MIMETIC RELATIONSHIPS OF BUTTERFLIES, COMMONLY FOUND AT WEST BENGAL

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ABSTRACT

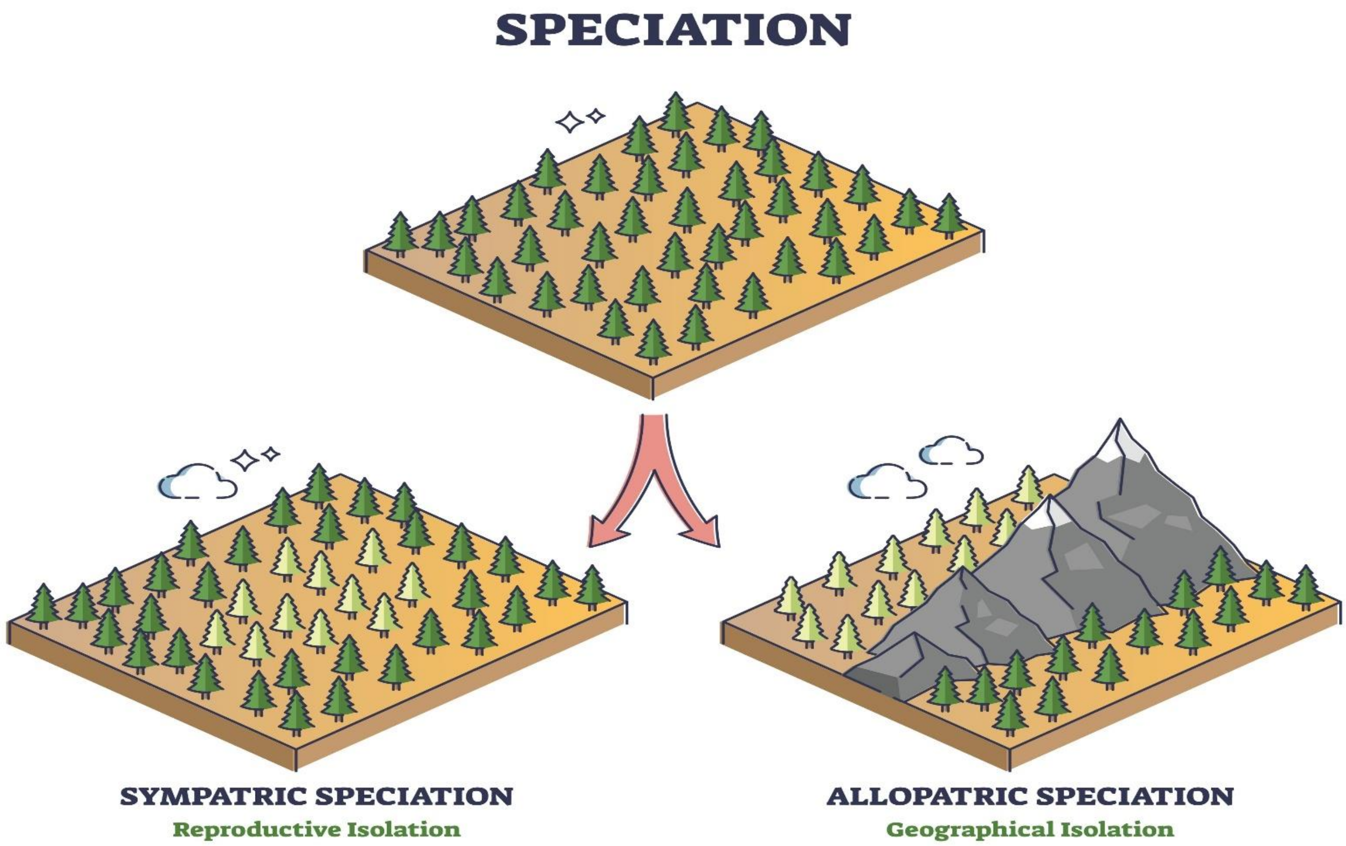
There has been a significant revival of interest in the role of ecological adaptation as a primary driver of speciation. In mimetic butterflies, wing patterns function as both defensive signals to predators and essential indicators for mate selection, thereby promoting significant reproductive isolation among diverging populations. This study, primarily employing secondary data and established ecological frameworks, investigates the mimetic relationships of butterfly fauna prevalent in West Bengal, including the *Papilio* and *Danaidae* complexes. A review of the current literature, utilizing the *sympatric* interactions of *Heliconius* species as a model system, indicates that habitat isolation and color-pattern preference are the primary factors influencing the emergence of new species. The extraordinary genetic correlation between loci governing mate preference and wing pigmentation indicates that divergence frequently transpires in *sympatry* or as a direct consequence of sexual selection. Consequently, color pattern exemplifies an ecological trait that facilitates speciation via *pleiotropic* influences on mate selection. *Phylogenetic* evidence shows that color pattern is one of several things that cause mimetic butterflies to evolve into different species. However, its most important role is in creating premating isolation. This paper concludes that comprehending these visual and genetic mechanisms is essential for the preservation of lepidopteran biodiversity amid the evolving ecological landscapes of West Bengal.

