International Journal of Ecology and Environmental Sciences 48: 801-815, 2022
ISSN: 2320-5199 (Online); https://doi.org/10.55863/ijees.2022.6801

Directive Strategies for Conservation and Threat Mitigation in Similipal Biosphere Reserve

BISHAL KUMAR MAJHI[1], PRIYANKA JENA[2], B. ANJAN KUMAR PRUSTY[2]* AND ARUN KUMAR MISHRA[3]

[1]G B Pant National Institute of Himalayan Environment, North East Regional Centre, Chandranagar, Itanagar -791113, Arunachal Pradesh, India

[2]Department of Environment Studies, Berhampur University, Berhampur-760007, Odisha, India

[3]Office of the Regional Chief Conservator of Forests, Rourkela Circle, Rourkela, Odisha, India

E-mail: bishalkm@gmail.com, priyankajena9999@gmail.com, anjaneia@gmail.com, arunkumarmishra5@gmail.com

***Author for Correspondence**

ABSTRACT

Biosphere Reserves (BR), the multipurpose protected areas with boundaries circumscribed by a legislative framework, are recognized as the 'laboratory for sustainable development'. Similipal Biosphere Reserve (SBR) in Odisha, one of the BRs in the eastern zone of India, has an array of habitats and ecosystems such as mountains, grasslands, wetlands, moist deciduous forests, and is rich in biological resources (e.g., flora and fauna), including some of the endemic species. The available reports, as acquired from the web-based search engine, reveal the presence of floral assemblage encompassing aquatic plants, bryophytes, algal diversity, lichens, edible fruits, medicinal plants; and the faunal richness inclusive of almost all the animal taxa, *viz*., mammals, aves, reptiles, amphibia, pisces and a range of invertebrate species. Further, reports on traditional ecological knowledge (TEK) and ethnobotanical aspects from the SBR are also available. This article highlights, in brief, various ecological and socio-economical facets of SBR based on the available reports and scholarly literatures. Since most of the scientific explorations have been undertaken from an academic perspective, there is a need for intervention with a pluralistic approach for the conservation of natural resources in this biosphere reserve. This article is an offshoot of an attempt to consolidate the existing reports/literature on the SBR and prioritize management interventions to mitigate the threats. Further, to facilitate an efficient, comprehensive management plan, a way forward, by identifying and integrating broad aspects for conservation, is presented that is applicable for SBR and all PAs of the country in general.

Key words: Afforestation, Biodiversity, Biosphere Reserve, Conservation, Ecology, Sanctuary

INTRODUCTION

The multipurpose protected areas (PAs) with boundaries delimited by a statutory framework are known as Biosphere Reserves (BR). The concept of Biosphere Reserves was launched in 1975 as a part of UNESCO's Man and Biosphere Programme (MAB), dealing with the conservation of ecosystems and the genetic resources contained therein. Currently, there are 714 BRs in 129 countries, including 21 transboundary sites belonging to the World Network of Biosphere Reserves (UNESCO nd a). The primary aim of a BR is to preserve the biodiversity of the representative ecosystems, traditional ecological knowledge (TEK) of inhabitants and genetic resources. They provide local solutions to global challenges pertaining to the conservation of biological resources and cultural diversity and facilitate enhancement in socio-economic conditions of the local populace through a participatory conservation approach. Considering the nation's diversity of ecosystems and the need for their long-term conservation, the Man and Biosphere Committee of India identified potential sites for designation as BRs, which started in 1979. As of now, there are 18 BRs in the country, covering approximately 90,000 km^2 area (WII, nd).

Biosphere Reserves promote biodiversity conservation through sustainable utilization of biological resources, and management based on sound ecological principles and the efforts of local communities. They serve as a living laboratory for testing and demonstrating the management of natural resources for sustainable development (UNESCO nd b) in an integrated manner. But overexploitation of natural resources due to their increasing demand and

lowering regeneration potential has been a concern for some of the BRs. Due to relentless anthropogenic activities, the BRs all over the globe are under tremendous pressure. In this regard, Odisha, the hot bowl for agriculture and mining in India, is no exception. Of the 18 BRs in India, Odisha has only one notified BR, i.e., the Similipal Biosphere Reserve (SBR), which faces various natural and anthropogenic threats that have curbed the safekeeping of natural resources. This article highlights, in brief, various ecological and socio-economical aspects of the BR, based on the consolidation of available literature. We have also identified the gaps those need to be fulfilled to facilitate sustainable management of natural resources leading to the reserve's long-term conservation.

STUDY AREA

Similipal Biosphere Reserve (SBR), located in Odisha (20°17' to 22° 34' N and 85°40' to 87°10' E, Fig. 1) is one of the first eight BRs of India declared by the Government of India (vide notification no. 16/2/85 MAB CSC) on 22nd June 1994. Initially, Similipal was designated as a Tiger Reserve under Project Tiger in May 1973; subsequently, the Government of Orissa declared Similipal as a Wildlife Sanctuary in 1979 with an area of 2750 km^2. Later in 1986, the Government of Orissa proposed a portion (303 km^2) of the sanctuary as a National Park. Thereafter the UNESCO added it to its list of World Network of Biosphere Reserves (WNBR) in May 2009. The 5569 km^2 biosphere reserve has a central region of around 2750 km^2 as Similipal Tiger Reserve, from the entire 7043.04 km^2 landscape of Mayurbhanj Elephant Reserve. The core, buffer, and transition zones of SBR are within the geographical coverage of 845 km^2, 2129 km^2 and 2595 km^2, respectively (UNESCO nd c) The core area (critical tiger habitat) is managed strictly for conservation. The buffer zone is managed for biodiversity conservation and sustainable development with regulated and/or permitted activities including

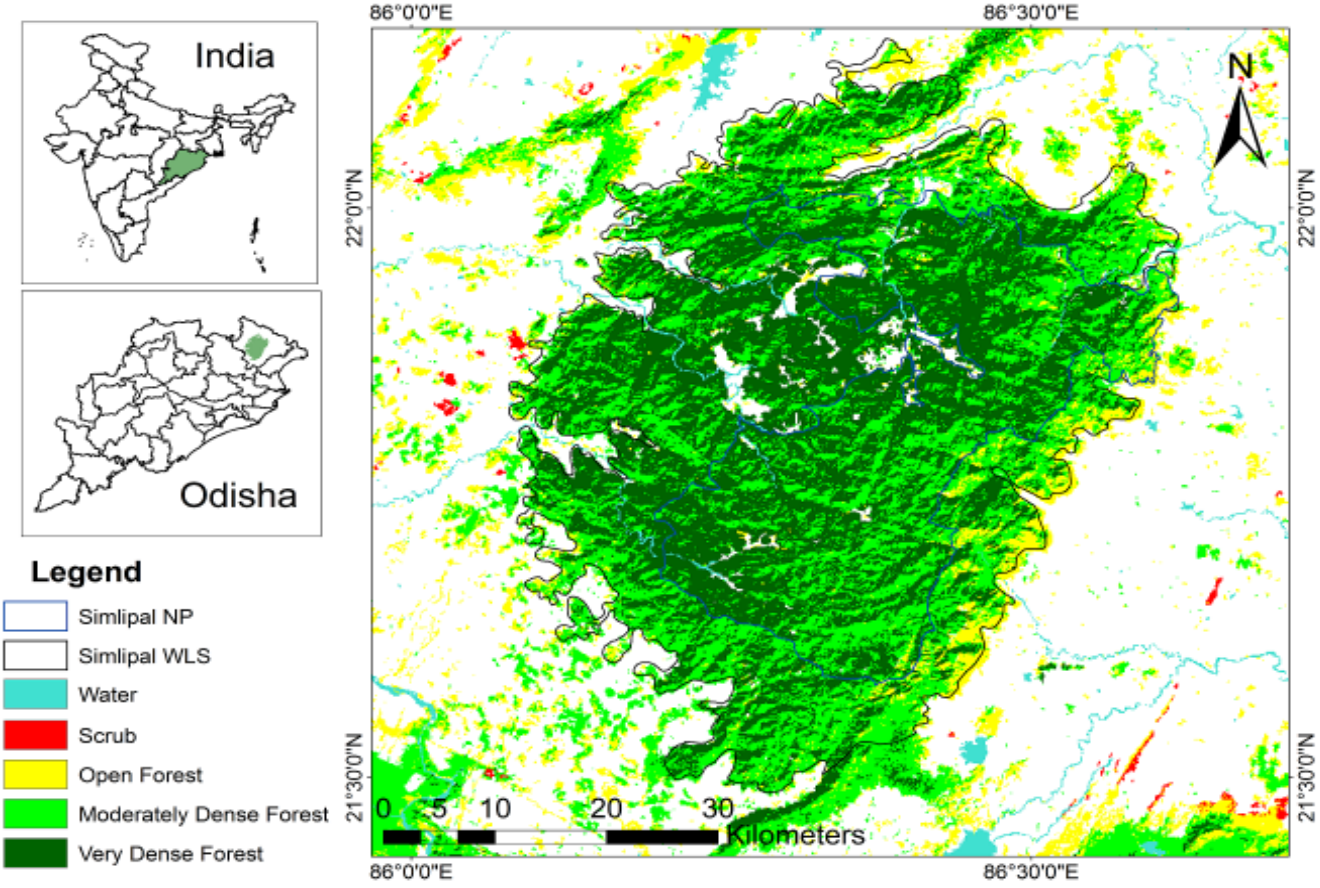

Figure 1. Map of Similipal Biosphere Reserve (SBR) with demarcation of Wildlife Sanctuary (WLS) and National Park (NP)

limited recreation, tourism, fishing and grazing to reduce pressure on the core zone. In the transition zone, conservation knowledge and management skills are applied primarily to foster alternate livelihoods and minimize dependence on the forest.

