Chapter-2

The Study Area: Nanda Devi Biosphere Reserve

2.1 Introduction

The NDBR is an important high altitude Himalayan protected area. It is one of least disturbed protected areas of world (Anonymous, 1987 and Gupta, 2002). The NDBR was named after the principal peak of the region i.e. Nanda Devi (7817 m); the bliss giving goddess. It is also the second highest peak of India. Historically, the region has witnessed some of major international adventure, political and socio-conservational events, thus making it world famous. It has been an internationally recognized tourism center for naturalists, adventure tourists, scientists etc. for its exceptionally unique natural landscapes, endemic biodiversity (flora and fauna), high degree of inaccessibility and rich indigenous culture etc. (Banerjee, 2001 and 2003; Singh and Mal, 2009 and Srivastava, 1999a and b).

The Nanda Devi was the highest peak of British Empire. It was also the highest climbed peak until 1950’s ascent of Annapurna. Thereafter, the Nanda Devi peak and its vicinity due to its highly technical slopes and challenges for adventure became the dream destination for mountaineers from all over the world. Later in 1974, world famous community-based forests conservation movement Chipko Andolan also took place in Lata-Reni area of Dhauli Ganga valley in NDBR under the leadership of Gaura Devi. Recently, the implications of conservation and management planning on local environment and communities of NDBR is one of the most debated topics among academicians, researchers, conservationists, planners, and environmentalists across the world (Maikhuri et al., 2000 and Singh and Mal, 2009).

The NDBR has been divided into three zones viz. core zones (national parks), buffer zone and transition zone for management and conservation purpose (Kumar, 2002 and Negi, 2002). There are two core zones i.e. Nanda Devi National Park (NDNP-Core Zone 1) and Valley of Flowers National Park (VoFNP-Core Zone 2) and both of them are internationally recognized for their unique and pristine natural landscapes, biodiversity and scenic beauty. Both the core zones are declared as UNESCO’s world heritage sites (MoEF, 2003 and 2004). The buffer zone surrounds the core zones from all sides, whereas the transition zone mainly lies in the southern parts of buffer zone. The core, buffer and transition zones are managed in such a manner that pressure of human activities gradually decreases from core to transition zone. Consequently, there is very low pressure in the core zones, followed by relatively high pressure in buffer and
higher pressure in transition zone (Banerjee, 2001; 2003; Srivastava, 1999a and b and Singh and Mal, 2009).

2.1.1 The Core Zones
The core zones are free from human habitation and are strictly protected. In VoFNP, tourists and research activities are allowed in restricted manner; whereas occasional mountaineering, scientific and ecological expeditions are allowed in NDNP. A maximum of 500 tourists are allowed to visit outer parts of NDNP every year since 2001. However, the inner parts are rarely visited as it was closed in 1982 for tourism. The VoFNP, on the other end, is visited by about 6500 tourists/year (Singh et al., 2009). The camping is not allowed inside it by any visitor except scientists with prior permission. Thus, the anthropogenic pressure in core zones is very low.

2.1.2 The Buffer Zone
There are 47 villages in the buffer zone. Human activities are managed in a way that protects the core zones. Human activities include restoration activities, value addition to resources, limited and regulated tourism activities and marginal grazing and collection of medicinal plants/herbs etc. Marginal human activities are permitted to reduce their effects on core zones. Sustainable human activities are encouraged and people are guided to use the natural resources of the buffer zone judiciously. Research and educational activities are encouraged. Experimental research areas are used for understanding the processes and functioning of ecosystem. Degraded landscapes are included in restoration areas to develop them to natural and near-natural ecosystems (Banerjee, 2001 and 2003).

2.1.3 The Transition Zone
It is the outermost part of reserve. The zone is inhabited by nearly 55 villages. The villagers are totally dependent on local forestry for fodder, fuel, livestock grazing, house building, agricultural tools and various other purposes. Local knowledge of conservation and management skills are applied and resource utilization is managed in harmony with the objectives of NDBR. Developmental activities such as eco-restoration, eco-tourism, cultivation of medicinal plants, bee-keeping, training programmes etc. are encouraged. The Joshimath and Lambagad area was demarcated as transition zone based on its dependence on the reserve particularly for fodder, fuel and medicinal plants. The Ghat and Bedani-Auli areas in Chamoli district and parts of Bageshwar and Pithoragarh districts have been demarcated in view of the protection of wildlife and dependence of inhabitants for various purposes.
The NDBR has a long history (about 70 years) of different zones (Core, buffer and transition) being identified and added to conservation unit at different points of time since its inception in 1939. Consequently, its area and conservation status has changed over the years.

2.2 Historical Evolution of NDBR
Initially, an area of 182.63 km$^2$ was designated as Nanda Devi Sanctuary in the year of 1939. It was the inner most part of Nanda Devi Basin in Rishi Ganga valley of Chamoli district. The sanctuary was upgraded to NDNP (624.6 km$^2$) in 1982 bringing outer parts of Nanda Devi Basin (whole of Rishi Ganga Valley) in it. An area of 1612.12 km$^2$ was further added in 1988 as buffer zone and NDNP was upgraded as NDBR, bringing its total area to 2236.74 km$^2$. The buffer zone consisted of areas in the vicinity of NDNP, including 12 villages of Dhauli Ganga valley in Chamoli, 5 villages in Gori Ganga valley in Pithoragarh and 2 villages in Pinder river valley. Dhauli Ganga formed western boundary (Malari to Reni village), Girthi Ganga northern boundary (Malari village to Unta Dhura pass), an unnamed ridge and Gori Ganga eastern boundary (from Unta Dhura ridge to Martoli village), many ridges and peaks and Pinder River (Martoli to Khati village) south-eastern boundary, Nanda Ghunti peak to Batharatoli the southwestern boundary (Anonymous, 1987; Banerjee, 2001; 2003; Srivastava, 1999a and b).

