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Genetic Diversity in Endangered Species Conservation

Brief: Explore genetic diversity and its importance in the conservation of endangered species

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Chapter 1: Introduction

1.1 Background

Genetic diversity is considered variation at the DNA level which is necessary for adaptation, long-term survival, and resilience for populations as well for species. DNA is the raw material which is inherited from generation to generation as the demographic process in a population such as reproduction, dispersal, and survival, is reflected by patterns of genetic variation (IUCN, 2024). Thus, genetic differences among populations enable species to adapt to vironmental changes, and genetic diversity means safeguarding biodiversity.

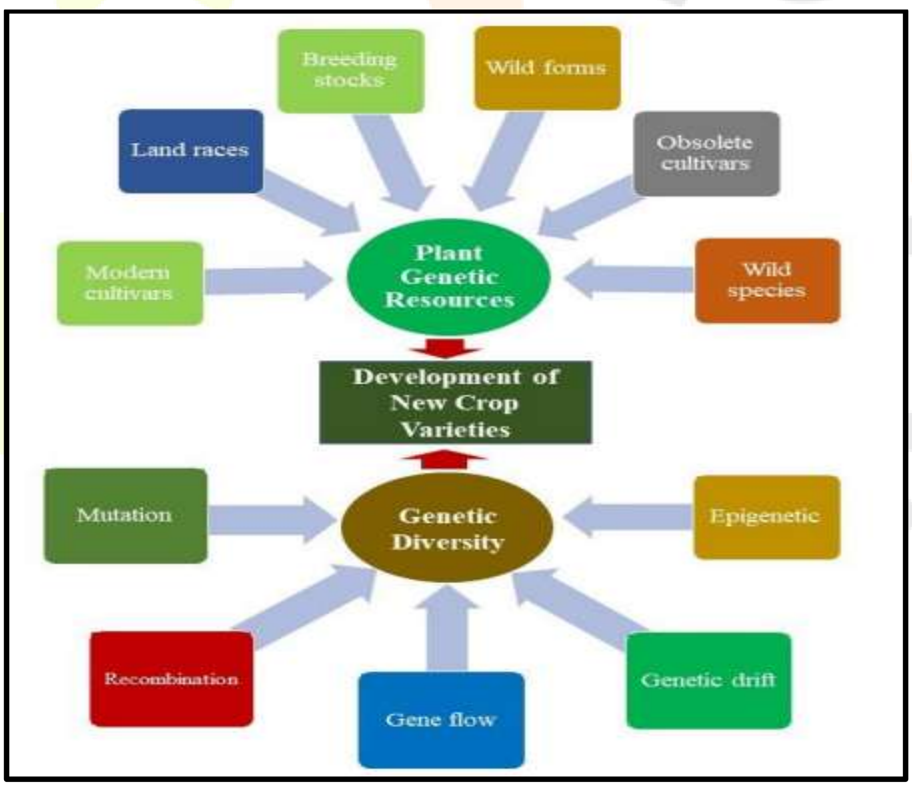

Figure 1.1: Different sources of genetic diversity and development of new crop varieties

(Source: Salgotra *et al.* 2023)

As shown in Figure 1.1, there is a wide range of genetic resources present in plants that can give rise to novel varieties of horticultural crops. In this context, several biotechnological techniques, such as high-throughput sequencing, cryopreservation, and genetic engineering, are carried out to conserve and preserve rare and endangered plant genetic resources or ***PGRs. [Referred to Appendix 1]***

1.2 Rationale

A lack of genetic variety among plant populations has been observed in plant populations, which is evident from *Phytophthora infestans* that caused fungal infection in potatoes across several regions of India and China (Wang *et al.* 2019).

Low gene flow between countries made this particular species highly susceptible to pathogens due to weakened immune systems. Apart from these, species such as Cheetah or *Acinonyx jubatus* hibited low genetic diversity due to population bottlenecks. It is found that the Tasmanian tiger or Thylacine has been extinct due to low genetic diversity, and habitat destruction. Besides, the Northern White Rhinoceros are almost extinct as they are susceptible to disease with low genetic diversity.

Lowered genetic diversity results in a fragmented, disruptive ecosystem interconnected to human survival. The "Central European Institute of Technology" ***CEITEC*** demonstrated the extremely perilous conservation status of Asiatic and African Cheetahs as they are categorised as endangered by IUCN (Prost *et al.* 2022). These cheetahs had genetic uniformity and genetic depletion that weakened their immune systems and made them susceptible to disease. ***[Referred to Appendix 2]***

To protect the endangered species due to reduced genetic diversity, this study emphasises conserving strategies that can be adopted to increase these species over time.