This lies within two biogeographical regions: the Mahanadian east coastal region of the Oriental realm and the Chhotanagpur biotic province of the Deccan peninsular zone (Rodgers and Panwar 1988). Different soil types such as red and yellow soil, laterite soil, black soil, grey yellow soil, Rendzina soil and Planosol are present in this BR (Ramakrishna et al. 2006). The area experiences a combination of warm and humid climate, with temperature varying from 2°C in winter to about 39°C in summer. The SBR receives about 185 cm of annual average rainfall through south-west monsoon (between June and September) and north-east monsoon (during November). Although SBR has a predominantly moist deciduous Sal Forest, it also has patches of sizeable dry deciduous forest and semi-evergreen forests. The highest peak in the Similipal hill range is Khairiburu (~ 1200 meters). Several waterfalls, streams and rivers originate from the SBR and drain into major rivers, such as the Budhabalang, Baitarani and Subarnarekha.

There are about four villages inside the core area of the SBR, namely Jenabil, Kabatghai, Jamunagarh and Bakua. Further, 61 villages are located inside the buffer zone and 1200 villages in the transitional zone of this BR with a total population of about 4,50,000 (Odisha Profile, 2018). The scheduled tribes constitute 73.44 % of the total population of Similipal (Kumar et al. 2017). The tribal inhabitants of Similipal are heavily dependent on forest resources for their livelihood, especially the non-timber forest products (NTFP), along with other livelihood support from agriculture, daily-wage earning and hunting.

METHODS

The present compilation on SBR results from a comprehensive review of available scientific literatures (research articles, reports, dissertations, and doctoral thesis) and data sets from online portals/ archives. Appropriate literatures were downloaded using different web-based search engines (e.g., Scopus, Web of Science, Google Scholar, Sodhganga) and academic social-networking site for the scientific community (e.g., Research Gate) through a pre-defined search protocol, using a set of relevant keywords. The keywords included Similipal, Similipal Biosphere Reserve, Flora, Fauna, Ecology and Forest Resources of Similipal Biosphere Reserve, Threats to Similipal Biosphere Reserve, and Conservation in Similipal Tiger Reserve. Additionally, information was also gathered from different government departments, frontline forest officials, news reports, personal communications with stakeholders, and different non-government organisations working for the biodiversity of this area.

RESULTS

The ecological diversity of the SBR includes floral and faunal diversity hosted by an array of ecosystems, *viz*., mountains, grasslands, wetlands, and different forest types (Fig. 1). Owing to the rich biodiversity and natural resource base (NRB), several researchers have attempted to explore and enumerate various aspects *viz.*, taxonomy, ecology, anthropology, geological aspects, remote sensing-based exploration, and conservation issues (Fig. 2). Based on the available records on the SBR, the consolidated findings have been enumerated in the following sections.

Research on Ecological Diversity

Floral Diversity

The pioneering floristic analysis has been carried out and reported in this Biosphere Reserve by Saxena and Brahmam (1989) reporting the total plant species to be 1076. Further studies reveal the occurrence of 1254 species of plants (under 715 genera and 178

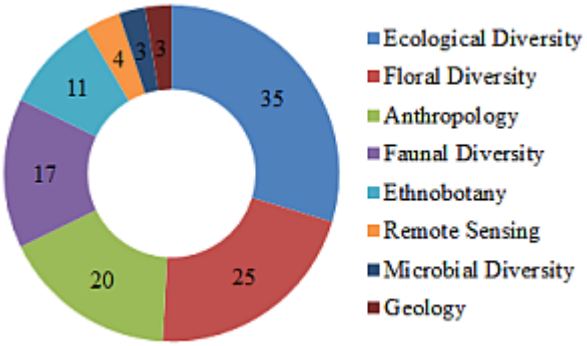

Figure 2.Thematic areas of research publications in Simlipal Biosphere Reserve

families), which is 46% of the floral diversity of the state of Odisha (Swain and Nanda 1991, Swain and Nanda 1997, Tripathy and Patro 1997, Dash 2010, Misra et al. 2013). This floral assemblage includes 839 species of dicotyledons, 346 species of monocotyledons, 04 species of gymnosperms and 65 species of pteridophytes (Reddy et al. 2007, Mishra et al. 2011). Several important species are found in the SBR including two critically endangered species, *viz*., *Saraca asoca* and *Symplocos racemosa. Eria meghasaniensis, Aspidopterys tomentosa* and *Habenaria panigrahiana* are some of the endemic species apart from other taxa reported from Similipal (Saxena and Brahmam 1989, 1994-96, Misra 1997). Research on medicinal plants in the SBR have been documented by Pandey et al. (2000, 2002), Pandey and Rout (2003), Rout (2005), Rout et al. (2009), Routh and Panda (2010) and Misra et al. (2013). Sethy (2009) documented 573 species of medicinal plants in the SBR. As per the available records Reddy et al. (2008) studied wetlands in different forest blocks of the SBR. Aquatic plant diversity during the years 2006 and 2007 was reported wherein out of 149 aquatic plant species many possessed medicinal and fodder values. Owing to increased exploitation, Reddy et al. (2008) suggested largescale propagation of valuable plants such as *Bacopa monnieri, Centella asiatica, Hygrophila auriculata* that could minimize the present pressures on them. Subsequently, Singh and Kumar (2012) reported the lichen wealth in the transitional zones of this SBR and recorded 141 species of lichens in the SBR (129 species being the new records for the state and 03 species for the country), Furthermore, Satapathy et al. (2021), documented an additional 96 species of lichen mass in the SBR, of which 15 species were abundantly colonized trees like *Mangifera indica, Simarouba glauca* and *Madhuca longifolia.* These studies on lichens by Satapathy et al. (2021) warrant further exploration of lichen diversity in the core and buffer zones of this BR. Among other plant forms, a total of 274 algal taxa, 43 species of bryophytes and 128 species of aquatic angiosperms were recorded in the biosphere reserve by Mohapatra et al. (2010) based on the surveys conducted during 2005-2007. There has also been documentation of 14 species of algal taxa including 09 species of cyanobacteria and 05 species of green algae (Bhakta et al. 2020), considering the colonization on the soil crusts of the BR. Of the 149 species of bryophytes reported in Odisha (Mishra et al. 2016), this BR hosts 33 species (Alam et al. 2013). Comprising of 8% of the country's orchid diversity, the SBR holds a sum of 94 orchid species as well (Sethy 2009).

Faunal Diversity

Description of the faunal resources (invertebrates and vertebrates) has been presented by Anon (1999), Patro and Panda (1994), Bal (2002), Ramakrishna et al. (2006) and Sethy (2009). The faunal diversity of Similipal comprises nearly 55 species of mammals (Anon 1999, Swain 2000, Ramakrishna et al. 2006, Sahu et al. 2011, Debata and Palita 2020), over 364 species of birds (Dev 1986, Nair 2007, 2010), 60 species of reptiles (Dutta et al. 2009, Dash et al. 2015), about 21 species of amphibians (Dutta et al. 2009), over 66 species of fishes (Sethy et al. 2009, Baliarsingh et al. 2013). The invertebrates in the BR include 20 species of molluscs (Sethy et al. 2007), 41 orthopteran species (Sethy 2009), 188 species of butterflies (Satapathy et al. 1985, Sethy et al. 2007, Nair 2011), 58 species of odonates (Das et al. 2012) and a diversity of arthropods (Satpathy et al. 1985, Dey 2000, Mohanty 2008, Das et al. 2012).