<table>
<thead>
<tr>
<th>Table 2.1 Details of Different Zones of NDBR</th>
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<tr>
<td><strong>Particular</strong></td>
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<tr>
<td>Core Zone-I</td>
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<tr>
<td>Buffer Zone</td>
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<td><strong>Sub Total</strong></td>
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<tr>
<td>Core Zone-II</td>
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<td>Buffer Zone</td>
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<td></td>
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<tr>
<td>Transition Zone</td>
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<tr>
<td><strong>Sub Total</strong></td>
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<tr>
<td><strong>Grand Total</strong></td>
</tr>
</tbody>
</table>

Source: Modified after Banerjee, 2003 and Kumar, 2002

The NDNP was declared as World Heritage Site by UNESCO in 1992. A large area (3623.95 km$^2$) was further added to NDBR in 2000 bringing VoFNP (87.5 km$^2$) and its surroundings, Kamet-Abu Gamin area, Saraswati river-Mana pass area and Malari-Lapthal area in it. The
NDBR was included in world network of biosphere reserves in 2004. The other core zone (VoFNP) was also declared as World Heritage Site in 2005. An area of about 524 km\(^2\) was further added as the transition zone, which was recently identified in 2002. Presently, the total area of NDBR is 6384 km\(^2\), of which the core zones, buffer and transition zone cover areas of 712.1 km\(^2\), 5148.57 km\(^2\) and of 524 km\(^2\) respectively. The NDNP and VoFNP cover areas of 624.62 km\(^2\) and 87.5 km\(^2\) respectively (Table 2.1). Both the core zones of NDBR are internationally recognized for their mountaineering history and subsequent conservation and management planning to conserve pristine landscapes, biodiversity and scenic beauty.

### 2.2.1 Nanda Devi National Park (Core Zone-I)

The Nanda Devi basin (present NDNP) has been an internationally recognized tourism site for its exceptional natural beauty, flora and fauna, high degree of inaccessibility etc. Available records suggest that first known attempt to enter the Nanda Devi basin (inner Nanda Devi sanctuary) was made by W.M. Graham in 1883, followed by T. G. Longstaff in 1907 and later by Huge Rutledge in 1926, 1927 and 1932. They all proved futile until 1934 when Eric Shipton and W H Tilman successfully explored the route to the inner basin of Nanda Devi. Later in 1936, Tilman and NE Odell made the first ascent of Mt Nanda Devi (7817 m), which was most outstanding mountaineering success and also the highest climbed mountain till that time (Gupta, 2002 and Srivastava, 1999a and b).

The writings of Eric Shipton and HW Tilman about the explorations and ascent of Nanda Devi in 1930-40s made it an international tourism destiny. At the instance of Shipton and Tilman, an area of 182.63 km\(^2\) of Nanda Devi basin was declared as Nanda Devi Sanctuary in 1939 for occurrence of rare wildlife species such as Musk deer, Snow leopard, Black and Brown bear etc. Thereafter, Nanda Devi attracted large numbers of mountaineers and naturalists from all over the world leading to accelerating growth of tourism activities. The intensity and pressure of adventure tourism in the basin can be understood from the fact that about 22 expeditions including more than 209 mountaineers with 1050 porters and 2500 goats and sheep visited the area in 1982 (Gupta, 2002). Upto 1980s, the tourism had become prime source of livelihood for local people. Majority of the local people worked as porters and guides in the mountaineering expeditions in Nanda Devi basin and earned handsome money. Among the other economic activities were the marginal agriculture, transhumance, grazing (sheep), collection of medicinal plants and honey, bee-keeping, illegal hunting etc. (Maikhuri et al., 2000; Silori, 2004) but tourism was preferred economic activity as it produced lot of wealth for local communities in very short span of time (Singh and Mal, 2009).
However, at the same time, tourism also had several negative impacts on local environment. Tourists carried tonnes of packed food and other essential things required for mountaineering in basin but generally never carried the waste material back. They left all the non-biodegradable and toxic materials (plastic bottles, cans and wrappers and raincoats etc.) in the basin. The requirements of fuel-wood for preparation of food etc. were met from local forests and meadows. Consequently, unregulated anthropogenic activities especially the adventure tourism activities, grazing, hunting and deforestation etc. led to many ecological problems such as accumulated garbage, declining wildlife and degradation of forests and grasslands etc. in the Nanda Devi basin. Therefore, all the anthropogenic activities were completely banned (except occasional scientific expeditions) in Nanda Devi basin with its declaration as National Park in 1982 (Anonymous, 1987; Gupta, 2002; Maikhuri et al., 2000; Silori, 2004).

Complete ban on the anthropogenic activities in Nanda Devi basin, especially the tourism, became a major problem for local people at later stages because; 1) tourism was principal source of income, 2) local people were left with no livelihood options consequently, survival of local people became very difficult and 3) there was no compensation for local people. Therefore, the dependent people of Nanda Devi region were unsatisfied with its status as National Park and its closure for tourism and other activities. Many areas (core zone, buffer zone and transition zone) were added to NDNP in subsequent years, upgrading it to NDBR but there was no change in its management (ban) status. Contrary to this, six expedition teams on the name of study and cleaning were allowed to approach Nanda Devi basin during 1993-2003, which further unsatisfied local people.

After a ban of nearly two decades (1982-2002), the ecological conditions of NDNP have improved in the absence of anthropogenic activities. The wildlife and forests cover have improved. The droppings and pug-marks of Leopard, Black bear, Bharal and Musk deer are now very common in forests and meadows (Sathyakumar, 1993 and 2004). However, negative implications on local communities can also be easily seen. The youth out-migrated to the cities of northern India for livelihood opportunities. As a result, abandoned houses and absence of young and child population are very common in the villages. The migration was age and gender specific leading to imbalance in age-sex composition. The total population of villages, mainly engaged in tourism activities, has significantly declined (Silori, 2004).

Also, many of the traditional agro-species (crops and domestic animals) have significantly declined and many have become endangered, because local people are not there anymore to
take care of their cattle. Yak is an important example of disappeared domestic animals. The loss of local population (Bhotia tribe), domestic animals, agro-species etc., scientifically speaking, is loss of genetic and species biodiversity, which is a major ecological disaster (Maikhuri et al., 2000; Silori, 2004 and Singh and Mal, 2009).