1.3 Aim and Objectives

Aim

The aim of this research was to explore the role of genetic diversity in enhancing the conservation and survival of endangered species with a focus on ecosystem stability and species adaptation.

Objectives

- To assess the importance of genetic diversity in improving the resilience of endangered species, such as habitat loss, climate change, and disease outbreaks.
- To evaluate the impacts of reduction in genetic diversity concerning survival rates and reproductive success among critically endangered species across various regions.
- To analyse the current conservation strategies for the survival of endangered species.

1.4 Significance

The present study is highly significant as it demonstrated different aspects of genetic diversity among plants, and animal species contributing to the need for conservation status. Moreover, the impacts of reduced genetic diversity and conservation strategies are conferred in this study, which is essential for endangered species.

Chapter 2: Literature Review

2.1 The role of genetic diversity in endangered species resilience

Genetic diversity is the presence of a variety of genes within a species contributing to ***variation*** in traits such as colour, size and resistance to disease. Moreover, genetic diversity caters to the aspects of ***evolutionary resilience*** as a broad gene pool enables the population to survive environmental changes such as habitat loss or climate shifts (Kardos *et al.* 2021). This is essential for endangered species as they encounter rapidly changing environments. On a similar note, Bragg *et al.* (2021) claimed that species in possession of higher genetic variation can withstand environmental stressors such as temperature fluctuations, climate changes, and habitat loss owing to their adaptive traits.

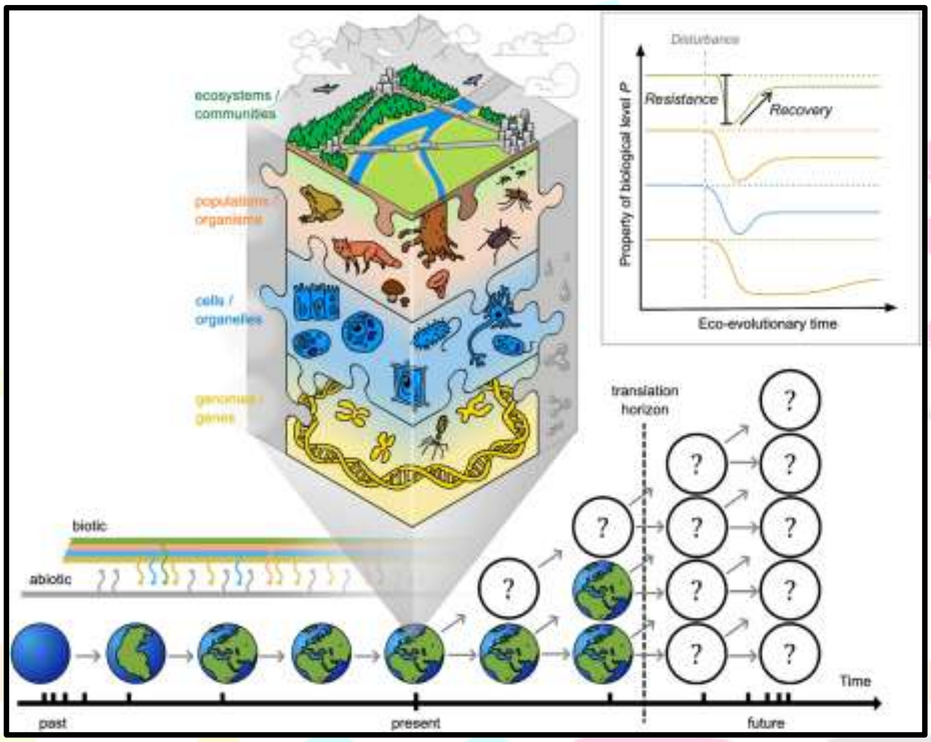

Figure 2.1: Biological Resilience Framework

(Source: Thorogood *et al.* 2023)

Biological resilience is mediated by connections among, and within the levels of organisations. As shown in the above figure, with the commencement of time, there has been a rise in genetic diversification in post-biotic and abiotic species which lead to resilience and recovery of species. From the studies carried out by Santos *et al.* (2019), it was found that African elephants <u>*Loxodonta africana*</u> with more genetic diversity were adaptable to environmental changes as they resisted habitat loss and poaching.Apart from these, species with higher genetic diversity can produce offspring that can tolerate temperature fluctuations to ensure higher survival rates. As viewed by Söderquist *et al.* (2020), ***inbreeding depression*** can be mitigated through genetic diversity, which is common among smaller populations, and harmful traits can become prevalent with a decrease in fitness. Furthermore, genetic diversity is a core aspect of the "essential biodiversity variables" or ***EBVs*** for the long-term persistence of species and minimising genetic erosion (Hoban *et al.* 2022). Besides, the differences in environmental sensitivity can also be understood with a population of higher genetic diversity due to the presence of adaptive traits.