The SBR holds the highest tiger populations in the state, with a significant proportion being melanistic (Dash *et al.* 2015). Apart from tiger, other mammals such as Asian Elephant (*Elephas maximus*), Gaur (*Bos gaurus*), Rusty-spotted Cat (*Prionailurus rubiginosus*), Striped-necked Mongoose (*Herpestes vitticollis*), Asian Small-clawed Otter (*Aonyx cinereus*) are some of the conservation priority species in this biosphere reserve (Sethy 2009). Sahu et al. (2011) reported on the density and distribution of ungulate species in the Similipal Tiger Reserve, and the density was low as compared with other landscapes in India. Nayak et al. (2014) indicated the impact of low ungulate population on survivability of predators in the tiger reserve. Thus, the conservation action plan for the SBR should include detailed strategy for management of prey and predator populations in the biosphere reserve. Debata and Palita (2020) reported different ecological aspects of bats in the SBR such as species richness, diversity, and abundance, based on their survey conducted during 2013-2015. Three frugivorous and 18 insectivorous bat species were recorded.

The first checklist on avifauna was provided by Dev (1986) and thereafter by Dutta et al. (2009), which reported to be encompassing about 304 species of birds in the SBR. Greater Spotted Eagle (*Clanga clanga*), Pale-capped Pigeon (*Columba punicea*), Ferruginous Duck (*Aythya nyroca*), Jerdon's Baza (*Aviceda jerdoni*), Thick-billed Green Pigeon (*Treron curvirostra*) are some of the species, which require special attention for conservation (Nair 2007, 2010, Palei et al. 2016).

Dutta et al. (2009) provided a detailed description of herpetofauna in SBR. The SBR is home to around 70% of the terrestrial reptiles of Odisha. A sizable population of reptiles which includes one species of crocodile (Marsh Crocodile, *Crocodylus palustris*), six species of turtles, 20 species of lizards and about 33 species of snakes including King Cobra (*Ophiophagus hannah*) are found in the SBR (Dutta et al. 2009). The reporting of Red-necked Keelback (*Rhabdophis subminiatus*) in Similipal by Sahoo et al. (2012) is the only record of the species from Odisha.

Although there has been a poor documentation on amphibians in this BR, the area hosts one of the endemic species, i.e. Similipal bush frog (*Philautus similipalensis*) (Dutta 2003, Dutta et al. 2009) which is a critically endangered species. This species was later synonymised to Raorchestes sanctisilvaticus (Mirza et al. 2019). The SBR is known to harbour a rich diversity (about 31 species) of freshwater fish and nekton fauna (Baliarsingh et al. 2013, Sethy et al. 2009) owing to the pristine rivers, streams, and waterfalls in the biosphere reserve. The aquatic ecosystems in Similipal are an abode to about 42 genera of fishes, which includes 24 species as first records in the SBR.

Of the 470 invertebrate odonate species seen in India, 58 have been reported from the buffer areas of the SBR (Das et al. 2012). Despite the prevailing anthropogenic pressures and associated threats, Das et al. (2012) ascribed such high odonate species diversity to the availability of resources and suitable habitats in the SBR. Nair (2011) reported three species of butterflies from Similipal, those were endemic to the Himalayas and northeastern parts of India. For this, the Similipal hill range has been considered a hub for exchanging species between different bio-geographical zones, providing a conducive habitat for new species. The reports by Satapathy et al. (1985) and Sethy et al. (2007) insisted for the protection and conservation of the genetic diversity of butterflies. In addition, reports on malaco-diversity (Sethy et al. 2007), silkworm (Dev 2000), honey bees (Mohanty 2008) and microbial diversity (Rath et al. 2009, Dash et al. 2011) in the SBR are also available.

Remote Sensing-based Research

In addition to the research on different taxa, ecological explorations have also been undertaken through GIS-RS tools (Saranya et al. 2014, Saranya and Reddy 2016), wherein the spatial changes in the forest and land cover of the SBR were analyzed. Anthropogenic activities reportedly led to massive deforestation of the area during the mid-90s. However, assessment in the subsequent years revealed a decrease in the rate of deforestation due to various interventions for conservation and management of the natural resource base (NRB) in the SBR. Mohanta and Nandi (2017) reported on the land cover composition and surface temperature variations in different sectors of the SBR from the data accessed through MODIS. The findings revealed an increase in open forest in the transition and buffer zones of the biosphere reserve. In contrast, the dense forests witnessed a rising vegetation cover/ greenery trend as evident from the satellite imagery, with no greater surface temperature variations throughout the year. Recently, Mahato et al. (2021) analyzed different geographic attributes of the site to collect data on forest health using GIS techniques, which included Normalized Difference Vegetation Index (NDVI), Soil and Atmospherically Resistant Vegetation Index (SARVI), Modified Chlorophyll Absorption Ratio Index (MCARI) and Moisture Stress Index (MSI). The eastern and central parts of the SBR are found to have excellent vegetation cover, whereas moderate vegetation cover have been observed in the southern and northern part of the SBR. This report of Mahato et al. (2021) warrants conservation initiatives in the degraded pockets of the SBR.

Studies on Soil Nutrient Dynamics

The first available report on the chemical characterization of the soil of the SBR was that of Saikh et al. (1998 a, b), which revealed the impact of deforestation and cultivation on the cation

exchange capacity (CEC) and exchangeable bases (e.g. Ca, Mg, Na and K) and Carbon, Nitrogen and Phosphorus in the soil. A reduction of C:N, C:P, organic carbon and total nitrogen were found from cultivated lands, which was contradictory to the levels reported in the virgin evergreen forest soils (Saikh et al. 1998a). Further, Saikh et al. (1998b) observed high CEC and base cations (Ca and K) in the evergreen forest soil, reportedly due to a reduction of farming (cultivation) practices inside the reserve. Both these reports deduced that soil CEC has correlation with the organic carbon content and that the articles emphasized the role of evergreen vegetation cover in reviving the soil productivity, as the evergreen vegetation cover might facilitate the regeneration of weathered soils and organic matter accumulation.

Research on Anthropological Aspects

Owing to the existence of around 12,500 of tribal population (Sahoo et al. 2013) inside the BR, various anthropological aspects have been examined (Dash 1992, Mohanty 1995, Mishra 2002, Rout 2008, Upadhyay 2012, Sial 2021) highlighting different social issues. Dikshit and Malik (2000) highlighted issues relating to over-dependence on NTFPs and monoculture plantations for timber wood affecting the ecological integrity of the BR. Developmental projects in the mining-rich state of Odisha have been lined up for noticeable economic gains, wherein the price is paid by the environment and the local populace. The impact of conservation induced displacement, resettlement and rehabilitation of the natives who are totally dependent on the forests of the Similipal Tiger Reserve have been statistically analyzed by Sahoo (2012). Survey carried out by Sahoo et al. (2013) indicated the loss of forest cover (>40% area) and wildlife. This kind of social questionnaire-based surveys are an indication of forest health and sustainable livelihood in PAs where civil conflicts are a challenge for ecological studies.

Dash and Behera (2012) reported on the pressure on NTFP extraction by the local populace using econometric techniques and statistical tools. It was found that households in the core areas tend to depend more on NFTPs than denizens of the buffer areas (Dash and Behera 2016). The rehabilitation and resettlement policy for shifting forest dwellers out of PAs has been connected to tribals' livelihood status and income profile (Mahapatra et al. 2015), which contradicted the perception of poverty to relocation. Agarwalla and Saha (2019) studied the forestry and socioeconomic factors to understand the livelihood patterns of the denizens, especially the tribals. Further, human health, especially maternity conditions, were examined in a tribe residing in the SBR to understand the availability of and accessibility to healthcare practices and facilities (Mukhopadhyay and Ray 2019).

The social, cultural, economic and developmental issues concerning one of the semi-nomadic tribes, i.e., Kharia tribe, which is one of the Particular Vulnerable Tribal Groups (PVTGs) inhabiting the Similipal hill areas has been examined intensively (Tudu and Mohapatra 2020). Saha and Agarwalla (2021) reported a case study on the forest dwellers of SBR and identified the factors affecting the dependence on forest, wherein people were found dependent mainly on peripheries than core areas. Thus, zonation of the site is a prerequisite for developing any strategy for sustainable development by reducing forest dependence. Thus, by research, social aspects of the natives of forests are covered, diversion of funds for tribal developments might help in designing better policies for upliftment of the locals and parallel conservation of the protected area.

