ISSN NO. 2320-5407

Journal homepage: http://www.journalijar.com

INTERNATIONAL JOURNAL OF ADVANCED RESEARCH

RESEARCH ARTICLE

Nanda Devi Biosphere Reserve as a successful example of old traditions and new approaches in long-term research and their analyses

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Manuscript Info

Manuscript History:

Received: 12 February 2014
Final Accepted: 22 March 2014
Published Online: April 2014

Key words:
Biosphere reserve**,** Himalaya, New generation BR, Publication, Seville Strategy, Sustainable development, Review

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Abstract

The concept of Biosphere Reserves (BRs) is to deal with one of the most important questions of reconciling the conservation of biological diversity and consequently promoting economic and social development and maintenance of associated cultural values. This study focuses on identification of the research strength and gaps in Nanda Devi Biosphere Reserve (NDBR), Uttarakhand, India with a point of view of global Biosphere Reserve concept (Seville Strategy for 21st century) for how the BR could be reoriented to meets the requirement of a new generation BR. Out of 676 research publications chosen for the compilation, synthesis and review from Indian Himalayan Region (IHR), NDBR showed remarkable contribution (43%) as compared to other six HBRs. Moreover, analysis of 283 research publications on different aspects of biodiversity in NDBR, revealed its strength in terms of biodiversity and scope of research. The review of two decades (1990-2010) available literature showed that NDBR contributes to the needs of society as a whole, by showing a way to a more sustainable future. Outcomes of this study have proven NDBR as a successful candidate among old tradition BRs as it accomplishes major goals set for the new generation BRs (Seville Strategy for 21st century).
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Introduction

Biosphere reserves are natural Protected Areas (PAs) included in a global network organized by the United Nations Educational, Scientific, and Cultural Organization (UNESCO). Over 40 years of its existence the programme has contributed significantly towards building a harmonious balance between the human activities and ecosystem conservation. The Biosphere Reserves represent characteristic ecosystems in different biogeographic regions and consider human communities as their integral component. Broadly, the BR objectives include: i) ensuring in-situ conservation (at all levels of biodiversity ranging from genes to ecosystems) in totality as part of wider ecosystem; ii) widening the understanding (through research and monitoring) of components of ecosystems; iii) achieving integrated development (improved quality of life for indigenous communities living in and around) of the area. The BRs are, therefore, sites for experimenting with and learning about Sustainable Development (UNESCO 2011). The concept of biosphere reserves was initiated by a Task Force of UNESCO's Man and the Biosphere (MAB) Programme in 1974. To date, 580 biosphere reserves has been designated in 114 countries in all regions of the world under World Network of Biosphere Reserves (Domingues *et al.,* 2012). The network is a key component in MAB's objective for achieving a sustainable balance between the sometimes conflicting goals of conserving biological diversity, promoting economic development and maintaining associated cultural values. Biosphere reserves are sites where this objective is tested, refined, demonstrated and implemented.

Fourth World Congress on National Parks (NPs) and PAs held in Caracas, Venezuela, in February 1992, the world's protected-area planners and managers adopted many of the ideas (community involvement, the links between conservation and development, the importance of international collaboration) that are essential aspects of biosphere reserves. The Congress also approved a resolution in support of biosphere reserves. In this context, the Executive Board of UNESCO decided in 1991 to establish an Advisory Committee for Biosphere Reserves. This Advisory Committee considered that it was time to evaluate the effectiveness of the 1984 Action Plan, to analyze its implementation and to develop a strategy for biosphere reserves as we move into the 21st Century. To this end, and in accordance with Resolution 27/C/2.3 of the General Conference, UNESCO organized the International Conference on Biosphere Reserves at the invitation of the Spanish authorities in Seville (Spain) from 20 to 25 March 1995. It is important to mention here that biosphere reserve created before the Seville conference should use additional efforts to entirely complete all multi-factions of BRs as is required by the Seville Strategy. However, it was pointed out that the main difficulty is to make the 'old BR' a functioning one. It has been observed that most of the 'old' BRs are very valuable sites for long-term research and monitoring, and preservation of natural ecosystems and have been explored for last few decades. At this stage this is necessary to identify those BRs which have been designated before Seville strategy but still can be considered as successful model for conservation as required by Seville strategy.