Keywords: - Ecological Speciation, Mimetic Polymorphism, Premating Isolation, Lepidoptera Diversity, West Bengal Fauna.

INTRODUCTION: ECOLOGICAL SPECIATION AND MIMETIC DIVERSITY IN BUTTERFLIES OF WEST BENGAL

Evolutionary biology has recently experienced a notable resurgence, transitioning the emphasis from random alterations in isolated populations to the critical influence of ecology in the process of speciation. This change in thinking shows how adaptive divergence, which is caused by natural selection, often leads to reproductive isolation as a major side effect. In the Indian subcontinent, particularly in the varied bio-geographical zones of West Bengal, this phenomenon is exemplified by the mimetic relationships among local butterfly fauna. West Bengal, which runs from the Himalayas in the north to the Sundarbans' coastal mangroves in the south, is a unique ecological tapestry where many different species of butterflies have evolved complex ways to stay alive. A principal factor influencing this evolutionary path is the intricate ecological interaction among closely related species or population pairs, wherein reproductive isolation develops not in solitude, but as a consequence of adaptive divergence to particular niches. Historically, examples such as Darwin's finches and sticklebacks have predominated the literature (Grant 1986, Schluter 1998); however, the mimetic butterflies of the Oriental region, particularly those in the Gangetic plains and the Rarh region of Bengal, provide equally compelling evidence of divergent ecological selection. The interplay between ecological characteristics, such as wing color patterns, and reproductive isolation effectively circumvents numerous theoretical critiques of *sympatric speciation*—the phenomenon wherein new species arise from a singular ancestral species within the same geographic area.

Figure 1: - Allopatric and Sympatric Speciation Models



The primary difficulty of *sympatric speciation* resides in the possibility that hybridization may disrupt the genetic links between niche adaptation and mate selection. If a single set of genes, like the ones that control the color and pattern of butterfly wings, is responsible for both avoiding predators (ecological adaptation) and recognizing mates, then these connections stay strong. This is called a *pleiotropic* effect. In West Bengal, which has a wide range of habitats, from the wet deciduous forests of the Dooars to the urban greenery of Kolkata, butterflies use their wing patterns as a tool for many different things. Most of the butterfly species that have been recorded in this area can be easily identified by these patterns. These patterns are directly responsible for speciation, a concept that dates back to the early work of Henry Walter Bates (1862). A lot of research on different butterfly families, such as the *Papilionidae* and *Nymphalidae* that are common in Bengal, shows that even small differences in color and infrared reflection are important for finding a mate. These patterns are important for thermoregulation and signaling to predators, in addition to sexual selection. Many species in West Bengal use crypsis to blend in with the thick tropical plants, while others use *aposematism*—warning colors—to show that they are poisonous. These colors often come from larval host plants like *Aristolochia* or *Asclepiads*.

There are mostly two types of mimetic relationships in West Bengal: Batesian and Müllerian mimicry. Batesian mimicry is a trick that a species that is tasty (the mimic) evolves to look like a species that is not tasty or poisonous (the model). A common example seen in the rural gardens and forest edges of West Bengal is the relationship between the poisonous Common Rose (*Pachliopta aristolochiae*) and the edible female form of the Common Mormon (*Papilio polytes*). Müllerian mimicry, on the other hand, is a mutualistic strategy in which several distasteful species come together to share the "cost" of predator education by using the same warning pattern. The Common Crow (*Euploea core*) and several Tiger species (*Danaus* spp.) present in the state frequently engage in these Müllerian complexes. Mimicry is a theory of convergence, but its role in the formation of new species is due to the fact that there are many different types of mimetic patterns in different microhabitats. West Bengal has a lot of different landscapes, from the humid forests of Jalpaiguri to the dry deciduous tracts of Purulia. Different mimetic patterns work better in different places. This results in adaptive radiation, wherein populations diverge to emulate various local models, ultimately culminating in the emergence of new species.