The local people struggled for nearly two decades to reopen it for tourism activities, so that they can revive employment opportunities and survive in their own area without any difficulty. Over this issue, there have been conflicts between Park authority and local people. Consequently, frustration of the mass burst-out in 1998 in the form of Jhapto-Cheeno Andolan i.e. Snatch the Resource movement. The Local people entered the NDNP with their cattle claiming their resource rights. It was however a peaceful movement. It was unfortunate that the world famous people for community based conservation initiatives i.e. Chipko Andolan in Lata-Reni area (entry points to NDNP) of 1974 had to initiate Jhapto-Cheeno Andolan caused by complete ban on NDNP. As a result of continuous struggles by local people, some parts of the NDNP (upto Dibrugheta campsite) were reopened in 2003 for limited tourism (500 tourists every year). It did give some relief to them. The local people are now practicing community based eco-tourism in open parts of NDNP and surroundings.

At the same time, many attempts have been made by government to compensate and reduce the resource dependency of local people by giving subsidized LPG connections, solar lantern, domestic weaving machines, wool carding plants etc. Also, local people were provided other livelihoods options like jobs in soil conservation works, management of weed water holes and water percolation holes etc. In most cases, these efforts of government could not satisfy the locals and they are still struggling to reopen all the parts of NDNP. However, the community struggles are not very intense now since they are earning some money from tourism in the open parts of NDNP and its surroundings.

2.2.2 Valley of Flowers National Park (Core Zone-II)
The VoFNP has been relatively quiet with regard to international activities, conservation and management related impacts on local communities and natural landscapes. The VoF was first discovered by Col Edmund Smythe in 1862 (Symthe, 1938). British legendary mountaineers Frank S Smythe and PL Holdsworth incidentally reached this valley after a successful expedition of Mt. Kamet in 1931. Frank S Smythe was so fascinated by its natural beauty and variety of flowers that he revisited the valley in 1937 and published a book The Valley of
Flowers. His writings made this valley world famous for nature tourism (MoEF, 2004). The VoF is part of upper Bhyundar Valley (Singh et al., 2009).

The Bhyundar Valley, historically, was the home of migratory pastoralists (Kala, 2005). There were four human settlements, i.e., Govindghat, Bhyundar, Pulna and Ghangaria. The Ghangaria was used as base camp for grazing activities in VoF in summers. Every year, sheep and goats used to camp there during early June to late September. In 1936, a Gurudwara (Hemkund Sahib) was established close to the VoF at the Hemkund Lake (4329 m above msl). The cost free stay and food were provided to the visitors at Ghangaria (base camp at 3275 m above msl) by Gurudwara Trust. It attracted mass-tourism in the valley (Singh and Kaur, 1980 and Kaur, 1983). The valley, however, remained largely less affected by tourism activities as the valley was poorly accessible due to poor road network (Singh et al., 2009).

Introduction of road network in 1970s made the valley more accessible and further a major tourism center. Since then, tourists have increased by many folds and caused several ecological problems in the valley (Singh and Kaur, 1980). VoF (87.5 km²) was declared as National Park in 1982 to conserve it from negative impacts of tourism and other anthropogenic activities. Consequently, it led to complete protection of valley from grazing and other human interventions (Singh et al., 2009).

However, the ban on grazing and regulation of tourism activities was not a big problem to local people as in case of NDNP because, 1) there were other tourism centers (livelihood options) in the vicinity of VoF, 2) the local people were not solely dependent on the grazing and tourism in VoFNP, and 3) people were already leaving their traditional living style shifting to tourism activities to Hemkund Sahib (Singh et al., 2009). Thus, there have not been major negative impacts on livelihood of local people due to ban on grazing. The biodiversity, on the other end, has improved (Kala, 2004a and b). The valley became part of NDBR in 2000 and world heritage site in 2005. The valley is, presently, one of the largest tourism centers for pilgrims in Indian Himalaya.

2.3 Objectives of NDBR

Following objectives have been identified for functioning of NDBR on the basis of UNESCO’s guidelines (Banerjee, 2001 and 2003; MoEF, 2003 and 2004; Negi, 2002 and Srivastava, 1999a and b):
• Ensure the conservation of landscapes, ecosystems, species and genetic variations in core zones (Nanda Devi National Park and Valley of Flowers National Park), buffer zone and transition zone.

• Encourage the traditional resource use system in the buffer zone.

• Promote economic development that is culturally, socially and ecologically sustainable at local level.

• Develop the strategies leading to improvement and management of natural resources in the buffer zone.

• Provide support for research, monitoring, education and information exchange related to local, national and global issues of conservation and development.

• Sharing of knowledge generated by research through site-specific training and education.

• Development of community spirit in the management of natural resources keeping alive the traditional knowledge and experiences.

• Encourage community owned tourism in the buffer area in general and also in the core areas in a very restricted and regulated way.

2.4 Present Spatial Extent

Geographically, the NDBR mainly lies in upper watersheds of right bank tributaries of river Alaknanda i.e. Saraswati River, Rishi Ganga, Dhauli Ganga, Girthi Ganga, Ganesh Ganga in Garhwal and Pindar River and Gori Ganga watersheds in Kumaon Himalayan regions of Uttarakhand State. Administratively, it is located in three districts of Chamoli (Garhwal), Pithoragarh and Bageshwar (Kumaon). Its spatial extent is between the geographic coordinates of 79°13’ E to 80°17’ E longitude and 31°04’ N to 30°06’ N latitude (Figure 2.1). Series of rivers, mountain ridges and lakes defines the boundary of NDBR. A detailed description of its boundaries has been given by Banerjee (2001 and 2003) and Srivastava (1999a and b).

2.4.1 Northern Boundary

Northern boundary of reserve follows the fragmented ridges and valleys from Kalandi Khal (5968 m) to Arwa Tal (western direction) and to Ghastoli along Arwa Nala (southwest direction). It, then, follows the Saraswati river and turns northward (upstream) to Khiam, Paschimi Kamet Glacier, Deo Tal to Mukut Parwat (7242 m) on the Indo-Tibetan international boundary. It then runs eastward through Mukut Parwat along the international boundary to Niti Pass (5300 m) via Ganesh Parwat (6535 m) and Tapcha Pass (6027 m).
2.4.2 North-Eastern Boundary

Indo-Tibet international boundary forms the north-eastern boundary of NDBR. It follows Niti Pass (5300 m), Belcha Dhura (5384 m), Kiogad Pass (5493 m), Unta Dhura (5400 m) and Gonkha Gad upto Finga. Thereafter, it follows Bumpa Dhura (6355 m) to Burphu Dhura (6210 m) via unnamed peaks (5749 m and 5069 m) to Ralam Peak (4964 m) and forms the rest of the boundary.