India is one of the biggest contributors in the biosphere reserve programme. Ministry of Environment and Forests (MoEF), Government of India, has as on December 2011, date established 18 BRs and many other sites have been proposed as potential BRs. As of now, the designated 18 BRs in the country cover approximately 90,000 km^2 area. Among them, HBRs are at the top of the priority considering with their unique biophysical setting and life support values. The protected area network in the Indian Himalayan region comprises of 7 biosphere reserves (Table 1), 25 national parks and 98 wildlife sanctuaries occupying 9.90 % area of Indian Himalaya (Task Force Report 2010). Considering representativeness, naturalness and uniqueness, the biodiversity elements of these reserves have highlighted conservation values of the reserves. The rich biodiversity of these reserves to great extent owes their existence to age old cultural values of the society, wherein, protection of the various life forms maintained through sacred groves and village communities efforts.

Keeping the progression of BRs in last few decades in mind, present study is focused on review of available information on HBRs with a specific focus on NDBR. We adopted a point of view of global Biosphere Reserve concept (Seville Strategy for 21st century) for how the BR could be reoriented to meet the requirement of a new generation BR. We aimed to extract information on what trends the publications showed in last two decades in HBRs and what successful initiatives have been setup with respect to sustainable management in NDBR. We also highlighted the potential areas need to be explored. We concluded by underlining the success stories for the reserve which can be replicated in other BRs of the globe.

Method

Study area

Amongst HBRs, NDBR has been globally recognized for its naturalness, unique geographical settings, representative habitat and species diversity. NDBR is located between $30^0$05'-$31^0$02'N Latitude, $79^0$12'-$80^0$19' E Longitude in Northern part of west Himalaya and comprises of parts of Chamoli district in Garhwal; and Bageshwar and Pithoragarh districts in Kumaun in the Uttarakhand State (Figure 1). This is the second biosphere reserve designated by Government of India, represents the unique combination of mountain ecosystems including traditional agro-ecosystems, mixed temperate and sub alpine forests, alpine meadows and glaciers. In recognition of its uniqueness, the reserve has been included in World Network of Biosphere Reserves (WNBR) by UNESCO since 2004. Also, the Nanda Devi and the Valley of Flowers National Parks, forming core zone of NDBR, have been inscribed on the World Heritage List by UNESCO under Natural Criteria vii and x. Realizing that the BRs are sensitive candidates to address issues of conservation and development in the region it is important to understand the successful initiatives taken and challenges remains in HBRs.

Data collection and analysis

Present paper is a combination of comparative analysis of literature on different aspects of biodiversity and review of the same. Standard approaches were used during preparation of this paper. First, we identified the major aspects of biodiversity i.e., Floral, Faunal, Ethnobiological, Socioeconomic, Geophysical, Management and Development and Miscellaneous taken into consideration for research during last few decades across Indian Himalayan Region (IHR) and we kept only publication with study sites in Himalayan Biosphere Reserve. Literature was collected from different libraries, NGOs and central and state level research organizations from entire region and reviewed. The literature assembled belongs to the peer reviewed journals and authors having vast experience in research and management issues in their respective disciplines. An attempt was made to include the most representative

publications as well as a good number of the less noted, but also important research work. Further the collection was supplemented with google searches and google scholar searches to find hard to collect types and most recent papers. To ensure that all publications are related to HBRs, we used all possible combination of research terms related to above mentioned biodiversity aspects (Table 1). For detailed analysis, information on 676 publications was kept in a MS-Access bibliographic database form. Standard statistical approaches were followed and figures were drawn accordingly. Data analysis was performed in MS-Excel Worksheet.

Review

Initially, several papers were reviewed for relevance and significance which was later enhanced by inclusion of papers. Further, an extensive review of the literature was carried out and finally all the possible outcomes were pooled to highlight the research achievements, research gaps and priorities for Nanda Devi Biosphere Reserve. The use of most of the regional and localized journals was mostly avoided for two reasons. First, the regional and localized journal and its literature are narrow in scope and cannot be extrapolated for BR as a whole. Second, majority of literature in these journals lacks an explicit standard terminology and definition of the study it contains which limits their applicability in comprehensive review.

Results

Publication statistics on HBRs

Analysis on 639 research publication from HBRs revealed maximum contribution in research came from NDBR (283: 43%) followed by MBR (117: 17%), DDBR (103: 15%), and CDBR (82: 12%). (Figure 2).

