
S. gairdneri gairdneri	Trout	-	Above 1400
Family Cyprinidae			
Tor putitora	Mahseer, Sahar	T, R	Up to 700
Labeo dero	Gardi	T	Up to 700
L. dyocheilus	Ther	T	Up to 850
Surssocheilus hexagonolepis	Catly	T, R	Up to 850
S. spinulosus	Catly	T	Up to 850
Puntius clavatus	-	R, Ra	
Schizothorax richardsonii	Asla	A	Up to 1600
Schizothoraicthys progastus	Chuche asla	A	
S. curvifrons	Asla	T	
Barilius bendelisis	Korang, Joia	Ra, R, Ro	Up to 850
B. bendelisis chedra	Korang, Joia	Ra, R, Ro	Up to 850
B. vagra	Chirkay	Ra, R, Ro	Up to 850
Danio aequipinnatus	Vhitti	T, R	
D. naganensis	Vhitti	T, R	
Semiplotus Semiplotus	Chepti	T	Up to 850
Garra gotyla gotyla	Budhna	Ra R, Ro,T	Up to 900
G. gotyla stenorhynchus	Budhna	Ra, R , Ro,T	Up to 900
G. annandalei	Budhna	Ra, R, Ro,T	Up to 900
G. lamta	Budhna	Ra, R, Ro,T	
G. mcclellandi	Budhna	Ra, R , Ro,T	

G. mullya	Budhna	S	
Crossocheilus latius latius	Lohari	T, R	Up to 700
Cyprinus carpio	Carp	Farms	
Ctenopharyngodon idlus	Ghas khane machha	Farms	
Family Homalopteridae			
Balitora bruccei	Teetai maccha	T, R	
Family Sisoridae			
Pseudecheneis sulcatus	Kahrey	S	Up to 400
Glyptothorax gracilis	Kahray	S	Up to
G. sinense manipurensis	Kahray	S	
G. sinense sikkimensis	Kahray	T, R	
G. basnetii	Kahray	T, R	
G. bhutiai	Kahray	T, Ra, R	
G. conirostrae	Kahray	HS	Above 1400
G. deyi	Kahray	HS	Above 1400
G. trilineatus	Kahray	HS	Above 1400
Euchiloglanis hogarti	Loolay	HS	Above 900
Bagarius bagarius	Ganchha maccha	T, R, Ra	
Laguvia ribeiroi ribeiroi	Ganchha maccha	T, R, Ra	
L. ribeiroi jorethangensis	Ganchha maccha	T, R, Ra	
Family Cobitidae			
Nemacheilus butanensis	Gadela	A	
N. carletoni	Gadela	A	
N. corica	Gadela	A	
N. devdevi	Gadela	A	
N. sikkimensis	Gadela	A	
N. kanjupkhulensis	Gadela	A	
N. multifaciatus	Gadela	A	
N. spilopterus	Gadela	R	

N. bevani.	Gadela	R	
Acanthophthalmus pangia	Lamo gadela	T	
Family Schilbeidae			
Clupisoma montana	Jalkapoor	R	Up to 850
Pseudeutropius antherinoides	-	—	
Family Channidae			
Channa gachua	Hilay	R	up to 850
Family Anguilidae			
Anguilla bengalensis	Balm	R	up to 650
Family Siluridae			
Ompok bimaculatus	-	-	-

A = All streams, L = Lachen, La = Lachung, T = Teesta, R = Rangit, Ra = Rangpo,

Ro = Rongni, S = Small streams, HS = Higher stretch

A brief description of the status and distribution of a few important species of fish from the waters of rivers and lakes of Teesta basin in Sikkim is given below.

4.2.1 *Salmo trutta fario* (Brown trout)

Salmo trutta fario has world wide distribution and found in high altitude oligotrophic waters. It is one of the most important commercial fish in the world due to its good quality of meat. Brown trout, a carnivorous fish, is voracious and generally feeds on fish fry, fingerlings and macro-invertebrates. In India it is an exotic fish and known as trout and Kashmiri fish in Sikkim. It is distributed from 1400 m – 2400 m in Teesta, Lachen Chhu, Lachung Chhu and Rangpo Chhu, where they are dominant in catch composition. Brown trout is also being reared in the Yuksom in West Sikkim, Menmoi Chho and Chhangu lake in East Sikkim, Lachen and Lachung fish farms of North Sikkim. From these farms they are released in Rimbi Chhu, Rangpo Chhu, Lachen Chhu and Lachung Chhu streams.

4.2.2 *Salmo gairdneri gairdneri* (Rainbow trout)

Rainbow trout is found throughout the world in cold waters. It is also one of the best commercial fish in the world. It is exotic in India and distributed in high altitude areas of Himalaya. This species was not found in rivers and lakes during our surveys but it is being reared in Sikkim and is released in high altitude streams of Teesta river system. This species is not well established in Sikkim waters as compared to that of Brown trout.

4.2.3 *Schizothorax richardsonii* (Snow trout)

Snow trout is found throughout Himalaya. It is herbivorous in food habit. In Sikkim it is locally called ‘Asla’ and is very common in all the tributary streams of Teesta river. It is distributed from 300 m – 1,600 m. It breeds from late summer to monsoon season. Most of the capture fishery in Sikkim depends on this species of snow trout.

4.2.4 *Schizothoraicthys curvifrons* (Snow trout) ?

This brown color species of snow trout is also common in Himalaya, but not so common in Sikkim. It feeds mostly on filamentous algae. A few specimens of this fish in river Teesta near Mangalbare village in South Sikkim were found. One of the specimens had attained a length of 42 cm. It is important for fishery purpose due to its large size (Plate 4.1).

4.2.5 *Schizothoraicthys progastus* (Snow trout)

This is one of the most common Himalayan species and it is locally called 'Chuche Asla'. It is herbivorous in food habit and very common in all streams of Teesta river system. It is distributed mainly in the tropical and temperate regions (300 to 1,600 m). This species is important contributor to fish catch in Sikkim (Plate 4.2).

4.2.6 *Tor putitora* (Mahseer)

Tor putitora is popularly known as Himalayan mahseer or Golden mahseer. It is distributed throughout the Himalaya and is known to be endemic to Himalaya and has been classified as an endangered species in India. The fish is omnivorous and is used as a game fish. In Sikkim it is called 'shahar' and 'mahseer'. It is a migratory fish, which ascends from foothills to Teesta river system during late summer to monsoon. It is available in Rangit river up to Jorthang and in Teesta river up to Singtam (400 m). They also come in catch in Rani Khola and Rangpo

Chhu during May to August. The stretch of Rangit river up to Jorthang has been identified as a breeding ground for mahseer.

4.2.7 *Acrossocheilus* (*Surssocheilus*) *hexagonolepis*

S. hexagonolepis is found in waters of Eastern Himalaya. In Sikkim it is locally known as ‘Catli’. It performs local migration from mainstream to tributaries. The specimen of this fish were collected from the waters of Teesta, Rangpo Chhu, Rangit river, Rangbang Khola and Rani Khola. The habitat of fish extends up to an altitude of 950 m. Next to snow trout it contributes to the main capture fishery in Sikkim (Plate 4.3).

4.2.8 *Acrossocheilus spinulosus*

It was rarely recorded from Teesta river near Mangalbare in South Sikkim. Earlier its type locality was recorded from Sikkim (Talwar and Jhingran, 1991). It is also known to perform a local limited migration (Plate 4.4).

4.2.9 *Puntius clavatus*

During the field survey, this species could not be recorded in Teesta river system, Menon (1999) described it as a threatened species. It has been recorded from Teesta river in Sikkim and is found in the lower stretches of rivers. This species is not much exploited species in Sikkim due to its low fishery importance.

4.2.10 *Labeo* species

Two species *Labeo dero* (Gardi), *Labeo dyocheilus* (Ther) are found in Teesta and Rangit rivers. They are very rarely reported in the catch.

4.2.11 *Barilius* spp. (Hill trout)

Barilius spp. are most common Himalayan species. Locally they are called 'Khasrey'. Two species of hill trout namely *Barilius bendelisis* and *B. vagra* were recorded from Teesta, Rani Khola, Rangpo Chhu and Rangit river. They are usually landed with the help of hook and used as fish bait to catch large fish.

4.2.12 *Garra* spp.

This group of fish is known as Budhna in Sikkim. The group is comprised of 6 species *viz*. *Garra gotyla stenorhynchus, G. gotyla gotyla*, *G. lamta, G. mcclellandi, G. annandalei* and *G. mullya*. Generally, they are found in small streams. These species were recorded from Rangpo Chhu, Rangbang Khola, Rishi Khola and Rani Khola. This group is distributed from 300 m to 900 m.

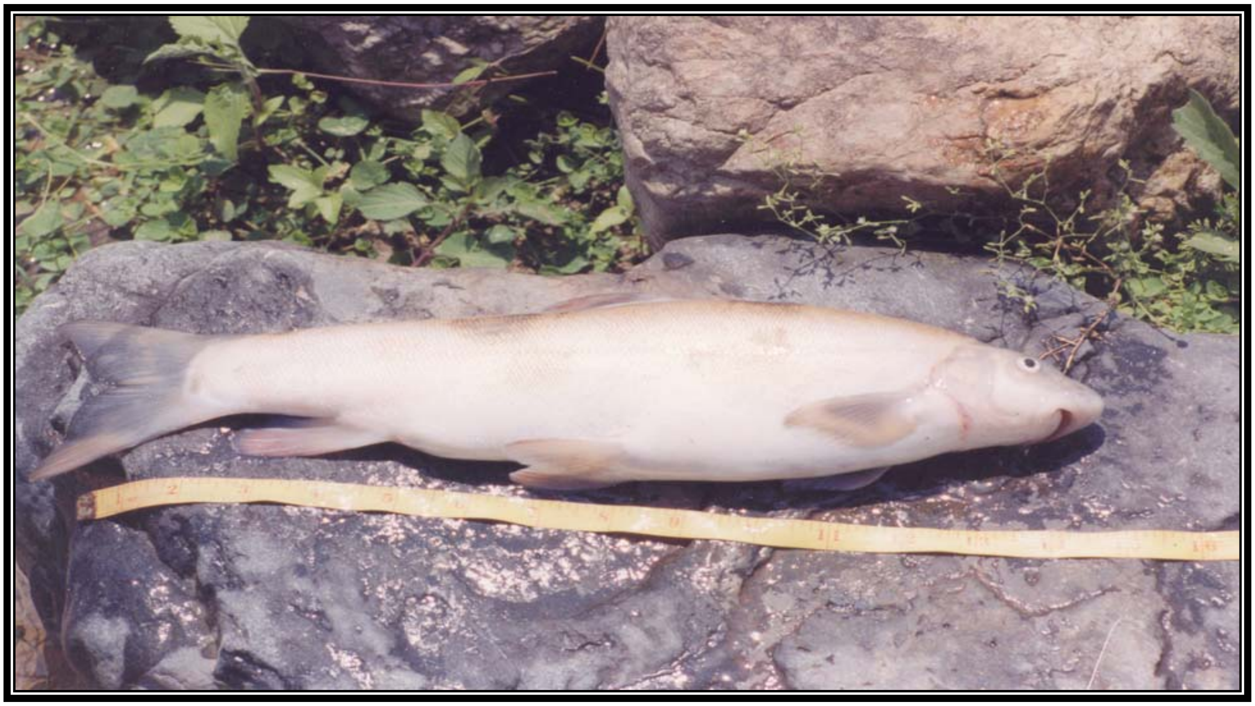

Plate 4.1 An adult specimen of *Schizothoraicthys curvifrons* (Snow trout)

Plate 4.2 An adult specimen of *Schizothoraicthys progastus* (Snow trout)

Plate 4.3 An adult specimen of *Acrossocheilus hexagonolepis* (catli)