2.4.3 South-Eastern Boundary

South-eastern boundary follows the Brij Ganga Pass (4768 m) to Rajamba peak (along Ralam Gad) (6895 m), Dhasi peak (5460 m) and Hansaling (5430 m). The boundary follows the Poting glacier to Namik glacier crossing the Gori Ganga River. Further, it runs from an unnamed peak (5962 m) to Madari peak (4427 m) and Sodhara Madir (2198 m). Thereafter, it runs along from Ratanpani peak (4072 m) along Pindari River.

2.4.4 Western Boundary

Western boundary of reserve runs along a ridge arising from head of Panpatia Glacier (unnamed peak-5553 m) to Chanukhamba III (6974 m) via an unnamed peak (5773 m). It, then,
follows Caukhamba III (6974 m) to Chaukhamba I (7138 m) along ridge through unnamed peaks (6721 m and 6557 m) to Kalandi Khal (5968 m).

2.5 Physiography

The NDBR represents a variety of physiographic units; from very rough and undulating terrain in the western, southern, eastern and central part to relatively flat (typical Tibetan plateau type) landscapes in the northern fringes (Figure 2.2). Geologically, the northern fringes of the NDBR i.e. Mana-Niti-Lapthal-Sumna-Topi Dhunga-Unta Dhura-Kingar La are typical representatives of Tibetan plateau (Trans-Himalayan landscape), where slopes are almost gentle and flat. The bedding (layers) of rocks sometimes becomes almost vertical. The rocks are not very hard. One can easily find the alternate layers of soft and hard rocks (Plate 2.1). At some places, rocks give an impression of very hard and thin layered soil (slate) but are so soft that one can easily break them without any aid (hammer etc.). Thus, the rocks are not fully compressed, representing incomplete physical process and Tethys sediments.

Figure 2.2 Physiography/Landscape of NDBR (Background-Landsat ETM+ image, 15 October 1999)
Variety of fossils of Tethys Sea are well preserved in rocks and surface of the northern part of reserve (Plate 2.2). The Laptal, Kinger La and Jayanti Dhura areas are full of Tethys fossils. Such state of the fossils and rocks is an indication of entire Tethys sea bed uplifted as a result of collision of Indian and Eurasian continental plates. Consequently, the soft and uncompressed rocks and fossils are highly exposed. We could explore nearly 8-9 types of fossils belonging to category of Ammonite Fossils (Plate 2.3) during the survey of 2010.
The other parts of the reserve are representatives of typical Himalayan terrain and slopes. The region is characterized with very steep slopes, peaks, ridges and deep gorges (Plate 2.4a and b). The rocks are very hard and fully composed (Plate 2.5). There are some of the world’s famous peak systems in reserve. The Nanda Devi peaks system (Dunagiri-7066 m; Changbang-6864 m; Kalanka-6391 m; Rishipahar-6992 m; Nanda Devi East-7434 m; Nanda Khat-6611 m; Trishul-7120 m; Nanda Ghungti-6368 m) that also forms the boundary of NDNP, is known for its very
steep slopes. NDNP is a cup-shaped basin, in which the Nanda Devi main (7817 m) is the prominent peak. The NDNP is segmented by a series of parallel ridges with north-south orientation rising from encircling mountain walls. The most important is the Devisthan-Rishikot ridge, which separates inner core zone (inner sanctuary) from rest of the basin (outer sanctuary) (Banerjee, 2001 and 2003 and Khacher, 1978).

Plate 2.4b Steep Slopes of Mt. Nanda Devi: Representative Example of Himalayan Slopes
(Photo taken from Dharansi Pass in NDNP)

Plate 2.5 Hard and Composed Rock in NDBR (Photo taken in VoFNP)
In the northeastern part, the prominent massif is Kamet. It consists of a few very steep sloped peaks such as Kamet (7756 m), Mana (7272 m), Mukut Parwat (7242 m) and Ganesh Parwat (6535 m). In the western side, the prominent peak system is Caukhamba III (6974 m), Chaukhamba I (7138 m) and Satopanth (7075 m). The VoFNP is surrounded by Gauri Parbat (6590 m) and Rataban (6126 m) in the east, Kunthkhal (4430 m) in the west, Saptsgiri (5038 m) in the south and Nilgiri Parvat (6479 m) in the north. Valley portion of the park is wide alpine meadow in east-west direction along the Puspawati River. North and South slopes are gentle at base and rise abruptly to snow clad rocky slopes (Srivastava, 1999a).

The altitudinal range of NDBR ranges between 1416 m to 7817 m above msl. The upper value of the reserve i.e. 7817 has been registered as 7799 m by ASTER sensor (vertical inaccuracy/error of 18 m) as a result of highly rugged terrain (Figure 2.3). Most of the area of reserve (75 per cent) is found in greater altitudes; between 3000 to 6000 m. A very small area is found beyond the range of 2000-6000 m (Table 2.2). Thus, the average altitude is very high.
Table 2.2 Altitudinal Ranges and their Area Profile in NDBR

<table>
<thead>
<tr>
<th>Altitudinal Range</th>
<th>Area (km²)</th>
<th>Percentage</th>
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<tbody>
<tr>
<td>1416-2000</td>
<td>30.62</td>
<td>0</td>
</tr>
<tr>
<td>2000-3000</td>
<td>462.35</td>
<td>7</td>
</tr>
<tr>
<td>3000-4000</td>
<td>1161.18</td>
<td>18</td>
</tr>
<tr>
<td>4000-5000</td>
<td>2402.22</td>
<td>37</td>
</tr>
<tr>
<td>5000-6000</td>
<td>2166.43</td>
<td>33</td>
</tr>
<tr>
<td>6000-7000</td>
<td>240.2</td>
<td>4</td>
</tr>
<tr>
<td>7000-7799</td>
<td>6.42</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>6469.42</td>
<td>100</td>
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Source: Calculated from ASTER GDEM2