Review

Floral aspect of biodiversity

The series of papers provide an introduction, overviews and checklists (Rawal and Pangety 1994; Bankoti *et al.,* 1990; Joshi and Samant 2004; Samant and Joshi 2005), conservation priorities (Samant *et al.,* 1996; Uniyal et al 2002; Kala 2005), habitat specificity (Kala 2004) and extinction (Joshi and Samant 2004) etc of different floral communities. Further analysis of this most explored discipline (n=97) explores a wide range of flora (n>1000) in which angiosperms are at the top (58%). Other classes like bryophytes (12%), pteredophytes (11%), fungi (11%), lichens (6%) and gymnosperm (1%) still need more attention. Over 30 species, including Red Data Book entries, have been categorized under different threat categories as per new IUCN criteria. Nearly 55% species are native to Himalaya and about 235 species are endemic or near endemic (Joshi 2002). In last few years the pressure on some important medicinal plants as well as valuable forest communities has been increased. To minimize the unwarranted effect of anthropogenic pressure on ecosystems, Maikhuri *et al.* (2000), have proposed the participation of people in rehabilitation of land in Himalaya through the introduction of new techniques and provision of livelihood options. Rao *et al.,* have suggested mixed plantation of multipurpose trees valued by local communities could be grown successfully on degraded lands in Himalaya (Rao *et al.,* 2000). To formulate any management strategy for timberline it is prerequisite to carry out faunal study in detail (Rawal and Dhar 1997). In other part of world studies have been carried out alarming the upward migration of species in today's climate change scenarios (Moen *et al.,* 2004). However it may not be the only possible scenario; some species could go against this trend. Therefore, some studies discuss potential mechanisms for unexpected downward range shift of mountain plant species under climate change (Lenoir *et al.,* 2010) are essentially required in target BR for better management and to identify all possible scenarios. Still there is a lot of work in the lower group particularly algae and lichens are required urgently and orientation of focus to other category may become a serious problem. More enhance research in this category through the generation of diversity distribution grid map for long term monitoring may be helpful to find out the habitat and species shift conditions.

Faunal aspect of biodiversity

This category has been explored widely by a number of authors by conducting population, habitat and threat studies on different groups of fauna during last few decades (Sharma *et al.,* 2005, Joshi *et al.,* 2005, Uniyal 2004). The analysis on this second most explored category of biodiversity (n= 518) resulted in checklist of variety of important fauna in NDBR. Arthropoda dominates faunal category (44.2%) followed by Aves (44.0%) while Mammalia (5.5%), Mollusca (2.7%), Amphibian (1.5%), Annelida (1.1%), Reptiles (0.58%) and Pisces (0.2%) remained relatively neglected (Joshi 2002). Uniyal has suggested that habitat and behavior study of some important Himalayan faunal species are needed for their proper conservation in natural habitat (Uniyal 2004). The depredation of livestock is a major problem in NDBR. Mohan has suggested for more focused research in this direction which may help the BR managers to develop long term strategies (Mohan 1997).

Ethnobiological aspect of biodiversity

It has been observed worldwide that people living in complex and harsh conditions have considerable botanical and ecological knowledge about the natural products. These are ranging from traditional use of specific plants and animals, essential knowledge critical to harvesting natural resources, through complex understanding of the

functioning of local ecosystems, to cultural beliefs and religious views of man-environmental relations (Berkes 1999; Davis and Wagner 2003). They have accumulated this knowledge through experience of close contact with the natural environment (Davis and Wagner 2003). Regarding NDBR, a series of studies which examined local resource utilization and valuation of surrounding forest/alpine communities, have been carried out (Maikhuri *et al.,* 2001; Samant and Pant 2006; Joshi *et al.,* 2000; Samant *et al.,* 1996; Maikhuri *et al.,* 1998; Bhatt 1999; Farooque 2000). The local community specially the *Bhotiyas* inside the BR are living with their traditional knowledge which helps them to survive in complex conditions of BR. Cultivation and indigenous use of medicinal and aromatic plants cultivated by *Bhotiya* tribes have a promising economic potential in NDBR (Maikhuri *et al.,* 1998, 2001; Joshi *et al.,* 2000). The indigenous livestock and cattle breeds of *Bhotiyas* and their management, treatment and cross breeding systems have been highlighted (Farooque 2000). Many regions of BR are under illegal and excessive exploitation of important plant and fauna species and it is a serious problem in front of BR managers. Illiteracy and lack of knowledge of sustainable environmental education is responsible for such conditions (Bhatt 1999). For sustainable development of threatened species, alternate methods of conserving natural resources and wildlife like awareness and training programmes (Bhatt 1999; Samant *et al.,* 1996), development of agrotechniques (Joshi *et al.,* 2000; Samant and Pant 2006) and mass propagation of potential species (Samant *et al.,* 1996) are need to be adopted and popularized among the inhabitants. Strategies also need to be developed for BR region to benefit from its rich heritage and knowledge base. The role local's indigenous knowledge in shaping resource use in BRs is of great interest for management of varied ecosystems inside. There is an option to integrate indigenous knowledge into contemporary frameworks for conservation and sustainable management. The use of experience-based knowledge by scientists represents an important emerging area of biological research (Sillitoe 1998; Huntignton 2000; Balram *et al.,* 2004; Brook and McLachlan 2005: Halme and Bodmer 2007).

