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Butterfly-Host plant relationships ecological significance and conservation needs- A review

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Abstract
Butterflies, admired for their beauty and ecological importance, exhibit intricate relationships with specific host plants that are critical for their survival and reproduction. This review explores the dependency of 35 butterfly species on their host plants, highlighting the specialized interactions that define these relationships. Host plants are crucial as they provide necessary nutrients and habitat for butterfly larvae, with many species evolving to detoxify or sequester plant chemicals for defense. The review also underscores the broader ecological significance of these interactions, including their role in pollination, food webs, and as indicators of environmental health. However, these relationships are increasingly threatened by habitat loss and fragmentation, climate change, pesticide use, and invasive species. Habitat destruction reduces available resources and isolates butterfly populations, while climate change disrupts the synchrony between butterflies and their host plants. Pesticides directly harm butterflies and their larvae, and invasive species outcompete native host plants. Effective conservation strategies are essential to address these challenges, including habitat preservation and restoration, creating butterfly-friendly environments, and implementing policy measures to protect butterflies and their host plants. It aims to comprehensively understand these relationships and their conservation needs, offering valuable insights for researchers, educators, and policymakers to support butterfly populations and ecosystem health.

Keywords: Butterfly-Host plant, ecological significance, relationship

Introduction

Butterflies, with their vibrant colors and delicate forms, are one of the most admired groups of insects. These insects belong to the order Lepidoptera, which also includes moths (Schlaepfer, 2006) [21]. Butterflies undergo complete metamorphosis, involving four distinct stages: egg, larva (caterpillar), pupa (chrysalis), and adult. This complex life cycle is closely intertwined with their environment, particularly with specific plants that serve as their hosts during the larval stage. Host plants are vital for butterfly reproduction and survival. They provide the necessary nutrients and habitat for the developing larvae. The relationship between butterflies and their host plants is often highly specialized (Saldivar & Wilson, 2024) [19]. Many butterfly species have evolved to feed exclusively on certain plant species or families, developing mechanisms to detoxify plant chemicals and even sequester them for their own defense. This specialization often leads to a co-evolutionary relationship where both the plant and the butterfly influence each other's development and survival. The importance of butterflies and their host plants extends beyond their ecological roles. Butterflies are excellent indicators of environmental health and biodiversity. They are sensitive to changes in their environment, making them valuable for monitoring the impacts of habitat loss, climate change, and pollution (Upadhyay *et al*., 2023) [25]. Moreover, butterflies contribute to the pollination of many plants, including those of economic importance. Their interactions with plants also support a diverse range of other organisms, forming intricate food webs. Host plants play a crucial role in the life cycle of butterflies. During the larval stage, caterpillars are entirely dependent on these plants for their nutrition. The choice of host plant affects the growth, development, and survival of the larvae (Smilanich & Muchoney, 2022) [24]. For instance, the monarch butterfly (*Danaus plexippus*) lays its eggs exclusively on milkweeds (*Asclepias* spp.), which provide cardiac glycosides that the caterpillars sequester for defense against predators (Pocius *et al*., 2021) [14]. This dependency highlights the critical nature of preserving host plants to ensure the survival of butterfly populations. The decline in butterfly populations globally has raised concerns about the loss of biodiversity and the degradation of ecosystems. Habitat destruction, agricultural intensification, pesticide use, and climate change are major threats to both butterflies and their host plants (Braak *et al*., 2018) [2]. Conservation efforts must focus on preserving and restoring habitats, protecting native vegetation, and mitigating the impacts of climate change. Understanding the specific needs and interactions of butterflies and their host plants is essential for developing effective conservation strategies.

This review aims to provide a comprehensive overview of the relationships between butterflies and their host plants. By compiling a list of 35 butterfly species and their associated host plants, we aim to shed light on the dependencies and ecological roles of these insects. This information is crucial for several reasons highlighting the importance of host plants in the life cycle of butterflies can inform conservation efforts. Protecting and restoring native host plants can support butterfly populations and broader ecosystem health. This can serve as a valuable resource for researchers, educators, and conservationists. It can guide further studies on butterfly-plant interactions and inform educational programs that raise awareness about the importance of biodiversity. By understanding the specific needs of different butterfly species, policymakers and land managers can make informed decisions to protect and enhance butterfly habitats. This includes creating butterfly-friendly landscapes in urban and agricultural areas.

1. Ecological Significance of Butterfly-Host Plant Relationships

Butterfly-host plant relationships are a quintessential example of ecological interdependence and co-evolution. These interactions are not only fascinating from a biological perspective but also play a critical role in maintaining the health and stability of ecosystems. This section delves into the ecological significance of these relationships, highlighting their complexity and importance.