2.6 Geology

Geologically, the area falls within the Greater Himalaya (Himadri System), Zanskar range and Trans-Himalayan region. The crystalline rocks are found in the Rishi Ganga basin and are subdivided into four formations i.e. Lata, Ramni, Kharapatal and Martoli (Maruo, 1979). The VoFNP falls in the Zanskar range. The rocks are primarily sedimentary. The Milam area falls within the Trans-Himalayan zone, which is located to north and northeast of Greater Himalayan main ranges. The Pindari and Kaphni areas fall within the Greater Himalaya or Himadri system. It lies north of the Main Central Thrust (MCT) belt and includes high altitude zone with a large proportion of area under snow. Broadly, NDBR is composed of two types of formations i.e. Vaikrita and Tethys sediments (Figure 2.4). The southern part is almost composed of high-grade metamorphic of Vaikrita Group (Valdiya, 1973) and northern is of Tethys sediments (Bisht et al., 2004). Maruo (1979) and Bisht et al. (2004) gives following account of geology of Nanda Devi region.

2.6.1 Vaikrita Group

Vaikrita Group was originally termed for the crystalline rocks in the Spiti region. It forms a thrust sheet over the Munsyari formation of Lesser Himalaya. The rocks between the Vaikrita Thrust and the Trans-Himadri Fault are designated as the Vaikrita Group. It is separated from Munsyari formation by Vaikrita Thrust, which makes a distinct change in style and orientation of structures and registers a jump in the grade of metamorphism form green-schist facies to upper amphibolites facies (Valdiya et al., 1999). It is subdivided into following groups.

2.6.1.1 Joshimath Formation

Rocks of Joshimath (Lata formation) occur in the lower course of the Dhauli Ganga and Rishi Ganga rivers. In the lower part of formation, germetiferous mica schists and garnet mica
quartzose schists predominate and mica quartzites are subordinate constituent. They are fine to medium grained. Between the confluences of the Rishi Ganga and the Dhauli Ganga and Bhangiul, they are mylonitised and are associated with some coarse augen gneisses. A schistose amphibolite, approximately 10 m thick band along with the augen gneiss near the confluence is also exposed. Few thin bands of calc-silicate schist are intercalated in the mylonitic zone. Highly sheared sericite-chlorite quartzites at Tapovan belongs to the Munsyari formation and the probable Vaikrita thrust runs at Bhangiul with about 50° NW trend and about 30° NE dip (Bisht et al., 2004 and Maruo, 1979).

![Figure 2.4 Geological Setup of NDBR](Source: Modified after Maruo, 1979)

### 2.6.1.2 Pandukeshwar Formation

A thick series of mica quartzite overlies the alternations of the garnet schists conformably exposed all along the track route from Lata to Dibrugreta. The quartzites are fine to medium grained. They are cleaved parallel to bedding plane. Medium grained garnet mica quartzose schists are interbanded in various horizons of the quartzite. The quartzites are segmented by a NNE-SSW trending fault at Dibrugreta. Thickness of the series of quartzites is about 3500 m in present area. It overlies garnet mica schists and is overlain by a highly metamorphosed sedimentary series of gneisses, augen gneisses and clac-silicate rocks. The thickness of the Pandukeshwar formation seems to have been reduced considerably by Malari-Dibrugreta fault,
which separates it from Pindari formation. The NNE-SSW trending transverse fault is likely to be the southern extension of Malari fault. It may extend to Wan valley in the south, being a right lateral fault of regional scale. There are some dark colored intrusive within quartzites along Dibrugeta Nallah along the fault (Bisht et al., 2004 and Maruo, 1979).

2.6.1.3 Pindari Formation
On the both side of the Rishi Ganga, across the Malari-Dibrugeta fault, highly metamorphosed rocks of the Pindari formation are distributed. It is composed of Pelito-psammitic gneisses, calc-silicate gneisses and migmatite with abundant feldspar porphyroblasts and quartzofelspathic leucosomes. A pile of the calc-silicate banded gneisses of about 1500 m thick occur between Bhujgara to Patalkhan. The gneisses are characterized with thinly alternative banded structures. These layers often show rhythmic alternations and might reflect original sedimentary structure having thin bed of different carbonate contents. Foliations planes of gneisses and migmatites fluctuate from N 20°E strike and 40° to 50° SE dip to N 60° E strike and dips of about 30° SE in middle and upper part of the formation. Small-scale open folds are observed on the foliation planes throughout the formation. The upper part of the Pindari formation in the study area seems to be a transition to calc-schist and biotite porphyroblastic schist, described as Budhi Schist by Heim and Gansser (1939) and forms the marker bed between basement complex and Tethyan sediments. These rocks are well exposed beyond Patalkhan (Bisht et al., 2004 and Maruo, 1979).

2.6.2 Tethys Sediments
The area north of the Vaikrita group is made up of Tethys sediments. Martoli, Ralam and Garbyang formation of Tethys sediments are present in the upper reaches of the Nanda Devi Massif and also exposed over the tops of Devasthan I and II peaks. Tethys Sediments are separated from Pindari formation by series of normal faults designated as Trans-Himadri Fault. The normal faults, separating the basement complex from the Tethys sedimentary cover above, is recognized in the Gori Ganga Valley at Martoli, Darma valley at Baling, Kali valley near Budhi and Dhuali Valley at Malari. However, Nanda Devi Massif is thrusted over Pindari formation within apparently dips very low towards NE (Bisht et al., 2004 and Maruo, 1979).

2.6.2.1 Martoli Formation
Rocks of the Martoli formation belong to the Tethys sediments. These are exposed in the upper course of the Rishi Ganga and in the basal part of the Nanda Devi massif. The term Martoli was introduced by Heim and Gansser (1939) after village of same name in the Gori Ganga valley for
the entire sequence exposed between Central Crystalline and Ralam Conglomerate. The rocks comprises of silvery grey phyllite with arenite bands, foliated quartzite, biotite schist, grey phyllite and quartzite with scattered garnet, porphyroblastic biotite schist, dark grey pyritous phyllite, quartzite and garnetiferous mica schist (Bisht et al., 2004 and Maruo, 1979).