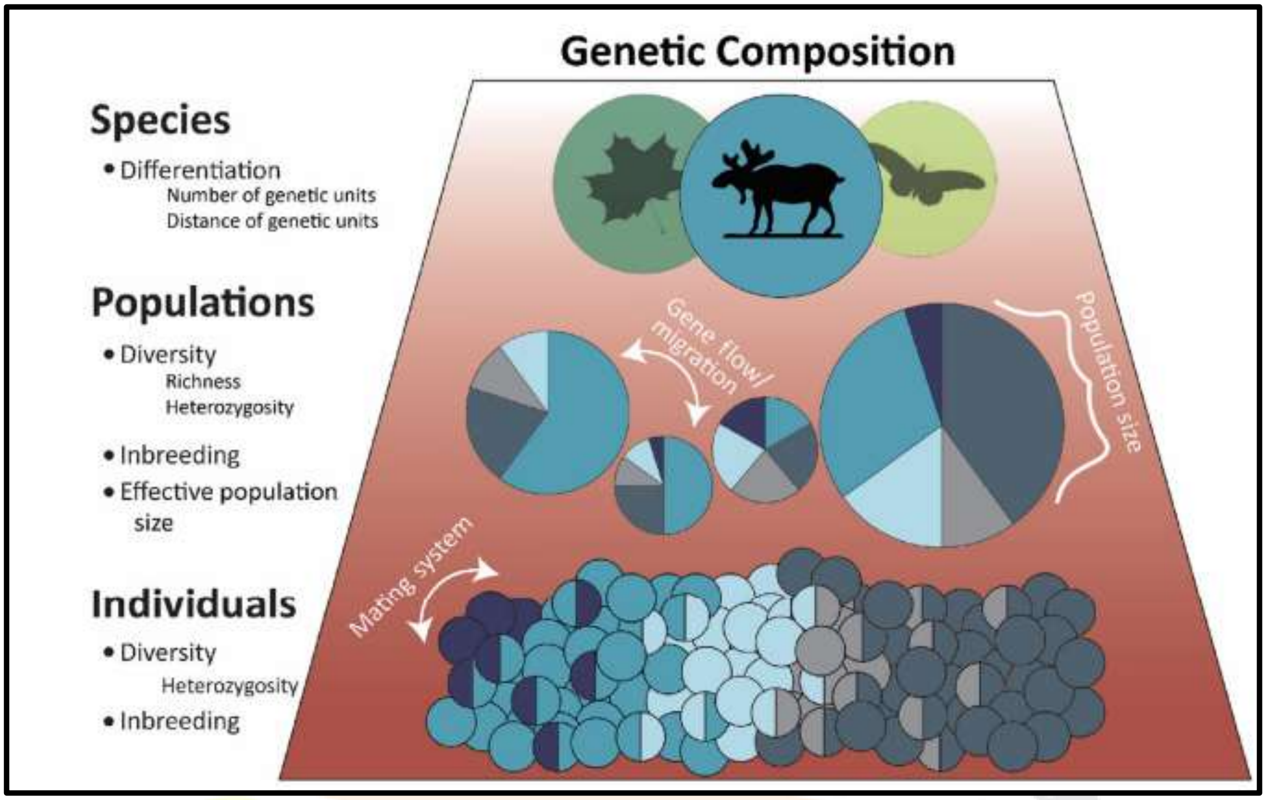

Figure 2.2: Four EBVs

(Source: Hoban *et al.* 2022)

Figure 2.2 depicts the level of biological organisations, such as populations and individuals corresponding to species at the topmost level, where the number and distance of genetic units are paramount. Thus, genetic differentiation, that is, genetic diversity, is responsible for building resilience among species.

2.2 Consequences of Reduction in genetic diversity on Reproduction and survival rates of endangered species

Reduced genetic diversity poses ample risks to endangered species, especially in isolated or small populations. In this context, as stated by De Kort *et al.* (2021), a genuine consequence of reduced genetic diversity is the lowered capability of the species to combat environmental stressors such as pollution, habitat fragmentation, and climate change. Moreover, the species lose their necessary traits to survive in altered environmental changes, such as reproductive, morphological, and behavioural traits, due to reduced genetic diversity, and there can be a decline in population diversity regarding environmental changes. Besides, Swarup *et al.* (2021) imprinted that populations with higher genetic diversity can be ***less susceptible*** to disease as low genetic diversity is invariably related to the weakened immune system of the population. However, a smaller gen pool can be beneficial to preserve specific advantageous traits with its stabilisation offering survival advantages, although they can be short-term. Besides, there can be reduced competition among the population with efficient use of the existing resources.