1.1. Co-evolutionary dynamics

The relationship between butterflies and their host plants is often highly specialized, resulting from a long history of co-evolution (Benson *et al*., 1975) [1]. Butterflies and plants have developed mutual adaptations that enhance their survival and reproductive success. For example, many plants have evolved chemical compounds that deter herbivores, yet certain butterfly species have adapted to detoxify these compounds or even use them to their advantage. This mutual adaptation illustrates the intricate evolutionary arms race between herbivores and plants (Dobler, 2001) [4].

1.2. Roles in ecosystems

Butterflies contribute to ecosystems in several significant ways. As pollinators, adult butterflies facilitate the reproduction of various flowering plants. Although they are not as efficient as bees, butterflies visit a wide range of plants, aiding in cross-pollination and genetic diversity (Porter, 2023) [16]. This role is crucial for the reproduction of many wild plants and some agricultural crops.

Caterpillars, the larval stage of butterflies, serve as primary consumers in food webs. They feed on plant tissues, converting plant biomass into animal biomass. This process not only influences plant community dynamics but also supports higher trophic levels (Polis & Strong, 1996) [15]. Caterpillars are a vital food source for many predators, including birds, mammals, and other insects. The decline in butterfly populations can thus have cascading effects throughout the food web, impacting a wide range of species.

1.3. Indicators of environmental health

Butterflies are often considered bioindicators, species that can provide insight into the health of the environment. Due to their sensitivity to habitat changes, climate variations, and pollution, fluctuations in butterfly populations can signal broader ecological shifts (Kremen, 1992) [9]. Monitoring butterfly populations can therefore help ecologists detect and diagnose environmental issues. For example, a decline in specific butterfly species might indicate the degradation of their host plant habitats or the impact of pesticide use.

1.4. Habitat specificity and diversity

The diversity and specificity of butterfly-host plant relationships contribute to the overall biodiversity of ecosystems. Each butterfly species often relies on a narrow range of host plants, which supports a diversity of plant species (Hawkins & Porter, 2003) [6, 16]. This specificity ensures that different butterfly species occupy various niches, reducing direct competition and promoting a rich tapestry of biodiversity.

The presence of diverse butterfly species can also enhance the structural complexity of habitats. For example, in tropical forests, butterflies and their larval host plants contribute to the vertical stratification of the forest, with different species utilizing various canopy layers and understories. This stratification supports a wide array of other organisms, from microbes to large mammals, creating a more resilient and productive ecosystem (Richter *et al*., 2023) [18].

1.5. Climate change and adaptation

Climate change poses significant challenges to butterfly-host plant relationships. Shifts in temperature, precipitation patterns, and seasonal cycles can disrupt the synchrony between butterflies and their host plants (Posledovich *et al*., 2018). Understanding the ecological significance of these relationships helps in predicting and mitigating the impacts of climate change. Conservation strategies that focus on preserving the temporal and spatial availability of host plants can enhance the resilience of butterfly populations. Additionally, studying the adaptive capacities of both butterflies and their host plants to changing conditions can inform more effective conservation practices.

2. Butterfly-host plant relationships

Butterflies and their host plants form a critical component of many ecosystems. The relationship between a butterfly species and its host plant is a key determinant of the butterfly's lifecycle and survival. Each butterfly species has evolved to utilize specific host plants for laying eggs and providing nourishment to its larvae (Menasagi & Kotikal, 2012; Nallu *et al*., 2017) [10]. This section presents a detailed table listing 35 butterfly species and their corresponding host plants, along with the reasons for their dependence on these plants. Table 1 below highlights the intricate relationships between various butterfly species and their host plants. Understanding these dependencies is vital for conservation efforts, as it allows for targeted strategies to protect both the butterflies and the plants they rely on. By preserving and restoring the natural habitats of these plants, we can support the survival of butterfly populations and maintain the ecological balance of their environments.

Table 1: List of different butterflies along with their host plant and their reason for dependency

Sl No:	Name of the species	Vernacular name	Host plant	Dependency	Reference
1.	*Danaus plexippus*	(Monarch)	Milkweeds (*Asclepias* spp.)	Sequesters cardiac glycosides for defense against predators	(Pocius *et al*., 2021) [14]
2.	*Vanessa cardui*	Painted Lady	Thistles (*Cirsium* spp.), Mallows (*Malva* spp.)	Provides essential nutrients and a suitable environment for larval development	(Saldivar & Wilson Rankin, 2024) [19]
3.	*Pieris rapae*	Cabbage White	Crucifers (Brassicaceae)	Detoxifies glucosinolates for growth	(Okamura *et al*., 2019) [28]
4.	*Agraulis vanillae*	Gulf Fritillary	Passionflowers (*Passiflora* spp.)	Sequester compounds for predator deterrence	(De Castro *et al*., 2019)

