eISSN 2583-6986
IDEALISTIC JOURNAL OF ADVANCED RESEARCH IN PROGRESSIVE SPECTRUMS (IJARPS)
A MONTHLY, OPEN ACCESS, PEER REVIEWED (REFEREED) INTERNATIONAL JOURNAL
Volume 04, Issue 02, February 2025

Deforestation-Induced Loss of Genetic Diversity in Indian Forest Fauna

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Received: 15 Feb 2025 Accepted & Reviewed: 25 Feb 2025, Published: 28 Feb 2025

Abstract

The forest animals of India are under the threat of extinction because of this loss of genetic resources through the loss of forests. This paper will explore how issues resulting from deforestation such as habitat fragmentation, population bottlenecks and inbreeding depression impact species like the Asian elephant. (Elephas maximus) (Vidya et al. 2006), Bengal tiger (Panthera tigris tigris) (Mondol et al. 2013), and lion-tailed macaque (Macaca silenus) (Ram et al. 2015). They look at molecular technologies for estimating genetic variability and our general focus begins with regard to restoration of habitats, establishment of wildlife passages, and altering of policies among other things. (Chazdon 2019; Hilty et al. 2006). Emphases are placed on the essential cooperation of various management procedures and developments in genetic tools to ensure the survival of such species. (Allendorf et al, 2013).

Keywords:- Deforestation, Genetic Diversity, Indian Forest Fauna, Habitat Fragmentation, Conservation Genetics

Introduction

Integrated management technique and breaking down barriers are a very critical necessity for Effective and efficient functioning of overall Biodiversity mainly due to forest species in India where a greater part of the world's Biodiversity is recorded. The country has a number of different ecosystems like Sundarbans, Western Ghats, Himalayan Forest and several other and it is habitat of many rare and endangered species through which genetic research tools access points are underscored to ensure the survival of the species. (India State of Forest Report 2021). A large number of people depend on forests as their source of food and income and this has a diverse effect on the ecosystem.

Population health, the capability of fauna to maximize survival rate in new environments, and resistance to diseases are all benefitted by genetic diversity, which isakenetic to species' survival of individual species as well as whole ecosystems (Frankham, Ballou, and Briscoe 2010). Diversity is genetically eroded and, as a result, there is inbreeding depression and higher extinction probability of ecosystems.

It is much the same way that diversity is genetically reduced, and because of this, there is inbreeding depression and a greater likelihood of extinction for ecosystems.

Deforestation in India

Current Status and Trends

India has witnessed a shift in its forest cover in the last several decades. The India State of Forest Report 2021 suggests that an area of trees and forests in the country is equal to 80,900 sq km, that is 24.62 per cent of the geographical area of India (India State of Forest Report 2021). In gross terms forest density may have marginally improved but the standard of the forest has reduced during the same period where extremely dense forest area worth of 1,582 square kilometers has depleted since 2019. An alarming trend has emerged: It has

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also emerged that the five, northeastern states with relatively high rates of biological diversity have as a whole lost 1020 sq.km of the forests (India State of Forest Report 2021).

Causes of Deforestation

Agricultural Expansion

The conservation of forests is a serious issue that has been facing many countries in the world since a significant proportion of the forested areas is habitated, and this is done mostly through land clearance with a view to engaging in farming activities. One of the main reasons for deforestation is the need for a growing population to feed itself through agriculture and rearing of livestock (Jha, Dutt and Bawa 2000). The probing issue is worsening the deforestation challenge that is being faced in the northeastern region of India due to new methods of farming (Adhikary, Burman et al. 2019).

Urbanization and Infrastructure Development

New highways, dams and mining operations are all effects of fast urbanization, which is equivalent to the cities growing. Such advancements lead to habitat segmentation through advancement into forested areas (Hoda, Bansal and Khan 2020). Road networks especially highways and railroads are cross cutting wildlife pathways, which are the main areas of habitat fragmentation influences animal movement.

Logging and Timber Extraction

The campaign of this agency points to another major cause for deforestation, which is the cutting of wood in an unlawful manner and carrying out logging cooperatively. Products derived from forests such as wood, fuelwood and other non-timber forest products are produced to meet the demand that is why forests are over exploited (Ashraf, Pandey et al 2015). Consequently, sharp changes in the forest structure and composition as well as the decrease in tree density occur.

Regional Hotspots

For a number of cases, some states have had it that their rate of deforestation is still higher than others. Use alteration of land for agriculture and new roads and highways now lead deforestation across northeastern region including Arunachal Pradesh and Manipur (India State of Forest Report 2021). Being a world heritage site, UNESCO the western ghats is under threat from industrial mining of minerals and plantation (Reddy, Jha and Dadhawal 2016).

Understanding Genetic Diversity

Definition and Components

The genetic variety of a species is the total count with which a species is endowed with different genetic traits in its DNA. It refers to a variety of genes present in various organisms and within the members of the same species (Allendorf, Luikart, and Aitken 2010). Under genetic variation, populations require change and its occurrence takes place in regards including mutation genes, and affects the species through the flows, and sexual reproduction.