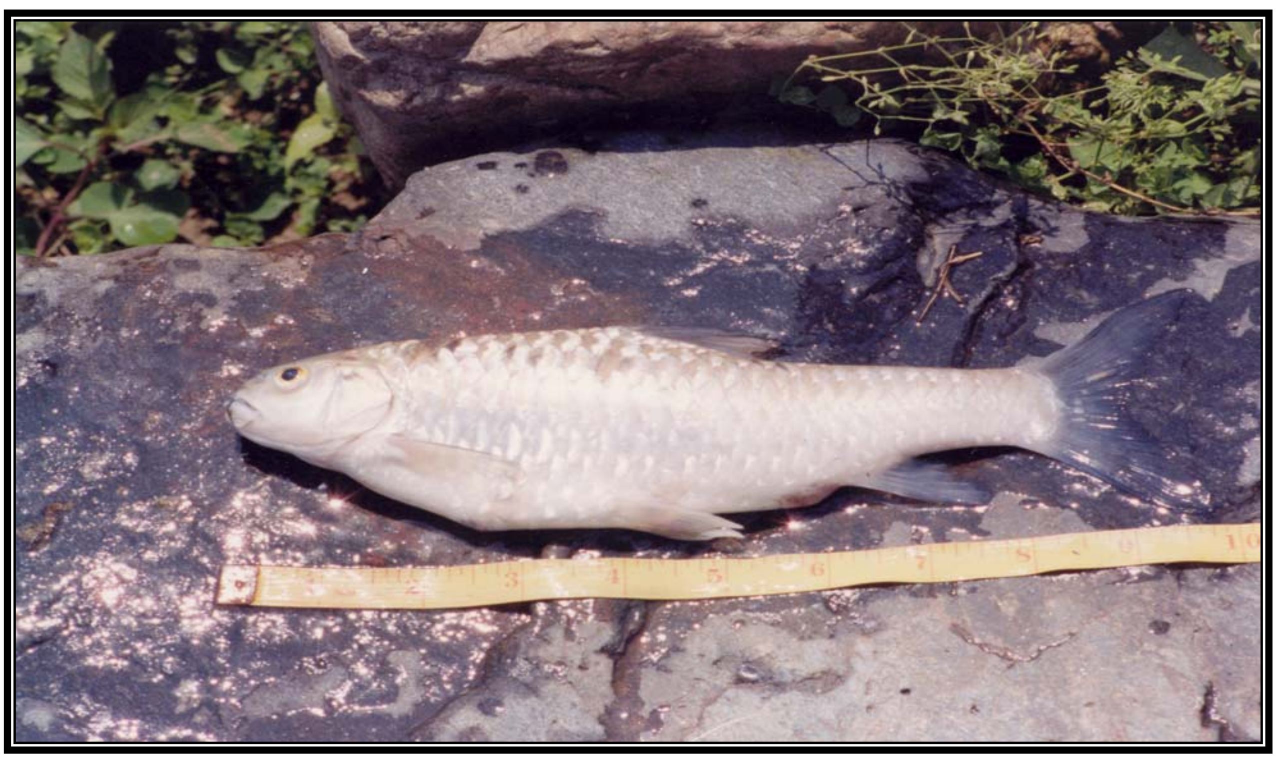

Plate 4.4 An adult specimen of *Acrossocheilus spinulosa* (catli)

4.2.13 *Crossocheilus latius latius*

It is found in lower reaches of tributary streams of Teesta river like Rani khola, Rangpo Khola, Rishi Khola and Rangbang Khola. In Sikkim, this species is not so important for fishery purpose.

4.2.14 *Anguilla bengalensis* (Freshwater eel)

In Himalaya, fresh water eels are found in very few streams. In Sikkim it is found only in the Rangit river. Locally it is called as ‘Bam’. It has not been recorded above altitude of 650 m in Teesta river. In India *Anguilla bengalensis* has been described as endangered fish (Menon, 1999).

4.2.15 *Noemacheilus* spp.

Noemacheilus group of fish is most common in Himalaya. They feed on nymph of aquatic insects. It is popularly known as Gadela in Sikkim. Six species of *Noemacheilus viz*. *N. beavani, N. carltoetoni, N. corica, N. devdevi. N. multifaciatus* and *N. spilopterus* are found from tributary streams of Teesta i.e. Rani khola, Ben Khola and Rishi Khola. Usually, these bottom feeder fishes do not come in the catch that is made by hooks and cast nets. They were landed with the help of local fishermen by diverting a small part of stream.

4.2.16 *Glyptothorax* spp.

Glyptothorax is known as ‘Kaharey maachha’ in Sikkkim. Though, 8 species have been recorded earlier from Sikkim but only two species namely *Glyptothorax gracilis* and *G*. *sinense* could be recorded from the middle stretch of Teesta river (800 to 1,100 m.).

4.2.17 *Euchiloglanis hodgarti*

It is locally known as ‘Looley machha’ and found in comparatively colder waters, where temperature of water always remains below 10º C. These species were recorded from Teesta (Lachen Chhu and Lachung Chhu) between 1,400 and 2,000m).

4.2.18 *Pseudecheneis sulcatus*

It is called ‘Kabhrey machha’ in Sikkim. It does not come in traditional fish catch made by hooks and caste nets. This species was found in streams like Rangpo Khola, Ben Khola, Rishi Khola, etc. They were caught with the help of local fishermen by damming a small part of stream. In Sikkim it is not considered as important fish for fishery purpose.

4.2.19 Other Fishes

Balitora bruccei, Clupisoma sp., *Bagarius bagarius*, *Laguvia ribeiroi* and *Chana orientalis* are some of the other fishes, which are found in Teesta river and its various tributaries in Sikkim.

4.3 FISH MIGRATION IN SIKKIM

Fish migration is a specific phenomenon and related with the breeding behaviour. Most of the species of fish are periodic in breeding and require specific ground throughout the life. Mahseer (*Tor putitora*) is an important migrant in Himalayan rivers, which migrates from warmer plains to high reaches in cold water region. Mahseer is a true potamodromous migratory fish in Sikkim, travels a long distance from Teesta barrage (foothill) to Rangit, Teesta and Rangpo Chhu during late summer to monsoon months for breeding. The water turbidity, temperature and nature of river bed are considered to be important stimuli for the migration of mahseer (Bhatt *et. al*. In press). Most of the brooders of mahseer were found to prefer river Rangit for spawning. The fingerlings and juveniles live in these rivers till next September to mid October and descend to water of plains while adults after spending whole summer and monsoon in these streams return back to warmer waters. The river Rangit up to Jorthang has been identified as breeding ground for mahseer while in river Teesta they were found up to Singtam. The brooders of mahseer are usually landed in these streams with the help of hooks during monsoon.

Surssocheilus hexagonolepis and snow trout are considered to perform local migration. *S. hexagonolepis* moves to small tributaries from main stream while snow trout like *S. richardsonii, S. progastus* move downstream during summer to monsoon. The exotic trout *S. trutta* *fario* and *S. gairdneri gairdneri* are restricted to high altitude waters for all time in Sikkim.

4.4 ENDEMIC AND THREATENED SPECIES

In India, 199 of a total 674 inland fish species are considered to be endemic. In Himalayan region, only 7 species *viz*. *Acrossocheilus spinulosus, Schizothorax macrophthalmus, S. rarensis, Psilorhynchus pseudecheneis, Myersglanis blythii, Nemacheilus carltoni* and *N. devdevi* are endemic. There is no report of endemic species recorded from Sikkim. However, three species namely, *Acrossocheilus spinulosus* and *Noemacheilus devdevi* are endemic to Eastern Himalaya and *N. carltoni* is endemic to Himalaya. The species like *Clupisoma bhandarii, Glyptothorax basnetii*, *G. bhutiai, G. deyi* are the new records from Sikkim waters (Tamang, 2001) and are not reported from other places in India.

None of the fish species inhabiting the rivers and lakes in Sikkim has been included in IUCN red list so far. Menon (1999) described 19 threatened species of India, which also inhabit Teesta waters in Sikkim. Of these, 15 species are rare and 4 species viz. *Anguilla bengalensis*, *Puntius clavatus*, *Ompok bimaculatus* and *Pseudeutropius antherinoides* are supposed to be endangered. Generally, deterioration of water quality, stream regulation, degradation of breeding grounds of fish and over exploitation in Himalaya are the factors responsible for the depletion of fish populations. Though, in Sikkim, the conditions are not so bad so far and these endangered species are not much exploited.

4.5 FISH INTRODUCTION IN SIKKIM

The introduction of fish in any part may be intentional and accidental. Intentional introductions have widely been occurring for different reasons like for food, for sports and to control disease vectors. In India intentional introduction of fish in a large number of rivers and lakes has been occurring for many decades. The waters of Teesta river too are not unaffected by this practice. *Salmo trutta fario* and *S. gairdneri gairdneri* have been introduced in upper stretches of rivers and in a few high altitude lakes. Former species is well adapted and has now dominated upper stretches of river Teesta, Rangit and Rangpo Chhu. There is no case study of interaction between these exotic and native fish in Sikkim. However, the dominant occurrence of exotic fish in upper stretches indicates that they may have eliminated native species from these stretches. A general perception is that the fish introduction without baseline data is not a healthy practice. Also, *Cyprinus carpio* and *Ctenopharyngodon idlus* are being reared in fish farms and lacustrine water of Sikkim. There is also a possibility of threat of accidental introduction of these species in rivers. Because *C. carpio* has a wide range of adaptation, therefore, their drift in running water may cause a heavy loss of ichthyofaunal diversity in Sikkim.

4.6 FISHERIES DEVELOPMENT IN SIKKIM

A large proportion of people of Sikkim are non vegetarian in food habit. Despite the fact that Sikkim is rich in fish resources and legal fishing is allowed, the people are not much dependant on fish to fulfill their non-vegetarian diet. However, the process on fisheries development is underway in Sikkim. Fisheries Department in Sikkim came into existence in 1974 under the Forest Department. The main objective was to motivate fish culture in rural areas as an economic measure for upliftment of socio-economic conditions of farmers. In spite of typical climatic and topographic conditions the department assisted farmers financially to construct small sized fish ponds. During 1991, 83 farmers were provided with loans. Most of the farmers selected, were from North and West districts. The number of beneficiaries has been increasing since 1991. However, fish farming has not developed in Sikkim to the extent and people largely depend on supply of fish from West Bengal. The state government has developed many fish farms in Sikkim and provided the facilities to fishermen. These are described briefly in the following paragraphs.

4.6.1 Fish Farms in Sikkim

For the regular supply of fish seeds many fish farms have been developed in Sikkim. At present about 13 fish farms have been running in Sikkim. Of which 8 farms have been established for the breeding of Common carp (*Cyprinus carpio*) at Rangpo, Rorathang and Kabi in East

Sikkim, Lingthem and Gyathang in South Sikkim, Soreng, Rothak and Geyzing in West Sikkim (see Fig. 4.1). Four farms located at Lachen and Lachung in North Sikkim, Menmoi Chho in East Sikkim and Yuksom in West Sikkim have been developed for exotic trout (*Salmo trutta fario* and *S. gairdneri gairdneri*). There is only one breeding centre for mahseer (*Tor putitora*), which is located at Bagua in South Sikkim. Seeds of Indian major carp, grass carp and silver carp are procured from West Bengal and supplied to farmers. The artificial breeding of these carp species has not been done so far in the state of Sikkim. But department is planning for their breeding at Rothak.

Some of the farms at Lachen, Lachung, Menmoi Chho and Yuksom have been releasing fish seeds of exotic trout for many years in natural waters viz. Lachen Chhu, Lachung Chhu, Rangpo Chhu and Rimbi Chhu. As a result, one negative aspect of these exotic species is that they have out numbered over all native fish species in upper stretches of Teesta river.

4.6.2 Fish Catch in Sikkim

The total legal fish catch in Sikkim increased gradually from 20 to 90 tons for a period of 11 years from 1980–1991. Accordingly, the numbers of licenses issued to fishermen increased from 100 to 400 during the same period (Table 4.3). To avoid illegal fishing, State Fishery Department issues licenses every year to local people. The licenses have two broad categories namely, rod and line and cast net at

Rs. 30 and Rs. 50 per annum, respectively. The cast nets and hooks are widely used in Sikkim by fishermen.

Table 4.3 Year-wise fish catch and number of licenses issued in Sikkim

Year	Production (in tons)	No. of Licenses
1980-81	20	100
1981-82	46	172
1982-83	50	180
1983-84	60	160
1984-85	60	180
1985-86	75	245
1986-87	70	250
1987-88	75	300
1988-89	80	380
1989-90	85	340
1990-91	90	400

(Source: Sikkim Fisheries Department)

4.6.3 Daily Fish Catch in Sikkim (a case study)

Teesta river system harbours more than 50 species of fish. However, all the species do not contribute to daily fish catch. The fish catch largely depends on the fishing methods. The inhabitants of Sikkim mostly use cast nets and hooks for fishing. Therefore, only column feeder fish is found in the catch. The capture fishery in Sikkim is not well developed, despite the fact that most of the population in Sikkim is non-vegetarian in food habit. The fish catch differs among the lower, middle and higher stretches of rivers. Most of the population inhabits lower reaches in Sikkim, Therefore, maximum catches were observed in the lower stretches of Teesta and its tributaries, which gradually decreased towards higher stretches (Table 4.4). The fish catch is greatly affected by seasonal rhythms in streams. In monsoon fishing activities decrease considerably, which also affect the total fish catch. In upper stretches, it almost becomes nil during monsoon. Usually snow trout, mahseer and catli are important components of daily fish catch in lower stretches of Teesta, Rangit and Rangpo Chhu while catli and mahseer are replaced by exotic trout in upper stretches. In small streams, *Garra* spp. and *Barilius* spp. also contributed to fish catch in addition to snow trout, mahseer and catli. In monsoon, fishermen use small cast nets in Teesta and land small sized fish like *Barilius* spp., *Danio* spp., etc. Some of them are used as bait to trap larger fish by using hooks.

4.6.4 Game Fishing

The concept of game fishing in Sikkim is not well developed. But many tourists and local inhabitants were found to use modern hooks for fishing near Singtam in East Sikkim for thrill of joy. Since many reservoirs are proposed on the river Teesta, which may encourage game fishing in future.