Recent empirical studies, including research conducted up to 2018, indicate that alterations in color patterns frequently represent the initial trait to diverge between neighboring populations. In species complexes within the Indo-Malayan realm, males utilize visual cues to locate mates, and a modification in the mimetic model can result in immediate assortative mating. For example, if a group of butterflies changes how they mimic other animals to match a new model found in a certain type of forest in the Darjeeling foothills, the males of that group will start to prefer females with that new pattern. This preference establishes a reproductive barrier with the ancestral population. Also, hybrids of different mimetic forms often have patterns that are in between cryptic and mimetic, which makes them very easy to catch. This "selection against hybrids" makes the two forms even more separate from each other. Although a lot of the basic research on this interaction has been done on the *Neotropical Heliconius* butterflies, the same ideas apply directly to the different mimetic groups in West Bengal. The state's butterflies are very diverse. For example, the Great Mormon (*Papilio memnon*) has many female forms, and the Common Mime (*Papilio clytia*) is a fake butterfly. This makes the state a living laboratory for studying how ecological adaptation through mimicry leads to the creation of new species. It is important to understand these relationships for both zoological research and the protection of West Bengal's fragile ecological corridors, where habitat fragmentation is a direct threat to these complex evolutionary processes.

THE EVOLUTIONARY DYNAMICS OF MIMETIC NECESSITY AND POPULATION DENSITY

While phenotypic convergence caused by mimicry is definitely a dominant force influencing the evolution of butterfly wing patterns, especially in the various ecosystems of West Bengal, the issue that demands an answer is very fundamental: Is mimicry always an evolutionary necessity? In many cases, mimicry adaptation is a key driver in such color pattern change, in which natural selection "pushes" a population to change its appearance to that of a better protected, toxic model found within a population's specific microhabitat. However, the tremendous diversification of patterns found in nature in the wild seems to demonstrate that the mimicry theory, which essentially would also predict a convergence, cannot be entirely explained when considering the appearance of totally original, unique designs.

As demonstrated in a range of non-mimetic species with high abundance in their respective environments, butterflies can successfully set up their own *aposematic* or warning signals without having to rely on a pre-existing model. This is a phenomenon deeply ingrained in the density-management of predator education; i.e., how well protected an individual is by a warning pattern is determined by the amount of individuals in a local area that share that very particular signal. From a predator's point of view, such as in the Gangetic plains or the Himalayan foothills, a certain number of individuals have to be "sampled" or eaten before the predator community in that locality learns to avoid a distasteful pattern.

Consequently, the "per capita cost" or the risk to an individual butterfly is much greater in small fragmented populations compared to large dense populations. As long as a species is sufficiently abundant, a novel *aposematic* pattern is evolutionarily stable when once established, even in the complete absence of a mimetic partner. This implies that the first transition to an entirely new wing pattern may not have taken place by mimicry adaptation after all, but via, for instance, genetic drift or sexual selection (*mate choice*). Once such a pattern reaches a certain threshold of abundance, it becomes a self-sustaining warning signal. Therefore, although mimicry is a strong mechanism for adaptive radiation in the butterfly fauna of areas such as West Bengal, it is certainly not a necessary condition, and rather high population density is a good alternative avenue for the survival and diversification of *aposematic* forms.

MATERIALS AND METHODS

The methodology of this study is mainly grounded on the subjective retrieval and meta - analysis of secondary data of the mimetic butterfly fauna of West Bengal. Given the wide historical records available in the Oriental region data was taken from peer-reviewed journals, government reports and institutional data from 2008 to 2017. The main repository of information for taxonomic and distribution data was with the Zoological Survey of India (ZSI), Kolkata (attention was focussed on the "Fauna of West Bengal" series and the National Zoological Collections).