5.	*Vanessa Atalanta*	Red Admiral	Nettles (*Urtica dioica*)	High nitrogen content supports rapid growth	(Hofstra *et al*., 1985) [30]
6.	*Limenitis archippus*	Viceroy	Willows (*Salix* spp.), *Poplars* (Populus spp.)	Sequesters salicylic acid for defense	(Lambers *et al*.,2009)
7.	*Papilio Troilus*	Spicebush Swallowtail	Spicebush (*Lindera benzoin*), Sassafras (*Sassafras albidum*)	Essential oils provide chemical defenses	(Setzer, 2016) [32]
8.	*Junonia coenia*	Buckeye	Plantains (*Plantago* spp.	Sequesters iridoid glycosides for defense	(Carper *et al*., 2019) [33]
9.	*Nymphalis antiopa*	Mourning Cloak	Willows (*Salix* spp.), Elms (*Ulmus* spp.)	High nutritional value supports growth	(Byers & Richards, 1986) [34]
10.	*Speyeria Cybele*	Great Spangled Fritillary	Violets (*Viola* spp.)	Provides essential nutrients for larval development	(Sims, 2017) [36]
11.	*Polyommatus icarus*	Common Blue	*Lotus corniculatus.*	Larvae develop faster and gain more weight when feeding on cyanogenic plants, suggesting an ability to metabolize excess nitrogen for growth	(Goverde *et al*., 2008) [37]
12.	*Colias philodice*	Clouded Sulphur	Legumes (Fabaceae)	Nitrogen-rich plants support larval growth	(Karowe, 2007) [38]
13.	*Ariadne merione merione*	Castor butterfly	*Ricinus communis* L.	Influences the reproductive success and breeding patterns of *A. merione*	(Atluri *et al*., 2010) [39]
14.	*Aglais urticae*	Small Tortoiseshell	Nettles (*Urtica dioica*)	High nitrogen content supports larval growth	(Xi *et al*., 2024) [40]
15.	*Polygonia c-album*	Comma	Nettles (*Urtica dioica*), *Elm (Ulmus* spp.)	Nutritional content supports development	(Schneider *et al*., 2024) [41]
16.	*Graphium sarpedon*	Common Bluebottle	*Cinnamomum camphora*	Essential oils provide chemical defenses	(Li *et al*., 2010) [42]
17.	*Strymon bubastus*	Neotropical hairstreak	*Phyla nodiflora* and *Waltheria ovata*	Provides essential nutrients for larval growth	(Vargas *et al*., 2016) [43]
18.	*Aglais io*	Peacock Butterfly	Nettles (*Urtica dioica*)	High nitrogen content supports rapid growth	(Serruys & Van Dyck, 2014) [44]
19.	*Danaus gilippus*	Queen	*Asclepias nyctaginifolia.*	Support growth and larvae and nectar plants. It satisfies their caloric needs as adults.	(Saul-Gershenz *et al*., 2020) [45]
20.	*Junonia coenia*	Common Buckeye	Plantains (Plantago spp.), Snapdragons (Antirrhinum spp.)	Sequesters iridoid glycosides for defense	(Carper *et al*., 2019) [33]
21.	*Papilio rutulus*	Western Tiger Swallowtail	Willows (Salix spp.), Cottonwoods (Populus spp.)	Nutritional value supports larval growth	(Dowell & Scriber, 2023) [46]
22.	*Colias eurytheme*	Orange Sulphur	Legumes (Fabaceae)	Nitrogen-rich plants support larval development	(Sourakov & Sourakov, 2024) [47]
23.	*Zerene cesonia*	Southern Dogface	Legumes (Fabaceae)	High nitrogen content supports growth	(Vargas *et al*., 2015) [48]
24.	*Pontia protodice*	Checkered White	Crucifers (Brassicaceae)	Provides essential nutrients for development	(Harvey & Fortuna, 2012) [49].
25.	*Papilio crino*	Common Banded Peacock	Rutaceae family	Sequesters essential oils for chemical defense	(Deschamps-Cottin *et al*., 1997) [50]
26.	*Pieris napi*	Green-veined White	Crucifers (Brassicaceae)	Detoxifies glucosinolates for growth	(Okamura *et al*., 2019) [28]

3. Factors Affecting Butterfly-Host Plant Dynamics

3.1. Habitat Loss and Fragmentation

Habitat loss and fragmentation are among butterfly populations and host plants' most significant threats. Urbanization, deforestation, and agricultural expansion have led to the widespread destruction of natural habitats, reducing the availability of suitable environments for butterflies to thrive (Josephitis, 2014) [7]. As habitats are destroyed, butterflies lose the plants they rely on for laying eggs and feeding their larvae. Fragmentation further compounds this problem by isolating remaining habitat patches, making it difficult for butterflies to find and colonize these areas. This isolation can lead to reduced genetic diversity, increased inbreeding, and a higher risk of local extinctions. Additionally, fragmented landscapes often lack the continuity needed for butterflies to move freely between habitats, which is crucial for maintaining healthy populations and enabling butterflies to adapt to environmental changes (Wynhoff *et al*., 1996) [27].