Figure 2.3: American Chestnut forest

(Source: Powell *et al.* 2019)

Apart from these, ***habitat fragmentation*** is common in the reduction in genetic diversity which was studied in Australian Freshwater fish, *Macquaria australasica* by "population genetic and riverscape genetic analyses and simulations" (Pavlova *et al.* 2017). It was found that there was limited gene flow among these species which heightened the risks of extinction of the species along with inbreeding depression. In this way, harmful genetic traits can be exposed, which could have been masked in a diverse population due to the presence of other dominant traits. On the other hand, Powell *et al.* (2019) claimed that reduced genetic diversity can give rise to ***population bottlenecks*** where the loss of important genetic traits can be prominent as it prevents species from responding to evolutionary pressures. Population bottleneck was evident in the American Chestnut tree, *Castanea dentata*, which was once dominant in North America, was wiped out by the pathogen *Cryphonectria parasitica*, which was brought from Asia (Refer to Figure 2.3). 90% of the chestnut population was destroyed by ***chestnut blight*** where the bottleneck was evident which gave rise to limited tolerance to blight (Stoltz and Husband, 2023).

2.3 Global efforts and conservation strategies for endangered species

Conservatives have become paramount for the endangered species, and conservationists have developed various strategies to increase genetic diversity. Commitments to conserving genetic diversity became important under the "Convention on Biological Diversity", or ***CBDs*** draft post-2020 "global biodiversity framework" or ***GBF*** (Hoban *et al.* 2023). Moreover, the "Global Strategy for Plant Conservation" or ***GSPC*** is essential for the conservation of plant species with its "2011-2020 target" of a 75% increase in plant diversity (CBD, 2020). The "International Union for Conservation of Nature" ***IUCN*** assessed the importance of genetic diversity by prioritising conservation efforts (Schmidt *et al.* 2023). In this context, IUCN emphasised the need for the conservation of African gorillas, *Gorilla beringei* where poaching and habitat loss led to a reduction in genetic diversity. With the "International Gorilla

Conservation Program" or ***IGCP,*** the species received a status of "endangered" from "critically endangered" as the numbers of the species increased from 1004 in 2018 to 1063 in 2023 (Africa Geographic, 2019).

Apart from these, *Paeonia decomposita* was regarded as an endangered species due to fragmentation of natural habitats in China and had superior economic, and medicinal value. For this reason, plant breeding programs were carried out in different parts of China, which included "amplified fragment length polymorphisms", or ***AFLP,*** and "inter simple sequence repeats," or ***ISSR*** (Wang, 2020). Besides, ***translocation strategies*** were applied to North American bighorn sheep, *Ovis canadensis*, catering to future ecological restoration and inbreeding dispersion (Flesch *et al*. 2020). Lastly, the "US Endangered Species Act" or ***ESA*** of 1973 is the most effective law to protect at-risk species where 99% of species listed in it avoided extinction (WWF, 2024). For this reason, conservation is helpful in increasing the genetic diversity among the population.

2.4 Eco Evolutionary Theory

The resilience of endangered species can be well understood with eco-evolutionary theory or EET as it addresses local ecological problems from the past to the present. This theory demonstrates the evolutionary changes and ecological processes regarding the adaptability and survival of species. Genetic diversity is the core component of adaptation that allows species to respond to environmental shifts followed by heightening survival, or resilience. Additionally, while ***conservation*** is considered, EET highlights that the primary focus must not be on preserving the endangered population, as safeguarding genetic variations is equally important (Thorogood *et al*. 2023). Therefore, by maintaining genetic diversity, an acquired resistance can be provided to future disturbances.

Chapter 3: Methodology

3.1 Research philosophy

Research philosophy is the assumption and development of knowledge for a particular study. In this present study, the researcher adopted the "***interpretivism philosophy***" this philosophy, and the researcher can get an insight into social life followed by the development of scientific knowledge regarding phenomena (Ali *et al*. 2021). In this study, the researcher gained insights into the core aspects of genetic diversity along with the requirement of conserving endangered species.