In today's changing climate and socioeconomic scenarios, many of migratory villages are unwilling to live with their traditional system. At this stage it is necessary to document their traditional and indigenous knowledge for long term persistence of their knowledge. The documentation of local knowledge can provide important avenues for discussion and building dialogue between scientists and the communities in which they work (Turner *et al.,* 2000).

Socioeconomic aspect of biodiversity

The conservation sites have been a major source of natural resources for the surrounding communities (Samant *et al.,* 2005; Majila and Kala 2010; Singh and Rawat 2011). A wide variety of natural products are harvested in NDBR region, especially wood for fuel, and constructions, medicines; a wide variety of wild fruits are collected together with the medicinal plants from surrounding forest as well as alpine communities. Households in NDBR are significantly dependent on the harvests of forests and alpines resources (Samant *et al.,* 1996; Silori 2001, 2004), cultivation (Rao *et al.,* 2002; Negi 2007), ecotourism (Silori 2004; Kent 2005) etc. In last few years the resources have been overexploited by the local communities due to high market demands and economic returns. Silori has suggested for some alternative income generation activities to reduce dependent on natural resources (Silori 2007). The participation of local people/youth may have the ability to influence the impact of eco-adventure tourism in NDBR (Silori 2004; Kent 2005). Now days the interest of local people has changed from age-old practices to other quick money driven activities. The livelihood options are changing due to difficulties in traditional activities (Negi 2007), crop damage and live stock depredation has damaged economic conditions of local people in many regions (Rao *et al.,* 2002) and land use changing by policy maker have a great impact on subsidiary occupations (Nautiyal *et al.,* 2005) etc. The involvement of local people in policy making may be one option to recognize human aspect of environment and so as to improve and identify the livelihood options (Negi 2007). At the same time in order to develop and implement effective policy regarding the socio-economic use of NDBR resources, it is essential for stakeholders to access to accurate and cost-effective techniques for mapping and monitoring the whole BR region.

Geophysical aspect of biodiversity

Complex geophysical setting of NDBR is one among its most peculiar features for what it considered as one of the biodiversity hotspot and heritage site of the world. Uneven landmasses, terrains and vast altitudinal range made it suitable as a reservoir of valuable species. Like other PAs, NDBR steadily being linked with issues related to people's concern on traditional knowledge, access to genetic resources, sharing of benefit, policy conflicts and overall sustainable development (Rawal and Dhar 2001). But what really the theoretical basis for PA establishment is its regional geo-biophysical values (IUCN 1980; Vane-Wright *et al.,* 1991). A few studies have carried out in this aspect regarding the natural hazards (Kimothi *et al.,* 2002), land use and landcover (Sahai and Kimothi 1994; Maikhuri *et al.,* 2003), history of landmasses (Nainwal et al 2008), priorities for conservation (Negi et al 1998) and management strategies (Nautiyal and Kaechele 2007) etc. A detailed comparative analysis of satellite imagery of different time periods showed that the forest resources of NDBR have been well conserved after its notification (Sahai and Kimothi 1994). Keeping in mind water scarcity, landslides and earthquakes and other natural hazards in the region, scientists have shown their concerns towards, selection of species for soil and water conservation in the

region (Negi *et al.,* 1998), an urgent need to evaluate the traditional and modern house building technologies to face any unforeseen natural hazard (Kimothi *et al.,* 2002). Considering other challenges in BR, glacial retried a major challenge to recent research. It can be well examined through the study of chronology of late quaternary glaciations which may be helpful in determining the historical background, present status and future prospects of glacial habitats (Nainwal et al 2007). Besides, failure of aforestation and reforestation efforts to develop degraded lands in BR region could be attributed largely to ignorance of people's essential needs and no-cooperation (Maikhuri *et al.,* 2002).