2.6.2.2 Kapartal Formation
Rocks of the Khapartal formation belonging to the Tethys sediments are exposed in the upper course of the Rishi Ganga and in the basal part of the Nanda Devi massif. It consists predominantly of well-cleaved black pelitic schists in the lower and middle part of the formation.

2.7 Water: Drainage Patterns and Rivers
The drainage pattern in NDBR is mainly dendritic. The pattern at some places is also determined by tectonic features and thus is structurally controlled. Such examples are tributaries of Gori Ganga and Rishi Ganga and Girti Ganga etc. These follow NW-SE fracture patterns and show a typical rectangular pattern. The Girthi Ganga follows the east-west orientation along Himadri Fault. The Sundarghunga and Pindari rivers follow N-E trending lineament. Most of the rivers in northwestern part of NDBR follow strikes of underlying rocks i.e. NW-SE direction. Major rivers of reserve are Alaknanda, Saraswati, Dhauli Ganga, Girthi Ganga, Ganesh Ganga, Pindari River, Gori Ganga, etc. (Bisht et al., 2003).

2.7.1 The Alaknanda River
The Alaknanda is one of two rivers that form the River Ganga at Dev Prayag. The river originates from Alakpuri near the snouts of Bhagirath and Satopanth glaciers. The main course is known as Vishnu Ganga from its origin till the confluence with Dhauli Ganga (Vishnu Prayag) and thereafter (downstream) as Alaknanda. The main course follows west-east trend from its origin to Mana village and then north-south upto Vishnu Prayag. The main course is joined by the Saraswati River near Mana village, which originates from Deotal near Mana Pass. It follows north-south direction.

2.7.2 The Dhauli Ganga
The Dhauli Ganga is more popularly known as white river. It is a principal tributary of the Alaknanda that originates from Malla Painkhanda near Niti Pass. It joins Alaknanda at Vishnu Prayag near Joshimath town. The orientation of Dhauli Ganga is largely north-south. It marks the western boundary of old NDBR and separates from new NDBR. Amrit Ganga and Girthi
Ganga; two major rivers terminate in it near Gamshali village and Malari village respectively. It has most tortuous course among the other rivers of NDBR (Bisht et al., 2003). The whole course of river upto Tapovan is very narrow with almost perpendicular cliffs on either sides, thus the river is hardly visible. There are three nick points in the river bed between the villages of Malari and Tapovan indicating rejuvenation process of the region. The last fall is the greatest one (six miles above Tapovan), where the river falls about 150 feet in just 250 yards (Banerjee, 2001 and 2003 and Srivastava, 1999a and b).

### 2.7.3 The Rishi Ganga

Rishi Ganga drains the NDNP and is the longest river (29 kms) of reserve. It is a major tributary of Dhauli Ganga, which emerges from the South Nanda Devi and South Rishi Glacier in NDNP. It receives water from various torrents emerging out of Trishul, Ramni Glaciers etc. from both sides in NDNP and ultimately joins the Dhauli Ganga at Reni village. It, as a result of downward erosion, forms the world famous and deep gorge popularly known as Rishi Gorge. The orientation of the river is mostly east-west that largely divides the NDNP in two parts; the northern and southern part. The drainage pattern of the catchment is of dendritic type (Bisht et al., 2003).

### 2.7.4 The Pindar River

The Pindar River is one of the major tributaries of Alaknanda that drains the southern parts of reserve. It originates from Pindari and Kafni glaciers (3720 m) in Bageshwar district. The drainage shows rectangular pattern from Pindari Glacier to Bhadang (1997 m) at the confluence with Sundardhunga Gad and follows southward direction upto 10 kms. It later shifts in SW direction.

### 2.7.5 The Girthi Ganga

Girthi Ganga drains the northern parts of NDBR. It originates from the Girthi glacier. It joins Dhauli Ganga at Malari village. The other glaciers that feed the main Girthi Ganga are Bhilmagorao and Siranchu through Bhilmagorao and Siranchu Gad. Most of its feeding glaciers and tributaries are located to its south. There is no major river (except Kio Gad) emerging from the northern sides (Lapthal). The orientation of the main river is nearly west-east and its tributaries follow north-south direction. The main river is structurally controlled and follows east-west direction along Trans-Himadri Fault.
2.7.6 The Gori Ganga

The drainage pattern of the Gori Ganga catchment is a typical example of dendritic type. It originates from Milam glacier in Pithoragarh district and drains eastern parts of NDBR. It is one of the major rivers of reserve (Plate 2.6). Some other rivers of catchment i.e. Lawan Gad, Goankha Gad, Burphu Gad, Shanlang Gad, Ralam Gad etc. terminate in it. The orientation of the river is roughly north-west to south-east and the tributaries mainly follow the west-east trend. The tributaries are mainly structurally controlled. This part of the reserve has some of the huge glaciers of reserve such as Milam, Lawan, Pacchu, Burphu, Shalang, Poting etc.

Plate 2.6 Gori Ganga Valley (Photo taken from Rialkot village in Kumaon part of NDBR)

2.8 Climatic Conditions

The NDBR enjoys distinct microclimatic conditions in different parts due to varied physiography, high elevation range, orientation of river valleys and mountain ridges etc. However, paucity of meteorological observations hinders the understanding of distinct climatic regimes of different areas in reserve. Therefore, the climatic conditions can also be studied based on proxy data e.g. vegetation, glaciers, carbon dating of rocks etc.
Considering vegetation as an indicator of climate, the reserve can be broadly divided into two parts; 1) the Trans-Himalayan region (Northern part-beyond Girthi Ganga gorge) and Himalayan region (eastern, southern and western parts). These two regions have two completely distinct vegetation characteristics. The region beyond the Girthi Ganga gorge (Trans-Himalayan region that represents typical Tibetan landscape), represents high altitude desert type vegetation. Most of the land is barren and upper layers of soils and rocks are very loose. Medium sized glaciers are present. The vegetation is poorly visible. The trees are almost absent and only small-sized vegetation is present. Poor growth of vegetation indicates very dry and cold climatic conditions in this part of reserve. The duration of summer season is very short. Average temperature is very low and winter extends from October to April. The amount of precipitation (snowfall) is low.