4.7 STRESSES ON FISH POPULATIONS IN SIKKIM

Several hydrobiological studies have suggested that natural and man made factors greatly influence the biological productivity of waters (e.g. Pant and Bisht, 1981; Dobriyal and Singh, 1988). The monsoonal surface run off, landslides, road construction activities, etc. increase the suspended load in river and lake water that results into deterioration of water quality and quality of fish food. The siltation and high turbidity in water adversely affect the fish population and monsoonal floods cause the high mortality of fish in the Himalayan rivers. The water current velocity, water discharge and water level are important factors for the survival of spawn and fertilization of fish (Joshi, 1991). The natural and man–made alterations in these factors may cause downstream drift of hill stream fish. Such types of natural stresses are common in Himalaya including Sikkim.

The man made alterations like stream regulations change the physiological rhythm of fish (Jhingran, 1989). The barrages and dams generally hamper the fish migration and destroy the breeding grounds of fish. Mahseer is one of the main sufferers in Himalayan rivers. In addition, overexploitation and faulty fishing techniques like poisoning, damming and use of dynamite, etc. are also responsible for the elimination of fish. The maximum fishing activities were observed in the Rongni Chhu. On the other hand, except for water diversion in small streams there was no illegal fishing method in use.

4.8 MITIGATION MEASURES

The natural fish populations of many Indian rivers have declined both qualitatively and quantitatively (Jhingran, 1983; Das *et al*. 1986).

This problem has been discussed many times by different authors which emphasized the need of rational exploitation and management of fishery resources. In order to conserve the fish populations, following measures are recommended:

i) The damming of river should be avoided in that region where fish migrates or if necessary low dams should be encouraged,

ii) There should be improvements in fish habitats by protecting the stream banks, maintaining natural pools and riffles in the river channel,

iii) Fish pass (fish ladders) must be provided in dams and barrages for the migratory fish,

iv) Watershed should be treated to minimize the siltation in rivers,

v) Faulty or illegal fishing techniques should be prohibited,

vi) Fishing during breeding seasons in identified breeding grounds should be prohibited,

vii) The aquaculture research and artificial breeding should be encouraged in the area,

viii) Cultural fisheries should be emphasized in the region to minimize the fishing loads on natural water resources, and

ix) Careful steps must be taken during the introduction of exotic fish species. They should be reared in stagnant waters. In rivers they may eliminate indigenous species.

Table 4.4 Average daily catch and main fish species in the river Teesta in different stretches

Season	River	Elevation range (m)	Catch (in kg)	Fish composition
Winter	Teesta, Rangit, Rangpo	250–340	12.0	*Schizothorax richardsonii, Schizothraicthys progastus, Tor putitora, Acrossocheilus hexagonolepis, Labeo* spp., Garra spp.
	Teesta, Rangit, Rangpo Rani Khola, Rishi Khola	350-650	14.0	*Schizothorax richardsonii, Schizothraicthys progastus, S. curvifrons, Acrossocheilus hexagonolepis, Labeo* spp.
	Teesta, Rangit, Talung	650-750	8.0	*Schizothorax richardsonii, Schizothraicthys progastus, S. curvifrons, Acrossocheilus hexagonolepis, Labeo* spp.
	Teesta, Lachung, Lachen	750-1600	3.0	*Schizothorax richardsonii, Schizothraicthys progastus, S. curvifrons, Salmo trutta fario*
Monsoon	Teesta, Rangit, Rangpo	250–340	7.0	*Schizothorax richardsonii, Schizothraicthys progastus, Tor putitora, Acrossocheilus hexagonolepis, Labeo* spp., *Barilius* spp., *Garra* spp.
	Teesta, Rangit, Rangpo Rani Khola, Rishi Khola	350-650	9.0	*Schizothorax richardsonii, Schizothraicthys progastus, S. curvifrons, Acrossocheilus hexagonolepis, Barilius* spp., *Garra* spp.

	Teesta, Rangit, Talung	650-750	2.0	*Schizothorax richardsonii*, *Schizothraicthys progastus*, *S. curvifrons*, *Acrossocheilus hexagonolepis*, *Labeo* spp.
	Teesta, Lachen, Lachung	750-1600	-	-
Post Monsoon	Teesta, Rangit, Rangpo	250–340	10.0	*Schizothorax richardsonii*, *Schizothraicthys progastus*, *Tor putitora*, *Acrossocheilus hexagonolepis*, *Labeo* spp.
	Teesta, Rangit, Rangpo Rani Khola, Rishi Khola	350-650	12.0	*Schizothorax richardsonii*, *Schizothraicthys progastus*, *S. curvifrons*, *Acrossocheilus hexagonolepis*, *Labeo* spp.
	Teesta, Rangit, Talung	650-750	7.0	*Schizothorax richardsonii*, *Schizothraicthys progastus*, *S. curvifrons*, *Acrossocheilus hexagonolepis*, *Labeo* spp.
	Teesta, Lachen, Lachung	750-1600	3.0	*Schizothorax richardsonii*, *Schizothraicthys progastus*, *S. curvifrons*, *Salmo trutta fario*

CHAPTER - 5

PROTECTED AREAS

5.1 INTRODUCTION

Teesta basin in Sikkim is characterized by varied topography, wide altitudinal range, extreme climatic condition and diverse geo-biological setup. It is, therefore, home to diverse ecological systems inhabited by rich biologically diverse flora and fauna. This biological resource, in recent times has been under tremendous pressure due to wide array of developmental activities that are underway. In order to preserve and conserve the rich diversity of flora and fauna, more than 46% of its geographic area has been brought under protected framework in the form of Biosphere Reserve, National Park and Wildlife Sanctuaries setup (Table 5.1 and Fig. 5.1) under the Wildlife (Protection) Act, 1972. In addition to the existing protected areas, more areas have been proposed to be brought under Wildlife Protection framework (see Table 5.1). A brief description of each of these protected areas is given below.

Table 5.1 Summary of the Protected Areas in Sikkim

Name of the WLPA	District	Area in sq km	Notification Date
1. Khangchendzonga	North and West	1784.00	26-8-1977
2. Khangchendzonga Biosphere Reserve	North, South West	2619.92	7-2-2000
3. Shingba Rhododendron Sanctuary	North	43	5-12-1992
4. Barsey Rhododendron Sanctuary	West	104	8-6-1996
5. Kyongnosla Alpine Sanctuary	East	31	5-12-1992
6. Fambonglho Wildlife Sanctuary	East	51.76	2-4-1984
7. Maenam Wildlife Sanctuary	South	35.34	9-3-1987
8. Pangolakha Wildlife Sanctuary		124	7-11-2000

5.2 KHANGCHENDZONGA BIOSPHERE RESERVE

Khangchendzonga Biosphere Reserve (KBR) was established in February 7th, 2000 and extends over the North, South and West districts of Sikkim. It is located between 27° 25' to 27° 55' N latitude and 88° 03' to 88° 38' E longitude and cover 2619.92 sq km of area. KBR is comprised of two core zones covering an area of 1784.00 sq km and four buffer zones covering an area of 835.92 sq km. The elevation in the biosphere varies from 1220 m to 8,598 m and encompasses the Khangchendzonga National Park and Reserved Forests of North, South and West Sikkim districts of Sikkim. In the north, the boundary of KBR runs along the boundary of Khangchendzonga National Park (KNP) and Lungnak La ridge (5,537 m); in the east its boundaries are defined by Teesta river, in the south its boundary follows the boundaries of various Reserved Forest Blocks of South and West Forest Divisions and in the west, it is bounded by Singalila range, which forms the international boundary between India and Nepal. The KBR, therefore, is comprised of high peaks *viz*. Khangchendzonga (8,598 m), Kabru Dome (6545 m), mSiniolchu (6,886 m), Mt. Pandim (6,691 m), Narsingh (5,825 m) and high altitude glacial lakes like North and South Lhonak Chho, Green lake, Lachchmi Pokhari to name a few of them and one of the largest glaciers, Zemu and Chanson, Jongsang, Nepal Gap, Tent Peak, South Simvo and Hidden glaciers. Therefore, KBR is comprised of varied ecosystems ranging from sub-tropical to alpine to arctic ecosystems and also defines a number of tributary watersheds of Teesta river basin.

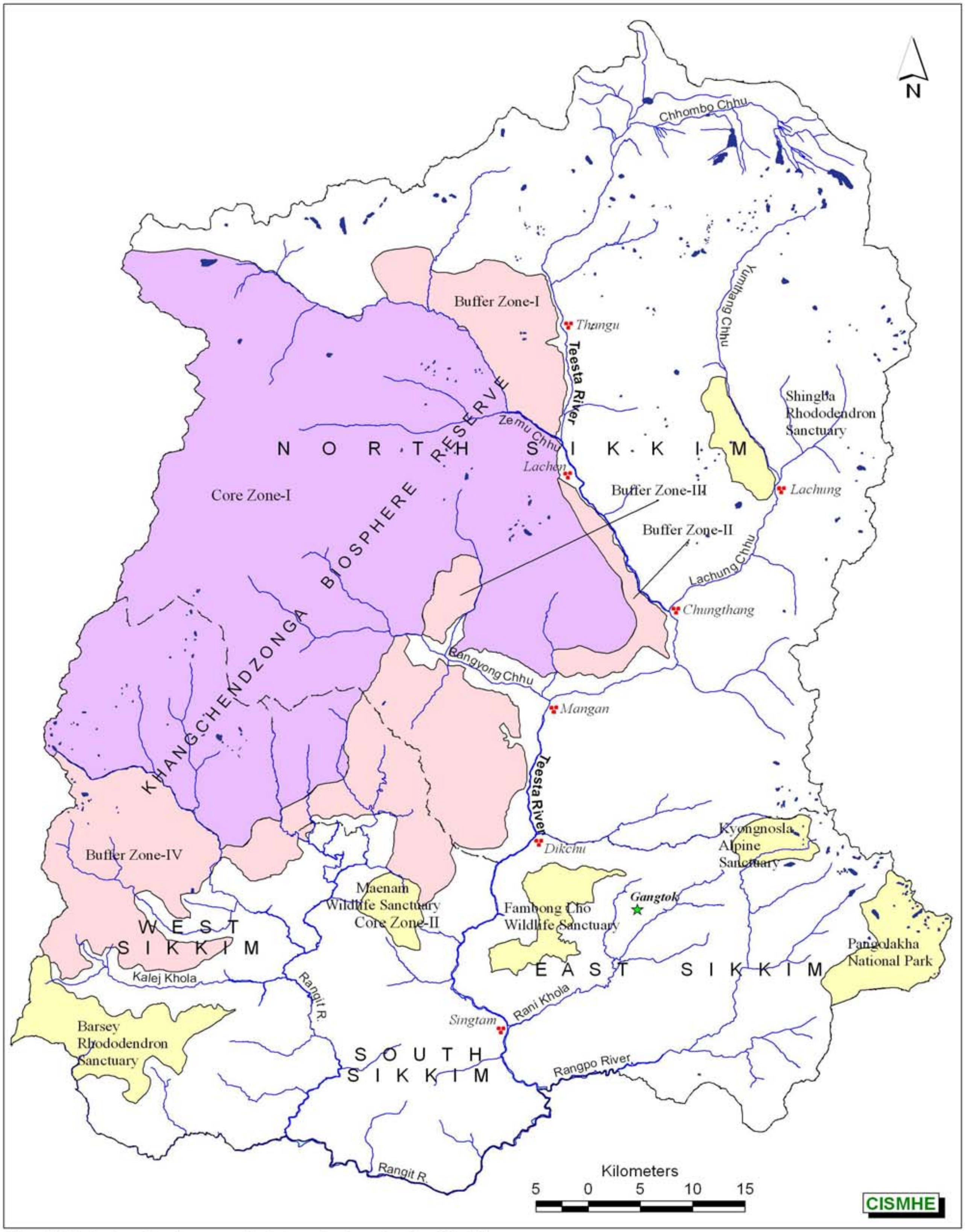

Fig.5.1 Protected areas in Teesta basin in Sikkim

Khangchendzonga National Park (KNP) forms the Core Zone-I of the Biosphere Reserve, whereas Maenam Wildlife Sanctuary forms the Core Zone-II of the reserve. The four buffer zones cover an area of 835.92 sq km. Buffer Zone-I is located on the north-eastern part of the reserve covering an area of 154.48 sq km comprised mainly of left bank slopes of Lhonak Chhu valley and right bank slopes of Teesta river valley from Thangu up to Lachen. Buffer Zone-II is comprised of right bank slopes of Lachen valley from Lachen to Tong and Sanklang Reserved Forest with an area of 55.29 sq km. Buffer Zone-III extends over an area of 29.37 sq km and is comprised of Reserved Forest on the left bank of Rangyong Chhu. Buffer Zone-IV is comprised of Reserved Forest in the upper catchment of Prek Chhu and Rel Chhu with an area of 596.78 sq km. All the buffer zones are comprised of degraded coniferous forests in these areas and require immediate conservation measures.