As the pressure on natural resources is increasing rapidly, there is an urgent need to explore those areas which are still untouched. Many of the forests and high altitude grasslands are quite large, located in remote areas and have been experiencing rapid changes. However, few studies have been carried out to determine the spatial distribution and health of high altitude forests and grasslands using various remote sensing techniques in last few decades. Combination of remotely sensed data with ground based information may be helpful in planning conservation measures for BR (Sahai and Kimothi 1994). The rate and intensity of land use and land cover changes are very high now days and the first step to develop a successful conservation and management strategy is assessment of cause and consequences (Brandt and Townsend, 2006). Therefore, there is an urgent need to develop rehabilitation models suited to diverse set of ecological and socio-economic conditions in the reserve.

Management and *Development aspect of biodiversity*

Biosphere reserves are complex environments where approach of sustaining man and ecosystem together is followed for conservation of biodiversity. This characteristic introduces complexities in planning and management because of neglecting local community needs. In short, conflict is more likely to emerge in the absence of shared understanding about rules of access, clear government regulations and effective means of enforcement and dispute resolution. NDBR is not untouched with such conflicts. After the notification of NDBR, complexities in land use and land cover dynamics (Nautiyal *et al.,* 1998), resource management (Maikhuri *et al.,* 2000; Nautiyal *et al.,*, 2002), forest management (Roa and Saxena 1996), adventure tourism (Silori 2001) and conservation programme (Roa *et al.,* 2000) etc. have been increased. Realizing the above, reorientation in forest management framework and present policies related to production landscapes in NDBR regions (Roa and Saxena 1996), implementation in the top-down conservation programme which led to a breakdown of local community's relationship to the natural environment (Rao *et al.,* 2000), enhancement in policy incentives for cultivation of crops with fewer risks of damages by wildlife (Maikhuri *et al.,* 2000) and participation of local in conservation through integrating resource conservation with socio-economic development and environment with cultural conservation (Maikhuri *et al.,* 2000; Silori 2001) may reduce the above mentioned complexities in BR. Such steps will not only help to resolve the local people-policy conflicts but also improve the local economy and achieve the biodiversity conservation goal.

Figure 1. Location of study sites in Nanda Devi Biosphere Reserve, Uttarakhand in Western Himalaya.