Traditional-cum-Ethnobotanical Research

Dikshit et al. (2000), Pandey and Rout (2003), Mishra et al. (2008, 2011), Thatoi et al. (2008), Rout et al. (2009), Rout and Thatoi (2009), Routh and Panda (2010), Kumar et al. (2017) described the ethnobotanical, nutritional, anti-microbial and traditional pharmacological aspects of the *Dioscorea* sp. and other medicinal plant species. Behera (2006) and Kumar et al. (2012) reported on the wild food and medicinal sources preferred by tribal groups residing in the SBR. Eleven *Dioscorea* species (out of total 79 edible wild plant species) were reported along with documentation on their harvesting and consumption patterns (Kumar et al. 2012), which emphasized on the conservation, exploration, and efficient use of these resources to mitigate poverty and food shortages. Mohanta et al. (2006) provided a vivid description of antidotes for various diseases using plant resources following traditional medicine remedial techniques as per the inputs from local tribe health specialists.

DISCUSSION

Although attempts have been made to consolidate the available information on the NRB of the SBR based on earlier reports, the apparent gaps in scientific exploration and reporting are clear. Different components such as hydrological issues, fire regime, regeneration aspects and traditional knowledge can make the reporting more comprehensive and inclusive. Despite the research works undertaken by several researchers till date, the primary purpose of the SBR i.e., ensuring desired functions of the designated biosphere reserves, is yet to be realized. Thus, there is an urgent need to develop a coordinated program to strengthen research on critical issues and formulate a perspective plan for sustainable management of natural resources and holistic development in the biosphere reserve as suggested earlier by Mishra (2010), Dash and Behera (2013) and Jena et al. (2022). Some of the proposed initiatives for conservation and natural resources management in the SBR are discussed further.

***Creation of Natural Resource Database*:** The available literature reveals that most of the inventory studies in the BR include only flora and fauna (Das and Das 1997), therefore, other natural recourses need to be enumerated to create a comprehensive database. The creation of a database of natural resources (microbial, floral, and faunal assemblages, and abiotic factors influencing the ecological functioning), socio-economic profiles for Similipal, and visualization with aid of spatial tools is essential. Latest satellite images of the BR can reveal the utilization of natural resources on a spatial gradient. Furthermore, regular monitoring at appropriate intervals is essential to examine the temporal changes in the dynamics of the NRB. This will facilitate in developing better understanding on the spatio-temporal dynamics of natural resources and their utilization, which needs to be followed up by developing indicators for assessing them and simulations to predict their future status.

***Ecological Health Assessments (Soil and Limnological Aspects)*:** Every ecosystem has its significance, which requires an independent monitoring strategy to estimate the productivity and regeneration potentials. Maintaining the equilibrium in soil and limnological profiles are crucial for ecosystem functioning, which can help in developing strategies for remediating habitats contaminated by inorganic and organic pollutants. Since, the rivulets and springs feed the water bodies in the SBR, the ecological health assessment of such aquatic ecosystems are of prime importance and the future research must include the eco-hydrological aspects of the SBR.

Fire Ecology and Management: Fire ecology is another crucial aspect in the management of this BR, as forest fire has been a regular and periodic incidence in the biosphere reserve. Owing to its impacts on the forest ecosystem, extensive research must be undertaken to ascertain its cause, impacts, and remedies. This requires long term studies to record episodes of forest fire and regeneration after the fire has occurred to predict its future occurrence, severity, and implications, and help in develop resilience mechanisms. Furthermore, the fire vulnerability index through remote sensing can aid in fire management practice in the biosphere reserve. Assessment of soil quality and microbial biomass and diversity after the fire incident and comparing it with the unburned areas may open new insights to impacts of forest fire on the soil health.

Carrying Capacity Assessment: In maintaining the health of an ecosystem, carrying capacity assessment plays a vital role. In the case of SBR, carrying capacity assessment for different zones can be carried out to understand the resource availability vis-à-vis population status of other species and their dependency on the NRB. This will help in carrying out the Population Viability Analysis and determining the maximum population of any taxon that can be allowed in the identified zones. This would also aid in developing plans for translocation of the individuals or to facilitate population induction, especially for the threatened taxa.

Promotion of Sustainable Ecotourism: Promoting ecotourism in and around the PAs are to be an integral part of PA management. However, to maintain a balance, sustainable ecotourism needs to be practiced reaping optimum ecological benefits/services. The tourist footfalls can act as an early warning system for restricting the booming ecotourism sector and preventing overexploitation of crucial biological resources. Both the local populace and PA's natural resources and habitats can benefit from tourism if integrated with ecosystem sustainability. To support the local denizens for forest and wildlife

conservation, the state government initiated "Community Managed Nature Tourism" (CMNT) scheme aiming at the development of ecotourism in the state (Eco Tour Odisha, 2019). The forest dependent local community members were the major stakeholders and beneficiaries of this scheme. The members of Ecotourism Group (ETG) have substantially been benefitted from this alternate source of income, who once used to rely majorly on forest-based products. Tribal mass and women are now increasingly engaged in conservation of the NRB. A recent report (Eco Tour Odisha 2019) states that the nature camps in Similipal have performed very well in generating a revenue of INR 13 million by January 2020 (Indian Express 2020). Such type of sustainable ecotourism models is also in practice in other PAs, such as that of Keoladeo National Park (KNP), Bharatpur, Rajasthan (Zeeshan et al. 2017).

Prioritization of Habitat-cum-Taxa and Corridor Connectivity: The zonation in the BR (e.g., core area, buffer area) has well recognized benefits. As Similipal is a tiger reserve and an elephant reserve, zonation of the BR has facilitated all-round protection of wildlife. However, the available reports are suggestive of a skewed preference in conservation action programme, wherein focus has been given to charismatic and larger species only (e.g., tigers), whereas herpetofauna, invertebrates and useful microbes have not been considered adequately. Thus, for an inclusive management of the BR, there is a need for paradigm shift in the focus of habitat and/or species conservation. It is essential to prioritize each taxon in the SBR, based on a comprehensive assessment of their population status and prevailing threats. The conservation approach should be species-centric and habitat-oriented. However, habitat conservation should not be patch-specific but must focus on providing contiguity and connectivity with other conservation areas. Thus, the establishment of corridors will help in long-term conservation facilitating exchange of genetic material and reduce population decline induced by inbreeding depression.

Defining Space for Ex-situ Conservation: The SBR contains genetic elements evolved over millions of years that hold the key to future adaptations and survival, and have tremendous potential for economic development, owing to the emerging new trends in biotechnology. Sustainable harvesting of medicinal plants and wild edibles and putting them into a market value chain can generate tremendous capital. Since several wild varieties of crops are available in the biosphere reserve, a gene bank can be created, and the local denizens could be made the guardians of such gene bank with provisions of incentivizing their conservation efforts. In addition, Similipal has been an adobe to several varieties of orchids (Sethy 2009), which necessitates the establishment of an orchidarium and infusing proper skills for the local populace, thereby facilitating livelihood support to them.

Socio-economic Upliftment: Although the ecological health of the SBR is crucial, its inhabitants, humans and their development are also an integral part of this BR (Mohapatra 2012). The role of biosphere reserves in addressing issues of climate change vulnerability in different sectors, *viz*., water, agriculture, forestry, tourism, and animal husbandry needs to be realized to help both the local populace and indigenous communities in finding better livelihood options. As suggested by Mohanty (1995), socio-economic profiling of the local denizens is essential and plans should be made to enhance their sustainable living with focus on health and education. Zeeshan et al. (2017) reported on the dependency of neighbouring villagers on NRB of KNP in Bharatpur, Rajasthan. This study suggested that PA management effectiveness primarily depends on models developed in a participatory manner to facilitate sustainable management of forest resources and reduced burden on the PA. Recently, Jena et al. (2022) provides a well-organized framework for natural resource management (NRM) in Lakhari Valley Wildlife Sanctuary (LVWS), Odisha, and suggested various measure to be taken up for socio-economic upliftment in PAs. In addition to various efforts from the government and non-government organizations, improving livelihood and conservation initiatives in the region to promote local communities' welfare and maintain natural heritage is indispensable. The local/native inhabitants need to be well incentivized for conservation and be provided with alternative livelihood sources to reduce their dependency on the forest. There are several means of alternative livelihood for the people in the SBR, among which ecotourism is the most lucrative and profit-making source. Further, additional works such as forestry and other activities

(e.g. development of meadow and water harvesting structures and other related works), which with trivial training, can be delivered effectively. Such initiatives must include the traditional knowledge held by the local populace and tribes. The aspect of Human-wildlife conflict causing damage to socio-economic profile of humans and death of animals has been sparsely analysed in an around SBR. Roadkills of animals as studied in Behera et al. (2021) can be done here also.