Area of Core Zone	
Khangchendzonga National Park	1784.00 sq km
Area of Buffer Zones	
Buffer Zone-I	154.48 sq km
Buffer Zone-II	55.29 sq km
Buffer Zone-III	29.37 sq km
Buffer Zone-IV	596.78 sq km
Total Buffer Zone Area	**835.92 sq km**
Total Biosphere Reserve Area	**2919.92 sq km**

5.2.1 Topography and Climate

The topography of the biosphere reserve is quite varied ranging from lower hills to the snow-clad mountains with altitude ranging from about 1,220 m to 8,598 m. There are some river systems like Zemu Chhu, Lhonak Chhu, Rangyong Chhu, Prek Chhu, Umram Chhu, Rukel Chhu, Rimbi Chhu, etc. in the biosphere reserve.

Due to altitudinal variations, the climate in different parts of the biosphere reserve varies from place to place. The weather is pleasant during spring (March-May) and autumn (September-November) and it is freezing in winter at high altitudes. The biosphere also experiences a wide range of relative humidity varying from 70% in the month of December to 95% in July. The rainfall varies from 2,000 to 5,000 mm per annum.

The KBR is least disturbed ecosystem and has only two small eco-villages. Tsoka, one of the two villages, belongs to Tibetan community with an area of 13 acres and a human population of only 90. The other small village is comprised of retired army personnel of Nepalese community (Gurung), situated in an area of 10 acres of land. It is also surrounded by other rural villages which belong to other communities like Lepchas, Bhutias and Nepalese. About 75% of house holds are considered to be poor and they directly or indirectly depend on the biosphere reserve for their livelihood. The economy of the area is of mixed type and rural folk mostly depends on agriculture, horticulture and animal husbandry.

5.2.2 Forests

Khangchendzonga Biosphere Reserve is known as one of the richest biodiversity areas in Sikkim Himalaya. Due to its unique geographical position and varied climatic conditions, the forests represent diverse plant communities which include diverse vegetational types of many foreign elements as well as endemic species. The following forest types or vegetational types have been demarcated in the biosphere reserve as per the classification of Champion & Seth (1968). They are Sub-tropical broad leaved hill forests, Broad leaved temperate forests, Mixed coniferous forests, Sub-alpine and Alpine forests.

5.2.2.1 *Sub-tropical broad leaved forests*

These forests occur on hilly terrain up to an altitude of 1,800 m and are comprised mainly of mixture of different elements. The tree canopy is comprised of *Alangium chinense, Alnus nepalensis, Castanopsis hystrix, Ficus semicordata, Litsea doshia, Macaranga denticulata, Malus sikkimensis, Quercus glauca, Rhododendron arboreum, Saurauia napaulensis, Schima wallichii*, etc. Among predominant shrubs are *Boehmeria platyphila, Buddleja asiatica, Melastoma malabathricum, Mussaenda roxburghii, Oxyspora paniculata, Prinsepia utilis* and *Rubus ellipticus*. Common climbers are the species of *Cissus, Dioscorea, Pathenocissus, Piper, Raphidophora, Smilax, Tetrastigma*, etc. The ground storey is represented by many small herbs and tall undershrubs. *Achyranthus bidentata, Bidens pilosa, Drymaria villosa, Eupatorium odoratum, Galinsoga parviflora, Gnaphalium affine, Gynura pseudochina, Houttuynia cordata, Hydrocotyle asiatica, Oxalis corniculata, O. griffithii, Plantago major, Persicaria capitata, Ranunculus diffuses*, etc. are the common dominant herbs.

5.2.2.2 *Temperate forests*

These forests are found between 1,800 m and 3,500 m altitudes and can be further divided into sub-types : a) Broad leaved temperate forests and b) Mixed coniferous forests.

a) *Temperate broad leaved forests*

These forests are found between 1700 and 2700 m and are dominated by evergreen oaks and laurels. There are also a number of deciduous tree species but these form small proportion. These forests are thick and rich in ground flora as well as epiphytic vegetation. Important tree species are *Acer campbelli, Alnus nepalensis, Betula alnoides, Carpinus viminea, Castanopsis tribuloides, Corylus ferox, Engelhardtia spicata, Lithocarpus elegans, Lyonia ovalifolia, Machilus edulis, Magnolia campbellii, Malus sikkimensis, Quercus lamellosa, Rhododendron grande, Semingtonia populnea,* etc. The second storey is very dense and diverse, and comprises of *Agapetes serpens*, *Berberis angulosa, B. insignis, Cotoneaster microphyllus, Hydrangea stylosa,* *Hypericum hookerianum, Mahonia napaulensis, Pittosporum napaulense, Sambucus adnata, Spiraea canescens, Viburnum mullaha*, etc. Climbers are few and represented by species of *Aristolochia griffithii, Ceropegia pubescens, Clematis montana, C. acuminata, Dicentra scandens, Hedera nepalensis, Holboelia latifolia*, etc. The groundflora is represented by *Aconogonum molle, Arisaema griffithii, A. jacquemontii, A. propinquum, Begonia josephii, Bistorta vaccinifolia, Euphorbia sikkimensis, Hedychium* sp., *Impatiens falcifer, I. kingii, I. urticifolia, Koenigia nepalensis, Panax pseudoginseng, Persicaria capitata, Pilea anisophila, Roscoea purpurea*, etc. There are few insectivorous species like *Drosera peltata, Utricularia multicaulis, U. wallichiana*, etc. are also found in moist and shaded places.

b) *Mixed temperate coniferous forests*

These are dense evergreen forests and found between 2,700 and 3,500 m. The common tree species are *Abies densa, Cupressus corneyana, Larix griffithiana, Tsuga dumosa* and *Taxus wallichiana*.

5.2.2.3 *Sub-alpine and Alpine forests*

The Sub-alpine forest is found above elevations of 3,500 m and are comprised of dense growth of small stunted trees and large shrubs with patches of junipers. Important species found in this forest are *Abies densa, Betula utilis, Juniperus recurva, Rhododendron* spp., etc. At higher elevations the vegetation comprises of alpine moorland where tree growth is arrested and bushes form dense clumps. *Rhododendron* *anthopogon, R. lepidotum, R. leptocarpum, R. nivale, R. vaccinoides,* etc. are some of the dwarf scrubs at higher elevations. The alpine pastures are composed mainly of perennial mesophytic herbs with some grass species. The predominant alpine herbs are: *Aconitum hookeri, Caltha palustris, Cypripedium himalaicum, Cassiope selaginoides, Corydalis juncea, Meconopsis paniculata, Nardostachys grandiflora, Parnassia nubicola, Primula capitata, P. minutissima, P. sikkimensis, Podophyllum hexandrum, Potentilla coriandrifolia, P. peduncularis, Saxifraga* spp., *Saussurea gossypiphora*, etc.

More than 34% of Biosphere Reserve area is under forest cover. However, only 8.12% is under dense canopy category and 26.66% is under open forest category. Alpine scrub covers about 7.10% of the reserve area. As it is a high altitude reserve with elevations more than 8,000 m, more than 14% of its area is either under perpetual snow or glaciers. Further 26.58% of the reserve is strewn with rocks, boulders and barren slopes.

5.2.3 Floristic diversity

The Khangchendzonga Biosphere reserve harbours about 1225 species of angiosperms, out of about 4000 species of angiosperms in Sikkim Himalaya. The dicotyledons are represented by 1030 species belonging to 379 genera and 105 families (out of 913 genera and 165 families in Sikkim Himalaya), while the monocotyledons are represented by 15 families and 111 genera (out of 26 families and 339 genera in

Sikkim Himalaya) (Table 5.2). Gymnosperms are represented by 5 families, 9 genera and 10 species (out of 9 families, 14 genera and 18 species in Sikkim).

Asteraceae is the most dominant family of dicots with 48 genera and 123 species followed by Rosaceae with 15 genera and 69 species, while Orchidaceae with 32 genera and 51 species is the largest family of monocots (Tables 5.3 – 5.5).

These species were recorded during the field visits conducted between Dec., 2002 and Dec., 2004. For recent information on identification and nomenclatural changes recent books, research papers, and monographs were consulted.

Table 5.2 Status of different groups of vascular plants in Khangchendzonga Biosphere Reserve

Group	Family	Genera	Species
Angiosperms	120	490	1225
Dicots	105	379	1030
Monocots	15	111	195
Gymnosperms	5	9	10
Pteridophytes	22	37	57

Table 5.3 List of dominant families of dicots and monocots in Khangchendzonga Biosphere Reserve

Families	Genera	Species
Asteraceae	48	123
Rosaceae	15	69
Orchidaceae	32	51
Poaceae	31	46
Scrophulariaceae	10	44
Ericaceae	9	42
Primulaceae	6	42
Caryophyllaceae	9	38
Brassicaceae	9	38
Polygonaceae	9	34

Table 5.4 The largest families of dicots by number of species

Family	Khangchendzonga Biosphere Reserve (KBR)	Sikkim
Asteraceae	123	253
Rosaceae	69	126
Scrophulariaceae	44	112
Ericaceae	42	60
Primulaceae	42	94
Caryophyllaceae	38	51
Brassicaceae	38	78
Polygonaceae	34	76

Saxifragaceae	34	63
Ranunculaceae	33	68

Table 5.5 Largest families of monocots by number of species

Family	KBR	Sikkim
Orchidaceae	51	445
Poaceae	46	280
Liliaceae	25	95
Juncaceae	15	36
Araceae	13	40
Cyperaceae	13	147
Zingiberaceae	12	52
Amaryllidaceae	6	6
Haemodoraceae	4	12
Commelinaceae	3	22

5.2.4 Fungi

Rich growth of fungal flora is encountered in the humid areas of the reserve, ranging from lower hills to the higher elevations. During rainy season, many edible fungi are collected by local communities and used as a substitute for vegetables. Sometimes some species are dried and stored for use in future. Some of the edible fungi belong to different genera viz. *Agaricus, Boletus, Clavaria, Lycoperdon, Polyporus*, etc. Besides these edible fungi, there are also found some deadly poisonous fungi. *Rossula tinctoria*- a source of rossuline, and *Amanita* sp. – a source of amanitin, also occur in the biosphere reserve. Some other fungal species collected from the reserve belong to genera like *Calocybe, Coprinus, Clitocybe, Flammula, Lentinus, Mycena, Mutinus, Panus, Peziza, Tremella* and *Xylaria*.

5.2.5 Lichens

The biosphere is also rich in lichen diversity, which is represented by all growth forms i.e. the Crustose, Foliose and Fruticose types found in different eco-climatic zones of the reserve. However, they are more predominant in sub-tropical and temperate zones of the reserve. Some predominant lichen species found in the biosphere reserve are *Cladonia furcata, C. chlorophaea, Collema furfuraceum, Coccocarpia erythroxylii, Hypogymnia vittata, Leptogium azureum, Lobaria discolor, L. kurokawae, L. pseudopulmonaria, L. retigera, Nephroma helveticum, Parmelia adangescens, Parmelina aurulenta, P. wallichiana, Parmotrema mellisii, P. nilgherrense, P. subtinctorium, P. tinctorum, Peltigera dolichorrhiza, Plastismatia erosa, Stereocaulon paradoxum, Solorina crocea, Usnea baileyi, U. longissima,* etc.

5.2.6 Pteridophytes

The biosphere is also very rich and diverse in pteridophytic flora. Pteridophytes occur on slopes of rocky mountains in all climatic areas but are more predominant in temperate zone. Some common pteridophytes found in the biosphere reserve are: *Arthromeris wallichiana, Asplenium ensiforme, Coniogramme caudata, C. subcordata, Dicranopteris linaris, Diplazium frondosum, Gleichenia gigantea, Lepisorus angustus, L. leiopteris, L. nudus, Loxogramma involuta, Microsorium membranaceum, Nephrolepis cordifolia, Phymatopteris erythrocarpa, Phymatosorus cuspidatus, Polypodiastrum argutum, Polystichum lentum, P. semifertile, Pteris aspericaulis, P. biaurita, P. critica, Pyrrosia floculosa, P. mollis, Selaginella monosperma, S. involvens, Sphenomeris chinensis*, etc. *Dryopteris berbigera* and *Polysticchum precscottianum* are very common in the alpine region.

5.2.7 Endemic Taxa

The endemic species are confined mainly to the regions of Zemu, Lhonak and Lachen valleys in the biosphere reserve. Some of the endemic taxa found in reserve and other north-eastern states are *Abies densa, Agapetes incurvata, Betula utilis, Codonopsis foetens, Gentiana prainii, Hypericum filicaule, Larix griffithii, Listera alterniflia, Lonicera magnibracteata,* etc.