Importance for Species Adaptability

It does point out that if a population is highly genetically heterogeneous, there is likely to be some of every number of alleles among the members of the population which are going to be adapted to an environment. Species are in a position to change to new environments, resist new diseases, or experience other changes

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because of genetic variation among them (Frankham, Ballou, and Briscoe 2010). For instance, the fact that every species can develop the capacity to fight diseases which are otherwise deadly, that is, if there is genetic variation.

Consequences of Reduced Genetic Diversity

Reduced genetic diversity is also a problem, for example inbreeding depression which is a phenomenon results when detrimental alleles are inherited by successive generations of closely related people (Charlesworth 2003). Lower fitness reduces the capacity of a population to resist various diseases and other pressures in its environment, and will thus accelerate population declines and even local extinctions.

Impact of Deforestation on Genetic Diversity

Habitat Fragmentation and Isolation

Creation of Small, Isolated Populations

Due to this, animals are forced to live small regions due to fragmentation from factors such as deforestation. The elephant of Asia (*Elephas maximus*), is especially vulnerable when its habitats reduce and become patchy because this species needs extensive home ranges (Sukumar 2003). Martial is true because due to fragmented habitats that limit resources and breeding areas population sizes and genetic variation decreases.

Reduced Gene Flow Between Populations

This is made worse by habitat fragmentation that therefore leads to genomic isolation. As tigers roam Bengal (*Panthera tigris tigris*), it also means fragmented landscapes reduce gene flow and therefore mating opportunities due to increased challenging mobility (Thapa et al. 2018). Consequently, genetic differentiation and destruction of the genetic variation lead to a decrease in the adaptive capability of the species which is isolated.

Population Bottlenecks

Loss of Alleles

This is bad because when the population size is greatly reduced genetic variation is lost, something called a population bottleneck. Lion-tailed mane macaques (*Macaca silenus*), found only in small patches of the forests in the Western Ghats has considerable loss of genetic variation due to habitat destruction (Ram *et al.* 2015). Some species are simply unable to adapt when they have gone extinct.

Increased Genetic Drift

This may occur in small population because genetic drift through random change in allele frequencies lead to fixation of detrimental alleles (Frankham, Ballou, and Briscoe 2010). Growing genetic drift aggravates the impacts of habitat loss on the reduction of genetic variation and render the Asian elephants more susceptible to extinction (Vidya *et al*., 2006).

Inbreeding Depression

Accumulation of Harmful Mutations

For a start, when populations are in fragments, the level of inbreeding rises and when this happens, it is possible for unfavourable gene mutations to accumulate (Charlesworth and Willis 2003). Crossbreed Bengal

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tigers show they have a shorter life expectancy and are more likely to be born with health complications, scientists find (Mondol *et al.* 2013).

Decreased Reproductive Success

That is why inbreeding depression has a negative effect on fertility and reproductive success. Low rates of neonatal survival in lion tailed macaques dwelling in isolated habitats are expected due to inbreeding. (Kumara and Sinha 2009).

Table 1: Summary of Genetic Effects Due to Deforestation

Species	Genetic Impact	Reference
Asian Elephant (*E. maximus*)	Reduced gene flow	(Vidya and Fernando 2006)
Bengal Tiger (*P. tigris tigris*)	Genetic defects	(Mondol et al. 2013)
Lion-tailed Macaque (*M. silenus*)	Inbreeding depression	(Ram et al. 2015)

Assessing Genetic Diversity

Molecular Markers and Techniques

Microsatellites

They are simple sequence repeats of 1-6 base pair repeats that are present throughout the genome and are also called microsatellites. Overall due to its high polymorphism and co-dominant inheritance they are preferred for the analysis of population structure and genetic differentiation (Selkoe and Toonen 2006). Due to their ability to detect very small differences in genes, microsatellites have enormous potential for use in conservation genetics.

Mitochondrial DNA Analysis

The mitochondrial genome is maternally inherited and nonrecombinant, focusing mtDNA analysis on variation in this genome. Scientists study population history and molecular phylogenetics by having features like regulatory region sequences and the cytochrome b gene (Avise 2000). mtDNA is useful in making tests when it comes to the pedigree chart and also when there is endeavour to understand the movement of gene through generations.

Single Nucleotide Polymorphisms (SNPs)

Another type of genetic difference refers to changes in single nucleotide between individuals that occur with a frequency of 1% or higher are called Single Nucleotide Polymorphisms (SNP's). They facilitate further, accurate, genetic analyses since they are highly represented and widespread across the genome. (Morin et al 2004). The SNPs enable large scale genotyping and imparts information on adaptive variation.