3.2 Research Approach

For conducting an in-depth analysis of research, the research approach is pivotal, where the most common approaches are deductive inductive, and abductive approach. For this study, a "deductive approach" has been considered by the researcher where generalisation of findings can be done. Moreover, the deductive approach explains the relationships between the variables and concepts (Okoli, 2023). In this context, the researcher has been able to understand the intricate relationship between genetic diversity and the extinction of populations across the world. Furthermore, the deductive approach examines the outcomes of findings, which was beneficial for the researcher as the outcomes of reduced genetic diversity was understood.

3.3 Research Design

The design of research caters to the overall strategy of the research to evaluate various components in a logical way. For this particular study, the researcher adheres to the "***explanatory design***", which gives proper insights into a particular situation (Kirby *et al.* 2024). In this context, the key elements of genetic diversity, such as evolutionary resilience, inbreeding depression, and habitat fragmentation, are well understood.

3.4 Data collection method

Data collection has been performed through a "***qualitative method***" as information was collection through articles and journals. In this regard, most of the information was retrieved from "PubMed", "Nature" and "Google Scholar." The role and importance of genetic diversity along with the conservation of endangered species, were evaluated while maintaining the research efficacy.

Inclusion	**Exclusion**
● Relevant and properly cited articles were chosen from "PubMed", "Nature" and "Google Scholar." ● Articles and journals with authentic information and the English language were considered.	● Irrelevant and improperly cited articles were discarded ● Articles other than English and improperly structured papers were excluded.

Table 3.1: Inclusion exclusion table

(Source: Author)

Keywords	***And/Or***	***Keywords***	***And/Or***
Genetic diversity	And	Endangered species	Or
Conservation	Or	environmental changes	And
population bottlenecks	And	EBVs	Or

Table 3.2: Boolean table

(Source: Author)

3.5 Data Analysis

For the evaluation of research objectives, data analysis is considered an important step where the researcher analyses collected data to achieve its objectives. ***Thematic analysis*** was undertaken for this research, which helped the researcher to make codes and themes for the interpretation of results. Thematic analysis is suitable for qualitative research, where a detailed evaluation of various literature is conducted, followed by the formation of suitable themes (Dawadi, 2020).

Chapter 4: Results and Discussion

4.1 Introduction

Results and discussion are crucial chapters in a dissertation as they help in gathering important information on the basis of the topic. Thus, in the current study regarding genetic diversity in endangered species conservation, the data collected through secondary research and forming themes helps in navigating the research questions and meeting the objectives of the study.

4.2 Findings

4.2.1 Theme 1

Assessment of the importance of genetic diversity in improving the resilience of endangered species to habitat loss, climate change, and disease outbreaks

Author	**Methodology**	**Findings**
(Salgotra and Chauhan, 2023)	Secondary qualitative	The study reveals the relevance of plant Genetic Resources (PGRs) in improving resistance to adverse factors within the farming System and food Security. Consequently, it stresses genetic conservation, the use of technologies, supporting local communities and increased availability of PGR collection to meet the demand of the increasing population.
(Gibson, 2021)	Secondary qualitative	The paper establishes that the efficiency of the genetic structure of the host population against parasitism is rather low. The genetically similar population is more vulnerable to diseases after population shrinkage. This linkage between genetic diversity and disease is central to conservation, agriculture and disease control. Hence, there should be an enhanced focus on genetic variation in population control.

Table 4.1: Significance of genetic diversity

(Source: Author)

4.2.2 Theme 2

Evaluation of the impacts of reduction in genetic diversity concerning survival rates and reproductive success among critically endangered species across various regions

Author	**Methodology**	**Findings**

(Wang *et al.* 2019)	Primary quantitative	The research conducted in this area identified that the WHL is genetically the most threatened of all the primates largely due to reduced genetic variation that has probably been an effect of a small population history and a very recent origin. This decrease in genetic variation, along with the fragmentation of habitats in the recent past, may have negative effects on survival and reproductive ability, which highlights the importance of habitat restoration.
(Sadler *et al.* 2023)		The work reveals that depleted genetic variation due to fishing affects survival rates among the endangered species. These differences are explained by habit and life cycle differences or methodological differences. Greater management through establishing protected areas and restoration programs should, therefore, focus on such issues as loss of genetic diversity and come up with measures and strategies that can support the species to recovery.