5.2.8 Threatened species

The biosphere reserve harbours a number of plant species that are listed in endangered and threatened categories. Some of the rare and threatened plants found in the biosphere reserve are *Aconitum* *ferox, Aristolochia griffithii, Balanophora involucrata, Brycarpum himalaicum, Cyperipedium himalaicum, Ephedra gerardiana, Gentiana prainii, Hypericum filicaule, Listera alternifolia, Lonicera magnibracteata, Nardostachys grandiflora, Panax pseudo-ginseng, Podophyllum hexandrum, Rheum nobile, Rhododendron anthopogon, R. setosum, Taxus wallichiana*, etc.

5.2.9 Fauna

Many high altitude animals of the Eastern Himalaya are found in this Biosphere Reserve. The mammalian species include the Snow leopard, Leopard, Clouded leopard, Red panda, Himalayan tahr, Musk deer, Bharal, Serow, Marco polo sheep, Barking deer, Lesser cats, Tibetan wolf, Mountain fox, Himalayan Black bear, marmots and monkeys. Avi-fauna is comprised of about 550 species of birds which include high altitude pheasants like Monal, Impejan, Tragopan and Blood pheasants (which is a state bird). Tibetan snow cock, Himalayan snow cock, Snow partridge, Hill partridge, Lammergier, Eagle-owl, Tibetan horned eagle-owl, eagles, falcons, hawks and, snow and rock pigeons are some of the important constituents of the wide diversity of avi-fauna of the reserve.

5.3 KHANGCHENDZONGA NATIONAL PARK

Khangchendzonga National Park (KNP) comprises the Core Zone-I of the Khangchendzonga Biosphere Reserve and was notified on August 26, 1977 covering an area of 1784.00 sq km with elevation ranging from 1,829 m to 8,598 m. It is bounded in the north by the Tent Peak (7,365 m) and the ridge of Zemu glacier. The eastern boundary is marked by the ridge of the Mt. Lamo Angdang (5,862 m). The southern boundary is demarcated by ridges of Narsingh (5,825 m) and Pandim (6,691 m) peaks. The western boundary is defined by the India-Nepal international border and the Nepal Gap peak. Except for Tsoka village, there are no settlement located inside the park. The park area has now been extended to 1,784 sq km in May, 1997 to include continuous tract of mountains and to maintain the ecosystem continuity to conform with the Core Zone-I boundary of Khangchendzonga Biosphere Reserve in the north.

It is home to some of the rare and endangered plant species such as *Saussurea lappa, Paphiopedilum* spp., *Nepenthes khasiana*, etc.

Khangchendzonga National Park (KNP), which comprises the Core Zone-I of the reserve, has more than 32% of park area under permanent snow and glaciers. Moraines also occupy about 16% of the park area. Forest cover in the park is 20.40% of which 5.7% is under dense category and rest is under open category.

5.4 MAENAM WILDLIFE SANCTUARY

Maenam WLS is located in South Sikkim above the town of Ravongla and covers an area of about 3,500 hectares with its highest point being at Maenam. Maenam-Tadong ridge running north-south in the sanctuary acting as a water divide between Teesta and Rangit rivers, adds to the uniqueness of the micro-climates of the sanctuary. It is a home of Red panda, a smaller relative of well known Giant panda. The common mammals found in this sanctuary are Goral, Serow, Barking deer, Marbled cat, Leopard cat and Civet cat. Avi-fauna is represented by Blood pheasant, Hill patridge, Magpies, Eagles, Bhee-necked pitta, Sun birds, etc.

Maenam WLS constitutes the Core Zone-II of the Khanchendzonga Biosphere Reserve and therefore, has more than 92.0% of its area under forest cover. Dense forests comprise 18% of these while 74% forests are of open canopy category. Further, alpine scrub and temperate scrub constitute another 4.8% of the sanctuary area and only 2.8% of area is under barren/ rockyland landcover class.

5.5 SHINGBA RHODODENDRON SANCTUARY

It is located near Yumthang in North Sikkim and contains a vast variety of rhododendrons and extends over an area of 43 sq km. It was notified on 5-12-1992. The sanctuary is bounded on its southern periphery by the Yakchey La and on the northern periphery by the Yumthang Valley known for its alpine meadow and hot springs. It is bounded in the east by Chuba-Sagochen mountain ranges and on the west by part of Chomzomei Tso extending up to Lava pass. Yumthang Chhu flows through the sanctuary. The sanctuary is known for the abundance of rhododendron trees and shrubs, 40 species/ varieties of which are recorded from Sikkim alone. The fauna of the sanctuary consists of the Serow, Goral, Leopard cat, Civet cat, etc. Most common birds of the sanctuary are Blood pheasant, Monal pheasant, Snow pigeon and Blue magpie.

As the sanctuary is located at higher altitudes about 6% of its area is under permanent snow and glaciers. Further moraines cover 6.8% its area. The area under forests is about 27% of which 25.8% is under open forests and only 1.4% is under dense forests. Alpine scrub constitute 10.29% of the sanctuary area. More than 48% of the sanctuary is under barren slopes and rockyland.

The rare and endemic *Rhododendron nevium*, the state tree, occurs only in this sanctuary in addition to the rich ground flora comprised of primulas, potentillas, gentians, saxifrages, poppies and aconites. Silver fir, maples, rhododendron scrubs and trees laden with lichens are the characteristic floral elements of this sanctuary. Brown trout was introduced into Yumthang Chhu at Phunyi in 1978 and have been flourishing well since then.

5.6 KYONGNOSLA ALPINE SANCTUARY

It is situated around the area adjoining the Tsomgo (Chhangu) lake along the Nathula Road at a distance of about 31 km east of Gangtok in East Sikkim. The sanctuary is rich in flora and fauna and abounds in alpine flowers like poppies, primulas and rhododendrons.

Many rare and endangered medicinal plants such as *Podophyllum hexandrum*, *Aconitum* spp. and *Nardostachys grandiflora* occur in the sanctuary. The orchid *Cypripedium elegans* is endemic to this area. *Abies densa* is the predominant tree along with a wide variety of rhododendrons that are found in the sanctuary. Dense bushes of bamboos at the lower altitudes, mostly belonging to *Arundinaria* spp. form an ideal habitat for animals like the Red panda. Sub-alpine forest, alpine pastures, Birch-Rhododendron scrub and Deciduous alpine scrub are the predominant forest types found in the sanctuary.

Forests cover 33.62% of the Kyongnosla Alpine Sanctuary while alpine scrub constitute 13.7% of the sanctuary area. Rockyland and barren slopes constitute 48.6% of the sanctuary area.

Bird diversity is represented by different types of laughing thrushes in shrubs and on the forest floor; the blue whistling thrush, redstarts and forktails near waterfalls and hill-streams; warblers, tit-babblers, tree-creepers, white-eyes, wrens, rose finches, yellow- bellied fantail flycatchers, mynas, yuhanas, black eagle, blackwinged kite and kestrels. The pheasants such as monal and blood pheasant are also found here. Kyongnosla Alpine Sanctuary also acts as a stopover for migratory birds before going down to the Indian plains or back to Siberia.

5.7 BARSEY RHODODENDRON SANCTUARY

The Barsey Rhododendron Sanctuary lies in the south west corner of the West Sikkim district and is spread over 104 sq km area with

Singalila range, the international border with Nepal defining the western boundary. Rambong Khola, the boundary between Sikkim and West Bengal, forms the southern boundary. The sanctuary extends over an area of 105 sq km with altitude varying from 1,600 m to 4,600 m.

The banks of rivers between 2,400 and 4,000 m are generally covered with rhododendrons sometimes to the total exclusion of other wooded vegetation, especially near the snowy mountains. Such conditions prevail throughout the Singalila range due to its proximity with the Khangchendzonga range. The large trees existing in the sanctuary are *Abies densa*, *Juniperus pseudo-sabina*, and *Juniperus recurva*. The silver fir extends to 3,900 m, the junipers to 4,500 m. Luxuriant growth of a number of rhododendrons is found in this sanctuary. *Rhododendron arboreum, R. cinnabarinum, R. falconeri, R. barbatum, R. campanulatum* and *R. hodgsoni* are most common rhododendrons. *Acer caudatum, Betula utilis, Lyonia ovalifolia, Prunus rufa, Pyrus foliolosa* and *P. macrophylla* are some of the predominant herbaceous species. *Arundinaria spathiflora* and *A. racemosa* are also found in this sanctuary with an upper limit of about 3,800 m. The shrubby vegetation is quite dense and almost covers the patches of herbaceous plants that exist beneath it. *Saxifraga ligulata, Potentilla, Clintonia, Polygonum* and two species of ferns are all some of the commonly occurring herbaceous plants. *Gaultheria nummularia*, small willows and *Cassiope fastigiata* cover the ground with their dense growth in open gentle slopes. Towards the upper limit of rhododendrons and other shrubs, a wide variety of herbaceous plants are found. Primulas are abundant and

Primula sikkimensis, *P. reticulata*, *P. stuartii* and *P. denticulata* are the predominant species.

The sanctuary area is under 88.33% forest cover. Dense forests cover 19.72% of the sanctuary area and open forests cover 68.61% of the total area of the sanctuary. Alpine scrub and temperate scrub cover 4.9% of the sanctuary.

Faunal elements are represented by Leopard, Leopard Cat, Marbled Cat, Himalayan Yellow Throated Marten, Common otter, Himalayan palm civet, Wild dog, Indian fox, Jackal, Himalayan black bear, Wild Boar, Red Panda, Serow, Assamese Macaque, Rhesus Macaque and Himalayan langur. The avi-faunal elements are represented mainly by Crimson horned pheasant, Monal pheasant and Kaleej pheasant, Crestless porcupine, Rufous tailed hare, Chinese pangolin, Flying squirrel, Giant squirrel and Himalayan mouse hare are the most common rodent species found in this region.

5.8 FAMBONG LHO WILDLIFE SANCTUARY

Fambong Lho WLS is located about 25 km from Gangtok and covers an area of 51.76 sq km above the road between Singtam and Dikchu with the highest point at a place called Tinjure at 2,749 m where a wooden observation tower of the Forest Department exists. The sanctuary is the home of Himalayan black bear, Red panda, Civet cat and many varieties of birds and butterflies. The Binturong or Bear-Cat

(*Arctictis binturong*) is a rare civet reported from here. The vegetation is comprised mainly of Oaks (*Quercus* sp.), Katus (*Castanopsis* sp.), Champ (*Michelia* sp.), Kawlo (*Machilus* sp.), Kimya (*Morus* sp.) and bamboo forests, ferns and *Tsuga dumosa*.

5.9 PANGOLAKHA WILDLIFE SANCTUARY

The Pangolakha Wildlife Sanctuary is located over a geographical area of 128 sq km and is situated in East Sikkim. It was notified on 7th November, 2000. It accounts for 5.88% of the total protected area network and is spread over in 1.8% of the geographical area of the state. The altitude varies from 1,200 m to 4,757 m. The Pangolakha range separates Sikkim from Bhutan in the southeast, where Red panda, Gaur and Tibetan wolf occur. The Sikkim stag was last reported from this range. The formation of PA in the region which is largely forest will create a contiguous habitat with those forests of Bhutan.

The Pangolakha-Rachela RF and its alpine zone support a large number of mammals and birds such as Monal pheasant, Tragopan, Blood pheasant, etc. Most of them are highly endangered and enlisted as highly vulnerable and volatile species. The supreme predator tiger follow a trail that they do for a quite number now. The Indian bison (*Bos gaurus*), Takin (*Budorcas taxicolor*) and Serow (*Capricornis sumatraensis*) are some of the species present in the sanctuary (Lachungpa and Awasthi, 2000). It is also a place that has a variety of medicinal plants, viz. *Clematis alpine, Peducularis fissa, Potentilla* *fulgens*, etc. Due to its rich species diversity the sanctuary has been proposed to be upgraded to a national park.

5.10 PROPOSED PROTECTED AREAS

In addition to the above described existing protected areas, there are 6 additional protected areas, which have been proposed under the biodiversity hotspot program (Table 5.6). With the inclusion of these, Sikkim’s protected areas would cover an area of 3,871 sq km (53% of Sikkim’s total area).

