2 Key Ecological Theories Relevant to Species Endangerment

2.1 Island biogeography theory and its application to habitat fragmentation

The Island Biogeography Theory (IBT), originally formulated by MacArthur and Wilson, provides a foundational framework for understanding species richness in isolated habitats, such as islands. This theory posits that the number of species on an island is determined by a dynamic equilibrium between immigration and extinction rates, which are influenced by the island's size and isolation (Laurance, 2008). In the context of habitat fragmentation, IBT has been applied to predict species diversity in fragmented landscapes, treating habitat patches as "islands" within a "sea" of inhospitable environments (Dondina et al., 2017). However, the theory's applicability is limited by its simplistic assumptions, as it often overlooks factors such as edge effects, the surrounding matrix, and anthropogenic influences that can significantly alter species dynamics in fragmented habitats.

Despite these limitations, IBT remains a crucial tool in conservation biology, providing insights into the effects of area and isolation on species richness. It has been integrated with other ecological theories to better predict biodiversity patterns in fragmented landscapes. For instance, combining IBT with niche theory has revealed complex interactions between habitat heterogeneity and species richness, suggesting that increased habitat heterogeneity can lead to both positive and negative effects on species diversity due to area and dispersal limitations (Kadmon and Allouche, 2007). This integration highlights the need for a more nuanced approach to conservation strategies in fragmented ecosystems.

2.2 Metapopulation theory and species survival in fragmented landscapes

Metapopulation theory offers a complementary perspective to IBT by focusing on the dynamics of species populations across fragmented landscapes. It emphasizes the importance of local population interactions, migration, and the conditions necessary for species persistence in fragmented habitats. Unlike IBT, which primarily considers static factors like area and isolation, metapopulation theory accounts for the dynamic processes of colonization and extinction among habitat patches, providing a more detailed understanding of species survival in fragmented environments (Luo et al., 2021).

This theory is particularly relevant for species that exist in fragmented landscapes, where local extinctions can be offset by recolonization from neighboring patches. The connectivity between these patches is crucial for maintaining genetic diversity and population stability. Studies have shown that maintaining ecological corridors and enhancing habitat connectivity can significantly improve species survival rates in fragmented landscapes (Luo et al., 2021). By focusing on the movement and interaction of species across a network of habitat patches, metapopulation theory provides valuable insights for designing effective conservation strategies that promote long-term species persistence.

2.3 Ecological niche theory and species vulnerability to climate change

Ecological Niche Theory (ENT) is pivotal in understanding species vulnerability to environmental changes, particularly climate change. This theory posits that the distribution and abundance of species are determined by their ecological niches, which are defined by the range of environmental conditions and resources that a species can utilize (Kadmon and Allouche, 2007). As climate change alters these conditions, species with narrow niches or specialized habitat requirements are more vulnerable to extinction due to their limited ability to adapt to new environments.

The integration of ENT with other ecological theories, such as island biogeography, has provided deeper insights into how species richness and community composition are affected by environmental changes. For example, the niche-based theory of island biogeography incorporates climatic niches as predictors of species richness, highlighting the importance of niche diversity in maintaining biodiversity (Beaugrand et al., 2024). This approach underscores the need for conservation strategies that consider the ecological niches of species, promoting resilience to climate change by preserving a diversity of habitats and environmental conditions. By understanding the specific niche requirements of species, conservationists can better predict and mitigate the impacts of climate change on biodiversity.