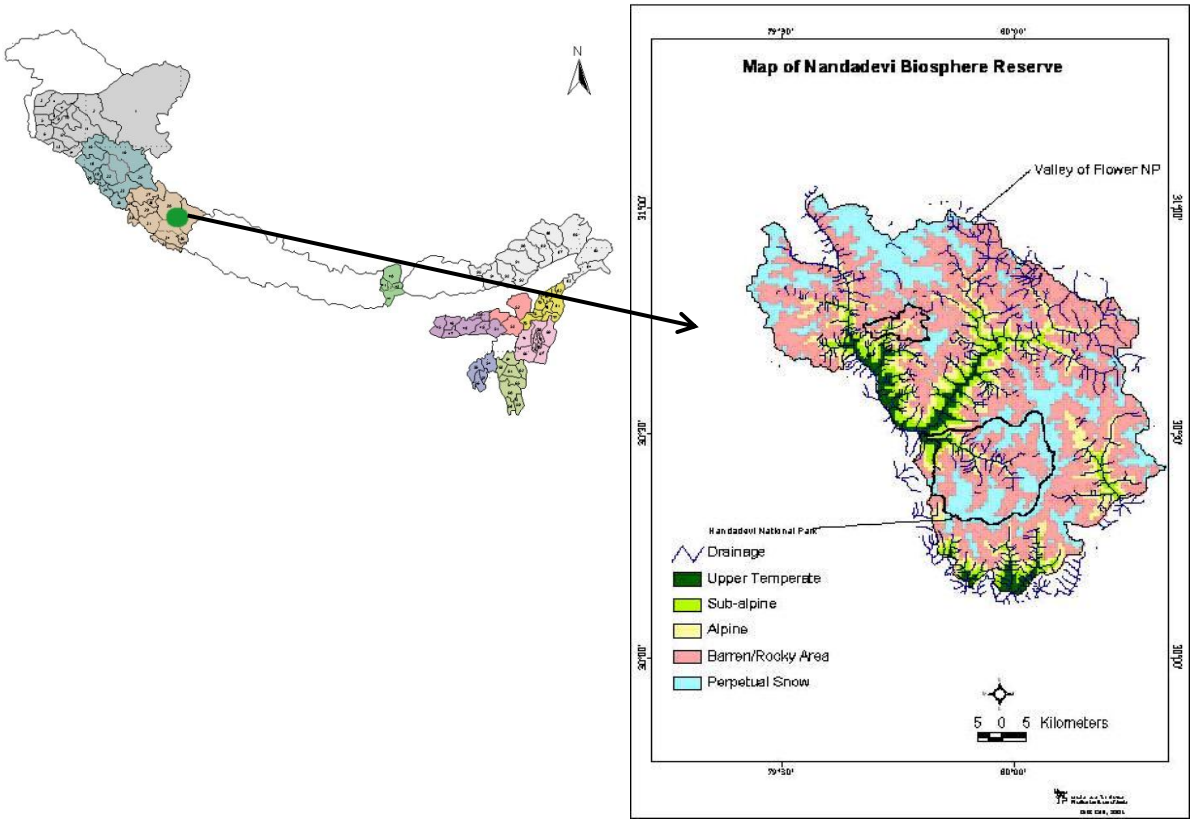

Figure 2. Patterns of publications (%) in Himalayan Biosphere Reserves over the last two decades.

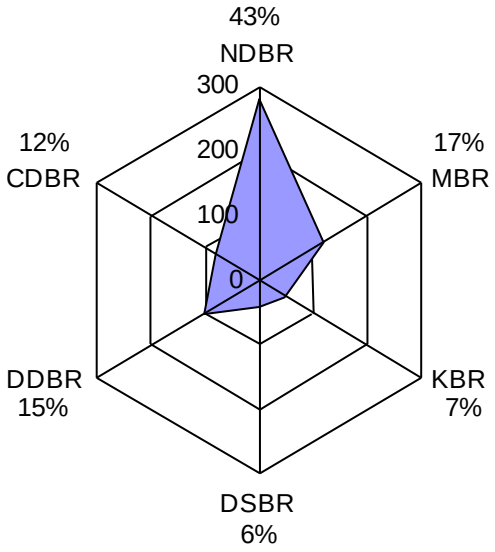

Table 1. The progression of Biosphere Reserves designation in India (till December 2011).

S.No.	Biosphere Reserve	State	Date of Notification	Area covered (Km^2)	Altitudinal range (m)
1	Nanda Devi (NDBR)	Uttarakhand	January 18, 1988	5,860	1500-7816
2	Manas (MBR)	Assam	March 14, 1989	2,837	60-150
3	Dirbru-Saikhowa (DSBR)	Assam	July 28, 1997	765	110-126
4	Dehang Debang (DDBR)	Arunachal Pradesh	September 12, 1998	5,111	500-1600
5	Kangchendzonga (KBR)	Sikkim	February 7, 2000	2,619.	1220-8550
6	Cold Desert (CDBR)	Himachal Pradesh	August 28, 2009	7,770	3300-6600

Table 2. The possible combinations of research terms related to major aspects of Biodiversity used during collection of literature.

<table>
<tr><th>General terms</th><th>Floral /Faunal</th><th>Ethnobiological / Socio-economic</th><th>Management and Devolopment/Geophysical</th></tr>
<tr><td rowspan="3">Himalayan Biosphere Reserves (HBRs), Indian Himalayan Region (IHR), Nanda Devi (NDBR), Manas (MBR), Dirbru-Saikhowa (DSBR), Dehang-Debang (DDBR), Kangchendzonga (KBR), Valley of flower (VOF), Nanda Devi National Park (NDNP), core zone, buffer zone, transition zone, world haritage site, alpines, glacieres etc.</td><td>Flora, angiosperm, gymnosperm, bryophytes, pteredophytes, fungi, lichens, plant species, forests community, alpines community, timberline, ecological studies, fauna, animal, micro-organisms, arthropoda, aves, mammalia, mollusca, amphibian, annelida, reptiles and pisces etc.</td><td>Indigenous knowledge, traditional knowledge, vaidyas, ecotourism, medicinal plants, ethno-veterinary, wild edibles, value addition, market values, livelihood options</td><td rowspan="2">Resource use pattern, man-livestock issues, man-resources issues, man-policy issues, park-policy issues, protected area management, solid waste management, awareness programmes, water resources availability, glaciers retreat, soil, earthquakes, and history of landmasses.</td></tr>
<tr><td colspan="2">Community analysis, species inventory, new records, habitat studies, population study, threatened species, nativity, endemism, species extinction etc.</td></tr>
<tr><td colspan="3">Land use changes, landslides, natural hazards, eco-development, land rehabilitation, livestock depredation, climate change, medicinal plant cultivation, aforestation, reforestation, advancement in technology etc.</td></tr>
</table>

Table 3. Research and Development based strength and research gaps and priorities in Nanda Devi Biosphere Reserve.