Table 5.6 Protected areas proposed under biodiversity hotspot program

Name	Area (sq km)
Kitam Sanctuary	13
Pangolakha National Park	108
Tholung Wildlife Sanctuary	230
Dzongri Wildlife Santuary	468
Nimphu Wildlife Sanctuary	167
Khangchendzonga National Park	946
(International Biosphere Reserve Extension)	

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ANNEXURE

Annexure-I

Table 1. Some important medicinal plants of Sikkim with their therapeutic uses

Sl. No.	Botanical Name	Vern./Local Name*	Altitude (m)	Part/s Used	Distribution	Medicinal Importance
1.	*Abelmoschus*	Musk-dana *manihot*	600-2400	Fruit	Singtom, Tong, Gyalzing, Legship	Seeds yield a fatty oil; decoction of dried capsule given in fever and dysentery
2.	*Abroma angusta*	Ulatkambal	Up to 1500	Root	Singtam, Mangalbare	Paste of root applied to treat itch
3.	*Achyranthes bidentata*	Chir-chita	Up to 2400	Whole plant	Singtam, Dikchu, Chungthang	Root infusion taken in malarial fever; Leaf extract supposed to facilitate delivery.
4.	*Aconitum ferox*	Bikh	3000-3500	Tuber	Menmoi Chho	Tubers are used for sedative and narcotic effects; useful in fever , diarrhea and rheumatism
5.	*Acorus calamus*	Bojho	1000-2000	Rhizome	Tong, Lachung	Rhizome powder used as a tonic; also used in fever and skin diseases
6.	*Ageratum conyzoides*	Osari	Up to 2700	Leaves	Singtam, Chung-thang, Lachen,	Leaf extract is given to treat piles; cuts, wounds and sore Gangtok, Legship healing
7.	*Allium cepa*	Palandu	Up to 1800	Bulb/Leaf	Singtam, Tong Pelling, Rangpo	Bulb used in medicines; digestive and skin ailments
8.	*Allium sativum*	Lashuna	Up to 2500	Bulb/Leaf	Singtam, Gangtok Chungthang, Lachen, Lachung	Bulb useful in bronchial asthma, respiratory, digestive and blood diseases; leaves & bulbs added to food preparations as spice
9.	*Aloe barbadensis*	Ghirtkumari	Up to 1000	Leaves	Lower Teesta valley	Fleshy leaves useful in burning sensation; Leaf extract used stomachic, emmenogogue, anthelemintic and purgative
10.	*Alnus nepalensis*	Utis	1000-2600	Bark	Sangklang, Selem, Tong, Chungthang, Lachung	Bark used in local medicine
11.	*Alternanthera sessilis*	Kanchari	Up to 1500	Leaves	Lower valley	Leaves used as vegetable; useful in anemia

12.	*Amaranthus caudatus*	Rajagiri	Up to 2500	Leaves	Lachung, Lachen	Leaves cooked for vegetable; roasted seeds are digestive
13.	*Amomum subulatum*	Barihadaela,	Up to 1800 Bara-elachi	Seeds	Sunglak, Mangle, Chakung Chhu, Chungthang	Seeds are used for flavouring food
14.	*Arisaema speciosum*	Sump-ki-khumb	1700-3000	Tuber	Yoksum, Rate Chhu, Gangtok, Lachen	Paste of tuber useful in burning; induce vomiting
15.	*Artemisia nilagirica*	Titapati	Up to 2000	Leaves	Chungthang,	Extract of leaves useful in wound healing; antiseptic, diuretic, anthelmintic
16.	*Bauhinia variegata*	Koeralo	Up to 1500	Flower, Leaf	Tong, Singtam, Legship, Jorthang, Gyalzing	Flower eaten as vegetable. Ash of dried leaves taken in cough
17.	*Bergenia ciliata*	Pakhanbhed	1500-3000	Rhizome	Lachung	Root powder used against diarrhoea and vomiting; also for kidney stone problems
18.	*Bidens pilosa*	Kurroa	Up to 2500	Whole plant	Singtam, Legship, Chungthang, Lachung	Plant extract with honey used in cough and bronchitis; useful in leucoderma
19.	*Brassica campestris*	Kali Sarson	Up to 1000	Root	Lower Teesta Valley	Roots edible, rich in calcium and vitamins
20.	*Bridelia retusa*	Khaja	Up to 800	Bark, root	Lower Teesta Valley	Bark yield tannin; boiled with water used to treat gum diseases. Decoction of roots given in diarrhoea
21.	*Bryonopsis laciniosa*	Garugmara	Up to 1600	Seed	Lower Teesta valley	Seeds used in local medicine for treatment of diabetes
22.	*Buddleja asiatica*	Gogun	Up to 1700	Leaf, root	Sherwani, Rangpo, Legship	Leaf extract used in skin diseases; roots as an abortifacient
23.	*Callicarpa arborea*	Sumalis Guainlo	Up to 1600	Bark	Selem, Tong, Chungthang	Bark is used as masticatories and dyes; bitter tonic and carminative
24.	*Camellia sinensis*	Chai, Cha	Up to 1800	Leaf	Temi, Sakyong	Leaves used for tea; boiled tea effective in eye trouble.

25.	*Capsicum annuum*	Mirch	Up to 2500	Fruit	Rangpo, Chung-thang, Lachung	Fruits are the source of condiment chillie; good source of vita. C. fruits hanged on the door to ward off evil spirits.
26.	*Centella asiatica*	Brahmi	600-2300	Whole Plant	Tarko, Lachung	Plant juice is used in the treatment of mental disorder; intellect promotion in children: also useful in hypertension
27.	*Choerospondias pinnata*	Amra	250-900	Fruits	Rangpo, Tarko	Leaves and fruits effective in cold
28.	*Cinnamomum tamala*	Tejpata	Up to 1500	Bark, leaf	Selem, Chung-thang, Tong	Bark and dried leaves used for flavouring tea and food; Bark chewed in dyspepsia and throat irritation
29.	*Cissampelos pariera*	Akanadu	Up to 1000	Leaf, root	Mangalbare, Rorathang, Rangpo Khola	Roots and leaves believed as an antidote to snake; root extract used in constipation and gastric and urinary troubles
30.	*Clematis nepaulensis*	Lamrya	1500-2000	Leaf	Lachung, Chung-thang	Leaf extract used as antiseptic in skin ailments
31.	*Colebrookia oppositifolia*	Binda	Up to 1200	Leaf	Mangle, Tarko Jorethang	Leaf paste applied on wounds
32.	*Costus speciosus*	Keu	Up to 1500	Stem,	Rangpo, Tong, root	Extract of root and stem is Legship given orally to cure urinary tract infections
33.	*Cucurbita maxima*	Sitaphal	Up to 2300	Seed	Singtam, Legship, Ravong, Chung-thang	Seed considered as anthelmintic; edible
34.	*Curcuma longa*	Haldi	Up to 1700	Rhizome	Ravong, Lachung Chungthang	Rhizome used as dye and condiment; useful in blood and skin problems
35.	*Cynodon dactylon*	Dhub	Up to 2000	Whole plant	Gangtok, Singtam, Legship	Plant is believed pious and used in several religious ceremonies; plant extract useful in piles
36.	*Daphne bholua*	Kagate	1900-3400	Bark,	Lachen, Lachung	Bark is used in paper making;

				Leaf		Leaf paste useful in eczema; as an ornamental shrub
37.	*Datura stramonium*	Dhatura	Up to 1500	Seed	Tarko, Tong	Seeds medicinal; as toxicant
38.	*Dioscorea bulbifera*	Ratalu	Up to 1800	Tuber	Gangtok, Singtam Yoksum	Tuber is edible; dried tuber is used as an antiseptic appied on burns and wounds
39.	*Drymaria cordata*	Abizal	Up to 2000	Whole plant	Tarko, Mangle, Rangpo, Legship, Tashiding, Chungthang	The aqueous paste of plant is useful in bile complaints. Young leaves cooked as vegetable.
40.	*Eleusine coracana*	Mandua, Ragi	900- 2600	Seeds	Selem, Magan, Chungthang, Lachen, Lachung	Local beverage, Thumba, made from boiled seeds; flour of the grain used to soften the skin
41.	*Emilia sonchifolia*	Hirankhuri	Up to 2000	Whole plant	Tong, Chungthang, Ravong	Plant uses as febrifuge; Leaf juice used in eye inflammation and night - blindness
42.	*Engelhardtia spicata*	Silapoma, Mauwa	500-2100	Bark	Selem, Chukung-chhu, Chungthang, Lachung, Pelling	Bark extract used in diarrhoea; also used to produce fish intoxicant
43.	*Ephedra gerardiana*	Somlata	4000-5000	Whole plant	Thangu	It yields the alkaloid ephedrine; useful in cold
44.	*Eupatorium adenophorum*	Kala bansa	300-1000	Leaves	Mangalbare, Tarko, Dikchu	Leaves juice effective in cuts and blood clotting
45.	*Euphorbia hirta*	Dudhi	250-1400	Whole plant	Singtam, Rangpo, Legship, Gyalzing	Plant used in bronchial infection and asthma; latex is applied on sores
46.	*Evodia fraxinifolia*	Khanakpa	1000-1400	Fruits	Singtam, Rangpo Khola, Mangan	Fruits are used to make chutney useful in dysentery
47.	*Ficus religiosa*	Peepal	Up to 1600	Whole plant	Legship, Singtom, Magan, Gyalzing	Plant regarded as a sacred tree; fig and Barks are medicinal;used in bronchitis and skin ailments.
48.	*Fraxinus floribunda*	Lankooree	300-1000	Bark	Selam, Mangan, Rangpo	Soft boiled bark is applied on the gout affected part

49.	*Galinsoga parviflora*	Marchya	Up to 2000	Leaf	Gangtok, Legship, Gyalzing	Leaf is rubbed on the skin against nettle stings
50.	*Geranium nepalense*	Bhandu, Ratanjot	Up to 1800	Whole plant	Gangtok, Chungthang	Plant infusion used in fever and renal disorders; root paste effective in eczema and itching
51.	*Girardinia diversifolia*	Awa	Up to 2600	Leaf	Gangtok, Lachung, Ravong La	Leaf juice is given in gonorrhoea
52.	*Gynocardia odorata*	Ghnatey	Up to 1200	Seed	Dikchu, Rangpo, Singhik- Tong, Ranipul, Teesta valley	Seeds contain cyanogenic glycoside, gynocardine, used as fish poison
53.	*Hedera nepalensis*	Laguli Ivoy	Up to 3000	Leaf,	fruit Chhu, Chungthang, Gyalzing	Ravongla,Chakung Leaf juice given in dyspepsia; Leaf and fruit paste applied on ulcers
54.	*Hedychium spicatum*	Ban Haldi, Kapur-kachri	Up to 3000	Rhizome	Dzongu, Gangtok, Tong, Chung-thang, Pelling	Roasted rhizome given in asthma; decoction of rhizome with saw-dust of *Cedrus* taken in tuberculosis
55.	*Hedyotis corymbosa*	Daman papar	Up to 2500	Whole plant	Singtam, Gangtok, Pelling	Plant extract useful in fevers and liver diseases
56.	*Heracleum wallichii*	Chimphing	1500-2500	Seeds	Lachen	dried seeds are taken orally during influenza
57.	*Holarrhena pubescens*	Aulay Khirra	250-800	Bark, leaf, seed	Tarko	Fresh or dried bark is orally taken with water during amoebic dysentery; leaves and seeds as febrifuge
58.	*Holboellia latifolia*	Gulfa	1200-2500	Fruit, leaf	Dzongu, Rangpo, Chungthang, Lachung	Ripe pulp of fruit edible; paste of leaves applied on wounds of cattle
59.	*Houttuynia cordata*	Nombaring	1000-2400	Leaves	Tarko, Mangle, Lachung	Leaves eaten as vegetables; rich source of vitamin A
60.	*Hydrocotyle nepalensis*	Choti-brahmi	1500-2500	Leaf	Selem, Chung-thang, Lachung, Ravongla	Leaf powder with water given in insomnia; soothing
61.	*Impatiens racemosa*	Chunchuni	915-3000	Seeds	Yakla, Lachung	Powder of roasted Seeds with honey given to relieve cough and cold
62.	*Imperata*	Sauraun	Up to 2000	Roots	Mangalbare, Ravong	Root extract used as tonic

	cylindrica				Chakung Chhu	
63.	*Lantana camara*	Kuri	Up to 2000	Roots	Mangalbare, Gangtok, Dzongu	Root powder useful in pyorrhoea disease
64.	*Lyonia ovalifolia*	Ayanr	1000-3000	Leaf	Dzongu, Chung-thang, Lachen, Lachung	Young leaves poisonous to cattle
65.	*Lindera neesiana*	Sittimur	1950-2450	Bark, Fruit	Lachen, Chakung Chhu	Bark and fruits are used medicinally
66.	*Litsea glutinosa*	Kawala	900-1700	Bark, fruit	Tong, Dzongu	Plaster made from the Bark applied on fractured bones
66.	*Mallotus philippensis*	Ruina	Up to 1200	Fruit	Mangalbare, Tarko,	Red dye obtained from the Legship fruits; the powder from fruits used as anthlelmintic and purgative
67.	*Mangifera indica*	Aanp	Up to 1000	Fruit, Seed	Singtam, Legship Rangpo	Resin and seed useful in diarrhoea.
68.	*Mesua ferrea*	Nagesuri	300-1000	Bark,	Rangpo, Singtam flowers	Oil from the flowers used as perfume; Bark used in skin disease
69.	*Mimosa pudica*	Lajwanti	Up to 1000	Root	Tarko, Mangle	Roots are useful in digestive trouble
70.	*Musa balbisiana*	Kera	Up to 1800	Fruit, spadix	Rangpo, Singtam, Gangtok, Dzongu	Fruit is laxative and useful in intestinal disorders; spadix used in cough and cold.
71.	*Nardostachys grandiflora*	Jatamansi	3600-4800	Rhizome	Yumesamdong, Kupup	Dried rhizome is used medicinally; antiseptic
72.	*Ocimum tenuiflorum*	Tulsi	upto 2500	Whole plant	Gangtok, Lachung Legship	It is regarded as sacred plant; leaves are taken with tea in fever
73.	*Oroxylum indicum*	Paksam	250-900	Seeds	Singtam, Dikchu, Lower Dzongu	Dried seeds are orally taken in throat complications and hypertension
74.	*Oxalis corniculata*	Amrul	Up to 1800	Leaf	Tarko, Singtam, Legship, Gangtok	Leaf juice dropped in cararact and conjectivitis