Traditional Ecological Knowledge in PA Management: The traditional knowledgebase held by the native denizens of PAs result from centuries of human innovation and experiments with nature. It is a great repository of indigenous knowledge pertinent to natural resource conservation, e.g., ethnobiological studies (Pandey and Rout 2003) and traditional ecological knowledge (TEK). Although state of the art tools and techniques could be employed in conservation action, due emphasis be given for integrating the TEK in all the conservation and management action programmes. In a recent reporting on LVWS, Odisha, Jena et al. (2022) emphasized on participatory approach in PA management by integrating the TEK in conservation action programmes. As tribals are an integral part of the biosphere reserve, they must be made aware of the ecological wealth of this BR, and their socio-religious beliefs, cultures and traditional knowledge on NRM including language, tradition, culture, scripts, costumes and cuisines, must be preserved, recorded, advertised and utilized, whenever applicable.

To develop strategy for sustainable development with unbiased conservation actions, as suggested by Sahu (1985), Sahu (2005) and Jena et al. (2022), both PA managers and researcher fraternity need to infuse dynamism into the entire program. More importantly, the biosphere reserve's conservation and development paradigm must be essentially synchronized with the broad philosophy of national plans, guided by the principle of *"Faster, Sustainable and More Inclusive Growth"*. Furthermore, it is high time that the biosphere reserve programs in the country must attempt to build an appropriate synergy with the National Action Plan on Climate Change (NAPCC-2008), to address the urgent and critical concerns of the country through a directional shift in the development pathway. By striving towards a holistic goal, the health of the ecosystem and the humans could be in a better state wherein both the environment and the economy can flourish, reorienting the local challenges to national and global dimensions. The biosphere reserves can pro-actively consider integrating conservation efforts within their research and management plans targeting the communities and the ecosystems at parallel and proximate lines. Fulfilling the Man and Biosphere (MAB) program's objectives and goals will help achieve a better ecosystem. The scientific temper must be kept up and periodic assessments and corrective measures as proposed in Figure 3 must be taken in sync with changing time. However, while linking BRs with climate change issues and sustainable development, it would be essential to review the appropriateness of boundaries and functions of existing zones. The reserves wherein these zones have not been adequately defined should get the attention of the respective governments for taking up the issue on a priority basis. In view of these specifics, various threats have been identified and enumerated in Table 1, highlighting some of the conservation efforts for the SBR. This will help the decision makers and managers making an efficient and effective action plan and formulating a comprehensive management plan with respect to this biosphere reserve and/or protected area. Many of these suggestions can be applicable to other PAs as well. Furthermore, as advocated by Zeeshan et al. (2017), a coordination between micro-level (villages inside and on the periphery of the PA) and macro-level (regional or national) conservation governance strategy would ensure sustainable livelihood support for the denizens and reduced burden on the PAs in the country.

ACKNOWLEDGEMENTS

We acknowledge the encouragement and support of the Director, GB Pant National Institute of Himalayan Environment, and Vice Chancellor, Berhampur University.

Authors' Contributions: All authors contributed equally

Conflict of interest: The authors declare that there are no conflicts of interest.

Table 1. Threats prevailing in the Similipal Biosphere Reserve and suggested conservation strategies

Threats/ Issues	Indicator (s)	Conservation strategies	Priority	Mechanism of Implementation	Frequency of Intervention	Anticipated Benefits	Target Beneficiaries
Deforestation	Loss of forest density, Tree remnants, Girdling	Plantations, Afforestation, Check on tree clearance, Policy formulation and timely execution	High	Field visits, Surveys, Data assessment from Remote Sensing, Mapping Forest variables	Yearly	Conservation of ecosystem, Habitat restoration	Flora and fauna of the forest, State Forest department, Environmentalists, the Public
Local interference (Agricultural practice & Livestock)	Forest clearance, Grassland expansion, High density of cattle	Promotion of agroforestry, organic farming, apiculture, horticulture, and Limiting herd size, Feed arrangements for livestock	Medium	Landscape analysis, Questionnaire survey, Provision of organic farm inputs, livestock and feed	Yearly	Improvement in forest cover (tree density), Ecological connectivity, Improvement of the economy of local populace	Local inhabitants, Forest ecosystem
Non- local interference (Mining, Timber collection, Tourism related pollution)	Mining activities, Presence of tree stem, Littering	Regulation of stringent norms, Heavy taxation, fines, and punishments	High	Surveillance and Awareness, Participatory approach towards conservation	Regular	Strike on deforestation, Reduction of pollution	Forest wealth
Soil pollution	Less vegetation growth, reduced algal growth, Littering of wastes	Monitoring soil health, usage of organic fertilizers, afforestation, Proper waste disposal	Medium	Assessment of soil quality, Supply of organic fertilizers, Treatment of wastes	Regular	Reduction of soil erosion, Healthy soil composition, minimization of pollution	Farmers, Local people
Eco-hydrological issues	Physio-chemical parameters	Reduce contamination from source, Water treatment plans, Bio-filter approach, Provision of artificial ponds for wildlife	High	On source check on discarding sewage, Monitoring, and assessment, setting up water treatment devices, Setting up artificial ponds, Plantations along with water bodies	Regular	Minimal soil erosion and contamination, No water shortage during summer months	Flora and fauna of the forest, Local inhabitants
Natural calamities (Cyclones)	Information from the meteorological department	Embarking the forest premises with selective plantation of cyclone-resistant trees	Medium	Mangrove plantations in the coastal areas, Plantation of cyclone-resistant trees and their protection	Decadal	Reduce the stress of cyclones, reduction of soil erosion, protection of other trees	Life, property, and ecosystem

Threats/ Issues	Indicator (s)	Conservation strategies	Priority	Mechanism of Implementation	Frequency of Intervention	Anticipated Benefits	Target Beneficiaries
Human-wildlife conflict	Loss of properties, human life and death of animals by the humans	Creating awareness and avoiding human-wildlife interaction	High	Conducting focused group discussion in villages and convincing the villagers for refraining from aggressive interaction with wildlife, provisioning of appropriate compensation in the event of property loss	Yearly	Protection of properties, human life and wildlife	Human and wildlife
Forest fires	High temperature, Low humidity	Regulated cutting of trees, discarding unwanted logs, Installation of fire-fighting devices, permits for burning in the premises	High	Monitoring of vegetation density, Setting up of fire-fighting equipment and sensors	Yearly	Protection of forest flora and fauna	Wild animals, Floral resources
Poaching	Census data of animals	Obeying wildlife rules, Strict punishments for hunting	High	Awareness among people, Providing incentives for conservation	Regular	Natural security of forest resources, Healthy ecosystem	Wildlife, Conservationists
Exploitation of endemic floral species	Disappearance of useful (medicinal) plants	Propagation of beneficial floral species	Medium	Preparation of seed banks, Research on their composition and genetics	Yearly	Protection of forest integrity	Forest floral wealth, Researchers, Pharmacists (ethno-practioners)
Invasive and Exotic Species	Flourishing of new species	Eradication of harmful exotic species, Control on their spread	Low	Identification via inspection, Headlong way to regulate the reproduction of the exotic species	Yearly	Safe from undue harm to native species, Uphold natural ecological aspects	Fauna and flora of forests
Administrative issues	Instability in ecosystem conservation and management	Proper implementation of laws and forest revenue management	Medium	Patrolling, Awareness, Regulation of rules	Decadal	Habitat protection, Resource fortification	Ecosystem, Forest resources
Threats to tribal people	Fear and hatred towards Government and Public	Participation of public and government for socio-economic upgradation of tribes	Medium	Creation of awareness among people, Arrangement of programs for their economic stability	Yearly	On-time protection of forest resources by the natives	Tribes, Natives, Forest wealth