Successful initiatives/achievement	Research Gaps	Priorities
Initiatives • Eco-Development activity • Value addition • Rehabilitation of landscape • Ecotourism- Policy and infrastructure support • Social welfare activity • Protection and communication system • Compensation for wild animal victims ***Success stories*** • Successful implementation of participatory processes for planning and management • Remarkable waste management in Hemkund-Valley of Flowers area • Successful initiatives to provide alternatives to natural resource dependencies • Systematic documentation and dissemination of information on BR • Successful protection of Core Area leading to its recognition as World Heritage Site (Natural site) and nomination in UNESCO MAB Net of Biosphere Reserves • Of these, a case of managing non-degradable waste through participation of inhabitants has received wide popularity.	• *Flora* and *Fauna* (i) Diversity-distribution and grid maps; (ii) Habitat relation and status assessment of threatened taxa; (iii) Quantifi cation of ethno-biological values; (iv) Inventory and assessment of lower groups (pteridophytes, bryophyts, algae, fungi, lichens, etc.). • *Socio-ecological* (i) Human dependence and consequent impact on resources; (ii) Valuation of ecosystem goods and services; (iii) Change detection (spatio/temporal); (iv) Ecotourism potential assessment; (v) Best practices – societal adaptation to changing scenarios. • *Geo-physical* (i) Glacier retreat and impacts on downstream ecology; (ii) Hydrological systems; energy options; (iii) Weather monitoring and climate change evidences. • *Development* and *Management* (i) Optimal use of scientific evidences in management strategies; (ii) Man animal confl icts and their resolutions; (iii) Needs assessment, public awareness, and negotiations; (iv) Alternative livelihood options and income generation; (v) Protection and communication network.	• Development of a Perspective Plan (5 year) and its effective implementation • Improving monitoring and networking of BR through use of modern tools • Development of specific training capsules for diverse groups of stakeholders considering their needs and relevance with BR specific issues • Development of user-friendly information portal for NDBR • Establish baseline information on value of ecosystem services emanating from the BR • Developing alternate modals/strategies for sustainable use and management of BR resources under changing climate and economic scenarios • Strengthen participation of communities and private sector in reserve management

Table 4. Progression in Nanda Devi Biosphere Reserve towards achieving 'new generation' Biosphere Reserve criteria.

Seville strategy goals	Achievements in NDBR
1. Use biosphere reserves to conserve natural and cultural diversity 1.1. Improve the coverage of natural and cultural biodiversity by means of the world network of biosphere reserves. 1.2. Integrate biosphere reserves into conservation planning	• >650 research publication in HBRs • >250 research publications in NDBR • >1000 floral species (nearly 3% threat, 23.5% endemic or near endemic; 55% native to Himalaya) • >500 faunal species
2. Utilize biosphere reserves as models of land management and of approaches to sustainable development 2.1. Secure the support and involvement of local people 2.2. Ensure better harmonization and interaction among the different biosphere reserve zones 2.3. Integrate biosphere reserves into regional planning	• Eco-Development activity • Rehabilitation of landscape • Ecotourism-Policy and infrastructure support • Conflict resolution
3. Use biosphere reserves for research, monitoring, education, and training 3.1. Improve knowledge of the interactions between humans and the biosphere 3.2. Improve monitoring activities 3.3. Improve education, public awareness and involvement 3.4. Improve training for specialists and managers	• Social welfare activity • Protection and communication system • Compensation for wild animal victims value addition • Management expertise (training, exchanges, support documents etc.)
4. Implement the biosphere reserve concept 4.1. Integrate the functions of biosphere reserves 4.2. Strengthen the World Network of Biosphere Reserves	• Potential mountain Biosphere Reserve to fulfill all the functions as conceptualized • Classical case for absolute conservation of core zone, the participatory eco-development activities in buffer zone • Success stories act as baseline to discover strengths and priorities in other low profile HBRs