75.	*Panax pseudo-ginseng*	Gingseng	1800-2800	Root	Lachen, Laghep, Samdong, Kalep	Tuberous root is used in diabetes; aphrodisiac
76.	*Phytolaca acinosa*	Jaringo	1500-2700	Leaf	Lachen	Fresh leaves are boiled and consumed during bodyache
77.	*Picrorhiza kurrooa*	Kutki	3000-5000	Root	Kupup, Zemu	Dried roots are used in liver disorders; purgative, catharitic
78.	*Piper longum*	Pipla	Up to 300	Roots, fruits	Jorethang, Rayung	Unripe fruits are used as altetrative and tonic; roots used as antidote to snake bite
79.	*Podophyllum hexandrum*	Mayapple	3000-4000	Fruits, roots	Menmoi Chho, Thangu	Fruit is effective in cancer disease; roots are emetic, purgative, vermifuge and alterative
80.	*Prunus cerasoides*	Paiyun	1000-2000	Bark,	Gangtok, Dzongu, Ravong	Bark used in psychomedicine; fruit edible, rich source of Vitamin C
81.	*P. rufa*	Lekh Paiyum	2700-3900	Leaf	Lachen	Young leaves poisonous
82.	*Rauwolfia serpentina*	Chota chand, Sarpagandha	Up to 800	Tuber	Legship	Roots powder useful in fever, epilepsy; hypertension
83.	*Rhododendron arboreum*	Lali Gurans	1600-3000	Flowers	Lachung, Lachen	Flowers are fermented into local wines which is believed to be an antidote for altitude sickness
84.	*R. setosum*	Tsallu Gurans	3000-4500	Leaf	Yumthang	Leaves could be distilled for aromatic oils ; useful in perfumery and cosmatics
85.	*Rumex nepaensis*	Halhalay	1800-3000	Leaf	Lachung	Leaf extract appied on wounds and cuts; against nettle sting
86.	*Saurauia roxburghii*	Aule Gogun	300-1200	Leaf	Legship, Rangpo, Ranipul	Leaves are used for preparing hair powder
87.	*Schima wallichii*	Chilaune	300-2000	Stem, Bark	Rangpo, Tarko, Tong, Chungthang	Contact with bark causes intense itching
88.	*Swertia chirayita*	Chirowto	1600-2600	Whole	Chhaten, Lachen	Plant decoction is orally

				plant		taken during fever
89.	*Taxus baccata*	Thamsing	2400-3400	Bark, leaves	Yumthang	Extract of leaves and Bark useful in ovarian cancer
90.	*Terminalia belerica*	Barra	Up to 1000	Fruits	Rangpo, Jorethang	Dried fruits powder taken during stomach disorder.
91.	*Thalictrum foliolosum*	Mamira	2100-3000	Roots	Phodanchen	Roots are used in ophthalmia
92.	*Thysanolaena latifolia*	Amliso	Up to 1800	Roots	Dikchu, Singtam	Root paste is applied to check boils; root extract is used as a mouth wash
93.	*Tinospora cordifolia*	Gurjo	Up to 1400	Stem	Lower Teesta valley	Stem is used for general debility, dyspepsia fever and urinary trouble
94.	*Toona ciliata*	Tun	300-1760	Wood	Rangpo, Legship, Gangtok, Mangan	Plant is valued for scented timber
95.	*Urtica dioica*	Sisnu	1000-2000	Roots	Chungthang, Lower Dzongu	Root paste is applied on minor fractures
96.	*Viola biflora*	Banafsa	2500-4500	Whole plant	Chhangu, Thangu	Plant extract with tea useful to relieve bronchitis cold and cough
97.	*Viola diffusa*	Banafsa	1400-2500	Whole plant	Gangtok, Lachung, Dzongu, Ravongla	Plant used in cold and cough
98.	*Woodfordia fruticosa*	Dhaiki	Up to 600	Flowers	Jorethang	Dried flowers used in dysentery; disorders of mucous membrane; haemorrhoides
99.	*Zanthoxylum alatum*	Bokay	600-1800	Twigs Seeds	Chungthang, Lachen	Young twigs are used as timur toothbrushes; Seeds are also effective in toothache
100.	*Zingiber officinale*	Adrak	Up to 1200	Rhizome	Singtam, Dzongu, Legship	Rhizome used to flavour tea and food; useful in cold and cough

Table 2. Some timber yielding tree species of Sikkim Himalaya

Sl. No.	Name of species	Family	Height (m)	Common/ Vern. Name	Altitude (m)	Distribution
1.	*Abies densa*	Pinaceae	<40	Gobre Salla	2800-4000	Lachen, Yumthang

2.	*Betula utilis*	Betulaceae	<12	Bhujpata	3000-4200	Yumthang, Lachen, Lachung
3.	*Castanopsis indica*	Fagaceae	3-20	Katus	400-1500	Rorathang, Tarko, Tong
4.	*Canarium bengalense*	Burseraceae	25-45	Gokul	Up to 1000	Tarko, Mangalbare, Singtam
5.	*Choerospondias axillaris*	Anacardiaceae	10-15	Lapsi	Up to 1000	Tarko, Rangpo,
6.	*Cryptomeria japonica*	Taxodiaceae	<40	Tarpin	1800-2300	Damthang, Ravongla
7.	*Dysoxylum gobarum*	Meliaceae	10-48	Lasunia	600-900	Tarko, Dikchu,
8.	*Juglans regia*	Juglandaceae	20-30	Okhra	1800-2500	Chakung Chhu, Lachung,
9.	*Juniperus recurva*	Cupressaceae	<20	Tongsa	2900-4200	Yathang Yumthang
10.	*Larix griffithiana*	Pinaceae	10-20	Bergi	2400-3600	Yathang, Yumthang
11.	*Pinus roxburghii*	-do-	10-35	Dhup	1000-2000	Gangtok, Gyalzing
12.	*P. wallichiana*	-do-	12-45	Dhupi	1700-3300	Lachung, Lachen
13.	*Podocarpus neriifolius*	Podocarpaceae	15-30	-	900-1400	Sevoke, Lopchu
14.	*Quercus lamellosa*	Fagaceae	7-20	Bajrant	1800-2600	Ravongla, Tashiding
15.	*Shorea robusta*	Dipterocarpaceae	25-45	Sal	300-1200	Rangit, Rangpo, Singtam
16.	*Tectona grandis*	Verbenaceae		Teek	Up to 800	Rangit, Jorethang, Tarko, Rangpo
17.	*Terminalia myriocarpa*	Combretaceae	8-30	Panisaj	600-1600	Rangit, Jorthang, Tarko, Tadong
18.	*Tsuga dumosa*	Pinaceae	12-40	Tenge-Salla	2400-3600	Chhaten, Lachen
19.	*Toona ciliata*	Meliaceae	20-30	Toona	300-1800	Rangpo, Singtam, Rangit, Gangtok

Table 3. Some dye yielding plants of Sikkim

Sl. No.	Botanical Name	Family	Vern. Name (m)	Altitude	Part used
1.	*Berberis aristata*	Berberidaceae	Chuutro	1650-2500	Stem, root
2.	*Dioscorea glabra*	Dioscoreaceae	Bantarul	1200	Tuber
3.	*Dendrobium hookerianum*	Orchidaceae	-	1000-1500	Flower
4.	*Erythrina arboescens*	Fabaceae	Phaledo	Up to 1500	Flower
5.	*Impatiens balsamina*	Balsaminaceae	-	250-1800	Leaf
6.	*Indigofera caerulea*	Fabaceae	Indigo	Up to 1500	Flower
7.	*I. hebepetala*	-do-	-	2100-2500	Flower
8.	*Juglans regia*	Juglandaceae	Okhra	1800-2500	Bark
9.	*Malotus philippensis*	Euphorbiaceae	Ruina	300-1600	Fruit
10.	*Rhus javanica*	Anacardiaceae	-	1000-1800	Fruit
11.	*Rubia sikkimensis*	Rubiaceae	Manjestha	800-1200	Fruit
12.	*Rumex nepalensis*	Polygonaceae	Halhalay	1500-2500	Leaf

Table 4. Cereales and pseudocereales

Sl	Botanical name	Fl. & Fr.	Nep. Name	Cutiv./Wild	Altitude (m)	Distribution in Sikkim	Uses
1	*Oryza sativa*	Oct - Nov	Dhan	Cultivated	Up to 1600	Throughout terai to temeperate	Seed cooked as rice;straw used for fodder and mat preparation
2.	*Triticum aestivum*	Apr - May	Gahun	Cultivated	Up to 2000	Terai to temperate Sikkim	Seed for meal flour;straw used as fodder
3.	*Hordeum vulgare*	Mar - Apr	Jau	Cultivated	Up to 2500	Temperate Sikkim	Seeds are used for meal flour and

							beer; straw for fodder
4.	*H. aegiceras*	Mar - Apr	Jau	Cultivated	2000-2700	Temperate Sikkim	Seed for meal flour, beer; straw for fodder
5.	*Zea mays*	Aug - Oct	Makai	Cultivated as a main crop	Up to 2700	Terai to temperate Sikkim	Seed used for meal flour;everage preparation
6.	*Echinochloa colonum*	May-Jun	Jungli-Sanma	Wild	Up to 1800	Terai to warm temperate Sikkim	Fodder grass
7.	*E. crusgalli*	Jun - Oct	Sanma	Wild	Up to 1800	Lower Sichey Basti to Gangtok	Fodder grass
8.	*E. frumentacea*	Aug - Oct	Sanma	Cultivated	Up to 2000	Sikkim terai to temperate zone	Seed used as food; source of beer; straw is used for fooder
9.	*Eleusine coracana*	Oct - Nov	Kodo	Cultivated	Up to 2500	Lower Sikkim terai to higher temperate areas	Seed used for meal flour, also source of beer; straw is used as good fooder.
10.	*Eleusine indica*	Sep - Oct	Jangli kodo	Cultivated	Up to 2700	Throughout Trop., sub-trop. and temperate Sikkim	Fodder; as a weed
11.	*Setaria italica*	Sep - Oct	Kaguni	Cultivated	Up to 1800	Tropical & sub-tropical Sikkim	Provide staple food and also potent source of beer; straw is used as fodder
12.	*Fagopyrum esculentum*	Aug - Nov	Phafer	Wild	Up to 1800	Sub-trop.and temp. Himalaya	Leaves cooked as vegetables;Seeds for nutritious flour
13.	*F. tataricum*	Aug - Nov	Teete Paphar	Cultivated	Up to 2500	Temperate areas	Seeds provide as staple food
14.	*Panicum miliacum*	Aug - Oct	China	Cultivated	Up to 1600	Sub-tropical Sikkim	Seeds used for flour and also cooked as rice; leaves used

						for fodder
15. *Pennisetum americanum*	Sep - Oct	Tumri	Cultivated	Up to 1000	Tropical Sikkim and straw for	Seeds used for food fodder
16. *Amaranthus spinosus*	Oct - Nov	Latte	Cultivated	Up to 2500	Throughout	Seeds or grains provide light food

Table 5. Pulses

Species	Fl. & Fr.	Nep.name	Family	Alt.(m)	Distribution	Uses
1. *Cajanus cajan*	Jul - Nov	Rahridal	Fabaceae	Up to 2300	Trop., sub-trop. and temperate	Seeds are comprise an imp. pulse; stem yields good fibre, used for making baskets
2. *Cicer arietinum*	Mar - Apr	Chanadal	Fabaceae	Up to 2000	Trop.,sub-trop. and temperate	Seeds are edible; young plant is also used for fodder
3. *Glysine max*	Aug - Oct	Bhatmass	Fabaceae	Up to 2700	Throughout Sikkim	Seeds are edible
4. *Lens culinaris*	Apr	Musuridal	Fabaceae	Up to 1700	Trop. and sub-trop. Sikkim	Seeds comprise an important pulse; also used as fodder
5. *Lathyrus sativus*	Aug - Oct	Khesari	Fabaceae	Up to 1700	Trop. and sub-trop. Sikkim	Whole plant used as fodder
6. *Macrotyloma uniflorum*	Aug – Nov	Gahat	Fabaceae	Up to 1800	Trop. and sub-trop. Sikkim	Seeds comprise an important pulse; young plant used as fodder
7. *Phaseolus vulgaris*	Jul - Nov	Semi	Fabaceae	Up to 2500	Trop., sub-trop. and temperate forest	Seeds are used as pulse and leaves for fodder
8. *Pisum sativum*	Mar - May	Matar	Fabaceae	Up to 2500	Trop.,sub-trop. and temperate forest	Young Seeds used vegetables and dry for pulses.
9. *Vigna angularis*	Aug - Oct	Adjuki bean	Fabaceae	Up to 2500	Trop.,sub-trop. and temperate forest	Seeds are used as pulse and young stem used as fodder

10. *Vigna mungo*	Sep - Nov	Masdal/ kalodal	Fabaceae	Up to 2000	Trop.,sub-trop. and temperate	Seeds comprise an important pulse forest
11. *V. radiata*	Aug - Nov	Moongdal	Fabaceae	Up to 1000	Tropical	Seeds comprise an important pulse; useful in dysentery and constipation
12. *V. umbellata*	Sep - Nov	Rainsdal	Fabaceae	Up to 2000	Trop., sub-trop. and temperate forest	Seeds are used as pulse; whole plant used as fodder.