The impact of habitat loss and fragmentation is particularly pronounced in specialized butterfly species that have narrow host plant preferences. These species are more vulnerable to habitat changes because they cannot easily switch to alternative plants. Conservation efforts must prioritize the preservation and restoration of continuous habitats, ensuring that there are corridors or stepping stones that allow butterflies to move between habitat patches. By maintaining and enhancing habitat connectivity, we can support the survival and resilience of butterfly populations (Brückmann *et al*., 2010).

3.2. Climate change

Climate change is another critical factor affecting butterfly-host plant dynamics. Alterations in temperature,

precipitation patterns, and seasonal cycles influence the distribution, abundance, and phenology of both butterflies and their host plants. Recent studies have shown that climate change is causing butterfly species to shift their ranges upwards in elevation and towards higher latitudes. Kerner *et al*. (2022) [8] found that alpine butterflies are moving upslope faster than their host plants, potentially leading to mismatches in their relationships. Wilson *et al*. (2007) [26] observed similar uphill shifts in butterfly communities in central Spain, accompanied by declines in species richness, particularly at lower elevations. Schweiger *et al*. (2008) [22] used ecological niche models to predict substantial spatial mismatches between a monophagous butterfly and its host plant under various climate change scenarios. These mismatches could result in significant range contractions for the butterfly, especially if both species have limited dispersal abilities. These findings highlight the complex interactions between climate change, butterfly distributions, and their host plants.

3.3. Pesticide use

The widespread use of pesticides in agriculture and urban environments poses a significant threat to butterflies and their host plants. Pesticides, including insecticides and herbicides, can have both direct and indirect effects on butterfly populations (Pekin, 2013) [13]. Insecticides can have significant impacts on butterflies at various life stages. Chronic and acute toxicity studies show that common agricultural insecticides like chlorantraniliprole and beta-cyfluthrin are highly toxic to monarch butterflies, affecting eggs, larvae, pupae, and adults. Even sublethal exposure to pesticides can lead to reduced wing length in adult monarchs, potentially impacting their migratory success (Olaya-Arenas *et al*., 2020) [12]. The effects of insecticides on butterflies are complex, interacting with various biotic and abiotic factors and manifesting at multiple levels from molecular to metapopulation (Braak *et al*., 2018) [2]. While some studies have found relatively weak effects on larval survival and development, stronger sublethal effects are often observed in adults (Olaya-Arenas *et al*., 2020) [12]. However, there is a need for more comprehensive research on the impacts of chemical insecticides on non-target Lepidoptera, given their ecological importance.

3.4. Invasive Species

Invasive plant species can significantly disrupt butterfly-host plant relationships by outcompeting native host plants, altering habitat structure, and reducing overall plant diversity (Gallien *et al*., 2016) [5]. These invasions can lead to a decline in butterfly diversity and abundance, particularly affecting specialist species with specific host plant requirements. However, the impact of exotic plants on butterflies is complex. In some cases, butterflies may adapt to use exotic plants as hosts, potentially serving as a "life raft" for certain populations (Braga, 2023) [3]. For instance, *Euphydryas editha taylori* in Oregon became dependent on an exotic host plant for survival (Severns & Warren, 2008) [23]. Nevertheless, the overall effect of non-native plants on lepidopteran communities is generally negative, reducing species richness, abundance, and host specialization. Conservation efforts must carefully consider the role of exotic plants in butterfly ecosystems to develop effective management strategies (Severns & Warren, 2008) [23].

5. Conclusion

In conclusion, butterfly-host plant relationships are a cornerstone of ecosystem health and biodiversity, shaped by intricate co-evolutionary dynamics. This review has highlighted the critical dependencies between various butterfly species and their specific host plants, emphasizing the ecological significance and the threats posed by habitat loss, climate change, pesticide use, and invasive species. Understanding these interactions is essential for developing effective conservation strategies, which should focus on habitat preservation and restoration, creating butterfly-friendly environments, and implementing robust policy measures. By protecting these relationships, we can ensure the continued survival of butterfly populations and the overall health of our ecosystems, benefiting both nature and humanity.

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