In the Himalayan part, there are six meteorological observatories (Badrinath, Ghangaria, Joshimath, Mana, Tapovan and Munsyari). Except Joshimath and Munsyari, all the observatories have been discontinued long back. Available meteorological data suggest that climatic conditions in Himalayan part of reserve are generally dry and cold, as the region is situated in deep interiors of Greater Himalaya. Generally, the rainfall and temperature decrease from south to north following increasing elevations in the Himalayan part of reserve. Thus, valley of northern sides of NDBR such as Upper Alaknanda, Upper Dhauli Ganga, Rishi Ganga valley etc. are extremely cold and dry relative to valleys located to southern sides such as lower Alaknanda, Pindar river valley, lower Gori Ganga valley. The southern parts or reserve receive full monsoon in the month of July (Banerjee, 2001 and Srivastava, 1999a). Also, the conditions are extremely cold at the higher altitudes. Lower elevations remain snow bound for more than six months of a year, while the higher reaches (4500 m) remain snow bound throughout the year (Khacher, 1978 and Tak, 1987).

Lush green vegetation cover (Pine, Deodar, Oak etc.) characterize the eastern, southern and western part. The southern aspects of valleys with east-west orientation have very dense vegetation than northern aspect. It is so because, the monsoon winds directly strike southern aspects leading moist conditions and eventually to very dense vegetation. Even the southern slopes of valleys where monsoon winds rarely reach, account for lush green vegetation because direct insolation on these slopes melts the snow of higher altitudes that regularly drains the lower slopes (Khacher, 1978).
The available climate statistics do not necessarily represent the climatic conditions of entire NDBR but of southern sides, as the observatories are located in the south-west and southeastern boundary. Srivastava (1999a) and Banerjee (2000) suggest three seasons in reserve viz. 1) Winters extend from November to March. Heavy snowfall occurs from December to February, 2) Summers are very short, and generally extends from April to mid June and 3) Rainy season extends from mid June to September. The month of October remains calm.

2.8.1 Rainfall
Climate statistics suggest that spatial pattern of rainfall is under the great influence of location and orientation of various ridges. Average rainfall in eastern part of reserve (2536.1 mm at Munsyari) is more than in western part (566.2 mm at Mana, 91 mm at Badrinath, 1359 mm at Ghangaria, 760.5 mm at Tapovan and 1105.4 mm at Joshimath). The rainfall is highly seasonal in reserve and is associated with monsoon. South-eastern, southern and south-western portion of the reserve receives heavy monsoon rains during July and August. The rainfall is extremely heavy as high ridges of Nanda Ghunti, Trishul-Mrigthuni-Nandakhat-Traill’s pass on their north, act as barrier for the monsoon winds, causing considerable updraft of warm air (Khacher, 1978). In the western part (Munysyari), heavy rainfall is received in the months of July (645.1 mm) and August (649.1 mm). On the other hand, the rainfall is about 237.2 mm in June and 204.0 in July in Joshimath. The Munysyari even in September receives more rains (323.7mm) than Joshimath (113.7 mm). The other observatories also show similar trend. Winter precipitations are mostly in the form of snowfall. These are very uncertain and associated with western disturbances. Snowfall occurs from October to mid May. Occasionally, there are thunderstorms associated with hails in April-May.

2.8.2 Temperature
The average temperature of reserve is low due to high elevations. The season of summer is very short, generally lasting from mid May till late August. Winters are very extreme and extend from the month of November to April. The temperature varies considerably with elevations and from place to place. The maximum temperature reaches to almost 32° to 35° C in the month of July, whereas minimum temperature goes below 0° C in the month of January (-22° C) (Banerjee, 2001; Singh and Mal, 2009; Srivastava, 1999a and b).

Average mean minimum and maximum temperature conditions for Chamoli and Pithoragarh districts are very similar. Highest mean maximum temperature is recorded in the months of May and June, whereas lowest mean maximum is recorded in January. Highest mean minimum
temperature is recorded in the months of June, July and August, whereas lowest mean minimum temperature is January. Mean maximum temperature in eastern side ranges from 13.9°C to 28.6°C and in western side 13.3°C to 28.4°C. Mean minimum temperature in eastern side ranges from 2.3°C to 17.9°C and in western part 2.6°C to 17.9°C.

2.9 Land Use/Cover

Four land use/cover classes i.e. forests, bareland, glaciers and rivers are prominent in NDBR (Singh and Mal, 2009). Vegetation cover accounts for 1817.24 km², which is 28.46 per cent of total geographical area of reserve. All the valleys located in the southern side of the reserve are characterized by thick forests cover. The river valleys having north south orientation allows the monsoon winds to reach to deep interiors, therefore the limits of the vegetation extends further northward e.g. Dhauli Ganga and Alaknanda river valleys (Figure 2.5). Wasteland and glaciers cover 2907.39 and 1659.38 km², which are 45.54 and 25.99 per cent of the total geographical area of reserve respectively (Table 2.3).

Figure 2.5 Land Use/Cover in NDBR (Source: Singh and Mal, 2009)
Table 2.3 Land Use/Cover Pattern of NDBR- 1999

<table>
<thead>
<tr>
<th>Classes</th>
<th>Total Area (km$^2$)</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forests</td>
<td>1817.24</td>
<td>28.46</td>
</tr>
<tr>
<td>Bare land</td>
<td>2907.39</td>
<td>45.54</td>
</tr>
<tr>
<td>Glaciers</td>
<td>1659.38</td>
<td>25.99</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>6384.00</strong></td>
<td><strong>100.00</strong></td>
</tr>
</tbody>
</table>

Source: Singh and Mal, 2009

Bare land occupies the areas of steep slope and between the tree line and glaciers. The glaciers are found at higher elevations. All the above stated land use/cover classes are very dynamic as they rapidly change with changing seasons. A little change in land use/cover categories as a result of changing weather is clearly reflected. The road network is very poor. The river valleys of Dhauli Ganga and Alaknanda rivers are well covered with roads. Also, some roads exist in the lower parts of reserve e.g. Pinder river valley. Not all the roads are open for general public due to the strategic location of area.