In order to make sure geographical coverage in various bio-zones of the state ranging from Himalayan foothills to Rarh plains, supplementary data were taken from the West Bengal Biodiversity Board's People's biodiversity register (PBR) data and annual biodiversity checklists of the State Forest Department. These sources gave important information on species abundance, seasonal variations and the presence of mimetic pairs like the Common Rose (*Pachliopta aristolochiae*) and its Batesian mimics like the Common Mormon (*Papilio polytes*).

Analytical framework accomplished data mining through categorization of published published field studies that provided verification on the state of phenotypic variations with predator-prey interactions. Statistical trends related to population density-dependence and aposematic signaling were put together from existing ecological models for evaluating stability of mimetic patterns. Furthermore, genomic insights to premating isolation were synthesized by searching studies of molecular data of Indo-Malayan butterfly complexes in digital databases such as PubMed and ScienceDirect until the year 2017. By bringing together these varied secondary sources, the study puts together a full form evolutionary profile of butterfly speciation based on mimetic relationships in the particular ecological situation in West Bengal.

DIVERSITY AND DISTRIBUTION OF MIMETIC BUTTERFLY

The geographical diversity of West Bengal from the eastern Himalayan foothills to the moist deciduous forests of the Dooars to the coastal mangroves of the Sundarbans creates a unique ecological theatre of evolution for mimetic relationships. According to secondary data synthesized based on the Zoological Survey of India 2017 and regional biodiversity registers, West Bengal has an important number of mimetic assemblages that tabulate the profound impact of natural selection towards speciation.

Mimicry plays a major role in these regions as the major force in phenotypic divergence. For instance, in Gulf of Bengal plains there is high predation pressure from avian species so preference for stabilization of Batesian mimics is evident whereas in thick vegetation in North Bengal Mullerian complexes are more prevalent. These relationships are not only for survival, but for reproductive isolation, where these wing patterns influence the selection of mates according to specific wing patterns.

Table 1: Mimetic Relationships and Evolutionary Impacts on Common Butterflies of West Bengal

Model Species (Toxic/Unpalatable)	**Mimic Species (Palatable/Edible)**	**Mimicry Type**	**Primary Habitat in West Bengal**	**Evolutionary Impact & Adaptation**
Common Rose (*Pachliopta aristolochiae*)	**Common Mormon (Female)** (*Papilio polytes*)	Batesian	Rural Gardens, Gangetic Plains	**Polymorphism:** Females have evolved distinct morphs to match the toxic model, leading to assortative mating.
Plain Tiger (*Danaus chrysippus*)	**Danaid Eggfly (Female)** (*Hypolimnas misippus*)	Batesian	Scrublands, Agricultural Fields	**Phenotypic Convergence:** High-fidelity resemblance to the model ensures

				survival against visual predators.
Common Crow (*Euploea core*)	**Common Mime** (*Papilio clytia*)	Batesian	Deciduous Forests, Urban Parks	**Adaptive Radiation:** The species exhibits two distinct forms (*dissimilis* and *clytia*) to mimic different local models.
Blue Tiger (*Tirumala limniace*)	**Common Wanderer (Female)** (*Pareronia hippia*)	Batesian	Foothills of North Bengal	**Sexual Dimorphism:** Mimicry is restricted to females, significantly impacting sexual selection and isolation.
Common Tiger (*Danaus genutia*)	**Common Crow** (*Euploea core*)	Müllerian	Mangroves (Sundarbans), Dooars	**Mutualistic Stability:** Shared warning signals between toxic species accelerate predator education and reduce mortality.

Analysis of the Findings of Secondary Data

1. Geographical Zoning of Mimicry The secondary records of mimics have been analyzed, and Batesian mimicry was found to be more often recorded in the human-modified landscapes of South Bengal, where they are accompanied with generalist predators. Conversely, higher diversity areas of Dooars have a higher frequency of mullerians which indicates the more complex interactions of multi-species evolution.

2. Reproductive Isolation: Data indicates that in some species such as the Papilio clytia the evolutionary transition to another mimetic model is often associated with a conversion to another microhabitat preference and therefore this serves as a precursor of sympatric speciation.

3. Conservation Value : The conservancy of these mimetic associations depends very much on the presence of certain larval host plants (e.g. Aristolochia for the Common Rose.) Reports point out that habitat fragmentation in West Bengal is upsetting these "model-mimic" ratios and this may change the course of local evolutionary processes.