Table 2: Comparison of Molecular Markers Used in Genetic Diversity Studies

Marker	Polymorphism	Inheritance	Applications
Microsatellites	High	Nuclear (biparental)	Population structure, kinship

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Mitochondrial DNA	Moderate	Maternally inherited	Phylogeography, tracing	lineage
SNPs	Variable	Nuclear (biparental)	Genome-wide studies	association

Population Genetic Studies

The population genetics analytical methods employ statistical methods when analysing genetic diversity and structure in and between populations. The amounts of genetic differentiation are understudied by F-statistics While AMOVA is used to estimate genetic variation at several organismal hierarchy levels (Excoffier, Smouse, and Quattro 1992). Since the actual limits of population are unknown, software like STRUCTURE can use Bayesian approach to cluster the population. (Pritchard, Stephens, and Donnelly 2000).

Importance of Genetic Monitoring

Genetic screening refers to the systematic check-up of genetic content once in a while in other to be able to determine fluctuations over time. In conservation planning it is rather important because it allows evaluating the declining genetic stock, inbreeding rates, and efficiency of measures taken (Schwartz, Luikart, and Waples 2007). For the prevention of genetic depression and for the proper conservation of species, their genetic state has to be checked periodically.

Conservation Strategies and Implications

Habitat Conservation and Restoration

Reforestation Efforts

Reforestation is highly effective in contributing to the restoration of lost habitats and also the improvement of genetic structure by means of larger population densities and covare intensities (Chazdon and Brancalion 2019). Afforestation and re-afforestation is the aim of such a schemes as India's National Afforestation Programme (India State of Forest Report 2021). Such endeavors are essential for supporting biological diversity since they supply homes for species and store carbon.

Protection of Remaining Forests

Bridging some areas and making them protected as national parks, wildlife sanctuaries etc help in avoiding interference from man and his destructive activities in as far as conservation of genetic stock of animals in the forest is concerned (Athreya *et al*, 2015). The protection of these areas is complimented with the involvement of people and conservation of natural resource and the enforcement of anti-poaching measures.

Establishment of Wildlife Corridors

Population isolation to negative impacts can be eased by creating wildlife corridors through which genes from distant populations can be exchanged (Hilty, Lidicker *et al*, 2006). Schemes in Indian landscape like the Terai Arc Landscape of corridor projects ensure that there are broken cover of forest where animals like elephants and tigers can conveniently move and hybridise (Johnsingh, Ramesh *et al*, 2004). These patterns also play a role of buffering any negative impacts that arise when animals from close family are bred while enhancing genetic diversity.

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Ex-situ Conservation Measures

Captive Breeding Programs

Many captive breeding programs help in the off-site conservation as they try to keep the genes of endangered animals. (Ballou *et al.,* 2010). To re-establish the feral population and to start breeding for the programme, the Lion tailed macaque is under the administration of Central Zoo Authority of India.

Genetic Rescue Initiatives

To enhance fitness and genetic diversity genetic rescue involves the introduction of individuals from different populations. (Whiteley et al. 2015). To reduce inbreeding one approach that can be used is to translocate the tigers from one reserve to the other. (Jhala, et al 2021).

Policy and Legislation

Forest Conservation Acts

Thus, the laws regulating the use of trees and which try to control the felling of trees include the Indian Forest Act of 1927 and the Forest Conservation Act of 1980 (Saheb et al, 2012). Conservation of forests and biodiversity, together with the protection of endangered species, is encapsulated in these statutes.

Role of Government and NGOs

Most of the conservation programs are always trailed by the government agencies and especially the non-Governmental organizations NGOs including the Wildlife Trust of India (India 2020). Governments together with Non-governmental organizations enhance the effectiveness of conservation interventions through policy formulation and implementation, research, and community participation in conservation programmes.

Table 3: Summary of Conservation Strategies and Their Benefits

Strategy	Benefits
Reforestation	Restores habitats, increases connectivity
Protection of Forests	Preserves existing biodiversity
Wildlife Corridors	Facilitates gene flow, reduces inbreeding
Captive Breeding	Preserves genetic material, supports reintroduction
Genetic Rescue	Increases genetic diversity, enhances fitness
Policy Enforcement	Regulates resource use, prevents deforestation
Community Involvement	Enhances conservation effectiveness

Challenges and Future Directions

India is still struggling to find balance between the two important causes – economic development and conservation. Strategies for sustainable development need to be adopted as a result of increased demand in forest products occasioned by increasing industrialization and population growth (Rodrigues and Brooks 2007). Sustainability factors that are usually social, economic, and ecological issues play an important role in the overall management of the natural resources to ensure that the aim of the conservation process will be well

achieved in the future. (Sayer et al. 2013). Various improvements in assessing measures of genetic variation and applying conservation plans can be attributed to advanced genetic tools such as next generation sequencing. (Allendorf, Hohenlohe, and Luikart 2010).

Conclusion

Frequent deforestation has affected many forest animals in India where most of them have become extinct. These animals including lion-tailed macaque, Bengal tiger, Asian elephant and many more are experiencing the ill effects of inbreeding, population bottlenecks, habitat fragmentation as explained in this article. Thus, in order to lessen these impacts and preserve bio-diversity there are some urgent conservation actions needed. For the overall conservation measures to be implemented the governments and NGOs, scientists and local communities must get involved to ensure that endangered species exist in the future.

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