Table 4.2: Impacts of reduction in genetic diversity

(Source: Author)

4.2.3 Theme 3

Analysis of the current conservation strategies for the survival of endangered species

Author	**Methodology**	**Findings**
(Theissinger *et al.* 2023)	Survey	The study finds out that reference genomes are fundamental to every aspect of conservation and biodiversity genomics, from orienting the genetic variation to finding out the adaptive traits and solving the inbreeding problems. Examples are illustrated in their application in the regulation of species' genetic variability, identification of structure variants, and climatic changes. The incorporation of reference genomes is useful in strengthening the

		conservation and management compartments as well as in the formulation of adaptive measures.
(Teixeira and Huber, 2021)	Systematic literature review	The study underscores that the presence of a neutral genetic diversity is inadequate in predicting the risk of extinction of species. Therefore, an effective strategy of conservation with the incorporation of functional genetic diversity, ecological interactions and demographic history can be vital. The knowledge regarding these factors can help in making better conservation efforts and enhance the chances of long-term survival of the endangered species.

Table 4.3: Conservation strategies for endangered species

(Source: Author)

4.2 Discussion

Theme 1

According to the study of Salgotra and Chauhan (2023), Plant Genetic Resources (PGRs) play a key role in enhancing resistance to the adverse aspects in the farming systems focusing on the need for genetic conservation in order to meet the demand of people. A similar sentiment is echoed through the literature review section of the study, where it is underscored that genetic diversity surrounds a variety of genes within a species, which contributes to trait variations related to resistance to diseases (Kardos *et al.* 2021). Based on the literature review, the study has grounded its claim on the fact that genetic differentiation is crucial for species adaptation or evolution, mentioning factors such as habitat destruction and climate change as forming the basis of such changes (Hoban *et al.* 2022). Bragg *et al.* (2021) also noted that species with higher Genetic variation can cope with environmental stressors because of adaptive traits possessed. This is well illustrated in the study of Gibson (2021), where it is clearly presented and suggested that a genetically diverse population is actually less prone to diseases and other negative factors, further confirming the implied importance of genetic variation in population and disease regulation.

The integration of the biological resilience framework in ***Figure 2.1*** also discusses that genetic diversification over time can significantly contribute to the recovery and resilience of the endangered species. This framework synchronises well with the conclusion of the study which says that genetic variations are the central idea surrounding conservation efforts as it helps in the enhancement of the ability of the population to recover from adverse situations. The study by Santos *et al.* (2019) in the literature review section supported this by stating that African elephants, *Loxodonta africana*, with greater genetic diversity, were successful enough to adapt to the changes in the environment, which strengthens the focus of the study on the advantages of genetic variations.

Theme 2

Wang *et al.* (2019) highlighted many vulnerabilities of the species, like the White-headed Langur, which has faced mainly low genetic variation due to the reduction of population and also habitat fragmentation. This has deteriorated the reproductive cycle, which has made survival tough for the species. This exceptionally believed was reverberated in the literature review section of the research, where it was noticed that minimal genetic variation can subvert the capacities of the species to get through environmental trends, for example, climate change and fragmentation of the habitat. Kort *et al.* (2021) have said this can prompt limited morphological characteristics, which are significant for species survival.

As expressed by Sadler *et al.* (2023) the endangerment of the species implies that the genetic variations are drained due to elements, for example, overfishing, which thusly endangers the sustenance of the species. These findings can be connected with the study of Swarup *et al.* (2021), who have said that a lower genetic diversity is connected with a weaker immune system which can make species more vulnerable to diseases. Consequently, the studies have demonstrated an earnest requirement for management approaches, for example, the restoration and protection of habitat to counter the loss of genetic diversity. Pavlova *et al.* (2017) acknowledge that fragmentation of habitat and restricted gene flow is typical in the reduction of genetic variation and inbreeding depression, as observed in the Freshwater fish of Australia *Macquaria australasica*.

The study by Powell *et al.* (2019) also focused on population bottlenecks, which result in low variability. This can hamper certain elements from evolving and adapting to different scenarios. This was also experienced by the American Chestnut tree, where a pathogen *Cryphonectria parasitica* had eradicated about 90% of the population, further compounded by the low genetic diversity available in the remaining trees.

Theme 3

Conservation strategies related to endangered species have substantially evolved with the rising understanding of genetic diversity along with its impacts on the survival of the species. In the study by Theissinger *et al.* (2023), the critical role of reference genome in the conservation of biodiversity is underscored, which is a digital nucleic acid sequence database that helps in understanding genetic variations and adaptive traits along with the inbreeding issues. Therefore, through the integration of reference genomes, conservation efforts can help in the regulation of the genetic variability of species by better managing the changes in climate and strengthening overall management efforts. In a similar context, Teixeira and Huber (2021) said that there are limitations in completely relying on neutral genetic diversity for predicting the risks that can result in the extinction of specific species. Thus, advocating strategies such as the integration of functional genetic diversity, demographic history, and ecological interactions can contribute to better and more sustainable conservation efforts.