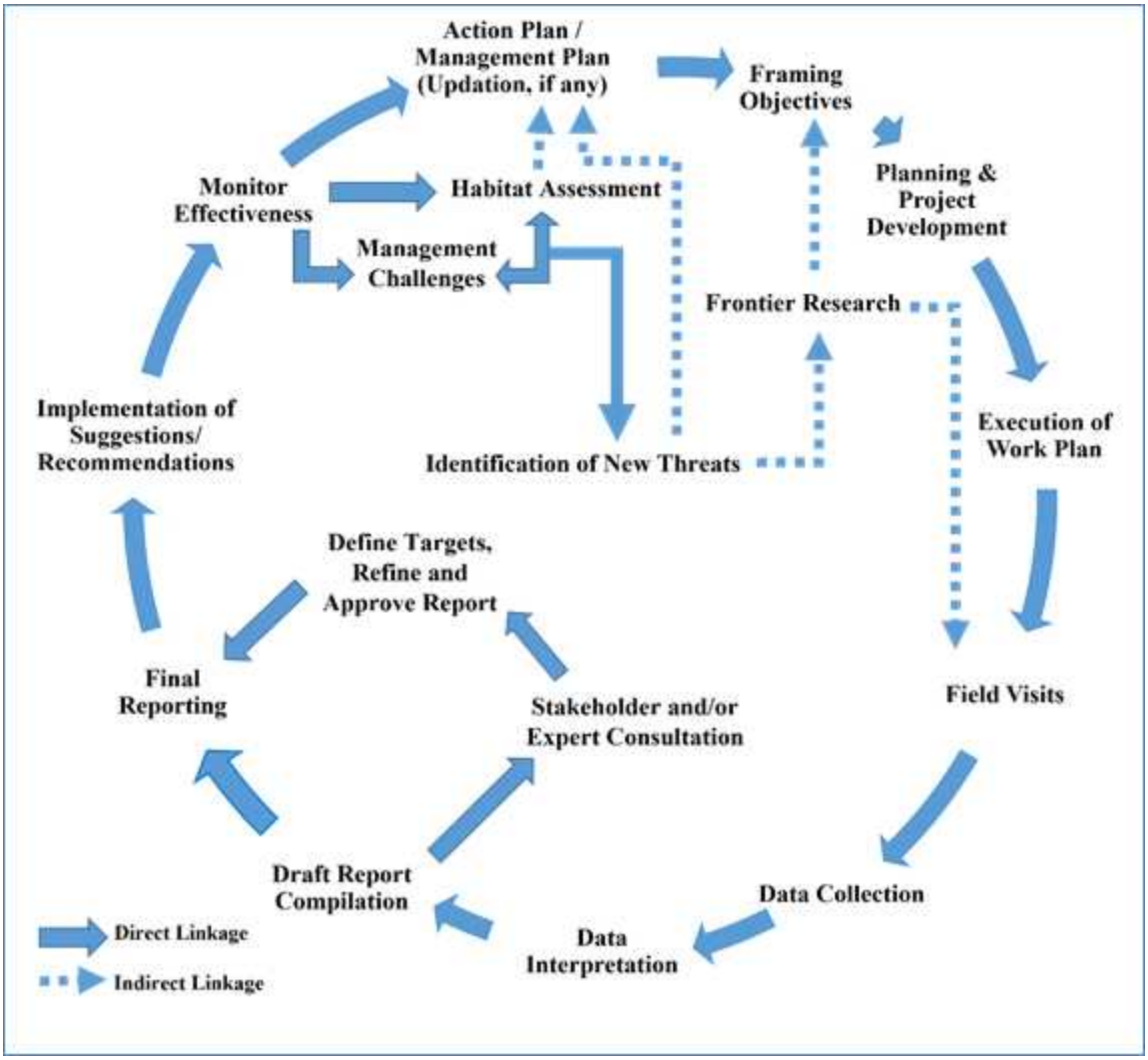

Figure 3.Conservation Action Plan Cycle for Protected Areas

REFERENCES

Agarwalla, S. and Saha, D. 2019. A study on forestry and sustainable livelihood with special reference to Similipal National Park, Odisha. Artha Beekshan. 48 pages.

Alam, A., Behera, K., Vats, S. and Iqbal, M. 2013. A preliminary study on bryodiversity of Similipal Biosphere Reserve (Odisha), India. Archive for Bryology, 157, 1-9.

Anon. 1999. Checklist of Animals: Similipal Tiger Reserve and Similipal Biosphere Reserve, Published by Field Dir., Similipal Tiger Reserve, Bhanjapur, Baripada. Pp.vi + 49

Bal, S. 2002. Some productivity aspects of ten keystone species of Similipal biosphere reserve. Ph.D. Thesis, Utkal University, Odisha.

Baliarsingh, B.K., Kosygin, L., Swain, S.K. and Nayak, S.K. 2013. Species Diversity and Habitat Characteristics of Freshwater Fishes in the Similipal Biosphere Reserve, Odisha with Some New Records. Biological Forum - An International Journal, 5, 64-70.

Behera, K.K. 2006. Ethnomedicinal plants used by the tribals of similipal Bioreserve Orissa, India: a pilot study. Ethnobotanical Leaflet, 10, 149–173.

Behera, S., Nayak, S., Dash, P.K., and Swain, S.K. 2021. Wildlife roadkill in Odisha, India: The threat to biodiversity needs to be addressed. Arxius de Miscel lania Zoologica, 19, 151-159. https://doi.org/10.32800/amz.2021.19.0151.

Bhakta, S., Dutta, P., Sahu, E. and Bastia, A.K. 2015. Soil Crust Algae of Similipal Biosphere Reserve (SBR), Odisha. Journal of Advanced Microbiology, 2, 54-63.

Das, S. and Das, B.P. 1997. Similipal Biosphere Reserve: Genesis of a Historical Reality, Similipal: A Natural habitat of Unique Biodiversity. Odisha Environmental Society, Bhubaneswar.

Das, S.K., Ahmed, R.A., Sajan, S.K., Dash, N., Sahoo, P., Mohanta, P., Sahu, H.K., Rout, S.D. and Dutta, S.K. 2012. Diversity, distribution and species composition of Odonates in buffer areas of Similipal Tiger Reserve, Eastern Ghat, India. Academic Journal of Entomology, 5, 54-61.

Dash, J. 1992. Ecology and techno economic development of the forest based groups in Similipal hills. Ph.D. Thesis, Utkal University, Odisha.

Dash, M. and Behera, B. 2012. Management of Similipal

Biosphere Reserve forest: Issues and challenges. Advances in Forestry Letter, 1(1), 7–15.

Dash, M. and Behera, B. 2013. Biodiversity conservation and local livelihoods: A study on Similipal Biosphere Reserve in India. Journal of Rural Development, 32(4), 409–426.

Dash, M. and Behera, B. 2016. Determinants of household collection of non-timber forest products (NTFPs) and alternative livelihood activities in Similipal Tiger Reserve, India. Forest Policy and Economics, 73, 215–228.

Dash, P. K., Mohapatra, P. K., and Kar, M. 2011. Diversity of Cyanobacteria from freshwater bodies of Similipal biosphere reserve, Orissa, India. E-planet, 9, 1-14.

Dash, P.K, Mahapatra, P.K., Kar, M., Dhal, N.K. and Rout, N.C. 2008. Bryoflora of Similipal Biosphere Reserve with special reference to Liverworts and hornworts, Similipal biosphere Reserve, Odisha, India. Biannual Bulletin of Regional Plant Research Centre, 2(1&2), 32-37.

Dash, P.K. 2010. Biodiversity of aquatic plants of similipal biosphere reserve Orissa India. Ph.D. Thesis, Utkal University, Odisha.

Dash, P.K., Mohapatra, P.P. and Biswal, A.K. 2015. Glimpses of Biodiversity of Odisha. Odisha Biodiversity Board, Bhubaneswar, Odisha.

Debata, S. and Palita, S.K. 2020. Diversity and Abundance of Bats within the Human-Dominated Transitional Zone of Similipal Biosphere Reserve, India: Implications for Conservation. Proceedings of the National Academy of Sciences, India Section B: Biological Sciences, 90, 353-363.

Dev, U.N. 1986. Checklist of the birds of Similipal. Newsletter–Nature and Wildlife Conservation Society of Orissa, 4, 1-57.

Dey, D. 2000. Environmental impact assessment in reproductive behaviour and decreasing population of model ecorace of wild tasar silkmoth *Antheraea paphia* Linn of Similipal Biosphere Reserve, Orissa, India. Ph.D. Thesis, Utkal University, Odisha.

Dikshit, N. and Malik, S.S. 2000. Similipal Biosphere Reserve: Home of cultivated and wild Oryza species. Indian Journal of Plant Genetic Resources, 13 (3), 302-304.

Dikshit, N., Sivaraj, N. and Dikshit, S. 2016. Ethnobotany and traditional health care practices in Similipal Biosphere Reserve, Odisha. Ecology, Environment and Conservation, 22, 1191-1197.

Dutta, S.K. 1997. Herpetofauna assessment of north-eastern Orissa with special reference to Similipal, pp. 92-104 In: Tripathy, P.C., Patro, S.N. (Eds.) Similipal: A Natural Habitat of Unique Biodiversity. Orissa Environmental Society, Bhubaneshwar.

Dutta, S.K. 2003. *Philantus similipalensi,* A new species of Rhacophorid frog in Similipal Biosphere Reserve, Orissa, India. Russian Journal of Herpetology, 10(1), 25-32.