Discussion

Review

NDBR was established in 1988, as the first generation of biosphere reserves. There were excellent facilities for research and monitoring activities through National Man and Biosphere Reserve, India and Forest Department, Joshimath, Uttarakhand. The BR is situated in northern western part in India and consists of two National Parks. There are several small villages and tourist resorts close to the BR. The main activities are livestock rearing, traditional agriculture, tourism research, education and recreation. Research activities on NDBR have to be seen in the light of long-term scientific research. The studies so far carried out include investigation of forest, its resources, specialized flora and fauna, ethnobiological and sociocultural aspects are reflections of societal and developmental changes.

Besides, studies on timberline zones, geographical aspects with integration of RS/GIS techniques are indicator of global environmental changes. Major part of NDBR has been in a focus of taxonomic and ecological research in last two decades. Since 1988 the middle part of the reserve which represents the sanctuary "Nanda Devi National Park" was main focus of research and the research was confined to the questions of management of the part, conflict

of use and environmental protection. Topics include the monitoring of forests and taxonomic wealth through expeditions. After designation of NDBR, other studies also included in reserve's research that had been carried out earlier. The first decade contributes purely traditional kind of environmental studies which later in second decade transformed in more enhanced and innovative form. Several developmental activities like solid waste management, community participation and capacity building, land use patterns etc were started at the beginning of second decade. The need for better integration into regional planning was also likely to become more evident in NDBR. While representing a classical case for absolute conservation of core zone, the participatory eco-development activities in buffer zone have resulted into increased co-operation between inhabitants and management. Unique bio-physical values of the reserve and its sensitivity towards changing climate and human interventions, however, call for improved attention from different stakeholders. Although, NDBR has been proven as potential site for conservation as many successful initiatives has been set up in the BR but still there are many research gaps which are need to be undertaken (see Table 3).

Global scenario

All above data represent the unique basic ecosystem characteristic, which is actual for monitoring, environmental status and evaluation of human influence at the environment. The reserve is included into international Biosphere Reserve Network, and in this quality it realizes its potential for global mentoring. This is amongst those few BRs who have two core zones and successful conservation of which has led its recognition as World Heritage Site. Several research institutions and universities are engaged in developing several kinds of projects and some of them have been established permanent plots, weather observatory, green house nursery, conservation models etc. Since a lot of research has been carried out in NDBR till date, Lead-BR centre, GB Pant Institute of Himalayan Environment and Development, Almora, India (a nodal centre for HBRs) has been established to accumulate and synthesize the literature data. All the data accumulated for this long period is now well documented and stored, digitized and centralized. The reserve has represented its data and has taken part in long-term biota changes observation of the processed of climate changes within the framework of the UN convention for /Global climate change performance. Besides, high standard of scientific research being performed in this reserve and its international reputation and importance could be strong argument for conservation model even when not fully implementing the Seville Strategy (see Table 4). Considering the above, NDBR has a powerful potential for scientific research performance in the field of environment protection and ecological safety. This potential can be successfully used for global monitoring purposes.

Conclusions

NDBR in the Indian Himalaya sets a case having potential of becoming a potential mountain Biosphere Reserve to fulfill all the functions as conceptualized. While representing a classical case for absolute conservation of core zone, the participatory eco-development activities in buffer zone have resulted into increased co-operation between inhabitants and management. Unique bio-physical values of the reserve and its sensitivity towards changing climate and human interventions, however, call for improved attention from different stakeholders**.** At this stage efforts should also be made to explore the research strengths and priorities in other low profile HBRs keeping the outcomes on NDBR as a baseline. Therefore, it is suggested that a detailed review on available information on the potential of the recent or more distant past of existing HBRs need to be undertaken to gain insights. This will ensure that the values of low profile BRs do not remain underestimated. Development options, successful initiatives and priorities discussed above could be implemented in Biosphere Reserves policy and action plans for long-term management of HBRs.

Acknowledgement

Authors are grateful to the Director of the Institute for providing the necessary facilities to carry out this work. Sincere thanks goes to LEAD-BR project of the Institute funded by MoE&F and CSIR (09/560 (0015)/2011-EMRI), Govt. of India for the financial support. We also thank the local, regional and national libraries and institutions for their generous help during collection of literature. Society for Conservation of Nature (SCON) is highly acknowledged for kind suggestions and support during preparation of this MS.

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