Table 6. Vegetables

Botanical name	Fl. & Fr.	Nep.name (m)	Altitude in Sikkim	Distribution	Uses
1. *Brassica oleracea* var. *capitata*	Sep - Nov	Bandkopi	Up to 2500	Trop., sub-trop. and temperate	Cultivated for vegetable
2. *B. oleracea* var. *botrytis*	Sept - Nov	Fulkopi	Up to 1600	Trop., sub-trop. and temperate	Cultivated for vegetable
3. *Capsicum annuum*	Oct - Nov	Khorsani	Up to 2500	Trop., sub-trop. and temperate	Fruits are the source of popular condiment ‘chilli’; good source of vitamin C.
4. *Capsicum indicum*	Oct - Nov	Simlamirch	Up to 1500	Trop., sub-trop. and temperate	Fruits are used for vegatables
5. *C. frutescens*	Oct - Nov	Jhine khorsani	Up to 2500	Tropical to temperate	Fruits are used as condiment; also medicinal
6. *Lycopersicon esculentum*	Oct - Nov	Tamatur	Up to 1800	Trop., sub-trop.	Fruits are used for vegetables
7. *Solanum melongena*	Oct - Nov	Bengan	Up to 2000	Trop., sub-trop. and temperate	Fruits are used for vegetables
8. *Solanum tuberosum*	Mar - Jun	Aalu	Up to 2500	Tropical to temperate	Tubers are used as vege-tables; infusion of leaves given in dismenorrhoea.
9. *Amaranthus spinosus*	Oct - Nov	Lal sag	Up to 2500	Temperate Sikkim	Leaves are cooked for vege-tables.
10. *Brassica juncea*	Feb - Mar	Thulo pate,	Up to 2000	Sub-trop.and	Leaves are cooked for vege-

var. *folicosa*		rai		temp. Sikkim	tables; source of vitamin A.
11. *Chenopodium album*	Feb - Mar	Bhetu	Up to 2500	Tropical to temp. Sikkim	Leaves are cooked for Leafy vegetables
12. *Trigonella foenium-graceum*	Feb - Mar	Methi	Up to 2000	Tropical to temp. Sikkim	Leaves are cooked for Leafy vegetables
13. *Spinacea oleracea*	Apr - Jul	Palak	Up to 2000	Tropical to temp. Sikkim	Leaves used for vegatables
14. *Fagopyrum esculentum*	Sep - Nov	Ongal	Up to 2500	Tropical to temp. Sikkim	Leaves and young twings used for vegetables. Flour of Seeds used as a substitute of wheat
15. *F. tataricum*	Sep - Nov	Phaphar	Up to 3000	Tropical to temp.Sikkim	Seeds flour used as staple food; leaves for vegetables.
16. *Daucus carota*	Feb - Apr	Gajar	Up to 1800	Tropical and sub-tropical Sikkim	roots used as vegetables; Seeds used medicinally
17. *Benincasa hispida*	Jul - Aug	Kubindo	Up to 1500	Tropical and sub-tropical Sikkim	fruits cooked for vegetables; Seeds given in gonorrhoea
18. *Cucurbita maxima*	Aug - Oct	Phersi	Up to 2000	Trop., sub-trop. and temperate	Fruits and leaves cooked for vegetables
19. *Cucumis sativus*	Aug - Oct	Khakra	800-2000	Trop., sub-trop. and temperate	Fruits edible
20. *Lagenaria siceraria*	Mar - Nov	Lauki	Up to 1600	Tropical and sub-tropical Sikkim	Young fruits are cooked for vegetables; dried pericarp of fruit used as vessel to store seed materials
21. *Luffa acutangula*	Aug - Nov	Pateghironla	Up to 1700	Tropical and sub-tropical Sikkim	Fruits are cooked for vegetables
22. *Luffa cylindrica*	Jul - Nov	Ghironla	Up to 1200	Tropical	Fruits are cooked for vegetables
23. *Momordica charantia*	Aug - Dec	Titekarela	Up to 1500	Tropical and sub-tropical Sikkim	Fruits are cooked for vegetables
24. *Sechium edule*	Aug - Dec	Eskush; Chaote	Up to 2000	Trop., sub-Trop. and temperate	Fruits are cooked for vegetables
25. *Trichosanthes anguina*	Jun - Nov	Chachinda	Up to 1600	Tropical and sub-tropical sikkim	Fruits are cooked for vegetables

26. *Colocasia esculenta*	Jun - Nov	Pindalu	Up to1200	Tropical and sub-tropical Sikkim	Tuber and Leaf cooked for vegetables
27. *Amorphophallus bulbifer*	May - Nov	Oal	Up to 1500	Tropical and sub-tropical sikkim	Tubers edible
28. *Dioscorea alata*	Aug - Dec	Ghar Tarul	Up to 2500	Trop., subTrop. and temperate	Tubers are roasted or boiled for vegetable
29. *D. hamiltonii*	Aug - Dec	Van Tarul	ca 1200	Tropical Sikkim	Tubers edible
30. *D. bulbifera*	Sept - Jan	Githa	Up to 1500	Tropical and sub-tropical Sikkim	Tubers are boiled and used as vegetable
31. *Ipomoea batatas*	Nov - Jan	Sakarkanda	Up to 1000	Tropical Sikkim	Roots edible; ornamental

Table 7. Miscellaneous Vegetables

Botanical name	Fl. &Fr.	Nep.name	Alt(m)	Distribution	Uses
1. *Asparagus filicinus*	May-Jul	Kurilo	Up to 1800	Tropical and sub-tropical Sikkim	Young twings edible; medicinally used in nervous disorder; as a tonic
2. *Bauhinia purpurea*	Feb - Mar	Taki	Up to 800	Tropical valley	Flower bud cooked as vegetable
3. *B. variegata*	Feb - May	Kuiralo	Up to 1000	Tropical valley	Young flower cooked for vegetables; yield fibre from Bark
4. *Bambusa tulda*	Jan	KarateBans, Mahal	Up to 1500	Tropical and sub-tropical Sikkim	Young bud of rhizomes are edible
5. *Moringa oleifera*	Feb - Mar	Drumstick	Up to 800	Tropical valley	Green pods are cooked for vegetables
6. *Dryopteris* sp.	-	Nigro	Up to 2000	Trop., sub-trop. and temperate	Young twigs and leaves are cooked for vegetables
7. *Houttuynia cordata*	Apr - Jun	GandheSag	1000-2000	Sub-tropical and temperate	Leaves are cooked for vegetable; salad prepar.
8. *Dendrocalamus hamiltonii*	-	Choyabans	1000-2000	Sub-tropical and temperate	Young buds of rhizome are eaten; pickle

9. *Agaricus bisporus*	Jul - Aug	Dalechiyu	2000	Sub-tropical and temperate	Basidiocarp or whole fungi are eaten
10. *Musa bulbisiana*	Jan - Nov	Kera	Up to 1750	Tropical and sub-tropical Sikkim	Flowers and immature fruits are cooked for vegetables
11. *Cardamine macrophylla*	Aug - Sep	Simrayo	2000-2700	Temperate	Leaves are used for vegetables

Table 8. Spices and condiments

Botanical name	Fl. & Fr.	Nep.name	Alt.(m)	Distribution	Uses
1. *Allium sativum*	Jun - Sep	Lahsun	Up to 1400	Tropical and sub-tropical Sikkim	Bulb and leaves are used to flavour food; as medicinal
2. *A. wallichii*	Jun - Sep	Pharam	2400-4600	Temperate and alpine	Leaves are used as condiment; medicinal
3. *A. cepa*	Apr - Jul	Pyaj	Up to 1750	Tropical and sub-tropical Sikkim	Bulbs and leaves are used for vegetables; medicinally useful in skin problem and digestive problems
4. *Curcuma longa*	Jul - Sep	Besar	Up to 1700	Tropical and sub-tropical Sikkim	Rhizome yield a dye; condiment
5. *Zingiber officinale*	Sep - Nov	Adrak	Up to 1200	Tropical sikkim	rhizome used to flavour food and drinks
6. *Amomum subulatum*	Apr - May	Alaichi	Up to 1800	Tropical and sub-tropical Sikkim	Seeds are used for flavoring food
7. *Cinnamomum tamala*	Apr - May	Tejpatta	450-2100	Tropical and sub-tropical Sikkim	Leaves and bark used medicinally; Leaves are used to flavour food
8. *Cuminum cyminum*	May - Jun	Jeera	Up to 1000	Tropical Sikkim	Seeds are used as spice; carminative
9. *Mentha arvensis*	Jul - Sep	Pudina	Up to 2500	Throughout Sikkim	Leaves and young twigs are used to flavour food and drinks
10. *Coriandrum sativum*	May - Jun	Dhania	Up to 2700	Throughout sikkim cultivs	Leaves and young twigs are used to flavour food and salad.

Table 9. Horticulture fruits

Botanical name	Fl. &Fr.	Nep.name	Altitude(m)	Distribution	Uses
1. *Aearmelos*	Feb - Aug	Bel	Up to 800	Tropical Sikkim	Fruit pulp eaten raw or made into refreshing drink; useful in digestive disorders
2. *Carica papaya*	Througout the year	Meva	Up to 1200	Tropical Sikkim	Fruits edible
3. *Castanopsis indica*	Feb - Oct	Dalne katus	Up to 1000	Tropical Sikkim	Fruits edible
4. *Citrus aurantifolia*	Jan - Dec	Nimbu kagti	Up to 1700	Tropical and sub-tropical Sikkim	Fruits used for juice
5. *C. medica*	Jan - Dec	Bimiro	Up to 1800	Tropical and sub-tropical Sikkim	Fruits used for pickels and juice
6. *C. reticulata*	Jan - Dec	Suntala	Up to 1800	Tropical and sub-tropical Sikkim	Fruits edible
7. *C. grandis*	Jan - Dec	Bogote	Up to 1000	Tropical Sikkim	Fruits edible
8. *Dillenia indica*	Jul - Jan	Tantari	Up to 800	Tropical Sikkim	Fruits edible
9. *Eriobotrya japonica*	Jan - Nov	Lokat	Up to 800	Tropical Sikkim	Fruits edible
10. *Juglans regia*	Mar - Oct	Dante Akhor	Up to 2500	Sub-tropical and temperate	Fruits are eaten at maturity
11. *Mangifera indica*	Feb - Jul	Aam	Up to 1000	Tropical Sikkim	Fruits edible
12. *Morus alba*	Feb - Jun	Kimbu	Up to 2500	Tropical and sub-tropical Sikkim	Fruits edible
13. *Musa bulbesiana*	Jun - Nov	Kera	Up to 1750	Tropical and sub-tropical Sikkim	Fruits edible
14. *Phyllanthus emblica*	Feb - Nov	Rukhamala	Up to 1600	Tropical and sub-tropical Sikkim	Fruits eaten raw or pickled
15. *Prunus persica*	Feb - Jul	Aaru	Up to 2000	Trop., sub-trop. and temperate	Fruits edible
16. *P. cerasoides*	Oct - Mar	Panyu	2000-2400	temperate	Fruits edible at maturity

17. *P. armeniaca*	Mar -Jun	Khumani	Up to 2000	Tropical and sub-tropical Sikkim	Fruits edible; flowers useful in agiculture
18. *Pyrus malus*	Mar - Jun	Seb	1600-2500	Temperate	Fruits edible
19. *Psidium guajava*	Mar - Sep	Ambak	1200	Tropical Sikkim	Fruits edible
20. *Phoenix sylvestris*	Apr - Nov	Khajur	Up to 500	Tropical Sikkim	Fruits edible
21. *Punica granatum*	Apr - Dec	Dadim	Up to 1200	Tropical Sikkim	Fruits edible
22. *Syzygium cumini*	Mar - Jul	Jamun	Up to 1000	Tropical Sikkim	Fruits edible; important tree of social forestry
23. *Vitis venifera*	Apr - Sep	Angur	Up to 1500	Tropical and sub-tropical Sikkim	Fruits edible; as a tonic

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