Dutta, S.K., Nair, M.V., Mohapatra, P.P. and Mahapatra, A.K. 2009. Amphibians and Reptiles of Similipal Biosphere Reserve. Regional Plant Research Centre, Bhubaneswar, Orissa. 174 pages.

Eco Tour Odisha. 2019. Community managed nature tourism in Odisha. Annual Report 2018-19. Forest and Environment Department, Government of Odisha. 48 pages.

Indian Express. 2020. https://www.newindianexpress.com/cities/bhubaneswar/2020/feb/10/similipal-tops-as-nature-camps-yield-golden-returns-in-odisha-2101411.html

Jena, P., Majhi, B.K. and Prusty, B.A.K. 2022. Intersectoral Approach for Mitigtion of Threats and Pressures on Lakhari Valley Wildlife Sanctuary, Odisha, India. International Journal of Ecology and Environmental Sciences, 48, 213-227. https://doi.org/10.55863/ijees.2022.0113

Kumar, S., Das, G., Shin, H.S. and Patra, J.K. 2017. *Dioscorea* spp. (a wild edible tuber): A study on its ethnopharmacological potential and traditional use by the local people of Similipal Biosphere Reserve, India. Frontiers in Pharmacology, 8,. https://doi.org/10.3389/fphar.2017.00052

Kumar, S., Jena, P.K. and Tripathy, P.K. 2012. Study of wild edible plants among tribal groups of Similipal Biosphere Reserve Forest, Odisha, India; with special reference to Dioscorea species. International Journal of Biological Technology, 3, 11-19.

Mahapatra, A., Tewari, D. and Baboo, B. 2015. Displacement, Deprivation and Development: The Impact of Relocation on Income and Livelihood of Tribes in Similipal Tiger and Biosphere Reserve, India. Environmental Management, 56,. 10.1007/s00267-015-0507-z.

Mahato, P.S., Bandhopadhyay, K. and Bhunia, G.S. 2021. Assessment of Forest Health using Remote Sensing—A Case Study of Similipal National Park, Odisha (India). Pp. 213-235, In: Mahato, P.S., Bandhopadhyay, K. and Bhunia, G.S. (Eds.), Spatial Modeling in Forest Resources Management. Springer Publishers.

Mishra, B.K. 2010. Conservation and management eûectiveness of Similipal Biosphere Reserve, Orissa, India. Indian Forester, 136(10), 1310-1326.

Mishra, M., Dash, P.K., Alam, A., Sahoo, S. and Das, R. 2016. Current status of diversity and distribution of Bryophytes of Odisha. Plant Science Today, 3(2),186-194.

Mishra, N., Rout, S.D. and Panda, T. 2011. Ethno- zoological studies and medicinal values of Similipal Biosphere Reserve, Orissa, India. African Journal of Pharmacy and Pharmacology, 5(1), 6-11.

Mishra, R.C., Sahoo, H.K., Mahapatra, A.K. and Reddy, R.N. 2011. Additions to the flora of similipal biosphere reserve, Orissa, India, Journal of Bombay Natural History Society, 108, 69-76.

Mishra, R.K. 2002. Phytosociological study of forest ecosystems of similipal biosphere reserve Orissa. Ph.D. Thesis, Utkal University, Odisha.

Mishra, R.K., Upadhyay, V.P. and Mohanty, R.C. 2008. Vegetation Ecology of Similipal Biosphere Reserve, Orissa, India. Applied Ecology and Environmental Research, 6(2),89-98

Misra, R.C. 1997. The Status of Rare, Endangered and Endemic Flora of Similipal Forest. Bhubaneswar. Orissa Environmental Society.

Misra, R.C., Sahoo, H.K., Pani, D.R. and Bhandari, D.C. 2013. Genetic resources of wild tuberous food plants traditionally used in Similipal Biosphere Reserve, Odisha. India. Genetic

Resource and Crop Evolution, 60, 20-33.

Mirza, Z.A., Wareker, P., Mohapatra, P.P., Raju, D., Patil, P., Dutta, S.K. and Pal, S. 2019. Endangered or an artifact of unsound taxonomy? Case of the critically endangered bush frog *Philautus sanctisilaticus* Das and Chanda, 1997. Zootaxa, 4683(4), 563-576.

Mohanta, K. and Nandi, D. 2017. Monitoring Vegetation and Land Surface Temperature Dynamics in Similipal Biosphere Reserve, Odisha. International Journal of Geosciences, 8, 1344-1360.

Mohanta, R., Rout, S.D. and Sahu, H. 2006. Ethnomedicinal plant resources of Similipal Biosphere Reserve, Orissa, India. Zoos' Print Journal, 21, 2372-2374. 10.11609/JoTT.ZPJ.1435.2372-4.

Mohanty, B. 2008. Impacts of wild honey bee *Apis dorsata* on biodiversity and tribal economy of similipal biosphere reserve. Ph.D. Thesis, Utkal University, Odisha.

Mohanty, P.K. 1995. Stimulants and barriers to planned development a study of the hill Kharia a hunting and gathering tribe of similipal hills Orissa. Ph.D. Thesis, Utkal University, Odisha.

Mohapatra, S.D. 2012. Impact of resource dependence by local communities on Similipal Tiger Reserve. Ph.D. Thesis, Pondicherry University.

Mukhopadhyay, S. and Ray, R. 2019. Mother Care among Some Bathudi Tribal Women in Similipal Reserve Forest Area in Eastern India. Pp. 313-325, In: Behera, M.C. (Ed.), Shifting Perspectives in Tribal Studies: from an anthropological approach to interdisciplinarity and consilience. Shifting Perspectives in Tribal Studies. Springer, Singapore.

Nair, M.V. 2007. On the occurrence of Jerdon's Baza *Aviceda jerdoni* in Simlipal Tiger Reserve, with some observations on behaviour and vocalization. Indian Birds, 3(2), 61–62.

Nair, M.V. 2010. Thick-billed Green-Pigeon *Treron curvirostra* in Similipal Hills, Orissa: an addition to the avifauna of peninsular India. Indian Birds, 6(1), 19–20.

Nair, M.V. 2011. Three new butterfly records for peninsular India: Dusky Yellow-breasted Flat *Gerosis phisara* (Moore) (Hesperiidae), Common Gem *Poritia hewitscr* Moore (Lycaenidae) and Great Nawab *Polyura eudamippus* (Doubleday) (Nymphalidae) from Similipal Hills, Odisha, India. Journal of Threatened Taxa, 3, 1624-1628.

Nayak, A.K., Yadav, S.P. and Behera, S.R. 2014. Seasonal occurrence of available prey densities in Similipal Tiger Reserve, Mayurbhanj, Odisha, India. International Journal of Conservation Science, 5, 379-386.

Odisha profile, 2018, Directorate of Economics & Statistics, Odisha Arthaniti' O' Parisankhyan Bhawan, Heads of Department Campus, Bhubaneswar – 751001.

Palei, H.S., Sahu, H.K. and Nayak, A.K. 2016. Estimating the density of Red Junglefowl *Gallus gallus* (Galliformes: Phasianidae) in the tropical forest of Similipal Tiger Reserve, eastern India. Journal of Threatened Taxa, 8(2), 8495–8498.

Pandey, A.K. and Rout, S.D. 2003. Ethnobiology of Similipal Biosphere Reserve, Pp. 85-86. In: XIII Annual Conference of Indian Association for Angiosperm Taxonomy and International Symposium on Plant Taxonomy: Advances and Relevance. University Department of Botany, T.M. Bhagalpur University, Bhagalpur, India.

Pandey, A.K., Rout, S.D. and Pandit, N. 2002. Medicinal plants of Similipal Biosphere Reserve. Pp. 681-686. In: Das, A.P. (Ed.).Perspectives of Plant Biodiversity, Bishen Singh Mahendra Pal Singh, Dehradun.

Pandey, A.K., Varma, S.K., Pandit, N. and Singh, L.A.K. 2000. Medicinal Plants of Similipal Biosphere Reserve. Journal of Indian Botanical Society, 79 (Supp), 52-53.

Patro, S.N. and Panda, G.K. 1994. Eastern Ghats in Orissa: Environment, Resources and development. Orissa Environmental Society. 103 pages.

Ramakrishna, Siddiqui, S.J., Sethy, P. and Das, S. 2006. Faunal Resources of Similipal Biosphere Reserve, Mayurbhanj, Orissa. Conservation Area Series, 28, 1-87.

Rath, S.K., Mohapatra, N., Dubey, D., Panda, S.K., Thatoi, H.N. and Dutta, S.K. 2009. Anti-microbial activity of *Diospyros melanoxylon* Bark from Similipal Biosphere Reserve, Orissa, India. African Journal of Biotechnology, 3(9), 1924-1928.