2.10 The Biodiversity

NDBR harbors rich biodiversity. The unique geographical location, climate along with large altitudinal variations has endowed NDBR with highly luxuriant and diverse flora and fauna (Khacher, 1978 and Samant, 1993). The diversity is reflected in variety of forests heights and animals. It is one of the rich biodiversity regions of India in terms of habitat and species endemism (Hajra and Balodi, 1995; Kala, 2005 and Samant and Joshi, 2005).

2.10.1 The Flora

Botanical Survey of India, Dehradun and Wildlife Institute of India, Dehradun based on the altitude and floristic combination identified about 800 species of plants and five vegetation zones (Hajra and Balodi, 1995 and Samant and Joshi, 2004 and 2005). However, their description of the vegetation of reserve is restricted to old NDBR and does not include the newly added parts e.g. Lapthal. They identified following forests types in the reserve.

A) Temperate Forests: These are distributed between the altitudinal ranges of 2000-2800 m. These are of two types. A) Deciduous forests; these are found in Murana and Chiwari and includes deciduous broad-leaved species. B) Evergreen forests; these are also found alongwith the deciduous forests in Murana and Chinwari and dominated by the coniferous trees. *Pinus* are the dominant species.
B) Sub Alpine Forests: These are distributed between the altitudinal ranges of 2800-3800 m. These are of two types. A) Deciduous forests; these are well distributed in Dudh Ganga, Lata Kharak, Sainikarak, Himtoli, Dibrugheta, Deodi Trishul Nallah, Ramni, Bagnidhar and Bhujgara. *Salix and Populus* are the dominant species. B) Evergreen forests occur in the same localities. Trees are dominated by *Pinus and Smilax* species in evergreen forests.

C) Alpine Scrubland: These are distributed between the altitudinal ranges of 3800-4500 m. This type of vegetation is found well above tree-line. Main species are *Hododendron anthopogon* etc.

D) Alpine Meadows (3800-4500 m): These are mainly dominated by herbaceous species. Few scrubs such as *Juniperus indica*, *Rhododendron anthopogon*, *Cassiope fastiglata*, *Salix hylematica* are mainly found in alpine meadows.

E) Moraines (Above 4500 m): The characteristics species of the moraines are *Saxifraga pulvinria*, *S. himisphaerica* etc.

Singh and Mal (2009) reported three vegetation zones viz. temperate, alpine and alpine scrubs and meadows.

A) Temperate Vegetation: Temperate vegetation occurs between 2000-2800 m above msl. The forests are restricted to lower reaches of river valleys of Dhauli Ganga, Alakananda, Rishi Ganga, Bhundyar Ganga, and Pindar river valley (Figure 2.6 and Plate 2.7). Total area of this vegetation type is 303.27 km², which is about 16.68 per cent of total vegetation cover of reserve (Table 2.4). Dominant species are *Deodar, Oak, Pine, Buransh*, etc.

<table>
<thead>
<tr>
<th>Vegetation Types</th>
<th>Total Area (km²)</th>
<th>Total Area (in %)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperate Vegetation</td>
<td>303.27</td>
<td>16.68</td>
</tr>
<tr>
<td>Alpine Vegetation</td>
<td>1178.7</td>
<td>64.85</td>
</tr>
<tr>
<td>Alpine Scrub &amp; Meadows</td>
<td>335.41</td>
<td>18.45</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>1817.38</strong></td>
<td><strong>100</strong></td>
</tr>
</tbody>
</table>

Source: Singh and Mal, 2009

B) Alpine Vegetation: These are found between 2800 m to 3800 m above msl. The vegetation is distributed well above the temperate vegetation in upper reaches of Dhauli Ganga River, upper Rishi Ganga River, upper Alakananda and Pindar River valley, Lata Kharak, Saini Kharak,
Debrugheta, Deodi Trishul Nalah, Ramni, Bagnidhar and Bhujgara etc. Temperate and alpine vegetation can be easily differentiated in some areas like Lata-kharak. This type of vegetation is well spread in both the national parks. Stands of Alpine forests are relatively fine in NDNP than VoFNP. In NDNP, these are found right from Lata Kharak to Ramni and in VoFNP throughout the bad of the valley (Figure 2.6). A very distinctive feature of this vegetation is the trailing lichen festooning the trees (Adhikari, 2004). The understory of forest is formed by *shrub rhododendron*. This vegetation is also observed in upper reaches of village of Reni, Lata, Tolma, Dunagiri, Suraithota, Tapovan, Bhundyar, Pandukeshwer, etc. (Plate 2.8a and b). Total area of this vegetation type is 1178.7 km$^2$, which is about 64.85 per cent of the total vegetation cover of reserve (Table 2.4).
C) Alpine Scrub and Meadows: These are distributed between the timber-line (3800 m) and the permanent snow line (4500 m) (Khacher, 1978 and Samant, 1993). These are found in both the national parks and cover large areas. Alpine scrubs are dominant from 3800 m to 4100 m above msl. Beyond 4000 m above msl, alpine meadows are found. Alpine meadows are well spread from 4200 m to 4500 m (Figure 2.6). These are dominant above the village of Kosa in Niti Valley and village of Lambagad in Mana valley. Total area of this vegetation type is 335.41 km², which is about 18.45 per cent of total vegetation cover of reserve (Table 2.4).
2.10.2 The Fauna
The NDBR has a wide variety of mammalian species. Various faunal surveys in the reserve have reported about 18 important wildlife species. Lamba (1987a and b) recorded 15 mammal species. Sathyakumar (1993) identified 3 other species. The important wildlife species are Black bear, Brown bear, Common leopard, Snow leopard, Bharal (blue sheep), Goral, Red fox, Tahr, Musk deer etc.

2.11 Conclusion
The NDBR is an important protected area of Indian Himalaya. It has two national parks of international repute. Both the national parks are UNESCO’s world heritage sites. The reserve has also been included in the world network of biosphere reserve. Both the national parks are internationally recognized for various endangered and endemic plants and animal species, near-natural and natural landscapes. The NDBR is also known for the famous Chipko Andolan. Physiography of the reserve is highly diverse with high altitudinal variations leading to varied climatic conditions. The climatic conditions are very dry and cold. Also, there are number of huge glaciers, which have reduced in size over the period of time. The vegetation mainly belongs to temperate, alpine and alpine meadows.

References


