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CHAPTERS

Niche Partitioning and Resource Utilization Strategies of Butterflies (Lepidoptera: Rhopalocera) in India

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Abstract:- Niche partitioning and resource utilization strategies play crucial roles in shaping the ecological dynamics and coexistence of species within communities. This study focuses on investigating the niche partitioning and resource utilization strategies of butterflies belonging to the order Lepidoptera, specifically the suborder Rhopalocera. Butterflies are known for their diverse ecological adaptations and behaviours, making them an ideal group for studying niche differentiation. Through an extensive review of the existing literature and field observations, we examine the various mechanisms employed by butterflies to partition resources and reduce competition within their habitats. These mechanisms include spatial, temporal, and dietary niche partitioning, as well as differences in habitat preference, larval host plant selection, and adult feeding strategies. Spatial niche partitioning is observed through variations in butterfly species' distribution patterns and preferences for specific microhabitats within their respective habitats. Some species may utilize different vertical or horizontal strata, while others display preferences for open areas or forested regions. Temporal niche partitioning is evident through variations in seasonal activity patterns, diurnal or nocturnal behavior, and specific time periods for mating or foraging. Dietary niche partitioning is a key strategy employed by butterflies, primarily through specialization on specific larval host plants. This specialization can lead to unique interactions between butterflies and plants, with some species relying on toxic or unpalatable plants for defence or mimicry. Adult butterflies also exhibit resource utilization strategies by selecting specific nectar sources based on floral morphology, availability, and optimal energy gain. Understanding the mechanisms of niche partitioning and resource utilization strategies among butterflies has important implications for conservation efforts and ecosystem management. By identifying key factors that promote coexistence and reduce competition, we can develop effective strategies to preserve butterfly populations and their associated habitats. The objectives of this study are to contribute to our knowledge of butterfly ecology and provide insights into the complex interactions between butterflies, their resources, and their environments. The findings enhance our understanding of community dynamics and the factors shaping biodiversity patterns within ecosystems, ultimately aiding in the conservation and management of butterfly populations and their habitats.

Keywords- Niche, Butterfly, Lepidoptera, Rhopalocera, community, mimicry, coexistence, niche partitioning

1. INTRODUCTION

1.1. Niche

(i) The role and position of a species within its ecosystem is called its niche. A species needs specific sets of conditions physical and biological to survive, reproduce and thrive. Physical factors include temperature, water availability, humidity, and food resources. Biological conditions are different types of animals and plants in the niche of a species. Niche also encompasses the interaction between species and their environment.[1,2]

(ii) Two forms of a niche are studied:

(a) **Fundamental Niche[3]:** An n-dimensional hypervolume in which each dimension corresponds to a state of the environment that would permit a species to exist indefinitely in the absence of other species.[4,5] It is a purely theoretical concept. Because species do not use all the n-dimension in their environment.

(b) **Realized Niche:** A part of a fundamental niche that is actually occupied by a species after its interaction with other species.[6]

(iii) Niche Overlap: Co-occurring species share parts of their niche space with others is called niche overlap. It can be of two levels:

(a) High niche overlap: When two or more two species have similar ecological niches and consume the same resources, this is called high niche overlap. The competition for resources like food, space, and other necessary resources is very high. It may lead to conflictual interactions i e., competition, and exclusion for some species. It can leads to the following consequences:

i. Competition for Resources: When multiple species compete for the same resources, such as specific host plants or nectar sources, there may be increased competition and potentially limited availability of those resources. This competition can affect the survival, growth, and reproduction of the competing species.[7, 8]

ii. Resource Partitioning: In response to high niche overlap, species may partition resources in various ways to reduce competition. This could involve utilizing slightly different microhabitats, feeding at different times or locations, or exploiting different parts of a shared resource. Resource partitioning helps to reduce direct competition and allows coexistence.[9]

iii. Evolutionary Pressures: High niche overlap can drive natural selection and shape the evolution of species. Over time, species may adapt to reduce competition by developing specialized traits, such as different feeding behaviours, shifts in feeding times, or changes in habitat preferences. This evolutionary response can lead to further niche differentiation and reduce competition.[10]

iv. Ecological Interactions: High niche overlap can also lead to complex ecological interactions among species. For example, it may trigger predator-prey relationships, parasitism, or mutualistic interactions. These interactions can have cascading effects on the entire ecosystem, influencing the abundance and distribution of other organisms.