Reddy, C.D., Pattnaik, C., Mohapatra, A. and Biswal, A.K. 2007. Phyto-sociological Observation of Tree Diversity of Tropical Forest of Similipal Biosphere Reserve, Orissa, India. Tawania, 52(4), 352 -359

Reddy, C.S., Mohapatra, A. and Biswal, A.K. 2008. Aquatic Plant Diversity of Similipal Biosphere Reserve, Orissa, India. Pp. 55-66. In: Proceedings of the National Seminar on Conservation of Eastern Ghats. EPTRI, Hyderabad.

Rodgers, W.A. and Panwar, H.S. 1988. Planning a Wildlife Protected Area Network in India. Wildlife Institute of India. New Forest, Dehra Dun. 314 pages.

Rout, S.D. 2005. Medicinal plants of Similipal Biosphere Reserve. Ph.D. Thesis, T.M. Bhagalpur University, Bhagalpur.

Rout, S.D. 2008 Anthropogenic threats and biodiversity conservation in Similipal Biosphere Reserve, Orissa, India. Tiger Paper, 35(3), 22–26.

Rout, S.D. and Thatoi, H.N. 2009. Ethnomedicinal practices of Kol tribes in Similipal Biosphere Reserve, Orissa, India. Ethnobotanical Leaflets, 13, 379–387.

Rout, S.D., Panda, T. and Mishra, N. 2009. Ethnomedicinal studies on some pteridophytes of Similipal Biosphere Reserve, Orissa, India. International Journal of Medicine and Medical Sciences, 1(5), 192-197.

Routh, S.D. and Panda S.K. 2010. Ethno-medicinal Plant Resources of Mayurbhanj District, Orissa. Indian Journal of Traditional Knowledge, 9(1), 68-72

Saha, D. and Agarwalla, S. 2021. People's Forest Dependence: A Case Study of Similipal Biosphere Reserve, India. Review of Development and Change, 26, 63-82.

Sahoo, D., Sahu, H., Dutta, S.K. and Uppadhyay, H.S. 2012. Sighting of Red-necked keelback (*Rhabdophis subminiatus*) in Similipal Tiger Reserve, Orissa, India. Tiger Paper, 39.

Sahoo, M. 2012. Anthropology of displacement: Case of conservation induced displacement and its impact on indigenous people in Similipal Tiger Reserve, Odisha. Afro

Asian Journal of Anthropology and Social Policy, 3, 45-52.

Sahoo, S., Puyravaud, J.P., Davidar, P. 2013. Local knowledge suggests significant wildlife decline and forest loss in insurgent-affected Similipal Tiger Reserve, India. Tropical Conservation Science, 6(2), 230–240. https://doi.org/10.1177/194008291300600205

Sahu, B.N. 1985. Similipal as a Biosphere Reserve in the natural context. Pp 86-94. In: Patro, S.N. and Mitra (Eds.) Conservations of Similipal in its wilderness. Orissa Environmental Society, Bhubaneswar.

Sahu, H.K., Dutta, S.K. and Sahoo, D. 2011. Study on ecological density and distribution of ungulates in Similipal Tiger Reserve, Orissa, Final Report, Submitted to the Field Director, Similipal Tiger Reserve, Baripada.

Sahu, S.K. 2005 Similipal: A step for conservation. Indo-US workshop, North Orissa University. 22 pages.

Saikh, H., Varadachari, C. and Ghosh, K. 1998a. Effects of deforestation and cultivation on soil CEC and contents of exchangeable bases: a case study in Similipal National Park, India. Plant and Soil, 204, 175-181.

Saikh, H., Varadachari, C. and Ghosh, K. 1998b. Changes in carbon, nitrogen and phosphorus levels due to deforestation and cultivation: a case study in Similipal National Park, India. Plant and Soil, 198, 137-145.

Saranya, K.R.L. and Reddy, C.S. 2016. Long term changes in forest cover and land use of Similipal Biosphere Reserve of India using satellite remote sensing data. Journal of Earth System Science, 125, 559-569.

Saranya, K.R.L., Reddy, C.S., Rao, P.V.V. and Jha, C.S. 2014. Decadal time scale monitoring of forest ûres in Similipal Biosphere Reserve, India using Remote sensing and GIS; Environmental Monitoring and Assessment, 186(5), 3283–3296.

Satapathy, K., Pradhan, S. and Upreti, D.K. 2021. Addition of 96 lichen species to the state of Odisha from Similipal Biosphere Reserve. DOI: https://doi.org/10.3897/arphapreprints.e65955.

Satpathy, B.N., Pradhan, K.C. and Nayak, B.K. 1985. Preservation of Natural Gene Pool of Turru, Silkworm *Antheraea mylitta* Drury in Similipal. Pp. 6l-68. In: Patro, S. N. and Mitra (Eds.).Conservation of similipal in its wilderness, Orissa Environmental Society, Bhubaneswar.

Saxena, H.O. and Brahmam, M. 1989. The Flora of Similipahar (Similipal), Orissa. Regional Research Laboratory, Bhubaneswar.

Saxena, H.O. and Brahmam, M. 1994-96. Flora of Orissa Vol-l-IV, Orissa Forest Development Corporation, Bhubaneswar.

Sethy, P.G.S. 2009. Faunal resources in Similipal Biosphere Reserve, Mayurbhanj, Orissa, a part of Eastern Ghats. EPTRI-ENVIS Newsletter, 15, 3-7.

Sethy, P.G.S., Sahu P. and Mishra S.S. 2009. On the occurrence of two Balitorid fishes of genus *Schistura* mceleland from Similipal Biosphere Reserve. Records of the Zoological Survey of India, 108(4), 37-40.

Sethy, P.G.S., Sahu, P. and Siddiqi, S.Z. 2007. Butterfly fauna in similipal biosphere reserve, Mayurbhanj, North Orissa, India. Indian Forester, 133(10), 1403-1410.

Sethy, P.G.S., Sahu, P. and Siddiqi, S.Z. 2007. Malacofaunal Diversity in Similipal Biosphere Reserve, Mayurbhanj, NorthOrissa. India Geobios, 34, 109-112.

Sial, M.K. 2021. A study on livelihood of tribal people in Similipal National park of Odisha. Ph.D. Thesis, Fakir Mohan University, Balasore.

Singh, K.P. and Kumar, K.A. 2012. A note of the lichens from Similipal Biosphere Reserve, Odisha, India, Indian Journal of Forestry, 35, 383-390.

Swain, D. 2000. Studies on the elephants of Orissa their conservation and management. Ph.D. Thesis, Utkal University, Odisha.

Swain, D. and Nanda, F. 1991. Study of plant diversity in a newly established preservation plot inside Similipal National Park, Odisha, Pp. 73-91. In: Similipal: A Natural Habitat of Unique Diversity. Odisha Environmental Society, Bhubaneshwar.

Swain, D. and Nanda, F. 1997. Study of Plant Diversity in Newly Established Preservation Plot Inside Similipal National Park. Bhubaneswar: Orissa Environmental Society.

Thatoi, H.N., Panda, S.K., Rath, S.K. and Dutta, S.K. 2008. Anti-microbial Activity and Ethno-medicinal Uses of some Medicinal Plants from Similipal Biosphere Reserve, Orissa. Asian Journal of Plant Sciences, 7(3), 260-267.

Tripathy, P.C. and Patro, S.N. 1997. Similipal, a Natural Habitat of Unique Biodiversity. Forest and Environment Department, Orissa Environmental Society, Orissa, India.

Tudu, F. and Mohapatra, R. 2020. Social life of hill kharias of Mayurbhanj of Odisha in eastern India: A historical analysis. Journal of Critical Reviews, 7, 846-853.

UNESCO. nd a. https://en.unesco.org/biosphere.

UNESCO. nd b. https://www.unesco.org/news/en/natural-sciences.

UNESCO. nd c. http://www.unesco.org/new/en/natural-sciences/environment/ecological sciences/biosphere-reserves/asia-and-the-pacific/india/similipal/.

Upadhyay, V.P. 2012. Human ecology of a village in Similipal Biosphere Reserve, Odisha, India. Plant Science Research, 34 (1&2), 54-59.

WII. nd. http://www.wiienvis.nic.in/Database/Biosphere Reserves_8225.aspx

Zeeshan, M., Prusty, B.A.K. and Azeez, P.A. 2017. Protected area management and local access to natural resources: a change analysis of the villages neighboring a world heritage site, the Keoladeo National Park, India. Earth Perspectives, 4, 2. DOI 10.1186/s40322-017-0037-3.

Received:30th July 2021
Accepted:30th August 2022