The findings can thus be aligned with the literature review, which focuses on the broader conservation efforts highlighted in the ***CBD*** and ***GBF,*** which focuses on genetic diversity as the primary aspect of the prevention of species (Hoban *et al.* 2023). For example, ***IUCN*** has emphasised the conservation efforts for safeguarding species like the African Gorilla or *Gorilla beringei,* which has led to increased numbers due to programs such as ***IGCP,*** addressing the loss of genetic diversity due to habitat degradation and poaching (Africa Geographic, 2019). In addition, conservation efforts for safeguarding plant species such as *Paeonia decomposita* in China have also been made, which further underscores the role of genetic strategies, such as ***AFLP,*** in restoring species through medicinal and economic value (Wang, 2020).

4.3 Summary

The current chapter highlighted the significance of genetic diversity in working on the resilience of endangered species to environmental issues, for example, climate change, loss of habitat and outbreak of diseases. The discussion chapter underlined the impact of decreased genetic diversity on the survival and reproduction of the species, zeroing in on the job of conservation strategies in protecting biodiversity.

Chapter 5: Conclusion

5.1 Conclusion

The current study has highlighted the significance of genetic diversity alongside its effects on endangered species with the assistance of strategies advanced by IUCN, like AFLP and IGCP. The research has used an interpretivism research philosophy with a deductive approach and explanatory research design. Also, the findings and discussion chapter have expressed that genetic diversity can assist with working on the resilience of endangered species to handle issues like climate change and loss of habitat.

5.2 Linking with Objectives

Objective 1: To assess the importance of genetic diversity in improving the resilience of endangered species, such as habitat loss, climate change, and disease outbreaks

The first objective was efficiently linked with the discussion section, which states that genetic diversity enhances the resilience of species to environmental changes.

Objective 2: To evaluate the impacts of reduction in genetic diversity concerning survival rates and reproductive success among critically endangered species across various regions

The second objective of the study was efficiently linked with the discussion section, which stated that a reduced genetic diversity could lower the resilience of species to environmental stressors.

Objective 3: To analyse the current conservation strategies for the survival of endangered species

The third objective of the study was efficiently linked with the discussion section, which stated that global conservation strategies can help improve genetic diversity for species.

5.3 Limitations

The research provided invaluable insights regarding the role of genetic diversity in conservating endangered species. However, the study was completely based on secondary data collection, which can limit the focus on specific conservation strategies.

5.4 Future Scope

Future endeavours of this study can further navigate the strategies that can help in conservating endangered species. Moreover, researchers in future can gather significant information from this study regarding Genetic Diversity in Endangered Species Conservation.

5.5 Recommendations

Promotion of habitat connectivity

The establishment of wildlife corridors can help in the enhancement of the flow of genes among isolated species helping in the maintenance of genetic diversity (Tantipisanuh *et al*. 2024). For example, the ***Banff Wildlife Crossing*** in ***Canada*** was developed in order to enable animals like Wolves and grizzly bears to cross highways safely (Richardson, 2020). This approach has helped in the maintenance of genetic diversity, which enabled different species to interbreed and minimise the effects related to genetic isolation.