(b) Low niche overlap: It allows sustainable co-existence of species.[11,12] It is considered essential for the coexistence of synoptic species (having the ability to live with other species in a niche without interference).

(iv) Resource Partitioning: Resource partitioning refers to the division of limited resources among coexisting species in order to reduce competition and promote coexistence. It is a phenomenon observed in ecological communities where different species evolve to utilize different portions of resources within the same habitat. By utilizing different resources or utilizing the same resources in different ways, species can reduce direct competition and increase their chances of coexisting. Resource partitioning can occur in various dimensions, such as spatial, temporal, or dietary, and can involve differences in habitat use, foraging strategies, feeding heights, prey preferences, or other resource-related traits. Resource partitioning helps promote species diversity and ecological stability by allowing multiple species to occupy and persist in the same ecosystem.

(v)Advantages of Ecological Niche:

(a) Optimum utilization or exploitation of all available resources in a niche by different species.

(b) Suitable substratum and microclimate are furnished by a species in its ecological niche.

(c) Competition among different species in a niche can be minimized by partitioning of resource utilization.

1.2. Three Aspects of Ecological Niche:

(i) Spatial or Habitat Niche: Joseph Grinnell's (1928) thought of a niche in terms of the microhabitat that a species occupies- it is now called a spatial niche.[13] Spatial or habitat niche represents the physical space occupied by an organism. Thus, in a habitat occupied by many species, each species is confined to a microhabitat. No two species can occupy the same habitat. O'Neill provided an interesting example of a habitat niche. He identified seven species of millipedes living on the forest floor of a maple-oak forest. All seven species occur in the same basic trophic level as all are detritus feeders. The log of maple oak has several gradients in the decomposition stage from the centre to the position underneath the leaf litter. These gradients constitute distinct microhabitats and each species of millipede occupies a specific different microhabitat.

(ii) Tropical Niche: The term "tropical niche" refers to a specific ecological niche or habitat found in tropical regions of the world. Tropical regions are characterized by warm climates and high levels of biodiversity. The tropical niche encompasses a wide range of ecosystems, including rainforests, coral reefs, mangrove forests, and savannas. Within the tropical niche, numerous plant and animal species have adapted to thrive in the unique conditions of these environments. They have developed various strategies to cope with the high temperatures, abundant rainfall, and intense competition for resources. For example, many tropical plants have large leaves to capture sunlight in the dense forest canopy, while others have developed mechanisms to deal with nutrient-poor soils. The tropical niche is known for its incredible species diversity and interdependence among organisms. It supports a vast array of plant and animal life, including iconic species like toucans, jaguars, orangutans, and colourful tropical fish. The interplay between species and their environment in the tropical niche is essential for maintaining the overall health and balance of these ecosystems.

(iii) Hyper-volume or Multidimensional Niche: The concept of hyper-volume or multidimensional niche is derived from the ecological niche theory, which describes the multidimensional environmental space in which a species can exist. In traditional niche theory, a species occupies a specific ecological niche defined by a set of environmental conditions (e.g., temperature, humidity, food availability) that allow it to survive, reproduce, and persist. However, in reality, the niche of a species is not limited to a single dimension or set of conditions but exists in a multidimensional space. The hyper-volume or multidimensional niche represents the entire range of environmental conditions in which a species can persist. Instead of considering a single niche axis, such as temperature or food availability, the multidimensional niche incorporates multiple factors simultaneously. These factors can include abiotic conditions (temperature, precipitation, elevation), biotic interactions (competition, predation), and other ecological variables. By considering the multidimensional niche, researchers can better understand the complexity of species' ecological requirements and interactions. It allows for a more comprehensive assessment of the factors influencing species distributions, population dynamics, and community assembly. The concept of hyper-volume niche has been applied in various ecological studies and modelling approaches. For instance, species distribution models (SDMs) use environmental variables to predict the potential distribution of species based on their multidimensional niche requirements. These models incorporate multiple environmental factors to identify suitable habitats and potential range shifts under different scenarios, such as climate change. Overall, the hyper-volume or multidimensional niche provides a more realistic representation of species' ecological requirements and interactions, considering the complexity of the natural environment and the multitude of factors that influence species' distributions and persistence.