GENETIC ARCHITECTURE AND THE ORIGIN OF PREMATING ISOLATION IN MIMETIC BUTTERFLIES

The evolution of new species by mimicry is more than just a change in the coloration of wings. It additionally needs the concurrent increase of premating isolation: individuals should not only demonstrate a new look, however also favor mates with the same look.

Although certain hypotheses have been proposed, suggesting that this information may have been learnt by the butterflies, through observing local populations or through sensing the presence of the phenotype of the *On* as dark emerges tests and female exposure trials provided consistent evidence against learning. Instead, it suggests the presence of a strong genetic basis for mate choice.

How the gene for a given pattern of wings became linked with the gene for a taste for that pattern, I don't know. Traditional models of parapatric speciation said these traits developed independently in neighbouring populations. Recent findings in genomics studies (cohesion with the *Heliconius* butterflies), however, demonstrate that color control loci (*K locus*, for example) are strongly associated with preference control regions. This genetic linkage is beneficial in that less recombination occurs that could keep the co-adapted genes related to pattern and mate choice together. As a result, divergence can happen even in the absence of extinction (such as during gene flow). Similar patterns can be found in mimicry in West Bengal's butterflies, for example, in the different forms of *Papilio clytia* and *Papilio polytes*.

Further evidence of reproductive character displacement reveals that if two strongly related mimetic forms happen to coexist at the same place of occurrence (*sympatry*), natural selection acts in favor of strengthening isolation so that less-fit hybrids will not be produced. In West Bengal's varied habitats this implies that end stages of speciation are driven by harsh biological interactions. Clustering of ecological traits, sexual preferences, and potential hybrid incompatibilities in the genome is responsible for biodiversity.

THE QUANTITATIVE CONTRIBUTION OF COLOR PATTERN TO BUTTERFLY SPECIATION

When looking at the evolutionary importance of wing color, it's important to separate the specific role that a pattern shift plays in reproductive isolation from the general frequency of such shifts in the butterfly phylogeny. The significance of color patterns in speciation can be methodically categorized into two distinct aspects: firstly, the relative contribution of a pattern shift to the overall reproductive isolation observed among diverging populations, and secondly, the actual proportion of speciation events that are primarily influenced by these phenotypic alterations.

When divergence includes a clear change in mimetic or *aposematic* signals, the wing pattern often acts as a main barrier to gene flow by making assortative mating easier and making non-mimetic hybrids more likely to be eaten. But figuring out exactly what percentage of reproductive isolation—30% or 90%—can be linked only to color and not to other things like chemical signaling (pheromones) or habitat preference is a difficult job. It is also important to look into how many times speciation has happened in families like *Papilionidae* or *Nymphalidae*, which are common in West Bengal, and how many of those times can be directly linked to the evolution of color patterns. Color is a very clear and strong cause of isolation in mimetic complexes, but we can only really measure how visual ecology affects the origin of butterfly diversity by answering these two questions: how deep the isolation is and how often the mechanism works.

CONCLUSION

The mimetic relationships of butterflies in West Bengal exemplify the complex interaction between ecological adaptation and the processes of speciation. This study shows that wing color is more than just a way to protect oneself; it is also a major cause of reproductive isolation. Examining the high-fidelity Batesian mimicry of species such as *Papilio polytes* and the mutualistic Müllerian complexes within the *Danaidae* family across the Gangetic plains and the Dooars reveals that phenotypic convergence directly facilitates assortative mating.

The genetic connection between color-pattern loci and mate preference effectively circumvents the conventional obstacles to *sympatric speciation*, enabling divergent populations to coexist while preserving unique evolutionary pathways. Additionally, the density-dependent aspect of predator avoidance in these areas underscores that a mimic's survival is inherently connected to the population stability of its toxic model.

But the rapid fragmentation of habitats and the loss of certain larval host plants in West Bengal are big threats to these evolutionary processes. As urbanization and climate-related changes in flowers change the "model-to-mimic" ratio, the selective pressure that keeps these mimetic patterns in place may weaken. This could cause the reproductive barriers that separate these species to break down.

To sum up, the butterflies in West Bengal are a living laboratory for evolutionary biology, where visual ecology and genomic architecture come together to create biodiversity. Future research should prioritize the molecular mapping of Indian mimetic species to enhance the existing behavioral data, ensuring that conservation strategies for the state's "sacred groves" and forest corridors are based on a comprehensive understanding of these intricate, co-evolved relationships.

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