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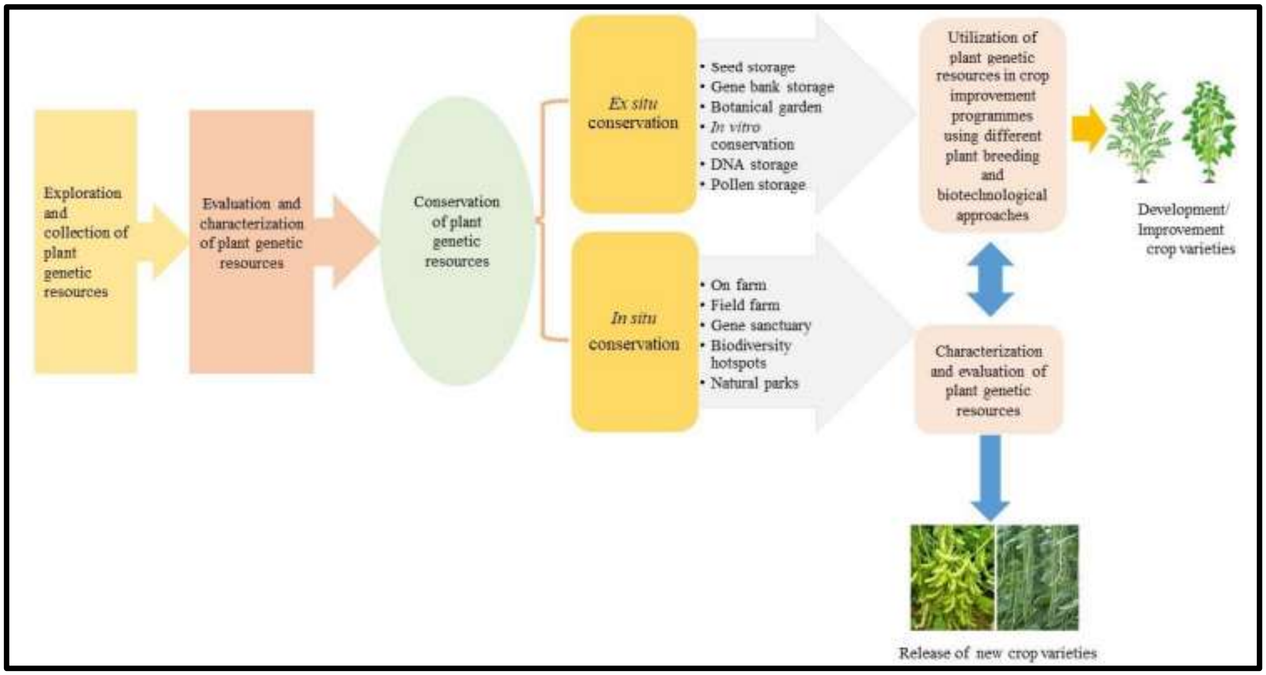
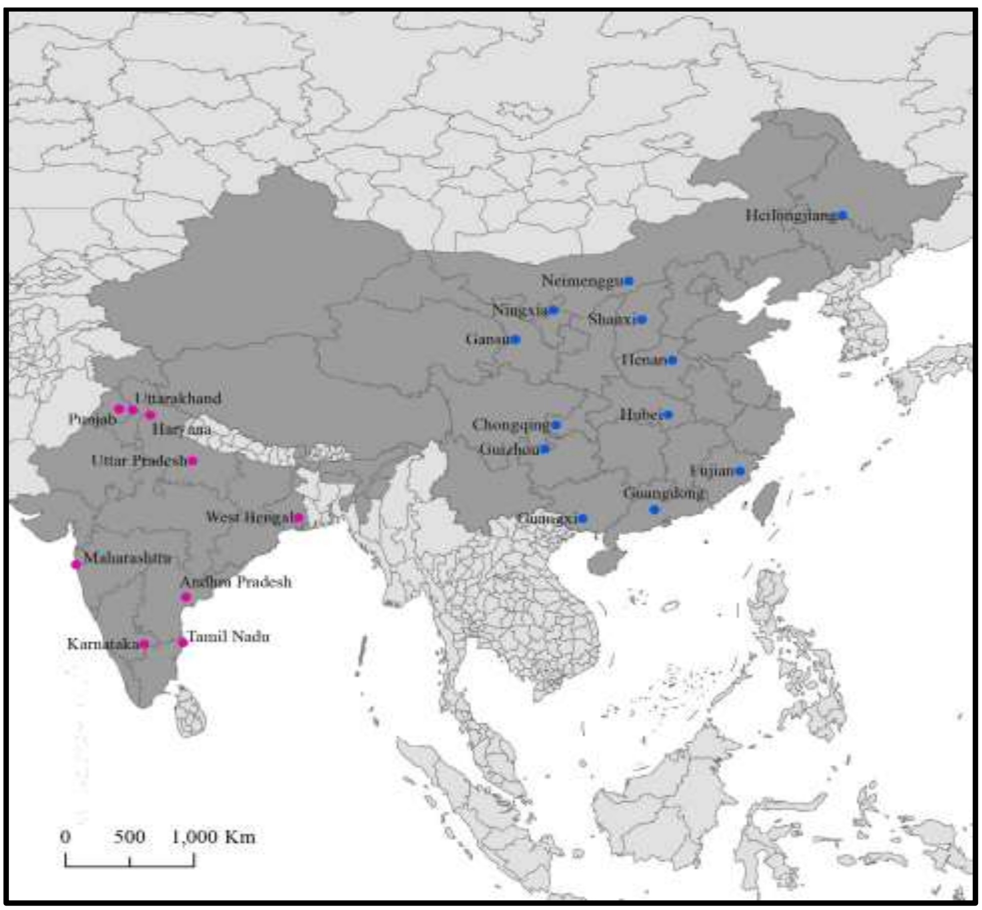
Appendices

Appendix 1: Conservation of PGRs



(Source: Salgotra *et al*. 2023)

Appendix 2: geographic locations of the Phytophthora infestans populations



(Wang *et al*. 2019)