1.3. Introduction to niche partitioning and resource utilization strategies

Niche partitioning and resource utilization strategies are important concepts in ecology that describe how different species adapt and coexist within an ecosystem by utilizing available resources in distinct ways. These strategies help reduce competition and promote biodiversity within a community. Here are some key aspects of niche partitioning and resource utilization strategies:

(i) Niche Partitioning: Niche partitioning refers to the process by which species divide and specialize in resource use, thereby reducing competition for limited resources. This division can occur along various dimensions, including space, time, and resource type. By occupying different niches, species can coexist and minimize direct competition. For example:

- **(a) Spatial Partitioning:** Species may occupy different areas within an ecosystem. For instance, tree-dwelling and ground-dwelling bird species utilize vertical space differently in a forest.
- **(b) Temporal Partitioning**: Species may exhibit activity patterns or use resources at different times of the day or year. Nocturnal and diurnal species are an example of temporal partitioning.[14]
- **(c) Resource Niche Partitioning:** Species may specialize in utilizing specific resources, such as different food sources or prey items. This reduces competition for the same resources. An example

is different bird species having distinct beak shapes for accessing different food sources like insects, nectar, or seeds.

(ii) Resource Utilization Strategies: Species employ various strategies to optimize resource utilization and reduce competition. These strategies include:

(a). Trophic Level Differentiation: Species may occupy different positions within a food chain, consuming different resources or having different feeding habits. This allows for efficient utilization of resources at different trophic levels and reduces direct competition.

(b). Morphological Adaptations: Species may have distinct morphological features or adaptations that enable them to access specific resources. For example, long beaks in birds adapted for probing flowers, or specialized teeth in carnivores for tearing flesh.

(c). Habitat Selection: Species may preferentially occupy different microhabitats within an ecosystem, utilizing different resources or environmental conditions. This promotes coexistence by reducing competition for the same habitat.[15]

(d). Niche Shifts: Species can exhibit niche shifts, adjusting their resource utilization strategies in response to changes in the environment or interactions with other species. This adaptive flexibility allows for coexistence by minimizing competition.[16]

1.4. Uses of the studies of niche overlap

The study of niche overlap, which examines the extent to which different species share or utilize similar ecological niches, has several important uses and applications in ecology. Here are some of the key uses of studying niche overlap:

Fig. 1: Common Jezebel (*Delias eucharis*)

Fig. 2: Painted Lady (*Vanessa cardui*)

(i) Competition and Coexistence: Niche overlap provides insights into the competitive interactions between species. When two or more species have significant niche overlap, it suggests that they may compete for similar resources, leading to potential competition. Understanding the extent of niche overlap helps ecologists predict and analyze the outcomes of competition, such as competitive exclusion, resource partitioning, or coexistence.

(ii) Biodiversity and Community Structure: Niche overlap influences the structure and diversity of ecological communities. High niche overlap can lead to competitive exclusion, reducing species diversity. Conversely, lower niche overlap allows for the coexistence of multiple species, promoting biodiversity. By quantifying niche overlap, researchers can assess the factors that shape community structure and understand the mechanisms that contribute to maintaining species diversity.

(iii) Conservation and Ecosystem Management: Studying niche overlap can inform conservation strategies and ecosystem management. By identifying species with high niche overlap, conservation efforts can focus on preserving habitat quality and resources necessary for coexistence. Additionally, understanding the degree of niche overlap can help identify potential threats, such as invasive species, which may intensify competition and disrupt native species' ecological niches.

(iv) Species Interactions and Network Dynamics: Niche overlap analysis contributes to understanding species interactions within ecological networks. It helps identify direct and indirect interactions, such as competition, predation, and mutualism, by assessing the shared utilization of resources. This information is vital for comprehending the stability and dynamics of complex ecological networks and predicting the consequences of species loss or introduction.

(v) Ecological Restoration and Species Reintroduction: Knowledge of niche overlap can guide ecological restoration efforts and species reintroduction programs. By considering the niche requirements and overlap with existing species, managers can make informed decisions on habitat restoration or select suitable sites for reintroducing endangered species. Understanding niche overlap also aids in evaluating potential impacts on resident species and predicting the success of reintroduction efforts.

CONCLUSION

The niche of butterflies species depends on several aspects of the host plants, interaction with climatic factors, interaction with other species, and dependency. Co-existence with other species of the same order or phylum can be successful if the partitioning of resources is well-defined. Natural changes in the surrounding conditions induce evolutionary changes in the behaviour and approach of butterflies but anthropogenic changes do not permit them to undergo such a time taking process. Here, the threat to their niche is reported by several authors.

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